

**Assessment and Minimization of Potential
Environmental Impact of Solid Waste Management
System in Metropolitan Cities of the Developing
Countries Using Life Cycle Assessment (LCA) as a
Tool**

Thesis Submitted by

Samir Das

Doctor of Philosophy (Engineering)

Department of Civil Engineering,
Faculty Council of Engineering & Technology
Jadavpur University
Kolkata, India

2024

JADAVPUR UNIVERSITY

Kolkata – 700032, India

INDEX NO. 141/17/E

1. Title of the thesis:

Assessment and Minimization of Potential Environmental Impact of Solid Waste Management System in Metropolitan Cities of the Developing Countries Using Life Cycle Assessment (LCA) as a Tool.

2. Name, Designation & Institution of the Supervisor/s:

Dr. Amit Dutta

Professor, Department of Civil Engineering,
Jadavpur University, Kolkata – 700032, India
Mob: 9051511555; Email: amittt555@gmail.com

&

Prof. Shibnath Chakrabarty

Professor, Department of Civil Engineering,
Jadavpur University, Kolkata – 700032, India
Mob: 9831129563; Email: shibnath.chakrabarty@jadavpuruniversity.in

3. List of Publications:

- **Das, S., Dutta, A., Chakrabarty, S., 2019.** “Assessment of Potential Environmental Impact (PEI) of Municipal Solid Waste Management (MSWM) System Practiced in Kolkata Using Life Cycle Assessment (LCA) Methodology”. International Journal of Research and Analytical Reviews (IJRAR), Volume-6, Issue-2, June 2019, Page No. 375-384. URL: http://www.ijrar.org/viewfull.php?&p_id=IJRAR19K6624.
- **Das, S., Dutta, A., Chakrabarty, S., 2019.** “Assessment of Potential Environmental Impact (PEI) of Municipal Solid Waste (MSW) Management System Using Life

Cycle Assessment (LCA) Methodology.” 4th RS&TC-2019, West Bengal (Northern Region), 18th & 19th December, 2019 at Alipurduar College and in 27th WBSS&TC-2020, Organized by Department of Science & Technology and Biotechnology, Government of West Bengal, 28th & 29th February, 2020 at Science City, Kolkata (Abstract).

- Banerjee, S, **Das, S.**, Dutta, A., 2020. “An Integrated Solid Waste Management System for Minimization of Greenhouse Gas Emission: A Case Study of Kolkata”. International Conference on Water Energy and Environmental Sustainability (WEES) 2020, January 13-15, 2020, National Institute of Technology, Durgapur, India.
- **Das, S.**, Dutta, A., Chakrabarty, S., 2024. “Estimation of Pollution Generation from Municipal Solid Waste Management (MSWM) System by Gaseous Emission Using Linear Programming (LP) Model”. 6th Regional Science Congress, West Bengal (Northern Region), 15th & 16th January, 2024 at Ananda Chandra College, Jalpaiguri (Abstract).
- **Das, S.**, Dutta, A., Chakrabarty, S., 2025. “Evaluation of the Optimized Operational Plan of the Municipal Solid Waste Management (MSWM) System Using Cost Based Linear Programming (LP) Model”. 7th Regional Science and Technology Congress, 2024-25, Region 1 (Northern Region), West Bengal, 24th & 25th January, 2025 at Siliguri College (Abstract).

4. List of Patents:

None.

5. List of Presentations in National/International/Conference/ Seminar:

- **Das, S.**, Dutta, A., Chakrabarty, S., 2019. “Assessment of Potential Environmental Impact (PEI) of Municipal Solid Waste (MSW) Management System Using Life Cycle Assessment (LCA) Methodology.” 4th RS&TC-2019, West Bengal (Northern Region), 18th & 19th December, 2019 at Alipurduar College and in 27th WBSS&TC-2020, Organized by Department of Science & Technology and Biotechnology, Government of West Bengal, 28th & 29th February, 2020 at Science City, Kolkata.
- **Das, S.**, Dutta, A., Chakrabarty, S., 2024. “Estimation of Pollution Generation from Municipal Solid Waste Management (MSWM) System by Gaseous Emission Using

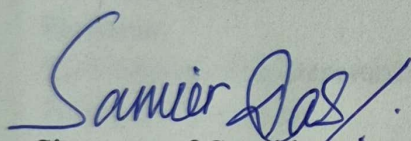
Linear Programming (LP) Model”. 6th Regional Science Congress, West Bengal (Northern Region), 15th & 16th January, 2024 at Ananda Chandra College, Jalpaiguri.

Statement of Originality

I, **Samir Das**, registered on **29.03.2017** do hereby declare that this thesis entitled "**Assessment and Minimization of Potential Environmental Impact of Solid Waste Management System in Metropolitan Cities of the Developing Countries Using Life Cycle Assessment (LCA) as a Tool**" contains literature survey and original research work done by the undersigned candidate as part of Doctoral studies.

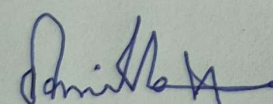
All information in this thesis have been obtained and presented in accordance with existing academic rules and ethical conduct. I declare that, as required by these rules and conduct, I have fully cited and referred all materials and results that are not original to this work.

I also declare that I have checked this thesis as per the "Policy on Anti Plagiarism, Jadavpur University, 2019", and the level of similarity as checked by ithenticate software is 6%.


Signature of Candidate:

Date: **18.03.2024**

Certified by Supervisor(s):

 **18/03/2024**

Dr. Amit Dutta,

Professor

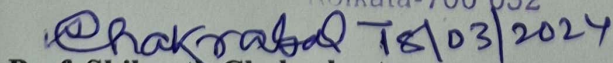
Civil Engineering Department,

Jadavpur University *Professor*

Department of Civil Engineering

Jadavpur University

Kolkata-700 032

 **18/03/2024**
Prof. Shibnath Chakrabarty,

Professor

Civil Engineering Department, J.U.

Jadavpur University

Professor

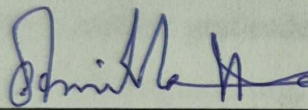
Department of Civil Engineering

Jadavpur University

Kolkata-700 032

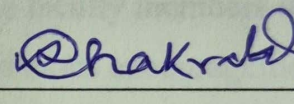
Certificate from the Supervisor/s

This is to certify that the thesis entitled "Assessment and Minimization of Potential Environmental Impact of Solid Waste Management System in Metropolitan Cities of the Developing Countries Using Life Cycle Assessment (LCA) as a Tool" submitted by **Samir Das**, who got his name registered on 29.03.2017 for the award of **Ph.D. (Engg.)** degree of Jadavpur University is absolutely based upon his own work under the supervision of **Dr. Amit Dutta** and **Prof. Shibnath Chakrabarty** and that neither his thesis nor any part of the thesis has been submitted for any degree/diploma or any other academic award anywhere before.

 18/03/2024

Dr. Amit Dutta
Professor
Civil Engineering Department
Jadavpur University

Professor
Department of Civil Engineering
Jadavpur University
Kolkata-700 032

 18/03/24

Prof. Shibnath Chakrabarty
Professor
Civil Engineering Department
Jadavpur University

Professor
Department of Civil Engineering
Jadavpur University
Kolkata-700 032

ACKNOWLEDGEMENT

Several persons contributed to the completion of this Ph.D. thesis. I would like to express my heartfelt gratitude to each of them. First and foremost, I am immensely grateful to my Ph.D. supervisors, **Dr. Amit Dutta**, Professor, Environmental Engineering Division, Department of Civil Engineering, Jadavpur University, and **Prof. Shibnath Chakrabarty**, Professor, Environmental Engineering Division, Department of Civil Engineering, Jadavpur University, for their invaluable generous guidance, intellectual contribution, and persistent support throughout the study process. This achievement would not have been achievable without their unwavering support. I consider it as a great opportunity to do my doctoral thesis under their guidance and to learn from their research expertise. I will remain forever indebted to them rest of my life.

My heartfelt gratitude, indebtedness and regards to all the faculty members of Department of Civil Engineering, Jadavpur University, for their continuous encouragements, supports and valuable advices.

The thesis work required a huge number of data sets, and it would be appropriate to appreciate the assistance provided by the Kolkata Municipal Corporation, the West Bengal Pollution Control Board, and other government departments. I would like to thanks the author of various published papers and books, which I have frequently consulted.

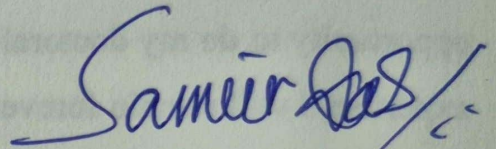
I sincerely acknowledge the help of my colleagues of the Department of Civil Engineering, Jalpaiguri Government Engineering College and Jadavpur University for their constant inspiration and kind supports to doing the work.

I would like to express my appreciation to Samran Banerjee and Sourav Chakraborty, the Research Scholars of Environmental Engineering Division, Department of Civil Engineering, Jadavpur University; for their good will and co-operation.

I would also acknowledge my gratefulness to my employers for extend me to take the opportunity of doing my Ph.D. work. I would like to express my sincere gratitude to Dr. Amitava Ray, Principal, Jalpaiguri Government Engineering College and Dr. Goutam Bairagi, HOD, Civil Engineering Department, Jalpaiguri Government Engineering College, for their unconditional support.

I express my sincere gratitude to all my friends and well-wishers, and my students for their good will and encouragements and supports they provided.

Last, but not the least, I am very much indebted to my wife and my daughter, who supported me in every possible way to see the completion of this work. I acknowledge the appreciation, understanding, inspiration and support I received from them. I deeply thank my parents for their unconditional trust, timely encouragement, and endless patience. It was their love that raised me up again when I got weary. This thesis would not have been possible without them.



Samir Das

Date: 18-03-2024

Place: Department of Civil Engineering

Jadavpur University

ABSTRACT

The production of waste is an inevitable consequence of modern civilization. The lack of adequate waste management systems has led to serious environmental problems. In developing countries, the lack of adequate waste management systems has led to serious environmental problems. In developing countries, the lack of adequate waste management systems has led to serious environmental problems. In developing countries, the lack of adequate waste management systems has led to serious environmental problems.

*Dedicated to my parents, my daughter
and my wife.*

The purpose of this study is to assess the environmental impact of the waste management system in the city of [City Name]. The study is divided into two main parts: a literature review and a field study. The literature review covers the general concepts of waste management and the specific issues related to the city of [City Name]. The field study involves the collection of data on the waste management system in the city of [City Name].

The study is divided into two main parts: a literature review and a field study. The literature review covers the general concepts of waste management and the specific issues related to the city of [City Name]. The field study involves the collection of data on the waste management system in the city of [City Name]. The study is divided into two main parts: a literature review and a field study. The literature review covers the general concepts of waste management and the specific issues related to the city of [City Name]. The field study involves the collection of data on the waste management system in the city of [City Name].

The study is divided into two main parts: a literature review and a field study. The literature review covers the general concepts of waste management and the specific issues related to the city of [City Name]. The field study involves the collection of data on the waste management system in the city of [City Name]. The study is divided into two main parts: a literature review and a field study. The literature review covers the general concepts of waste management and the specific issues related to the city of [City Name]. The field study involves the collection of data on the waste management system in the city of [City Name].

The study is divided into two main parts: a literature review and a field study. The literature review covers the general concepts of waste management and the specific issues related to the city of [City Name]. The field study involves the collection of data on the waste management system in the city of [City Name]. The study is divided into two main parts: a literature review and a field study. The literature review covers the general concepts of waste management and the specific issues related to the city of [City Name]. The field study involves the collection of data on the waste management system in the city of [City Name].

The study is divided into two main parts: a literature review and a field study. The literature review covers the general concepts of waste management and the specific issues related to the city of [City Name]. The field study involves the collection of data on the waste management system in the city of [City Name]. The study is divided into two main parts: a literature review and a field study. The literature review covers the general concepts of waste management and the specific issues related to the city of [City Name]. The field study involves the collection of data on the waste management system in the city of [City Name].

ABSTRACT

The production of waste is an unavoidable consequence of modern civilization. The lack of resources, space, high population growth rates, and outdated methods used in developing countries has led to an inefficient Solid Waste Management (SWM) system. As a result, pollutant production rates are rising on a global scale. The unplanned and ongoing expansion of metropolitan areas makes Municipal Solid Waste Management (MSWM) more and more costly and complicated. An Integrated Solid Waste Management (ISWM) system must be implemented instead of the current dumping system of municipal solid waste to reduce the impact of several pollutants and to achieve sustainable development.

To measure the eco-friendliness of MSWM activities, an inventory of pollutants and their quantitative environmental impacts in different impact categories must be determined. Considering the current data availability, the Life Cycle Assessment (LCA) is one of the most appropriate tools for assessing the environmental impact of MSWM systems in order to determine the best MSWM strategies.

The literature review shows a lack of research on the total pollutants generated by the MSWM system, the quantitative effects of the pollution using LCA and the resulting optimal cost solution, especially in Kolkata, a metropolitan city in India, a developing country. In this study, an effort has been made to assess and minimize the Potential Environmental Impact (PEI) of the MSWM system, practiced in metropolitan cities of developing countries, using LCA methodology considering the cost-effectiveness and quantitative environmental impact, maintaining all system operational constraints.

A generic linear programming (LP) model has been developed while considering all components and cost of MSWM system with possible pollutants generation and PEI for the Kolkata. The quantitative impacts of MSWM activities have been evaluated with the help of a systems approach i.e. LP model with the LCIA methodology of LCA. The LP model is run for different cases to find out the eco-friendliness of the activities considering the cost and PEI and compared. To generate the LP equation, a software program was developed in LINDO V9.0 optimization software.

The model for the MSWM system of the study area, Kolkata, includes gaseous emissions from the transportation sector, incineration plant, composting facility, and landfill, as well as liquid pollutants from landfill leachate. The model is run for different scenarios of existing SWM and proposed ISWM systems and compared to determine the suitability of the system in terms of cost-effectiveness and eco-friendliness.

Kolkata Municipal Corporation (KMC) currently generates ~4600 MT of Municipal Solid Waste (MSW) per day. At present, the source segregation partly started in Kolkata. The informal rag pickers collect about 5% of the recyclables from waste at the households' level, containers, and compactor locations. 95% of the waste goes to the Dhapa landfill from which ~4.21% of the materials was further separated. Thus, only around 9.21% of the total waste is recovered and recycled and the remaining waste is dumped in a landfill with silt. At present the landfill lacks a gas collecting facility, leachate management system, and liner.

The model has been validated with the actual KMC datasheets of 2022. Excellent results are obtained from validating the LP model for the present scenario which shows that ~5% cost minimization, is possible. Consider that departmental vehicles transport 85% of total waste; whereas hired vehicles transport 15%. The total PEI came out to be 8.37×10^{-3} for the existing MSWM system of Kolkata.

The model is then implemented in both free modes, without vehicle-optimization and with vehicle-optimization for the existing SWM system. Optimizing the number of departmental vehicles results in a ~52.6% decrease in total transportation costs and a ~47.5% reduction in total SWM costs compared to the existing system without vehicle-optimization. However, the total incentive cost of vehicle-optimization is significant; in this situation, all departmental vehicles are required to make more trips than their assigned minimum. However, the PEI remains the same in both circumstances.

The result implies that the total emission of the departmental vehicle is ~90%. The departmental vehicles carry ~90% of the total waste in restricted condition. In case of the hired vehicles, the total emission is ~10% which carry ~10% of the total waste. The quantity of total gaseous pollutant emitted from the existing MSWM system of Kolkata is ~269641 MT per year.

The total gaseous pollutant generation contributed by the transport sector is around 4733 MT/year (~2%). Total contribution of CO₂ emission is the highest (99.1%). NO_x generation is the second largest (0.475%) which is higher than CO (0.26%) and HC (0.073%). SO₂ emission (0.022%) is much less compare to NO_x due to the stringent permissible sulphur percentage in diesel fuel.

The total gaseous pollutant emission from landfill in existing MSWM system of Kolkata is 264908 MT per year, which covers ~98% of the total gaseous pollutant emission. The major pollutants from landfill gases are CO₂ and CH₄, causing rise of global temperature. The percentage of CO₂ is around 73% whereas the CH₄ is about 27% of landfill gas generation. The percentage contributions of NH₃-N, and Cl to total liquid pollutants generation from landfill leachate in the present MSWM system are 29.3%, and 70.5%, respectively. The transport sector and landfill provide 12% and 88% of total PEI, respectively. The liquid pollutants of landfill account for approximately 52% of total PEI, while gaseous pollutants accounting for the remaining 36%. Among all the PEI sub-categories, HTPE is the highest (~29%) followed by ATP (~27%), HTPI (~23%), and TTPL (~8%), w.r.t. total PEI.

The proposed ISWM systems include three transfer stations on each side of KMC's perimeter, each with three material sorting, incineration, and composting facilities. Three specialized engineered landfill (ELF) sites are being considered for the disposal of process rejects, inerts, and silt. The validated model is then used to simulate the proposed ISWM system, both with and without departmental vehicle optimization. Without vehicle optimization, the system would cost Rs. 44,69,858 per day. The overall daily cost for ISWM systems with vehicle optimization is Rs. 20,07,230. When compared to the cost of the existing MSWM system without vehicle optimisation conditions, there is a 17.88% decrease in overall SWM cost and a 1.28% reduction in ISWM transportation cost. Although ELF includes a costly leachate collection infrastructure and a liner system, it

reduces landfill costs by approximately 18% due to lower material volume. However, without vehicle optimisation, ISWM led to a 12% increase in incentive costs.

Vehicle optimization on the proposed ISWM system reduces overall SWM costs by approximately 63% for unoptimized and 30% for optimized existing systems. It was discovered that incentive expenses had increased by 1.8%. Silt and process rejects are deposited far from the city, increasing transportation costs by 2.54%.

Waste sorting, composting, and incineration increase cost of operation by approximately 41% over net SWM costs without vehicle optimisation. Selling recycled materials, compost, and power generates significant revenue, accounting for approximately 37% of total expenses without vehicle optimisation and 57% with vehicle optimisation of proposed ISWM systems. Composting operations generate approximately 77% of revenue, while incineration yields about 20%. Selling recyclables only accounts for ~3% of the total due to the low volume of recyclables in developing nations' MSW.

The total cost is reduced by 55.1% and the transportation cost decreases by 50.8% in vehicle optimization condition w.r.t vehicle un-optimized condition of ISWM systems. Departmental vehicles contribute 90% of pollution and share ~81% of waste.

The proposed ISWM systems emit approximately 4.5×10^5 MT of gaseous pollutants annually. The transportation sector contributes 3637 MT (~0.8%) of pollutants per year. Annually, incinerators emit around 2.25×10^5 MT (50%) of gaseous pollutants, while composting plants generate approximately 2.22×10^5 MT (49.2%). The proposed ISWM system emits approximately 67% more gaseous pollutants than existing MSWM systems, primarily from incineration and composting. The overall pollutant emissions from landfill leachate are reduced by 99.7% when compared to the existing MSWM system due to improved leachate quality and less inert waste disposed in the ELF site with leachate treatment facilities of proposed ISWM systems.

In unoptimized vehicle conditions, approximately 44% of total waste enters the east transfer station, 19% enters the north transfer station, and 37% enters the south transfer station. To mitigate the earlier stated distribution discrepancy to avoid overburden, waste is transported in a 3:4:3 ratios to the North, East, and South transfer stations using the proposed ISWM system in vehicle-optimized condition. In this scenario, 40% of the waste is transferred to the east transfer station, 30% to the north transfer station, and the remaining 30% to the south transfer station.

The proposed ISWM system has a total PEI of 6.05×10^{-3} , resulting in a 27.7% reduction over the existing MSWM system. The PEI results show that incinerators account for around 69.1% of PEI under vehicle-optimized conditions, followed by composting at ~29.7% and transportation at ~1%. Landfilling accounts for only about 0.2% of total PEI. The proposed ISWM systems reduce GWP by approximately 68.3% when compared to the existing system, which comprises mainly of CO₂ and CH₄.

The local category accounts for approximately 98.9% of PEI in proposed ISWM systems. NO_x accounts for the largest percentage of PEI (~58.37%) among gaseous pollutants, followed by CO₂ (18.25%), SO₂ (16.85%), and CH₄ (6.28%).

The PEI comparison between BS-IV and BS-VI standards in the transport sector of a vehicle-optimized ISWM system shows that the transportation sector's PEI contribution can be reduced by 79.2%. In terms of PEI contribution from the transportation sector, AP shows a reduction of around 97%, while HTPe and TTPG show a reduction of approximately 79.2% in BS-VI standards, due mainly to lower SO₂ and NO_x emissions. Implementing BS-VI standards over BS-IV, the vehicle-optimized proposed ISWM system can lower overall PEI from various activities by 0.66% only because the effects of transport sector emissions in total PEI are lessened.

The model is also applied to the proposed ISWM systems with two operational ELF's instead of three. The overall costs of the vehicle-optimized ISWM system with two operational ELF's vary very slightly from the three dumpsites of the system. The overall cost of SWM increases by 1.87%, 4.16%, and 6.32% for the ES, NS, and NE configurations, respectively. The landfilling cost has also varied between 2% and 1% of the proposed ISWM system's normal vehicle-optimized condition. In comparison to the vehicle-optimized ISWM system, each of the two ELF configurations results in a net increase in pollutant emissions from the transportation sector ranging from a maximum of 30% to a minimum of 14%. Because departmental and hired vehicles travel further from boroughs to deposit waste and silt in transfer stations, the pollutant generation in two ELF configurations exceeds that of three ELF designs. The total PEI for the NS, NE, and ES configurations increased by 0.33%, 0.17%, and 0.17%, respectively, as a result of the generated pollutants.

Sensitivity analysis was performed under a variety of scenarios. Variation of $\pm 1\%$ in total waste generation results in $\pm 0.48\%$ in total SWM costs and $\pm 0.99\%$ in total PEI. When fuel prices vary by $\pm 5\%$, total SWM costs vary by $\pm 0.86\%$.

For every $\pm 10\%$ variation in CO₂, the total PEI varies by $\pm 1.8\%$. A 10% change in NO_x emission rate results in a $\pm 6\%$ change in total PEI. The variation in the emission of liquid pollutants has insignificant effects. The model analysis demonstrates that incorporating numbers of transfer stations and ELF in different directions of the city lowers both MSWM cost and PEI.

The model shows that the vehicle-optimized proposed ISWM system, along with the transfer station, provides an ideal combination of optimal cost and least PEI. The model also shows that in comparison to Waste-to-Energy incinerators, composting is highly profitable and there is a major impact on the SWM cost.

The model studies the pollution-minimization potential of existing and proposed ISWM systems, showing encouraging results. It also shows that the LCIA methodology of LCA can be successfully applied and used as a decision support tool to evaluate various waste management alternatives and obtain the optimal cost and PEI combination for the transporting, treatment, and disposal of municipal solid waste.

Though the research focuses on Kolkata city as the study area, and the datasets pertain to that of KMC, yet, it is important to note that the solutions suggested by the model are quite generic and the solutions can easily be implemented in any city in a developing country like India, thus promoting a development which is both environmentally and economically sustainable.

TABLE OF CONTENTS

Chapter Name	Page No.
Statement of Originality	i
Certificate from the Supervisor/s	iii
ACKNOWLEDGEMENT	v
ABSTRACT	ix
TABLE OF CONTENTS	xiii
LIST OF FIGURES	xxiii
LIST OF TABLES	xxxi
LIST OF ABBREVIATIONS	xxxvii
<i>Chapter-1</i>	1
1 INTRODUCTION	1
1.1 CHALLENGES OF PRESENT SOLID WASTE MANAGEMENT	1
1.2 ENVIRONMENTAL IMPACT AND SUSTAINABLE WASTE MANAGEMENT	4
<i>Chapter-2</i>	7
2 LITERATURE REVIEW	7
2.1 SOLID WASTE: GENERATION, SOURCE AND TYPE	7
2.2 MUNICIPAL SOLID WASTE (MSW) GENERATION	9
2.2.1 Past Studies Analysis on MSW Generation of Kolkata	13
2.3 MUNICIPAL SOLID WASTE (MSW) COMPOSITION	13
2.4 SOLID WASTE MANAGEMENT (SWM) SYSTEM	17
2.4.1 Case Studies of SWM System of Other Metropolitan Cities of Developing Countries	19
<i>2.4.1.1 Case Study- I: Solid Waste Management in Dhaka City, Bangladesh</i>	19
<i>2.4.1.2 Case Study- II: Solid Waste Management in Kathmandu, Nepal</i>	19

2.4.1.3 Case Study- III: Solid Waste Management in Hanoi, Vietnam	21
2.4.1.4 Case Study- IV: Solid Waste Management in Kuala Lumpur, Malaysia	21
2.5 EFFECT OF IMPROPER SOLID WASTE MANAGEMENT (SWM) SYSTEM	22
2.6 HEALTH EFFECT OF CO₂ AND CH₄	22
2.7 EFFECTS OF LOW CONCENTRATION OF ORGANIC COMPOUNDS ON HEALTH	23
2.8 LANDFILL GAS GENERATION AND ENERGY RECOVERY	24
2.9 ENVIRONMENTAL IMPACT OF LEACHATE	24
2.10 AIR POLLUTANTS FROM VEHICULAR EMISSION AND THEIR HEALTH EFFECTS	30
2.11 INTEGRATED SOLID WASTE MANAGEMENT (ISWM) SYSTEM	32
2.12 PROCEDURE FOR CALCULATION OF IMPACT	33
2.13 METHODS FOR ASSESSING ENVIRONMENTAL EFFECTS	34
2.13.1 Environmental Impact Assessment Methods	37
<i>2.13.1.1 Checklist method</i>	37
<i>2.13.1.2 Relative magnitude method</i>	37
<i>2.13.1.3 Environmental standards relation method</i>	37
<i>2.13.1.4 Impact potential method</i>	38
<i>2.13.1.5 Critical volume method</i>	38
<i>2.13.1.6 Environmental priority strategy</i>	39
<i>2.13.1.7 Tellus institute human health hazard ranking</i>	39
<i>2.13.1.8 Toxicity, persistence, and bioaccumulation profile</i>	39
<i>2.13.1.9 Mackay unit world model</i>	39
<i>2.13.1.10 Canonical environment model</i>	40
<i>2.13.1.11 Ecological risk assessment and human health risk Assessment</i>	40

2.14 BASIC COMPONENTS OF POTENTIAL ENVIRONMENTAL IMPACT	40
2.15 LIFE CYCLE IMPACT ASSESSMENT (LCIA)	41
2.15.1 Estimation of PEI_{LCIA}	43
<i>2.15.1.1 Assumptions and data</i>	43
<i>2.15.1.2 Computation of PEI_{LCIA}</i>	43
2.16 ENVIRONMENTAL IMPACTS:	45
2.16.1 Resource Use: Abiotic, Biotic Depletion and Land Use	45
2.16.2 Global Warming Potential (GWP)	46
2.16.3 Ozone Depletion Potential (ODP)	46
2.16.4 Acidification Potential (AP)	47
2.16.5 Eutrophication Potential (EP)	47
2.16.6 Photochemical Smog (PS)	47
2.16.7 Human Toxicity Potential (HTP)	48
2.16.8 Ecotoxicity Potential (ETP)	48
2.17 THE APPLICATION OF LIFE CYCLE IMPACT ASSESSMENT TO SOLID WASTE MANAGEMENT	50
2.18 RECENT STUDIES ON SWM OPTIMISATION MODEL IMPLEMENTATION	53
2.19 RESEARCH GAP	60
<i>Chapter-3</i>	61
3 OBJECTIVE AND SCOPE OF THE STUDY	61
3.1 OBJECTIVE OF THE PROPOSED WORK	61
3.2 SCOPE OF THE WORK	61
<i>Chapter-4</i>	63
4 DEVELOPMENT OF A MUNICIPAL SOLID WASTE MANAGEMENT (MSWM) OPTIMIZATION MODEL	63
4.1 BACKGROUND	63
4.2 MODEL DEVELOPMENT	64

4.2.1 Assumptions	64
4.2.2 Defining Parameters	68
4.2.3 Model	93
4.2.4 Incorporating Pollution Generation LP Equations	107
<i>4.2.4.1 Pollution generation equation from transport sector</i>	108
<i>4.2.4.2 Pollution generation equation from incineration plant</i>	116
<i>4.2.4.3 Pollution generation equation from composting plant</i>	116
<i>4.2.4.4 Liquid pollutant generation equation from landfill leachate</i>	117
4.2.5 Incorporating Potential Environmental Impact (PEI) LP Equations	120
<i>4.2.5.1 Global PEI calculation</i>	120
<i>4.2.5.2 Regional PEI calculation</i>	121
<i>4.2.5.3 Local PEI calculation</i>	123
4.2.6 Solving the LP model	138
Chapter-5	141
5 EXISTING SOLID WASTE MANAGEMENT (SWM) SYSTEM OF KOLKATA- THE STUDY AREA	141
5.1 BASE LINE PICTURE OF CITY OF KOLKATA	141
5.2 MONITORING MECHANISM OF THE SWM SERVICES	143
5.3 PHYSICAL AND CHEMICAL CHARACTERISTICS OF CITY GARBAGE	144
5.4 COLLECTION, STORAGE & TRANSPORTATION	149
5.4.1 Collection and Storage	149
5.4.2 Waste Segregation System	150
5.4.3 Waste Transportation	151
5.4.4 Deficiencies in the Existing Collection, Storage and Transportation System	153
5.5 TREATMENT AND DISPOSAL OF MSW	153
5.5.1 Treatment (Composting)	153
5.5.2 Disposal of Waste	154

Chapter-6	157
6 VALIDATION AND ANALYSIS OF A SOLID WASTE MANAGEMENT OPTIMISATION MODEL	157
6.1 IMPLEMENTING THE MODEL FOR EXISTING SWM SYSTEM	157
6.1.1 Operational and Maintenance Cost of Landfilling (Open Dumping)	158
6.1.2 Borough-Wise Garbage and Silt/Rubbish Generation	159
6.1.3 Types of Vehicles Currently Used by KMC for Waste Transportation	159
6.1.4 Maximum and Minimum Fraction Limit of Garbage Carried by Different Vehicles	160
6.1.5 Maximum and Minimum Trip Limits of Departmental Vehicles	160
6.1.6 Transportation Cost of KMC Vehicles	161
<i>6.1.6.1 Waste transportation cost for departmental and hired vehicles</i>	162
6.1.7 Air Pollution Generation from Transport Sector	165
<i>6.1.7.1 Emission factor of the gaseous pollutants</i>	165
6.1.8 Pollutant Generation from Landfilling	170
<i>6.1.8.1 Analysis for composition of MSW under existing case study</i>	171
6.1.9 Calculation of Leachate Formation	180
<i>6.1.9.1 Major heavy metals generation equation from existing landfill leachate</i>	182
6.2 MODEL VALIDATION IN EXISTING SCENARIO	182
6.3 IMPLEMENTING THE MODEL FOR EXISTING SWM SYSTEM WITH AND WITHOUT VEHICLE OPTIMIZATION	183
6.3.1 Observation of Results on Above Study	184
<i>6.3.1.1 Cost analysis</i>	184
<i>6.3.1.2 Pollution generation from transport sectors</i>	188
<i>6.3.1.3 Pollution generation from Dhapa landfill site</i>	194

6.3.1.4 Impact assessment of existing solid waste management system	197
a. Computation of weightage for different impact categories	197
b. Computation of equivalency factor for the municipal solid waste pollutants	201
c. Computation of normalizing values for different impact categories	208
6.3.1.5 Potential environmental impact (PEI) in different category for existing MSW model in Kolkata	217
Chapter-7	227
7 APPLICATION OF MODEL IN PROPOSED INTEGRATED SOLID WASTE MANAGEMENT (ISWM) SYSTEM OF KOLKATA	227
7.1 GENERAL DESCRIPTION	227
7.2 CONSIDERATION OF DISPOSAL SITES	233
7.3 SORTING AND RECYCLING	235
7.4 BALANCE FOR INCINERATOR	235
7.5 BALANCE FOR COMPOSTING	236
7.6 REVENUE FROM RECYCLABLE MATERIALS	237
7.7 REVENUE FROM COMPOST	237
7.8 COST OF COMPOSTING PLANT	237
7.9 COST OF INCINERATION PLANT	238
7.10 COST OF ENGINEERED LANDFILL	238
7.11 INCORPORATING TRANSFER STATIONS IN THE PROPOSED ISWM	238
7.11.1 Pollution Generation Equation for Heavy Duty LPT Trucks	240
7.12 TRANSFER STATIONS LOCATED VERY NEAR / INSIDE KMC BOUNDARY	243
7.12.1 Boroughs and Zones related to disposal sites or transfer stations	243
7.12.2 Present generation of garbage and silt/rubbish by borough	243

7.12.3 Vehicles types used by KMC at present for transportation of waste	243
7.12.4 Maximum and minimum fraction limits of waste carried by various types of KMC vehicles	243
7.12.5 Maximum and minimum trip limitations for departmental vehicles	244
7.12.6 Transportation cost of KMC vehicles	244
7.12.6.1 Waste transportation cost for departmental vehicles	244
7.12.6.2 Waste transportation cost for hired vehicles	247
7.13 AIR POLLUTION GENERATION FROM TRANSPORT SECTOR	248
7.14 POLLUTION GENERATION FROM INCINERATION	256
7.14.1 Gas Generation from 100MT of Garbage from Incineration in the Proposed ISWM System	256
7.14.2 Calculation of Gas Generation Rate from Incineration (Kg per MT of Waste)	258
7.14.3 Calculation of Gas Generation Rate from Incineration Meeting the Emission Standards (Kg per MT of Waste)	259
7.15 POLLUTION GENERATION FROM COMPOSTING	261
7.16 GENERATION OF LIQUID POLLUTANTS FROM LANDFILL LEACHATE	262
7.16.1 Land requirement for Engineered Landfill site (CPHEEO, 2016)	263
7.16.2 Calculation of Rate of Leachate Generation (L/MT of waste)	264
7.16.3 Sample Calculation of Rate of Heavy Metal Generation from Leachate (kg/MT of waste)	264
7.17 IMPLEMENTING THE MODEL FOR PROPOSED ISWM SYSTEMWITH VEHICLE OPTIMISATION	265
7.18 OBSERVATION ON ABOVE PROPOSED STUDY	265
7.18.1 Cost Analysis	265
7.18.2 Pollution Generation from Transport Sectors	271
7.18.2.1 Borough wise emission trend from departmental and	271

<i>private vehicles</i>	
7.18.2.2 Contribution to total pollutant emissions from different boroughs	272
7.18.2.3 Pollutant contribution from departmental and private KMC vehicles	274
7.18.3 Pollution Generation from Incineration Plant	276
7.18.4 Pollution Generation from Composting Plant	277
7.18.5 Pollution Generation from ELF Sites for Proposed ISWM System	278
7.19 POTENTIAL ENVIRONMENTAL IMPACT (PEI) IN DIFFERENT CATEGORY FOR PROPOSED ISWM MODEL IN KOLKATA	279
7.19.1 Computation of Weightage for Different Impact Categories	279
7.19.2 Computation of Equivalency Factor for the Municipal Solid Waste Pollutants	279
7.19.3 Computation of Normalizing Values for Different Impact Categories	279
7.19.4 Potential Environmental Impact (PEI) Value for proposed ISWM System	279
Chapter-8	289
8 COMPARATIVE STUDY OF SOLID WASTE MANAGEMENT SYSTEM OF KOLKATA	289
8.1 GENERAL DESCRIPTION	289
8.2 COMPARISON OF COST, POLLUTION GENERATION AND PEI FROM DIFFERENT SECTORS BETWEEN BOTH EXISTING AND PROPOSED ISWM SYSTEM IN VEHICLE UNOPTIMIZED CONDITIONS	289
8.2.1 Cost Analysis	289
8.2.2 Pollution Emission by Different Sectors	291
8.2.2.1 Pollution emission from transportation sectors	293
8.2.2.2 Pollution emission from composting and incineration plant (ISWM only)	295
8.2.2.3 Landfill gases (only in existing SWM system)	296

8.2.2.4 Landfill leachates	296
8.2.3 Comparative Analysis of PEI due to Pollutant Generation	297
8.2.3.1 Global	298
8.2.3.2 Regional	299
8.2.3.3 Local	300
8.3 COMPARATIVE STUDY CONSIDERING APPLICATION OF OPTIMIZED VEHICLE BETWEEN EXISTING AND PROPOSED SWM SYSTEM	305
8.4 CONSIDERATION OF BS VI NORMS FOR THE STUDY OF ISWM SYSTEM	308
8.4.1 Total Pollutant Emissions from KMC Vehicles under BS VI norms	315
8.5 COMPARATIVE ANALYSIS OF POLLUTANT EMISSION CONSIDERING BS-VI NORMS OVER BS-IV FOR PROPOSED ISWM SYSTEM	317
8.6 COMPARATIVE ANALYSIS OF POLLUTANT EMISSION FROM DIFFERENT VEHICLES USED CONSIDERING BS-VI NORMS OVER BS-IV FOR PROPOSED ISWM SYSTEM	320
8.7 COMPARATIVE ANALYSIS OF POTENTIAL ENVIRONMENTAL IMPACT (PEI) CONSIDERING BS-VI NORMS OVER BS-IV FOR PROPOSED ISWM SYSTEM	323
Chapter-9	325
9 MODEL ANALYSIS OF PRPOSED ISWM SYSTEM OF KOLKATA IN DIFFERENT OPERATING CONDITIONS	325
9.1 GENERAL DESCRIPTION	325
9.2 CASE STUDY: RUNNING WITH TWO OPERATIONAL DUMPSITE IN PROPOSED ISWM SYSTEM	325

9.2.1 Cost Analysis	326
9.2.2 Pollution Generation	327
9.3 PEI DUE TO POLLUTANTS	332
9.4 SENSITIVITY ANALYSIS OF PROPOSED ISWM SYSTEM	333
9.4.1 Effects on Variation of Waste Generation	333
9.4.2 Effects on Variation of Fuel Cost	334
9.4.3 Effects on Variation of Incentive Cost	335
9.4.4 Effects of Individual Variation of Emission Rate of CO₂ and NO_x	335
9.4.5 Effects of Individual Variation of Emission Rate of Chloride (Cl), Ammoniacal Nitrogen (NH₃-N) and Mercury (Hg)	335
<i>Chapter-10</i>	337
10 CONCLUSIONS	337
10.1 CONCLUSIONS	337
10.2 FUTURE SCOPE OF WORK	343
BIBLIOGRAPHY	345
ANNEXURE 6	377
ANNEXURE 7	403
ANNEXURE 8	421
ANNEXURE 9	425

LIST OF FIGURES

Figure No.	Title	Page No.
Figure- 1.1	Schematic of the problem	6
Figure- 2.1	Material flow and the generation of solid waste	8
Figure- 2.2	Generation trends of MSW in Indian cities	12
Figure- 2.3	A Typical potential environmental impact category hierarchy considering environmental factors	43
Figure-2.4	Phases of an LCA (Source: ISO 14040-2006)	50
Figure- 4.1	Material Flow Chart of Garbage at a disposal site	67
Figure- 4.2	Flowchart detailing steps for running the model in LINGO	139
Figure- 5.1	Borough division of KMC area	142
Figure- 5.2	Electoral ward division of KMC area.	143
Figure-5.3	Material flow diagram for existing MSW management system of Kolkata	147
Figure- 6.1	Typical landfill gas generation rate from RBW and SBW	171
Figure- 6.2	Year wise CH ₄ generation, entrapment and recovery from Dhapa landfill	178
Figure- 6.3	CH ₄ generation from 1987 to 2021 from existing Dhapa landfill site	179
Figure-6.4	Comparison of total cost for existing MSWM system in Kolkata	184
Figure-6.5	Quantity of waste transported to Dhapa disposal sites in Existing system	185
Figure-6.6	Total transportation cost of different KMC vehicles	187
Figure-6.7	Variation of incentive cost incurred by KMC vehicles	187
Figure-6.8	Variation of total fuel cost incurred by different KMC vehicles	187
Figure-6.9	Borough wise total waste generation and total pollutant contribution for existing system	189
Figure-6.10	Borough wise emission status for CO and NO _x for existing SWM	189
Figure-6.11	Borough wise emission status for CO ₂ for existing SWM	190

Figure-6.12	Emission of SO ₂ , HC and PM from different borough	190
Figure-6.13	Emission of benzene and butadiene from different borough	191
Figure-6.14	Pollutant contribution and waste carried by KMC vehicles for existing SWM system	191
Figure-6.15	Emission trends of CO from KMC vehicles for existing SWM system	192
Figure-6.16	Emission trends of SO ₂ from KMC vehicles for existing SWM system	192
Figure-6.17	Emission trends of CO ₂ from KMC vehicles for existing SWM system	193
Figure-6.18	Emission trends of NO _x from KMC vehicles for existing SWM system	193
Figure-6.19	HC and PM emission from KMC vehicles for existing SWM system	194
Figure-6.20	Benzene and butadiene emission from KMC vehicles for existing SWM system	194
Figure- 6.21	Generation of landfill gases from existing Dhapa landfill site	195
Figure- 6.22	Generation of NH ₃ -N and Cl from landfill leachate	196
Figure- 6.23	Generation of different heavy metals from landfill leachate	196
Figure- 6.24	Category wise PEI contribution of different gaseous pollutants in local perspective	219
Figure- 6.25	Category wise PEI contribution of different liquid pollutants in local perspective	219
Figure- 6.26	PEI contribution of different gaseous pollutants to global category	220
Figure- 6.27	PEI Contribution of different Gaseous Pollutants to Regional Category	221
Figure- 6.28	PEI contribution of liquid pollutants to HTPI	221
Figure- 6.29	PEI contribution of gaseous pollutants to HTPE	222
Figure- 6.30	PEI contribution of liquid pollutants to TTPL	222
Figure- 6.31	PEI contribution of gaseous pollutants to TTPG	223
Figure- 6.32	PEI contribution of liquid Pollutants to ATP	223
Figure- 6.33	Percent PEI contribution of different impact sub- categories to total PEI in local perspective	224
Figure- 6.34	Percent PEI contribution of different pollutants to total PEI in	225

	local perspective	
Figure- 6.35	PEI contribution of transport sector and landfill in existing SWM system	225
Figure- 7.1	Materials flow chart for garbage at a disposal site of ISWM System	228
Figure- 7.2	Borough division of KMC and proposed disposal sites	233
Figure- 7.3	Balance of intermediate central sorter (ICS)	236
Figure- 7.4	Balance for incinerator	236
Figure- 7.5	Balance for composting	237
Figure- 7.6	Comparison of total cost for different variables of Proposed ISWM system.	266
Figure- 7.7	Quantity of waste transported by individual KMC vehicle from different borough centres to the transfer stations/ ELF sites	267
Figure- 7.8	Quantity of daily waste feed to different transfer stations, different process components and ELF sites	269
Figure- 7.9	Cost contribution of different vehicles to total transportation cost	269
Figure- 7.10	Variation of fuel cost incurred by different KMC vehicles	270
Figure- 7.11	Variation of fixed running and idle cost incurred by different KMC vehicles	270
Figure- 7.12	Variation of incentive cost incurred by different KMC vehicles	271
Figure- 7.13	Comparative representations of borough wise total waste generation and total pollutant emission	272
Figure- 7.14	Emission status of CO and NO _x from different borough	273
Figure- 7.15	CO ₂ emission status of KMC vehicles from different borough	273
Figure- 7.16	Emission status of SO ₂ , HC and PM from different borough by KMC vehicles	273
Figure- 7.17	Benzene and Butadiene emission from different borough by KMC vehicles	274
Figure- 7.18	Pollutant contribution and waste carried by departmental and private vehicles	274
Figure- 7.19	CO ₂ emission status by departmental and private vehicles	275
Figure- 7.20	Major pollutant emission status by departmental and private vehicles	276

Figure- 7.21	Different pollutant generation from incineration	276
Figure- 7.22	Comparison of NO ₂ and SO ₂ emission from incinerator before and after meeting the emission standards	277
Figure- 7.23	Different pollutants generation from composting plant	277
Figure- 7.24	Generation of NH ₃ -N and Cl from landfill leachate for ISWM	278
Figure- 7.25	Different pollutant generation from ELF leachate	278
Figure- 7.26	Category wise PEI contribution of different gaseous pollutants	281
Figure- 7.27	Category wise PEI contribution of different gaseous pollutants	281
Figure- 7.28	PEI contribution of different gaseous pollutants to GWP	282
Figure- 7.29	PEI contribution of different gaseous pollutants to AP	282
Figure- 7.30	PEI contribution of different gaseous pollutants to HTPE and TTPG	283
Figure- 7.31	PEI contribution of Cl, Pb and NH ₃ -N to HTPI, TTPL and ATP	284
Figure- 7.32	PEI contribution of different liquid pollutant to HTPI, TTPL and ATP	284
Figure- 7.33	Percent PEI contribution of different impact sub- categories to total PEI in local perspective	285
Figure- 7.34	Percent PEI contribution of different pollutants to total PEI in local perspective	285
Figure- 7.35	Sector wise PEI contribution from different impact categories of ISWM system	286
Figure- 7.36	Category wise PEI contribution from different sector of ISWM system	287
Figure- 8.1	Cost analysis between existing SWM and proposed ISWM system	291
Figure- 8.2	Comparative analysis of different gaseous pollutants emission	292
Figure- 8.3	Comparative analysis of CO ₂ and CH ₄ emission	293
Figure- 8.4	Gaseous pollutant emissions from transportation sector	294
Figure- 8.5	CO ₂ emissions from transportation sector for both SWM systems	294
Figure- 8.6	Pollutant emissions from different types of vehicle	295
Figure- 8.7	Comparative NH ₃ -N emission and Chloride reduction between existing and proposed SWM system	297

Figure- 8.8	Comparative As, Hg, Pb, Cr, Cu, Zn, Ni, CN and phenol reduction between existing and proposed SWM system	297
Figure- 8.9	Comparison of PEI of each category and subcategory for existing and proposed system	298
Figure- 8.10	Comparative study of GWP between existing and proposed system	299
Figure- 8.11	Comparative study of AP between existing and proposed system	299
Figure- 8.12	Comparative study of POCP between existing and proposed system	300
Figure- 8.13	PEI comparative study of HTPI	301
Figure- 8.14	Comparative study of HTPI between existing and proposed system for Cl and NH ₃ -N	301
Figure- 8.15	Comparative study of HTPE for CO ₂ and CH ₄	302
Figure- 8.16	Comparative study of HTPE between existing and proposed system	302
Figure- 8.17	Comparative study of TTPG for CO ₂ and CH ₄	303
Figure- 8.18	Comparative study of TTPG reduction between existing and proposed system	303
Figure- 8.19	Comparative study of TTPL reduction	304
Figure- 8.20	Comparative study of TTPL reduction between existing and proposed system	304
Figure- 8.21	PEI Comparative study of ATP reduction for Cl, Zn and NH ₃ -N	305
Figure- 8.22	Comparative study of ATP reduction between existing and proposed system	305
Figure- 8.23	Comparative study of Cost between ESWM systems (with and without vehicle optimization) and proposed system with vehicle optimization condition	307
Figure- 8.24	Emission of CO ₂ from departmental and hired vehicles under BS-VI	315
Figure- 8.25	Emission of CO and NO _x from departmental and hired vehicles under BS-VI	316
Figure- 8.26	Emission of SO ₂ and PM from departmental and hired vehicles under BS-VI	316
Figure- 8.27	Emission of benzene and butadiene from departmental and hired vehicles under BS-VI	317

Figure- 8.28	Comparison of CO ₂ Emission under BS-IV and BS-VI	318
Figure- 8.29	Comparison of CO and SO ₂ Emission under BS-IV and BS-VI	319
Figure- 8.30	Comparison of NO _x , HC and PM Emission under BS-IV and BS-VI	319
Figure- 8.31	Comparison of Benzene and Butadiene Emission under BS-IV and BS-VI	320
Figure- 8.32	Comparison of CO Emission under BS-IV and BS-VI for Different Types of Vehicles	320
Figure- 8.33	Comparison of SO ₂ Emission under BS-IV and BS-VI for Different Types of Vehicles	321
Figure- 8.34	Comparison of CO ₂ Emission under BS-IV and BS-VI for Different Types of Vehicles	321
Figure- 8.35	Comparison of HC Emission under BS-IV and BS-VI for Different Types of Vehicles	322
Figure- 8.36	Comparison of NO _x Emission under BS-IV and BS-VI for Different Types of Vehicles	322
Figure- 8.37	Comparison of PM Emission under BS-IV and BS-VI for Different Types of Vehicles	323
Figure- 8.38	PEI comparison between BS-IV and BS-VI Standards in vehicle optimized ISWM system transportation sector	324
Figure- 9.1	Types of cost in proposed ISWM system in two dumpsite configurations	327
Figure- 9.2	Comparative emission of CO from transportation sector of proposed ISWM system in two dumpsite configuration	328
Figure- 9.3	Comparative emission of SO ₂ from transportation sector of proposed ISWM system in two dumpsite configurations	328
Figure- 9.4	Comparative emission of NO _x from transportation sector of proposed ISWM system in two dumpsite configurations	329
Figure- 9.5	Comparative emission of HC from transportation sector of proposed ISWM system in two dumpsite configurations	329
Figure- 9.6	Comparative emission of PM from transportation sector of proposed ISWM system in two dumpsite configurations	330
Figure- 9.7	Comparative emission of CO ₂ from transportation sector of proposed ISWM system in two dumpsite configurations	331
Figure- 9.8	Comparative emission of Benzene from transportation sector of proposed ISWM system in two dumpsite configurations	331
Figure- 9.9	Comparative emission of Butadiene from transportation sector of proposed ISWM system in two dumpsite configurations	332

Figure- 9.10	Effects on cost for variation of waste generation	334
Figure- 9.11	Effects on cost for variation of fuel cost	334
Figure- A-6.1	Gas production over five year period from RBW	389
Figure- A-6.2	Gas production over fifteen year period from SBW	390
Figure- A.6.3	Decision tree for aquatic LC ₅₀ hazard value (EPA, 1994c)	394
Figure- A.6.4	Decision tree for BOD half-life hazard value (EPA, 1994c)	394
Figure- A.6.5	Decision tree for hydrolysis half-life hazard value (EPA, 1994c)	395
Figure- A.6.6	Decision tree for BCF hazard value (EPA, 1994c)	395

LIST OF TABLES

Table No.	Title	Page No.
Table- 2.1	Per capita MSW generation of different countries	10
Table- 2.2	Generation trends of MSW in Indian cities (CPCB, 2016)	12
Table- 2.3	Study reports on assessed quantity of MSW generation of Kolkata	13
Table- 2.4	Relative composition of solid waste for low, middle and high income Country (Cointreau, 2006)	14
Table- 2.5	MSW composition of different developing countries (Srivastava et al., 2014)	15
Table- 2.6	The composition of MSW in different developing countries (Srivastava et al., 2014; CPCB, 2005)	15
Table- 2.7	Physical composition variation of MSW in Kolkata (Chattopadhyay et al., 2009)	16
Table- 2.8	Chemical Characteristics Variation of MSW in Kolkata (Chattopadhyay et al., 2009)	16
Table- 2.9	Typical data on the composition of leachate from new and mature landfill (Tchobanoglous et al., 1993; Aziz A. H. et al., 2012)	26
Table- 2.10	Physico-chemical parameters of leachate collected from uncontrolled landfill at Dhapa, Kolkata	28
Table- 2.11	Standards for treated leachate as per SWM rules 2016	29
Table- 2.12	National ambient air quality standards (CPCB, 2009)	32
Table- 2.13	Data needed for various levels of impact assessment (Fava et al., 1993)	35
Table- 2.14	Summary of various impact assessment methodologies (EPA, 1995b)	36
Table- 5.1	Quantitative garbage and silt/rubbish generation in different boroughs of KMC area	145
Table 5.2	Variations in MSW composition at Kolkata during 1970, 1995 & 2005 (Chattopadhyay et al., 2009)	146
Table- 5.3	Variation in chemical characteristics of MSW at Kolkata (Chattopadhyay et al., 2009)	146
Table- 5.4	Average physical composition of municipal solid waste	147
Table- 5.5	Recyclable materials	148

Table- 5.6	Mixed MSW components for landfill	149
Table- 5.7	Various types of vehicle used by KMC for waste transportation	152
Table- 6.1	Average distance from borough centre to Dhapa landfill site and their zones	158
Table- 6.2	Garbage and silt generation from different boroughs	159
Table- 6.3	Borough wise minimum and maximum garbage carrying quantity range (in fraction) for departmental and hired vehicles	160
Table- 6.4	Maximum and minimum trip limits of departmental vehicles with their incentives	161
Table- 6.5	Fixed running cost and fixed idle cost per day of different departmental vehicles	162
Table- 6.6	Average load capacity, fuel consumption and fuel charge in loaded and unloaded condition for departmental vehicles	163
Table- 6.7	Fuel cost for per ton waste transfer by departmental vehicles	163
Table- 6.8	Zone wise rate for transporting garbage and silt by hired vehicles	164
Table- 6.9	Fuel cost for transporting garbage and silt/ rubbish by hired Vehicles	164
Table- 6.10	Fuel consumption of departmental and hired vehicles	165
Table- 6.11	Vehicle wise weighted average of emission factors of the pollutants	166
Table- 6.12	Pollutant emission rate by DV1 per ton of garbage per trip	167
Table- 6.13	Pollutant emission rate by DV2 per ton of garbage per trip	167
Table- 6.14	Pollutant emission rate by DV3 per ton of garbage per trip	168
Table- 6.15	Pollutant emission rate by DV4 per ton of garbage per trip	168
Table- 6.16	Pollutant emission rate by hired vehicle per ton of garbage per trip	169
Table- 6.17	Pollutant emission rate by hired vehicle per ton of silt/ rubbish per trip	169
Table- 6.18	Typical values for ultimate analysis of RBW	171
Table- 6.19	Analysis of weights and chemical composition of RBW	172
Table- 6.20	Typical values for ultimate analysis of SBW	172
Table- 6.21	Analysis of weights and chemical composition of SBW	172
Table- 6.22	Molar composition of RBW & SBW	173
Table- 6.23	Molar ratio of RBW & SBW	173
Table- 6.24	Specific weight of respective gasses at NTP	174

Table- 6.25	Volume and percent of different gases in RBW	174
Table- 6.26	Volume and percent of different gases in SBW	174
Table- 6.27	Gas production distribution over the 5 years period	175
Table- 6.28	Gas production distribution over the 15 years period	176
Table- 6.29	Yearly gas production for solid waste having 75% RBW fraction & 50% SBW fraction	177
Table- 6.30	Landfill gas generation rate (g/MT/day) of Dhapa landfill site	180
Table- 6.31	Landfill leachate characteristics and Generation Rate for active Dhapa landfill	182
Table- 6.32	Total number of departmental vehicle at existing condition	183
Table- 6.33	Optimized data for different type of departmental vehicle	183
Table- 6.34	Output summary of cost for existing MSWM system of Kolkata	184
Table- 6.35	Analysis of waste transported by KMC vehicles in MT	186
Table- 6.36	The pairwise comparison matrix of importance of environmental impact between global, regional and local with respect to the local perspective	198
Table- 6.37	The pairwise comparison matrix of HTP, TTP and ATP with respect to the local perspective	200
Table- 6.38	Relative weightages of the impact categories in local perspective	201
Table- 6.39	Equivalency factor for global warming potential	203
Table- 6.40	Equivalency factor for acidification potential	204
Table- 6.41	Equivalency factor for photo- chemical ozone conversion potential	204
Table 6.42	The equivalency factors for HTPI and TTPL	205
Table 6.43	The equivalency factors for HTPE and TTPG	206
Table 6.44	The equivalency factors for ATP	207
Table- 6.45	Equivalency factors (EF_{ij}) of gaseous pollutants	207
Table- 6.46	Equivalency factors (EF_{ij}) of liquid pollutants	208
Table- 6.47	Normalizing value for global warming potential	209
Table- 6.48	Normalizing value for acidification potential	211
Table-6.49	Normalizing value for photo- chemical ozone conversion potential	212

Table-6.50	Normalizing value for human toxicity potential by ingestion (HTPI)	214
Table- 6.51	Normalizing value for human toxicity potential by inhalation (HTPE)	215
Table- 6.52	Normalizing value for aquatic toxicity potential (ATP)	216
Table- 6.53	Normalizing values (Nj) for different Sub- categories	217
Table- 6.54	PEI contribution of gaseous pollutants of existing SWM system	218
Table- 6.55	PEI contribution of liquid pollutants of existing SWM system	218
Table- 7.1	Current proportion of recyclable materials in Kolkata	229
Table- 7.2	Total recyclable waste components of garbage	230
Table- 7.3	Input material composition for thermal processing	230
Table- 7.4	Composition of composting plant feed	231
Table- 7.5	Amount of recyclable material sorted out from different operation	232
Table- 7.6	Segregation of inert materials from different operations	232
Table- 7.7	Borough wise zone division for proposed landfill site	234
Table- 7.8	Average distance from borough centre to proposed landfill site	234
Table- 7.9	Fuel Cost for transporting garbage from borough centre to transfer station by DV1 (Rs/MT)	245
Table- 7.10	Fuel cost for transporting garbage from borough centre to transfer station by DV2 (Rs/MT)	245
Table- 7.11	Fuel cost for transporting garbage from borough centre to transfer station by DV3 (Rs/MT)	246
Table- 7.12	Fuel cost for transporting garbage from borough centre to transfer station by DV4 (Rs/MT)	246
Table- 7.13	Average load capacity, fuel consumption and fuel charge in loaded and unloaded condition for heavy duty trucks	247
Table- 7.14	Per MT cost of transportation by heavy duty trucks from transfer station to respective disposal site	247
Table- 7.15	Zone wise rate for transporting garbage and silt by hired vehicles	247
Table- 7.16	Fuel cost for transporting garbage and silt/ rubbish by hired Vehicles	248
Table- 7.17	Pollutant emission rate by heavy duty truck (g/t/trip)	249
Table- 7.18	Pollutant emission rate by departmental vehicle DV1 (g/t/trip)	250
Table- 7.19	Pollutant emission rate by departmental vehicle DV2 (g/t/trip)	251

Table- 7.20	Pollutant emission rate by departmental vehicle DV3 (g/t/trip)	252
Table- 7.21	Pollutant emission rate by departmental vehicle DV4 (g/t/trip)	253
Table- 7.22	Pollutant emission rate by hired vehicle HV per ton of garbage per trip (g/t/trip)	254
Table- 7.23	Pollutant emission rate by hired vehicle HV per ton of silt per trip (g/t/trip)	255
Table- 7.24	Physical and chemical composition of incinerated waste (after presorting)	256
Table- 7.25	Analysis of chemical composition of incinerated waste	257
Table- 7.26	Approximate chemical formula of incinerated waste	257
Table- 7.27	Gas generation rate from incineration	259
Table- 7.28	Material balance for gas generation from incineration	260
Table- 7.29	Gas generation rate from incineration meeting the emission	261
Table- 7.30	Gas generation rate from composting plant	262
Table- 7.31	Landfill leachate characteristics for proposed landfill site meeting standards	263
Table- 7.32	Heavy metal generation rate from leachate meeting standards (Kg/MT)	264
Table- 7.33	Optimized data of departmental vehicle for proposed ISWM system	265
Table- 7.34	Output summary of cost for proposed ISWM system	266
Table- 7.35	Analysis of waste transported by KMC vehicles in MT	267
Table- 7.36	Daily waste feed to transfer stations, different processes and ELF sites for restricted and unrestricted condition of proposed ISWM system	268
Table- 7.37	PEI contribution of gaseous pollutants of proposed ISWM system	280
Table- 7.38	PEI contribution of liquid pollutants of proposed ISWM system	280
Table- 8.1	Types of cost in existing and proposed ISWM system	291
Table- 8.2	Pollutant emission from composting and incineration plant	295
Table- 8.3	Category-wise PEI comparison	298
Table- 8.4	Comparison of the operation cost and revenue by both SWM systems under vehicle optimization configuration	306
Table- 8.5	Vehicle wise weighted average emission factor of different	308

pollutants

Table- 8.6	Pollutant emission rate by DV1 per ton of waste per trip for BS VI (g/t/trip)	309
Table- 8.7	Pollutant emission rate by DV2 per ton of waste per trip for BS VI (g/t/trip)	310
Table- 8.8	Pollutant emission rate by DV3 per ton of waste per trip for BS VI (g/t/trip)	311
Table- 8.9	Pollutant emission rate by DV4 per ton of waste per trip for BS VI (g/t/trip)	312
Table- 8.10	Pollutant emission rate by HV per ton of waste per trip for BS VI (g/t/trip)	313
Table- 8.11	Pollutant emission rate by HV per ton of silt per trip for BS VI (g/t/trip)	314
Table- 8.12	Pollutant emission rate by heavy duty LPT truck per ton of silt per trip for BS VI (g/t/trip)	315
Table- 8.13	Pollutant emission from transportation sector for BS-IV and BS-VI	317
Table- 9.1	Types of cost in two dumpsite condition for proposed ISWM system	326
Table- 9.2	Comparison of PEI of each category and sub-category for all two dumpsite configurations	332
Table- 9.3	Effects on cost components in percentage for variation of waste generation	333
Table- A.6.1	Maximum facility discharge of liquid pollutants	398
Table- A.6.2	Material balance for gas generation	400
Table- A.6.3	Farakka coal consumption and emission data (Pit et al., 2016).	400

LIST OF ABBREVIATIONS

Table No.	Title
MSW	Municipal Solid Waste
LP	Linear Programming
USEPA	United States Environmental Protection Agency
CPCB	Central Pollution Control Board
KMC	Kolkata Municipal Corporation
SWM	Solid Waste Management
ISWM	Integrated Solid Waste Management
MSWM	Municipal Solid Waste Management
ESWM	Existing Solid Waste Management
SPM	Suspended Particulate Matter
COPD	Chronic Obstructive Pulmonary Disease
LEACHM	Leachate Estimation and Chemistry Model
SETAC	Society for Environmental Toxicology and Chemistry
PEI	Potential Environmental Impact
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
GWP	Global Warming Potential
AP	Acidification Potential
POCP	Photo- chemical Ozone Conversion Potential
ODP	Ozone Depletion Potential
HTPE	Human Toxicity Potential by Inhalation
HTPI	Human Toxicity Potential by Ingestion
TTPL	Terrestrial Toxicity Potential by Liquid
TTPG	Terrestrial Toxicity Potential by Gas
ATP	Aquatic Toxicity Potential

AHP	Analytic Hierarchy Process
CPHEEO	Central Public Health & Environmental Engineering Organization
MT	Metric ton
LFG	Landfill Gas
ELF	Engineered Landfill
EPA	Environmental Protection Agency

1 INTRODUCTION

Throughout history, both humans and other animals have relied on the resources of the earth to sustain life and dispose of garbage that is deemed unnecessary or unwanted (Tchobanoglous et al., 1997). Because population was small and there was a large area of land available for the absorption of such wastes, there were no major issues with waste disposal back then.

1.1 CHALLENGES OF PRESENT SOLID WASTE MANAGEMENT

People from rural and semi-urban areas have been migrating continuously into towns and cities throughout time. Thousands of tonnes of MSW have been produced as a result of the migration of people from rural to urban areas brought on by rapid industrialization and population growth of the country, India (Gupta et al., 2015). The proportion of the population living in urban areas has risen from 10.84% in 1901 to 35.39% in 2021; 25.70% in 1991 and 31.28% in 2011 (Statista, 2022). With a 2.05% increase from 2021 to 2022, approximately 35.87% of the population of India lives in urban areas (Statista, 2022). Between 1901 and 2011, the number of class I cities increased from 24 to 468, while the number of class II cities increased from 43 to 474 in the same time frame. (Shaban et al., 2020). Compared to class II cities, the population growth of class I cities are substantially higher. Several Indian cities lack basic infrastructure services, including municipal solid waste management system, water supply, and sewage systems, as a result of uncontrolled urban growth.

Most of the urban areas in the country suffer from severe solid waste-related issues. One inevitable result of human activity is waste. The amount and complexity of waste produced has increased because of urbanisation, economic growth, and rising living standards in cities (Guerrero et al., 2013). Equitable and sustainable development is threatened by the rapidly increasing population and industrialization, which wreaks havoc on natural resources and deteriorates the urban environment. In most developing-nation cities, improper solid waste management and disposal is a clear contributor to environmental damage (Narayana, 2009).

Currently, consumption of goods is increasing in the world and so is the generation of Municipal Solid Waste (MSW). MSW, sometimes referred to as urban waste, is a type of waste that is mostly collected by a local municipality from households, including commercial waste. Biomedical waste and industrial hazardous waste are not included in MSW. Now, almost 36% people of total population are living in urban India (World Bank, 2022). The country generates 160038.9 TPD of solid waste in total, out of which 152749.5 TPD is collected at a 95.4% collection efficiency, 79956.3 TPD (or 50%) is processed, and 29427.2 (18.4%) TPD is landfilled. 50655.4 TPD, or 31.7%, of the entire amount of waste generated is still unaccounted for (CPCB, 2021). Solid waste generation in small, medium, and large cities and towns is estimated to be 0.1 kg, 0.3-0.4 kg, and 0.5 kg per capita per day, respectively. In large cities, the amount of waste generated per person ranges between 0.20 to 0.6 kg (Kumar et al., 2017). In large metropolises, collection efficiency typically falls between 70 and 90%, while in many smaller cities; it is less than 50% (CPHEEO, 2000; Talyan et al., 2008). Over the past few decades, there has been an annual rise in the amount of waste generated per capita of 1 to 1.33%. The biodegradable fractions (40–60%) and inert (30–50%) in metropolitan areas represent the majority of MSW. Waste collection, sorting, transportation, and disposal are all unclear under the current situation. Successful waste processing requires source segregation, however household and community bin source segregation systems are not well-organized or planned.

One of the most important and required duties of Urban Local Bodies of India is Solid Waste Management. There are issues with health, sanitation, and environmental degradation due to inadequate performance of this service and lack of customer satisfaction. Most urban areas in the country suffer from severe solid waste-related issues. Waste and its management have become a persistent problem since town or city authorities have yet to make significant efforts in this area, even though waste accounts for the majority of municipal spending. The level of services provided for the collection and disposal of municipal solid waste, including garbage from hospitals and industries, as well as for making sure that environmental sanitation and public hygiene standards are met, has been gradually declining. Due to the lack of appropriate facilities to process and dispose of the increasing volume of MSW generated every day in metropolitan areas, MSW management is currently experiencing a critical phase (Sharholly et al., 2008).

Unscientific disposal has a negative effect on human health and other aspects of the environment. (Goutam et al., 2012).

In many other developing nations, like India, open dumping, or uncontrolled land disposal of solid waste, remains the predominant mode of disposal (Oakley et al., 2012). Municipal solid waste is typically disposed of in low-lying locations without any operational controls or measures (Sharma et al., 2018). Over 90% of the collected municipal waste is disposed of in an open manner without any treatment. It can result in an unpleasant smell, an increase in mice and vermin, and wind-blown litter. Through cockroaches, mice, wandering animals, etc., it can spread epidemics. It has the potential to produce greenhouse gases (GHGs) and contaminate nearby soil, which could contaminate ground water. Runoff from the waste disposal may also contaminate surface waters. As a result, the simultaneous physical, chemical, and biological breakdown of the solid waste produces landfill leachate and the extremely polluting landfill gas methane, which exacerbates the effect of global warming. In addition, CO₂, water, and trace elements like NH₃, sulphide, and volatile organic carbon compounds (VOCs) are produced at these dumpsites. CH₄ has a 28-fold higher 100-year global warming potential than CO₂ (Singh et al., 2018). The majority of the waste-transporting vehicles owned by municipal bodies are old enough to operate well. This results in a decrease in the efficiency of waste collection as well as an increase in contaminants that pose health risks. In addition to landfill gases, vehicle operations that involve the collection, storage, processing, and disposal of MSW to landfills release pollutants into the environment. These activities can include CO, SO₂, NO_x, CO₂, PM, hydrocarbons, benzene, and butadiene. These pollutants may have an adverse effect on human health and lead to environmental degradation.

Therefore, one of the main environmental issues facing Indian megacities is Municipal Solid Waste Management (MSWM) (Koushal et al., 2012). MSW management needs adequate infrastructure, maintenance, and continuous improvement of all processes. The continuous and unplanned expansion of metropolitan areas makes the MSW management more costly and complex (Kumari, 2019), and these unplanned and ongoing expansion of metropolitan areas makes it more and more costly and complicated (Sharholly et al., 2008). The difficulties in providing the desired level of public service in the urban areas are often attributed to the financial status of the municipal corporations in the city. The

Indian constitution states that solid waste management is under the jurisdiction of state list and is a component of public health and sanitation (CPHEEO, 2000). Since it is a local endeavor, the Urban Local Bodies are in charge of it. With the help of its employees, resources, and equipment, the Urban Local Body delivers solid waste services. Sometimes, private businesses are hired to do a portion of the job. There are extremely few urban local bodies in the nation that have created long-term strategies for effective solid waste management within their own cities. Establishing a long-term sustainable foundation for the system is crucial to achieving a long-term economic solution.

1.2 ENVIRONMENTAL IMPACT AND SUSTAINABLE WASTE MANAGEMENT

Environmental impact is a matter of global concern. Pollution of air, water and land is increasing day by day. The sustainability of the environment is deteriorated by improper and inadequate waste management (Banerjee et al., 2023). It is a man-made process, which is continuously polluted our environment. But the environment is not cleaned entirely by natural processes and its pollution becomes a major threat for sustainable development. So, proper management is needed to reduce the impact of several pollutants. To reduce the effect of pollution, the impact of pollution on our environment has to be measured first. After assessing the quantitative impact of pollution on ecosystem, human health and natural resources, we can proceed to decrease the pollution level to make our environment more hospitable. Anthropogenic sources (human activities) such as automobiles, the burning of fossil fuels to generate heat and power, industrial operations, and solid waste disposals etc. are the main cause to make the earth's surface more polluted.

An adequate Integrated Solid Waste Management (ISWM) should be approached in order to meet the requirements for a coherent waste management system. A methodical approach to waste management is to adhere to the waste management hierarchy. Therefore, it is necessary to have an effective waste management system that can control any flaws completely and adhere to all environmental, fiscal, and sustainable criteria. Applying the ISWM principles is necessary for proper SWM. With the goal of minimizing waste generation at its source, the ISWM approach recycles, reuses, and

processes waste, with material and energy recovery. The treated garbage is then safely disposed of in an engineered landfill site. Geographic Information System (GIS) can be suggested in the planning of waste bin positioning system and best possible routing of waste transport vehicles that can reduce overall SWM cost and pollution impacts on the environment in order to optimize waste collection and transportation system (Ghose et al., 2006; Khan and Samadder, 2014). As a result, ISWM is an essential management tool that helps an MSW management system both maximize its cost-effectiveness and reduce the level of pollution coming from different sectors. In order to achieve sustainable development, an ISWM system is therefore necessary, and in order to properly execute an ISWM system, a mathematical model for the MSW management of a city in a developing nation must be developed.

In present scenario, there are many limits stated by pollution control board and regulatory authorities (SWM Rules, 2016; CPCB, 2009). They have given specific standard limits for individual pollution emission concentration. But they do not suggest the combined effect of all the pollutants and thus the net effect is not actually assessed. So, the quantitative measurement of the environmental impact is also necessary.

Considering the present scenario, it is necessary to develop a mathematical model to make an appropriate balance between the reduced quantitative environmental impacts and cost effectiveness in the MSWM systems. It would also help in achieving maximum output, eliminating inefficiencies and facilitating cost-saving effort through proper planning and decision making regarding MSWM, especially in developing countries. The schematic for introducing the problem of the present study is shown in below.

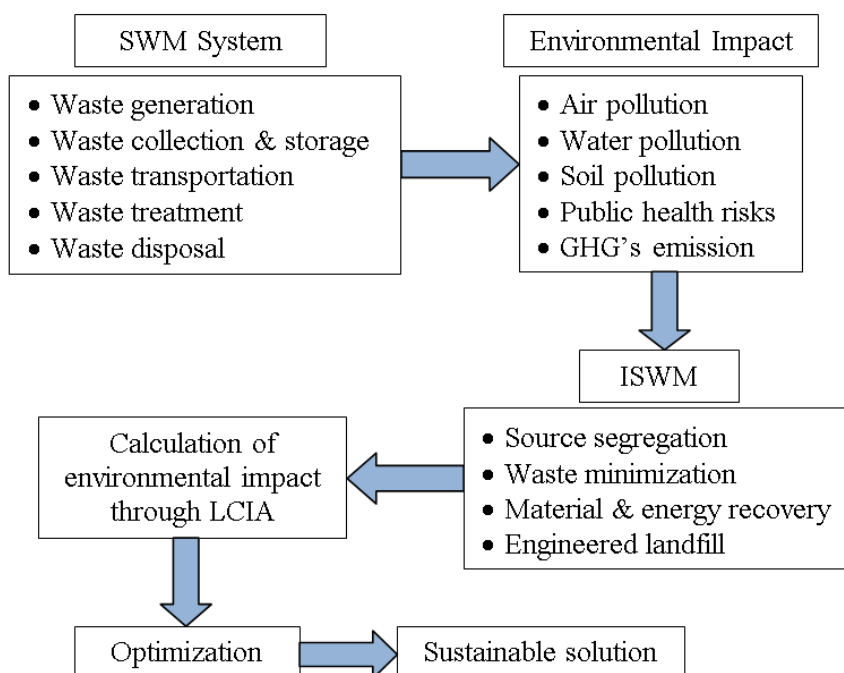


Figure- 1.1: Schematic of the problem

This thesis is made up of a series of chapters, beginning with the introduction and continuing with the following chapters: literature review; objective and scope of the study; development of municipal solid waste management (MSWM) optimization model; existing solid waste management (SWM) system of Kolkata- the study area; validation and analysis of solid waste management optimisation model; application of model in proposed integrated solid waste management (ISWM) system of Kolkata; comparative study of solid waste management system of Kolkata; model analysis of proposed ISWM system of Kolkata in different operating conditions; and a conclusion.

2 LITERATURE REVIEW

An extensive literature search was conducted for this chapter covering a wide range of topics related to the generation of municipal solid waste, including its toxicity and health effects, air pollution from the waste transport sector, and treatment processes such as incineration, engineered landfills, composting, and landfill gas. The literature search was also carried out for leachate-related contamination of surface and groundwater and pollution of land, the use of an integrated solid waste management approach, and the development of a Linear Programming (LP) model. The objective and scope of the present study have been identified based on the literature survey.

2.1 SOLID WASTE: GENERATION, SOURCE AND TYPE

Waste has been produced by humans since the dawn of civilization. The complexity of waste generated increased as civilization advanced. With the industrial revolution at the close of the 19th century, the universe of consumers expands. Mishra (2013) conducted research indicating that the production of non-biodegradable solid waste leads to an increasing amount of air pollution as well as global pollution. It appears that the increase in solid waste, which, if not adequately managed, may threaten both public health and the environment, is also primarily attributable to population growth and urbanization (Minghua et al., 2009).

According to the Resource Conservation and Recovery Act, almost everything we do generates waste, USEPA, 1976. Solid waste comprises any waste generated by commercial, industrial, mining, agricultural, or community activities; it also includes any municipal trash or refuse, sludge from wastewater treatment plants, water supply treatment plants, and air pollution control facilities, and other disposed things (USEPA, 2023). It is significant to remember that wastes that are physically solid are not the only kind of waste that fall within the definition of solid waste. It includes both the relatively homogeneous accumulation of waste from industry, agriculture, and mining as well as the very heterogeneous quantity of materials discarded from the urban community (Sufian et al., 2007).

Waste management has traditionally rested in the purview of engineering. The reason is that although mass manufacturing has advantages, it has additionally created challenges for the disposal of solid waste. This is all related to how technology has transformed society. Figure 2.1 provides a schematic illustration of the material flow and garbage generation that occurs in a technological society. It shows how and where solid waste is generated in a technological society.

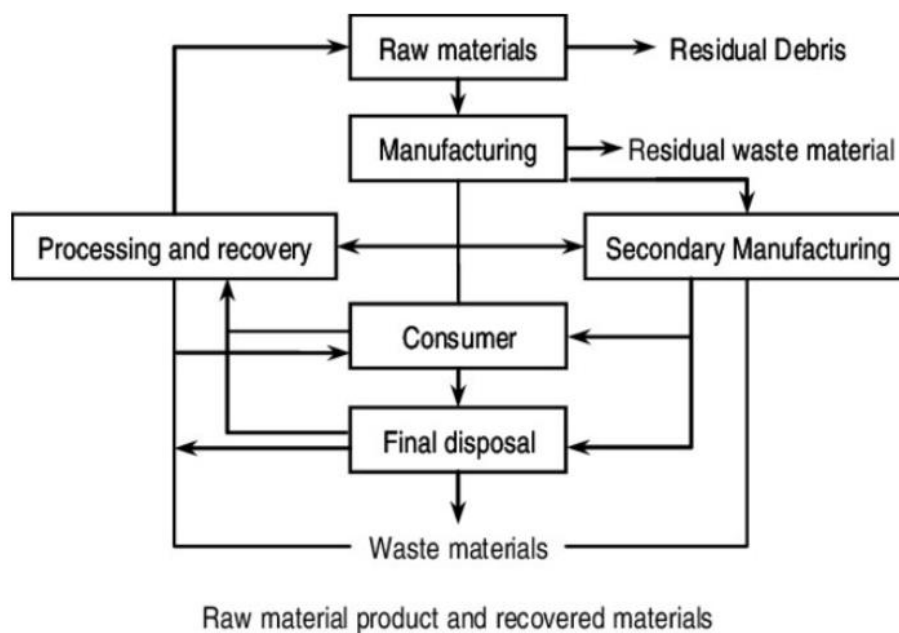


Figure- 2.1: Material flow and the generation of solid waste (Syed S., 2006)

Solid wastes are generated at the outset of the process, such as the mine wastes from a mine or the abandoned cornhusks from a cornfield, when raw materials are mined and produced. More waste are produced during the later stages of the processes as raw materials are transformed into items for consumption after they have been mined, collected, or otherwise obtained. As shown by the diagram in Figure 2.1, reducing raw material consumption and increasing the rate of waste material recovery and reuse are two of the greatest strategies to decrease the amount of solid waste that needs to be disposed off. Reducing the quantity and toxicity of waste produced is the most efficient approach to address the solid waste disposal issue; nevertheless, as people strive for greater living standards and a better life, they also tend to consume more items and produce more waste. As a result, society is looking for better ways to manage waste and ways to cut down on the quantity of waste that needs to be landfilled.

Solid waste is generated in metropolitan areas because of the product consumption process. Solid waste is also produced in metropolitan areas by various activities including air pollution control, wastewater treatment, street and park cleaning, etc. (Shafy et al., 2018). A society releases solid waste into the environment as an output and gets energy and raw materials as inputs from the environment. Such an imbalance between input and production deteriorates the environment over time. For designing of a solid waste management system, it is necessary to consider the total generation rates of solid waste for the community, the generation rates of public spaces, residential buildings, and commercial, industrial, and institutional establishments. The engineering management of solid wastes requires an understanding of the sources, types, composition, and rates of generation of solid wastes. Solid waste sources in a community are typically associated with zoning and land use (Flintoff, 1984).

Based on the source, composition, and potential for hazard, solid waste can be broadly divided into three categories- Municipal Solid Waste (MSW), Industrial Solid Waste and Biomedical Solid Waste. It can be further divided into household, commercial, industrial, building, or institutional waste based on where it came from. On the other hand, it is separated according to its contents, such as organic material, glass, metal, plastic, paper, etc. wastes are categorised as broadly as possible considering factors such as radioactivity, flammability, non-toxicity, and hazard potential.

2.2 MUNICIPAL SOLID WASTE (MSW) GENERATION

In the modern world, municipal solid waste (MSW) is a challenge that is increasing significantly along with a wide range of other issues on all fronts (Bahukahndi et al., 2022). Municipal solid waste (MSW), one of the most significant by-products of an urban lifestyle, is increasing at a rate that is even faster than urbanisation as the globe rapidly approaches an urban future (Tahir et al., 2015). Growing amounts of MSW are becoming a global financial burden and sustainability concern, but it also presents a chance to advance the circular economy (He et al., 2022). Understanding the quantity and types of waste generated within and near the municipality is crucial for planning waste management facilities within the same municipal waste management system (UNCHS, 1994). To prepare for future facility provision, projected increases in quantities of each waste stream should also be predicted. To choose the best course of action for treatment and disposal, it is also essential to understand the makeup of the waste stream (Yedla et

al., 2001). Global MSW generation was estimated to be 2,010 million metric tonnes (MMT) annually in 2016, and by 2050, it is predicted to reach about 3,400 MMT. This might result in a significant rise in MSW generation of roughly 70% in just 34 years (Sharma et al., 2020), Asia will contribute one-third of it, with China and India making significant contributions (Kumar et al., 2017). The amount of waste generated daily per person worldwide varies greatly, ranging from 0.11 to 4.54 kilograms on an average. High-income nations produce over 34%, or 683 million tonnes, of the world's garbage, but make up only 16% of the global population (World Bank, 2018). Waste generation in developed countries is more than the less developed countries. Table 2.1 shows the per capita MSW generation in different countries (Kawai and Tasaki, 2015; Hoornweg et al., 2012).

Table- 2.1: Per capita MSW generation of different countries

Country	Quantity (Kg/capita/day)
India	0.34-0.37
U.S.A.	1.25-2.58
U.K.	1.34-1.79
Singapore	0.94-1.49
Japan	0.9-1.71
China	0.31-1.02
Indonesia	0.49-0.52

As per the published report by the World Bank in 2012, the per capita waste generation in sub-Saharan Africa spans a wide range, from 0.09 to 3.0 kg per day; in East Asia per capita waste generation ranges from 0.44 to 4.3 kg per person per day for the region; in Eastern and Central Asia, the per capita waste generation ranges from 0.29 to 2.1 kg per person per day; per capita values ranging from 0.1 to 14 kg/capita/ day, for Latin America and the Caribbean region; in the Middle East and North Africa, per capita waste generation is 0.16 to 5.7 kg per person per day; the per capita values range from 1.1 to 3.7 kg per person per day for the OECD countries; In South Asia, per capita values ranging from 0.12 to 5.1 kg per person per day.

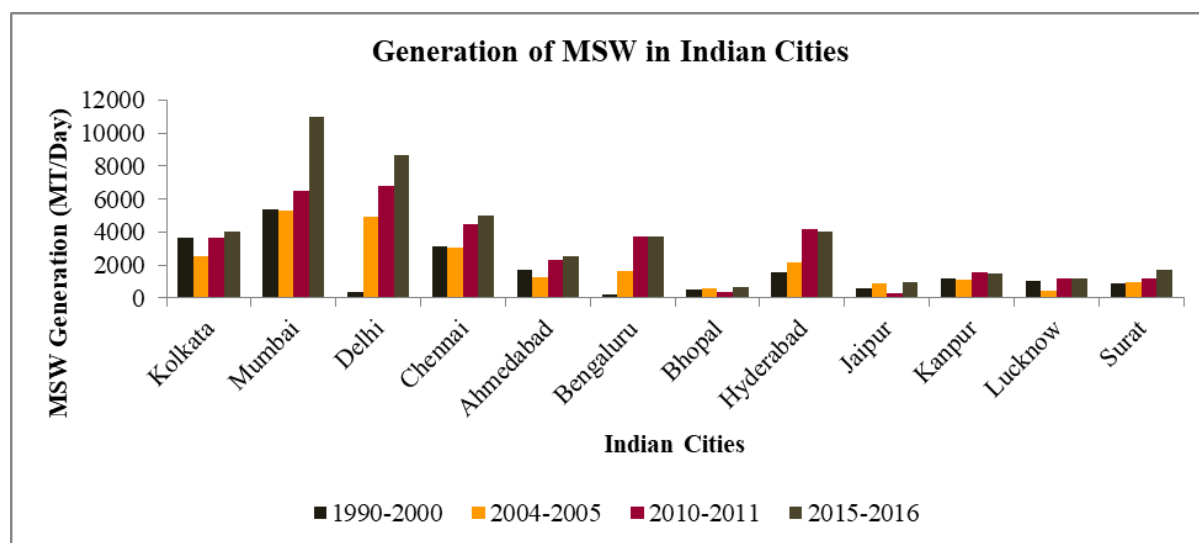
India is rapidly becoming a more urbanized nation, yet it still has a diverse population in terms of geography, climate, ecology, social structure, culture, and language. Due to growing urbanisation and shifting lifestyles, Indian cities currently produce eight times as much MSW as they did in 1947 (Sharholy et al., 2008). India had 1210 million people living there in 2011 as opposed to 1028 million in 2001. One of the main causes of the rising quantity of MSW in India is population increase. In developing countries the average rate of MSW generation is 0.3 - 0.5 kg/person/day (Mir et al., 2021). In India, per capita waste generation ranges 0.26-0.85 kg/day (Kumar et al., 2020), the yearly growth in MSW generation (volume) is projected to be 1.33% per capita (Srivastava et al., 2014). The rate of waste generation in India has increased significantly due to the rapid urbanization and population growth of the country (Shahab et al., 2022; Ahsan et al., 2014).

Compared to metropolises, smaller towns generate less MSW. In small towns and cities with populations under one lakh, the waste generation rate is 0.17–0.54 Kg/capita/day; in cities with populations between one to five lakhs, it is approximately 0.22–0.59 Kg/capita/day; in cities with populations between ten lakhs and twenty lakhs, it is 0.19–0.53 Kg/capita/day; and in cities with populations over two million, it is 0.22–0.62 Kg/capita/day (Koushal et al., 2012).

In just a decade from 2001, the quantity of waste produced by Indian cities has increased by 50% due to urban population growth and increasing per capita waste generation (Sharma, 2018). India is thus challenged with an imbalance between the amount of resources and services it has access to and its increasing urban population. According to a recent projection by the Central Pollution Control Board (CPCB), annual waste generation in India is expected to reach 165 MT by 2030. It is anticipated that the amount of hazardous, plastic, e-waste, and biomedical waste produced will rise correspondingly (ITA, 2023). Table 2.2 shows the generation trend of MSW in Indian cities (CPCB, 2016).

Table- 2.2: Generation trends of MSW in Indian cities (CPCB, 2016)

City	MSW Generation (MT/Day)			
	1990-2000	2004-2005	2010-2011	2015-2016
Kolkata	3692	2563	3670	4000
Mumbai	5355	5320	6500	11000
Delhi	400	4922	6800	8700
Chennai	3124	3036	4500	5000
Ahmedabad	1683	1302	2300	2500
Bengaluru	200	1669	3700	3700
Bhopal	546	574	350	700
Hyderabad	1566	2187	4200	4000
Jaipur	580	904	310	1000
Kanpur	1200	1100	1600	1500
Lucknow	1010	475	1200	1200
Surat	900	1000	1200	1680

**Figure- 2.2:** Generation trends of MSW in Indian cities

2.2.1 Past Studies Analysis on MSW Generation of Kolkata

A review of several reports regarding the history of waste generation in Kolkata reveals a great deal of variety in generation. Table 2.3 provides an explanation of the overall amount of MSW generation evaluated in these publications (ADB, 2005). The report of the Talukdar Committee stated that the amount of waste generated per day was 2115 MT in 1963, and the report of Mr. M.G. Kutty stated that the amount was 1500 MT per day. In 1992, 3150 MT of waste was produced daily, as reported in the Institute of Local Government & Urban Studies Report. Waste production, including silt content (200 MT/day), was projected in a 1999 KMC assessment study to be 2600 MT/day. According to multiple statistics, the KMC area currently generates between 4500 to 4600 MT of municipal solid waste per day.

Table- 2.3: Study reports on assessed quantity of MSW generation of Kolkata
(ADB, 2005; Chattopadhyay S, 2018)

Sl. Nos.	Source	Year of estimation	Estimated Quantity (MT/d)
1.	Talukdar Committee's Report	1963	2115
2.	Mr. M.G. Kutty's Report	1963	1500
3.	NEERI Report	1970	1640
4.	Task Force(CMDA Report)	1973	1600-1800
5.	Report of CE (MV & CON), CMC	1983	1800
6.	Calcutta Management Association Report (10 Boroughs)	1985-87	1750+200 (silt)
7.	Report of Institute of Local Govt. & Urban Studies	1992	3150
8.	Report of CMC	1993	3100-3400
9.	Report of KMC on assessment	1999	2400+200(silt)
10.	Study of Chattopadhyay S.	2018	4000

2.3 MUNICIPAL SOLID WASTE (MSW) COMPOSITION

To design and choose the collecting, processing, and disposal components of the system, the waste is often analysed to determine its physical and chemical characteristics (Flintoff, 1984). Climate and seasonal variations, the amount of local financing available

to waste service providers and municipalities, and the rate of generation of solid waste are the key elements that affect it. Other important factors are the physical attributes of the cities, the economy of the area, social norms, and customs of religion, awareness of public health, technical proficiency and administrative quality, and the need to meet environmental standards (WHO, 1976). The local economy has an effect on the composition of waste since wealthier communities use more packaged goods, which raises the amount of plastics, paper, glass, metals, and textiles in the waste stream. Waste management procedures may be significantly impacted by changes in the mix of waste (Kumar et al., 2017). Appropriate waste management system planning requires accurate data regarding the amount and composition of solid waste generated. The mix of MSW generated is indicative of economic standard of a nation (Srivastava et al., 2014). Table 2.4 shows the composition of MSW of high, middle and low income countries.

Table- 2.4: Relative composition of solid waste for low, middle and high income Country (Cointreau, 2006)

Parameters	Low Income Country	Middle Income Country	High Income Country
Organic matter	40-85	20-65	20-30
Paper	1-10	15-30	15-40
Plastic	1-5	2-6	2-10
Metal	1-5	1-5	3-13
Glass	1-10	1-10	4-10
Rubber, leather etc.	1-5	1-5	2-10
Others	15-60	15-50	2-10
Moisture content (%)	40-80	40-60	5-20
Density (Kg/m ³)	250-500	170-330	100-170
Calorific value (Kcal/Kg)	800-1100	1000-1300	1500-2700

Table 2.5 illustrates the waste composition generated in various developing countries of Asia. Most of the waste is made up of organic materials. The countries with the most organic material were found to be Indonesia (74%), China (59%), and Kathmandu, Nepal (67.8%).

Table- 2.5: MSW composition of different developing countries (Srivastava et al., 2014)

Parameters	Nepal	India	China	Vietnam	Indonesia	Malaysia
Organic matter	67.8	42.0	59.0	49.4	74.0	44.8
Paper and paper board	6.5	6.0	8.0	14.7	10.0	16.0
Plastics	0.3	4.0	10.0	15.1	8.0	15.0
Glass/ ceramics	1.3	2.0	3.0	9.7	2.0	3.0
Metals	4.9	2.0	1.0	3.4	2.0	3.3
Textiles and others	19.2	44.0	19.0	7.7	17.9	17.8

Similarly, Table 2.6 provides the composition of waste generated in metropolitan cities of India.

Table- 2.6: The composition of MSW in different developing countries (Srivastava et al., 2014; CPCB, 2005)

Parameter	Chennai	Delhi	Kolkata	Mumbai
Organics (%)	41	54	51	62
Recyclables (%)	16	16	11	17
Others (%)	43	30	38	21
Moisture Content (%)	47	49	46	54
C/N ratio	29	35	32	39
HCV (Kcal/Kg)	2594	1802	1201	1786

The physical and chemical properties influence the selection of collecting frequency, security measures to be taken during transportation and processing and disposal methods. Tables 2.7 and 2.8 show the variations in the physical composition and chemical properties of MSW in Kolkata in 1970, 1995, and 2005. Waste compositions varied significantly between two distinct years, which has been linked to shifts in socioeconomic circumstances in the region over this time (Chattopadhyay et al., 2009). There is an increasing amount of information indicating that formal recovery and recycling facilities will be a financially feasible option (Kaushal et al., 2012).

Table- 2.7: Physical composition variation of MSW in Kolkata
(Chattopadhyay et al., 2009)

Sl. No.	Parameters	1970	1995	2005
1	Biodegradables	40.36	44.29	50.56
2	Green coconut shells	4.95	8.51	4.50
3	Paper	3.17	4.64	6.07
4	Plastics	0.64	3.22	4.88
5	Metals	0.66	0.43	0.19
6	Glass & Crockery	0.38	1.72	0.34
7	Coal	6.08	3.10	-
8	Inert	40.76	26.82	29.60
9	Others*	3.00	7.27	3.86

All values are in percent by wet weight; *Bio-resistant and synthetic material.

Table- 2.8: Chemical Characteristics Variation of MSW in Kolkata
(Chattopadhyay et al., 2009)

Sl. No.	Parameters	1970	1995	2005
1	Moisture	42.84	61.57	46.00
2	pH	7.31	6.33	0.3-8.07
3	Loss on ignition	35.24	46.78	38.53
4	Carbon	19.58	25.98	22.35
5	Nitrogen as N	0.55	0.88	0.76
6	Phosphorous as P ₂ O ₅	0.57	0.58	0.77
7	Potassium as K ₂ O	0.40	0.93	0.52
8	C/N ratio	35.60	29.53	31.81
9	Calorific value kj kg ⁻¹	2300	2717	5028

All value is in percent by dry weight basis except pH, C/N ratio and calorific value.

As Table 2.7 illustrates, both the biodegradable fraction and the amount of plastic and paper used on a daily basis are at increasing levels. An increase in the use of domestic gas results in a decrease in the coal proportion. Because the proportion of organic matter in these wastes is large, biological treatment methods like composting and bio-gasification are suitable. In Table 2.8, chemical properties indicate a trend towards declining increment of moisture content. The main cause of this is probably the increased amount of fresh, unprocessed vegetable waste. Even though the calorific value of waste increased significantly in 2005, still it is not suitable for incineration.

2.4 SOLID WASTE MANAGEMENT (SWM) SYSTEM

Solid Waste Management (SWM) encompasses a variety of concerns that need to be considered to find solutions that are both environmentally sustainable and economically viable. These concerns include issues related to waste generation, collection, transportation of waste, recovery, and recycling, processing (thermal processing i.e. incineration, gasification, pyrolysis, and biological processing i.e. composting, biomethanation and disposal as well as issues related to technology, economics, law, and society (Akhter et al., 2015). The primary goal of SWM is to provide future generations with an uncontaminated, safe, and healthy environment that does not deplete natural resources (Abubakar et al., 2022). Effective SWM supports safe disposal, waste reduction, and recycling. On the other side, an ineffective SWM system impairs public health, produces environmental degradation, degrades natural resources, contributes to climate change, and has a negative impact on the quality of life of citizens and animals. The lack of resources, population growth, increasing urbanization, industrialization and other anthropogenic activities lead to severe issues with waste management and disposal (Lingan et al., 2014; Hajam et al., 2023). The six functional elements of municipal solid waste management are waste generation, handling and sorting, storage, and processing at the source, collection, sorting, processing, transformation, transfer and transport, and disposal, which can be used to categorize the various activities involved in managing waste (Byakodi et al., 2016).

The functional components of SWM system include the generation of solid wastes. The reduction of waste generation would be substantially aided if this function could be reduced by informing individuals on appropriate collection, transportation, disposal, and sorting techniques (Lagbas, 2015). Currently, waste generation is an activity that is

difficult to control. But going forward, there is probably a need to be more control over the generation of waste. One way to restrict the amount of waste generated is to minimize waste at the source, which is now a component of the system evaluations even though it is not under the control of solid waste management. Managing wastes until they get placed in storage containers for collection is the process of waste handling and sorting. Transporting loaded containers to the collection place is also included in the handling process.

To handle and store solid waste at the source, sorting waste components is a crucial step. Commingled waste is typically sorted at disposal sites, transfer locations, combustion premises, and materials recovery facilities. Bulky item separation, size-based screen separation of waste components, manual waste component separation, and ferrous and non-ferrous metal separation are common sorting techniques. MSW can undergo a number of biological and thermal procedures to convert its organic fraction. Aerobic composting is the biological transformation method that is most frequently utilized (Babu et al., 2021). Incineration is the thermal transformation method that is most frequently utilized. Waste transformation is the process of reducing size, weight, volume, or toxicity of waste without recovering any resources. A range of mechanical, thermal or chemical methods may be employed to achieve transformation (Dalal, 2017).

The two processes that make up the functional part of transfer and transport are (i) moving wastes from the smaller collection vehicle to the bigger transport equipment and (ii) moving the wastes to a processing or disposal facility, often over long distances. Usually, a transfer station is the place where it happens. All solid wastes currently are disposed off in landfills or uncontrolled disposal, irrespective of whether they are waste from various solid waste-processing plants, materials that remain from Materials Recovery plants (MRFs), refuse from the combustion of solid waste, or garbage from residential waste collection and transportation straight to a landfill (Raju et al., 2018).

To prevent leachate pollution of groundwater due to percolation or leaching, modern engineered landfills are constructed with an impermeable liner covering the bottom of the waste. This liner is often composed of multiple layers of thick plastic and sand. To stop water seepage when it is full, it is covered with layers of gravel, sand, clay, and top soil cover (Nayak, 2022). Before being released into the surface water or another medium, leachate from the bottom is pumped out and transferred for treatment (Mukherjee et al.,

2014). A few wells are drilled close to the landfill in order to monitor and perhaps reduce leachate contamination of groundwater. To generate revenue, the methane produced by anaerobic decomposition is captured and burned to provide heat or electricity (Zaks et al., 2011).

2.4.1 Case Studies of SWM System of Other Metropolitan Cities of Developing Countries

2.4.1.1 Case Study- I: Solid Waste Management in Dhaka City, Bangladesh

The Dhaka City Corporation (DCC) is responsible for waste collection and management. Every day, over 5000 tons of rubbish are generated in Dhaka, with just slightly more than half of that being properly collected and thrown away (Prodhan et al., 2020). As a result, huge quantities of waste are mishandled on a daily basis due to lack of fund and infrastructure (Yasmin et al., 2017). Improper management results in an enormous quantity of uncollected waste, which has led to environmental hazards all through the city. Community-based door-to-door rubbish collection has been established in some regions, which has improved service delivery. Informal recycling sectors contribute significantly to waste recovery while also providing employment possibilities. Waste is typically collected in a non-segregated way and dumped in small bins at residences. DCC-delegated entities then collect waste in vans and transport it to secondary collection stations. Waste trucks subsequently transport the waste to landfill locations. Waste is sometimes disposed of in unclean landfills, causing environmental and health dangers. Lack of source segregation and limited recycling facilities impede effective waste management. DCC has promoted waste management services through innovative approaches such as the 3Rs strategy, the development of a sanitary landfill, a waste-to-energy plant, and the conversion of organic waste into compost, all with the goal of reducing landfill dependency and promoting sustainable agriculture (Prodhan et al., 2020).

2.4.1.2 Case Study- II: Solid Waste Management in Kathmandu, Nepal

For more than a decade, solid waste management in Nepal's Kathmandu valley has been an issue, particularly in terms of landfill site selection. Kathmandu Municipal Corporation (KMC) collects almost all of Kathmandu City's waste. Wards of Kathmandu Metropolitan City are in charge of waste collection within their respective jurisdictions. In Kathmandu,

the private sector also collects solid waste. In addition to the dominant KMC, the number of solid waste management businesses has grown significantly in recent decades. There is no established route map for transporting collected solid waste to a transfer station or final disposal facility. Today, several private organizations carry waste. Currently, KMC only has one transfer station (TS) at Teku. All rubbish dumped on the roadside is cleaned, collected, and transported here by tippers and tractors. Scavengers sort the waste before transporting it to a landfill for eventual disposal (Alam et al., 2008).

According to the survey results, solid waste collection rates are far lower than the metropolis' reported 90%, and street sweeping uses around 51% of its solid waste budget. Because of the comparatively poor collection rates, city residents are encouraged to dump waste on public lands. As a result, too many of the city's resources are devoted to sweeping rather than collection. To ensure solid waste management, Kathmandu must recognize informal rubbish pickup, privatize, employ local methodologies, increase capacity, encourage bottom-up and participatory management styles, and control legislation (Dangi et al., 2009).

The current practice is to collect and transport waste and illegally dump it along river banks, resulting in serious environmental and public health hazards. At present, the solid waste of the Kathmandu valley is being dumped on the Bagmati River's bank close to Balkhu in Kathmandu, overlooking the impact on the health of the local people and water supplies. There is a lack of strong legislation, limited institutional experience, and insufficient political commitment to properly address waste management. Limited public knowledge and awareness about the environmental and health consequences of inappropriate garbage disposal hinders community engagement in waste management activities. Composting is the best environmentally friendly disposal technique because of the substantial amount of organic material in waste, more than 70%. This would increase operational lifespan of landfill and decrease the amount of waste that is delivered there. Also promoting the separation of recyclables at the point of generation can save treatment expenses and increase effectiveness of waste management systems. To improve MSWM in Nepal, it is imperative to invest in infrastructure, strengthen institutional capacities, and strengthen legislation (Pokhrel et al., 2005).

2.4.1.3 Case Study- III: Solid Waste Management in Hanoi, Vietnam

Hanoi, capital of Vietnam has a population of around 7 million. In 2011, the city generated around 2,372,500 tons of MSW, representing for 11% of national generation. The collection rate was 85%, with 84% going directly to landfills (without gas capture systems). This technique has negative environmental effects, increased greenhouse gas emissions, and reduced recyclable resources. Organic waste makes up 71% of municipal solid waste in Hanoi, indicating a significant opportunity for organic waste recovery (Thanh et al., 2015).

Waste management primarily relies on landfilling, with few waste-to-energy operations. Community-based waste management strategies have been tested in places such as Sai Son commune. (Hoa et al., 2016). At present, Vietnam has committed to collecting, transporting, and treating 100% of non-household waste by 2025 and 85% of waste discharged by households by 2025 (Hoang et al., 2020).

2.4.1.4 Case Study- IV: Solid Waste Management in Kuala Lumpur, Malaysia

Due to the rapid urbanization and population increase, Kuala Lumpur, capital of Malaysia, is facing considerable issues in handling MSW and the complexity of waste types generated on a daily basis (Zainu et al., 2015).

As of 2014, Kuala Lumpur produced around 3,100 tonnes of MSW per day, with a per capita generation rate of 1.62 kg/day. The waste makeup is largely organic, with food waste accounting for around 41%, followed by mixed paper and plastics. The city predominantly uses landfilling for disposal of waste that, while cost-effective, possesses adverse environmental effects (Karuppannan, S., 2016). Disposal sites are becoming rare, with many approaching the end of their useful lives. Despite government efforts to promote recycling, popular engagement and attitudes in Malaysia have remained lukewarm (Zainu et al., 2017). The city council is considering an integrated strategy to solid waste management to replace traditional work disposal methods (Omran et al., 2007).

2.5 EFFECT OF IMPROPER SOLID WASTE MANAGEMENT (SWM) SYSTEM

Ineffective municipal solid waste management (MSWM) practices can have adverse impacts on the environment, including the propagation of infectious diseases, contamination of the land and water, clogging of drains, and extinction of biodiversity (Ejaz et al., 2010; Saba et al., 2022). In many regions of the world, the open dumpsite approach to solid waste disposal is still in its infancy as a technique for managing solid waste. Due to outdated, ineffective, and unscientific methods used, it is among the worst services provided by local authorities in developing countries (Sankoh et al., 2013). The organic portion and heavy metals of MSW are significant (Meena et al., 2023) because they may have negative effects on environmental quality and public health.

Methane and other toxic organic gases production produce an unpleasant smell that poses a hygiene risk to human health. Contamination of hazardous materials occurs when hazardous waste is mixed with other wastes and garbage during the collecting process (Gutberlet et al., 2017). Pesticides, batteries that contain lead, mercury, or zinc, radioactive materials, e-waste, plastics, and other hazardous materials are combined with paper and burned, producing dioxins and other gases. There is a risk of cancer from these harmful gases.

2.6 HEALTH EFFECT OF CO₂ AND CH₄

Several polluting gases can have a variety of impacts on health (Manisalidis et al., 2020). Global warming is partially caused by greenhouse gases such as CO₂ and CH₄. The second most important man-made greenhouse gas that contributes to global warming is methane, after carbon dioxide (Talyan et al., 2007; Ganesan et al., 2017). It is well known that asphyxia or loss of consciousness can result from methane gas intoxication. However, there is little evidence available regarding methane gas inhalation-induced acute pulmonary toxicity (Jo et al., 2013). CH₄ has a long-term global warming potential that is 21–36 times greater than that of CO₂ over a 100-year period and approximately 80–84 times higher in the short term (Mohajan, 2012; Borisova et al., 2023). Thus, it is better for the environment to capture and flare CH₄ rather than dispose of it in a sanitary landfill without doing so. After carbon dioxide, methane (CH₄) is the second largest source of human-produced greenhouse gas increase since preindustrial times (Chandra et al., 2019).

MSW is the third largest manmade source of CH₄ emissions, accounting for 11% of total global CH₄ emissions (Singh et al., 2018). An inherent feature of the atmosphere of earth is the greenhouse effect, which traps radiation. The most widely recognised greenhouse gas that contributes significantly to global warming is CO₂ (Lin et al., 1999). The climate will warm in proportion to the concentration of greenhouse gases. Significant amount of CO₂ and CH₄ from landfill sites have a severe impact on human health, including illnesses affecting the skin, eyes, nose, and respiratory system (Abubakar et al., 2022).

2.7 EFFECTS OF LOW CONCENTRATION OF ORGANIC COMPOUNDS ON HEALTH

A number of organic compounds are toxic, including VOCs. Since VOCs are considered to be carcinogens, they are regarded as a particular class of air pollutants that may be dangerous for people living close to landfills as well as workers there (Kurbatova et al., 2024). VOCs have the potential to cause health concerns such as respiratory and neurological disorders when they are ingested, absorbed via skin, or inhaled (Liu et al., 2023). It is necessary to note, that these consequences relate to high concentrations, which are not invariably present near landfills. Workers in landfills, especially those who operate large machinery needed to compact the waste, are more likely to be exposed. Other major air pollutants and their impacts are, Suspended Particulate Matter (SPM) raises the mortality rates of various respiratory disorders, including bronchial asthma, chronic obstructive pulmonary disease (COPD), and several others diseases, (Kyung et al., 2020) corrodes metal, leaves dirt on property and structures, and impairs vision (Peavy et al., 1979). Because of SO₂, and subsequent production of acid rain, metals corrode, leaves become injured both acutely and over time, a variety of trees are attacked, the upper respiratory tract becomes irritated, and paint pigments are destroyed. In addition to SO₂, NO_x is another precursor of acid rain, which also affects the ecosystem. It damages leaves visibly, irritates the eyes and nose, produces a brown haze, inhibits plant growth, and corrodes metals (Singh et al., 2008). CO decreases blood oxygen levels, produces headaches, nausea, and dizziness, and hinders mental functions (Peavy et al., 1979). HC slows down plant growth and causes cancer.

2.8 LANDFILL GAS GENERATION AND ENERGY RECOVERY

As biodegradable solid waste inside landfills breaks down anaerobically, a variety of gases are produced, which are collectively referred to as landfill gas (LFG). The fundamental causes of this degradation include several biological, microbiological, chemical, and physical processes that occur simultaneously and are interrelated (Abdelli et al., 2020). Methane (CH₄) and carbon dioxide (CO₂) are the two major components of LFG (Kumar et al., 2016). According to Falzon, 1997, methane production in landfills normally begins 6 to 12 months after the dump closes, peaks shortly thereafter, and gradually declines over a 30- to 50-year period (Tsatsarelis et al., 2009; Chattopadhyay et al., 2018). Now, there is an increasing consensus that LFG should be regarded either as a large source of pollution and risk if moving unrestrained to the air and ground, or as a potential environmentally benign renewable power source (Thompson et al., 2005). Landfills are responsible for an estimated 818 million metric tonnes of CO₂ (MMtCO₂-eq), representing 13% of all anthropogenic methane emissions globally (Chattopadhyay et al., 2018). Based on estimates from the 1998 GHG emission inventory, the amount of waste created by LFG at disposal sites in India is projected to be between 7 and 8% of the total GHG emissions of the country, about 69 MMtCO₂-eq. Landfill gas can be captured and used to reduce greenhouse gas emissions, as well as the associated benefits of reducing odours, preventing damage to plants, lowering the risk of explosions, fires, and asphyxiation, and reducing smog (Smith et al., 2001). Additionally, this practice can be profitable. When methane from landfills escapes into the open, it combines with other pollutants in direct sunlight to create ground-level ozone, which is main constituent of photochemical smog.

2.9 ENVIRONMENTAL IMPACT OF LEACHATE

Sanitary landfilling is still a widely used and approved method of disposing of waste, however research on the impacts of waste on the environment and human health is inconclusive (Vaverkova, 2019). The global tendency continues to favour regulated, sanitary landfilling as the preferred method of disposing of municipal and certain solid industrial waste, even though the waste management hierarchy views landfilling as the last option. The main disadvantage of landfilling is the production of extremely polluted leachates, whose quantity, volumetric flow rate, and chemical composition are highly changeable, even though it is the least expensive choice in terms of capital and

exploitation expenses. Furthermore, the environmental effects and hazards caused by landfill wastes compel authorities to implement more stringent restrictions (Renou et al., 2008). Leachate is mostly produced by precipitation infiltrating through waste that has been dumped in a landfill. The percolating water becomes contaminated when it comes into touch with decomposing solid waste; if it then emerges from the waste material, it is known as leachate. During this breakdown of carbonaceous material, more leachate volume is created along with a complex mixture of organic acids, alcohols, aldehydes, and simple sugars, as well as methane and carbon dioxide (Harshita et al., 2021). Landfill leachate is a source of hazardous substances, such as nitrogen compounds, volatile organic compounds (VOCs), heavy metals (Cr, Cd, Pb, Ni, Cu, Hg), xenobiotic organic compounds, and halogenated organics like PCBs. Inorganic macro components are also present in the leachate (Wdowczyk et al., 2020; Kathpalia et al., 2003; Salam et al., 2021). Leachate quality is affected by several factors, including moisture, available oxygen, ambient temperature, elapsed time, and waste content. Various chemical and biological processes that occur during waste breakdown are governed by these parameters. While decomposition reactions and initial moisture content have an impact, the amount of external water entering the landfill mostly determines the amount of leachate produced. Precipitation, groundwater infiltration, the state of the waste, and the final cover design are factors that impact the amount of leachate (Adhikary et al., 2014).

The fresh leachate is generated mostly during the anaerobic decomposition phase, or the first several years of landfill waste deposition. It mostly consists of material that decomposes naturally. The concentration of most pollutants in the leachate reduces as the landfill ages (Kamboj et al., 2020). When the easily accessible biodegradable material is used up, the pH level increases to 7-8. The features of a fresh leachate and old leachate produced at a landfill site are displayed in Table 2.9.

Table- 2.9: Typical data on the composition of leachate from new and mature landfill
(Tchobanoglous et al., 1993; Aziz A. H. et al., 2012)

Constituents	New Landfill (less than 2 yrs), mg/l		Mature Landfill (greater than 10 yrs), mg/l
	Range	Typical	
BOD ₅	2,000-30,000	10,000	100-200
TOC	1,500-20,000	6,000	80-160
COD	3,000-60,000	18,000	100-500
Total Suspended Solids	200-2,000	500	100-400
Organic Nitrogen	10-800	200	80-120
Ammonia Nitrogen	10-800	200	20-40
Nitrate	5-40	25	5-10
Total Phosphorous	5-100	30	5-10
Ortho phosphorous	4-80	20	4-8
Alkalinity as CaCO ₃	1,000-10,000	3,000	200-1,000
pH*	4.5-7.5	6	6.6-7.5
Total Hardness as CaCO ₃	300-10,000	3,500	200-500
Calcium	200-3,000	1,000	100-400
Magnesium	50-1,500	250	50-200
Potassium	200-1,000	300	50-400
Sodium	200-2,500	500	100-200
Chloride	200-3,000	500	100-400
Sulphate	5-1,000	300	20-50
Total Iron	50-1,200	60	20-200

*Except pH, this is unit less.

To manage a landfill and treat the leachate, it is important to consider both the quantity and quality of leachate generated during the active phase of landfill and closure. Therefore, estimating the quantity of leachate is crucial (Yang et al., 2015) for constructing liner systems, estimating its negative effects, and providing leachate collecting and treatment facilities. It is not possible to directly quantify leachate in the case of a newly constructed or an existing landfill without a leachate collection system. In these situations, the only known technique is to estimate the quantity of leachate by modelling the site water balance under a variety of very speculative assumptions. There is numerous water balancing techniques that make it possible to estimate the amount of leachate from a landfill. The following techniques for water balance analysis can be applied to a landfill to estimate or predict leachate. The models include the following:

(i) The Soil Cover model; (ii) the UNSAT model; (iii) the Leachate Estimation and Chemistry Model (LEACHM); (iv) the two Dimensional water flows and solute transport in variably saturated porous media (HYDRUS2D) model. Significant water balance processes like precipitation, runoff, and evapotranspiration are included in these models. The following models are available: EPACMTP, FILL, HELP, MOBYDEC, PREFLOW, and FILL (Trankler et al., 2001; Grugnaletti et al., 2016).

The flora and fauna of the water body are affected by the generated pollutants that break down in the presence of moisture and rains, seeping into the groundwater reserve, sea, or river. Diseases of numerous kinds almost take over waste sites as breeding grounds. In addition, it causes the production of secondary pollutants such as H_2S and other gaseous hydrosulphurous pollutants when they react with the bacteria in the waste when moisture and temperature are present. Due to its enormous environmental relevance, effects of leachate on groundwater and other water resources have created a lot of attention recently. Groundwater resources are highly vulnerable to the migration of leachate from waste sites or landfills and, in certain cases, the discharge of contaminants from sediments if these processes are not appropriately controlled. Because of the recent surge in interest in the impact of water quality on human health, groundwater protection has become a major environmental problem. Planning and building water resources properly requires evaluating the quality of groundwater and creating plans to keep aquifers clean (Akinbile et al., 2011; Sabahi et al., 2009). When leachate streams enter the aquatic environment, it can have both acute and long-term negative effects on the ecosystem. These effects can be particularly severe, drastically reducing the populations of sensitive species and seriously reducing biodiversity. When organic materials and harmful metals coexist, both nearby and distant populations may experience a prolonged accumulation of toxins (Adeyemi et al., 2009).

The landfill leachate quality of the Dhapa dump site in Kolkata city was documented in the previous years by Chattopadhyay et al., 2009; Motling, 2014; and De et al., 2017. Table 2.10 below is a tabulation of their research findings.

Table- 2.10: Physico-chemical parameters of leachate collected from uncontrolled landfill at Dhapa, Kolkata

Parameters	Range as per Chattopadhyay et al., 2009	Range as per Motling, 2014	Range as per De et al., 2017
pH	7.48-8.00	7.8-9.0	7.8-8.6
Alkalinity	2900-3590	—	Not reported
Total solids	10051-14727	—	Not reported
TDS	Not reported	4300-30900	2320-15700
Total organic solids	2750-7000	Not reported	Not reported
Total inorganic solids	7543-7785	Not reported	Not reported
COD	3427-16000	2496-21120	1200-13200
BOD ₅	2075-7000	3408-14539	525-6440
NH ₄	Not reported	192-1230	168-4210
TKN	Not reported	238-1900	631-9139
Cd	0.04-0.05	Not reported	0.006-2.11
Cr	0.43-0.85	0.82-27.12	0.104-10.43
Fe	Not reported	2.6-14.7	0.8-11.25
Hg	0.002-0.009	0.005	0.16-2.65
Mn	Not reported	Not reported	0.68-3.90
Ni	0.6-0.73	0.22-4.45	0.2-0.77
Pb	0.07-0.08	0.48-12.98	0.37-1.14
Zn	0.16-0.85	0.4-7.76	1.00-25.14
Cu	0.06-0.28	0.17-3.4	0.14-0.68
As	0.005-0.009	0.02-0.36	0.0045-0.5610
Chloride	1234-3408	1060-3700	2103-6735
Nitrate	2.16-3.31	Not reported	9.45-59.2
Fluoride	0.36-0.86	Not reported	0.2-2.53

Except pH, all concentration is in mg/l.

When landfill sites are appropriately designed and engineered, such as when they are built on geologically impermeable materials or when they use impermeable liners consisting of

geo-textiles or engineered clay, the risks of leachate formation can be reduced. Moreover, landfilling is no longer permitted for the majority of toxic and difficult items.

As per Solid Waste Management Rules, 2016, the treated leachate before disposal should meet the standards according to the Schedule-II.B, standards for treated leachate. The details are given below in table 2.11.

Table- 2.11: Standards for treated leachate as per SWM rules 2016

Parameters	Standards (Mode of disposal)		
	Inland Surface Water	Public Sewers	Land disposal
Suspended Solids, mg/l, max	100	600	200
Dissolved Solids (Inorganic), mg/l, max	2100	2100	2100
pH value	5.5-9.0	5.5-9.0	5.5-9.0
Ammoniacal Nitrogen (as N), mg/l, max	50	50	-
Total Kjeldahl Nitrogen (as N), mg/l, max	100	-	-
BOD (3 days at 27 ⁰ C, mg/l, max)	30	350	100
COD, mg/l, max	250	-	-
Arsenic (as As), mg/l, max	0.2	0.2	0.2
Mercury (as Hg), mg/l, max	0.01	0.01	-
Lead (as Pb), mg/l, max	0.1	1.0	-
Cadmium (as Cd), mg/l, max	2.0	1.0	-
Total Chromium (as Cr), mg/l, max	2.0	2.0	-
Copper (as Cu), mg/l, max	3.0	3.0	-
Zinc (as Zn), mg/l, max	5.0	15	-
Nickel (as Ni), mg/l, max	3.0	3.0	-
Cyanide (as CN), mg/l, max	0.2	2.0	0.2
Chloride (as Cl), mg/l, max	1000	1000	600
Fluoride (as F), mg/l, max	2.0	1.5	-
Phenolic compounds (C ₆ H ₅ OH), mg/l, max	1.0	5.0	-

2.10 AIR POLLUTANTS FROM VEHICULAR EMISSION AND THEIR HEALTH EFFECTS

The complex and dynamic natural gaseous system known as the atmosphere is essential to the survival of life on Earth. When chemicals, particles, or biological materials are released into the atmosphere, they create air pollution and cause damage to people or other living things, as well as degrade the ecosystem (Sharma et al., 2013). Air pollution is often recognised with major stationary sources, but two thirds of the pollution in metropolitan areas comes from automobiles (Dey et al., 2020). The main pollutants released by vehicles running on petrol are carbon monoxide (CO), unburned hydrocarbons and nitrogen oxides (NO_x); the main pollutants released by vehicles running on diesel are particulate matter (PM), polycyclic aromatic hydrocarbons (PAH), nitrogen oxides (NO_x) and sulphur dioxide (SO₂). Moreover, vehicles with petrol engines release butadiene (BUTDN) and benzene (BENZ) (Lin et al., 2012; Ho et al., 2009; Zhang et al., 2020; Holman et al., 1999; Jie Lu, 2011). According to a 1996 WHO and UNEP report on Global Pollution and Health, Kolkata placed 41 among the most polluted cities in the world in terms of suspended particle matter (SPM). Primary sources of air pollution in the city, Kolkata, are motor vehicles exhaust (50%), industrial emissions (48%), and domestic cooking (2%) (Majumdar et al., 2008).

When fossil fuels are not completely burned, carbon monoxide is released. Headache, nausea, vomiting, weakness, dizziness, and finally loss of consciousness are the signs of carbon monoxide poisoning caused by inhalation (Manisalidis et al., 2020). Short-term ambient CO exposure has been associated with asthma, bronchiectasis, and pneumonia (Zhao et al., 2019; Bala et al., 2021). Because of its toxicity and tendency to bind haemoglobin more strongly than oxygen, carbon monoxide is known as the "silent killer" since it increases the probability of asphyxia-related deaths at high exposure levels and hypoxic tissue damage at low exposure levels (WHO, 2005).

Smog is made up of PM, which is deposited as soot. The concentrations of SO₂, NO₂, and PM₁₀ (particulate matter smaller than 10 microns) are mostly caused by local emissions. Mobile sources, industrial sources, coal-fired power plants, and residential heating are the main sources of emissions affecting the Kolkata region (Gupta et al., 2008). Climate change can be caused by particulate matter (PM), which may accumulate up in the upper atmosphere. The burning of substances containing carbon and sulphur, including diesel

and petrol, is specifically related to the generation of PM_{10} . Exposure has been connected to a range of health consequences, including cancer, heart attacks, and strokes, as well as mild symptoms like coughing and wheezing, increased risk of pre-existing lung disorders like bronchitis and COPD, and more (Traboulsi et al., 2017).

As low-sulphur fuels become more widely used, the amount of sulphur oxides remains decreasing. Nitrogen oxides (NO_x), which include nitrogen dioxide (NO_2) and nitric oxide (NO), are produced when fuel is used in automobiles, factories, and power plants. Urban air quality is harmed by these pollutants, raising issues with health and the environment (Kar et al., 2024). NO is produced by high-temperature combustion processes, and when it combines with oxygen in the atmosphere, it forms NO_2 . A primary source of NO_2 emissions is automobiles that run on fossil fuels. NO_2 is the main contributor to respiratory disorders, heart difficulties, and decreased lung function. One of the most significant gaseous air pollutants is sulphur dioxide (SO_2), which is produced by both natural and man-made sources. Sulphur dioxide causes type 2 diabetes and non-accidental mortality in addition to having adverse impacts on human respiratory, cardiovascular, and neurological systems (Khalaf et al., 2022). The substantial potential health impacts of atmospheric polycyclic aromatic hydrocarbons (PAHs), including mutagenicity and carcinogenicity, make them a subject of significant interest. The ambient air of Kolkata has been found to have a significant quantity of Polycyclic Aromatic Hydrocarbons (PAH). (Ambade et al., 2022). The primary representative of polycyclic aromatic hydrocarbons, or PAHs, is benzo[a]pyrene (B[a]P), which is frequently found in soil, sediments, surface water, and the air (Bukowska et al., 2022).

The National Ambient Air Quality Standards (NAAQS) is presented in table 2.12. Huge quantities of pollutant are added to the environment from the transportation sector of MSWM system. As a result, vehicles used to transport waste from collection stations to disposal sites have to conform to the emission standards established by the CPCB in our country.

Table- 2.12: National ambient air quality standards (CPCB, 2009)

Parameters	Permissible Limits	Concentration in ambient air	
		industrial, residential, rural and other area	ecologically sensitive area
Sulphur Dioxide (SO ₂) µg/m ³	Annual*	50	20
	24 hours**	80	80
Nitrogen Dioxide (NO ₂) µg/m ³	Annual*	40	30
	24 hours**	80	80
Particulate matter (size less than 10µm or PM ₁₀ µg/m ³	Annual*	60	60
	24 hours**	100	100
Particulate matter (size less than 2.5µm or PM _{2.5} µg/m ³	Annual*	40	40
	24 hours**	60	60
Ozone (O ₃) µg/m ³	8 hours**	100	100
	1 hour**	180	180
Lead (Pb) µg/m ³	Annual*	0.5	0.5
	24 hours**	1	1
Carbon monoxide (CO) µg/m ³	8 hours**	2	2
	1 hour**	4	4
Ammonia (NH ₃) µg/m ³	Annual	100	100
	24 hours***	400	400
Benzene (C ₆ H ₆) µg/m ³	Annual*	5	5
Benzo (a) pyrene (BaP) ng/m ³	Annual*	1	1
Arsenic (As) ng/m ³	Annual*	6	6
Nickel (Ni) ng/m ³	Annual*	20	20

2.11 INTEGRATED SOLID WASTE MANAGEMENT (ISWM) SYSTEM

The community has established an integrated solid waste management system after assessing the functional components for usability and ensuring that all interfaces and connections between components are optimised for economy and effectiveness. To mitigate the adverse impacts of this inadequate waste handling and control system, appropriate and efficient waste management regulations are required, which can be

implemented in an integrated manner. Efficient SWM reduces harmful effects on human health and the environment, conserve resources, enhances livability in communities (Abubakar et al., 2022). ISWM, is a way to deal with the increasing problems associated with disposing of MSW in municipalities in developing countries (Batista et al., 2021), it is a cost-effective and environmentally sustainable solution for promoting public health and societal welfare. ISWM is a comprehensive program that addresses waste prevention, recycling, treatment or processing and disposal of solid waste in order to protect the environment and public health (Sridevi et al., 2012; Somani et al., 2021). An effective waste management system includes waste collection and transportation, resource recovery through sorting and recycling, waste material recovery (e.g. compost), energy recovery through biological, thermal, or other processing, and waste transformation for safe and acceptable disposal that meets environmental standards (Mohanty et al., 2021). In developing nations, ISWM has grown as the standard approach in practice that emphasizes both the material components and the governance aspects (Wilson et al., 2013).

2.12 PROCEDURE FOR CALCULATION OF IMPACT

Improper solid waste management is carried out in developing countries due to a lack of economic resources and societal awareness, posing a hazard to the local, regional, and global environments (Ferronato et al., 2019). Environmental considerations have become an increasingly important aspect of MSWM planning.

In the current scenario, the combined effect of all pollutants is not evaluated, and hence the net effect is not calculated. Quantitative measurements are also necessary. To assess the environmental impact of raw material acquisition, processing, manufacturing, distribution, use, reuse, disposal, and degradation (Fava et al., 1993, 1994), the combined effect of all pollutants must be estimated quantitatively across all problem areas. In an effort to provide insight into environmental burdens of complex MSWM system, systems approach (considering the problem as an interactive system with many components) with quantitative Potential Environmental Impact (PEI) is of significant importance. The importance of generating a single unique PEI number is that it consider all contaminants and their types of impacts. PEI is the unrealized effect or impact that the emission of mass and energy would have on the environment on average (Cabezas et al., 1999). This combined score can be used to compare the environmental impact of similar or different situations, assess how environmentally friendly a process is, optimise the design of a

proposed management system, optimise the operation of current systems to reduce environmental impact, and establish pollution control guidelines. It may also have to do with the economics of the system, which aims to maximise efficiency by balancing profit and environmental effect. To develop a systematic technique, one must understand pollutant release to each environmental medium (air, water, soil) and the effects in several environmental categories (global, regional, and local). The various methods to assess environmental impacts are discussed in the next section.

2.13 METHODS FOR ASSESSING ENVIRONMENTAL EFFECTS

Inventory analysis is the identification and quantification of resource and energy use for a process (with a defined boundary) and the subsequent pollutant discharge to each environmental medium. Inventory refers to the quantity of material involved. The inventory of pollutants serves as the basis for estimating the total environmental impact of all pollutants (Curran, 2006). Approaches to determining and evaluating environmental impacts can be roughly divided into two categories: (i) Medium oriented, and (ii) Problem oriented.

In medium oriented methods environmental impacts are assessed considering effects of pollutants in different media (air, water, soil) e.g. Environmental Standard Relation method, Critical Volume method etc. Methods like Checklist, Relative Magnitude, Impact Potentials etc. fall under problem oriented type as these consider effects of pollutants in different environmental categories i.e. global category (global warming potential, ozone depletion potential etc.), regional category (acidification potential etc.) and local category (human toxicity potential, aquatic toxicity potential etc.). These methods may be either purely qualitative, quantitative or in between, i.e. semi quantitative in nature. These methods differ from each other in terms of data requirement, level of sophistication of impact calculation, impact categories covered. Table 2.13, shows the data needed for various levels of impact assessment (Fava et al., 1993).

Table- 2.13: Data needed for various levels of impact assessment (Fava et al., 1993)

Tier	Description	Data needed
Tier 1: Loading Assessment	Using only inventory data, evaluations are made based on volume or quantity, under the premise that "less is better."	Inventory items can be measured in mass, volume, or other physical quantity units.
Tier 2: Equivalency Assessment	Impact equivalency units are derived using algorithms based on hazard information, which are then used to assess inventory goods within a given impact category.	Equivalency algorithms based on hazard data are used in addition to Tier 1. Non-chemical loading information, as well as resource stock and yield, can also be included.
Tier 3: Toxicity, Persistence, and Bioaccumulation Assessment	Inventory items are evaluated using the interactive properties of a chemical, an organism (toxicity), and an ecosystem (persistence and bioaccumulation).	The same as Tier 1, with details on the toxicity and persistence (bioaccumulation) of chemical interactions with organisms and ecosystems.
Tier 4: Generic Exposure/ Effects Assessment	Generic environmental or human health information are used to estimate potential impacts of inventory items.	Same as Tier 1 plus generic environmental information and regional calibration model.
Tier 5: Site-specific Exposure/ Effects Assessment	Site-specific environmental or human health information is used to estimate potential impacts of inventory items.	Same as Tier 1 plus site-specific environmental information and a site-specific calibration model.

A thorough summary of publicly accessible data sources and their quality is provided by EPA (1994a, 1994b) and SETAC (Fava et al., 1994); the SETAC-sponsored data quality workshop acknowledged that the absence of data remains a major issue for impact assessments. Some tier 2 to tier 3 type models could rarely be supported by the environmental input and output that is currently available. Table 2.14 provides the summary information on each of the methods.

Table- 2.14: Summary of various impact assessment methodologies (EPA, 1995b)

Methods	Impact Categories Covered			Tier of Detail				
	Ecosystem	Human health	Natural resources	1	2	3	4	5
Checklist	*	*	*	*				
Relative magnitude	*	*	*	*				
Environmental standards relation	*	*	*		*			
Impact potentials	*	*	*		*			
Critical volume	*	*			*			
Environmental priority strategy	*	*	*		*			
Tellus Institute Human Health Hazard Ranking	*	*			*			
Toxicity, persistence, and bioaccumulation profile	*	*				*		
Mackay unit world model	*						*	
Canonical Environment Model	*						*	
Ecological risk assessment	*							*
Human health risk assessment		*						*

The medium-oriented methods appear straightforward, but they rely on adequate ambient concentration levels, supported by scientific evidences, regarding the toxicological and environmental health impacts across various mediums like air, water, and land. To utilize them effectively, new ambient criteria and subsequent standards need be developed that considering exposure and toxicity of contaminants across all environmental categories.

The problem-oriented impact potential method generates impact equivalence for several impact categories using scientific data on ecological and human health implications. In addition to toxicity, it considers the persistence and exposure potential for the chemical (TPBP) in local contexts. The impact potential method also suffers from a lack of data for a wide range of compounds. Nevertheless, the data bank has greatly improved due to the significant efforts of organizations like CML (Centre of Environmental Science), SETAC, USEPA, and other toxicological data banks. The approach allows for direct comparison of inventory items directly in which items or groups contribute most significantly to a particular impact category (EPA, 1995b).

2.13.1 Environmental Impact Assessment Methods

2.13.1.1 Checklist method

The checklist method (Fava et al., 1993; EPA, 1995b; Bishop, 2000) is a classification matrix that can be used to correlate specific inventory items with specific impacts or impact categories at tier 1 level (Ref. Table 2.12). Inventory data alone can be used directly without modification. However this method does not measure impacts. More detailed level of impact assessment may be required to distinguish the relative environmental importance of inventory items.

2.13.1.2 Relative magnitude method

The relative magnitude method (Fava et al., 1993; EPA, 1995b; Bishop, 2000) is another form of loading assessment in which the input and output data generated in the inventory analysis are associated with specific impact categories (Ref. Table 2.12).

2.13.1.3 Environmental standards relation method

The environmental standards relation (ESR) method (Schaltegger and Sturn, 1993, 1994, 1996; Vignes, 1999, 2001) is a weighting scheme originally developed by Schaltegger and Sturn (1993) to evaluate the environmental impacts of chemical releases in Switzerland. The purpose of ESR is to assess chemical releases to air, land and water based on their relative potential ecological and human health impact at tier 2 level (Ref. Table 2.12). However, the ESR scheme is not a thoroughly scientific based. Again the ambient standards may or may not reflect actual environmental impacts. In addition, the ESR weighting scheme only consider chemical releases.

2.13.1.4 Impact potential method

For different categories of impacts it is feasible to use algorithm to estimate the impact potential of various inventory items at tier 2 level (Ref. Table 2.12), (Fava et al., 1992, 1993; Consoli et al., 1993; Guinee, 1992a, 1992b; Guinee and Heijungs, 1993; Heijungs et al., 1992a, 1992b; EPA 1995b, 1998). These impact potential algorithms provide a means of converting different types of data generated in the inventory analysis into a common unit for comparison and or aggregation within impact categories. This allows for a direct comparison of inventory items to determine which inventory items, or groups of inventory items, contribute most significantly to a specific impact category. Algorithms for normalizing the contribution of substances to impact categories have been developed to yield the impact potential of various substances. The inventory data are multiplied by an equivalency factor to yield an impact potential value. A major concern of impact potentials is developing equivalency factors for all impact categories that relate inventory data to specific impacts.

The primary strength of the impact potentials is that they provide a means of normalizing the contribution of various substances within specific impact categories. This allows for a direct comparison of inventory items to determine which inventory items, or group on inventory items, contribute most significantly to specific impact categories. In addition, most of the impact potential algorithms are based on cause & effect relationship. One of the general weaknesses with the impact potentials is that many are based on number of assumptions.

2.13.1.5 Critical volume method

The critical volume method (EPA, 1995b; Postlethwaite and de Oude, 1996; Bishop, 2000) is the variation of the impact potential approach that is applicable to ecosystem and human health impacts at tier 2 level (Ref. Table 2.12). The critical volume method is used to determine the volume of air, water, or soil that is needed to dilute specific substances to a generally estimated toxicity threshold. To efficiently and successfully use the critical volume method, a new understanding and methodology for the impact equivalency approach must be created. However, exposure and toxicity information is generally lacking for many environmental and human impact areas with which to determine critical volume values.

2.13.1.6 Environmental priority strategy

The environmental priority strategy (EPS) (Swedish Environmental Research Institute, 1991, 1992, 1993; EPA, 1995b; Graedel and Allenby, 1995; Postlethwaite and de Oude, 1996) is based on implicit value judgments regarding the environmental impacts of various substances at tier 2 level (Ref. table 2.12). The overall environmental impact of a product system is calculated in semi-quantitative terms. The weakness of the EPS system is its reliance on value judgments to develop the Environmental Load Unit (ELU).

2.13.1.7 Tellus institute human health hazard ranking

This human health hazard ranking method (Tellus Institute, 1992a, 1992b, 1992c; EPA, 1995b), used by Tellus Institute as assessment of packaging materials (1992a, 1992b, 1992c), groups inventory items into two main categories for assessment: carcinogens and non-carcinogens at tier 2 level (Ref. Table 2.12).

2.13.1.8 Toxicity, persistence, and bioaccumulation profile

The toxicity, persistence, and bioaccumulation profile (TPBP) (Fava et al., 1992, 1993; Vigon and Jensen, 1992; EPA, 1994c, 1995b, 1998) considers the potency (toxicity) as well as the physical and chemical properties of substances to assess their fate and potential environmental impacts (SETAC, 1993) at tier 3 level (Ref. Table 2.12). It provides an approximate ranking of direct chemical hazard to human health and the environment based on their relative toxicity and potential for exposure. The input data used in the TPBP can be found from the following testing studies, which are readily described in the public and private literature:

- 1) Acute toxicity testing (LC_{50} , EC_{50} , TD_{50})
- 2) Chronic toxicity testing (NOEL)
- 3) Biodegradation (half-life, CO_2 evolution) and
- 4) Bioaccumulation (solubility, octanol/water coefficient, bioaccumulation factor)

2.13.1.9 Mackay unit world model

The Mackay unit world model (Mackay, 1979; Mackay and Paterson, 1981, 1990; EPA, 1995b) helps to explain the mechanisms and rates by which toxic substances are transported into and transformed within the natural environment. It is a Tier 4 type of model (Ref. Table 2.12). Drawbacks of the unit world method are that it focuses only on

the fate of chemicals; human health effects are not included and input data are lacking for many chemical substances and results cannot be validated by experimental observation.

2.13.1.10 Canonical environment model

Canonical environment model (Barnthouse et al., 1985a, 1985b; Suter et al., 1984, 1985; EPA, 1995b) is also of Tier 4 detail and is similar to, but somewhat more complex and realistic than the unit world method. Weakness of canonical environment modeling is that there are no means to account for non-chemical factors and to directly account for impacts on human health. It also does not measure impacts, but rather the fate and transformation of pollutants in different environmental media.

2.13.1.11 Ecological risk assessment and human health risk Assessment

The ecological risk assessment and human health risk assessment (EPA, 1992b, 1992c, 1996a; SETAC, 1997a; National Research Council, 1983; CEQ, 1989) assess adverse effects on ecology and human respectively, due to exposure to one or more stressors. These methods are site-specific and large technical resources are needed to perform a comprehensive assessment. However, the availability of this level of detail (i.e. Tier 5) would be rare in most of the cases.

According to the literature, under the current data availability scenario, the Life Cycle Impact Assessment (LCIA) approach is very suitable methods to assess the environmental impact of any process or system.

2.14 BASIC COMPONENTS OF POTENTIAL ENVIRONMENTAL IMPACT

The impact analysis component of the Life Cycle Assessment (LCA) is called Life Cycle Impact Assessment (LCIA). LCA is typically used to determine overall environmental effect of a product from all of the activities that take place during its life cycle (Khasreen et al., 2009). LCA concept is often referred to as ‘cradle to grave’ concept that means, to evaluate the environmental effects associated with any given activity from collection of raw materials from the earth to the point at which all residues are returned to the earth (Cutshaw et al., 2023). After initiation i.e., scoping & goal defining, LCA includes three separate but interrelated components-

1. Identification and quantification of energy, resource use and environmental release to air, water and land.
2. Technical qualitative and quantitative characterization and assessment of consequences on environment.
3. Evaluation and implementation of opportunities to reduce environmental burdens.

In the SETAC (Society of environmental Toxicity and Chemistry) sponsored LCIA workshop in 1992, three phase conceptual framework was developed, Classification, Characterization and Valuation.

Classification: The process of assignment and initial aggregation of life cycle inventory data to a relative homogeneous grouping of impacts (e.g. photochemical smog, lung disease, fossil-fuel depletion) within primary impact categories (e.g. eco-system, human health, natural resources).

Characterization: The qualitative and quantitative evaluation of potential impacts. The process of identifying impacts of concern (assignment endpoints) and selecting actual or surrogate characteristics (measurement end points) to describe the impacts. Characterization involves using specific impact assessment models to develop impact descriptors.

Valuation: The valuation phase of impact assessment involves assigning relative values or weights to the impacts based on their associated descriptors as derived in the characterization phase and stakeholder values. The primary objective of the valuation is to integrate the information on environmental impacts with stakeholders' values to establish the relative importance of impacts or categories of impacts. The summation of the normalized impact scores of different categories with their respective weightages provides the PEI.

2.15 LIFE CYCLE IMPACT ASSESSMENT (LCIA)

The basic concept of life-cycle assessment (LCA) is the assessment of the environmental impacts related to any specific activity, starting from the time raw materials are first extracted from the earth and ending when all of the residues are released back into the environment. The International Organisation for Standardisation (ISO) states that an environmental life cycle assessment (LCA) examines the environmental interventions and

potential effects at every stage of life of a product—from the procurement of raw materials through production, use, and disposal—or from cradle to grave. To do this, an inventory of relevant system inputs and outputs is compiled (inventory analysis), potential implications of those inputs and outputs are assessed (impact assessment), and the findings are interpreted (interpretation) in light of the goal of the study. The three main types of environmental impacts that require attention are human health, ecological concerns, and resource utilisation. The term "product" in the definition of life cycle assessment (LCA) encompasses not just product systems but also service systems, such as solid waste management systems. (Clift et al., 2000, Goran Finnveden, 1999).

The US EPA states that the Life Cycle Impact Assessment (LCIA) phase of an LCA involves assessing the possible effects that environmental resources and releases identified during the Life Cycle Inventory (LCI) may have on human health and the environment. Impact assessments have to take into account the consequences on the environment, human health, and resource depletion. An attempt is made to establish a connection between a process or product and any potential environmental effects through a life cycle impact assessment.

A Life Cycle Impact Assessment takes into account a variety of impacts, such as climate changes, ozone depletion, eutrophication, acidification, respiratory inorganics, ionizing radiation, ecotoxicity, photochemical ozone production, land use, and human toxicity (both cancer and non-cancer related). Each of these impact categories is given a set of resources and emissions then use impact assessment techniques to turn them into indicators. Different emissions and resources consumed, as well as different product options, can then be cross-compared in terms of the impact indicators (ILCD, 2010). The LCIA approach of evaluating the potential environmental impact takes into account the present inventory of pollutants. This makes the potential environmental impact determination (PEI_{LCIA}), sensitive to the current state of environment and it signifies the further potential deterioration from the present (in a sense of marginal effect).

LCIA has been widely used in research to select environmentally friendly process designs. e.g., solid waste management issues (Clift et al., 2000; Ekvall and Finnveden, 2000); environmental impact of a gas or oil de-sulfurization unit (Burgess and Brennan, 2001); chemical process route selection (Buxton et al., 1997; Cave and Edwards, 1997);

optimal design and scheduling of batch processes (Stefanis et al., 1997); solvent design (Pistikopoulos and Stefanis, 1998); etc.

2.15.1 Estimation of PEI_{LCIA}

2.15.1.1 Assumptions and data

For estimating PEI, the LCIA approach takes into account the interaction of mass and energy flows to the environment as a result of operations. It takes into account three impact categories (EPA, 1998): (1) global, (2) regional, and (3) local. The global category is largely concerned with the entire world, and adequate global pollutant inventories are used to evaluate the PEI component from this impact category. Similarly, the term "regional category" refers to a region like a state. The local category corresponds to the location of the local area (Bandyopadhyay et al., 2001; Dutta and Koshti 2002).

Figure 2.3 depicts the impact categories and sub-categories considered in this study.

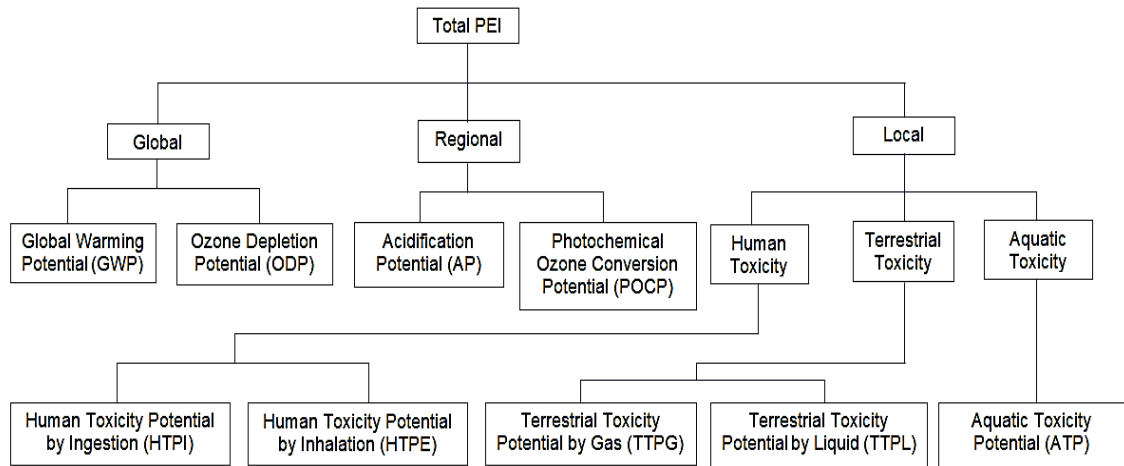


Figure- 2.3: A Typical potential environmental impact category hierarchy considering environmental factors

2.15.1.2 Computation of PEI_{LCIA}

The potential environmental impact based on the LCIA approach (PEI_{LCIA}) is computed as (Heijungs et al., 1992, 1992a, 1992b; Das et al., 2019)

$$PEI_{LCIA} = \sum_j [w_j \times \{ \sum_i (m_i \times EF_{ij}) / N_j \}]$$

Where w_j is weightage of impact sub-category j ; m_i is discharge rate of pollutant i (kg/year); EF_{ij} is equivalency factor for pollutant i in impact sub-category j ; and N_j is normalizing value for impact sub-category j .

The normalizing value N_j is estimated separately for global, regional and local categories as shown in below.

For all global impact sub-category j ,

$$N_j = \sum_k (I_{kj} \times EF_{kj})$$

Where I_{kj} the global annual is inventory of pollutant k with effect in global sub-category j ; and $\sum_k$ denotes all pollutants for the global sub-category j .

For all regional impact sub-category j ,

$$N_j = \sum_k (I_{kj} \times \text{Regional scale factor} \times EF_{kj})$$

Where I_{kj} the maximum is annual inventory of pollutant k in the region (state) responsible for impact sub-category j ; and $\sum_k$ denotes summation over all pollutants responsible for impact sub-category j .

Regional factors are related to sensitivity of the region to the impact sub-category.

For all local impact sub-category j ,

$$N_j = \sum_k (I_{kj} \times \text{Cluster multiplier} \times EF_{kj})$$

Where I_{kj} is the largest annual facility emission of pollutant k responsible for impact sub-category j in the region; Cluster multiplier is 1.5, to account for facility clustering effect; and $\sum_k$ denotes the summation over all pollutants responsible for impact sub-category j .

2.16 ENVIRONMENTAL IMPACTS:

The environmental impacts are defined according to the problem-oriented approach to Impact Assessment in Life Cycle Assessment. They can be calculated either for the component of the life cycle only or for the whole life cycle of the system. Both planned and accidental releases and their impacts are calculated using the following formula:

2.16.1 Resource Use: Abiotic, Biotic Depletion and Land Use

Abiotic resource depletion (ARD) includes depletion of non-renewable sources i.e., fossil fuels, metals, and minerals. The effect score is-

$$EI_{ard} = \sum_{j=1}^J \sum_{l=1}^L \frac{B_{l,j}}{EF_{ard,j}} \quad (-)$$

Where B_{ij} is quantity of resource j used in life cycle l

$EF_{ard,j}$ represents total estimated world reserves of that resource.

Biotic resource depletion (BRD) is related to the use of species threatened with extinction i.e. black rhino and sperm whale. It is calculated by:

$$EI_{brd} = \sum_{j=1}^J \sum_{l=1}^L \frac{B_{l,j}}{EF_{brd,j}} (yr^{-1})$$

Where $B_{i,j}$ is the use of species j in a life cycle stage l and $EF_{brd,j}$ is biotic depletion factor for that species.

Land use is expressed in square meters of land occupied for the delivery of the functional unit:

$$EI_{land} = \sum_{l=1}^L B_l \quad (m^2)$$

Where B_l is the land area in different stages of life cycle.

2.16.2 Global Warming Potential (GWP)

GWP represents total emissions of the greenhouse gases, (i.e. CO₂, N₂O, CH₄ etc.) B_{ij} multiplied by their respective GWP factors, EF_{gwp.j}:

$$EI_{gwp} = \sum_{j=1}^J \sum_{l=1}^L EF_{gwp.j} B_{l,j} \quad (\text{kg})$$

GWP factors are for different greenhouse gases expressed relative to the global warming potential of CO₂, which is therefore defined to be unity. $EF_{gwp.j}$ is calculated as:

$$EF_{gwp.j} = \left(\int_0^t a_i C_i(t) dt \right) / \left(\int_0^T a_{CO_2} C_{CO_2}(t) dt \right)$$

a_i and a_{CO₂} = Radiative forcing per unit concentration increase of greenhouse gas i and that of CO₂.

C_i(t) and C_{CO₂}(t) = Concentration of greenhouse gas i and that of CO₂ at time t after release

t = Number of years over which integration was made.

2.16.3 Ozone Depletion Potential (ODP)

The ODP category indicates the potential of emissions of CFC's and chlorinated HC's for depleting the ozone layer and is expressed by:

$$EI_{odp} = \sum_{j=1}^J \sum_{l=1}^L EF_{odp.j} B_{l,j} \quad (\text{kg})$$

$EF_{ODP.j}$ is calculated as:

$$EF_{ODP.j} = (\delta[O_3]_i / \delta[O_3]_{CFC-11})$$

δ[O₃]_i and δ[O₃]_{CFC-11} = Ozone breakdown in equilibrium state due to annual emissions (kg per year) of substance, i and that of CFC-11 released into atmosphere.

Where $B_{l,j}$ is emission of ozone depleting gas j . The ODP factors $EF_{ODP,j}$ represent depletion potential of emissions relative to the ozone depletion potential of CFC-11.

2.16.4 Acidification Potential (AP)

AP is based on the contributions of SO_2 , NO_x , HCL, NH_3 , and Fluorhydric Acid (HF) to potential acid deposition, i.e. on their potential to form H^+ ions. AP is calculated by:

$$EI_{ap} = \sum_{j=1}^j \sum_{l=1}^l EF_{ap,j} B_{l,j} \text{ (kg)}$$

Where $EF_{ap,j}$ represents acidification potential of gas j expressed relative to the ap of SO_2 and $B_{l,j}$ is emission of burden j per functional unit. $EF_{ap,j}$ is calculated as:

$$EF_{ap,j} = (\eta_i / \eta_{SO_2})$$

Where η_i and η_{SO_2} = Number of H^+ ions (mole/kg) which can be produced per kg of substance i and that of SO_2

2.16.5 Eutrophication Potential (EP)

EP is defined as the potential to cause over-fertilization of water and soil, which can result in increased growth of biomass. It is calculated as:

$$EI_{ep} = \sum_{j=1}^J \sum_{l=1}^l EF_{ep,j} B_{l,j} \text{ (kg)}$$

Where $B_{l,j}$ is emission of species such as NO_x , NH_4^+ , N, PO_4^{3-} & P. $Ef_{ep,j}$ represents their respective eutrophication potential EP is expressed relative to PO_4^{3-}

2.16.6 Photochemical Smog (PS)

Photochemical Smog or Oxidants creation potential is expressed relative to the PS of Ethylene & is calculated by:

$$EI_{ps} = \sum_{j=1}^J \sum_{l=1}^L EF_{ps,j} B_{l,j} \quad (\text{kg})$$

$B_{l,j}$ is emission of different contributory species (VOCs), classified into following categories: alkanes, ethylenes, alcohols, ketones & aldehydes; $EF_{ps,j}$ are their respective classification factors for photochemical smog formation. $EF_{ps,j}$ is calculated as:

$$EF_{ps,j} = [(a_i/b_i)/(a_{C_2H_4}/b_{C_2H_4})]$$

Where a_i and $a_{C_2H_4}$ = Change in O_3 concentration due to change in emission of i^{th} VOC and that of C_2H_4 .

b_i and $b_{C_2H_4}$ = Integrated emission of i^{th} VOC and that of C_2H_4 up to that time

2.16.7 Human Toxicity Potential (HTP)

HTP is calculated by adding human toxic releases to three different media, air, water and soil:

$$EI_{htp} = \sum_{j=1}^J \sum_{l=1}^L EF_{htp,jA} B_{l,jA} + \sum_{j=1}^J \sum_{l=1}^L EF_{htp,jW} B_{l,jW} + \sum_{j=1}^J \sum_{l=1}^L EF_{htp,jS} B_{l,jS} \quad (\text{kg})$$

Where $EF_{htp,jA}$, $EF_{htp,jW}$ and $EF_{htp,jS}$ are human toxicological classification factors for the effects of the human toxic emission to air, water and soil. $B_{l,jA}$, $B_{l,jW}$ and $B_{l,jS}$ represent the respective emissions of different toxic substances into the three media. These factors are calculated using tolerated daily intake of the toxic substances.

2.16.8 Ecotoxicity Potential (ETP)

ETP is divided into aquatic and terrestrial ecotoxicity, which are calculated as:

$$EI_{etpA} = \sum_{j=1}^J \sum_{l=1}^L EF_{etp,jA} B_{l,jA} \quad (\text{m}^3)$$

$$EI_{etpT} = \sum_{j=1}^J \sum_{l=1}^L EF_{etp,jT} B_{l,jT} \quad (\text{kg})$$

Where $EF_{etp.jA}$ and $EF_{etp.jT}$ represent Ecotoxicity classification factors of different toxic substances and $B_{l.jA}$ and $B_{l.jT}$ are their respective emissions to aquatic terrestrial ecosystems. ETP is based on the maximum tolerable concentrations of different toxic substances in water and soil. $EF_{etp.jA}$ is calculated as:

$$EF_{etp.jA} = (1/LC_{50})$$

where LC_{50} = Lethal concentration at which 50% of total population under test die after certain time period (96 hr).

$EF_{etp.jA}$ based on TPBP (EPA, 1998) is defined as:

$$EF = HV_{toxicity} \times (HV_{BOD} + HV_{HYD} + HV_{BCF})$$

Where $HV_{toxicity}$ is toxicity hazard value for LC_{50} or LD_{50} , HV_{BOD} is biological oxygen demand hazard value, calculated from BOD half-life. BOD half-life is the time required in days for a chemical to biodegrade such that its BOD in water is decreased to half of the original amount. HV_{HYD} is hydrolysis hazard value, calculated from Hydrolysis half-life. Hydrolysis half-life is the time required in days for the amount of substance to decrease to half of the original amount through hydrolysis reaction in water at pH 7. HV_{BCF} is bio-concentration factor hazard value, calculated from Aquatic Bio-concentration factor. Bio-concentration factor is a measure of a chemical's ability to bio-accumulate and is defined as the ratio of a chemical in fish to its concentration in water at steady state condition.

$EF_{etp.jT}$ is calculated by $(1/LD_{50})$ or $(1/TLV)$

Where LD_{50} = Median lethal dose at which 50% of test population die during a specified time period (14 days).

TLV = Time weighted average of threshold limit value i.e. the maximum amount of substance a worker can be exposed to over an 8 hour work day without any health damage.

2.17 THE APPLICATION OF LIFE CYCLE IMPACT ASSESSMENT TO SOLID WASTE MANAGEMENT

Since the early 1990s, researchers have seen the need for a dedicated decision support tool to assist solid waste managers and decision-makers in the planning, design, and implementation of effective waste management strategies. Various models have since been developed (Hanandeh and El-Zein, 2010). Solid waste management has been shown to contribute significantly to a variety of environmental issues. Because of the alarming increase in the generation of solid waste, management systems are required to completely address these environmental issues and eventually help society shift to one that is more environmentally friendly (Laurent et al., 2014). The methodology of LCA can be described by four interrelated phases, as shown in Fig. 2.4, namely goal and scope definition, Inventory analysis, impact assessment, and interpretation. The arrows of figure 2.4 indicate that the phases are continuously connected. The other phases need to be altered and enhanced if any incomplete or unacceptable components in one phase will affect the intended application of the entire study (Ozeler et al., 2006). The first steps, Goal and Scope definition, comprise the intended application and justification for carrying out the study, Inventory Analysis, identifies and quantifies energy and material usage and environmental releases; Impact Assessment aims to understand and evaluate the magnitude and significance of the potential environmental impacts of the usage and environmental releases of the product or services identified in the inventory analysis and interpretation integrates the findings of inventory analysis and impact assessment to produce conclusions and suggestions that are compatible with the purpose and scope of the study (Clift et al., 2000; Roy et al., 2009; Das et al., 2019; Naghibzadeh et al., 2014).

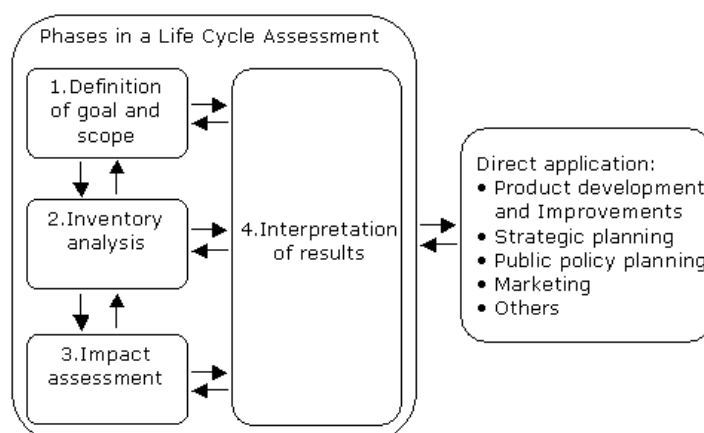


Figure-2.4: Phases of an LCA (Source: ISO 14040-2006)

Considering the above steps involved in LCA, analysis and quantitative assessment of the environmental profile over the entire life cycle of the MSWM system can be proposed so as to evaluate the impact and manage the system on the basis of sustainability. Also using this approach, potential impact of alternative processes designed to achieve similar objective can be intended in order to discover the most environmentally sound alternative.

The goal of conducting an LCA is to provide a wide perspective to the analysis of a process's life cycle by combining specific information in order to discover the most appropriate strategy to achieve the target while keeping constraints in mind. In the instance of solid waste management, the systems approach combined with LCA aids in identifying strategies to reduce environmental impacts while remaining cost-effective. This strategy is critical for developing countries such as India, where cost is a major consideration when determining how to reduce the environmental impacts of a Solid Waste Management System.

The many studies that have been done on the life cycle emissions of these systems, as well as the significant number of LCA computer models addressing MSW management, demonstrate that LCAs' are popular in analyzing MSWM systems. Over the past several years, many researchers and organizations such as the International Organization of Standardization (ISO) and the Society of Environmental Toxicology and Chemistry (SETAC) have contributed to the development of the technique used to conduct LCAs. The ISO revised the LCA requirements and principles in 2006. Various LCAs of MSW management systems have been compared, with most focusing on material-specific results (Cleary, 2009; Chen et al., 2015).

The following steps comprise a life cycle impact assessment.

1. **Selection and definition of impact categories** - identifying relevant environmental impact categories (e.g., global warming, acidification, terrestrial toxicity).
2. **Classification** - assigning LCI results to the impact categories (e.g., classifying carbon dioxide emissions to global warming).
3. **Characterization** - modeling LCI impacts within impact categories using science-based conversion factors (e.g., modeling the potential impact of carbon dioxide and methane on global warming).

4. **Normalization** - expressing potential impacts in ways that can be compared (e.g. comparing the global warming impact of carbon dioxide and methane for the two options).
5. **Grouping** - sorting or ranking the indicators (e.g. sorting the indicators by location: local, regional, and global).
6. **Weighting** - emphasizing the importance of potential impact categories.
7. **Evaluating and reporting LCIA results** - gaining a better understanding of the reliability of the LCIA results.

ISO published a standard for conducting impact assessments called ISO 14042, Life Cycle Impact Assessment (ISO 1998), which indicates that the first three processes - impact category selection, classification, and characterization - are required for an LCIA. Except for data evaluation (Step 7), the remaining phases are optional based on the purpose and scope of the study (Lee and Inaba, 2004).

In 2018, a research has examined the environmental effects using LCA technique of the present and proposed plastic waste management scenarios on various impact categories for the study area. The following scenarios are explored in the current study: landfilling without biogas recovery; incineration without energy recovery; and recycling and incineration with energy recovery. The environmental implications of all four scenarios were assessed and compared (Aryan et al., 2018).

The LCA studies of food waste management systems were the subject of a critical review in 2023, which also highlighted data trends and patterns and offered recommendations for future approaches to enhance environmental impacts (Batool et al., 2023).

Significant progress has been achieved in the use of Life Cycle Assessment (LCA) in waste management over the last five years. Researchers are increasingly using LCA to assess and compare the environmental impacts of different methods for dealing with waste in order to develop more sustainable practices.

In 2024, a study examined strategies such as recycling, gasification, and anaerobic digestion and discovered that these approaches had much lower environmental impacts than traditional methods such as landfilling and incineration (Ouedraogo et al., 2024)

In 2024, researchers have created frameworks that combine LCA with multicriteria optimization models. These models seek to assign waste streams to alternative valorization systems in order to reduce environmental impact while taking into account regional constraints and priorities (Abdullah et al., 2024).

2.18 RECENT STUDIES ON SWM OPTIMISATION MODEL IMPLEMENTATION

The multidisciplinary field of solid waste management requires knowledge of the social, economic, environmental, and physical impacts of a SWM system. Unlike the conventional approach, which focuses only on the disposal of solid waste, the ISWM approach seeks to lower the initial generation of waste through source reduction, and then further decrease the volume of materials being sent to treatment facilities and landfills through recycling and reuse. System analysis offers interdisciplinary support for SWM decision-making by harmonizing these ISWM methodologies. Municipalities around the world are having greater challenges managing waste effectively and economically. Increased waste volumes, restricted urban space for dumping/landfilling, rising public environmental awareness, stringent technical requirements on management alternatives, and waste prevention and recycling goals require an integrated solid waste management (ISWM) system that incorporates the best available techniques and programs to manage MSW (shafy et al., 2018). Given the enormous number of possible SWM alternatives and the way they are interrelated; selecting SWM methods that meet economic and environmental goals is a challenging task (Paul et al., 2018). Decision-makers have to find solutions that take into account a variety of objectives and strategies. In the decades that have followed, various waste planning models have been studied and implemented in the SWM field (Rodrigues et al., 2018). Three main factors were taken into account when constructing the models: waste recycling, environmental sustainability, and cost control.

A model is something that forecasts the outcomes of a proposed system that has not been implemented yet. The most fundamental type of SWM modeling is called linear programming; both the objective function and the constraints, which are made up of equalities and inequalities, are linear. Generally speaking, cost is regarded as the most objective function. LP models have the drawback of potentially involving an excessive number of variables and constraints, which might impact calculation time (Paul et al., 2020). LP optimization was used in the initial development of solid waste management

models with a single objective optimization scheme- cost optimization. These LP models tend to restrict the partial costs associated with a SWM system by simply taking into account waste flows from transfer stations to disposal sites (Anderson, 1968). In 1968, Anderson developed the first mathematical model for optimizing the waste management system. Since then, a number of researchers have developed solid waste management models to serve as decision-support tools for choosing processing methods, determining the location and size of waste processing facilities, managing vehicles and labour, and optimizing the entire system. Among the methods used is nonlinear programming, multi-objective programming, mixed integer linear programming, or MILP.

Daskalopoulos et al. developed a MILP model in 1998 to manage different MSW streams while taking into consideration their rates, contents, and adverse environmental effects. Optimization strategies were presented by Najm et al., 2002, for developing solid waste management systems at the lowest possible cost while taking a range of management procedures into account. In addition to the possible environmental effects of different MSW management strategies, the LP model takes into consideration the rates of solid waste generation, its composition, collection, transportation, treatment, and disposal. An ISWM model and a computer-based interface were created by Najm and El-Fadel, 2004, utilizing an Excel-Visual Basic environment.

In order to plan the management of municipal solid waste, Costi et al., 2004, suggested a mixed integer, non-linear decision model. This model identified the refuse flows that must be transported to recycling, processing, and disposal units and recommended the ideal amount, types, and locations for the plants. While the objective function takes into account all potential financial expenses, mass balance, sanitary landfill conservation, incinerator process requirements, and minimum recycling criteria are the sources of restrictions. A MILP model has been suggested by Badran and El-Hagar, 2006, as the best way to manage municipal solid waste in Port Said, Egypt. The goal is to reduce the daily transportation expenses from the districts to the collection stations and from the collection stations to the composting facilities and/or landfills by selecting a combination of collection stations from among the available sites. The capacity limitations for collection stations are a constraint for the objective function (i.e., cost).

In 2008, Pati et al., presented a mixed integer goal programming approach for a paper recycling system. The goals of the model are reverse logistics cost (C), budgetary

expenditures for recycling waste paper should be reasonable, non-relevant wastepaper target, the quality of waste paper collected should be improved at the vendor level and wastepaper recovery target, and wastepaper collection ought to be extended to the maximum extent possible.

In 2010, Noche et al., developed a logistic concept model for the optimal operations of solid waste facilities in Germany's "NRW State" of Duisburg City. Subject to physical constraints, the mathematical model takes into account economic and environmental factors when choosing options that will minimize the cost of waste collection, transportation, operation, and disposal.

To improve the fuel efficiency of conservation vehicles, Jovicic et al., 2011, concentrated on route optimization using GIS/GPS. They used the COPERT computer program to predict vehicle emissions for heavy-duty diesel vehicles that complied with EURO I standard, assuming that a typical municipal vehicle emits 900 g/km of CO₂. Nevertheless, this paper lacks detailed computations with stoichiometric equations for many contaminants. The amount of air pollutants (CO₂, CO, HC, NO_x, PM, and CO₂-eq) produced in Tallinn, Estonia, when the current garbage collection system using conservancy trucks is used was examined by Vilms et al. in 2015. The current waste transportation system uses trucks equipped with a pneumatic waste transfer system, which may reduce vehicle exhaust gases, noise pollution, and waste that leaks or drops from vehicles.

In 2021, Zaeimi and Rassaf developed and implemented a biobjective optimisation model in Qazvin, Iran, to reduce the expenses associated with facility location, transportation planning, and pollution emissions. Furthermore, demand or the quantity of waste generated is taken into account as a random parameter in light of the problem's unpredictable character. This leads to the development of a stochastic mathematical programming model with probable constraints.

A mixed-integer optimization model was developed by Barma et al. in 2022 for the MSW of Kano State, Nigeria. The model optimizes the total cost of solid waste management (SWM), which comprises the fixed costs associated with establishing, maintaining, and operating certain facilities as well as the cost of transporting various kinds of waste between different locations.

In 2022, Shaban et al., developed a generic optimisation model that can be used for SWMS optimisation in the Fayoum Governorate of Egypt. A new mixed-integer linear programming (MILP) model is developed for a SWM system design that incorporates source of waste production, collection/transfer stations, recycling facilities, incinerators, and landfills,. In order to minimize the net daily cost incurred in the system, the ideal number and placements of the various facilities as well as the best waste flow within the system are determined by the suggested MILP model.

In 1999, Gerlagh et al., proposed a linear programming model that minimizes the overall cost of solid waste in society and was applied in Bangalore, a large metropolis. The model considers Waste generating sector (home, office, and industry) as the input for the first component of the proposed model. The waste processing sector (rag pickers, waste purchasing shops, and waste treatment plants) is the second component and the third component is extracts (greenhouse gases).

In 2007, Rathi, developed a linear programming (LP) model to combine the various alternatives and participants engaged in MSW management in Mumbai. There are several alternatives and players engaged in managing MSW. Different costs associated with managing MSW were considered from an economic and environmental perspective.

In 2011, Gupta and Sharma presented an integer programming model for the integrated planning of solid waste management system of Jaipur. In the suggested method, waste would be collected at several municipal collection points, with the best routes selected to transport the waste to designated segregation sites. Once separated, the waste would then be transported by dumpers to a specific treatment plant.

In 2012, Tiwari et al., proposed an optimized model based on the adaptive neuro-fuzzy inference system model (ANFIS model) to estimate the amount of industrial solid waste generated for the densely populated Durg district of Chhattisgarh state, India.

In 2012, Karajgi et al., proposed a mathematical model to evaluate the production of electrical energy from municipal solid waste. The model simplified and reduced associated costs for a number of linear mass balance equations pertaining to the mass of waste (tons/day) collected from various sources.

In 2013, Patel and Meka, proposed combining empirical models in order to estimate the approximate production of solid waste in the state of Gujarat using an Empirical and Artificial Neural Network (ANN) Model Approach.

In 2017, Kolekar et al., developed a prediction models for the generation of MSW, based on the Fuzzy Inference System (FIS) in order to study the influences of the factors like age group, total population, per capita annual income, literacy rate, and monthly consumer expenditure on the temporal variability of MSW generation for Kolhapur city, India.

In 2019, Alam et al., suggested a fuzzy-based model to assess whether landfill sites are suitable for dumping of municipal solid waste while taking into account 32 Central Pollution Control Board (CPCB) recommended features for the Asansol Municipal Corporation (AMC) region of West Bengal, India. Both quantitative and qualitative variables are included in the attributes

In 2020, Roy and Paul, Using fuzzy logic, a mathematical model have been developed to forecast the overall amount of rural waste generation in the research area in west Bengal. To anticipate the generation of solid waste in rural areas, factors such as household size, population, per capita income, district-wise domestic product and literacy rate were taken into account as independent variables.

In 2021, Saxena et al., suggested a mixed integer linear programming model in order to minimize the total collection and transportation costs of solid waste management for Chennai, an Indian metropolis.

To provide suggestions for a better SWM, a thorough examination of the many aspects of SWM in general and solid waste mechanism of KMC in particular is carried out. To implement the ISWM system over current SWM system of Kolkata, a model that can compare the effects of the proposed and current systems must be developed.

In 2014 Paul et al., developed Geographic Information System (GIS) based Management Information System (MIS) for solid waste management in Kolkata. This study uses an overlay analysis of a geographic information system (GIS) and multicriteria decision analysis, as specified in the CPCB 2003 standards, to try and find the best location for the disposal of solid waste from the KMC region.

The limitations and challenges of the study include restricted data availability and did not consider the pollution generation from SWM, and its quantitative environmental impact. The study, as reported, did not include a thorough environmental impact assessment (EIA) or the public participation process. Ignoring community views or environmental impacts (for example, on wetlands or wildlife) might result in contradiction and long-term sustainability concerns.

In 2017, Paul et al., used GIS as a tool for optimized bin placement to design an efficient and cost effective collection system. The ArcGIS software's Network Analyst extension was used to identify the service area of a bin, vat, or container in the boroughs. In this study 15 numbers of boroughs are considered. This approach has used to estimate the amount of waste generated within service area of each bin, the number of handcart trips needed to transport waste from the service area to the designated bin, the size of the bins, the frequency of haulages, and the number of conservation staff members required to maintain each bin location.

The limitations and challenges of the study are the data accuracy and temporal relevance, and assumption in waste generation estimation. The amount of waste generated every location is difficult to estimate accurately and depends on the circumstances. The study may use average generation rates or secondary statistics that ignore variances owing to socioeconomic factors, commercial activity, or seasonal fluctuations. This may bias area of service boundaries and result in under- or overestimation of bin size, handcart trips, and labor requirements.

In 2018, Chattopadhyay, developed a liner programming model for MSW management system considering Kolkata. In this model all aspects of MSWM systems like waste generation, transportation, processing, disposal etc. has been considered. Pollution generations from transport sector and landfill have been considered separately to calculate the environmental impact qualitatively only. But, the pollution generation is not incorporated in the model to find out and minimize the quantitative impact. Only cost optimization of the systems has been considered into the model along with the operational constraints considering the data of 2007.

The limitations and challenges of the study is environmental impact considered qualitatively, not quantitatively. One of the most significant issues in MSWM is environmental sustainability, which includes emissions, groundwater pollution, and

worsening air quality. The model analyzes environmental pollution qualitatively, without incorporating quantitative indicators like emissions of gaseous pollutants, generation of liquid pollutants in leachate volume into its optimization function. This results in a one-sided solution based entirely on cost, which may offer choices that are economically efficient but environmentally detrimental.

In 2019, Paul et al., used the LINGO to develop a liner programming generic model for an integrated MSW management system for Kolkata. This model includes the waste generation rates, composition, transportation modes, processing methods, and profits from waste processing. But, pollutants generation from the system is not considered. In this study, the number of trips, mass balance, waste flows, processing facility capacity, landfill capacity, and transport vehicle capacity were all taken into account as constraints. During the analytical process alternative waste management strategies were taken into consideration. To determine the least expensive combination of technologies for the processing, treatment, and disposal of solid waste, the model is used as a decision support tool to assess different waste management options.

The limitations and challenges of the study is exclusion of environmental pollution as a factor. Environmental sustainability is a major challenge in disposal of waste today. While the model includes economic and operational characteristics, pollutant emissions from processing, transportation, and landfilling are completely removed from both the objective function and the restrictions. This absence results in a model that may choose technologically and economically optimal waste management solutions that are environmentally detrimental, thereby compromising long-term sustainability and regulatory compliance.

In 2020, Paul et al., developed a LP model to examines how the inclusion of transfer stations impacts overall efficiency and cost-effectiveness of an integrated MSW management system by integrating the effects of the station(s). In this study no pollutants generation and their effects are not considered at all. The study proposed three engineered landfill site for disposal of waste close to the KMC boundary. Subsequently, the model is employed as a tool for decision support in the assessment of diverse waste management options. It determines the most efficient combination of technologies for waste collection, transportation, processing, and disposal without considering the environmental effects.

The limitations and challenges of the study is complete omission of environmental impact assessment. Environmental considerations like greenhouse gases emissions, leachate generation, and particulate matter play an important role in modern waste management design. The model does not account for any pollutant generation (from transportation, processing, or landfilling), nor does it attempt to quantify or evaluate the impact on the environment. Decisions based on this approach may prioritize cost-efficiency over environmental sustainability, resulting in environmentally detrimental behaviors or non-compliance with legal frameworks such as CPCB (Central Pollution Control Board) standards.

2.19 RESEARCH GAP

The literature review demonstrates that there is a wealth of information on the increasing quantity of MSW and its overall effects on the environment and public health and the use of MSWM optimization mathematical model to find the future waste generation, to improve the collection efficiency and to determine the optimal operational cost. However, there is a dearth of research about the pollution generation from the MSWM system, the quantitative impacts of the pollutants from different sectors, and the corresponding optimal cost solution, particularly in Kolkata, a metropolitan city of India, a developing country.

The work done so far for the MSW management system does not consider the assessment of pollutant generation from various activities of the municipal solid waste management system for Kolkata, which represents a metropolitan city in a developing country, India. Linear programming model has been developed to find the optimal operational cost considering the possible constraints. Previous research also has not addressed the quantitative impact of pollutants generated through different MSW management system operations. Furthermore, the process for minimizing pollutants generation from various components of the MSW management system is not considered. Also, the life cycle impact assessment (LCIA) method has not yet been used to evaluate the environmental impact quantitatively from the municipal solid waste management systems in Kolkata.

Currently, there is a scarcity of literature that provides information on optimal operation plans while considering cost and PEI, particularly for the MSW management system of Kolkata, which represents the metropolitan city of developing nation like India.

3 OBJECTIVE AND SCOPE OF THE STUDY

3.1 OBJECTIVE OF THE PROPOSED WORK

The objective of the work is to establish a quantitative relationship between materials, fuels, pollutants, and the cost of municipal solid waste management system, considering its possible operational constraints of a major metropolitan city of India, Kolkata. This will be accomplished through a systems approach. Additionally, the potential environmental impacts of the Municipal Solid Waste Management (MSWM) system will be analyzed using Life Cycle Assessment (LCA) as a tool, aiming for optimized cost with minimum environmental impact.

3.2 SCOPE OF THE WORK

The proposed objectives of the present research work are aimed to achieve by fulfilling the following scopes:

- Studying of the generation pattern and characteristics of municipal solid waste of developing countries focusing on the study area Kolkata.
- Analyzing of the existing municipal solid waste management system of Kolkata and exploring its future scope.
- Conducting input and output analysis of different functional stages of municipal solid waste management system using LCA.
- Development of general purpose pollution prevention linear programming models for existing municipal solid waste management system and for proposed integrated municipal solid waste management system of Kolkata with due consideration of operations, environmental impacts and costs of the systems.
- Minimization of potential environmental impact for existing municipal solid waste management system and for proposed integrated municipal solid waste management system of Kolkata considering operations and costs.

Objective and scope of the study

- Identifying the eco-friendliness of the different components of the existing municipal solid waste management system and proposed integrated municipal solid waste management system.
- Suggesting optimized operation plans with due consideration of the costs and potential environmental impacts.

4 DEVELOPMENT OF A MUNICIPAL SOLID WASTE MANAGEMENT (MSWM) OPTIMIZATION MODEL

4.1 BACKGROUND

Solid waste management is the biggest challenge faced by small- and large-city authorities in developing countries. (Hussein et al., 2018). Municipalities throughout the world are having difficulties managing their waste more efficiently and cost-effectively as a result of increasing waste quantities and a scarcity of urban space for landfilling or disposal. An integrated solid waste management (ISWM) system incorporating the best available practices and programs is required to manage the Municipal Solid Waste (MSW) in an economically and environmentally responsible manner. Other requirements include growing public environmental awareness, strict technical requirements on management alternatives, and waste prevention and recycling goals. (Najm et al., 2002).

The conventional solid waste management (SWM) system aligns with the fundamental responsibilities of municipal entities, which include garbage collection, storage, transportation, and disposal. Though, these municipalities are facing increased adversities in managing the waste effectively and economically. Recycling, Reuse, minimization of waste, engineered landfill sites, waste to energy plants do not hold much importance. In many cities, the municipal or urban local bodies only handle a minor fraction of the potential waste generated by residential, commercial, industrial, institutions etc. Many cities manage more waste informally and outside of the municipal waste management system that is handled by local authorities (Furedy, 1994), which encourages open burning and illegal disposal. This approach has several drawbacks that can be linked to several issues, including the inadequacy of local municipalities to collect all of the waste generated, insufficient data, a lack of funding, incompetence, an increasing throwaway culture, inappropriate disposal sites, etc.

The problem of waste management can't be solve by any single methodology (Freduah, 2007). There is need of multiple strategies in such a way thus to minimize environmental and cost associated with the waste management system. The current analysis aims to incorporate the integrated best possible solutions in Kolkata to reduce the PEI as well as

the cost of the MSWM system. ISWM comprises of waste prevention, source reduction, reusing, and recycling, followed by processing to reduce the amount of materials transported for safe disposal. This chapter develops a solid waste management mathematical model considering all aspects of the system. The model consists of quantity of MSW generation along with its quality, various MSWM activities and their operational constraints and economics. Activities are building blocks of the system which include MSW collection, reuse and recycling, transportation, treatment, revenue generated from waste processing and safe disposal to landfill site; and constraints are capacities (processing plant capacity, transport vehicle capacity, landfill capacity), efficiencies (number of trips), finance (recycle amount) etc. Paths are the direction through which the MSW flow in the course of SWM. Impacts of such different paths would be evaluated with the help of systems approach i.e. LP model with PEI assessment by Life Cycle Impact Assessment (LCIA) approach. The cost involved while performing different activities would be evaluated and the total cost involvement for the entire path would be compiled and optimized. The optimization of the path would be done by judging the performance of the path in reducing environmental burden considering cost. This model helps to find the optimized path by changing the different constraint of MSWM system. The LP model will run for different cases to find out the eco-friendliness of the activities considering the cost components and compared.

The LINGO optimization software has been used to solve the linear programming model that includes several functional elements. The model is validated with the existing datasets of SWM system of Kolkata city of 2022 and further the model is extended for the proposed integrated municipal solid waste management system to explore its effect on pollution generation from different sectors, cost aspects and various operational parameters. This will help to predict the outcome of ISWM system which facilitates for environmental policy making in future SWM with sustainability.

4.2 MODEL DEVELOPMENT

4.2.1 Assumptions

Integrated solid waste management (ISWM) system is taken into consideration for an Indian city based on the following fundamental assumptions, as well as appropriate source segregation, central sorting, and treatment:

- It has been assumed that borough centers are the places where waste is generated.
- Two bin systems are provided at source (one for biodegradable waste and the other for non-biodegradable waste) for proper segregation of waste.
- A central or intermediate sorting facility will be constructed from which recyclable materials will be transported for recycling, with revenue generated from the sale of the recyclables.
- Silt and rubbish are dumped directly into landfills without any sorting or processing, while garbage is sorted and processed at the central/intermediate sorter before being sent to other processing plants.
- Depending on the properties, waste will be treated and disposed of accordingly. For example, waste with a high calorific value may be incinerated, while organic waste that decomposes naturally would be composted.
- All treatment processes will include pre-sorting facilities to separate inert and recyclable material from the central sorter. Inert, process rejects, and residues from the treatment plant will be sent directly to a designed landfill.
- Waste is transported by the municipal body using departmental and hired vehicles. Only garbage is collected by departmental vehicles, whereas rubbish and silt are transported by hired vehicles (silt and garbage are collected separately, not together).
- There are four types of departmental vehicles available, but there is only one type of privately hired vehicle.
- For each disposal site, the city is divided into zones.
- There are limitations on minimum and maximum trip counts for departmental vehicles and hired vehicles in each zone.
- For each zone, the departmental vehicles have to make a minimum number of trips.
- The incentives will be paid to the drivers and helpers of departmental vehicles if they complete more than the minimum number of trips. The payment of hired vehicles will be made based on the quantity of silt/ rubbish and garbage they transport to the disposal sites.
- The average waste generation data of the boroughs of the concerned municipality is taken into account while running the model.

- To make the model more flexible and realistic, the minimum and maximum waste carrying range (in fraction) for departmental and hired vehicles is established borough-wise based on the average waste carried by different types of vehicles from different boroughs. Cost of the processing plants and landfilling has been taken into account.
- The model neglects the cost of waste collection by municipal staff from households to the VAT/container location because it is almost constant and has little impact on cost optimization.
- The operational cost incinerator includes the cost of operating (including pre-sorter) and maintaining the incinerator, as well as the cost of transporting combustible waste from the sorting plant to the incineration.
- The pre-sorter cost, plant maintenance, and cost of transport from the central sorting facility to the composting plant are all included in the operational costs of composting plant.

With an intake of 100 MT of MSW, a material flow chart (Figure 4.1) has been developed based on the above assumptions. Out of this 100 MT waste, it is assumed that 5 MT of waste is segregated and recycled at household level and storage points and the remaining 95 MT of waste goes to the central sorting facility of an engineered landfill site and is subjected to different processing techniques present within that engineered landfill site. It is assumed that the city has *DE* number of disposal sites at different location. No solid waste disposal facilities is considered at western side of Kolkata as this side is extended upto river Ganga and the Howrah city is located on the other side with their own solid waste management system. Each disposal site *de* equipped with one central sorting station, one recycling facility, one incinerator, one composting facility and one landfill. From the central sorting facility, recyclable waste materials go to recycling facility, while combustible waste materials sent to incinerator, biodegradable waste materials go to composting plant, and inert waste sent to engineered landfill as shown in the Figure 4.1. To improve the efficiency of treatment processes waste materials from central sorting facility are delivered to the pre-sorting units of the incinerator and composting plants and the inert fraction are taken directly to the engineered landfill.

4.2.2 Defining Parameters

Indices

BH	Total number of boroughs. For KMC case, BH= 16.
bh	Index for boroughs (1..BH).
DE	Total number of disposal sites. For KMC case, DE =3.
de	Index for disposal site (1..DE).
DV	Total number of departmental vehicles. For KMC case, DV = 4.
dv	Index for departmental vehicle (1..DV).
HV	Total number of hired vehicles types. There is only one type of hired vehicle in KMC i.e. HV = 1.
hv	Index for private hired vehicle.
ZE	Total number of zones associated with each disposal site de . In KMC's case, ZE= 2.
ze	Index for zones associated with a particular disposal site dv (1..ZE).

Input data in the form of matrices

$bh\_fcost_{bh,de,dv}$	Average cost of fuel for transporting per ton waste from borough bh to disposal site de by a dv type vehicle, Rs/MT. (BH $\times$ DE $\times$ DV) matrix.
$bh\_fgdvmax_{bh,dv}$	Maximum fraction of garbage transported by dv type departmental vehicles from borough bh . (BH $\times$ DV) matrix.
$bh\_fgdvmin_{bh,dv}$	Minimum fraction of garbage transported by dv type departmental vehicles from borough bh . (BH $\times$ DV) matrix.
$bh\_fghvmax_{bh}$	Maximum fraction of garbage transported by hired vehicles hv from borough bh . (BH $\times$ HV) matrix.
$bh\_fghvmin_{bh}$	Minimum fraction of garbage transported by hired vehicles hv from borough bh . (BH $\times$ HV) matrix.

$bh\_hvcostg_{bh,de}$	Per ton transportation cost of garbage from borough bh center to disposal site de for a hired vehicle, Rs./MT. (BH $\times$ DE) matrix.
$bh\_hvcosts_{bh,de}$	Per ton transportation cost of silt from borough bh center to disposal site de for a hired vehicle, Rs./MT. (BH $\times$ DE) matrix.
bh_wg_{bh}	Amount of garbage generated in borough bh , MT. (BH $\times$ 1) matrix.
bh_ws_{bh}	Amount of silt generated in borough bh , MT. (BH $\times$ 1) matrix.
$truck\_cap$	Payload capacity of a heavy duty truck, MT.
cp_maxcap_{de}	Maximum capacity of the composting plant at a disposal site de , MT. (DE $\times$ 1) matrix.
cp_mincap_{de}	Minimum capacity of the composting plant at a disposal site de , MT. (DE $\times$ 1) matrix.
cp_ircost_{de}	Transportation cost of inorganic rejects from composting pre-sorter to landfill at de on a per ton basis, Rs/MT. (DE $\times$ 1) matrix.
cp_irf_{de}	Composting inorganic reject fraction coming out from the composting plant pre-sorter, at disposal site de . (DE $\times$ 1) matrix.
cp_opcost_{de}	Per ton operational cost of the composting plant including cost of construction and operation of composting plant and transportation cost from the central sorting facility to composting plant, Rs/MT. (DE $\times$ 1) matrix.
cp_prcost_{de}	Transportation cost of composting process rejects from composting plant pre-sorter to the landfill at disposal site de , Rs/MT. (DE $\times$ 1) matrix.
$cp\_prslcost_{de}$	Selling price of the compost, Rs/ ton for a disposal site de . (DE $\times$ 1) matrix.
cp_pry_{de}	Composting product (compost) to composting plant feed ratio at a disposal site de . (DE $\times$ 1) matrix.
cp_prf_{de}	Compost plant process rejects fraction coming out from the

composting plant at disposal site de . ($DE \times 1$) matrix.

$cp\_recycost_{de}$ Per ton transportation cost of recyclables from composting plant pre-sorter for a particular disposal site de to recycling facility at de , Rs/MT. ($DE \times 1$) matrix.

$cp\_revrecy_{de}$ Revenues earned from selling recyclable materials sorted out from composting pre-sorter at a disposal site de , Rs/MT. ($DE \times 1$) matrix.

cp_recyf_{de} Recyclable fraction of waste coming out from composting plant pre-sorter at de . ($DE \times 1$) matrix.

dv_cap_{dv} Average waste carrying capacity of a dv type of departmental vehicle, MT. ($DV \times 1$) matrix.

hv_capg_{hv} Average garbage carrying capacity for hired vehicle hv , MT. ($HV \times 1$) matrix.

hv_caps_{hv} Average silt carrying capacity for hired vehicle hv , MT. ($HV \times 1$) matrix.

dv_frcost_{dv} Fixed running cost for each dv type departmental vehicle, Rs. ($DV \times 1$) matrix.

dv_ficost_{dv} Fixed idle cost for each dv type departmental vehicle, Rs. ($DV \times 1$) matrix.

dv_nar_{dv} Total number of dv type departmental vehicles running. ($DV \times 1$) matrix.

dv_no_{dv} Total number of dv type vehicles in KMC fleet. ($DV \times 1$) matrix.

$fucost\_truck_{de}$ Fuel cost per ton of waste transported by heavy duty trucks from transfer station associated with disposal site de to disposal site de , Rs/MT. ($DE \times 1$) matrix.

f_inc_{de} kWh units of electricity generated by processing unit per MT of MSW in incinerator at disposal site de . ($DE \times 1$) matrix.

ics_adcost_{de} Per ton cost of additional dumping from sorter to landfill at de ,

	Rs/MT. $(DE \times 1)$ matrix
ics_maxcap_{de}	Maximum capacity of the central sorting facility at a disposal site de , MT. $(DE \times 1)$ matrix.
ics_mincap_{de}	Minimum capacity of the central sorting facility at a disposal site de , MT. $(DE \times 1)$ matrix.
ics_ddumpf_{de}	Direct dumpable fraction of solid waste coming out from sorter at disposal site de . $(DE \times 1)$ matrix.
ics_maxcpf_{de}	Compostable fraction of solid waste coming out from sorter at disposal site de . $(DE \times 1)$ matrix.
$ics\_maxincf_{de}$	Incinerable fraction of solid waste coming out from sorter at disposal site de . $(DE \times 1)$ matrix.
$ics\_tcostrecy_{de}$	Transportation cost of recyclable material segregated from the sorter at disposal site de to recycling facility, Rs/MT. $(DE \times 1)$ matrix.
$ics\_revrecy_{de}$	Revenue earned by selling per ton of recyclable materials generated from the sorting station attached to disposal site de , Rs/MT. $(DE \times 1)$ matrix.
ics_recyf_{de}	Recyclable fraction of solid waste coming out from sorter at disposal site de . $(DE \times 1)$ matrix.
$ics\_opcostsort_{de}$	Operational cost of sorting per ton of solid waste for the central sorting station associated with the disposal site de , Rs/MT. $(DE \times 1)$ matrix.
inc_tcosta_{de}	Per ton cost of transporting incinerator ash reject portion from pre sorter to landfill for a particular disposal site de , Rs/MT. $(DE \times 1)$ matrix.
inc_arejf_{de}	Incineration ash reject (incineration product) fraction coming out from the incinerator at disposal site de . $(DE \times 1)$ matrix.
inc_maxcap_{de}	Maximum capacity of the incinerator at a disposal site de , MT. $(DE \times 1)$ matrix.

inc_mincap_{de}	Minimum capacity of the incinerator at a disposal site de , MT. (DE $\times$ 1) matrix.
$inc\_irejtcost_{de}$	Transportation cost of transferring inorganic rejects from incinerator pre-sorter to landfill attached to disposal site de , Rs/MT. (DE $\times$ 1) matrix.
inc_irejff_{de}	Incineration inorganic reject fraction coming out from incinerator pre-sorter at disposal site de . (DE $\times$ 1) matrix.
inc_opcost_{de}	Operational cost of the incinerator at disposal site de , Rs/MT. It includes the construction and operational cost of incinerator and the transportation cost of incinerable waste from the sorting facility to the incinerator. (DE $\times$ 1) matrix.
$inc\_recycost_{de}$	Transportation cost of per ton recyclables from the incinerator pre-sorter attached to the disposal site de , to the recycling facility at de , in Rs/MT. (DE $\times$ 1) matrix.
inc_rev_{de}	Revenue that can be earned in selling one kWh unit of electricity generated from the incinerator associated with disposal site de , Rs/kWh. (DE $\times$ 1) matrix.
$inc\_revrecy_{de}$	Revenues earned from selling recyclable materials sorted out from incinerator pre-sorter at a disposal site de , Rs/MT. (DE $\times$ 1) matrix.
inc_recyf_{de}	Recyclable fraction of waste coming out from incinerator pre-sorter at de . (DE $\times$ 1) matrix.
lf_maxcap_{de}	Maximum capacity of the landfill at disposal site de , MT. (DE $\times$ 1) matrix.
lf_cost_{de}	Landfilling cost in Rs/MT of solid waste for the landfilling site associated with a disposal site de . It includes cost of land, liner, cover material, leachate collection and treatment cost. (DE $\times$ 1) matrix.
$ze\_maxtrip_{dv,de,ze}$	Maximum number of trips that a dv type departmental vehicle is allowed to undertake in zone ze of disposal site de . (DV $\times$ DE $\times$

ZE) matrix.

$maxze\_maxtrip_{dv}$	Maximum value of $ze\_maxtrip_{dv,de,ze}$ for a particular dv type vehicle, considering all disposal sites de . ($DV \times 1$) matrix.
$ze\_mintrip_{dv,de,ze}$	Minimum number of trips that a dv type departmental vehicle has to undertake in zone ze of disposal site de . ($DV \times DE \times ZE$) matrix.
$minze\_mintrip_{dv}$	Minimum value of $ze\_mintrip_{dv,de,ze}$ for a particular dv type vehicle, considering all disposal sites de . ($DV \times 1$) matrix.
r_incost_{dv}	Rate of incentive (per extra ton basis) to be paid to the driver and helper of a dv type vehicle for transporting waste over and above the minimum trips, Rs/MT. ($DV \times 1$) matrix.
$icost\_truck$	Fixed idle cost per heavy duty truck, Rs.
$truck\_na$	Number of heavy duty trucks actually running considering all the three disposal sites.
$truck\_no$	Total number of heavy duty trucks considering all the three disposal sites.
$rcost\_truck$	Fixed running cost per heavy duty truck, Rs.
$trips\_truck_{de}$	Maximum number of trips each heavy duty truck associated with disposal site (and transfer station) de is required to make. ($DE \times 1$) matrix.
$CO\_er\_dv_{bh,de}$	CO emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip. ($BH \times DE$) matrix.
$SO_2\_er\_dv_{bh,de}$	SO ₂ emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip. ($BH \times DE$) matrix.
$CO_2\_er\_dv_{bh,de}$	CO ₂ emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip. ($BH \times DE$) matrix.

$NO_x\_er\_dv_{bh,de}$	NO_x emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip. (BH $\times$ DE) matrix.
$HC\_er\_dv_{bh,de}$	HC emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip. (BH $\times$ DE) matrix.
$PM\_er\_dv_{bh,de}$	PM emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip. (BH $\times$ DE) matrix.
$BENZ\_er\_dv_{bh,de}$	BENZENE emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip. (BH $\times$ DE) matrix.
$BUTDN\_er\_dv_{bh,de}$	BUTADIENE emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip. (BH $\times$ DE) matrix.
$CO\_er\_hvg_{bh,de}$	CO emission rate by hired vehicle type hv to carry the waste from borough bh to disposal site de per MT of garbage per trip. (BH $\times$ DE) matrix.
$SO_2\_er\_hvg_{bh,de}$	SO_2 emission rate by hired vehicle hv to carry the garbage from borough bh to disposal site de per MT of garbage per trip. (BH $\times$ DE) matrix.
$CO_2\_er\_hvg_{bh,de}$	CO_2 emission rate by hired vehicle hv to carry the garbage from borough bh to disposal site de per MT of garbage per trip. (BH $\times$ DE) matrix.
$NO_x\_er\_hvg_{bh,de}$	NO_x emission rate by hired vehicle hv to carry the garbage from borough bh to disposal site de per MT of garbage per trip. (BH $\times$ DE) matrix.
$HC\_er\_hvg_{bh,de}$	HC emission rate by hired vehicle hv to carry the garbage from borough bh to disposal site de per MT of garbage per trip. (BH $\times$ DE) matrix.

$PM_{er\_hvg_{bh,de}}$	PM emission rate by hired vehicle hv to carry the garbage from borough bh to disposal site de per MT of garbage per trip. (BH $\times$ DE) matrix.
$BENZ_{er\_hvg_{bh,de}}$	BENZENE emission rate by hired vehicle hv to carry the garbage from borough bh to disposal site de per MT of garbage per trip. (BH $\times$ DE) matrix.
$BUTDN_{er\_hvg_{bh,de}}$	BUTADIENE emission rate by hired vehicle hv to carry the garbage from borough bh to disposal site de per MT of garbage per trip. (BH $\times$ DE) matrix.
$CO_{er\_hvs_{bh,de}}$	CO emission rate by hired vehicle type hv to carry the silt from borough bh to disposal site de per MT of silt per trip. (BH $\times$ DE) matrix.
$SO_2_{er\_hvs_{bh,de}}$	SO ₂ emission rate by hired vehicle hv to carry the silt from borough bh to disposal site de per MT of silt per trip. (BH $\times$ DE) matrix.
$CO_2_{er\_hvs_{bh,de}}$	CO ₂ emission rate by hired vehicle hv to carry the silt from borough bh to disposal site de per MT of silt per trip. (BH $\times$ DE) matrix.
$NO_x_{er\_hvs_{bh,de}}$	NO _x emission rate by hired vehicle hv to carry the silt from borough bh to disposal site de per MT of silt per trip. (BH $\times$ DE) matrix.
$HC_{er\_hvs_{bh,de}}$	HC emission rate by hired vehicle hv to carry the silt from borough bh to disposal site de per MT of silt per trip. (BH $\times$ DE) matrix.
$PM_{er\_hvs_{bh,de}}$	PM emission rate by hired vehicle hv to carry the silt from borough bh to disposal site de per MT of silt per trip. (BH $\times$ DE) matrix.
$BENZ_{er\_hvs_{bh,de}}$	BENZENE emission rate by hired vehicle hv to carry the silt from borough bh to disposal site de per MT of silt per trip. (BH $\times$ DE) matrix.

$BUTDN\_er\_hvs_{bh,de}$	BUTADIENE emission rate by hired vehicle hv to carry the silt from borough bh to disposal site de per MT of silt per trip. ($BH \times DE$) matrix.
$CO\_er\_truck_{de}$	CO emission rate by heavy duty truck to carry the waste from transfer station to disposal site de per MT of waste per trip. ($DE \times 1$) matrix.
$SO_2\_er\_truck_{de}$	SO ₂ emission rate by heavy duty truck to carry the waste from transfer station to disposal site de per MT of waste per trip. ($DE \times 1$) matrix.
$CO_2\_er\_truck_{de}$	CO ₂ emission rate by heavy duty truck to carry the waste from transfer station to disposal site de per MT of waste per trip. ($DE \times 1$) matrix.
$NO_x\_er\_truck_{de}$	NO _x emission rate by heavy duty truck to carry the waste from transfer station to disposal site de per MT of waste per trip. ($DE \times 1$) matrix.
$HC\_er\_truck_{de}$	HC emission rate by heavy duty truck to carry the waste from transfer station to disposal site de per MT of waste per trip. ($DE \times 1$) matrix.
$PM\_er\_truck_{de}$	PM emission rate by heavy duty truck to carry the waste from transfer station to disposal site de per MT of waste per trip. ($DE \times 1$) matrix.
$BENZ\_er\_truck_{de}$	BENZENE emission rate by heavy duty truck to carry the waste from transfer station to disposal site de per MT of waste per trip. ($DE \times 1$) matrix.
$BUTDN\_er\_truck_{de}$	BUTADIENE emission rate by heavy duty truck to carry the waste from transfer station to disposal site de per MT of waste per trip. ($DE \times 1$) matrix.
$CO_2\_inc_{de}$	CO ₂ emission rate from incineration plant at disposal site de per MT of garbage. ($DE \times 1$) matrix.
$NO_2\_inc_{de}$	NO ₂ emission rate from incineration plant at disposal site de per

	MT of garbage. (DE $\times$ 1) matrix.
$SO_{2\_inc_{de}}$	SO ₂ emission rate from incineration plant at disposal site <i>de</i> per MT of garbage. (DE $\times$ 1) matrix.
$CO_{2\_cp_{de}}$	CO ₂ emission rate from composting plant at disposal site <i>de</i> per MT of garbage. (DE $\times$ 1) matrix.
$CH_{4\_cp_{de}}$	CH ₄ emission rate from composting plant at disposal site <i>de</i> per MT of garbage. (DE $\times$ 1) matrix.
$NO_{2\_cp_{de}}$	NO ₂ emission rate from composting plant at disposal site <i>de</i> per MT of garbage. (DE $\times$ 1) matrix.
$SO_{2\_cp_{de}}$	SO ₂ emission rate from composting plant at disposal site <i>de</i> per MT of garbage. (DE $\times$ 1) matrix.
$NH_3-N\_dump_{de}$	Ammoniacal nitrogen (as N) generation rate from landfill leachate at disposal site <i>de</i> per MT of disposed waste.
TKN_dump _{de}	Total Kjeldhal nitrogen (as N) generation rate from landfill leachate at disposal site <i>de</i> per MT of disposed waste.
As_dump_{de}	Arsenic generation rate from landfill leachate at disposal site <i>de</i> per MT of disposed waste.
Hg_dump_{de}	Mercury generation rate from landfill leachate at disposal site <i>de</i> per MT of disposed waste.
Pb_dump_{de}	Lead generation rate from landfill leachate at disposal site <i>de</i> per MT of disposed waste.
Cr_dump_{de}	Total chromium generation rate from landfill leachate at disposal site <i>de</i> per MT of disposed waste.
Cu_dump_{de}	Copper generation rate from landfill leachate at disposal site <i>de</i> per MT of disposed waste.
Zn_dump_{de}	Zinc generation rate from landfill leachate at disposal site <i>de</i> per MT of disposed waste.
Ni_dump_{de}	Nickel generation rate from landfill leachate at disposal site <i>de</i>

	per MT of disposed waste.
CN_dump_{de}	Cyanide generation rate from landfill leachate at disposal site de per MT of disposed waste.
Cl_dump_{de}	Chlorine generation rate from landfill leachate at disposal site de per MT of disposed waste.
$Phenol\_dump_{de}$	Phenolic compounds generation rate from landfill leachate at disposal site de per MT of disposed waste.
w_gwp	Relative weightage of Global Warming Potential (GWP) impact sub-category in local perspective.
$ef\_gwp\_CO_2$	Equivalency factor of CO_2 for GWP.
$ef\_gwp\_CH_4$	Equivalency factor of CH_4 for GWP.
n_gwp	Normalizing value for GWP.
w_ap	Relative weightage of Acidification Potential (AP) impact sub-category in local perspective.
$ef\_ap\_SO_2$	Equivalency factor of SO_2 for AP.
$ef\_ap\_NO_x$	Equivalency factor of NO_x for AP.
$ef\_ap\_NH_3$	Equivalency factor of NH_3 for AP.
n_ap	Normalizing value for AP.
w_pocp	Relative weightage of Photochemical Ozone Conversion Potential (POCP) impact sub-category in local perspective.
$ef\_pocp\_CH_4$	Equivalency factor of CH_4 for POCP.
n_pocp	Normalizing value for POCP.
w_htpe	Relative weightage of Human Toxicity Potential by Inhalation (HTPE) impact sub-category in local perspective.
ef_htpe_BENZ	Equivalency factor of Benzene for HTPE.
ef_htpe_CO	Equivalency factor of CO for HTPE.

<i>ef_htpe_CO₂</i>	Equivalency factor of CO ₂ for HTPE.
<i>ef_htpe_H₂S</i>	Equivalency factor of H ₂ S for HTPE.
<i>ef_htpe_NH₃</i>	Equivalency factor of NH ₃ for HTPE.
<i>ef_htpe_NO_x</i>	Equivalency factor of NO _x for HTPE.
<i>ef_htpe_SO₂</i>	Equivalency factor of SO ₂ for HTPE.
<i>ef_htpe_BUTDN</i>	Equivalency factor of Butadiene for HTPE.
<i>ef_htpe_PM</i>	Equivalency factor of PM for HTPE.
<i>ef_htpe_CH₄</i>	Equivalency factor of CH ₄ for HTPE.
<i>ef_htpe_HC</i>	Equivalency factor of HC for HTPE.
<i>n_htpe</i>	Normalizing value for HTPE.
<i>w_ttpg</i>	Relative weightage of Terrestrial Toxicity Potential by Gas (TTPG) impact sub-category in local perspective.
<i>ef_ttpg_SO₂</i>	Equivalency factor of SO ₂ for TTPG.
<i>ef_ttpg_BENZ</i>	Equivalency factor of Benzene for TTPG.
<i>ef_ttpg_CH₄</i>	Equivalency factor of CH ₄ for TTPG.
<i>ef_ttpg_CO</i>	Equivalency factor of CO for TTPG.
<i>ef_ttpg_CO₂</i>	Equivalency factor of CO ₂ for TTPG.
<i>ef_ttpg_H₂S</i>	Equivalency factor of H ₂ S for TTPG.
<i>ef_ttpg_NH₃</i>	Equivalency factor of NH ₃ for TTPG.
<i>ef_ttpg_NO_x</i>	Equivalency factor of NO _x for TTPG.
<i>ef_ttpg_BUTDN</i>	Equivalency factor of Butadiene for TTPG.
<i>ef_ttpg_PM</i>	Equivalency factor of PM for TTPG.
<i>ef_ttpg_HC</i>	Equivalency factor of HC for TTPG.
<i>n_ttpg</i>	Normalizing value for TTPG.
<i>w_atp</i>	Relative weightage of Aquatic Toxicity Potential (ATP) impact

sub-category in local perspective.

<i>ef_atp_As</i>	Equivalency factor of Arsenic (As) for ATP.
<i>ef_atp_Phenol</i>	Equivalency factor of Phenol for ATP.
<i>ef_atp_Cd</i>	Equivalency factor of Cadmium (Cd) for ATP.
<i>ef_atp_Cl</i>	Equivalency factor of Chlorine (Cl) for ATP.
<i>ef_atp_CN</i>	Equivalency factor of Cyanide (CN) for ATP.
<i>ef_atp_Cr</i>	Equivalency factor of Chromium (Cr) for ATP.
<i>ef_atp_Cu</i>	Equivalency factor of Copper (Cd) for ATP.
<i>ef_atp_F</i>	Equivalency factor of Fluoride (F) for ATP.
<i>ef_atp_Hg</i>	Equivalency factor of Mercury (Hg) for ATP.
<i>ef_atp_NH₃-N</i>	Equivalency factor of Ammoniacal Nitrogen (NH ₃ -N) for ATP.
<i>ef_atp_Ni</i>	Equivalency factor of Nickel (Ni) for ATP.
<i>ef_atp_Pb</i>	Equivalency factor of lead (Pb) for ATP.
<i>ef_atp_Zn</i>	Equivalency factor of Zinc (Zn) for ATP.
<i>n_atp</i>	Normalizing value for ATP.
<i>w_htpi</i>	Relative weightage of Human Toxicity Potential by Ingestion (HTPI) impact sub-category in local perspective.
<i>ef_htpi_As</i>	Equivalency factor of Arsenic (As) for HTPI.
<i>ef_htpi_Phenol</i>	Equivalency factor of Phenol for HTPI.
<i>ef_htpi_Cd</i>	Equivalency factor of Cadmium (Cd) for HTPI.
<i>ef_htpi_Cl</i>	Equivalency factor of Chlorine (Cl) for HTPI.
<i>ef_htpi_CN</i>	Equivalency factor of Cyanide (CN) for HTPI.
<i>ef_htpi_Cr</i>	Equivalency factor of Chromium (Cr) for HTPI.
<i>ef_htpi_Cu</i>	Equivalency factor of Copper (Cd) for HTPI.
<i>ef_htpi_F</i>	Equivalency factor of Fluoride (F) for HTPI.

ef_{htpi_Hg}	Equivalency factor of Mercury (Hg) for HTPI.
$ef_{htpi\_NH_3-N}$	Equivalency factor of Ammoniacal Nitrogen (NH ₃ -N) for HTPI.
ef_{htpi_Ni}	Equivalency factor of Nickel (Ni) for HTPI.
ef_{htpi_Pb}	Equivalency factor of lead (Pb) for HTPI.
ef_{htpi_Zn}	Equivalency factor of Zinc (Zn) for HTPI.
n_{htpi}	Normalizing value for HTPI.
w_{ttpl}	Relative weightage of Terrestrial Toxicity Potential by Liquid (TTPL) impact sub-category in local perspective.
ef_{ttpl_Cl}	Equivalency factor of Chlorine (Cl) for TTPL.
ef_{ttpl_CN}	Equivalency factor of Cyanide (CN) for TTPL.
ef_{ttpl_Cr}	Equivalency factor of Chromium (Cr) for TTPL.
ef_{ttpl_Cu}	Equivalency factor of Copper (Cd) for TTPL.
ef_{ttpl_F}	Equivalency factor of Fluoride (F) for TTPL.
ef_{ttpl_Hg}	Equivalency factor of Mercury (Hg) for TTPL.
$ef_{ttpl\_NH_3-N}$	Equivalency factor of Ammoniacal Nitrogen (NH ₃ -N) for TTPL.
ef_{ttpl_Ni}	Equivalency factor of Nickel (Ni) for TTPL.
ef_{ttpl_Pb}	Equivalency factor of lead (Pb) for TTPL.
ef_{ttpl_Zn}	Equivalency factor of Zinc (Zn) for TTPL.
ef_{ttpl_As}	Equivalency factor of Arsenic (As) for TTPL.
ef_{ttpl_Phenol}	Equivalency factor of Phenol for TTPL.
ef_{ttpl_Cd}	Equivalency factor of Cadmium (Cd) for TTPL.
n_{ttpl}	Normalizing value for TTPL.

Variables

$atripdv_{dv,de,ze}$	Actual number of trips made by dv type departmental vehicle to a zone ze of a disposal site de .

$atriphvg_{de,ze}$	Actual number of trips made by hired vehicles hv in a zone ze of a disposal site de for collection of garbage.
$atriphvs_{de,ze}$	Actual number of trips made by hired vehicles hv in a zone ze of a disposal site de for collection of silt.
$costfuel_{dv}$	Cost of fuel incurred by dv type departmental vehicles for waste transportation, Rs.
$costfuel_{trucks}$	Fuel cost of the heavy duty trucks used for transporting dumpable waste from transfer station to disposal site landfills, Rs.
$costfx_{didl}_{dv}$	Total fixed cost for idle dv type departmental vehicles, Rs.
$costfx_{didl}_{trucks}$	Fixed idle cost of the heavy duty trucks, Rs.
$costfx_{dr}_{dv}$	Total fixed cost for running dv type departmental vehicles, Rs.
$costfx_{dr}_{trucks}$	Fixed running cost of the heavy duty trucks, Rs.
$costincv_{dv}$	Amount of incentive (in Rs.) to be paid to a dv -type vehicle for transporting waste more than the minimum stipulated number of trips.
$CTINCENT$	Total incentive payable to KMC departmental vehicle drivers and helpers in case they run trips more than their minimum requisite number of trips, Rs.
$compirej_{de}$	Inorganic reject amount transported from composting plant pre-sorter to the landfill for a particular disposal site de , MT.
$compd_{de}$	Compost produced in the composting plant at the disposal site de , MT.
$compr_{de}$	Composting process reject amount at a disposal site de , MT.
$comprecy_{de}$	Amount of waste recycled from the composting plant pre-sorter to the recycling facility related to disposal site de , MT.
$CTCOMP$	Total cost of composting, in Rs.
$costtrang_{dv}$	Waste (garbage only) transportation cost by dv type

	departmental vehicles, Rs.
$costtrang_{hv}$	Total garbage transportation cost by hired vehicles from borough centers to disposal sites, Rs.
$costtran_{hv}$	Total cost of transportation of solid waste (garbage and silt/rubbish) by hired vehicles, Rs.
$CTINCIN$	Total cost of incineration, in Rs.
$CTICS$	Total cost for sorting operation at central sorter, in Rs
$costtrans_{hv}$	Total silt transportation cost by hired vehicles from borough centers to disposal sites, Rs.
$costtrantrucks$	Total cost of transporting dumpable waste from transfer station to the disposal site landfills by the heavy duty trucks, Rs.
$CTLF$	Total landfilling cost, in Rs.
$CTTRANSP$	Total cost of transportation of waste to all the disposal sites, in Rs.
$CTREVCP$	Total revenue generated by selling compost, in Rs.
$CTREVINC$	Total revenue generated by selling electricity generated from incinerator, in Rs.
$CTREVRV$	Total revenue generated by selling recyclable materials from recycling facility, in Rs.
$dg_{dv_{dv,de,ze}}$	Amount of garbage transported by dv type departmental vehicle to a disposal site de from zone ze of de , MT.
$dg_{hv_{de,ze}}$	Amount of garbage transported by hired vehicle hv to disposal site de from zone ze of de , MT.
$de_{hv_{de,ze}}$	Amount of silt transported by hired vehicle hv to disposal site de from zone ze of de , MT.
$inc_{arej_{de}}$	Amount of incinerator ash products being transported from the incinerator to the landfill site, MT.

inc_irej_{de}	Inorganic reject portion separated from the incinerator pre-sorter and sent directly to landfill at a disposal site de , MT.
inc_pow_{de}	Total kWh units of electricity generated by incinerator at de .
inc_recy_{de}	Recyclable portion sorted out from incinerator pre-sorter and dispatched to the recycling facility, MT.
$notrucks_{de}$	Number of trucks associated with disposal site (and transfer station) de .
$quangdv_{bh,de,dv}$	Quantity of garbage transported from borough bh centre to disposal site de by dv type departmental vehicle, MT.
$quanghv_{bh,de}$	Quantity of garbage transported from a particular borough bh center to a disposal site de by a hired vehicle hv , MT.
$quanshv_{bh,de}$	Quantity of silt transported from a particular borough center bh to a disposal site de by a hired vehicle hv , MT.
$srad_{de}$	Additional amount of waste to be transferred directly from the sorting facility (after sorting but without any processing) to the landfill in case of emergency, MT. This value was equated to zero under normal circumstances.
$srcpf_{de}$	Feed entering into the composting plant from sorter at a disposal site de , MT.
$srdd_{de}$	Direct dumpable portion of waste stream (consisting of inert) that is not sorted through sorter and directly taken to landfill after visual inspection for a disposal site de , MT
$srgf_{de}$	Feed to sorting station associated with disposal site de , MT.
$srincf_{de}$	Feed from sorter to incinerator associated with disposal site de , MT.
$srrecy_{de}$	Amount of recyclable material segregated from the solid waste feed at the central sorting station associated with disposal site de , MT.

$xlfd_{de}$	Amount of waste being disposed in the landfill associated with disposal site de , MT.
$xlfg_{de}$	Total amounts of garbage transported to landfill at a disposal site de , MT.
$xlfrj_{de}$	Quantity of rejects from different processing methods like incineration inorganic reject, incineration ash, composting inorganic reject and composting process reject transferred to landfill at de , MT.
$xlsilt_{de}$	Total amounts of silt transported to landfill at a disposal site de , MT.
CO_{ems}_{dv}	Emission of CO by departmental vehicle type dv , g/trip.
$SO_{2\_ems}_{dv}$	Emission of SO ₂ by departmental vehicle type dv , g/trip.
$CO_{2\_ems}_{dv}$	Emission of CO ₂ by departmental vehicle type dv , g/trip.
$NO_x_{ems}_{dv}$	Emission of NO _x by departmental vehicle type dv , g/trip.
HC_{ems}_{dv}	Emission of HC by departmental vehicle type dv , g/trip.
PM_{ems}_{dv}	Emission of PM by departmental vehicle type dv , g/trip.
$BENZ_{ems}_{dv}$	Emission of BENZENE by departmental vehicle type dv , g/trip.
$BUTDN_{ems}_{dv}$	Emission of BUTADIENE by departmental vehicle type dv , g/trip.
CO_{ems}_{hv}	Emission of CO by hired vehicle hv carrying garbage, g/trip.
$SO_{2\_ems}_{hv}$	Emission of SO ₂ by hired vehicle hv carrying garbage, g/trip.
$CO_{2\_ems}_{hv}$	Emission of CO ₂ by hired vehicle hv carrying garbage, g/trip.
$NO_x_{ems}_{hv}$	Emission of NO _x by hired vehicle hv carrying garbage, g/trip.
HC_{ems}_{hv}	Emission of HC by hired vehicle hv carrying garbage, g/trip.
PM_{ems}_{hv}	Emission of PM by hired vehicle hv carrying garbage, g/trip.
$BENZ_{ems}_{hv}$	Emission of BENZENE by hired vehicle hv carrying garbage,

	g/trip.
<i>BUTDN_emsng_{hv}</i>	Emission of BUTADIENE by hired vehicle <i>hv</i> carrying garbage, g/trip.
<i>CO_emsns_{hv}</i>	Emission of CO by hired vehicle <i>hv</i> carrying silt, g/trip.
<i>SO₂_emsns_{hv}</i>	Emission of SO ₂ by hired vehicle <i>hv</i> carrying silt, g/trip.
<i>CO₂_emsns_{hv}</i>	Emission of CO ₂ by hired vehicle <i>hv</i> carrying silt, g/trip.
<i>NO_x_emsns_{hv}</i>	Emission of NO _x by hired vehicle <i>hv</i> carrying silt, g/trip.
<i>HC_emsns_{hv}</i>	Emission of HC by hired vehicle <i>hv</i> carrying silt, g/trip.
<i>PM_emsns_{hv}</i>	Emission of PM by hired vehicle <i>hv</i> carrying silt, g/trip.
<i>BENZ_emsns_{hv}</i>	Emission of BENZENE by hired vehicle <i>hv</i> carrying silt, g/trip.
<i>BUTDN_emsns_{hv}</i>	Emission of BUTADIENE by hired vehicle <i>hv</i> carrying silt, g/trip.
<i>CO_emsntruck_{de}</i>	Emission of CO by heavy duty truck, g/trip.
<i>SO₂_emsntruck_{de}</i>	Emission of SO ₂ by heavy duty truck, g/trip.
<i>CO₂_emsntruck_{de}</i>	Emission of CO ₂ by heavy duty truck, g/trip.
<i>NO_x_emsntruck_{de}</i>	Emission of NO _x by heavy duty truck, g/trip.
<i>HC_emsntruck_{de}</i>	Emission of HC by heavy duty truck, g/trip.
<i>PM_emsntruck_{de}</i>	Emission of PM by heavy duty truck, g/trip.
<i>BENZ_emsntruck_{de}</i>	Emission of BENZENE by heavy duty truck, g/trip.
<i>BUTDN_emsntruck_{de}</i>	Emission of BUTADIENE by heavy duty truck, g/trip.
<i>CO₂_emsn_inc_{de}</i>	Emission of CO ₂ from incineration plant.
<i>SO₂_emsn_inc_{de}</i>	Emission of SO ₂ from incineration plant.
<i>NO₂_emsn_inc_{de}</i>	Emission of NO ₂ from incineration plant.
<i>CO₂_emsn_cp_{de}</i>	Emission of CO ₂ from composting plant.
<i>SO₂_emsn_cp_{de}</i>	Emission of SO ₂ from composting plant.

$NO_2\_emsn\_cp_{de}$	Emission of NO_2 from composting plant.
$CH_4\_emsn\_cp_{de}$	Emission of CH_4 from composting plant.
$totalNH_3-N\_emsn_{de}$	Ammonical nitrogen (as N) emission from landfill leachate at disposal site <i>de</i> .
$totalTKN\_emsn_{de}$	Total Kjeldhal nitrogen (as N) emission from landfill leachate at disposal site <i>de</i> .
$totalAs\_emsn_{de}$	Total Arsenic emission from landfill leachate at disposal site <i>de</i> .
$totalHg\_emsn_{de}$	Total Mercury generation from landfill leachate at disposal site <i>de</i> .
$totalPb\_emsn_{de}$	Total Lead generation from landfill leachate at disposal site <i>de</i> .
$totalCr\_emsn_{de}$	Total chromium generation from landfill leachate at disposal site <i>de</i> .
$totalCu\_emsn_{de}$	Total Copper generation from landfill leachate at disposal site <i>de</i> .
$totalZn\_emsn_{de}$	Total Zinc generation from landfill leachate at disposal site <i>de</i> .
$totalNi\_emsn_{de}$	Total Nickel generation from landfill leachate at disposal site <i>de</i> .
$totalCN\_emsn_{de}$	Total Cyanide generation rate from landfill leachate at disposal site <i>de</i> .
$totalCl\_emsn_{de}$	Total Chlorine generation from landfill leachate at disposal site <i>de</i> .
$totalPhenol\_emsn_{de}$	Phenolic compounds generation from landfill leachate at disposal site <i>de</i> .
$pei\_gwp\_CO_2$	PEI contribution of CO_2 to GWP impact sub-category in local perspective.
$pei\_gwp\_CH_4$	PEI contribution of CH_4 to GWP impact sub-category in local perspective.
pei_gwp	Total PEI contribution of GWP impact sub-category in local

	perspective.
<i>pei_ap_SO₂</i>	PEI contribution of SO ₂ to AP impact sub-category in local perspective.
<i>pei_ap_NO_x</i>	PEI contribution of NO _x to AP impact sub-category in local perspective.
<i>pei_ap</i>	Total PEI contribution of AP impact sub-category in local perspective.
<i>pei_pocp_CH₄</i>	PEI contribution of CH ₄ to POCP impact sub-category in local perspective.
<i>pei_pocp</i>	Total PEI contribution of POCP impact sub-category in local perspective.
<i>pei_htpe_BENZ</i>	PEI contribution of Benzene to HTPE impact sub-category in local perspective.
<i>pei_htpe_CO</i>	PEI contribution of CO to HTPE impact sub-category in local perspective.
<i>pei_htpe_CO₂</i>	PEI contribution of CO ₂ to HTPE impact sub-category in local perspective.
<i>pei_htpe_H₂S</i>	PEI contribution of H ₂ S to HTPE impact sub-category in local perspective.
<i>pei_htpe_NH₃</i>	PEI contribution of NH ₃ to HTPE impact sub-category in local perspective.
<i>pei_htpe_HC</i>	PEI contribution of HC to HTPE impact sub-category in local perspective.
<i>pei_htpe_NO_x</i>	PEI contribution of NO _x to HTPE impact sub-category in local perspective.
<i>pei_htpe_SO₂</i>	PEI contribution of SO ₂ to HTPE impact sub-category in local perspective.
<i>pei_htpe_BUTDN</i>	PEI contribution of Butadiene to HTPE impact sub-category in

	local perspective.
<i>pei_htpe_PM</i>	PEI contribution of PM to HTPE impact sub-category in local perspective.
<i>pei_htpe_CH₄</i>	PEI contribution of CH ₄ to HTPE impact sub-category in local perspective.
<i>pei_htpe</i>	Total PEI contribution of HTPE impact sub-category in local perspective.
<i>pei_htpi_Phenol</i>	PEI contribution of Phenol to HTPI impact sub-category in local perspective.
<i>pei_htpi_As</i>	PEI contribution of As to HTPI impact sub-category in local perspective.
<i>pei_htpi_Cd</i>	PEI contribution of Cd to HTPI impact sub-category in local perspective.
<i>pei_htpi_Cl</i>	PEI contribution of Cl to HTPI impact sub-category in local perspective.
<i>pei_htpi_CN</i>	PEI contribution of CN to HTPI impact sub-category in local perspective.
<i>pei_htpi_Cr</i>	PEI contribution of Cr to HTPI impact sub-category in local perspective.
<i>pei_htpi_Cu</i>	PEI contribution of Cu to HTPI impact sub-category in local perspective.
<i>pei_htpi_F</i>	PEI contribution of F to HTPI impact sub-category in local perspective.
<i>pei_htpi_Hg</i>	PEI contribution of Hg to HTPI impact sub-category in local perspective.
<i>pei_htpi_Ni</i>	PEI contribution of Ni to HTPI impact sub-category in local perspective.
<i>pei_htpi_Pb</i>	PEI contribution of Pb to HTPI impact sub-category in local

	perspective.
<i>pei_htpi_Zn</i>	PEI contribution of Zn to HTPI impact sub-category in local perspective.
<i>pei_htpi_NH₃-N</i>	PEI contribution of NH ₃ -N to HTPI impact sub-category in local perspective.
<i>pei_htpi</i>	Total PEI contribution of HTPI impact sub-category in local perspective.
<i>pei_ttpg_SO₂</i>	PEI contribution of SO ₂ to TTPG impact sub-category in local perspective.
<i>pei_ttpg_BENZ</i>	PEI contribution of Benzene to TTPG impact sub-category in local perspective.
<i>pei_ttpg_CH₄</i>	PEI contribution of CH ₄ to TTPG impact sub-category in local perspective.
<i>pei_ttpg_CO</i>	PEI contribution of CO to TTPG impact sub-category in local perspective.
<i>pei_ttpg_CO₂</i>	PEI contribution of CO ₂ to TTPG impact sub-category in local perspective.
<i>pei_ttpg_H₂S</i>	PEI contribution of H ₂ S to TTPG impact sub-category in local perspective.
<i>pei_ttpg_NH₃</i>	PEI contribution of NH ₃ to TTPG impact sub-category in local perspective.
<i>pei_ttpg_NO_x</i>	PEI contribution of NO _x to TTPG impact sub-category in local perspective.
<i>pei_ttpg_PM</i>	PEI contribution of PM to TTPG impact sub-category in local perspective.
<i>pei_ttpg_BUTDN</i>	PEI contribution of Butadiene to TTPG impact sub-category in local perspective.
<i>pei_ttpg_HC</i>	PEI contribution of HC to TTPG impact sub-category in local

	perspective.
<i>pei_ttpg</i>	Total PEI contribution of TTPG impact sub-category in local perspective.
<i>pei_ttpl_As</i>	PEI contribution of As to TTPL impact sub-category in local perspective.
<i>pei_ttpl_Cd</i>	PEI contribution of Cd to TTPL impact sub-category in local perspective.
<i>pei_ttpl_Cl</i>	PEI contribution of Cl to TTPL impact sub-category in local perspective.
<i>pei_ttpl_CN</i>	PEI contribution of CN to TTPL impact sub-category in local perspective.
<i>pei_ttpl_Cr</i>	PEI contribution of Cr to TTPL impact sub-category in local perspective.
<i>pei_ttpl_Cu</i>	PEI contribution of Cu to TTPL impact sub-category in local perspective.
<i>pei_ttpl_F</i>	PEI contribution of F to TTPL impact sub-category in local perspective.
<i>pei_ttpl_Hg</i>	PEI contribution of Hg to TTPL impact sub-category in local perspective.
<i>pei_ttpl_NH₃-N</i>	PEI contribution of NH ₃ -N to TTPL impact sub-category in local perspective.
<i>pei_ttpl_Ni</i>	PEI contribution of Ni to TTPL impact sub-category in local perspective.
<i>pei_ttpl_Pb</i>	PEI contribution of Pb to TTPL impact sub-category in local perspective.
<i>pei_ttpl_Phenol</i>	PEI contribution of Phenol to TTPL impact sub-category in local perspective.
<i>pei_ttpl_Zn</i>	PEI contribution of Zn to TTPL impact sub-category in local

perspective.

<i>pei_ttpl</i>	Total PEI contribution of TTPL impact sub-category in local perspective.
<i>pei_atp_As</i>	PEI contribution of As to ATP impact sub-category in local perspective.
<i>pei_atp_Cd</i>	PEI contribution of Cd to ATP impact sub-category in local perspective.
<i>pei_atp_Cl</i>	PEI contribution of Cl to ATP impact sub-category in local perspective.
<i>pei_atp_CN</i>	PEI contribution of CN to ATP impact sub-category in local perspective.
<i>pei_atp_Cr</i>	PEI contribution of Cr to ATP impact sub-category in local perspective.
<i>pei_atp_Cu</i>	PEI contribution of Cu to ATP impact sub-category in local perspective.
<i>pei_atp_F</i>	PEI contribution of F to ATP impact sub-category in local perspective.
<i>pei_atp_Hg</i>	PEI contribution of Hg to ATP impact sub-category in local perspective.
<i>pei_atp_NH₃-N</i>	PEI contribution of NH ₃ -N to ATP impact sub-category in local perspective.
<i>pei_atp_Ni</i>	PEI contribution of Ni to ATP impact sub-category in local perspective.
<i>pei_atp_Pb</i>	PEI contribution of Pb to ATP impact sub-category in local perspective.
<i>pei_atp_Phenol</i>	PEI contribution of Phenol to ATP impact sub-category in local perspective.
<i>pei_atp_Zn</i>	PEI contribution of Zn to ATP impact sub-category in local

perspective.

pei_atp Total PEI contribution of ATP impact sub-category in local perspective.

4.2.3 Model

In order to reduce the cost of the solid waste management system, the objective function of the model should be the cost optimisation function, which is illustrated as follows:

Minimization of municipal solid waste management cost (objective function):

Minimization of MSWM cost = *Transportation cost + Incentive cost + Sorting cost + Incineration cost + Composting cost + Landfilling cost – Revenue earned from recycling – Revenue earned from composting – Revenue earned from incineration*

$$\text{Min MSWM cost} = CTTRANSP + CTINCENT + CTICS + CTINCIN + CTCOMP + CTLF - CTREVRV - CTREVCV - CTREVINC \quad (1)$$

- ✓ **CTTRANSP** is the total cost of transportation of solid waste to all the three disposal sites.
- ✓ **CTINCENT** is the incentive cost payable to the municipal departmental vehicle drivers and helpers in the event that they make more trips than their required minimum number of trips. It is paid on the basis of per ton of waste transported to the disposal sites over and above the minimum trips.
- ✓ **CTICS, CTINCIN, CTCOMP, CTLF** are the total sorting cost, incineration cost, composting cost and landfilling cost for all disposal sites *de*.
- ✓ **CTREVRV** is the total revenue generated from the sale of recyclables at recycling facilities for all disposal sites *de*.
- ✓ **CTREVCV, CTREVINC** are the revenues generated by selling compost and electricity from composting plant and incinerator for all disposal sites *de*.

In addition to cost optimization, this model has been incorporated and studies the equation of pollution generation from various sectors of the proposed ISWM system and the contribution of potential environmental impact by different pollutants. These equations have also been solved in accordance with the model.

Based on average waste carried by different types of vehicles from different boroughs, minimum and maximum garbage carrying range (in fraction) for both departmental and hired vehicles has to be considered. This makes the model flexible and more realistic as it indicates the optimum garbage carrying trend by different vehicles.

The following constraints on waste transportation are being made using the data.

Subject to the following constraints:

Garbage balance equation at any particular borough bh :

$$\sum_{de=1}^{DE} \sum_{dv=1}^{DV} quangdv_{bh,de,dv} + \sum_{de=1}^{DE} quanghv_{bh,de} = bh\_wg_{bh} \quad \forall bh = 1, 2, \dots, BH \quad (2)$$

$quangdv_{bh,de,dv}$ is the quantity of garbage transported from borough bh centre to disposal site de by dv type vehicles. $quanghv_{bh,de}$ is the quantity of garbage transported from a particular borough bh center to a disposal site de by a hired vehicle. bh_wg_{bh} is the amount of garbage generated in borough bh .

Silt/Rubbish balance equation for any particular borough bh :

$$\sum_{de=1}^{DE} quanshv_{bh,de} = bh\_ws_{bh} \quad \forall bh = 1, 2, \dots, BH \quad (3)$$

$quanshv_{bh,de}$ is the quantity of silt transported from a particular borough center bh to a disposal site de by a hired vehicle. bh_ws_{bh} is the amount of silt generated at a borough bh .

Maximum amount of garbage dispatched from borough bh centre by dv type vehicle:

$$\sum_{de=1}^{DE} quangdv_{bh,de,dv} \leq bh\_wg_{bh} \times bh\_fgdvmax_{bh,dv} \quad \forall bh = 1, 2, \dots, BH \quad \forall d = 1, 2, \dots, DV \quad (4)$$

$bh\_fgdvmax_{bh,dv}$ is the maximum fraction of garbage from bh borough that is transported by dv type departmental vehicles.

Minimum amount of garbage dispatched from borough bh centre by dv type vehicle:

$$\sum_{de=1}^{DE} quangdv_{bh,de,dv} \geq bh\_wg_{bh} \times bh\_fgdvmin_{bh,dv} \quad \forall bh = 1,2 \dots BH \quad \forall dv = 1,2, \dots DV \quad (5)$$

$bh\_fgdvmin_{bh,dv}$ is the minimum fraction of garbage from bh borough that is transported by dv type departmental vehicles.

Maximum amount of garbage dispatched from borough bh centre by hv type vehicle:

$$\sum_{de=1}^{DE} quanghv_{bh,de} \leq bh\_wg_{bh} \times bh\_fghvmax_{bh} \quad \forall bh = 1,2 \dots BH \quad (6)$$

$bh\_fghvmax_{bh,de}$ is the maximum fraction of garbage from bh borough that is transported by hv type hired vehicles.

Minimum amount of garbage dispatched from borough bh centre by hv type vehicle:

$$\sum_{de=1}^{DE} quanghv_{bh,de} \geq bh\_wg_{bh} \times bh\_fghvmin_{bh} \quad \forall bh = 1,2 \dots BH \quad (7)$$

$bh\_fghvmin_{bh,de}$ is the minimum fraction of garbage from bh borough that is transported by hv type hired vehicles.

Equating feed to central sorter located at a disposal site de :

$$srgf_{de} - \sum_{bh=1}^{BH} \sum_{dv=1}^{DV} quangdv_{bh,de,dv} - \sum_{bh=1}^{BH} quanghv_{bh,de} = 0 \quad \forall de = 1,2, \dots DE \quad (8)$$

$srgf_{de}$ is the feed to the central sorter associated with disposal site de .

Balancing input and output streams for the central sorting facility located at disposal site de :

$$srgf_{de} - srrecy_{de} - srdd_{de} - sradd_{de} - srcpf_{de} - srincf_{de} = 0 \quad \forall de = 1,2, \dots DE \quad (9)$$

$srrecy_{de}$ is the amount of recyclable material separated from the waste stream at the central sorting station associated with disposal site de , tons. $srad_{de}$ is the additional amount of waste to be transferred directly from the sorting facility (after sorting but without any processing) to the landfill in case of emergency. $srincf_{de}$ is the feed from sorter to incinerator associated with disposal site de , tons. $srcpf_{de}$ is the feed in tons entering the composting plant from sorter at a disposal site de . It is assumed that $srdd_{de}$ i.e. direct dumpable portion of solid waste (comprising of inert) is not sorted through sorter but is directly discharged to landfill after visual inspection.

Maximum amount recycled from sorter at disposal site de :

$$srrecy_{de} - srgf_{de} \times ics\_recyf_{de} \leq 0 \quad \forall de = 1, 2, \dots, DE \quad (10)$$

ics_recyf_{de} is the recyclable fraction of solid waste coming out from sorter at disposal site de .

Maximum amount sorted for direct dumpable at disposal site de :

$$srdd_{de} - srgf_{de} \times ics\_ddumpf_{de} \leq 0 \quad \forall de = 1, 2, \dots, DE \quad (11)$$

ics_ddumpf_{de} is the direct dumpable fraction of solid waste coming out from sorter at disposal site de .

Maximum amount of sorted feed to incineration plant:

$$srincf_{de} - srgf_{de} \times ics\_maxincf_{de} \leq 0 \quad \forall de = 1, 2, \dots, DE \quad (12)$$

$ics\_maxincf_{de}$ is the incinerable fraction of solid waste coming out from sorter at disposal site de .

Maximum amount of sorted feed to composting plant:

$$srcpf_{de} - srgf_{de} \times ics\_maxcpf_{de} \leq 0 \quad \forall de = 1, 2, \dots, DE \quad (13)$$

ics_maxcpf_{de} is the compostable fraction of solid waste coming out from sorter at disposal site de .

.

Balance of incinerator recyclables at disposal site de :

$$inc\_recy_{de} - srincf_{de} \times inc\_recyf_{de} = 0 \quad \forall de = 1, 2, \dots DE \quad (14)$$

inc_recy_{de} is the recyclable portion sorted out from incinerator pre-sorter and dispatched to the recycling facility, tons. inc_recyf_{de} is the recyclable fraction of waste coming out from incinerator at de . The incinerator pre-sorter is responsible for enhanced sorting and segregating out the recyclable fraction further.

Balance of incinerator inorganic rejects at disposal site de :

$$inc\_irej_{de} - srincf_{de} \times inc\_irejf_{de} = 0 \quad \forall de = 1, 2, \dots DE \quad (15)$$

inc_irej_{de} is the inorganic reject portion separated from the incinerator pre-sorter and sent directly to landfill at a transportation cost of $inc\_irejcost_{de}$ per ton. inc_irejf_{de} is the incineration inorganic reject fraction coming out from the incinerator, at disposal site de .

Balance of incinerator process ash rejects at disposal site de :

$$inc\_arej_{de} - srincf_{de} \times inc\_arejf_{de} = 0 \quad \forall de = 1, 2, \dots DE \quad (16)$$

inc_arej_{de} is the incinerator ash being transported from the incinerator to the landfill site at a transportation cost of inc_acost_{de} per ton for a particular disposal site de . inc_arejf_{de} is the incineration ash reject (incineration product) fraction generated from the incinerator feed, $srincf_{de}$, at disposal site de .

Electricity / power generated from incinerator at disposal site de :

$$inc\_pow_{de} - srincf_{de} \times f_{inc_{de}} = 0 \quad \forall de = 1, 2, \dots DE \quad (17)$$

inc_pow_{de} is the total kWh units of electricity generated by incinerator at disposal site de . $f_{inc_{de}}$ is the kWh units of electricity generated by processing unit in MT of MSW in incinerator at disposal site de .

Balance of compost plant recyclables at disposal site de :

$$comprecy_{de} - srcpf_{de} \times cp\_recyf_{de} = 0 \quad \forall de = 1, 2, \dots DE \quad (18)$$

$comprecy_{de}$ is the amount of waste recycled from the composting plant pre-sorter to the recycling facility, tons. cp_recyf_{de} is the recyclable fraction of waste coming out from composting plant pre-sorter at de . The composting plant pre-sorter is responsible for segregating out this portion.

Balance of composting inorganic rejects at disposal site de :

$$compirej_{de} - srcpf_{de} \times cp\_irf_{de} = 0 \quad \forall de = 1, 2, \dots DE \quad (19)$$

$compirej_{de}$ is the inorganic reject amount dispatched from composting pre-sorter to the landfill at a transportation cost of cp_ircost_{de} per ton. cp_irf_{de} is the composting inorganic reject fraction coming out from the composting plant at disposal site de . The inorganic reject portion of waste is sorted out by the composting plant pre-sorter and transported directly to landfill.

Balance of composting process rejects at disposal site de :

$$compr_{de} - srcpf_{de} \times cp\_prf_{de} = 0 \quad \forall de = 1, 2, \dots DE \quad (20)$$

$compr_{de}$ is the composting process reject amount in tons for a disposal site de . The process rejects are transferred directly to the landfill at a cost of cp_prcost_{de} per ton. cp_prf_{de} is the compost plant process rejects fraction coming out from the composting plant, at disposal site de .

Balance of composting plant product at disposal site de :

$$compd_{de} - srcpf_{de} \times cp\_pry_{de} = 0 \quad \forall de = 1, 2, \dots DE \quad (21)$$

$compd_{de}$ is the compost produced in the compost plant in the disposal site de , MT. cp_pry_{de} is the composting product (compost) fraction generated from compost plant feed, $srcpf_{de}$.

Balancing landfill amount at disposal site de :

$$xlf_{de} - xlsilt_{de} - xlf_{gde} - xlf_{rj_{de}} = 0 \quad \forall de = 1, 2, \dots DE \quad (22)$$

xlf_{de} is the amount of solid waste being disposed off in the landfill associated with disposal site de , MT. $xlsilt_{de}$ and xf_{gde} are the total amounts of silt and garbage

transported to the landfill at a disposal site de . $xlfrj_{de}$ are the rejects from different processing methods like incineration and composting transferred to landfill at disposal site de .

Silt balance in landfill at disposal site de :

$$xsilt_{de} - \sum_{bh=1}^{BH} quanshv_{bh,de} = 0 \quad \forall de = 1, 2, \dots, DE \quad (23)$$

Balance of direct dumpable and additional dumpable amount at landfill at disposal site de :

$$xlf_{de} - srdd_{de} - sradd_{de} = 0 \quad \forall de = 1, 2, \dots, DE \quad (24)$$

Balancing all process rejects to landfill at disposal site de :

$$\begin{aligned} xlfrj_{de} - inc\_irej_{de} - comp\_irej_{de} - inc\_arj_{de} - compr_{de} &= 0 \quad \forall de \\ &= 1, 2, \dots, DE \quad (25) \end{aligned}$$

Maximum and minimum capacity limits of central sorter at disposal site de :

$$srgf_{de} \leq ics\_maxcap_{de} \quad \forall de = 1, 2, \dots, DE \quad (26)$$

$$srgf_{de} \geq ics\_mincap_{de} \quad \forall de = 1, 2, \dots, DE \quad (27)$$

ics_mincap_{de} and ics_maxcap_{de} are the minimum and maximum capacity of the central sorting facility at a disposal site de .

Maximum and minimum capacity limits of incinerator at disposal site de :

$$srincf_{de} \leq inc\_maxcap_{de} \quad \forall de = 1, 2, \dots, DE \quad (28)$$

$$srincf_{de} \geq inc\_mincap_{de} \quad \forall de = 1, 2, \dots, DE \quad (29)$$

inc_mincap_{de} and inc_maxcap_{de} are the minimum and maximum capacity of the incinerator at a disposal site de .

Constraints for capacity of composting plant at disposal site de :

$$srcpf_{de} \leq cp\_maxcap_{de} \quad \forall de = 1, 2, \dots DE \quad (30)$$

$$srcpf_{de} \geq cp\_mincap_{de} \quad \forall de = 1, 2, \dots DE \quad (31)$$

cp_mincap_{de} and cp_maxcap_{de} are the minimum and maximum capacity of the composting plant at a disposal site de .

Constraints for maximum capacity of landfill associated with a disposal site de :

$$xlf_{de} \leq lf\_maxcap_{de} \quad \forall de = 1, 2, \dots DE \quad (32)$$

lf_maxcap_{de} is the maximum capacity of the landfill associated with a disposal site de . Minimum capacity of the landfill has not been fixed.

For each disposal site de , the municipal area is divided into ze number of zones. The zones are divided based on their nearness to the disposal site de . For each zone ze , of a disposal site de , the municipality has established maximum trip restrictions ($ze\_maxtrip_{dv,de,ze}$) and minimum trip limitations ($ze\_mintrip_{dv,de,ze}$) for dv type departmental vehicles. The drivers and the helpers are compensated with incentives for trips beyond the minimum trip restrictions considered for a particular zone ze . Similar to this, the hired vehicles (hv) are compensated according to the zone (of a disposal site, de) from which they are transporting garbage. The constraints are listed below and are based on the quantity of trips made by departmental or hired vehicles in zone ze of a disposal site de :

Number of trips made by departmental vehicles in a zone ze of a disposal site de :

$$atripdv_{dv,de,zn} \times cap\_dv_{dv} - \sum_{bh=1}^{BH} quangdv_{bh,de,dv} = 0 \quad \forall dv = 1, 2, \dots DV, \\ \forall de = 1, 2, \forall ze = 1, 2, \dots ZE \quad (33)$$

$atripdv_{dv,de,ze}$ is the actual number of trips made by dv type vehicle to a zone ze of a disposal site de . cap_dv_{dv} is the average waste carrying capacity of a dv type of vehicle. In calculating $\sum quangdv_{bh,de,dv}$, only those bh boroughs are considered which belong to the zone ze of the disposal site de .

Actual number of trips made by hired vehicles hv (which is only one type) in a zone ze of a disposal site de for collection of garbage:

$$atriphvg_{de,ze} \times capg_{hv} - \sum_{bh=1}^{BH} quanghv_{bh,de} = 0 \quad \forall de = 1,2 \dots DE, \\ \forall ze = 1,2 \dots ZE \quad (34)$$

$atriphvg_{de,ze}$ is the actual number of trips made by hired vehicles hv in a zone ze of a disposal site de for collection of garbage. $capg_{hv}$ is the average garbage carrying capacity for a hired vehicle hv . In calculating $\sum quanghv_{bh,de}$, only those bh boroughs are considered which belong to the zone ze of the disposal site de .

Actual number of trips made by hired vehicles hv in a zone ze of a disposal site de for collection of silt:

$$atriphvs_{de,ze} \times caps_{hv} - \sum_{bh=1}^{BH} quanshv_{bh,de} = 0 \quad \forall de = 1,2 \dots DE, \\ \forall ze = 1,2 \dots ZE \quad (35)$$

$atriphvs_{de,ze}$ is the actual number of trips made by hired vehicles hv in a zone ze of a disposal site de for collection of silt. $caps_{hv}$ is the average silt carrying capacity for a hired vehicle hv . In calculating $\sum quanshv_{bh,de}$, only those bh boroughs are considered which belong to the zone ze of the disposal site de .

Considering maximum trips of dv type departmental vehicle in zone ze of de :

$$atripdv_{dv,de,ze} \leq dv\_nar_{dv} \times ze\_maxtrip_{dv,de,ze} \quad \forall dv = 1,2 \dots DV, \forall de = 1,2, \dots DE, \forall ze = 1,2 \dots ZE \quad (36)$$

$ze\_maxtrip_{dv,de,ze}$ is the maximum number of trips that a dv type departmental vehicle is allowed to undertake in zone ze of disposal site de .

Maximum possible trip limit by dv type vehicle in all disposal site de , all zone ze :

$$\sum_{de=1}^{DE} \sum_{ze=1}^{ZE} atrip_{dv,de,ze} \leq dv\_nar_{dv} \times maxze\_maxtrip_{dv} \quad \forall dv = 1, 2, \dots, DV \quad (37)$$

For a particular dv type vehicle, considering all disposal sites de , the maximum value of $ze\_maxtrip_{dv,de,ze}$ is taken as $maxze\_maxtrip_{dv}$. dv_nar_{dv} is the number of dv type vehicles running.

Minimum possible trip limit by dv type vehicle in all disposal site de , all zone ze :

$$\sum_{de=1}^{DE} \sum_{ze=1}^{ZE} atrip_{dv,de,ze} \geq dv\_nar_{dv} \times minze\_mintrip_{dv} \quad \forall dv = 1, 2, \dots, DV \quad (38)$$

$ze\_mintrip_{dv,de,ze}$ is the minimum number of trips that a dv type departmental vehicle has to undertake in zone ze of disposal site de . For a particular dv type vehicle, considering all disposal sites de , the minimum value of $ze\_mintrip_{dv,de,ze}$ is taken as $minze\_mintrip_{dv}$.

Balancing amount of garbage transported by dv type departmental vehicle to disposal site de from zone ze of de :

$$dg\_dv_{dv,de,ze} - \sum_{bh=1}^{BH} quang_{dv,bh,de,dv} = 0 \quad \forall ze = 1, 2, \dots, ZE, \forall de = 1, 2, \dots, DE \\ \forall dv = 1, 2, \dots, DV \quad (39)$$

$dg\_dv_{dv,de,ze}$ denotes the amount of garbage transported by dv type departmental vehicle to a disposal site de from zone ze of de . $\sum quang_{dv,bh,de,dv}$ is the total amount of garbage taken by dv type vehicle to disposal site de from all those bh boroughs which belong to zone ze of de .

Balancing amount of garbage transported by hired vehicle hv to disposal site de from zone ze of de :

$$dg\_hv_{de,ze} - \sum_{bh=1}^{BH} quang_{hv,bh,de} = 0 \quad \forall ze = 1, 2, \dots, ZE, \forall de = 1, 2, \dots, DE \quad (40)$$

$dg_{hv_{de,ze}}$ is the amount of garbage transported by hired vehicle hv to disposal site de from zone ze of de . $\sum quanghv_{bh,de}$ is the total amount of garbage taken by hired vehicle hv to disposal site de from all those bh boroughs which belong to zone zn of de .

Balancing amount of silt transported by hired vehicle hv to disposal site de from zone ze of de :

$$de_{hv_{de,ze}} - \sum_{bh=1}^{BH} quanshv_{bh,de} = 0 \quad \forall ze = 1, 2, \dots, ZE, \forall de = 1, 2, \dots, DE \quad (41)$$

$de_{hv_{de,ze}}$ is the amount of silt transported by hired vehicle hv to disposal site de from zone ze of de . $\sum quanshv_{bh,de}$ is the total amount of silt taken by hired vehicle hv to disposal site de from all those bh boroughs which belong to zone ze of de .

Total cost of sorting associated with all disposal sites de :

$$CTICS - \sum_{de=1}^{DE} [srgf_{de} \times ics\_sortcost_{de}] - \sum_{de=1}^{DE} [srrecy_{de} \times ics\_recycost_{de} + srad_{de} \times ics\_adcost_{de}] = 0 \quad (42)$$

$ics\_sortcost_{de}$ is the sorting cost per ton of solid waste for the central sorting station associated with the disposal site de . $ics\_recycost_{de}$ is the cost of transporting recyclable material from the sorter associated with disposal site de to recycling facility, Rs/MT. Per ton cost of additional dumping is ics_adcost_{de} , Rs/MT.

Total cost of incineration associated with all disposal sites de :

$$CTINCIN - \sum_{de=1}^{DE} [srinf_{de} \times inc\_opcost_{de} + inc\_recy_{de} \times inc\_recycost_{de} + inc\_arej_{de} \times inc\_acost_{de} + inc\_irej_{de} \times inc\_irejcost_{de}] = 0 \quad (43)$$

inc_opcost_{de} is the operational cost of the incinerator at disposal site de , Rs/MT. It includes the construction and operational cost of incinerator and the transportation cost from the sorting facility to the incinerator. inc_recy_{de} is the per ton transportation cost of the recyclables from the incinerator pre-sorter attached to the disposal site de to the

recycling facility. Incinerator ash products, inc_arej_{de} , are transported from the incinerator to the landfill site at a transportation cost of inc_acost_{de} per ton for a particular disposal site de . Inorganic reject portion, inc_irej_{de} , separated from the incinerator pre-sorter are sent to landfill associated with a particular disposal site de at a transportation cost of $inc\_irejcost_{de}$ per ton.

Total cost of composting associated with all disposal sites de :

$$CTCOMP - \sum_{de=1}^{DE} [srcpf_{de} \times cp\_opcost_{de} + comprecy_{de} \times cp\_recycost_{de} + compirej_{de} \times cp\_ircost_{de} + compr_{de} \times cp\_prcost_{de}] = 0 \quad (44)$$

cp_opcost_{de} is the operational cost of the composting plant including cost of construction and operation of composting plant and transportation cost from the central sorting facility to composting plant, Rs/MT. $cp\_recycost_{de}$ is the per ton transportation cost of recyclables from composting pre-sorter for a particular disposal site de to recycling facility. $compirej_{de}$ is the inorganic reject amount dispatched from composting pre-sorter to the landfill at a transportation cost of cp_ircost_{de} per ton. The composting process rejects for the disposal site de , $compr_{de}$, are transferred directly to the landfill at a cost of cp_prcost_{de} per ton.

Total cost of landfilling associated with all disposal sites de :

$$CTLF - \sum_{de=1}^{DE} lf\_cost_{de} x = 0 \quad (45)$$

lf_cost_{de} is the landfilling cost in Rs/MT for the landfilling site associated with the disposal site de . It includes the cost of land, cost of liner, leachate management, final cover, etc.

Total revenue generated by selling recyclable materials:

$$CTREVR - \sum_{de=1}^{DE} [srrecy_{de} \times ics\_revrecy_{de} + inc\_recy_{de} \times inc\_revrecy_{de} + comprecy_{de} \times cp\_revrecy_{de}] = 0 \quad (46)$$

$ics\_revrecy_{de}$ is the revenue earned from selling per ton of recyclable materials generated from the sorting station attached to disposal site de . $inc\_revrecy_{de}$ and $cp\_revrecy_{de}$ are

the revenues earned from selling recyclable materials sorted out from incinerator pre-sorter and composting pre-sorter respectively, Rs/MT.

Total revenue generated by selling compost:

$$CTREVCP - \sum_{de=1}^{DE} compd_{de} \times cp\_prslcost_{de} = 0 \quad (47)$$

$cp\_prslcost_{de}$ is the selling price of the compost per ton.

Total revenue generated by selling electricity from incinerator:

$$CTREVINC - \sum_{de=1}^{DE} inc\_pow_{de} \times inc\_rev_{de} = 0 \quad (48)$$

inc_rev_{de} is the revenue earned in selling one kWh unit of electricity generated from the incinerator associated with disposal site de , Rs/kWh.

Total cost of transportation of waste to all the disposal sites:

$$CTTRANSP - costran_{hv} - \sum_{dv=1}^{DV} costrandv_{dv} = 0 \quad (49)$$

The total cost of transportation of solid waste to the disposal sites includes both the transportation cost of hired vehicles hv and cost of transportation incurred by the departmental vehicles dv . $costran_{hv}$ represents the total cost of transportation of waste by hired vehicles. $costrandv_{dv}$ denotes waste transportation cost by dv type departmental vehicles. Incidentally, hired vehicles collect and transport both garbage and silt, while departmental vehicles solely transport garbage. There is only one type of hired vehicle. Garbage and silt/rubbish hauling capacity for hired vehicles are thought to be different. Rates are different for garbage and silt collections. Additionally, charges for moving garbage and silt in hired vehicles are paid to them based on the different zones from which the wastes are being transported. All liabilities of hired vehicles are the responsibility of the respective private agencies.

Total cost of waste transportation by hired vehicles from borough centres to disposal sites:

$$costran_{hv} - costrang_{hv} - costrans_{hv} = 0 \quad (50)$$

Total cost of transportation by hired vehicles is the summation of garbage transportation cost by hired vehicles from borough centers to disposal sites, $costrang_{hv}$, and the silt transportation cost by hired vehicles from borough centers to disposal sites, $costrans_{hv}$.

Total cost of garbage transportation by hired vehicles from borough centres to disposal sites:

$$costrang_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanghv_{bh,de} \times bh\_hcostg_{bh,de} = 0 \quad (51)$$

$bh\_hcostg_{bh,de}$ is the per ton transportation cost of garbage from borough bh center to disposal site de for a hired vehicle, Rs./MT.

Total cost of silt transportation by hired vehicles from borough centres to disposal sites:

$$costrans_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanshv_{bh,de} \times bh\_hcosts_{bh,de} = 0 \quad (52)$$

$bh\_hcosts_{bh,de}$ is the per ton transportation cost of silt from borough bh center to disposal site de for a hired vehicle, Rs./MT.

Total cost of garbage transportation by dv type departmental vehicles is the summation of fuel cost, fixed cost of running vehicles and fixed cost of idle vehicles.

Waste transportation cost by dv type departmental vehicle from borough centre to disposal sites:

$$costrandv_{dv} - costfueldv_{dv} - costfxdidldv_{dv} - costfxdrdv_{dv} = 0 \quad \forall dv = 1, 2, \dots, DV \quad (53)$$

$costfueldv_{dv}$ is the cost of fuel incurred by dv type departmental vehicles for waste transportation. $costfxdrdv_{dv}$ and $costfxdidldv_{dv}$ are the total fixed cost for running and the total fixed cost for idle dv type departmental vehicles. The fixed costs include annualised capital cost of vehicles, maintenance cost and driver/helper cost. Everyday approximately 50 to 80% of the departmental vehicles run whereas other remain in idle/standby condition.

The cost of fuel incurred by dv type departmental vehicle:

$$costfuel_{dv} - \sum_{de=1}^{DE} \sum_{bh=1}^{BH} quang_{dv,bh,de,dv} \times bh\_fcost_{bh,de,dv} = 0 \quad \forall d = 1, 2, \dots, DV \quad (54)$$

$bh\_fcost_{bh,de,dv}$ is the average fuel cost for transporting per ton waste from borough bh to disposal site de by a dv type vehicle.

Total fixed cost for running dv type departmental vehicle:

$$costfxdr_{dv} - dv\_nar_{dv} \times dv\_fcost_{dv} = 0 \quad \forall dv = 1, 2, \dots, DV \quad (55)$$

dv_fcost_{dv} is the fixed cost for running each dv type vehicle.

Total fixed cost for idle dv type departmental vehicle:

$$costfxdidl_{dv} - (dv\_no_{dv} - dv\_nar_{dv}) \times dv\_icost_{dv} = 0 \quad \forall dv = 1, 2, \dots, DV \quad (56)$$

dv_no_{dv} is the total number of dv type of departmental vehicles in the municipality's fleet.

dv_icost_{dv} is the fixed idle cost for each dv type vehicle.

Calculation of incentives to be paid to dv -type departmental vehicle drivers and helpers can be approximated by:

$$CTINCENT - \sum_{de=1}^{DE} costinc_{dv} = 0 \quad \forall de = 1, 2, \dots, DE \quad (57)$$

$$costinc_{dv} = \left[\sum_{de=1}^{DE} \sum_{ze=1}^{ZE} dg_{dv,dv,de,ze} \times r\_incost_{dv} \right] - dv\_nar_{dv} \times minze\_mintrip_{dv} \times cap_{dv} \times r\_incost_{dv} = 0 \quad \forall dv = 1, 2, \dots, DV \quad (58)$$

$costinc_{dv}$ is the amount of incentive (in Rs.) to be paid to a dv -type vehicle for transporting waste more than the minimum stipulated number of trips. r_incost_{dv} is the rate of incentive (per extra ton basis) to be paid to the driver and helper of a dv type vehicle for transporting waste over and above the minimum trips.

4.2.4 Incorporating Pollution Generation LP Equations

The pollution generation equations from different sectors of MSWM system have been incorporated in this present study, in association with the equations related to cost

optimization model. The equations are described in accordance with transport sector, processing plants and landfill sites.

4.2.4.1 Pollution generation equation from transport sector

Emission of carbon monoxide (CO) by dv type departmental vehicles:

$$CO\_emsn_{dv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quangdv_{bh,de,dv} \times CO\_er\_dv_{bh,de} = 0 \quad \forall dv \\ = 1, 2, \dots DV \quad (59)$$

CO_emsn_{dv} is the emission of CO from dv type departmental vehicles in g/day. $CO\_er\_dv_{bh,de}$ is the CO emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip.

Emission of carbon monoxide (CO₂) by dv type departmental vehicles:

$$CO_2\_emsn_{dv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quangdv_{bh,de,dv} \times CO_2\_er\_dv_{bh,de} = 0 \quad \forall dv \\ = 1, 2, \dots DV \quad (60)$$

$CO_2\_emsn_{dv}$ is the emission of CO₂ from dv type departmental vehicles in g/day. $CO_2\_er\_dv_{bh,de}$ is the CO₂ emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip.

Emission of sulphur dioxide (SO₂) by dv type departmental vehicles:

$$SO_2\_emsn_{dv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quangdv_{bh,de,dv} \times SO_2\_er\_dv_{bh,de} = 0 \quad \forall dv \\ = 1, 2, \dots DV \quad (61)$$

$SO_2\_emsn_{dv}$ is the emission of SO₂ from dv type departmental vehicles in g/day. $SO_2\_er\_dv_{bh,de}$ is the SO₂ emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip.

Emission of nitrogen oxide (NO_x) by dv type departmental vehicles:

$$NO_x\_emsn_{dv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quangdv_{bh,de,dv} \times NO_x\_er\_dv_{bh,de} = 0 \quad \forall dv \\ = 1, 2, \dots DV \quad (62)$$

$NO_{x\_emsn_{dv}}$ is the emission of NO_x from dv type departmental vehicles in g/day.
 $NO_{x\_er\_dv_{bh,de}}$ is the NO_x emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip.

Emission of hydrocarbon (HC) by dv type departmental vehicles:

$$HC\_emsn_{dv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quangdv_{bh,de,dv} \times HC\_er\_dv_{bh,de} = 0 \quad \forall dv$$

$$= 1, 2, \dots DV \quad (63)$$

HC_emsn_{dv} is the emission of HC from dv type departmental vehicles in g/day.
 $HC\_er\_dv_{bh,de}$ is the HC emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip.

Emission of particulate matter (PM) by dv type departmental vehicles:

$$PM\_emsn_{dv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quangdv_{bh,de,dv} \times PM\_er\_dv_{bh,de} = 0 \quad \forall dv$$

$$= 1, 2, \dots DV \quad (64)$$

PM_emsn_{dv} is the emission of PM from dv type departmental vehicles in g/day.
 $PM\_er\_dv_{bh,de}$ is the PM emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip.

Emission of benzene (BENZ) by dv type departmental vehicles:

$$BENZ\_emsn_{dv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quangdv_{bh,de,dv} \times BENZ\_er\_dv_{bh,de} = 0 \quad \forall dv$$

$$= 1, 2, \dots DV \quad (65)$$

$BENZ\_emsn_{dv}$ is the emission of benzene from dv type departmental vehicles in g/day.
 $BENZ\_er\_dv_{bh,de}$ is the benzene emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip.

Emission of butadiene (BUTDN) by dv type departmental vehicles:

$BUTDN\_emsn_{dv}$

$$- \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quangdv_{bh,de,dv} \times BUTDN\_er\_dv_{bh,de} = 0 \quad \forall dv$$

$$= 1, 2, \dots DV \quad (66)$$

$BUTDN\_emsn_{dv}$ is the emission of butadiene from dv type departmental vehicles in g/day.

$BUTDN\_er\_dv_{bh,de}$ is the butadiene emission rate by departmental vehicle type dv to carry the waste from borough bh to disposal site de per MT of garbage per trip.

Emission of carbon monoxide (CO) by hv type hired vehicles carrying garbage:

$$CO\_emsn_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanghv_{bh,de} \times CO\_er\_hvg_{bh,de} = 0 \quad (67)$$

CO_emsn_{hv} is the emission of CO from hv type hired vehicles carrying garbage in g/day.

$CO\_er\_hvg_{bh,de}$ is the CO emission rate by hired vehicle type hv to carry the garbage portion from borough bh to disposal site de per MT of garbage per trip.

Emission of carbon dioxide (CO₂) by hv type hired vehicles carrying garbage:

$$CO_2\_emsn_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanghv_{bh,de} \times CO_2\_er\_hvg_{bh,de} = 0 \quad (68)$$

$CO_2\_emsn_{hv}$ is the emission of CO₂ from hv type hired vehicles carrying garbage in g/day. $CO_2\_er\_hvg_{bh,de}$ is the CO₂ emission rate by hired vehicle type hv to carry the garbage portion from borough bh to disposal site de per MT of garbage per trip.

Emission of sulphur dioxide (SO₂) by hv type hired vehicles carrying garbage:

$$SO_2\_emsn_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanghv_{bh,de} \times SO_2\_er\_hvg_{bh,de} = 0 \quad (69)$$

$SO_2\_emsn_{hv}$ is the emission of SO₂ from hv type hired vehicles carrying garbage in g/day. $SO_2\_er\_hvg_{bh,de}$ is the SO₂ emission rate by hired vehicle type hv to carry the garbage portion from borough bh to disposal site de per MT of garbage per trip.

Emission of nitrogen oxide (NO_x) by *hv* type hired vehicles carrying garbage:

$NO_{x\_emsng_{hv}}$

$$- \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanghv_{bh,de} \times NO_{x\_er\_hvg_{bh,de}} = 0 \quad (70)$$

$NO_{x\_emsng_{hv}}$ is the emission of NO_x from *hv* type hired vehicles carrying garbage in g/day. $NO_{x\_er\_hvg_{bh,de}}$ is the NO_x emission rate by hired vehicle type *hv* to carry the garbage portion from borough *bh* to disposal site *de* per MT of garbage per trip.

Emission of hydrocarbon (HC) by *hv* type hired vehicles carrying garbage:

$$HC\_emsng_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanghv_{bh,de} \times HC\_er\_hvg_{bh,de} = 0 \quad (71)$$

HC_emsng_{hv} is the emission of HC from *hv* type hired vehicles carrying garbage in g/day. $HC\_er\_hvg_{bh,de}$ is the HC emission rate by hired vehicle type *hv* to carry the garbage portion from borough *bh* to disposal site *de* per MT of garbage per trip.

Emission of particulate matter (PM) by *hv* type hired vehicles carrying garbage:

$$PM\_emsng_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanghv_{bh,de} \times PM\_er\_hvg_{bh,de} = 0 \quad (72)$$

PM_emsng_{hv} is the emission of PM from *hv* type hired vehicles carrying garbage in g/day. $PM\_er\_hvg_{bh,de}$ is the PM emission rate by hired vehicle type *hv* to carry the garbage portion from borough *bh* to disposal site *de* per MT of garbage per trip.

Emission of benzene (BENZ) by *hv* type hired vehicles carrying garbage:

$$BENZ\_emsng_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanghv_{bh,de} \times BENZ\_er\_hvg_{bh,de} = 0 \quad (73)$$

$BENZ\_emsng_{hv}$ is the emission of benzene from *hv* type hired vehicles carrying garbage in g/day. $BENZ\_er\_hvg_{bh,de}$ is the benzene emission rate by hired vehicle type *hv* to carry the garbage portion from borough *bh* to disposal site *de* per MT of garbage per trip.

Emission of butadiene (BUTDN) by *hv* type hired vehicles carrying garbage:

$$BUTDN\_emsng_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanghv_{bh,de} \times BUTDN\_er\_hvg_{bh,de} = 0 \quad (74)$$

$BUTDN\_emsng_{hv}$ is the emission of butadiene from hv type hired vehicles carrying garbage in g/day. $BUTDN\_er\_hvg_{bh,de}$ is the butadiene emission rate by hired vehicle type hv to carry the garbage portion from borough bh to disposal site de per MT of garbage per trip.

Emission of carbon monoxide (CO) by hv type hired vehicles carrying silt:

$$CO\_emsns_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanshv_{bh,de} \times CO\_er\_hvs_{bh,de} = 0 \quad (75)$$

CO_emsns_{hv} is the emission of CO from hv type hired vehicles carrying silt in g/day. $CO\_er\_hvs_{bh,de}$ is the CO emission rate by hired vehicle type hv to carry the silt portion from borough bh to disposal site de per MT of silt per trip.

Emission of carbon dioxide (CO₂) by hv type hired vehicles carrying silt:

$$CO_2\_emsns_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanshv_{bh,de} \times CO_2\_er\_hvs_{bh,de} = 0 \quad (76)$$

$CO_2\_emsns_{hv}$ is the emission of CO₂ from hv type hired vehicles carrying silt in g/day. $CO_2\_er\_hvs_{bh,de}$ is the CO₂ emission rate by hired vehicle type hv to carry the silt portion from borough bh to disposal site de per MT of silt per trip.

Emission of sulphur dioxide (SO₂) by hv type hired vehicles carrying silt:

$$SO_2\_emsns_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanshv_{bh,de} \times SO_2\_er\_hvs_{bh,de} = 0 \quad (77)$$

$SO_2\_emsns_{hv}$ is the emission of SO₂ from hv type hired vehicles carrying silt in g/day. $SO_2\_er\_hvs_{bh,de}$ is the SO₂ emission rate by hired vehicle type hv to carry the silt portion from borough bh to disposal site de per MT of silt per trip.

Emission of nitrogen oxide (NO_x) by hv type hired vehicles carrying silt:

$$NO_x\_emsns_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanshv_{bh,de} \times NO_x\_er\_hvs_{bh,de} = 0 \quad (78)$$

$NO_x\_emsns_{hv}$ is the emission of NO_x from hv type hired vehicles carrying silt in g/day. $NO_x\_er\_hvs_{bh,de}$ is the NO_x emission rate by hired vehicle type hv to carry the silt portion from borough bh to disposal site de per MT of silt per trip.

Emission of hydrocarbon (HC) by hv type hired vehicles carrying silt:

$$HC\_emsns_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanshv_{bh,de} \times HC\_er\_hvs_{bh,de} = 0 \quad (79)$$

HC_emsns_{hv} is the emission of HC from hv type hired vehicles carrying silt in g/day. $HC\_er\_hvs_{bh,de}$ is the HC emission rate by hired vehicle type hv to carry the silt portion from borough bh to disposal site de per MT of silt per trip.

Emission of particulate matter (PM) by hv type hired vehicles carrying silt:

$$PM\_emsns_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanshv_{bh,de} \times PM\_er\_hvs_{bh,de} = 0 \quad (80)$$

PM_emsns_{hv} is the emission of PM from hv type hired vehicles carrying silt in g/day. $PM\_er\_hvs_{bh,de}$ is the PM emission rate by hired vehicle type hv to carry the silt portion from borough bh to disposal site de per MT of silt per trip.

Emission of benzene (BENZ) by hv type hired vehicles carrying silt:

$$BENZ\_emsns_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanshv_{bh,de} \times BENZ\_er\_hvs_{bh,de} = 0 \quad (81)$$

$BENZ\_emsns_{hv}$ is the emission of benzene from hv type hired vehicles carrying silt in g/day. $BENZ\_er\_hvs_{bh,de}$ is the benzene emission rate by hired vehicle type hv to carry the silt portion from borough bh to disposal site de per MT of silt per trip.

Emission of butadiene (BUTDN) by hv type hired vehicles carrying silt:

$$BUTDN\_emsns_{hv} - \sum_{bh=1}^{BH} \sum_{de=1}^{DE} quanshv_{bh,de} \times BUTDN\_er\_hvs_{bh,de} = 0 \quad (82)$$

$BUTDN\_emsns_{hv}$ is the emission of butadiene from hv type hired vehicles carrying silt in g/day. $BUTDN\_er\_hvs_{bh,de}$ is the butadiene emission rate by hired vehicle type hv to carry the silt portion from borough bh to disposal site de per MT of silt per trip.

Total Emission of carbon monoxide (CO) from departmental vehicles:

$$totalCO\_emsn_{dv} - \sum_{dv=1}^{DV} CO\_emsn_{dv} = 0 \quad (83)$$

$totalCO\_emsn_{dv}$ is the total emission of CO from departmental vehicles in g/day.

Total Emission of carbon dioxide (CO₂) from departmental vehicles:

$$totalCO_2\_emsn_{dv} - \sum_{dv=1}^{DV} CO_2\_emsn_{dv} = 0 \quad (84)$$

$totalCO_2\_emsn_{dv}$ is the total emission of CO₂ from departmental vehicles in g/day.

Total Emission of sulphur dioxide (SO₂) from departmental vehicles:

$$totalSO_2\_emsn_{dv} - \sum_{dv=1}^{DV} SO_2\_emsn_{dv} = 0 \quad (85)$$

$totalSO_2\_emsn_{dv}$ is the total emission of SO₂ from departmental vehicles in g/day.

Total Emission of nitrogen oxide (NO_x) from departmental vehicles:

$$totalNO_x\_emsn_{dv} - \sum_{dv=1}^{DV} NO_x\_emsn_{dv} = 0 \quad (86)$$

$totalNO_x\_emsn_{dv}$ is the total emission of NO_x from departmental vehicles in g/day.

Total Emission of hydrocarbon (HC) from departmental vehicles:

$$totalHC\_emsn_{dv} - \sum_{dv=1}^{DV} HC\_emsn_{dv} = 0 \quad (87)$$

$totalHC\_emsn_{dv}$ is the total emission of HC from departmental vehicles in g/day.

Total Emission of particulate matter (PM) from departmental vehicles:

$$totalPM\_emsn_{dv} - \sum_{dv=1}^{DV} PM\_emsn_{dv} = 0 \quad (88)$$

$totalPM\_emsn_{dv}$ is the total emission of PM from departmental vehicles in g/day.

Total Emission of benzene (BENZ) from departmental vehicles:

$$totalBENZ\_emsn_{dv} - \sum_{dv=1}^{DV} BENZ\_emsn_{dv} = 0 \quad (89)$$

$totalBENZ\_emsn_{dv}$ is the total emission of benzene from departmental vehicles in g/day.

Total Emission of butadiene (BUTDN) from departmental vehicles:

$$totalBUTDN\_emsn_{dv} - \sum_{dv=1}^{DV} BUTDN\_emsn_{dv} = 0 \quad (90)$$

$totalBUTDN\_emsn_{dv}$ is the total emission of butadiene from departmental vehicles in g/day.

Total Emission of carbon monoxide (CO) from private hired vehicles:

$$totalCO\_emsn_{hv} - CO\_emsn_{hv} - CO\_emsn_{hv} = 0 \quad (91)$$

$totalCO\_emsn_{hv}$ is the total emission of CO from hired vehicles in g/day.

Total Emission of carbon dioxide (CO₂) from private hired vehicles:

$$totalCO_2\_emsn_{hv} - CO_2\_emsn_{hv} - CO_2\_emsn_{hv} = 0 \quad (92)$$

$totalCO_2\_emsn_{hv}$ is the total emission of CO₂ from hired vehicles in g/day.

Total Emission of sulphur dioxide (SO₂) from private hired vehicles:

$$totalSO_2\_emsn_{hv} - SO_2\_emsn_{hv} - SO_2\_emsn_{hv} = 0 \quad (93)$$

$totalSO_2\_emsn_{hv}$ is the total emission of SO₂ from hired vehicles in g/day.

Total Emission of nitrogen oxide (NO_x) from private hired vehicles:

$$totalNO_x\_emsn_{hv} - NO_x\_emsn_{hv} - NO_x\_emsn_{hv} = 0 \quad (94)$$

$totalNO_x\_emsn_{hv}$ is the total emission of NO_x from hired vehicles in g/day.

Total Emission of hydrocarbon (HC) from private hired vehicles:

$$totalHC\_emsn_{hv} - HC\_emsn_{hv} - HC\_emsn_{hv} = 0 \quad (95)$$

$totalHC\_emsn_{hv}$ is the total emission of HC from hired vehicles in g/day.

Total Emission of particulate matter (PM) from private hired vehicles:

$$totalPM\_emsn_{hv} - PM\_emsn_{hv} - PM\_emsn_{hv} = 0 \quad (96)$$

$totalPM\_emsn_{hv}$ is the total emission of PM from hired vehicles in g/day.

Total Emission of benzene (BENZ) from private hired vehicles:

$$totalBENZ\_emsn_{hv} - BENZ\_emsn_{hv} - BENZ\_emsn_{hv} = 0 \quad (97)$$

$totalBENZ\_emsn_{hv}$ is the total emission of benzene from hired vehicles in g/day.

Total Emission of butadiene (BUTDN) from private hired vehicles:

$$totalBUTDN\_emsn_{hv} - BUTDN\_emsn_{g_{hv}} - BUTDN\_emsn_{s_{hv}} = 0 \quad (98)$$

$totalBUTDN\_emsn_{hv}$ is the total emission of butadiene from hired vehicles in g/day.

4.2.4.2 Pollution generation equation from incineration plant

Total CO₂ generation from incineration plant:

$$CO_2\_emsn\_inc_{de} - \sum_{de=1}^{DE} CO_2\_inc_{de} \times srincf_{de} = 0 \quad (99)$$

$CO_2\_emsn\_inc_{de}$ is the total emission of CO₂ from incineration plant. $CO_2\_inc_{de}$ is the CO₂ emission rate from incineration plant at disposal site de per MT of garbage.

Total SO₂ generation from incineration plant:

$$SO_2\_emsn\_inc_{de} - \sum_{de=1}^{DE} SO_2\_inc_{de} \times srincf_{de} = 0 \quad (100)$$

$SO_2\_emsn\_inc_{de}$ is the total emission of SO₂ from incineration plant. $SO_2\_inc_{de}$ is the SO₂ emission rate from incineration plant at disposal site de per MT of garbage.

Total NO₂ generation from incineration plant:

$$NO_2\_emsn\_inc_{de} - \sum_{de=1}^{DE} NO_2\_inc_{de} \times srincf_{de} = 0 \quad (101)$$

$NO_2\_emsn\_inc_{de}$ is the total emission of NO₂ from incineration plant. $NO_2\_inc_{de}$ is the NO₂ emission rate from incineration plant at disposal site de per MT of garbage.

4.2.4.3 Pollution generation equation from composting plant

Total CO₂ generation from composting plant:

$$CO_2\_emsn\_cp_{de} - \sum_{de=1}^{DE} CO_2\_cp_{de} \times srcpf_{de} = 0 \quad (102)$$

$CO_2\_emsn\_cp_{de}$ is the total emission of CO₂ from composting plant. $CO_2\_cp_{de}$ is the CO₂ emission rate from composting plant at disposal site de per MT of garbage.

Total NO₂ generation from composting plant:

$$NO_{2\_emsn\_cp_{de}} - \sum_{de=1}^{DE} NO_{2\_cp_{de}} \times srcpf_{de} = 0 \quad (103)$$

$NO_{2\_emsn\_cp_{de}}$ is the total emission of NO₂ from composting plant. $NO_{2\_cp_{de}}$ is the NO₂ emission rate from composting plant at disposal site de per MT of garbage.

Total SO₂ generation from composting plant:

$$SO_{2\_emsn\_cp_{de}} - \sum_{de=1}^{DE} SO_{2\_cp_{de}} \times srcpf_{de} = 0 \quad (104)$$

$SO_{2\_emsn\_cp_{de}}$ is the total emission of SO₂ from composting plant. $SO_{2\_cp_{de}}$ is the SO₂ emission rate from composting plant at disposal site de per MT of garbage.

Total CH₄ generation from composting plant:

$$CH_{4\_emsn\_cp_{de}} - \sum_{de=1}^{DE} CH_{4\_cp_{de}} \times srcpf_{de} = 0 \quad (105)$$

$CH_{4\_emsn\_cp_{de}}$ is the total emission of CH₄ from composting plant. $CH_{4\_cp_{de}}$ is the CH₄ emission rate from composting plant at disposal site de per MT of garbage.

4.2.4.4 Liquid pollutant generation equation from landfill leachate

Total arsenic generation from landfill leachate:

$$totalAs\_emsn_{de} - \sum_{de=1}^{DE} As\_dump_{de} \times xlf_{de} = 0 \quad (106)$$

$totalAs\_emsn_{de}$ is the total arsenic emission from landfill leachate. As_dump_{de} is the arsenic generation rate from landfill leachate at disposal site de per MT of disposed waste.

Total mercury generation from landfill leachate:

$$totalHg\_emsn_{de} - \sum_{de=1}^{DE} Hg\_dump_{de} \times xlf_{de} = 0 \quad (107)$$

$totalHg\_emsn_{de}$ is the total mercury emission from landfill leachate. Hg_dump_{de} is the mercury generation rate from landfill leachate at disposal site de per MT of disposed waste.

Total chromium generation from landfill leachate:

$$totalCr\_emsn_{de} - \sum_{de=1}^{DE} Cr\_dump_{de} \times xlf_{de} = 0 \quad (108)$$

$totalCr\_emsn_{de}$ is the total chromium emission from landfill leachate. Cr_dump_{de} is the chromium generation rate from landfill leachate at disposal site de per MT of disposed waste.

Total lead generation from landfill leachate:

$$totalPb\_emsn_{de} - \sum_{de=1}^{DE} Pb\_dump_{de} \times xlf_{de} = 0 \quad (109)$$

$totalPb\_emsn_{de}$ is the total lead emission from landfill leachate. Pb_dump_{de} is the lead generation rate from landfill leachate at disposal site de per MT of disposed waste.

Total nickel generation from landfill leachate:

$$totalNi\_emsn_{de} - \sum_{de=1}^{DE} Ni\_dump_{de} \times xlf_{de} = 0 \quad (110)$$

$totalNi\_emsn_{de}$ is the total nickel emission from landfill leachate. Ni_dump_{de} is the nickel generation rate from landfill leachate at disposal site de per MT of disposed waste.

Total copper generation from landfill leachate:

$$totalCu\_emsn_{de} - \sum_{de=1}^{DE} Cu\_dump_{de} \times xlf_{de} = 0 \quad (111)$$

$totalCu\_emsn_{de}$ is the total copper emission from landfill leachate. Cu_dump_{de} is the copper generation rate from landfill leachate at disposal site de per MT of disposed waste.

Total zinc generation from landfill leachate:

$$totalZn\_emsn_{de} - \sum_{de=1}^{DE} Zn\_dump_{de} \times xlf_{de} = 0 \quad (112)$$

$totalZn\_emsn_{de}$ is the total zinc emission from landfill leachate. Zn_dump_{de} is the zinc generation rate from landfill leachate at disposal site de per MT of disposed waste.

Total cyanide generation from landfill leachate:

$$totalCN\_emsn_{de} - \sum_{de=1}^{DE} CN\_dump_{de} \times xlf_{de} = 0 \quad (113)$$

$totalCN\_emsn_{de}$ is the total cyanide emission from landfill leachate. CN_dump_{de} is the cyanide generation rate from landfill leachate at disposal site de per MT of disposed waste.

Total chloride generation from landfill leachate:

$$totalCl\_emsn_{de} - \sum_{de=1}^{DE} Cl\_dump_{de} \times xlf_{de} = 0 \quad (114)$$

$totalCl\_emsn_{de}$ is the total chloride emission from landfill leachate. Cl_dump_{de} is the chloride generation rate from landfill leachate at disposal site de per MT of disposed waste.

Total phenol generation from landfill leachate:

$$totalPHENOL\_emsn_{de} - \sum_{de=1}^{DE} PHENOL\_dump_{de} \times xlf_{de} = 0 \quad (115)$$

$totalPHENOL\_emsn_{de}$ is the total phenolic compounds emission from landfill leachate. $PHENOL\_dump_{de}$ is the phenolic compounds generation rate from landfill leachate at disposal site de per MT of disposed waste.

Total ammonical nitrogen (as N) generation from landfill leachate:

$$totalNH_3 - N\_emsn_{de} - \sum_{de=1}^{DE} totalNH_3 - N\_dump_{de} \times xlf_{de} = 0 \quad (116)$$

$totalNH_3 - N\_emsn_{de}$ is the total ammoniacal nitrogen (as N) emission from landfill leachate. $NH_3 - N\_dump_{de}$ is the ammoniacal nitrogen (as N) generation rate from landfill leachate at disposal site de per MT of disposed waste.

Total Kjeldahl nitrogen (as N) generation from landfill leachate:

$$toatalTKN\_emsn_{de} - \sum_{de=1}^{DE} TKN\_dump_{de} \times xlf_{de} = 0 \quad (117)$$

$totalTKN\_emsn_{de}$ is the total kjeldahl nitrogen (as N) emission from landfill leachate. TKN_dump_{de} is the kjeldahl nitrogen (as N) generation rate from landfill leachate at disposal site de per MT of disposed waste.

4.2.5 Incorporating Potential Environmental Impact (PEI) LP Equations

To estimate the PEI caused by various pollutant generated from different sectors of MSWM system, the equation of PEI for different impact categories and sub-categories are incorporated in this present study along with the cost optimisation. Three impact categories namely Global, regional and local are considered in this present study with different impact sub-categories.

4.2.5.1 Global PEI calculation

Under global category, sub-categories considered are Global Warming Potential (GWP) and Ozone Depletion Potential (ODP). In this study, ODP cannot be calculated as no such gasses are generating which can cause breakdown of ozone layer.

PEI calculation for global warming potential (GWP) impact sub-category

PEI contribution of CO₂ in GWP impact sub-category:

$$pei\_gwp\_CO_2 - [w\_gwp \times \{(totalCO_2\_emsn \times ef\_gwp\_CO_2)/n\_gwp\}] = 0 \quad (118)$$

$$totalCO_2\_emsn - [totalCO_2\_emsn_{dv} + totalCO_2\_emsn_{hv} + totalCO_2\_emsn_{inc_{de}} + totalCO_2\_emsn_{truck_{de}} + totalCO_2\_emsn_{cp_{de}}] = 0 \quad (119)$$

$pei\_gwp\_CO_2$ is the PEI contribution of CO₂ to GWP impact sub-category in local perspective. w_gwp is the relative weightage of GWP, $ef\_gwp\_CO_2$ is the equivalency factor of CO₂ for GWP and n_gwp is the normalizing value for GWP.

$totalCO_2\_emsn$ is the total emission CO₂ from the MSWM system in g/day. $totalCO_2\_emsn_{dv}$ is the total emission of CO₂ from departmental vehicles, $totalCO_2\_emsn_{hv}$ is the total emission of CO₂ from hired vehicles, $totalCO_2\_emsn_{truck_{de}}$ is the total CO₂ emission from LPT trucks, $totalCO_2\_emsn_{inc_{de}}$ is the total emission of CO₂ from incineration plant and $totalCO_2\_emsn_{cp_{de}}$ is the total emission of CO₂ from composting plant in g/day.

PEI contribution of CH₄ in GWP impact sub-category:

$$pei\_gwp\_CH_4 - [w\_gwp \times \{(totalCH_4\_emsn \times ef\_gwp\_CH_4)/n\_gwp\}] = 0 \quad (120)$$

$$totalCH_4\_emsn - totalCH_4\_emsn\_cp_{de} = 0 \quad (121)$$

$pei\_gwp\_CH_4$ is the PEI contribution of CH₄ to GWP impact sub-category in local perspective. w_gwp is the relative weightage of GWP, $ef\_gwp\_CH_4$ is the equivalency factor of CH₄ for GWP and n_gwp is the normalizing value for GWP.

$totalCH_4\_emsn$ is the total emission of CH₄ from the MSWM system in g/day. $totalCH_4\_emsn\_cp_{de}$ is the total emission of CH₄ from composting plant in g/day.

PEI contribution of GWP in global category:

$$pei\_gwp - pei\_gwp\_CO_2 - pei\_gwp\_CH_4 = 0 \quad (122)$$

pei_gwp is the total PEI contribution of GWP impact sub-category in local perspective

4.2.5.2 Regional PEI calculation

Under regional category, Acidification Potential (AP) and Photo-chemical Ozone Conversion Potential (POCP) sub-categories are considered and the appropriate equations are depicted below.

PEI calculation for acidification potential (AP) impact sub-category

PEI contribution of SO₂ in AP impact sub-category:

$$pei\_ap\_SO_2 - [w\_ap \times \{(totalSO_2\_emsn \times ef\_ap\_SO_2)/n\_ap\}] = 0 \quad (123)$$

$$totalSO_2\_emsn - [totalSO_2\_emsn_{dv} + totalSO_2\_emsn_{hv} + totalSO_2\_emsn_{inc_{de}} + totalSO_2\_emsn_{truck_{de}} + totalSO_2\_emsn_{cp_{de}}] = 0 \quad (124)$$

$pei\_ap\_SO_2$ is the PEI contribution of SO₂ to AP impact sub-category in local perspective. w_ap is the relative weightage of AP, $ef\_ap\_SO_2$ is the equivalency factor of SO₂ for AP and n_ap is the normalizing value for AP.

$totalSO_2\_emsn$ is the total emission SO₂ from the MSWM system in g/day. $totalSO_2\_emsn_{dv}$ is the total emission of SO₂ from departmental vehicles, $totalSO_2\_emsn_{hv}$ is the total emission of SO₂ from hired vehicles, $totalSO_2\_emsn_{truck_{de}}$ is the total SO₂ emission from LPT trucks, $totalSO_2\_emsn_{inc_{de}}$ is the total emission of SO₂ from

incineration plant and $totalSO_2\_emsn\_cp_{de}$ is the total emission of SO_2 from composting plant in g/day.

PEI contribution of NO_x in AP impact sub-category:

$$pei\_ap\_NO_x - [w\_ap \times \{(totalNO_x\_emsn \times ef\_ap\_NO_x)/n\_ap\}] = 0 \quad (125)$$

$$totalNO_x\_emsn - [totalNO_x\_emsn_{dv} + totalNO_x\_emsn_{hv} + totalNO_x\_emsn_{inc_{de}} + totalNO_x\_emsn_{truck_{de}} + totalNO_x\_emsn_{cp_{de}}] = 0 \quad (126)$$

$pei\_ap\_NO_x$ is the PEI contribution of NO_x to AP impact sub-category in local perspective. w_ap is the relative weightage of AP, $ef\_ap\_NO_x$ is the equivalency factor of NO_x for AP and n_ap is the normalizing value for AP.

$totalNO_x\_emsn$ is the total emission NO_x from the MSWM system in g/day. $totalNO_x\_emsn_{dv}$ is the total emission of NO_x from departmental vehicles, $totalNO_x\_emsn_{hv}$ is the total emission of NO_x from hired vehicles, $totalNO_x\_emsn_{truck_{de}}$ is the total NO_x emission from LPT trucks, $totalNO_x\_emsn_{inc_{de}}$ is the total emission of NO_x from incineration plant and $totalNO_x\_emsn_{cp_{de}}$ is the total emission of NO_x from composting plant in g/day.

PEI contribution of AP in regional category:

$$pei\_ap - pei\_ap\_SO_2 - pei\_ap\_NO_x = 0 \quad (127)$$

pei_ap is the total PEI contribution of AP impact sub-category in local perspective

PEI calculation for photochemical ozone conversion potential (POCP) impact sub-category

PEI contribution of CH_4 in POCP impact sub-category:

$$pei\_pocp\_CH_4 - [w\_pocp \times \{(totalCH_4\_emsn \times ef\_pocp\_CH_4)/n\_pocp\}] = 0 \quad (128)$$

$$totalCH_4\_emsn - totalCH_4\_emsn_{cp_{de}} = 0 \quad (129)$$

$pei\_pocp\_CH_4$ is the PEI contribution of CH_4 to POCP impact sub-category in local perspective. w_pocp is the relative weightage of POCP, $ef\_pocp\_CH_4$ is the equivalency factor of CH_4 for POCP and n_pocp is the normalizing value for POCP.

$totalCH_4\_emsn$ is the total emission of CH_4 from the MSWM system in g/day. $totalCH_4\_emsn\_cp_{de}$ is the total emission of CH_4 from composting plant in g/day.

PEI contribution of POCP in regional category:

$$pei\_pocp - pei\_pocp\_CH_4 = 0 \quad (130)$$

pei_pocp is the total PEI contribution of POCP impact sub-category in local perspective.

4.2.5.3 Local PEI calculation

Human Toxicity Potential by Ingestion (HTPI), Human Toxicity Potential by Inhalation (HTPE), Terrestrial Toxicity Potential by Gas (TTPG), Terrestrial Toxicity Potential by Liquid (TTPL), and Aquatic Toxicity Potential (ATP) are the impact sub-categories taken into consideration under the local category. The respective formulas for each impact sub-category are described below.

PEI calculation for human toxicity potential by ingestion (HTPI) impact Sub-category

PEI contribution of Arsenic (As) in HTPI impact sub-category:

$$pei\_htpi\_As - [w\_htpi \times \{(totalAs\_emsn \times ef\_htpi\_As)/n\_htpi\}] = 0 \quad (131)$$

pei_htpi_As is the PEI contribution of arsenic to HTPI impact sub-category in local perspective. w_htpi is the relative weightage of HTPI, ef_htpi_As is the equivalency factor of arsenic for HTPI and n_htpi is the normalizing value for HTPI. $totalAs\_emsn$ is the total emission of arsenic from the landfill leachate.

PEI contribution of Phenolic compounds (PHENOL) in HTPI impact sub-category:

$$pei\_htpi\_Phenol - [w\_htpi \times \{(totalPHENOL\_emsn \times ef\_htpi\_Phenol)/n\_htpi\}] = 0 \quad (132)$$

pei_htpi_Phenol is the PEI contribution of phenolic compounds to HTPI impact sub-category in local perspective. w_htpi is the relative weightage of HTPI, ef_htpi_Phenol is the equivalency factor of phenol for HTPI and n_htpi is the normalizing value for HTPI. $totalPHENOL\_emsn$ is the total emission of phenolic compounds from the landfill leachate.

PEI contribution of Cadmium (Cd) in HTPI impact sub-category:

$$pei\_htpi\_Cd - [w\_htpi \times \{(totalCd\_emsn \times ef\_htpi\_Cd)/n\_htpi\}] = 0 \quad (133)$$

pei_htpi_Cd is the PEI contribution of Cadmium to HTPI impact sub-category in local perspective. w_htpi is the relative weightage of HTPI, ef_htpi_Cd is the equivalency factor of cadmium for HTPI and n_htpi is the normalizing value for HTPI. $totalCd\_emsn$ is the total emission of cadmium from the landfill leachate.

PEI contribution of Chlorine (Cl) in HTPI impact sub-category:

$$pei\_htpi\_Cl - [w\_htpi \times \{(totalCl\_emsn \times ef\_htpi\_Cl)/n\_htpi\}] = 0 \quad (134)$$

pei_htpi_Cl is the PEI contribution of chlorine to HTPI impact sub-category in local perspective. w_htpi is the relative weightage of HTPI, ef_htpi_Cl is the equivalency factor of chlorine for HTPI and n_htpi is the normalizing value for HTPI. $totalCl\_emsn$ is the total emission of chlorine from the landfill leachate.

PEI contribution of Cyanide (CN) in HTPI impact sub-category:

$$pei\_htpi\_CN - [w\_htpi \times \{(totalCN\_emsn \times ef\_htpi\_CN)/n\_htpi\}] = 0 \quad (135)$$

pei_htpi_CN is the PEI contribution of cyanide to HTPI impact sub-category in local perspective. w_htpi is the relative weightage of HTPI, ef_htpi_CN is the equivalency factor of cyanide for HTPI and n_htpi is the normalizing value for HTPI. $totalCN\_emsn$ is the total emission of cyanide from the landfill leachate.

PEI contribution of Chromium (Cr) in HTPI impact sub-category:

$$pei\_htpi\_Cr - [w\_htpi \times \{(totalCr\_emsn \times ef\_htpi\_Cr)/n\_htpi\}] = 0 \quad (136)$$

pei_htpi_Cr is the PEI contribution of chromium to HTPI impact sub-category in local perspective. w_htpi is the relative weightage of HTPI, ef_htpi_Cr is the equivalency factor of chromium for HTPI and n_htpi is the normalizing value for HTPI. $totalCr\_emsn$ is the total emission of chromium from the landfill leachate.

PEI contribution of Copper (Cu) in HTPI impact sub-category:

$$pei\_htpi\_Cu - [w\_htpi \times \{(totalCu\_emsn \times ef\_htpi\_Cu)/n\_htpi\}] = 0 \quad (137)$$

pei_htpi_Cu is the PEI contribution of copper to HTPI impact sub-category in local perspective. w_htpi is the relative weightage of HTPI, ef_htpi_Cu is the equivalency

factor of copper for HTPI and n_htpi is the normalizing value for HTPI. $totalCu\_emsn$ is the total emission of copper from the landfill leachate.

PEI contribution of Fluoride (F) in HTPI impact sub-category:

$$pei\_htpi\_F - [w\_htpi \times \{(totalF\_emsn \times ef\_htpi\_F)/n\_htpi\}] = 0 \quad (138)$$

pei_htpi_F is the PEI contribution of fluoride to HTPI impact sub-category in local perspective. w_htpi is the relative weightage of HTPI, ef_htpi_F is the equivalency factor of fluoride for HTPI and n_htpi is the normalizing value for HTPI. $totalF\_emsn$ is the total emission of fluoride from the landfill leachate.

PEI contribution of Mercury (Hg) in HTPI impact sub-category:

$$pei\_htpi\_Hg - [w\_htpi \times \{(totalHg\_emsn \times ef\_htpi\_Hg)/n\_htpi\}] = 0 \quad (139)$$

pei_htpi_Hg is the PEI contribution of mercury to HTPI impact sub-category in local perspective. w_htpi is the relative weightage of HTPI, ef_htpi_Hg is the equivalency factor of mercury for HTPI and n_htpi is the normalizing value for HTPI. $totalHg\_emsn$ is the total emission of mercury from the landfill leachate.

PEI contribution of Nickel (Ni) in HTPI impact sub-category:

$$pei\_htpi\_Ni - [w\_htpi \times \{(totalNi\_emsn \times ef\_htpi\_Ni)/n\_htpi\}] = 0 \quad (140)$$

pei_htpi_Ni is the PEI contribution of nickel to HTPI impact sub-category in local perspective. w_htpi is the relative weightage of HTPI, ef_htpi_Ni is the equivalency factor of nickel for HTPI and n_htpi is the normalizing value for HTPI. $totalNi\_emsn$ is the total emission of nickel from the landfill leachate.

PEI contribution of Lead (Pb) in HTPI impact sub-category:

$$pei\_htpi\_Pb - [w\_htpi \times \{(totalPb\_emsn \times ef\_htpi\_Pb)/n\_htpi\}] = 0 \quad (141)$$

pei_htpi_Pb is the PEI contribution of lead to HTPI impact sub-category in local perspective. w_htpi is the relative weightage of HTPI, ef_htpi_Pb is the equivalency factor of lead for HTPI and n_htpi is the normalizing value for HTPI. $totalPb\_emsn$ is the total emission of lead from the landfill leachate.

PEI contribution of Zinc (Zn) in HTPI impact sub-category:

$$pei\_htpi\_Zn - [w\_htpi \times \{(totalZn\_emsn \times ef\_htpi\_Zn)/n\_htpi\}] = 0 \quad (142)$$

pei_htpi_Zn is the PEI contribution of zinc to HTPI impact sub-category in local perspective. w_htpi is the relative weightage of HTPI, ef_htpi_Zn is the equivalency factor of zinc for HTPI and n_htpi is the normalizing value for HTPI. $totalZn\_emsn$ is the total emission of zinc from the landfill leachate.

PEI contribution of Ammoniacal nitrogen (NH_3-N) in HTPI impact sub-category:

$$pei\_htpi\_NH_3 - N - [w\_htpi \times \{(totalNH_3 - N\_emsn \times ef\_htpi\_NH_3 - N)/n\_htpi\}] = 0 \quad (143)$$

$pei\_htpi\_NH_3-N$ is the PEI contribution of ammoniacal nitrogen to HTPI impact sub-category in local perspective. w_htpi is the relative weightage of HTPI, $ef\_htpi\_NH_3-N$ is the equivalency factor of ammoniacal nitrogen for HTPI and n_htpi is the normalizing value for HTPI. $totalNH_3-N\_emsn$ is the total emission of ammoniacal nitrogen from the landfill leachate.

PEI contribution of HTPI in local category:

$$\begin{aligned} &pei\_htpi - pei\_htpi\_Phenol - pei\_htpi\_Cd - pei\_htpi\_Cl - pei\_htpi\_CN \\ &\quad - pei\_htpi\_Cr - pei\_htpi\_Cu - pei\_htpi\_F - pei\_htpi\_Hg \\ &\quad - pei\_htpi\_Ni - pei\_htpi\_Pb \\ &\quad - pei\_htpi\_Zn - pei\_htpi\_NH_3 - N = 0 \quad (144) \end{aligned}$$

pei_htpi is the total PEI contribution of HTPI impact sub-category in local perspective.

PEI calculation for human toxicity potential by inhalation (HTPE) impact sub-category

PEI contribution of CO_2 in HTPE impact sub-category:

$$pei\_htpe\_CO_2 - [w\_htpe \times \{(totalCO_2\_emsn \times ef\_htpe\_CO_2)/n\_htpe\}] = 0 \quad (145)$$

$pei\_htpe\_CO_2$ is the PEI contribution of CO_2 to HTPE impact sub-category in local perspective. w_htpe is the relative weightage of HTPE, $ef\_htpe\_CO_2$ is the equivalency factor of CO_2 for HTPE and n_htpe is the normalizing value for HTPE. $totalCO_2\_emsn$ is the total emission of CO_2 from the MSWM system in g/day.

PEI contribution of SO_2 in HTPE impact sub-category:

$$pei\_htpe\_SO_2 - [w\_htpe \times \{(totalSO_2\_emsn \times ef\_htpe\_SO_2)/n\_htpe\}] = 0 \quad (146)$$

$pei\_htpe\_SO_2$ is the PEI contribution of SO_2 to HTPE impact sub-category in local perspective. w_htpe is the relative weightage of HTPE, $ef\_htpe\_SO_2$ is the equivalency factor of SO_2 for HTPE and n_htpe is the normalizing value for HTPE. $totalSO_2\_emsn$ is the total emission of SO_2 from the MSWM system in g/day.

PEI contribution of NO_x in HTPE impact sub-category:

$$pei\_htpe\_NO_x - [w\_htpe \times \{(totalNO_x\_emsn \times ef\_htpe\_NO_x)/n\_htpe\}] = 0 \quad (147)$$

$pei\_htpe\_NO_x$ is the PEI contribution of NO_x to HTPE impact sub-category in local perspective. w_htpe is the relative weightage of HTPE, $ef\_htpe\_NO_x$ is the equivalency factor of NO_x for HTPE and n_htpe is the normalizing value for HTPE. $totalNO_x\_emsn$ is the total emission of NO_x from the MSWM system in g/day.

PEI contribution of CH_4 in HTPE impact sub-category:

$$pei\_htpe\_CH_4 - [w\_htpe \times \{(totalCH_4\_emsn \times ef\_htpe\_CH_4)/n\_htpe\}] = 0 \quad (148)$$

$pei\_htpe\_CH_4$ is the PEI contribution of CH_4 to HTPE impact sub-category in local perspective. w_htpe is the relative weightage of HTPE, $ef\_htpe\_CH_4$ is the equivalency factor of CH_4 for HTPE and n_htpe is the normalizing value for HTPE. $totalCH_4\_emsn$ is the total emission of CH_4 from the MSWM system in g/day.

PEI contribution of NH_3 in HTPE impact sub-category:

$$pei\_htpe\_NH_3 - [w\_htpe \times \{(totalNH_3\_emsn \times ef\_htpe\_NH_3)/n\_htpe\}] = 0 \quad (149)$$

$pei\_htpe\_NH_3$ is the PEI contribution of NH_3 to HTPE impact sub-category in local perspective. w_htpe is the relative weightage of HTPE, $ef\_htpe\_NH_3$ is the equivalency factor of NH_3 for HTPE and n_htpe is the normalizing value for HTPE. $totalNH_3\_emsn$ is the total emission of NH_3 from the MSWM system in g/day.

PEI contribution of H_2S in HTPE impact sub-category:

$$pei\_htpe\_H_2S - [w\_htpe \times \{(totalH_2S\_emsn \times ef\_htpe\_H_2S)/n\_htpe\}] = 0 \quad (150)$$

$pei\_htpe\_H_2S$ is the PEI contribution of H_2S to HTPE impact sub-category in local perspective. w_htpe is the relative weightage of HTPE, $ef\_htpe\_H_2S$ is the equivalency factor of H_2S for HTPE and n_htpe is the normalizing value for HTPE. $totalH_2S\_emsn$ is the total emission of H_2S from the MSWM system in g/day.

PEI contribution of CO in HTPE impact sub-category:

$$pei\_htpe\_CO - [w\_htpe \times \{(totalCO\_emsn \times ef\_htpe\_CO)/n\_htpe\}] = 0 \quad (151)$$

$$totalCO\_emsn - totalCO\_emsn_{dv} - totalCO\_emsn_{hv} - totalCO\_emsn_{truck_{de}} = 0 \quad (152)$$

pei_htpe_CO is the PEI contribution of CO to HTPE impact sub-category in local perspective. w_htpe is the relative weightage of HTPE, ef_htpe_CO is the equivalency factor of CO for HTPE and n_htpe is the normalizing value for HTPE. $totalCO\_emsn$ is the total emission of CO from the MSWM system in g/day.

PEI contribution of Hydrocarbon (HC) in HTPE impact sub-category:

$$pei\_htpe\_HC - [w\_htpe \times \{(totalHC\_emsn \times ef\_htpe\_HC)/n\_htpe\}] = 0 \quad (153)$$

$$totalHC\_emsn - totalHC\_emsn_{dv} - totalHC\_emsn_{hv} - totalHC\_emsn_{truck_{de}} = 0 \quad (154)$$

pei_htpe_HC is the PEI contribution of HC to HTPE impact sub-category in local perspective. w_htpe is the relative weightage of HTPE, ef_htpe_HC is the equivalency factor of HC for HTPE and n_htpe is the normalizing value for HTPE. $totalHC\_emsn$ is the total emission of hydrocarbon from the MSWM system in g/day.

PEI contribution of Benzene (BENZ) in HTPE impact sub-category:

$$pei\_htpe\_BENZ - [w\_htpe \times \{(totalBENZ\_emsn \times ef\_htpe\_BENZ)/n\_htpe\}] = 0 \quad (155)$$

$$totalBENZ\_emsn - totalBENZ\_emsn_{dv} - totalBENZ\_emsn_{hv} - totalBENZ\_emsn_{truck_{de}} = 0 \quad (156)$$

pei_htpe_BENZ is the PEI contribution of benzene to HTPE impact sub-category in local perspective. w_htpe is the relative weightage of HTPE, ef_htpe_BENZ is the equivalency factor of benzene for HTPE and n_htpe is the normalizing value for HTPE. $totalBENZ\_emsn$ is the total emission of benzene from the MSWM system in g/day.

PEI contribution of Butadiene (BUTDN) in HTPE impact sub-category:

$$pei\_htpe\_BUTDN - [w\_htpe \times \{(totalBUTDN\_emsn \times ef\_htpe\_BUTDN)/n\_htpe\}] = 0 \quad (157)$$

$$totalBUTDN\_emsn - totalBUTDN\_emsn_{dv} - totalBUTDN\_emsn_{hv} - totalBUTDN\_emsn_{truck_{de}} = 0 \quad (158)$$

pei_htpe_BUTDN is the PEI contribution of butadiene to HTPE impact sub-category in local perspective. w_htpe is the relative weightage of HTPE, ef_htpe_BUTDN is the equivalency factor of butadiene for HTPE and n_htpe is the normalizing value for HTPE. $totalBUTDN\_emsn$ is the total emission of benzene from the MSWM system in g/day.

PEI contribution of Particulate matter (PM) in HTPE impact sub-category:

$$pei\_htpe\_PM - [w\_htpe \times \{(totalPM\_emsn \times ef\_htpe\_PM)/n\_htpe\}] = 0 \quad (159)$$

$$totalPM\_emsn - totalPM\_emsn_{dv} - totalPM\_emsn_{hv} - totalPM\_emsn_{truck\_de} = 0 \quad (160)$$

pei_htpe_PM is the PEI contribution of particulate matter to HTPE impact sub-category in local perspective. w_htpe is the relative weightage of HTPE, ef_htpe_PM is the equivalency factor of PM for HTPE and n_htpe is the normalizing value for HTPE. $totalPM\_emsn$ is the total emission of particulate matter from the MSWM system in g/day.

PEI contribution of HTPE in local category:

$$\begin{aligned} &pei\_htpe - pei\_htpe\_CO_2 - pei\_htpe\_SO_2 - pei\_htpe\_NO_x - pei\_htpe\_CH_4 \\ &\quad - pei\_htpe\_NH_3 - pei\_htpe\_H_2S - pei\_htpe\_CO - pei\_htpe\_HC \\ &\quad - pei\_htpe\_PM - pei\_htpe\_BUTDN - pei\_htpe\_BENZ = 0 \end{aligned} \quad (161)$$

pei_htpe is the total PEI contribution of HTPE impact sub-category in local perspective.

PEI calculation for terrestrial toxicity potential by liquid (TTPL) impact sub-category

PEI contribution of Arsenic (As) in TTPL impact sub-category:

$$pei\_ttpl\_As - [w\_ttpl \times \{(totalAs\_emsn \times ef\_ttpl\_As)/n\_ttpl\}] = 0 \quad (162)$$

pei_ttpl_As is the PEI contribution of arsenic to TTPL impact sub-category in local perspective. w_ttpl is the relative weightage of TTPL, ef_ttpl_As is the equivalency factor of arsenic for TTPL and n_ttpl is the normalizing value for TTPL. $totalAs\_emsn$ is the total emission of arsenic from the landfill leachate.

PEI contribution of Phenolic compounds (PHENOL) in TTPL impact sub-category:

$$pei\_ttpl\_Phenol - [w\_ttpl \times \{(totalPHENOL\_emsn \times ef\_ttpl\_Phenol)/n\_ttpl\}] = 0 \quad (163)$$

pei_ttpl_Phenol is the PEI contribution of phenolic compounds to TTPL impact sub-category in local perspective. w_ttpl is the relative weightage of TTPL, ef_ttpl_Phenol is the equivalency factor of phenolic compounds for TTPL and n_ttpl is the normalizing value for TTPL. $totalPHENOL\_emsn$ is the total emission of phenolic compounds from the landfill leachate.

PEI contribution of Cadmium (Cd) in TTPL impact sub-category:

$$pei\_ttpl\_Cd - [w\_ttpl \times \{(totalCd\_emsn \times ef\_ttpl\_Cd)/n\_ttpl\}] = 0 \quad (164)$$

pei_ttpl_Cd is the PEI contribution of Cadmium to TTPL impact sub-category in local perspective. w_ttpl is the relative weightage of TTPL, ef_ttpl_Cd is the equivalency factor of cadmium for TTPL and n_ttpl is the normalizing value for TTPL. $totalCd\_emsn$ is the total emission of cadmium from the landfill leachate.

PEI contribution of Chlorine (Cl) in TTPL impact sub-category:

$$pei\_ttpl\_Cl - [w\_ttpl \times \{(totalCl\_emsn \times ef\_ttpl\_Cl)/n\_ttpl\}] = 0 \quad (165)$$

pei_ttpl_Cl is the PEI contribution of chlorine to TTPL impact sub-category in local perspective. w_ttpl is the relative weightage of TTPL, ef_ttpl_Cl is the equivalency factor of chlorine for TTPL and n_ttpl is the normalizing value for TTPL. $totalCl\_emsn$ is the total emission of chlorine from the landfill leachate.

PEI contribution of Cyanide (CN) in TTPL impact sub-category:

$$pei\_ttpl\_CN - [w\_ttpl \times \{(totalCN\_emsn \times ef\_ttpl\_CN)/n\_ttpl\}] = 0 \quad (166)$$

pei_ttpl_CN is the PEI contribution of cyanide to TTPL impact sub-category in local perspective. w_ttpl is the relative weightage of TTPL, ef_ttpl_CN is the equivalency factor of cyanide for TTPL and n_ttpl is the normalizing value for TTPL. $totalCN\_emsn$ is the total emission of cyanide from the landfill leachate.

PEI contribution of Chromium (Cr) in TTPL impact sub-category:

$$pei\_ttpl\_Cr - [w\_ttpl \times \{(totalCr\_emsn \times ef\_ttpl\_Cr)/n\_ttpl\}] = 0 \quad (167)$$

pei_ttpl_Cr is the PEI contribution of chromium to TTPL impact sub-category in local perspective. w_ttpl is the relative weightage of TTPL, ef_ttpl_Cr is the equivalency factor of chromium for TTPL and n_ttpl is the normalizing value for TTPL. $totalCr\_emsn$ is the total emission of chromium from the landfill leachate.

PEI contribution of Copper (Cu) in TTPL impact sub-category:

$$pei\_ttpl\_Cr - [w\_ttpl \times \{(totalCr\_emsn \times ef\_ttpl\_Cr)/n\_ttpl\}] = 0 \quad (168)$$

pei_ttpl_Cu is the PEI contribution of copper to TTPL impact sub-category in local perspective. w_ttpl is the relative weightage of TTPL, ef_ttpl_Cu is the equivalency factor of copper for TTPL and n_ttpl is the normalizing value for TTPL. $totalCu\_emsn$ is the total emission of copper from the landfill leachate.

PEI contribution of Fluoride (F) in TTPL impact sub-category:

$$pei\_ttpl\_F - [w\_ttpl \times \{(totalF\_emsn \times ef\_ttpl\_F)/n\_ttpl\}] = 0 \quad (169)$$

pei_ttpl_F is the PEI contribution of fluoride to TTPL impact sub-category in local perspective. w_ttpl is the relative weightage of TTPL, ef_ttpl_F is the equivalency factor of fluoride for TTPL and n_ttpl is the normalizing value for TTPL. $totalF\_emsn$ is the total emission of fluoride from the landfill leachate.

PEI contribution of Mercury (Hg) in TTPL impact sub-category:

$$pei\_ttpl\_Hg - [w\_ttpl \times \{(totalHg\_emsn \times ef\_ttpl\_Hg)/n\_ttpl\}] = 0 \quad (170)$$

pei_ttpl_Hg is the PEI contribution of mercury to TTPL impact sub-category in local perspective. w_ttpl is the relative weightage of TTPL, ef_ttpl_Hg is the equivalency factor of mercury for TTPL and n_ttpl is the normalizing value for TTPL. $totalHg\_emsn$ is the total emission of mercury from the landfill leachate.

PEI contribution of Nickel (Ni) in TTPL impact sub-category:

$$pei\_ttpl\_Ni - [w\_ttpl \times \{(totalNi\_emsn \times ef\_ttpl\_Ni)/n\_ttpl\}] = 0 \quad (171)$$

pei_ttpl_Ni is the PEI contribution of nickel to TTPL impact sub-category in local perspective. w_ttpl is the relative weightage of TTPL, ef_ttpl_Ni is the equivalency factor of nickel for TTPL and n_ttpl is the normalizing value for TTPL. $totalNi\_emsn$ is the total emission of nickel from the landfill leachate.

PEI contribution of Lead (Pb) in TTPL impact sub-category:

$$pei\_ttpl\_Pb - [w\_ttpl \times \{(totalPb\_emsn \times ef\_ttpl\_Pb)/n\_ttpl\}] = 0 \quad (172)$$

pei_ttpl_Pb is the PEI contribution of lead to TTPL impact sub-category in local perspective. w_ttpl is the relative weightage of TTPL, ef_ttpl_Pb is the equivalency factor of lead for TTPL and n_ttpl is the normalizing value for TTPL. $totalPb\_emsn$ is the total emission of lead from the landfill leachate.

PEI contribution of Zinc (Zn) in TTPL impact sub-category:

$$pei\_ttpl\_Zn - [w\_ttpl \times \{(totalZn\_emsn \times ef\_ttpl\_Zn)/n\_ttpl\}] = 0 \quad (173)$$

pei_ttpl_Zn is the PEI contribution of zinc to TTPL impact sub-category in local perspective. w_ttpl is the relative weightage of TTPL, ef_ttpl_Zn is the equivalency factor of lead for TTPL and n_ttpl is the normalizing value for TTPL. $totalZn\_emsn$ is the total emission of zinc from the landfill leachate.

PEI contribution of Ammoniacal nitrogen (NH₃-N) in TTPL impact sub-category:

$$pei\_ttpl\_NH_3 - N - [w\_ttpl \times \{(totalNH_3 - N\_emsn \times ef\_ttpl\_NH_3 - N)/n\_ttpl\}] = 0 \quad (174)$$

$pei\_ttpl\_NH_3-N$ is the PEI contribution of ammoniacal nitrogen to TTPL impact sub-category in local perspective. w_ttpl is the relative weightage of TTPL, $ef\_ttpl\_NH_3-N$ is the equivalency factor of ammoniacal nitrogen for TTPL and n_ttpl is the normalizing value for TTPL. $totalNH_3-N\_emsn$ is the total emission of ammoniacal nitrogen from the landfill leachate.

PEI contribution of HTPI in local category:

$$\begin{aligned} &pei\_ttpl - pei\_ttpl\_Phenol - pei\_ttpl\_Cd - pei\_ttpl\_Cl - pei\_ttpl\_CN \\ &\quad - pei\_ttpl\_Cr - pei\_ttpl\_Cu - pei\_ttpl\_F - pei\_ttpl\_Hg \\ &\quad - pei\_ttpl\_Ni - pei\_ttpl\_Pb \\ &\quad - pei\_ttpl\_Zn - pei\_ttpl\_NH_3 - N = 0 \end{aligned} \quad (175)$$

pei_ttpl is the total PEI contribution of TTPL impact sub-category in local perspective.

PEI calculation for terrestrial toxicity potential by gas (TTPG) impact sub-category

PEI contribution of CO₂ in TTPG impact sub-category:

$$pei\_ttpg\_CO_2 - [w\_ttpg \times \{(totalCO_2\_emsn \times ef\_ttpg\_CO_2)/n\_ttpg\}] = 0 \quad (176)$$

$pei\_ttpg\_CO_2$ is the PEI contribution of CO₂ to TTPG impact sub-category in local perspective. w_ttpg is the relative weightage of TTPG, $ef\_ttpg\_CO_2$ is the equivalency factor of CO₂ for TTPG and n_ttpg is the normalizing value for TTPG. $totalCO_2\_emsn$ is the total emission of CO₂ from the MSWM system in g/day.

PEI contribution of SO₂ in TTPG impact sub-category:

$$pei\_ttpg\_SO_2 - [w\_ttpg \times \{(totalSO_2\_emsn \times ef\_ttpg\_SO_2)/n\_ttpg\}] = 0 \quad (177)$$

$pei\_ttpg\_SO_2$ is the PEI contribution of SO₂ to TTPG impact sub-category in local perspective. w_ttpg is the relative weightage of TTPG, $ef\_ttpg\_SO_2$ is the equivalency factor of SO₂ for TTPG and n_ttpg is the normalizing value for TTPG. $totalSO_2\_emsn$ is the total emission of SO₂ from the MSWM system in g/day.

PEI contribution of NO_x in TTPG impact sub-category:

$$pei\_ttpg\_NO_x - [w\_ttpg \times \{(totalNO_x\_emsn \times ef\_ttpg\_NO_x)/n\_ttpg\}] = 0 \quad (178)$$

$pei\_ttpg\_NO_x$ is the PEI contribution of NO_x to TTPG impact sub-category in local perspective. w_ttpg is the relative weightage of TTPG, $ef\_ttpg\_NO_x$ is the equivalency factor of NO_x for TTPG and n_ttpg is the normalizing value for TTPG. $totalNO_x\_emsn$ is the total emission of NO_x from the MSWM system in g/day.

PEI contribution of CH₄ in TTPG impact sub-category:

$$pei\_ttpg\_CH_4 - [w\_ttpg \times \{(totalCH_4\_emsn \times ef\_ttpg\_CH_4)/n\_ttpg\}] = 0 \quad (179)$$

$pei\_ttpg\_CH_4$ is the PEI contribution of CH₄ to TTPG impact sub-category in local perspective. w_ttpg is the relative weightage of TTPG, $ef\_ttpg\_CH_4$ is the equivalency factor of CH₄ for TTPG and n_ttpg is the normalizing value for TTPG. $totalCH_4\_emsn$ is the total emission of CH₄ from the MSWM system in g/day.

PEI contribution of NH₃ in TTPG impact sub-category:

$$pei\_ttpg\_NH_3 - [w\_ttpg \times \{(totalNH_3\_emsn \times ef\_ttpg\_NH_3)/n\_ttpg\}] = 0 \quad (180)$$

$pei\_ttpg\_NH_3$ is the PEI contribution of NH₃ to TTPG impact sub-category in local perspective. w_ttpg is the relative weightage of TTPG, $ef\_ttpg\_NH_3$ is the equivalency factor of NH₃ for TTPG and n_ttpg is the normalizing value for TTPG. $totalNH_3\_emsn$ is the total emission of NH₃ from the MSWM system in g/day.

PEI contribution of H₂S in TTPG impact sub-category:

$$pei\_ttpg\_H_2S - [w\_ttpg \times \{(totalH_2S\_emsn \times ef\_ttpg\_H_2S)/n\_ttpg\}] = 0 \quad (181)$$

$pei\_ttpg\_H_2S$ is the PEI contribution of H₂S to TTPG impact sub-category in local perspective. w_ttpg is the relative weightage of TTPG, $ef\_ttpg\_H_2S$ is the equivalency

factor of H₂S for TTPG and n_ttpg is the normalizing value for TTPG. $totalH_2S\_emsn$ is the total emission of H₂S from the MSWM system in g/day.

PEI contribution of CO in TTPG impact sub-category:

$$pei\_ttpg\_CO - [w\_ttpg \times \{(totalCO\_emsn \times ef\_ttpg\_CO)/n\_ttpg\}] = 0 \quad (182)$$

pei_ttpg_CO is the PEI contribution of CO to TTPG impact sub-category in local perspective. w_ttpg is the relative weightage of TTPG, ef_ttpg_CO is the equivalency factor of CO for TTPG and n_ttpg is the normalizing value for TTPG. $totalCO\_emsn$ is the total emission of CO from the MSWM system in g/day.

PEI contribution of Hydrocarbon (HC) in TTPG impact sub-category:

$$pei\_ttpg\_HC - [w\_ttpg \times \{(totalHC\_emsn \times ef\_ttpg\_HC)/n\_ttpg\}] = 0 \quad (183)$$

pei_ttpg_HC is the PEI contribution of HC to TTPG impact sub-category in local perspective. w_ttpg is the relative weightage of TTPG, ef_ttpg_HC is the equivalency factor of HC for TTPG and n_ttpg is the normalizing value for TTPG. $totalHC\_emsn$ is the total emission of hydrocarbon from the MSWM system in g/day.

PEI contribution of Benzene (BENZ) in TTPG impact sub-category:

$$pei\_ttpg\_BENZ - [w\_ttpg \times \{(totalBENZ\_emsn \times ef\_ttpg\_BENZ)/n\_ttpg\}] = 0 \quad (184)$$

pei_ttpg_BENZ is the PEI contribution of benzene to TTPG impact sub-category in local perspective. w_ttpg is the relative weightage of TTPG, ef_ttpg_BENZ is the equivalency factor of benzene for TTPG and n_ttpg is the normalizing value for TTPG. $totalBENZ\_emsn$ is the total emission of benzene from the MSWM system in g/day.

PEI contribution of Butadiene (BUTDN) in TTPG impact sub-category:

$$pei\_ttpg\_BUTDN - [w\_ttpg \times \{(totalBUTDN\_emsn \times ef\_ttpg\_BUTDN)/n\_ttpg\}] = 0 \quad (185)$$

pei_ttpg_BUTDN is the PEI contribution of butadiene to TTPG impact sub-category in local perspective. w_ttpg is the relative weightage of TTPG, ef_ttpg_BUTDN is the equivalency factor of butadiene for TTPG and n_ttpg is the normalizing value for TTPG. $totalBUTDN\_emsn$ is the total emission of benzene from the MSWM system in g/day.

PEI contribution of Particulate matter (PM) in TTPG impact sub-category:

$$pei\_ttpg\_PM - [w\_ttpg \times \{(totalPM\_emsn \times ef\_ttpg\_PM)/n\_ttpg\}] = 0 \quad (186)$$

pei_htpe_PM is the PEI contribution of particulate matter to TTPG impact sub-category in local perspective. w_ttpg is the relative weightage of TTPG, ef_ttpg_PM is the equivalency factor of PM for TTPG and n_ttpg is the normalizing value for TTPG. $totalPM\_emsn$ is the total emission of particulate matter from the MSWM system in g/day.

PEI contribution of HTPE in local category:

$$\begin{aligned} &pei\_ttpg - pei\_ttpg\_CO_2 - pei\_ttpg\_SO_2 - pei\_ttpg\_NO_x - pei\_ttpg\_CH_4 \\ &\quad - pei\_ttpg\_NH_3 - pei\_ttpg\_H_2S - pei\_ttpg\_CO - pei\_ttpg\_HC \\ &\quad - pei\_ttpg\_PM - pei\_ttpg\_BUTDN - pei\_ttpg\_BENZ = 0 \end{aligned} \quad (187)$$

pei_ttpg is the total PEI contribution of TTPG impact sub-category in local perspective.

PEI calculation for aquatic toxicity potential (ATP) impact Sub-category

PEI contribution of Arsenic (As) in ATP impact sub-category:

$$pei\_atp\_As - [w\_atp \times \{(totalAs\_emsn \times ef\_atp\_As)/n\_atp\}] = 0 \quad (188)$$

pei_atp_As is the PEI contribution of arsenic to ATP impact sub-category in local perspective. w_atp is the relative weightage of ATP, ef_atp_As is the equivalency factor of arsenic for ATP and n_atp is the normalizing value for ATP. $totalAs\_emsn$ is the total emission of arsenic from the landfill leachate.

PEI contribution of Phenolic compounds (PHENOL) in ATP impact sub-category:

$$pei\_atp\_Phenol - [w\_atp \times \{(totalPHENOL\_emsn \times ef\_atp\_Phenol)/n\_atp\}] = 0 \quad (189)$$

pei_atp_Phenol is the PEI contribution of phenolic compounds to ATP impact sub-category in local perspective. w_atp is the relative weightage of ATP, ef_atp_Phenol is the equivalency factor of phenolic compounds for ATP and n_atp is the normalizing value for ATP. $totalPHENOL\_emsn$ is the total emission of phenolic compounds from the landfill leachate.

PEI contribution of Cadmium (Cd) in ATP impact sub-category:

$$pei\_atp\_Cd - [w\_atp \times \{(totalCd\_emsn \times ef\_atp\_Cd)/n\_atp\}] = 0 \quad (190)$$

pei_atp_Cd is the PEI contribution of Cadmium to ATP impact sub-category in local perspective. w_atp is the relative weightage of ATP, ef_atp_Cd is the equivalency factor of cadmium for ATP and n_atp is the normalizing value for ATP. $totalCd\_emsn$ is the total emission of cadmium from the landfill leachate.

PEI contribution of Chlorine (Cl) in ATP impact sub-category:

$$pei\_atp\_Cl - [w\_atp \times \{(totalCl\_emsn \times ef\_atp\_Cl)/n\_atp\}] = 0 \quad (191)$$

pei_atp_Cl is the PEI contribution of chlorine to ATP impact sub-category in local perspective. w_atp is the relative weightage of ATP, ef_atp_Cl is the equivalency factor of chlorine for ATP and n_atp is the normalizing value for ATP. $totalCl\_emsn$ is the total emission of chlorine from the landfill leachate.

PEI contribution of Cyanide (CN) in ATP impact sub-category:

$$pei\_atp\_CN - [w\_atp \times \{(totalCN\_emsn \times ef\_atp\_CN)/n\_atp\}] = 0 \quad (192)$$

pei_atp_CN is the PEI contribution of cyanide to ATP impact sub-category in local perspective. w_atp is the relative weightage of ATP, ef_atp_CN is the equivalency factor of cyanide for ATP and n_atp is the normalizing value for ATP. $totalCN\_emsn$ is the total emission of cyanide from the landfill leachate.

PEI contribution of Chromium (Cr) in ATP impact sub-category:

$$pei\_atp\_Cr - [w\_atp \times \{(totalCr\_emsn \times ef\_atp\_Cr)/n\_atp\}] = 0 \quad (193)$$

pei_atp_Cr is the PEI contribution of chromium to ATP impact sub-category in local perspective. w_atp is the relative weightage of ATP, ef_atp_Cr is the equivalency factor of chromium for ATP and n_atp is the normalizing value for ATP. $totalCr\_emsn$ is the total emission of chromium from the landfill leachate.

PEI contribution of Copper (Cu) in ATP impact sub-category:

$$pei\_atp\_Cu - [w\_atp \times \{(totalCu\_emsn \times ef\_atp\_Cu)/n\_atp\}] = 0 \quad (194)$$

pei_atp_Cu is the PEI contribution of copper to ATP impact sub-category in local perspective. w_atp is the relative weightage of ATP, ef_atp_Cu is the equivalency factor of copper for ATP and n_atp is the normalizing value for ATP. $totalCu\_emsn$ is the total emission of copper from the landfill leachate.

PEI contribution of Fluoride (F) in ATP impact sub-category:

$$pei\_atp\_F - [w\_atp \times \{(totalF\_emsn \times ef\_atp\_F)/n\_atp\}] = 0 \quad (195)$$

pei_atp_F is the PEI contribution of fluoride to ATP impact sub-category in local perspective. w_atp is the relative weightage of ATP, ef_atp_F is the equivalency factor of fluoride for ATP and n_atp is the normalizing value for ATP. $totalF\_emsn$ is the total emission of fluoride from the landfill leachate.

PEI contribution of Mercury (Hg) in ATP impact sub-category:

$$pei\_atp\_Hg - [w\_atp \times \{(totalHg\_emsn \times ef\_atp\_Hg)/n\_atp\}] = 0 \quad (196)$$

pei_atp_Hg is the PEI contribution of mercury to ATP impact sub-category in local perspective. w_atp is the relative weightage of ATP, ef_atp_Hg is the equivalency factor of mercury for ATP and n_atp is the normalizing value for ATP. $totalHg\_emsn$ is the total emission of mercury from the landfill leachate.

PEI contribution of Nickel (Ni) in ATP impact sub-category:

$$pei\_atp\_Ni - [w\_atp \times \{(totalNi\_emsn \times ef\_atp\_Ni)/n\_atp\}] = 0 \quad (197)$$

pei_atp_Ni is the PEI contribution of nickel to ATP impact sub-category in local perspective. w_atp is the relative weightage of ATP, ef_atp_Ni is the equivalency factor of nickel for ATP and n_atp is the normalizing value for ATP. $totalNi\_emsn$ is the total emission of nickel from the landfill leachate.

PEI contribution of Lead (Pb) in ATP impact sub-category:

$$pei\_atp\_Pb - [w\_atp \times \{(totalPb\_emsn \times ef\_atp\_Pb)/n\_atp\}] = 0 \quad (198)$$

pei_atp_Pb is the PEI contribution of lead to ATP impact sub-category in local perspective. w_atp is the relative weightage of ATP, ef_atp_Pb is the equivalency factor of lead for ATP and n_atp is the normalizing value for ATP. $totalPb\_emsn$ is the total emission of lead from the landfill leachate.

PEI contribution of Zinc (Zn) in ATP impact sub-category:

$$pei\_atp\_Zn - [w\_atp \times \{(totalZn\_emsn \times ef\_atp\_Zn)/n\_atp\}] = 0 \quad (199)$$

pei_atp_Zn is the PEI contribution of zinc to ATP impact sub-category in local perspective. w_atp is the relative weightage of ATP, ef_atp_Zn is the equivalency factor of lead for ATP and n_atp is the normalizing value for ATP. $totalZn\_emsn$ is the total emission of zinc from the landfill leachate.

PEI contribution of Ammoniacal nitrogen ($\text{NH}_3\text{-N}$) in ATP impact sub-category:

$$pei\_atp\_NH_3 - N - [w\_atp \times \{(totalNH_3 - N\_emsn \times ef\_atp\_NH_3 - N)/n\_atp\}] = 0 \quad (200)$$

$pei\_atp\_NH_3\text{-N}$ is the PEI contribution of ammoniacal nitrogen to ATP impact sub-category in local perspective. w_atp is the relative weightage of ATP, $ef\_atp\_NH_3\text{-N}$ is the equivalency factor of ammoniacal nitrogen for ATP and n_atp is the normalizing value for ATP. $totalNH_3\text{-N}_emsn$ is the total emission of ammoniacal nitrogen from the landfill leachate.

PEI contribution of HTPI in local category:

$$\begin{aligned} &pei\_atp - pei\_atp\_Phenol - pei\_atp\_Cd - pei\_atp\_Cl - pei\_atp\_CN - pei\_atp\_Cr \\ &\quad - pei\_atp\_Cu - pei\_atp\_F - pei\_atp\_Hg - pei\_atp\_Ni - pei\_atp\_Pb \\ &\quad - pei\_atp\_Zn - pei\_atp\_NH_3 - N = 0 \quad (201) \end{aligned}$$

pei_atp is the total PEI contribution of ATP impact sub-category in local perspective.

$$\begin{aligned} &pei\_total - pei\_gwp - pei\_ap - pei\_pocp - pei\_htpi - pei\_htpe - pei\_ttpl \\ &\quad - pei\_ttpg - pei\_atp = 0 \quad (202) \end{aligned}$$

pei_total is the total PEI contribution of all impact categories and sub-categories.

4.2.6 Solving the LP model

To generate and solve the LP equation, a software programme was developed in LINDO V9.0 optimization software. LINGO software is a simple tool for utilizing the power of linear and nonlinear optimization to formulate large problems concisely, solve them, and analyze the solution. Optimization helps us to find the answer that yields the best result, attains the highest profit, output, or achieves the lowest cost, waste, or discomfort. Often these problems involve making the most efficient use of our resources including money, time, machinery, staff, inventory, and more (LINDO Systems Inc., 2004). It is compatible with Windows platforms. The various input data for running the programme was fitted into excel spread sheet. LINGO imported the data from these spread sheets and generate LP equation and solve the model. The results from the LP solution was taken to form the solution report. After interpreting the solution report, relevant data tables were generated in Excel. The relevant results will be used for analyzing and interpreting the different causes of SWM systems. A flow chart of the whole process is shown in the following figure 4.2.

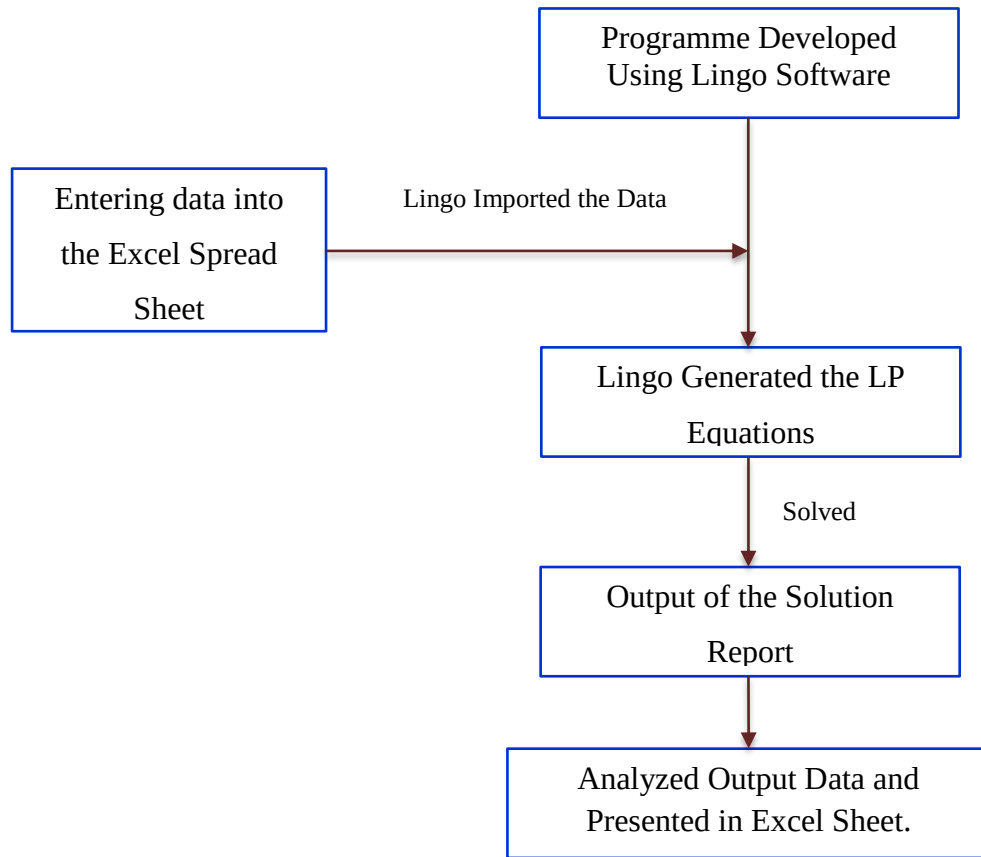


Figure- 4.2: Flowchart detailing steps for running the model in LINGO

Chapter-5

5 EXISTING SOLID WASTE MANAGEMENT (SWM) SYSTEM OF KOLKATA- THE STUDY AREA

5.1 BASE LINE PICTURE OF CITY OF KOLKATA

Kolkata is one of the four metropolitan cities of India and is the capital of the state of West Bengal. The city is in the eastern part of India at 22°30'N latitude and 88°30'E longitude (Kmcgov, 2019). Elevation ranges from 1.5 to 9.0 m above sea level. It has stretch linearly along the banks of the river Hoogly. The river Hooghly is the principal waterway and forms the western boundary of Kolkata, however, the natural drainage of the Kolkata Municipal Corporation (KMC) area is away from the river, to the east and south. The eastern and southern regions contain numerous low-lying areas, marshes, wetlands, and shallow lakes or jheels (KEIP, ADB, 2005). The climate of Kolkata is hot and humid. Average temperature ranges between 10° C and 40° C. Relative Humidity varies between 85 percent in August and 68 per cent in March. On an average (KEIP, ADB, 2005), the city receives 1400-1600 mm rainfall annually (Kmcgov, 2019).

The predominant land use pattern of the city may be termed as mixed i.e. residential and commercial. To be very precise, any part of the city cannot be clearly differentiated from the other as per land use pattern. As the city of Kolkata never came up in a planned way but in much chaotic manner as and where opportunities are available. Household are the single largest generators of municipal solid waste and contribute about 55 percent of the total waste in the city and the rest 45 percent waste are generated by commercial, institutional, medical and others. The city has all around 252 markets, out of which 96 are registered private markets, 23 are K.M.C. own market, out of 9 wholesale market only two are owned by K.M.C. another 124 nos. of market are unregistered roadside market and spread all over the city.

Kolkata is about a 206.08 sq. km area covered under KMC (Kmcgov, 2019), comprised of 16 boroughs and 144 electoral wards. It has a total population of 10.5 millions as per census 2011, including a floating population of approximately 6.0 million. The slums and the urban poor population is about 1.4 million, around 31.35% of total resident population (4.5 million) of Kolkata (Census, 2011). The MSW generation rate is about 500-550 g per

capita per day (gpcd), average, for the resident population, 250 gpcd for the floating population (Chattopadhyay et al., 2009), and the total generation and disposal was about 4,500MT per day (Kmcgov, 2019; SEP, 2021). The Figure 5.1 and Figure 5.2 show the borough and electoral ward divisions of KMC.

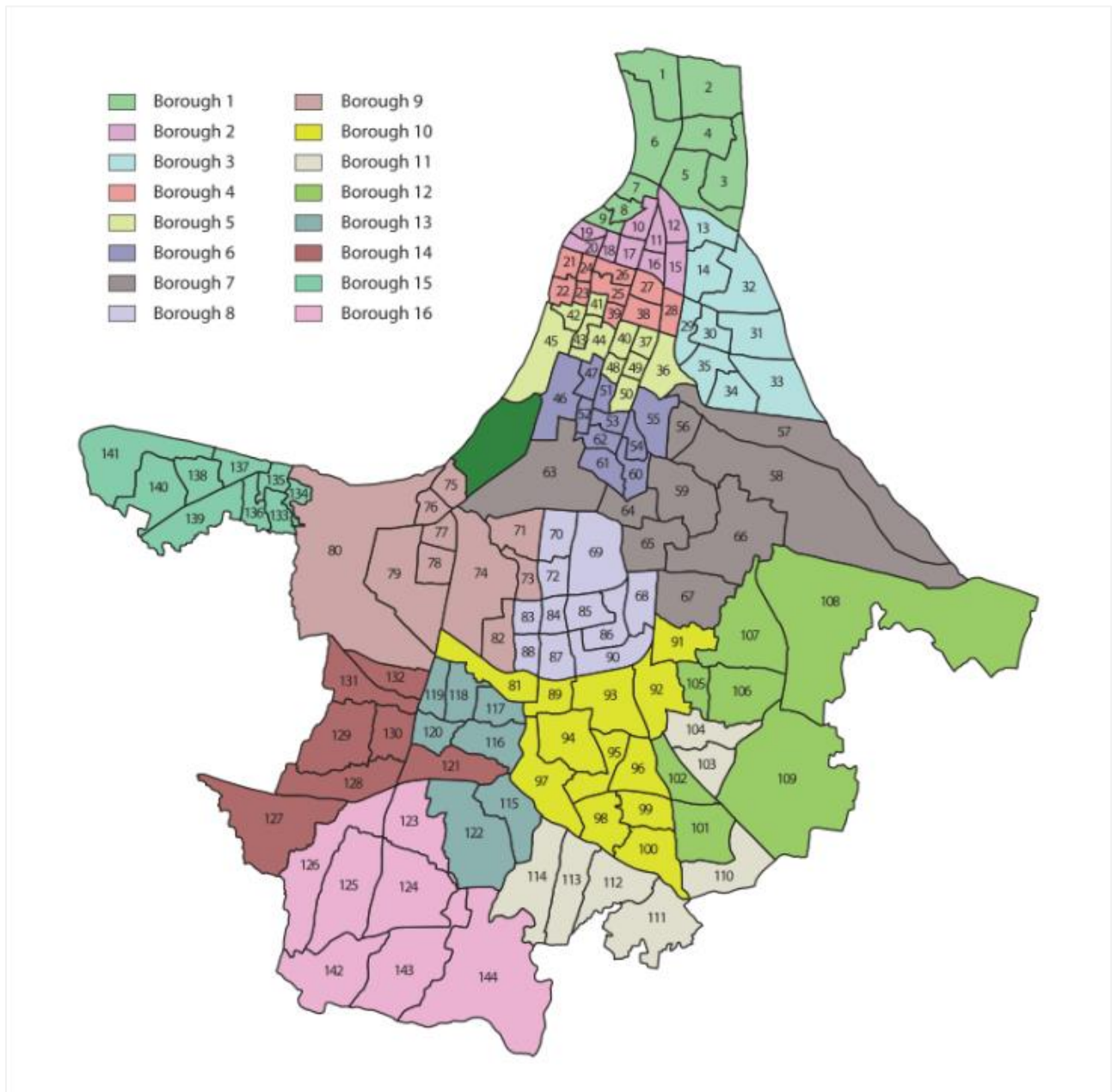


Figure- 5.1: Borough division of KMC area

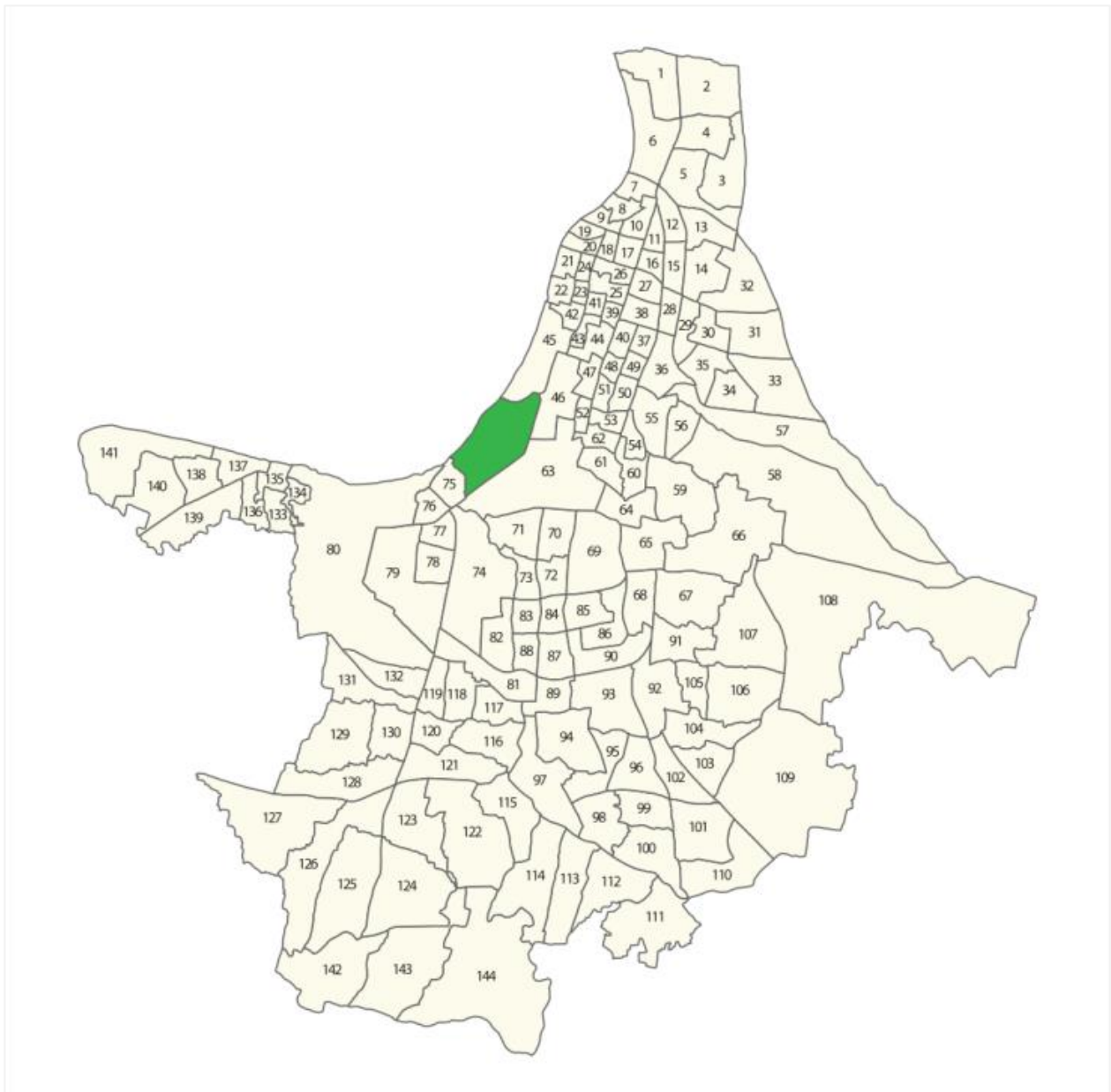


Figure- 5.2: Electoral ward division of KMC area.

5.2 MONITORING MECHANISM OF THE SWM SERVICES

The city of Kolkata is divided into 16 nos. of borough and 144 electoral wards. In each borough Assistant Director (Conservancy) are the head who is assisted by the Conservancy Supervisors and Administrative Staff for running the establishment work in all the wards and each ward has a conservancy setup which is headed by the Conservancy Overseer, assisted by the Sub- overseer, Conservancy Mazdoors, Methors and Domes. The collection, transportation and disposal of the Municipal Solid Waste (MSW) is primarily executed and managed by KMC with total work force of around 15000 employees, 10,000 of whom are principally responsible for street sweeping and door to

door collection. Prior to 2010, conservation services were only available until midday. However, to increase collection efficiency and improve the appearance of the city, about 7000 people working under the West Bengal Urban Employment Scheme are now working in the afternoon and, in some locations, into the evening also (Kmcgov, 2019). The Solid Waste Management Department has been successful in primary collection of 90% of total waste generation by 10:30 a.m. and transported to the landfill site by 2:00 p.m. by engaging on an average 400 nos. of vehicles from KMC area (Kmcgov, 2023). Executive Engineer (Civil), Assistant Engineer (Civil) and Sub- Assistant Engineer (Civil) monitor the disposal site. The whole monitoring system is controlled by one Chief Metropolitan Engineer (SWM). One Deputy Chief Engineer (Civil) are looks after the primary collection and part of the transportation which done by contractors and part of disposal. Another Deputy Chief Engineer (Mechanical) looks after the part of transportation which is done by departmental vehicles, maintenance of all vehicles including ambulance or pool cars etc. bulldozers and Pay loaders used in the disposal site are also maintained by him.

5.3 PHYSICAL AND CHEMICAL CHARACTERISTICS OF CITY GARBAGE

The analysis of garbage is carried out normally to know its physical as well as chemical characteristics. Refuse characteristics depend upon a number of factors such as food habits, cultural traditions, socio-economic factors and climatic conditions. Refuse characteristics vary not only from city to city but even within the same city itself and also seasonally. The desired frequency of collection, safety measures to be taken during transport, and methods of processing and disposal are all influenced by the physical and chemical features. In Kolkata as well as in India stratified random sampling method is very difficult because of the complexity in accurately dividing the population ratio in various socio economic groups. Therefore, quartering method may be suitable in India as well as in Kolkata (NEERI, 1995). Variation of physical composition and chemical characteristics of MSW in Kolkata during 1970, 1995, and 2005 are presented in Tables 5.2 and 5.3. There are significant differences in the waste composition for the two different years which have been attributed to changes in socio- economic conditions in the area during this time period (Chattopadhyay et al., 2009).

The solid waste generation of Kolkata is about 4600 MT/day. The total waste generation consists of 90% of garbage and 10% of inorganic silt or rubbish (Chattopadhyay et al., 2007). Table 5.1, Table 5.2, Table 5.3 and Table 5.4 shows the quantitative waste generation in different boroughs of KMC area (predicted from KMC collection and transportation records), the wide variation of physical composition and chemical parameters of garbage of MSW at Kolkata during 1970, 1995 and 2005 (NEERI, 1995, 2005) and average physical composition of MSW in KMC area respectively.

Table- 5.1: Quantitative garbage and silt/rubbish generation
in different boroughs of KMC area

Borough	Garbage (MT/day)	Silt (MT/day)
1	281.318	30.256
2	276.087	18.102
3	282.697	30.227
4	246.304	19.134
5	297.156	25.799
6	369.263	52.887
7	380.772	94.165
8	252.868	60.311
9	419.369	38.984
10	531.177	46.581
11	150.491	2.709
12	131.701	3.382
13	222.834	5.336
14	101.902	7.052
15	34.971	0.086
16	121.8	31.5

Table 5.2 shows an increasing trend for the biodegradable fraction, and also shows an increase in the day-to-day use of plastic and paper. A decrease in the coal fraction is reflected due to an increase in the utilization of domestic gas. The amount of paper and plastics, including materials such as food containers and wrapping materials, is noted to be much lower than in developed countries.

Table 5.2: Variations in MSW composition at Kolkata during 1970, 1995 & 2005
(Chattopadhyay et al., 2009)

Sl. No.	Parameters	1970	1995	2005
1	Biodegradables	40.36	44.29	50.56
2	Green coconut shells	4.95	8.51	4.50
3	Paper	3.17	4.64	6.07
4	Plastics	0.64	3.22	4.88
5	Metals	0.66	0.43	0.19
6	Glass & Crockery	0.38	1.72	0.34
7	Coal	6.08	3.10	-
8	Inert	40.76	26.82	29.60
9	Others*	3.00	7.27	3.86

All values are in percent by wet weight

**Bio-resistant and synthetic material*

Table- 5.3: Variation in chemical characteristics of MSW at Kolkata
(Chattopadhyay et al., 2009)

Sl. No.	Parameters	1970	1995	2005
1	Moisture	42.84	61.57	46.00
2	pH	7.31	6.33	0.3-8.07
3	Loss on ignition	35.24	46.78	38.53
4	Carbon	19.58	25.98	22.35
5	Nitrogen as N	0.55	0.88	0.76
6	Phosphorous as P ₂ O ₅	0.57	0.58	0.77
7	Potassium as K ₂ O	0.40	0.93	0.52
8	C/N ratio	35.60	29.53	31.81
9	LCV kcal kg ⁻¹	549.32	648.91	1201

All value is in percent by dry weight basis except pH, C/N ratio and calorific value.

The chemical characteristics listed in Table 5.3 show an increasing trend in moisture content. This is most likely due to the presence of a higher proportion of fresh and

unprocessed vegetable waste. Although the calorific value of waste has risen substantially in the year 2005, it is still not in the range suitable for incineration. Table 5.4 shows the average physical composition of MSW of Kolkata (Chattopadhyay et al., 2009; SEP, 2019).

Table- 5.4: Average physical composition of municipal solid waste

Total Compostables	50.56		
Recyclables	Paper	6.07	11.48
	Plastic	4.88	
	Glass	0.34	
	Metal	0.19	
Others including inert	Inert	29.6	37.96
	Rubber & Leather	0.68	
	Rags	1.87	
	Wooden matter	1.15	
	Coconut	4.5	
	Bones	0.16	
Total	100		

(All values are expressed in percentage on wet weight basis)

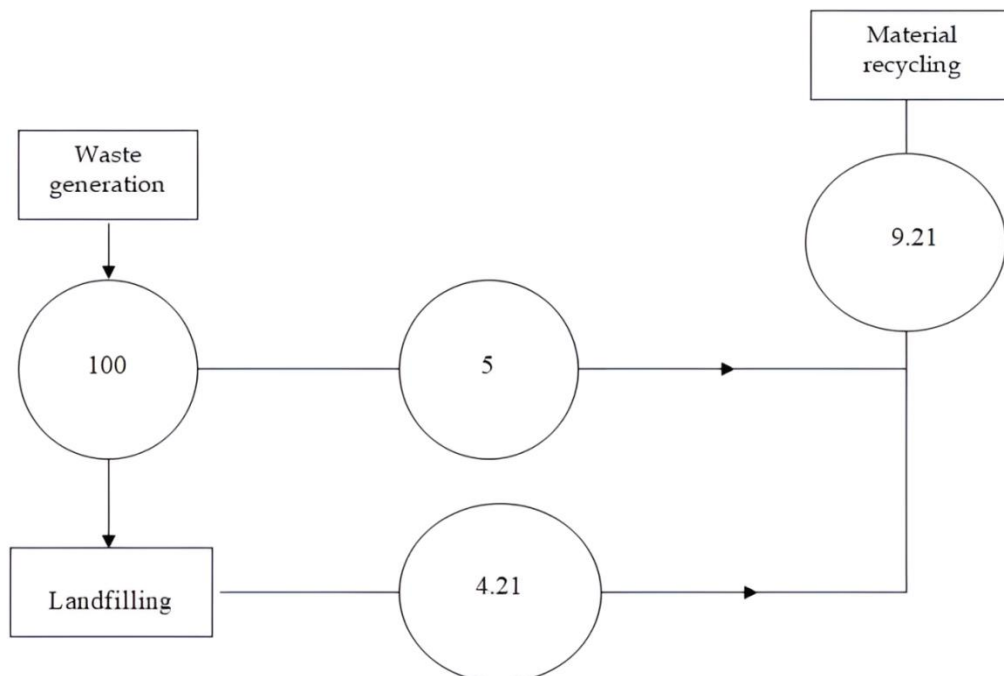


Figure-5.3: Material flow diagram for existing MSW management system of Kolkata

From the process of consumption of product the municipal solid waste is generated. The municipal solid waste in Kolkata is mixed in nature i.e. biodegradable and recyclable. Most of the wastes are going to the landfill site and some portions are recycled from the source or vat points as well as from landfill site. Figure 5.3 shows that if we consider that 100 MT of municipal solid waste are generated, out of these 5% are segregated at source or vat points and the 4.21% are segregated at landfill site. The total recyclable portions of 9.21 ton are coming to the material recycling process unit and the rest 90.79 ton of solid waste are gone to the landfill site. From the waste characteristics of Kolkata, the recyclable portions and the residue from recycling are computed below in Table- 5.5. The average compositions of municipal solid waste of Kolkata are shown in Table- 5.4.

Table- 5.5: Recyclable materials

Materials/ components	Original composition	Recyclable Portion at Source and at Landfill	Residue from recycling portion for landfill
Paper	6.07	5.00 (82%)	1.07
Plastic	4.88	3.38 (70%)	1.50
Glass	0.34	0.27 (80%)	0.07
Metal	0.19	0.15 (80%)	0.04
Rubber & leather	0.68	0.41 (60%)	0.27
Total	12.16	9.21	2.95

Mixed municipal solid waste components (decomposable and non- decomposable) excluding recyclable materials for landfilling are shown in Table- 5.6.

Table- 5.6: Mixed MSW components for landfill

Mixed MSW Components (excluding recyclable materials)			
Decomposable Materials		Non- decomposable Materials	
Components	Portions (% of w/w)	Components	Portions (% of w/w)
Food waste	50.56	Plastic	1.50
Paper	1.07	Glass	0.07
Rags	1.87	Metal	0.04
Wooden matter	1.15	Inert	29.60
Coconut	4.50	Rubber & leather	0.27
-	-	Bones	0.16
Total	59.15		31.64
	90.79		

5.4 COLLECTION, STORAGE & TRANSPORTATION

5.4.1 Collection and Storage

The waste of Kolkata city is putrescible in nature, as the average biodegradable portion is higher. It is necessary to collect regularly and dispose of this type of generated waste. KMC is responsible for collection, transportation, disposal and treatment of the waste generated in the city of Kolkata. KMC now collects 4500 MT of solid waste per day on an average (Kmcgov, 2019; SEP, 2021) out of 4590 MT of generated solid waste with 98% collection efficiency (SEP, 2021). The primary drawback of the collection system is the careless mixing of various municipal solid waste components, which reduces the possibility of an efficient recovery of recyclable elements. Therefore, in this scenario, collection, transportation, and disposal of municipal solid waste constitute a complex set of operations. However, the waste generation in Kolkata is considered to be 4600 MT per day as on 2022 (From projected KMC waste generation data).

The field staff commences their work at 5.30 am and continues till 12.00 noon with a break of half an hour in between. For solid waste management service each ward is divided into 7-10 blocks and each block is provided with 8-10 sweepers. After the first mastering, conservancy workers carry out sweeping and cleaning of roads and pavements

and thereafter remove the collected garbage to the assigned vat or containers. This task is completed by about 7.30 am.

From 7.30 am onwards the conservancy workers move on to their assigned areas with their hand carts giving whistle signal, calling the residents to bring their garbage. This process continues till 10.30 am. Garbage thus collected is taken to the nearest vat or container from where vehicles pick up the garbage and transport the same to the disposal ground. At present door to door collection of waste implement in all 144 wards effectively.

The main difficulty is in the commercial areas where it is difficult to enforce discipline. Large hotels and restaurants have their own vats from which wastes are collected and transported regularly by KMC or private vehicles on a fee-for-service basis. Small establishments dispose-off their wastes on the road or in a nearby vat cleared by the KMC or by their own sweepers. In the case of markets, wastes are regularly collected from the vats earmarked for the market. Wastes from roadside or unauthorized markets are often dumped on the roads and are collected by KMC street sweepers (Chattopadhyay et al., 2009).

There were 650 no. of total collection points in the city. The containers are of 4.5 m³ and 7 m³ in size. KMC almost removed the open garbage collection points with the help of 131 numbers of modern scientific waste compactor stations and movable compactors. At present 245 numbers portable compactor containers, 80 number Hook loaders, 93 number of Movable Compactors of 14 cubic meter capacity and 2 number of 8 cubic meter capacity are used for odorless and spillage-free transportation of wastes. Additional 50 numbers of 8 cubic meter capacity and 20 numbers of 14 cubic meter capacity movable compactor will be procured shortly (Kmcgov, 2023). The trash is scattered inside and outside the bins, and some of them are overflowing as a result of the containers' inadequate capacity. In the KMC region, cleaning the roadway and collection/vat stations is compulsory.

5.4.2 Waste Segregation System

According to a study of KEIP, 2003, an average of 25.3% of domestic waste and 51% of commercial waste are recyclable due to the lack of a sorting and source segregation

system in the KMC area. The collection efficiency may rise if appropriate sorting and segregation are enabled at the source. Although rag-pickers recycle 10% of waste in informal sector, they do so in an unorganized, unclean manner without any assistance from the government.

At present the source segregation system is not fully adopted in Kolkata. Hence there is very less scope of effective recovery of recyclable materials. Source segregation increase the amount of recyclable recovered, which reduces waste generation need for landfill space. To create better environmental condition and efficient waste management system in Kolkata, KMC adopted the method of source segregation of bio-degradable and non-biodegradable waste in 7 wards like 33, 47, 64, 103, 110, 115 130 in 2019-20 and source segregation is now ongoing in full swing in another 20 wards and gradually expanding in remaining 117 wards depending upon the availability of fund (Kmcgov, 2023).

5.4.3 Waste Transportation

Presently mixed waste (Bio-degradable and recyclable) are collected from residential, commercial and market area. In waste transportation system of KMC area, it uses its own departmental vehicles and private hired vehicles. 15% of garbage and total amount of silt/rubbish are carried by private hired vehicles whereas remaining 85% of waste (garbage) is transported by its own departmental vehicles. The hauling capacity of this hired vehicles are 4 MT for manually loaded and 7 MT for Payloader loaded garbage transportation whereas 6 MT for manually loaded and 9 MT for Payloader loaded silt/rubbish transportation.

However, the departmental vehicles were of these two types which are:

- Manually loaded Tipper Trucks (8 m^3): The hauling capacity of 3 MT of generated waste to the Dhapa landfill site from different open vats/open dumping sections per single trip.
- Payloader loaded Tipper Trucks (11 m^3): With a hauling capacity of around 7 MT of MSW in one single trip to Dhapa.

However, over the past few years, KMC has started to modernize departmental vehicles by adding compactors, which has resulted in a notable difference. Currently, KMC uses

four distinct types of departmental vehicle, which are represented in a table 5.7 below. For hired vehicles, hauling capacity of 7 MT for garbage transportation and 9 MT for silt transportation has been taken into consideration, assuming they are all Pay-loader loaded.

Table- 5.7: Various types of vehicle used by KMC for waste transportation

Vehicle Type	Capacity (MT)	Characteristics
Payloader loaded Tipper Trucks (11 m ³)	7	With a hauling capacity of around 7MT of MSW in one single trip to Dhapa
Stationary compactor cum hook loader combination (10.5 m ³)	9	245 numbers of stationery compactors to be placed at 131 compactor station. Each compactor reduces 30% waste volume by applying 140 bar pressure. KMC is also acquiring 80 hook loaders to haul these stationary compactors to Dhapa. Each hook loader can haul one stationary compactor at a time.
Movable compactor (14 m ³)	10	93 numbers of these vehicle takes waste from six 4.5 m ³ containers (or from handcarts), compact it at 140 bar pressure and hauls waste to landfill site.
Movable compactor (8 m ³)	7	2 numbers of 8 m ³ capacity movable compactors. These smaller sized compactors can maneuvers narrow streets and lanes.

5.4.4 Deficiencies in the Existing Collection, Storage and Transportation System

- ✓ No waste segregation/sorting are practiced fully.
- ✓ There is not any engineered landfill available for safe disposal.
- ✓ Currently, absence of any incinerator/RDF based plant in Kolkata.
- ✓ Due to irregular activity of the present 700 TPD compost plant which is running on PPP (public-private partnership) model at Dhapa disposal ground that processes only 150 TPD on irregular basis.
- ✓ The average density of waste in KMC area is as high as 600 kg/m³ which make compaction largely unnecessary.
- ✓ Due to high biodegradable fraction (50.56%), high C/N ratio (31.81%) and high moisture content (46%) in waste, composting may be a viable cost effective option for KMC area.
- ✓ In a feasibility study of a Waste to Energy project with MSW in Kolkata, mass burn technology has been considered, instead of more advanced and costly systems such as gasification, pyrolysis and plasma-arc. The possibility of RDF fuel production was abandoned due to low market policy.
- ✓ However, to make mass burn incineration or any other processing project successful, sorting/segregation of waste is mandatory.
- ✓ However no. of collection points remains in bad condition due to lack of public awareness, citizen pouring the waste randomly at the collection point after clearance.
- ✓ The operational efficiency of KMC owned is around 50%.
- ✓ Recyclable materials cannot be segregated and reused after compaction, as compactor receives mixed waste.

5.5 TREATMENT AND DISPOSAL OF MSW

5.5.1 Treatment (Composting)

A mechanized composting plant of capacity 700 TPD was installed by KMC initially. Presently the plant is operated with a capacity of 500 TPD. The existing composting plant is located at Dhapa landfill and Windrow composting method is followed for the biological processing of the waste. The 700 TPD plant started functioning from the year 2000 though it is not fully functional since 2003 due to mixed waste with high inert

content and low marketing of the compost. Presently, the plant processes only 150 TPD of garbage during non-monsoon period.

5.5.2 Disposal of Waste

More than 98% of the total waste generated in the KMC area is disposed at Dhapa landfill situated in the eastern fringe of the city. At Dhapa disposal site all the garbage-loaded vehicles are weighed in the four existing weighbridges with capacity of 30 MT to measure quantity of waste brought at the disposal site. For improvement of monitoring system and increasing the efficiency, CCTV system has been installed. For smooth waste disposal system numbers of unloading platforms were also constructed. In the year 2013-14, KMC has already received 2 (two) no. of bulldozers from KEIP under ADB project and the machines are now in operation at Dhapa disposal site.

The total area of the Dhapa landfill site is 21.47 ha where 4400-4600 MT of waste per day is disposed. Two nos. of bulldozer are deployed at the disposal ground for spreading and compaction of the garbage. Another dumping ground is operated at Garden Reach with a landfill area of 3.52 ha which receives around 100-150 MT per day. The landfilling procedure follows the open dumping. The Dhapa landfill lacks a liner system, a leachate management facility, or a gas management system. Bulldozers or dumpers just disperse the waste without compaction or subsequent levelling. There is currently no transfer station as the average distance of Dhapa is 10 km from collection point. Leachate percolating into the environment and simultaneously contaminating groundwater and land regions is the main drawback of open dumping. The standard of leachate sample showed much higher concentrations of solids, BOD, COD and Chloride than the standards allowed for discharge to the inland surface water (Das and Bhattacharya, 2013; Mandal, 2007). According to KEIP 2005, wetlands in Dhapa showed very high BOD and COD value. The quality of ground water enclosing Dhapa landfill sites had been monitored by Kolkata Environmental Improvement Project (KEIP) 2005 which showed the result of a presence of higher limits of lead (Pb) and iron (Fe) whereas presence of arsenic (As) was found as slightly above than permissible limit. Phenolic compound was also persistent in Dhapa areas. So, all these results and their cumulative impact shows that the existing landfill site Dhapa has been exhausted and there need a better engineered

landfill site (ELF) with all the facilities to meet the socio- economic standards with a sustainable environment.

KMC needs to establish an Integrated Solid Waste Management System (ISWM) and adhere to the ISWM hierarchy of waste management in order to successfully implement the Municipal Solid Waste Management Rules, 2016. In the very near future, it is anticipated that SWM will be controlled in a more contemporary and scientific manner. The entire SWM system will need to be reorganized and overhauled to do this. Implementing the Integrated Solid Waste Management (ISWM) principle is a necessary component of effective municipal solid waste management. ISWM is the implementation of feasible techniques, technologies and management systems which cover all types of solid wastes from all sources to achieve these two objectives of (a) waste reduction and (b) efficient management system after waste reduction.

An efficient ISWM system takes into account how to prevent, recycle, and manage solid waste in a way that primarily protects environmental and human health. A strong integrated solid waste management system depends on the interaction of strategic factors like social awareness, participation, technology, governance, and financial resources with functional components like generation, segregation, storage, collection, processing, and disposal. This can be accomplished by applying the ISWM optimisation model to enhance the current MSW management system in Indian cities, and specifically in the KMC area. In order to improve the SWM system in Indian cities in general and the KMC area in particular, this thesis study offers an ISWM optimisation model considering the potential environmental impact.

Chapter-6**6 VALIDATION AND ANALYSIS OF A SOLID WASTE MANAGEMENT OPTIMISATION MODEL**

6.1 IMPLEMENTING THE MODEL FOR EXISTING SWM SYSTEM

To compare the potential environmental impact in different sectors and cost minimization for the existing SWM system with respect to the proposed Integrated SWM system, it is needed to apply the developed model to the existing case. The model developed in subchapter 4.2.3 has been implemented for the present condition of SWM system of Kolkata city. Based on the present scenario, the cost minimization objective function has changed due to certain irregularities of existing system. Due to the absence of central sorter, incineration plant and composting plant, there will not be any cost of sorting, cost of incineration, revenue generated from recyclable materials, selling compost and electricity from incineration. Thus, it has been implemented to the modified objective function which is depicted as follow:

Minimization of objective function (Modified equation based on equation no. 1 of chapter- 4, sub-chapter- 4.2.3):

Minimization of MSWM cost = Transportation cost + Incentive cost + Landfilling cost

$$\text{Min MSWM cost} = \text{CTTRANSP} + \text{CTINCENT} + \text{CTLF} \quad (203)$$

All the cost optimized equations and pollution generation equations for transport sector and gas and leachate pollutants generation from landfill is remain unchanged and applied for the present municipal SWM case study. Existing municipal SWM system is basically open dumping of waste without any liner system and gas collection facility, operated at Dhapa disposal site. Around 5% recyclables of the garbage is taken out by the informal rag pickers from the household, container and vat point level. If 5 to 6% of irregular garbage transformation to compost is ignored, rest 95% of the garbage is reaching to the dumping ground, Dhapa. Informal rag pickers further separated out around 4.21% of the recyclable material in Dhapa. Thus, 9.21% of the entire amount of waste is recovered as recyclable, whereas the remaining 90.79% is dumped in landfills together with silt and

other waste. In absence of thermal processing, its capacity is considered as “zero” for existing system. Same is considered for biological processing because of irregular processing and earning of meager amount of royalty by KMC.

The distance from various KMC borough central points to the Dhapa landfill site and their zones is presented below in Table 6.1. It is situated in ward 58 of borough 7 on the eastern edge of the city.

Table- 6.1: Average distance from borough centre to Dhapa landfill site and their zones

Zone- 1	Distance (Km)	Zone- 2	Distance (Km)
Borough- 3	7.03	Borough- 1	10.92
Borough- 4	7.67	Borough- 2	8.74
Borough- 5	6.45	Borough- 9	9.04
Borough- 6	5.94	Borough- 11	10.24
Borough- 7	1.65	Borough- 13	11.52
Borough- 8	5.195	Borough- 14	14.0
Borough- 10	8.07	Borough- 15	15.98
Borough- 12	4.03	Borough- 16	16.1

6.1.1 Operational and Maintenance Cost of Landfilling (Open Dumping)

Other than recyclables and compost, mixed MSW and compost rejects are dumped in a landfill. In the absence of a liner system, leachate, or gas collection systems, landfilling is essentially open dumping. The operational and maintenance costs of open dumping system are determined by taking into account the following factors: (i) labour and establishment costs (general, skilled, administration/management, miscellaneous, contingency); (ii) capital and maintenance costs (equipment for bulldozers, mobile equipment, spare parts, fuel, trip tokens, ribbons, etc.); and (iii) utility costs (power and utilities, miscellaneous, contingency). Cost of landfilling (open dumping) per ton of waste, including cost of land has been considered to be 100 Rs/MT (Chattopadhyay, 2018).

6.1.2 Borough-Wise Garbage and Silt/Rubbish Generation

The current average daily garbage and silt/rubbish generation from 16 boroughs in KMC areas is stipulated in Table 6.2. The total waste generation is considered around 4600 MT/day which has been considered from KMC datasets for the purpose of present study. KMC records 95% of total waste generated while 5% is recycled at the house-hold level.

Table- 6.2: Garbage and silt generation from different boroughs

Borough	Garbage (MT/day)	Silt (MT/day)	Total Waste (MT/day)
1	281.318	30.256	311.574
2	276.087	18.102	294.189
3	282.697	30.227	312.924
4	246.304	19.134	265.438
5	297.156	25.799	322.955
6	369.263	52.887	422.150
7	380.772	94.165	474.937
8	252.868	60.311	313.179
9	419.369	38.984	458.353
10	531.177	46.581	577.758
11	150.491	2.709	153.200
12	131.701	3.382	135.083
13	222.834	5.336	228.170
14	101.902	7.052	108.954
15	34.971	0.086	35.057
16	121.800	31.500	153.300

6.1.3 Types of Vehicles Currently Used by KMC for Waste Transportation

The details of various types of departmental vehicles associated with their capacity and characteristics, used by KMC to transport waste from different borough center to Dhapa disposal site are shown in table 5.7, in previous chapter 5.

Presently, waste transportation system uses private-owned hired vehicles to transport 15% of the daily generated garbage and entire amount of the silt/rubbish. The Hauling capacity of these privately owned vehicles is 7 MT for garbage and 9 MT for silt, assuming waste is being loaded onto these vehicles using pay loaders. Each of these visits open vat location(s) and the vehicles proceed to the dumping ground after exceeding the haulage capacity. The remaining 85% of MSW (garbage portion only) is transported by four categories of KMC owned vehicles. Currently, KMC has

modernized its waste transportation system with the purchase of compactors, and the system has undergone significant improvements recently.

6.1.4 Maximum and Minimum Fraction Limit of Garbage Carried by Different Vehicles

Borough wise minimum and maximum garbage carrying quantity range (in fraction) for departmental and hired vehicles are shown in table 6.3.

Table- 6.3: Borough wise minimum and maximum garbage carrying quantity range (in fraction) for departmental and hired vehicles

Br No	DV1		DV2		DV3		DV4		HV	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	0.031	0.133	0.476	0.728	0.164	0.245	0.000	0.000	0.075	0.15
2	0.001	0.073	0.501	0.745	0.173	0.252	0.000	0.000	0.075	0.15
3	0.002	0.105	0.501	0.774	0.172	0.262	0.000	0.000	0.055	0.13
4	0.022	0.124	0.479	0.724	0.165	0.244	0.000	0.000	0.075	0.15
5	0.036	0.136	0.498	0.677	0.172	0.228	0.000	0.000	0.075	0.15
6	0.000	0.100	0.535	0.714	0.185	0.241	0.000	0.000	0.055	0.13
7	0.000	0.072	0.516	0.760	0.178	0.257	0.000	0.000	0.065	0.14
8	0.001	0.103	0.519	0.763	0.179	0.258	0.000	0.000	0.045	0.12
9	0.001	0.093	0.501	0.745	0.173	0.252	0.000	0.000	0.075	0.15
10	0.001	0.003	0.536	0.780	0.186	0.264	0.000	0.000	0.075	0.15
11	0.003	0.095	0.205	0.410	0.065	0.131	0.083	0.185	0.365	0.44
12	0.002	0.104	0.521	0.865	0.161	0.240	0.000	0.000	0.000	0.07
13	0.022	0.124	0.240	0.482	0.078	0.157	0.032	0.134	0.215	0.29
14	0.021	0.123	0.353	0.697	0.101	0.180	0.000	0.000	0.215	0.29
15	0.000	0.010	0.025	0.050	0.000	0.000	0.000	0.000	0.915	0.95
16	0.021	0.123	0.312	0.656	0.089	0.168	0.000	0.000	0.215	0.29

6.1.5 Maximum and Minimum Trip Limits of Departmental Vehicles

Primarily based on the distance between borough to disposal site Dhapa, concentration of waste generation points and accessibility of vehicles to the collection points, the KMC area are divided into two zones, zone 1 and zone 2. Borough 3 to borough 8, borough 10 and borough 12 fall under zone1 and Borough 1, borough 2, borough 9, borough 11 and borough 14 to borough 16 fall under zone 2. Borough wise distance and their zones are mentioned in Table 6.1.

For departmental vehicles maximum and minimum trip limits are considered. Maximum and minimum trip limits of departmental vehicles are derived based on past few years of KMC data on availability of vehicles in different garages, use of vehicles in different boroughs, the number of trips by different vehicles, and amount of waste transportation. Each running departmental vehicles has to make minimum trips. Incentives are given to the drivers and helpers for carrying wastes more than the minimum trip but up to the maximum trip limit. Maximum and minimum trip limits and incentive of departmental vehicles are shown in table 6.5.

Table- 6.4: Maximum and minimum trip limits of departmental vehicles with their incentives

Type of departmental vehicles	Zone 1 (near to transfer station)		Zone 2 (far from transfer station)		Capacity (MT)	Rate of Incentive per extra ton (Rs / MT)
	Max trips	Min trips	Max trips	Min trips		
DV1 (1 driver and 1 helper)	4	2	2	2	7	17
DV2 (1 driver and 1 helper)	4	1	2	1	9	25
DV3 (1 driver and 1 helper)	4	1	2	1	10	19
DV4 (1 driver and 1 helper)	4	1	2	1	7	19

6.1.6 Transportation Cost of KMC Vehicles

Waste transportation cost is the sum total of transportation cost for departmental and hired vehicles carrying waste from the storage points to the treatment and disposal sites. Transportation cost of departmental vehicles include fuel cost, fixed cost of running vehicle and fixed cost of idle vehicle maintained by KMC. Fuel consumption for four different types of departmental vehicles is considered on the basis of waste loaded run condition and empty run condition. Fixed running cost of departmental vehicles is calculated on the basis of depreciation, rate of interest and all wages for different types of running vehicles. Whereas, for idle vehicles i.e. vehicles under maintenance, the fixed costs are calculated on the basis of depreciation, interest rate and maintenance wages only. (Paul et al., 2017; Chattopadhyay, 2018).

6.1.6.1 Waste transportation cost for departmental and hired vehicles

Fixed cost for running and idle departmental vehicles

Fixed cost of running departmental vehicles DV1, DV2, DV3 and DV4 are calculated on the basis of depreciation (assuming scrap value 10% of capital cost, life of vehicle as 10 years), interest (10% on reducing loan), wages of driver and helper [Basic, Dearness Allowances (D.A.), Medical Allowances (M.A), House Rent Allowances (H.R.A) including 30% overtime allowances), wages of garage staff including administration and managerial, annual operational and maintenance costs (10% of capital cost). For the calculation of fixed cost of idle departmental vehicles, wages of driver and helper are not considered as optimized numbers of drivers and helpers are available which is almost used regularly by the running vehicles. Detailed analysis of fixed and idle costs is shown in *annexure- 6.1*. Table 6.5 shows a summary of daily running and idle vehicle counts as well as daily fixed running and fixed idle costs for various departmental vehicles.

Table- 6.5: Fixed running cost and fixed idle cost per day of different departmental vehicles

Type of vehicles	Total no. of vehicles	Vehicles in operation	Idle vehicles	Fixed cost for each running vehicles/day (Rs.)	Fixed cost for each idle vehicles/day (Rs.)
DV1	28	20 (70%)	8	8907.01	5945.15
DV2	300	240 (80%)	60	11532.98	7478.42
DV3	95	80 (84%)	15	6962.89	4847.26
DV4	3	2 (66%)	1	6353.49	4237.97

Fuel cost for departmental vehicles

The distance covered by each loaded and unloaded trip is considered equal for each borough as the distances are based on the borough centre to disposal site Dhapa. Table 6.6 displays the fuel consumption and fuel expenses for loaded and unloaded conditions (in Rs./km) based on the diesel price of Rs. 92.76/L (as on July, 22) and the typical load carrying capacity for departmental vehicles. Table 6.7 shows various fuel costs for carrying waste from the borough centres to the Dhapa disposal facility. In *annexure- 6.2*,

a sample computation is presented. Fuel cost includes fuel required for operation of compactors.

Table- 6.6: Average load capacity, fuel consumption and fuel charge in loaded and unloaded condition for departmental vehicles

Departmental Vehicle Type	Average Load Capacity (MT)	Fuel consumption in loaded condition (Km/L)	Fuel consumption in unloaded condition (Km/L)	Fuel Charge (Rs./Km)	
				Loaded Condition	Unloaded condition
DV1	7	1.67	2.33	55.545	39.811
DV2	9	1.43	1.67	64.867	55.545
DV3	10	0.909	1.11	102.046	83.568
DV4	7	1.25	1.67	74.208	55.545

Table- 6.7: Fuel cost for per ton waste transfer by departmental vehicles

Fuel cost for transporting garbage from borough to Dhapa by DVvehicle (Rs/MT)				
Borough	DV1	DV2	DV3	DV4
Borough 1	148.755	146.100	202.690	202.415
Borough 2	119.059	116.933	162.226	162.006
Borough 3	95.765	94.055	130.486	130.309
Borough 4	104.483	102.618	142.366	142.172
Borough 5	87.864	86.295	119.721	119.558
Borough 6	80.916	79.472	110.255	110.105
Borough 7	22.477	22.076	30.626	30.585
Borough 8	70.768	69.505	96.426	96.295
Borough 9	123.146	120.947	167.795	167.567
Borough 10	109.932	107.969	149.790	149.587
Borough 11	139.492	137.002	190.069	189.810
Borough 12	54.898	53.918	74.802	74.701
Borough 13	156.929	154.127	213.827	213.536
Borough 14	190.712	187.308	259.859	259.506
Borough 15	217.684	213.798	296.611	296.207
Borough 16	219.319	215.404	298.838	298.432

Waste transportation cost for hired vehicles

Hired vehicles carry garbage and silt or rubbish separately so, transportation cost (Rs/MT) for hired vehicles are considered for silt or rubbish and garbage separately for different zones. Carrying capacities of garbage and silt or rubbish for hired vehicle are considered as 7 MT/trip and 9 MT/trip respectively. Zone wise rate for transporting garbage and silt by hired vehicles from borough to Dhapa disposal site is taken from KMC dataset as shown Table 6.8 and the fuel costs for both garbage and silt carrying by hired vehicles are shown in Table 6.9.

Table- 6.8: Zone wise rate for transporting garbage and silt by hired vehicles

Zone Division	Rate of Garbage Transport (Rs./MT)	Rate of Silt/Rubbish Transport (Rs./MT)	Distance from Borough Centre to Zone Border
1	418	399	<8.5 Km
2	504	486	≥8.5 Km

Table- 6.9: Fuel cost for transporting garbage and silt/ rubbish by hired Vehicles

Borough No.	Transportation cost of garbage by hired vehicles	Transportation cost of garbage by hired vehicles
Borough- 1	504	486
Borough- 2	504	486
Borough- 3	418	399
Borough- 4	418	399
Borough- 5	418	399
Borough- 6	418	399
Borough- 7	418	399
Borough- 8	418	399
Borough- 9	504	486
Borough- 10	418	399
Borough- 11	504	486
Borough- 12	418	399
Borough- 13	504	486
Borough- 14	504	486
Borough- 15	504	486
Borough- 16	504	486

6.1.7 Air Pollution Generation from Transport Sector

The importance of pollutants generation from MSW transport sector cannot be ignored because it is a part of the Kolkata as well as global air pollution problem. The city produces an average of 4600 MT of waste each day, and collected and subsequently carried to the landfills outside the city and adds significantly to air pollution there. The main long-term threat to air quality of Kolkata, comes from CO, particulate matter (PM), NO_x, and hydrocarbon emissions from motor vehicles, all of which are raising concerns. So in order to eradicate the total air pollution, we have to minimize the pollution generation from MSW transportation sector.

Table 6.10 shows the average weight carrying capacity per trip and fuel (diesel) consumption of departmental and private hired vehicles which has been fed into the calculation of weighted average emission factors for different gaseous pollutants.

Table- 6.10: Fuel consumption of departmental and hired vehicles

Vehicle Type	Avg. load Capacity (MT)	Fuel consumption (Loaded) Km/L	Fuel consumption (Unloaded) Km/L	Avg. fuel consumption (Km/L)
DV1	7	1.67	2.33	2
DV2	9	1.43	1.67	1.55
DV3	10	0.909	1.11	1
DV4	7	1.25	1.67	1.46
HV_G	7	3.3	4.2	3.75
HV_S	9	3.3	4.2	3.75
LPT Truck	20	7.0	8.3	7.65

6.1.7.1 Emission factor of the gaseous pollutants

For the present case study, different gaseous pollutants considered are CO, CO₂, NO_x, SO₂, Hydrocarbons (HC), Particulate Matter (PM), Benzene and Butadiene contributed by transport sector. Table 6.11 shows the weighted average of the emission factors of the different pollutants.

Table- 6.11: Vehicle wise weighted average of emission factors of the pollutants

Vehicle Type	Capacity (MT)	CO	HC	NO _x	PM	BENZ	BUTDN
DV1	7	4.250	1.162	7.557	0.684	0.0058	0.0011
DV2	9	4.4039	1.216	7.845	0.773	0.0062	0.0011
DV3	10	4.592	1.2825	8.197	0.881	0.0067	0.0012
DV4	7	4.435	1.227	7.9026	0.79	0.0063	0.0011
HV_G	7	3.651	0.951	6.437	0.34	0.0042	0.00065
HV_S	9	3.651	0.951	6.437	0.34	0.0042	0.00065
LPT Truck	20	2.250	0.310	1.970	0.02	0.0019	0.00015

The weighted average emission factors (g/km) for these specific pollutants are taken into consideration with the use of prior case studies, year wise distribution of no. of vehicles and their respective emission factors (CPCB, 2000a) of the pollutants and method of extrapolation. The distance from various boroughs to the disposal ground has been taken into account when calculating the pollution emission rate because there is only one disposal ground, Dhapa that is being taken into consideration. Density of the fuel is considered 820 kg/m³. Percentage of carbon and sulphur assumed by weight are 87% and 0.035% respectively. Emission Factors of NO_x for above type of vehicles are more than CO and others because of diesel engine. Apart from Benzene and Butadiene, PM emission is less. Reduction of PM emission is basically not in nano particulate range and so, number of PM emitted does not reduce effectively. The calculated borough-wise rate of pollutant emission by departmental and hired vehicles per ton of waste per trip (g/t/trip) which has been fed as input data for running the LP model in LINGO is shown in the following Table 6.12, Table 6.13, Table 6.14, Table 6.15, Table 6.16 and table 6.17. The sample calculation for determining the rate of pollutant emission is shown in *annexure- 6.3*.

Table- 6.12: Pollutant emission rate by DV1 per ton of garbage per trip

Pollutant emission by departmental vehicle DV1 per ton of garbage per trip to DhapaLandfill (g/t/trip)								
Borough No.	SO₂	CO	CO₂	HC	NO_x	PM	BENZ	BUTDN
1	0.895	13.260	4059.810	3.625	23.580	2.134	0.018	0.003
2	0.717	10.613	3249.330	2.901	18.870	1.710	0.014	0.003
3	0.576	8.536	2613.590	2.330	15.180	1.374	0.012	0.002
4	0.629	9.313	2851.530	2.550	16.560	1.498	0.013	0.002
5	0.529	7.832	2397.960	2.140	13.930	1.260	0.011	0.002
6	0.487	7.213	2208.360	1.972	12.825	1.161	0.010	0.002
7	0.135	2.003	613.430	0.548	3.562	0.322	0.003	0.001
8	0.426	6.310	1931.380	1.725	11.220	1.015	0.009	0.002
9	0.741	10.980	3360.860	3.000	19.520	1.770	0.015	0.003
10	0.662	9.799	3000.245	2.679	17.424	1.580	0.013	0.003
11	0.839	12.434	3807.000	3.399	22.110	2.001	0.017	0.003
12	0.331	4.893	1498.260	1.338	8.701	0.787	0.007	0.001
13	0.945	13.988	4282.880	3.825	24.870	2.251	0.019	0.004
14	1.148	17.000	5204.890	4.648	30.230	2.736	0.023	0.004
15	1.310	19.404	5941.000	5.305	34.503	3.122	0.026	0.005
16	1.320	19.550	5985.619	5.345	34.762	3.146	0.027	0.005

Table- 6.13: Pollutant emission rate by DV2 per ton of garbage per trip

Pollutant emission by departmental vehicle DV2 per ton of garbage per trip to Dhapa Landfill (g/t/trip)								
Borough No.	SO₂	CO	CO₂	HC	NO_x	PM	BENZ	BUTADN
1	0.898	10.686	4078.480	2.950	19.040	1.876	0.015	0.003
2	0.719	8.550	3264.280	2.360	15.240	1.501	0.012	0.002
3	0.578	6.879	2625.620	1.899	12.260	1.207	0.010	0.002
4	0.631	7.506	2864.650	2.073	13.370	1.317	0.011	0.002
5	0.531	6.312	2408.990	1.743	11.240	1.108	0.009	0.002
6	0.489	5.813	2218.510	1.605	10.350	1.020	0.008	0.001
7	0.136	1.615	616.250	0.446	2.880	0.283	0.002	0.000
8	0.427	5.084	1940.270	1.404	9.060	0.892	0.007	0.001
9	0.744	8.850	3376.320	2.443	15.760	1.553	0.012	0.002
10	0.664	7.897	3014.040	2.181	14.069	1.386	0.011	0.002
11	0.843	10.020	3824.510	2.767	17.852	1.759	0.014	0.003
12	0.332	3.944	1505.150	1.089	7.026	0.692	0.006	0.001
13	0.948	11.274	4302.570	3.112	20.080	1.978	0.016	0.003
14	1.152	13.701	5228.820	3.783	24.410	2.405	0.019	0.003
15	1.315	15.640	5968.320	4.318	27.860	2.745	0.022	0.004
16	1.325	15.756	6013.144	4.351	28.068	2.766	0.022	0.004

Table- 6.14: Pollutant emission rate by DV3 per ton of garbage per trip

Pollutant emission by departmental vehicle DV3 per ton of garbage per trip to Dhapa Landfill (g/t/trip)								
Borough No.	SO₂	CO	CO₂	HC	NO_x	PM	BENZ	BUTADN
1	1.254	10.030	5697.140	2.801	17.902	1.924	0.015	0.003
2	1.003	8.027	4559.800	2.242	14.328	1.539	0.012	0.002
3	0.807	6.456	3667.670	1.803	11.524	1.239	0.009	0.002
4	0.880	7.044	4001.570	1.967	12.574	1.351	0.010	0.002
5	0.740	5.924	3365.070	1.654	10.574	1.136	0.009	0.002
6	0.682	5.455	3098.990	1.524	9.738	1.047	0.008	0.001
7	0.189	1.515	860.830	0.423	2.705	0.291	0.002	0.000
8	0.596	4.771	2710.320	1.332	8.517	0.915	0.007	0.001
9	1.038	8.302	4716.320	2.318	14.820	1.593	0.012	0.002
10	0.926	7.411	4210.250	2.069	13.230	1.422	0.011	0.002
11	1.175	9.404	5342.380	2.626	16.787	1.804	0.014	0.002
12	0.463	3.701	2102.520	1.034	6.607	0.710	0.005	0.001
13	1.322	10.579	6010.180	2.955	18.885	2.029	0.015	0.003
14	1.607	12.858	7304.030	3.591	22.952	2.467	0.019	0.003
15	1.834	14.676	8337.030	4.098	26.197	2.816	0.021	0.004
16	1.831	14.786	8320.376	4.130	26.394	2.837	0.022	0.004

Table- 6.15: Pollutant emission rate by DV4 per ton of garbage per trip

Pollutant emission by departmental vehicle DV4 per ton of garbage per trip to Dhapa Landfill (g/t/trip)								
Borough No.	SO₂	CO	CO₂	HC	NO_x	PM	BENZ	BUTADN
1	1.227	13.837	5568.180	3.828	24.656	2.465	0.020	0.003
2	0.982	11.075	4456.590	3.064	19.734	1.973	0.016	0.003
3	0.789	8.908	3584.650	2.464	15.873	1.587	0.013	0.002
4	0.861	9.719	3910.980	2.689	17.318	1.731	0.014	0.002
5	0.724	8.173	3288.900	2.261	14.563	1.456	0.012	0.002
6	0.667	7.527	3028.850	2.082	13.412	1.341	0.011	0.002
7	0.185	2.091	841.350	0.578	3.725	0.372	0.003	0.001
8	0.583	6.583	2648.970	1.821	11.729	1.172	0.009	0.002
9	1.015	11.455	4609.560	3.169	20.410	2.040	0.016	0.003
10	0.906	10.226	4114.950	2.829	18.220	1.821	0.015	0.003
11	1.150	12.975	5221.449	3.589	23.121	2.311	0.018	0.003
12	0.453	5.106	2054.930	1.413	9.099	0.910	0.007	0.001
13	1.294	14.597	5874.130	4.038	26.011	2.600	0.021	0.004
14	1.573	17.740	7138.690	4.908	31.610	3.160	0.025	0.004
15	1.795	20.249	8148.314	5.602	36.081	3.607	0.029	0.005
16	1.808	20.401	8209.503	5.644	36.352	3.634	0.029	0.005

Table- 6.16: Pollutant emission rate by hired vehicle per ton of garbage per trip

Pollutant emission by departmental vehicle HV per ton of garbage per trip to DhapaLandfill (g/t/trip)								
Borough No.	SO₂	CO	CO₂	HC	NO_x	PM	BENZ	BUTADN
1	0.478	11.390	2158.450	2.967	20.080	1.061	0.013	0.002
2	0.382	9.117	1727.550	2.375	16.074	0.849	0.011	0.002
3	0.307	7.330	1389.550	1.910	12.929	0.683	0.008	0.001
4	0.335	8.000	1516.050	2.084	14.106	0.745	0.009	0.001
5	0.282	6.728	1274.910	1.752	11.862	0.626	0.008	0.001
6	0.259	6.196	1174.090	1.614	10.924	0.577	0.007	0.001
7	0.072	1.721	326.140	0.448	3.034	0.160	0.002	0.000
8	0.227	5.419	1026.840	1.411	9.554	0.505	0.006	0.001
9	0.395	9.430	1786.840	2.456	16.620	0.878	0.011	0.002
10	0.353	8.418	1595.110	2.193	14.842	0.784	0.010	0.002
11	0.448	10.682	2024.040	2.782	18.830	0.995	0.012	0.002
12	0.176	4.204	796.570	1.095	7.412	0.391	0.005	0.001
13	0.504	12.020	2277.040	3.130	21.187	1.120	0.014	0.002
14	0.612	14.604	2767.240	3.804	25.750	1.360	0.017	0.003
15	0.699	16.670	3158.600	4.342	29.390	1.552	0.019	0.003
16	0.704	16.795	3182.323	4.375	29.610	1.564	0.019	0.003

Table- 6.17: Pollutant emission rate by hired vehicle per ton of silt/ rubbish per trip

Pollutant emission by departmental vehicle HV per ton of silt/ rubbish per trip to Dhapa Landfill (g/t/trip)								
Borough No.	SO₂	CO	CO₂	HC	NO_x	PM	BENZ	BUTADN
1	0.371	8.859	1678.794	2.308	15.618	0.825	0.010	0.002
2	0.297	7.091	1343.650	1.847	12.502	0.660	0.008	0.001
3	0.239	5.701	1080.761	1.486	10.056	0.531	0.007	0.001
4	0.261	6.222	1179.150	1.621	10.971	0.579	0.007	0.001
5	0.219	5.233	991.597	1.363	9.226	0.487	0.006	0.001
6	0.201	4.819	913.181	1.255	8.496	0.449	0.006	0.001
7	0.056	1.339	253.664	0.348	2.360	0.124	0.001	0.000
8	0.177	4.215	798.653	1.097	7.431	0.393	0.005	0.001
9	0.307	7.334	1389.764	1.910	12.927	0.683	0.008	0.001
10	0.275	6.547	1240.641	1.706	11.544	0.610	0.008	0.001
11	0.348	8.308	1574.253	2.164	14.646	0.774	0.009	0.001
12	0.137	3.270	619.554	0.852	5.765	0.304	0.004	0.001
13	0.392	9.349	1771.031	2.434	16.479	0.871	0.011	0.002
14	0.476	11.359	2152.298	2.959	20.028	1.058	0.013	0.002
15	0.544	12.966	2456.689	3.377	22.859	1.207	0.015	0.002
16	0.548	13.062	2475.140	3.402	23.030	1.216	0.015	0.002

6.1.8 Pollutant Generation from Landfilling

The MSW of the city is disposed of at two KMC disposal sites, which lack leachate collection and lining systems. There is a 21.4 ha dump site in Dhapa that is now being maintained by KMC. The location has been divided into two disposal areas: one in the west (13.3 ha), which takes waste from KMC approved private vehicles and one in the east (8.1 ha), which receives waste from KMC's own vehicles. The way waste is dumped has led to steep, shaky slopes, massive leachate accumulation within the waste mass, and leachate runoff into neighbouring water bodies. This facility receives more than 98% of the city's MSW. However, Garden reach has a small disposal ground that also receives less than 2% of the KMC waste with no gas recovery and leachate collection facilities (Chattopadhyay et al., 2009a; Chattopadhyay et al., 2010b).

It is found from the physical and chemical composition of MSW of Kolkata as shown in Table 5.2, Table 5.3 and Table 5.4 that the biodegradable portion is higher in comparison to the recycled portion. Due to the higher inert content, the energy generation is comparatively low. In the existing system, major portion of recyclable materials (9.21% of the total waste) are recovered by the rag-pickers and the remaining portion is dumped in the landfill along with silt and rubbish. Deposited waste composition is contemplated for landfill gas generation. Presence of high amount of moisture and easily degradable organic content produces higher amount of CH₄ gas.

For the present case study, Triangular model is used for the analysis of landfill gas generation (Chattopadhyay et al., 2018). The organic waste is divided into two sub category, one is Rapidly Biodegradable Waste (RBW) and another is Slowly Biodegradable Waste (SBW). The annual rates of degradation for rapid and slowly biodegradable wastes are based on this Triangular model. The degradation rate for RBW usually reaches the maximum within the first two years and continues further for 5 years whereas SBW attains its peak within 7 to 8 years and continues up to 15 years (Tchobanoglous et al., 1993). The biogas production is assumed to begin at the end of the first complete year of the landfill operation. LFG release is estimated based on the cumulative combination of the triangular curve formed from RBW and

SBW and the area under the release curve is represented as the total gas generated over that period. Figure 6.1 depicts the landfill gas generation rate from both RBW and SBW and their combined effect.

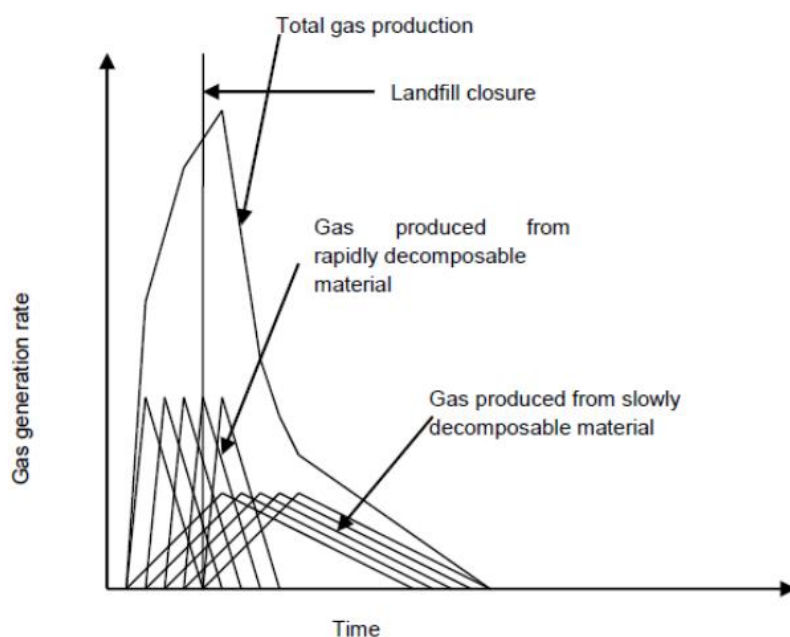


Figure- 6.1: Typical landfill gas generation rate from RBW and SBW

6.1.8.1 Analysis for composition of MSW under existing case study

Analysis for Rapidly Bio-degradable Waste (RBW)

Typical values of ultimate analysis (Tchobanoglous et al., 1993) for RBW are represented in Table 6.18. Table 6.19 shows the weight and chemical composition for the same.

Table- 6.18: Typical values for ultimate analysis of RBW

Component	(%)					
	C	H	O	N	S	Ash
Food waste	48.6	6.4	37.6	2.0	0.4	5.0
Paper	43.5	6.0	44.0	0.3	0.2	6.0

Table- 6.19: Analysis of weights and chemical composition of RBW

Component	Moisture Content (%)	Weight (kg)		Composition (kg)					
		Wet	Dry	C	H	O	N	S	Ash
Food Waste	72.50	50.56	13.904	6.757	0.890	5.228	0.278	0.056	0.695
Paper	6.00	1.07	1.006	0.438	0.060	0.443	0.003	0.002	0.060
Total		51.63	14.91	7.195	0.95	5.671	0.281	0.058	0.755

Analysis for Slowly Bio-degradable Waste (SBW)

Typical values of ultimate analysis and weights and chemical composition of slowly biodegradable wastes are shown in Table- 6.20 and Table- 6.21 respectively.

Table- 6.20: Typical values for ultimate analysis of SBW

Component	(%)					
	C	H	O	N	S	Ash
Rubber and Leather	69.0	9.0	5.8	6.0	0.2	10.0
Wooden Matter	49.5	6.0	42.7	0.2	0.1	1.5
Coconut	49.6	6.1	43.2	0.1	0.1	0.9
Rags	55.0	6.6	31.2	4.6	0.15	2.5

Table- 6.21: Analysis of weights and chemical composition of SBW

Component	Moisture Content (%)	Weight (kg)		Composition (kg)					
		Wet	Dry	C	H	O	N	S	Ash
Rubber and Leather	5.0	0.27	0.257	0.177	0.023	0.015	0.015	0.000	0.026
Wooden Matter	25.0	1.15	0.863	0.427	0.052	0.369	0.002	0.001	0.013
Coconut	40.0	4.5	2.700	1.339	0.165	1.166	0.003	0.003	0.024
Rags	10.0	1.87	1.683	0.926	0.111	0.525	0.077	0.003	0.042
Total		7.79	5.503	2.869	0.351	2.074	0.097	0.007	0.105

Molar composition of different elements (neglecting Ash)**Table- 6.22:** Molar composition of RBW & SBW

Elements		C	H	N	O	S
Kg/mole		12.01*	1.01*	14.01*	16.00*	32.06*
Total moles for:	RBW	0.5991	0.9406	0.02	0.3544	0.0018
	SBW	0.2389	0.3465	0.0069	0.1296	0.0002

* (Tchobanoglous et al., 1993)

Determination of approximate chemical formula

Taking N=1, the molar ratio for RBW and SBW are depicted in Table- 6.23, below.

Table- 6.23: Molar ratio of RBW & SBW

Elements		C	H	O	N	S
Molar Ratio	RBW	29.95	47.03	17.72	1	0.09
	SBW	34.62	50.22	18.78	1	0.03

From the ultimate analysis of RBW and SBW, the approximate chemical formula for RBW is $C_{29.95} H_{47.03} O_{17.72} N S_{0.09}$ and for SBW is $C_{34.62} H_{50.22} O_{18.78} N S_{0.03}$.

Calculation of gas production from RBW and SBW using linear model

For Rapidly Biodegradable Waste (RBW), the gas production equation is $C_{29.95} H_{47.03} O_{17.72} N S_{0.09} + 10.1275 H_2O \rightarrow 16.02625 CH_4 + 13.92375 CO_2 + NH_3 + 0.09 H_2S$

706.83 182.295 256.42 612.645 17 3.06

For Slowly Biodegradable Waste (SBW), the gas production equation is $C_{34.62} H_{50.22} O_{18.78} N S_{0.03} + 13.44 H_2O \rightarrow 18.51 CH_4 + 16.115 CO_2 + NH_3 + 0.03 H_2S$

781.10 241.92 296.16 708.84 17 1.02

At NTP, the specific weights of the generated gases are shown in Table 6.24 (Tchobanoglous et al., 1993)

Table- 6.24: Specific weight of respective gasses at NTP

Generated Gas	CH ₄	CO ₂	NH ₃	H ₂ S
Specific weight (Kg/m ³)	0.7167	1.9768	0.7708	1.5392

The volume of different gases generated from degradation of RBW and percentage of generated gases is as presented in Table- 6.25. Detail calculations are shown in *annexure- 6.4.1 of annexure 6.4.*

Table- 6.25: Volume and percent of different gases in RBW

Generated Gas	Volume of generated gas (m ³)	Percentage of Gas
CH ₄	8.250	51.71
CO ₂	7.150	44.81
NH ₃	0.509	3.19
H ₂ S	0.046	0.29
Total	15.955	100

Volume of gas per Kg dry weight of RBW = $15.955/14.91 = 1.07 \text{ m}^3/\text{Kg}$ of dry wt. of RBW

The volume of different gases generated from degradation of SBW and percentage of generated gases is as presented in Table- 6.26. Detail calculations are shown in *annexure- 6.4.2 of annexure 6.4.*

Table- 6.26: Volume and percent of different gases in SBW

Generated Gas	Volume of generated gas (m ³)	Percentage of Gas
CH ₄	3.180	52.00
CO ₂	2.760	45.13
NH ₃	0.170	2.78
H ₂ S	0.005	0.09
Total	6.115	100

Volume of gas per Kg dry weight of SBW = $6.115/5.503 = 1.11 \text{ m}^3/\text{Kg}$ of dry wt. of SBW

Determination of amount of gas at the end of each year from one kg of biodegradable waste

Rapidly Biodegradable Waste (RBW):

Let us consider a decomposition period of 5 years for rapidly biodegradable solid waste. *Figure A-6.1 of annexure 6.4* shows gas production over five year period from RBW. We use a triangular gas production model; Let h' be the height of the triangle. Volume of gas per kg dry weight of RBW = $1.07 \text{ m}^3/\text{kg}$ of dry weight of RBW.

$$1/2 \times 5 \times h' = 1.07$$

$$h' = 0.428 \text{ m}^3/\text{kg}/\text{yr}.$$

Table 6.27, shows the gas production distribution over the 5 years period of RBW.

Table- 6.27: Gas production distribution over the 5 years period

End of year	Rate of Gas Production (m^3/yr of dry weight of RBW)	Gas Production (m^3/kg of dry weight of RBW)
0	0	0
1	0.428	0.2140
2	0.321	0.3745
3	0.214	0.2675
4	0.107	0.1605
5	0	0.0535
Total	1.07	1.07

Slowly Biodegradable Waste (SBW):

Let us consider a decomposition period of 15 years for slowly biodegradable solid waste. We use a triangular gas production model; Let h'' be the height of the triangle. Volume of gas per kg dry weight of SBW = $1.11 \text{ m}^3/\text{kg}$ of dry weight of SBW. *Figure A-6.2 of annexure 6.4* shows gas production over fifteen year period from SBW.

$$1/2 \times 15 \times h'' = 1.11$$

$$h'' = 0.148 \text{ m}^3/\text{kg}/\text{yr}$$

Table 6.28, shows the gas production distribution over the 15 years period of SBW.

Table- 6.28: Gas production distribution over the 15 years period

End of year	Rate of Gas Production (m ³ /yr of dry weight of RBW)	Gas Production (m ³ /kg of dry weight of RBW)
0	0	0
1	0.0296	0.0148
2	0.0592	0.0444
3	0.0888	0.074
4	0.1184	0.1036
5	0.148	0.1332
6	0.1332	0.1406
7	0.1184	0.1258
8	0.1036	0.111
9	0.0888	0.0962
10	0.074	0.0814
11	0.0592	0.0666
12	0.0444	0.0518
13	0.0296	0.037
14	0.0148	0.0222
15	0	0.0074
Total	1.11	1.11

Estimation of yearly gas production

Calculation of biodegradability factors

It may be assumed that percentage of biodegradable portion for rapidly biodegradable solid waste and slowly biodegradable solid waste are 75% and 50% respectively. Equation is considered for totally decomposable or biodegradable portion and from that gases are calculated. But for RBW portion 25% are not at all degradable or very slowly degradable due to presence of non-biodegradable matter (lignin etc.). The reason is also same for SBW. At the end of 15 years total gas generation will be 0.15 m³/kg of total waste.

Fraction of waste that is rapidly biodegradable = $(14.91/100) \times 0.75 = 0.112$ kg of dry weight of RBW /kg of total waste.

Fraction of waste that is slowly biodegradable= $(5.503/100) \times 0.50 = 0.028$ kg of dry weight of SBW/kg of total waste.

Table 6.29 shows the yearly gas production of solid waste having 75% RBW fraction and 50% SBW fraction.

Table- 6.29: Yearly gas production for solid waste having 75% RBW fraction & 50% SBW fraction

End of year	Gas Generation from RBW (m ³ /Kg of total waste)	Gas Generation from SBW (m ³ /Kg of total waste)	Total Gas Generation (m ³ /Kg of total waste)
0			
	0.000000	0.000000	0.000000
1			
	0.023968	0.000400	0.024368
2			
	0.041944	0.001199	0.043143
3			
	0.029960	0.001998	0.031958
4			
	0.017976	0.002797	0.020773
5			
	0.005992	0.003596	0.009588
6			
		0.003796	0.003796
7			
		0.003397	0.003397
8			
		0.002997	0.002997
9			
		0.002597	0.002597
10			
		0.002198	0.002198
11			
		0.001798	0.001798
12			
		0.001399	0.001399
13			
		0.000999	0.000999
14			
		0.000599	0.000599
15			
		0.000200	0.000200
16			
Total			0.149810

Calculation of cumulative gas generations over a period of 35 years

Waste material that was dumped between 1987 and 2011 is used to estimate the total quantity of landfill gas generated. The landfill started in 1987, and it is expected that it will close in 2011. Gas entrapment began in 2012 since it takes a year to establish gas extraction facilities and provide top cover. The estimation of methane generation and recovery takes into account the effective extraction time for ten years following the landfill closure. This is predicated on the observation that, of the 15 years total effective gas production period, the first 10 years account for the majority of gas production. *Annexure 6.5* provides a detailed analysis of methane generation, trapping, and recovery. Figure 6.2 shows that there will be 1,73,871 t of methane entrapment and 12,27,014 t of total CH₄ generation between 1987 and 2021. Assuming a 50% recovery rate for the open dump site, 86,936 t of methane can be collected in total up to 2021, or ten years after closure. This would result in a likely 18,25,656 tCO₂-eq reduction in greenhouse gas emissions (Chattopadhyay et al., 2018).

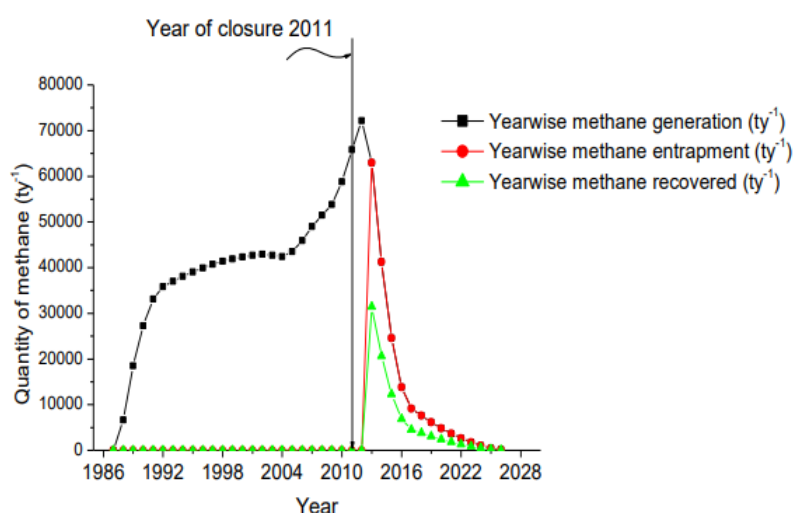


Figure- 6.2: Year wise CH₄ generation, entrapment and recovery from Dhapa landfill

Recovery percentage is only 7% of the total generation and there is no such entrapment and recovery facilities for the existing Dhapa landfill site, the cumulative CH₄ generation curve may be assumed as a rectangular in shape starting from 1987 to 2021 of only gas generation. The modified curve is depicted in the figure 6.3.

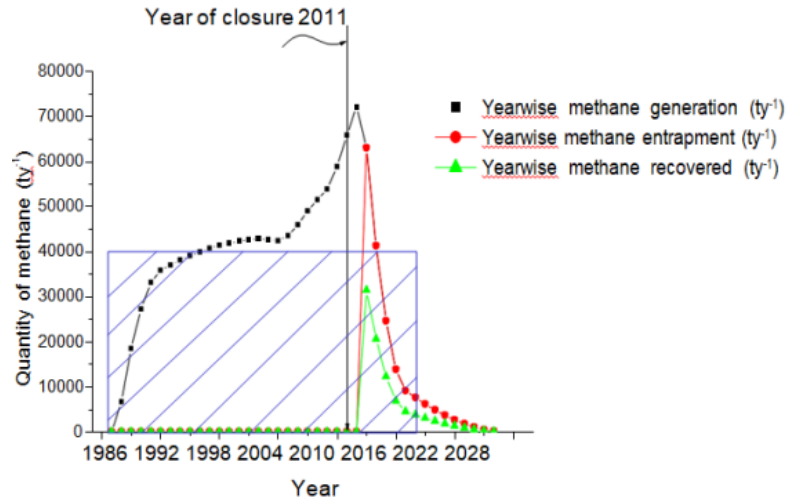


Figure- 6.3: CH₄ generation from 1987 to 2021 from existing Dhapa landfill site

Figure 6.3 shows an average methane generation rate of 40,000 MT/yr i.e. 150 m³/MT of total waste generation rate. As the RBW and SBW both have a simultaneous contribution to this 150 m³/MT of waste generation rate, the fact behind assuming the cumulative curve as a rectangular curve with a total CH₄ generation of 13,60,000 MT from 1987 to 2021 is justified.

Amount of CH₄ generation from 1MT of garbage is $(150 \times 47.7/100) = 71.55 \text{ m}^3$.

Volume of 16 g of CH₄ at 25°C = $(0.0224 / 273) \times 298 = 0.02445 \text{ m}^3$

So, 71.55 m³ of CH₄ at 25°C = $[(16/24.45) \times 71.55] \text{ kg} = 46.82 \text{ kg of CH}_4/\text{MT of garbage}$

Amount of CO₂ generation from 1MT of garbage is $(150 \times 47/100) = 70.50 \text{ m}^3$.

Volume of 44 g of CO₂ at 25°C = $(0.0224 / 273) \times 298 = 0.02445 \text{ m}^3$

So, 70.50 m³ of CO₂ at 25°C = $[(44/24.45) \times 70.50] \text{ kg} = 126.87 \text{ kg of CO}_2/\text{MT of garbage}$

Table 6.30 shows the principle landfill gas generation rate of Dhapa landfill site for per MT of garbage.

Table- 6.30: Landfill gas generation rate (g/MT/day) of Dhapa landfill site

Dumpsite	CO ₂	CH ₄
Dhapa	126870	46820

Major gas generation equation from existing Dhapa landfill**Total CO₂ generation from landfill site:**

$$CO_{2\_emsn\_dhapa\_de} - CO_{2\_dump\_de} \times Xlf_{de} = 0 \quad (204)$$

CO₂_emsn_dhapa_{de} is the total emission of CO₂ from Dhapa landfill. CO₂_dump_{de} is the CO₂ gas emission rate from landfill site per MT of garbage.

Total methane generation from landfill site:

$$CH_{4\_emsn\_dhapa\_de} - CH_{4\_dump\_de} \times Xlf_{de} = 0 \quad (205)$$

CH₄_emsn_dhapa_{de} is the total emission of methane from landfill. CH₄_dump_{de} is the methane emission rate from landfill per MT of garbage.

6.1.9 Calculation of Leachate Formation

In case of existing landfill site like Dhapa without leachate collection and treatment system, the quantity estimation for landfill leachate is possible only by using model analysis. For providing appropriate cost effective leachate management options like liners, top covers, collection and treatment, quantitative and qualitative estimation of leachate are the primary design parameters. The present dumping ground at Dhapa having 21.4 ha area has been used for around 20 years and now has got devastated (KEIP, 2005). The waste pile with no intermittent or top cover is nearly a vertical structure, with an average height of 20 metres. (Chattopadhyay et. al., 2007b). Currently, approximately 13 ha area adjacent to Dhapa site has been acquired by KMC and dumping is going on over there. MSW of Kolkata is polluted with heavy metals like Hg (1 mg/kg), Cd (3 mg/kg), total Cr (43.9 mg/kg), Cu (54.4 mg/kg) and Pb (788 mg/kg) (KEIP, 2005). Kolkata receives plenty of rainfall (1850 mm/year) and thus produces huge amount of leachate.

A study conducted by CPCB in and around Dhapa landfill in Kolkata found that leachate is highly polluted with organic and inorganic pollutants (Saha et. al., 2003). Natural leachate collected around the old dumping grounds at Dhapa is found to have 0.43-0.85 mg/L Cr, 0.04-0.05 mg/L Cd, 0.002-0.009 mg/L Hg, 0.07- 0.08 mg/L Pb and 0.06-0.28 mg/L Cu. Other than heavy metals natural leachate contains high BOD (375-425mg/L), COD (2455-2545mg/L), Cl (3520-3943mg/L), TKN (228.6- 585.5mg/L), TDS (9912-10186mg/L) and phenolic compounds < 1mg/L (KEIP, 2005).

For our present existing system, we have taken the quantity of leachate generated using EPA's Hydrologic Evaluation of Landfill Performance (HELP) model as 1000 L/m²/year (Basak, 2011). A quasi-two-dimensional hydrologic model called HELP is used to analyze the water balance of landfills, cover systems, and other solid waste containment facilities. The model uses daily climate data, landfill design data and soil data including waste characteristics for leachate estimation. The model is applicable to open, partially closed, and fully closed sites (EPA, 1994a; EPA, 1994b). The EPA-sponsored HELP model (Version 3.07) uses water balance method to calculate daily water inflows and outflows and storage changes for a unit area of the system over a certain period of time. The basic water balance equation used is

$$\text{Precipitation} = \text{Runoff} + \text{Evapotranspiration} + \text{Leakage} + \text{Change in water storage.}$$

Currently open dumping is carried out at an area of 13 ha adjacent to the present Dhapa dumping site of area 21.47 ha. So, the total land area considered for the existing Dhapa landfill is 21.47 + 13 = 34.47 ha.

The heavy metals generated from the leachate under consideration are Ammoniacal Nitrogen (NH₃-N), Arsenic (As), Mercury (Hg), Lead (Pb), Cadmium (Cd), Chromium (Cr), Copper (Cu), Zinc (Zn), Nickel (Ni), Cyanide (CN), Chlorine (Cl) and Phenol.

Table 6.31 represents the active Dhapa leachate characteristics and active leachate generation rate for different heavy metals generated. The leachate characteristics are considered from the De et. al., 2016. The mean values for different parameters have been contemplated for the characterization study. Leachate generation rate per ton of waste is 2.734 L/MT of waste. The sample calculation of active leachate generation rate (kg/MT of waste) is shown in *annexure 6.6*.

Table- 6.31: Landfill leachate characteristics and Generation Rate for active Dhapa landfill

Heavy metal	Active Dhapa leachate characteristics (mg/L)	Generation rate from landfill leachate(Kg/MT)
NH ₃ -N	1681.67	4.61×10^{-3}
As	0.03	8.202×10^{-8}
Hg	0.87	2.379×10^{-6}
Pb	0.60	1.640×10^{-6}
Total Cr	3.22	8.80×10^{-6}
Cu	0.32	8.75×10^{-7}
Zn	7.61	2.08×10^{-5}
Ni	0.51	1.394×10^{-6}
CN	3.0	8.202×10^{-6}
Cl	4050.73	0.0111
PHENOL	0.25	6.835×10^{-7}

The values shown in table 6.31 are fed as input data for the estimation of total heavy metal generation from Dhapa landfill site.

Sample calculation of active rate of leachate generation (kg/MT of waste) For NH₃-N, active leachate generation rate = active Dhapa leachate characteristics × leachate generation rate per ton of waste

Hence, Rate of NH₃-N generation = $(1681.67 \times 2.734) / 1000000 = 0.00461$ kg/ MT of waste

6.1.9.1 Major heavy metals generation equation from existing landfill leachate

The LP equations for different heavy metals have already been depicted in sub chapter 4.2.4.4.

6.2 MODEL VALIDATION IN EXISTING SCENARIO

The model is validated with 2022 actual KMC datasheets. The municipality officials have accomplished their own optimal SWM system in spite of not having an optimized model for KMC SWM system of Kolkata. The total cost of the MSW management system in

operation currently has been compared to the model outcomes taking into account the KMC scenario for 2022 to validate the model.

Considering 85% of total garbage is carried by departmental vehicle and 15% of total garbage is carried by hired vehicle, the existing model results a total cost of ₹55,00,706. The total cost in actual field situation is ₹57,94,350/day. So the cost variation is ~5% less in model compared to actual situation. The validation of the current model shown above demonstrates excellent performance and ~5% cost savings. Therefore, further investigation can be done using this basic model. The entire PEI came out to be 8.37×10^{-3} .

6.3 IMPLEMENTING THE MODEL FOR EXISTING SWM SYSTEM WITH AND WITHOUT VEHICLE OPTIMIZATION

Absence of any transfer station for the existing Kolkata MSW management system implies only usage of departmental and private hired vehicles owned by KMC for the present case study which is only incorporated in LP model generated in sub chapter 4.2.3 of chapter 4. The existing model is implemented without vehicle optimization (free mode considering all vehicles) and with optimizing the departmental vehicle, which leads to minimization of total cost. The following table shows number of running, idle, total vehicle before and after optimisation.

Table- 6.32: Total number of departmental vehicle at existing condition

Vehicletype	Capacity (MT)	Vehicles in operation	Idle Vehicle	Total noof vehicles
DV1	7	20	8	28
DV2	9	240	60	300
DV3	10	80	15	95
DV4	7	2	1	3

Table- 6.33: Optimized data for different type of departmental vehicle

Vehicletype	Capacity (MT)	Vehicles in operation	Idle Vehicle	Total noof vehicles
DV1	7	14	6	20
DV2	9	65	40	105
DV3	10	25	10	35
DV4	7	2	1	3

6.3.1 Observation of Results on Above Study

6.3.1.1 Cost analysis

Results obtained in lingo from implementation of the existing model without any vehicular optimisation and with vehicle optimisation are discussed below.

Table- 6.34: Output summary of cost for existing MSWM system of Kolkata

<i>Items</i>		Cost (Rs./day) (Without Vehicle Optimization)	Cost (Rs./day)(With Vehicle Optimization)
<i>Total SWM cost</i>	<i>Objectivefunction</i>	5443222	2854108
<i>Total transportation cost</i>	<i>COSTRANSP</i>	5016468	2376101
<i>Incentive cost</i>	<i>COSTINCENT</i>	8897	60150
<i>Landfilling cost</i>	<i>COSTLFL</i>	417857	417857

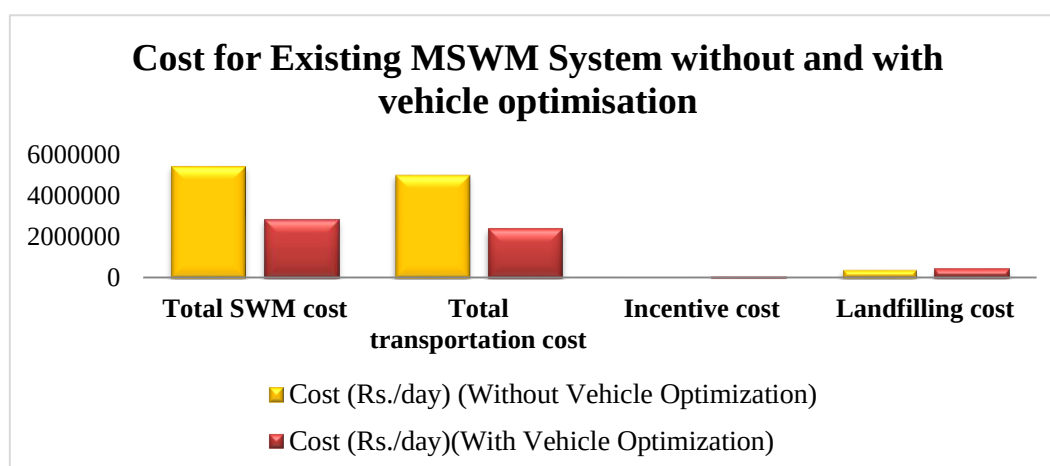


Figure-6.4: Comparison of total cost for existing MSWM system in Kolkata

We can see a significant difference in cost between the two conditions in the existing system. Optimization of vehicles has effectively reduced total cost by 47.5% and total transportation cost by 52.6%. But total incentive cost is higher in case of vehicle optimization. It has increase around 85% w.r.t. incentive cost, but this increment is only around 1% w.r.t. total cost. This is because in vehicle optimization departmental vehicles are made to have more trips and all departmental vehicles are making trips more than that their minimum trips assigned. As a result total no of vehicle required is significantly less. Whereas running cost of vehicle running and maintenance cost

of idle vehicles is significant in the case of existing model without optimization. For optimized model this cost is reduced significantly as no. of idle vehicle and running vehicle is significantly low. But as individual vehicle is making more trips so for drivers total incentive increases. Incentive is paid per no of trips. So drivers are being paid more in the optimized model (as only 1% of the total cost), it is a better management option for reducing the total SWM cost significantly. But landfill cost is same for both as vehicle optimization does not affect the amount of garbage produced or dumped in Dhapa. So it is same for both the cases.

Quantity of waste transported by individual KMC vehicle from different borough centres to the Dhapa disposal site is presented in Figure 6.5.

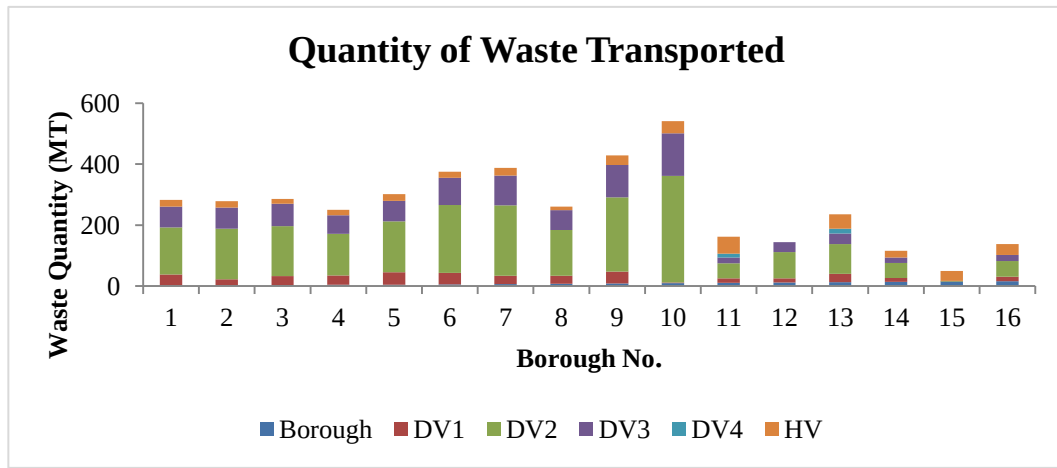


Figure-6.5: Quantity of waste transported to Dhapa disposal sites in Existing system

Figure 6.5 shows that DV1, DV2, DV3, Quantity of waste transported to Dhapa disposal sites in Existing system DV4 transfers 7.97%, 49.59%, 20.61%, 0.59% of garbage respectively. Though, the hired vehicle carries 21.21% of total waste (garbage+ silt). Here also, DV2 carries highest amount of garbage, since its number of vehicles is high and maximum garbage carrying range is also high, while the hired vehicles transport waste as per their minimum garbage carrying range. Among all, borough- 10, contribute the highest quantity of waste to the total.

A detail analysis of waste transportation from different borough centres by the KMC vehicles is shown in Table 6.35.

Table- 6.35: Analysis of waste transported by KMC vehicles in MT

Borough no.	DV1	DV2	DV3	DV4	HV (Silt + Garbage)
1	37.41529	153.8809	68.92291	0	68.92291
2	20.15435	165.6522	69.57392	0	69.57392
3	29.71153	163.5549	74.13735	0	74.13735
4	30.5417	137.1913	60.09818	0	60.09818
5	40.41322	166.7045	67.75157	0	67.75157
6	36.9263	223.0349	88.99238	0	88.99238
7	27.41558	230.7478	97.8584	0	97.8584
8	26.0454	150.2036	65.23994	0	65.23994
9	39.00132	243.234	105.681	0	105.681
10	1.593531	349.5145	140.2307	0	140.2307
11	14.29665	49.06007	19.71432	12.49075	32.20507
12	13.6969	86.39586	31.60824	0	31.60824
13	27.63142	96.79909	34.98494	15.50925	50.49419
14	12.53395	49.11676	18.34236	0	18.34236
15	0.34971	1.74855	0	0	0
16	14.9814	51.0342	20.4624	0	20.4624

Comparative Analysis of waste transportation cost, incentive cost, and fuel cost by different departmental and hired vehicles between existing system and existing optimized system are shown in Figure 6.6, Figure 6.7, and Figure 6.8 respectively. Due to higher value of running cost for DV2 type vehicles, the total transportation cost (Figure 6.7) and incentive costs are higher for DV2 vehicle among others (Figure 6.7). Only transportation cost has been considered for private hired vehicles.

In transportation cost, for vehicle optimized condition DV2 shows reduction in cost of 60.46% while DV1 and DV3 shows reduction in cost of 22.8% and 55.9% respectively. Cost of DV4 and HV remain same as there is total 2 number of DV4 running in both the cases so optimization has no effect on DV4 and for HV optimization is not done.

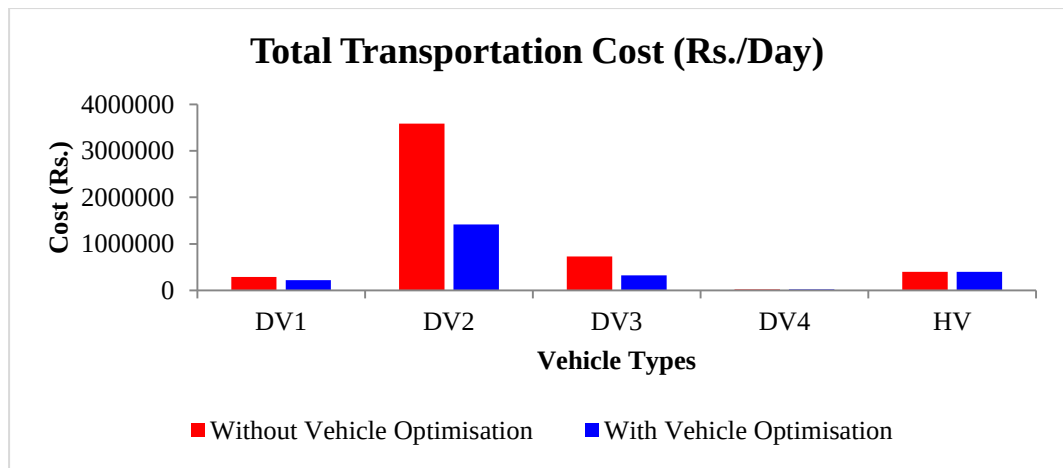


Figure-6.6: Total transportation cost of different KMC vehicles

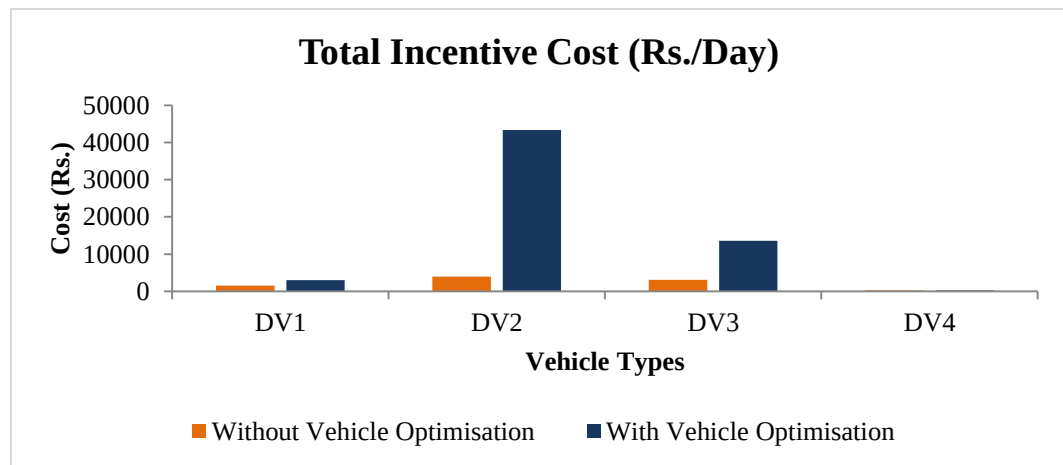


Figure-6.7: Variation of incentive cost incurred by KMC vehicles

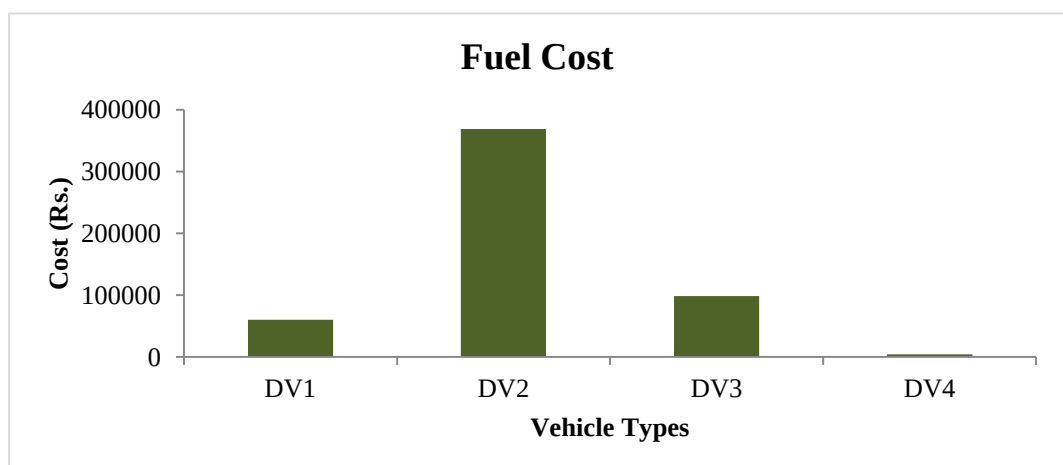


Figure-6.8: Variation of total fuel cost incurred by different KMC vehicles

Fuel cost is same for both the cases. As DV2 has the maximum number of vehicles in operation so fuel cost of DV2 is significantly higher than others.

6.3.1.2 Pollution generation from transport sectors

In case of existing MSW management system, the total pollutant generation contributed by transport sector of Kolkata is around 4733 MT/year. Total contribution of CO₂ emission is the highest ~ 4692 MT per year (99.1%). NO_x generation is the second largest ~ 23 MT/yr (0.48%) which is higher than CO (0.26%) and HC (0.073%). SO₂ emission (0.022%) is much less compare to NO_x due to stringent permissible sulphur percentage in diesel fuel. The emission of Benzene and Butadiene is very negligible in comparison with the rest of pollutants. The amount of pollution generation for different departmental and hired vehicles for different pollutant is shown in below figures. Highest emission is occurring in DV2.

Borough wise total pollutant emission from KMC vehicles

Total pollutant emission from solid waste transport sector is higher in borough 9 and borough 10 out of 16 boroughs, which are around 12.14% and 13.76% respectively that is influenced by higher waste generation, distance from landfill and sharing of waste fraction by departmental and private vehicles. Comparative analysis of borough wise total waste generation and borough wise total emissions contributing by different pollutants are shown in Figure 6.9. Contribution of total pollutants from borough 15 is negligible which is around 0.91% in comparison to others. As, the distance of borough 15 from Dhapa landfill is maximum with respect to others, minimum % of total waste (0.06%) is transferred to disposal site by KMC vehicles which causes minimum pollutant contribution as well amid other boroughs.

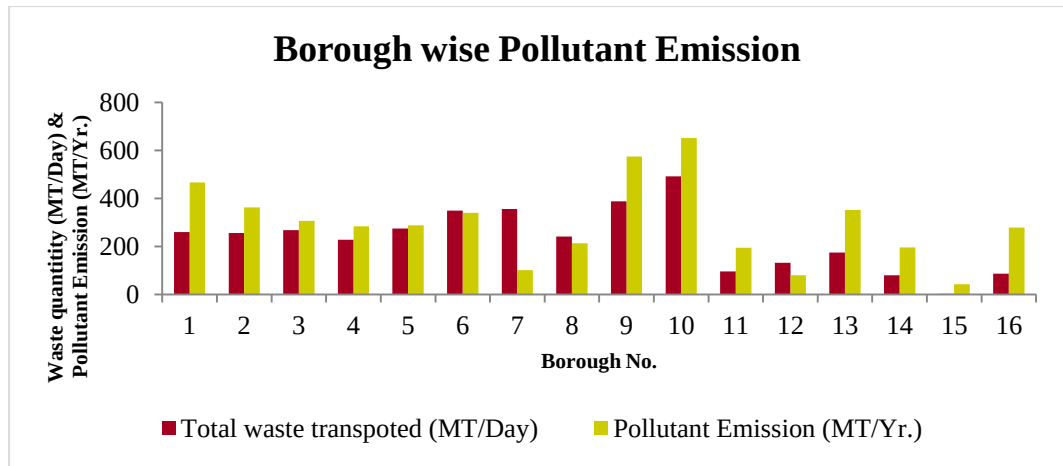


Figure-6.9: Borough wise total waste generation and total pollutant contribution for existing system

Borough wise individual pollutant emission from KMC vehicles

Individual pollutant emission for maximum and minimum contribution from borough 10 and borough 15 respectively is depicted in the following figures. Emission of CO and NO_x from borough 10 is 13.78% whereas it is 0.12% for borough 15. Figure 6.10 shows the emission status for CO and NO_x from different boroughs in MT/yr.

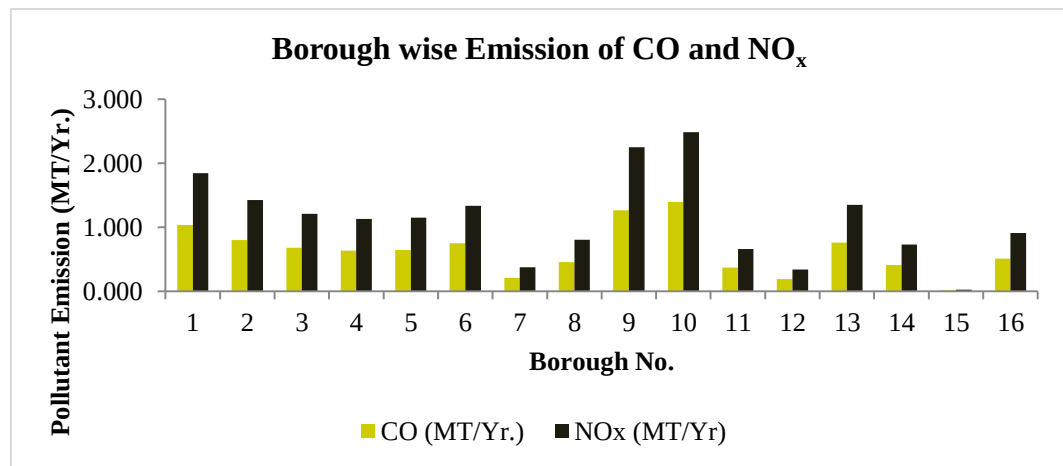


Figure-6.10: Borough wise emission status for CO and NOx for existing SWM

Figure 6.11 depicts the borough wise CO₂ emission contributed by different KMC vehicles. Maximum contribution of 14.29% of CO₂ is recorded in borough 10 and the minimum of 0.11% is recorded in borough 15.

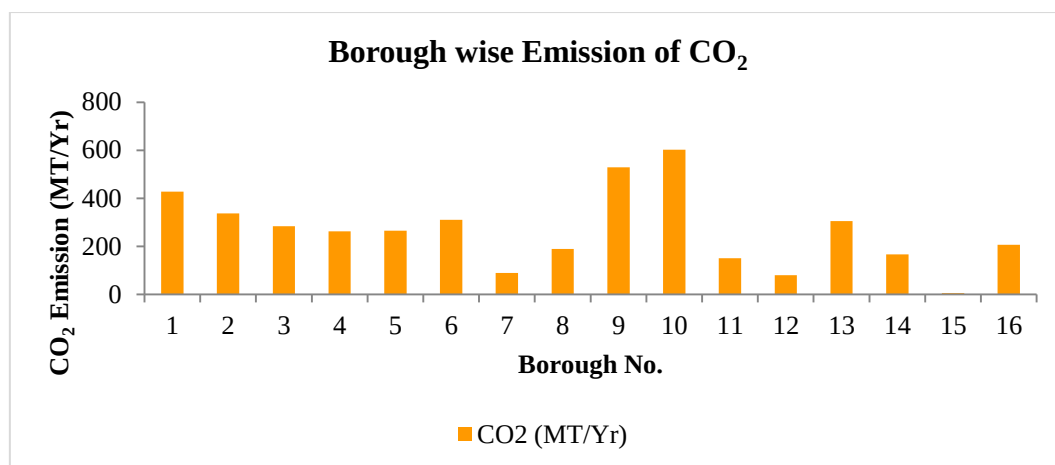


Figure-6.11: Borough wise emission status for CO₂ for existing SWM

Figure 6.12 and Figure 6.13 shows the borough wise emission trend (MT/yr) of SO₂, Hydrocarbons (HC), Particulate matter, Benzene and Butadiene. For borough 10, the percentage emission for these pollutants is recorded as 14.29%, 13.80%, 13.96%, 13.84% and 13.77% respectively among other boroughs.

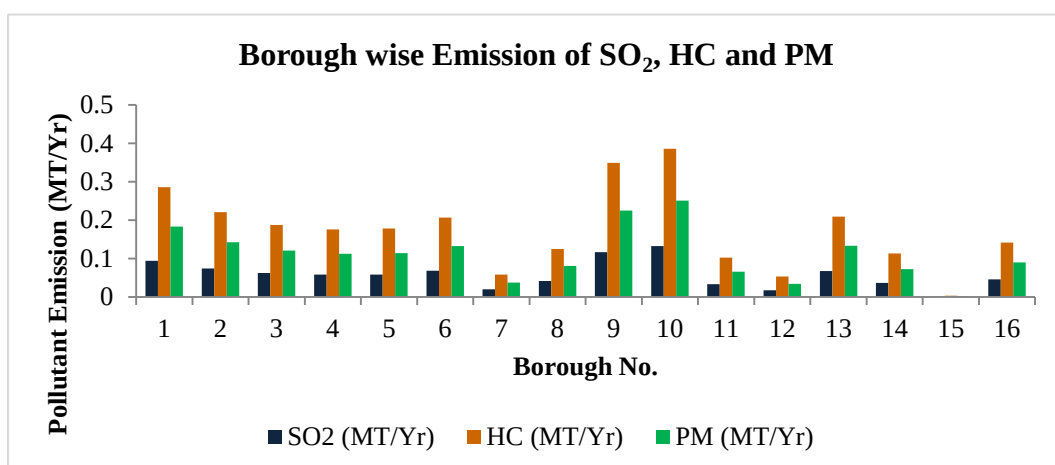


Figure-6.12: Emission of SO₂, HC and PM from different borough

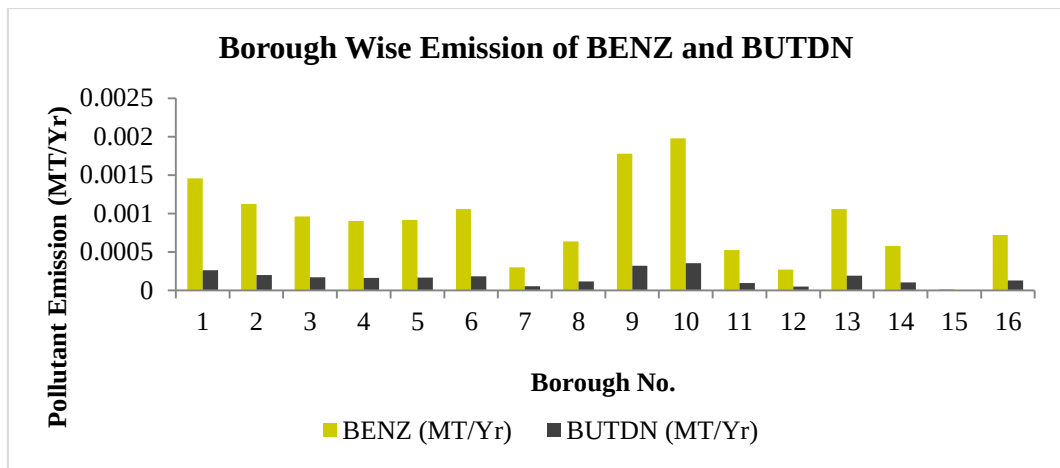


Figure-6.13: Emission of benzene and butadiene from different borough

Pollutant contribution from departmental and private KMC vehicles

The percentage contributions of departmental vehicle and hired vehicle in generation of total pollutants are shown in Fig 6.14. The result implies that the total emission of the departmental vehicle is 89.67%. The departmental vehicles carry 89.79% of the total waste due to incorporation of new compactor vehicles for the existing system. In case of the private vehicles (hired ones) the total emission is 10.33% which carry 10.21% of the total waste.

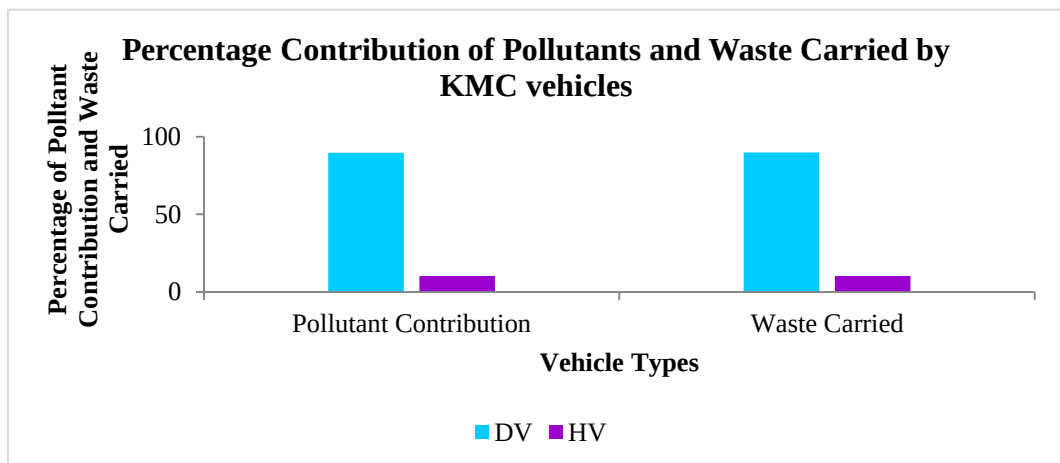


Figure-6.14: Pollutant contribution and waste carried by KMC vehicles for existing SWM system

Contribution of different pollutant to the total emission from KMC vehicles

Figure 6.15, 6.16, 6.17 and 6.18 shows the emission trend (MT/yr) of CO, SO₂, CO₂ and NO_x from different departmental and hired vehicles of KMC. Emission of CO₂, NO_x, CO and SO₂ from the departmental vehicles are 89.75%, 80.1%, 79.9%, and 89.75% respectively whereas respective emission from hired vehicles are 10.25%, 19.9%, 20.1% and 10.25%. among all other departmental vehicles, DV2 contribute the highest pollution as it perform highest number of trips to transport the maximum quantity of waste (ref. figure 6.5). The DV3 and HV contribute almost similar quantity of pollution as they carry almost same quantity of total waste (ref. figure 6.5).

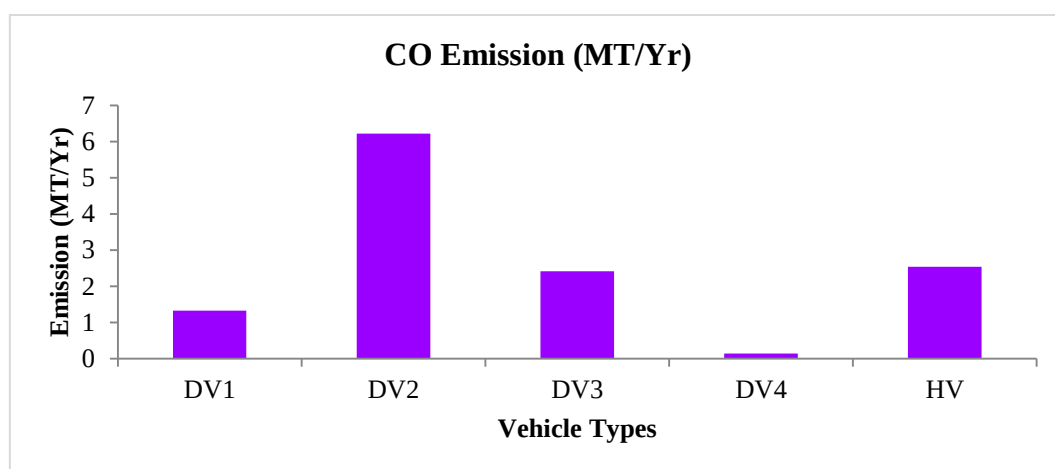


Figure-6.15: Emission trends of CO from KMC vehicles for existing SWM system

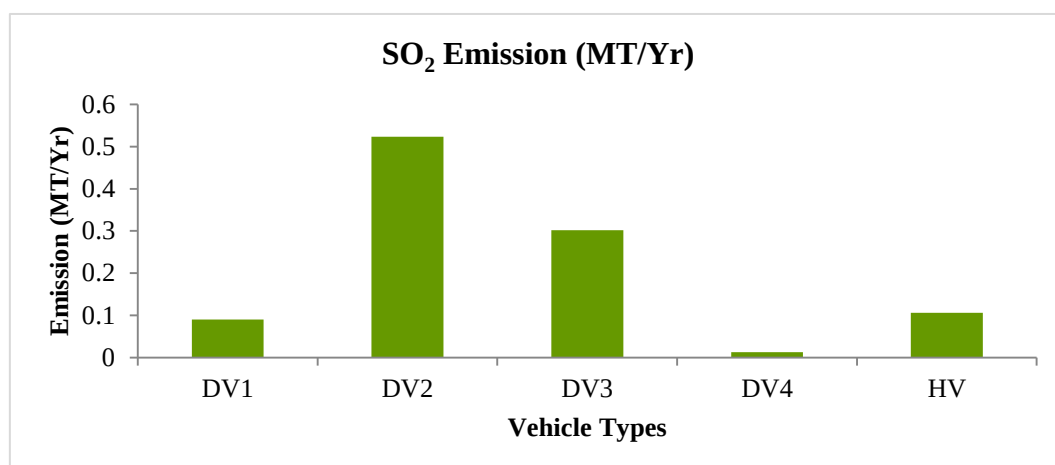


Figure-6.16: Emission trends of SO₂ from KMC vehicles for existing SWM system

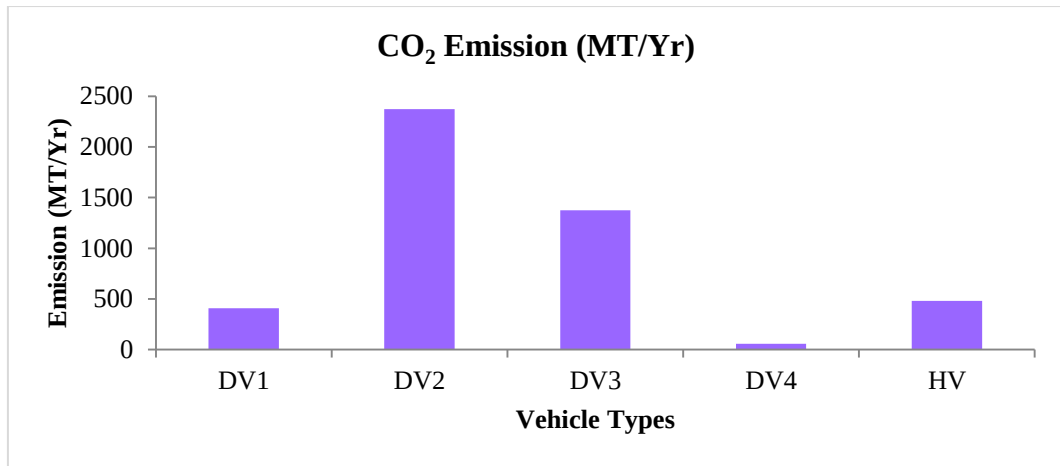


Figure-6.17: Emission trends of CO₂ from KMC vehicles for existing SWM system

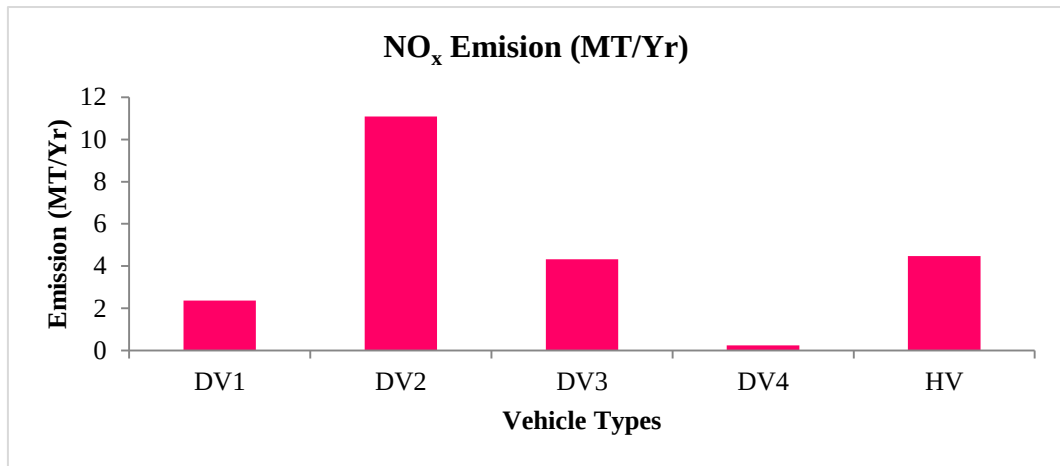


Figure-6.18: Emission trends of NO_x from KMC vehicles for existing SWM system

Emission of HC, PM, Benzene and Butadiene from the departmental vehicles are 80.9%, 88.4%, 83.3%, and 85.1% respectively whereas respective emission from hired vehicles are 19.1%, 11.6%, 16.7% and 14.9%. Figure 6.19 shows the emission of HC and PM and the figure 6.20 shows the emission of Benzene and Butadiene from different KMC vehicles.

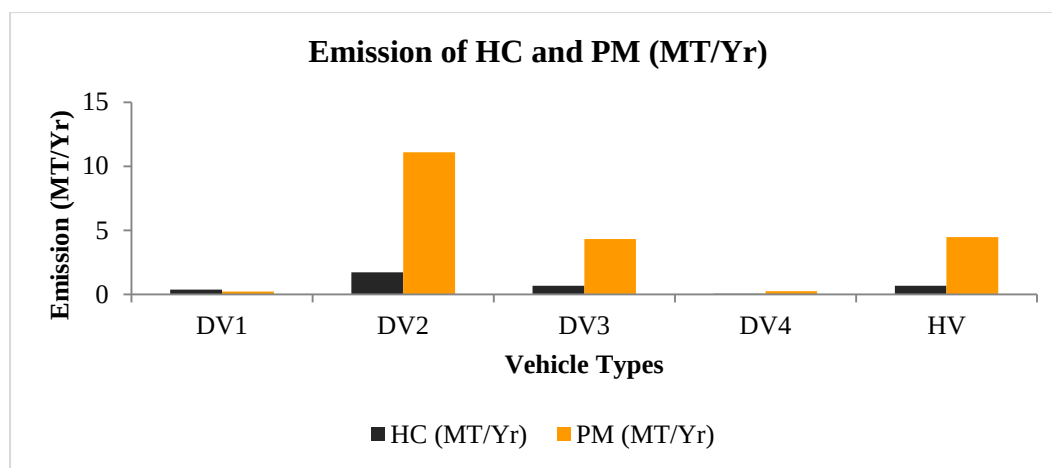


Figure-6.19: HC and PM emission from KMC vehicles for existing SWM system

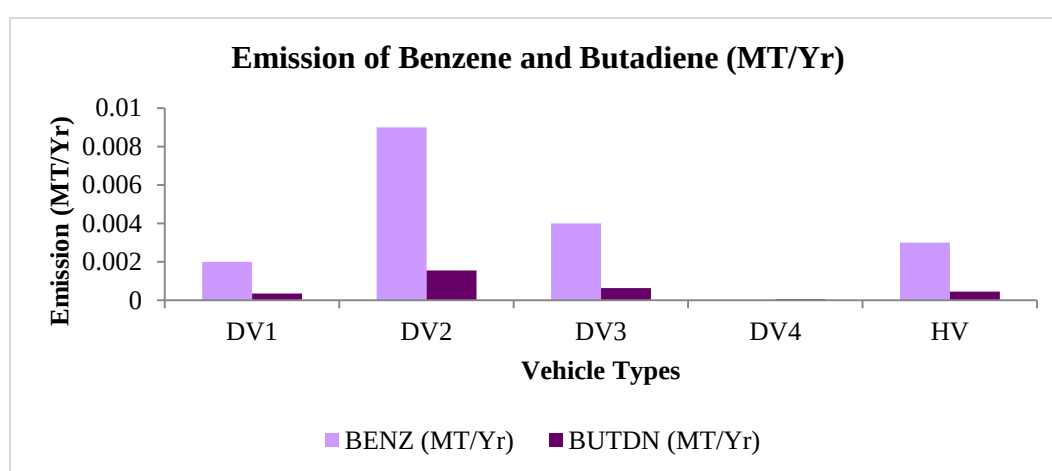


Figure-6.20: Benzene and butadiene emission from KMC vehicles for existing SWM system

6.3.1.3 Pollution generation from Dhapa landfill site

Dhapa landfill contributes both landfill gas generation and landfill leachate generation followed by initiation of heavy metals.

Pollution generation from landfill gas

The major pollutants from landfill gases are CO₂ and CH₄, which cause in the rise of global temperature. The total quantity of gaseous pollutants generation from Dhapa landfill site is ~264908 MT per year. The percentage generation for CO₂ is around 73% (~193499 MT/yr), whereas the CH₄ generation is about 27% (~71409 MT/yr). However, the methane percentage is less here, but the effect of methane is dangerous for the

environmental sustainability. Figure 6.21 depicts the graph analysis of these two pollutants generating from landfill.

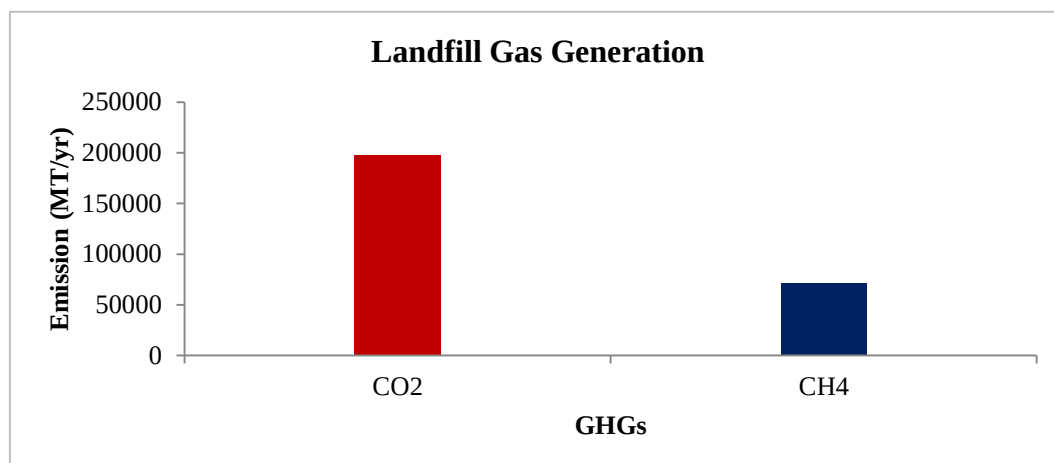


Figure- 6.21: Generation of landfill gases from existing Dhapa landfill site

Pollution generation from landfill leachate and generation of heavy metals

Open dumping of solid waste produces leachate at a rate of 1000 L/m²/year on average, which contains a significant amount of liquid pollutants and heavy metals. The liquid pollutants and heavy metals found in leachates are NH₃-N, As, Hg, Pb, Cr, Cu, Zn, Ni, CN, Cl and Phenol. The generation of Ammoniacal Nitrogen (NH₃-N) and Chloride (Cl) concentration is depicted in figure 6.22. The percentage contributions of NH₃-N, and Cl to total liquid pollutant generation from landfill leachate in the present SWM system are 29.3% (~7 MT/yr), and 70.5% (~17 MT/yr), respectively. Under all conditions, chloride (Cl) in leachate is very mobile, inert, and non-biodegradable (Lindamulla et al., 2022). As a result, it can be used as a potent pollutant indicator as well as a leachate plume tracer element (Kumar et al., 2005; Abunama et al., 2022). High chloride levels in leachate can be induced by the presence of large amounts of soluble salts from anthropogenic sources such as kitchen waste from houses, restaurants, and hotels (Abunama et al., 2022). Slow leaching of nitrogen-producing wastes, combined with no substantial mechanism for N-NH₃ transition in landfills, results in a high concentration of ammoniacal nitrogen in leachate over time (Aziz et al., 2004). Other liquid pollutants including heavy metals contribute only 0.2%, including As, Hg, Pb, Cr, Cu, Zn, Ni, CN, and Phenol. Figure 6.23 depicts the generation of As, Hg, Pb, Cr, Cu, Zn, Ni, CN, and Phenol.

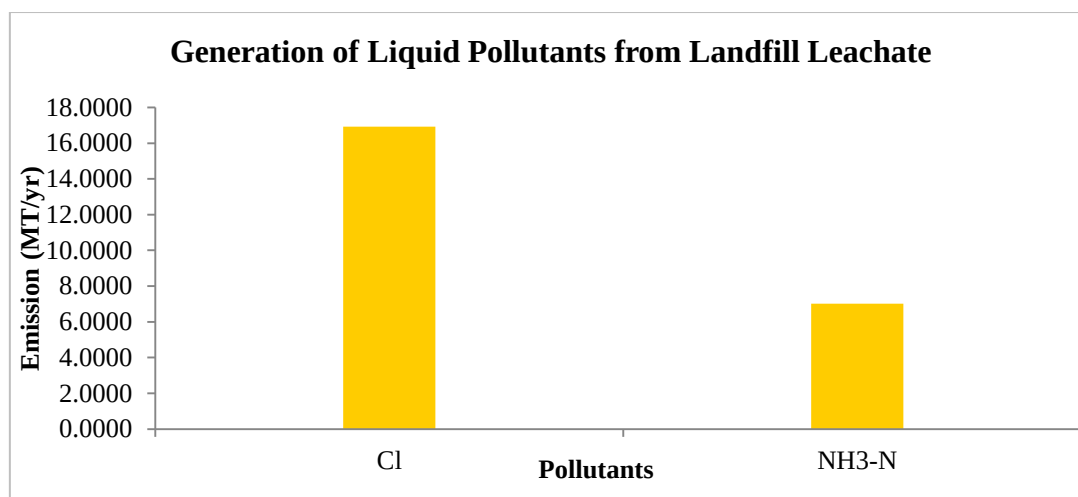


Figure- 6.22: Generation of NH₃-N and Cl from landfill leachate

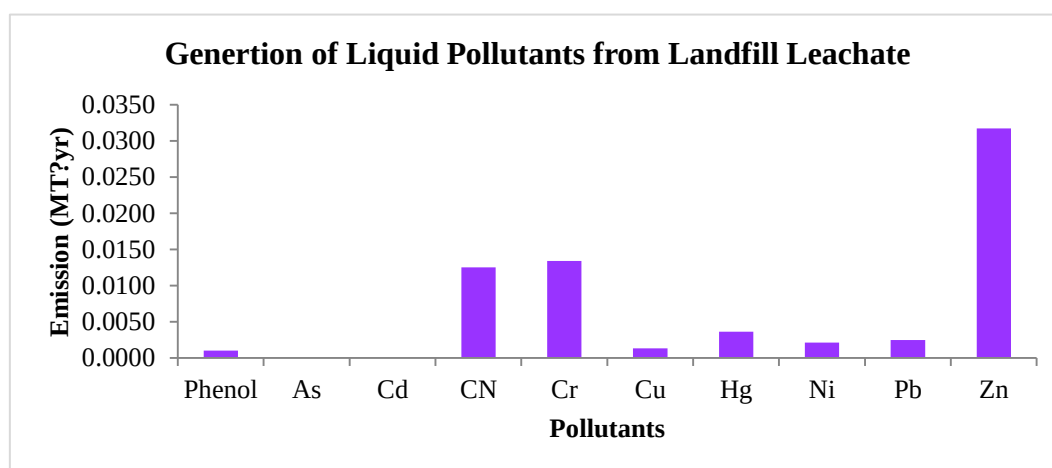


Figure- 6.23: Generation of different heavy metals from landfill leachate

The presence of Hg in leachate suggested that domestic electronic wastes such as batteries, fluorescent lamps, medical thermometers, thermostats, and so on were disposed of alongside MSW (Cheng and Hu, 2012). The presence of Pb-Cr batteries, coloured polythene bags, discarded plastic items, and empty paint containers at the disposal site may have contributed to the presence of Cr in the leachate samples (Parth et al., 2011). Cr is also found in leather tanning and electroplating effluents (Aravind et al., 2015). Zn is primarily obtained via agrochemicals such as fertilizers and pesticides (Parth et al., 2011). These values, however, are almost insignificant, yet their negative consequences are severe enough to endanger human health due to ground water contamination.

6.3.1.4 Impact assessment of existing solid waste management system

a. Computation of weightage for different impact categories

The Analytic Hierarchy Process (AHP), a multi criteria analysis method created by Saaty (1977, 1980, 1990), is used to establish the weightage elements. The US EPA has also suggested using AHP for this purpose (EPA, 1998). The inputs were generated with a 'local perspective'. A team was asked to reach a consensus on the inputs. The group of decision maker included two process engineers, two environmental engineers, one chemist and one ecologist. They were asked to fill the pairwise comparison matrix based on following scale:

1 = equally important or preferred;

3 = slightly more important or preferred;

5 = strongly more important or preferred;

7 = very strongly more important or preferred;

9 = extremely more important or preferred;

Intermediate values (2, 4, 6 and 8) are used to reflect compromise. To reflect the dominance of the other element, the reciprocals are used.

Potential environmental impact category hierarchy for the Analytic Hierarchy Process (AHP) problem is shown in Figure- 2.3. It is a 3-tier problem. The first step is finding the weightages of global, regional and local impact categories. The second step is finding the weightages for sub-categories of the three categories. In the next step, the weightages for the items under the sub-categories Human Toxicity Potential (HTP) and Terrestrial Toxicity Potential (TTP) are found. The weightages of the three levels are combined to generate weightages of each of the nine sub-categories of impact.

The pairwise comparison matrix of importance of environmental impacts between global, regional and local with respect to the local perspective is shown in Table 6.36.

Table- 6.36: The pairwise comparison matrix of importance of environmental impact between global, regional and local with respect to the local perspective

	Global	Regional	Local
Global	1	1/3	1/9
Regional	3*	1	1/5
Local	9**	5***	1

* Regional is slightly more important or preferred than Global (3)

** Local is Extremely more important or preferred than Global (9)

*** Local is Strongly more important or preferred than Regional (5)

Saaty's method (Harker, 1989) computes W as the principle right eigenvector of the matrix A :

$$A_W = \lambda_{max} W$$

where λ_{max} is the maximum eigen value of the matrix,

$$\text{or, } W_i = \frac{\sum_{j=1}^n a_{ij} W_j}{\lambda_{max}} \quad \text{for all } i = 1 \dots n$$

The computation of the principal right eigenvector is accomplished by raising the matrix A to increasing power k and then normalizing the resulting system:

$$W = \lim_{k \rightarrow \infty} \frac{A^k e}{e^T A^k e}$$

where, e is unit column vector and e^T represents the transpose of vector

$$W^1 = A^1 e / e^T A^1 e$$

The pairwise comparison matrix A for the categories was taken as follows:

$$A = \begin{bmatrix} 1 & 0.33 & 0.11 \\ 3 & 1 & 0.2 \\ 9 & 5 & 1 \end{bmatrix}$$

The weightages for each of the element is found out as

$$A^1 e = \begin{bmatrix} 1.444 \\ 4.2 \\ 15 \end{bmatrix} \text{ and } e^T A^1 e = 20.644$$

$$W^1 = \begin{bmatrix} 0.07 \\ 0.203 \\ 0.727 \end{bmatrix}; W^2 = \begin{bmatrix} 0.06935 \\ 0.1773 \\ 0.7533 \end{bmatrix}; W^3 = \begin{bmatrix} 0.0704 \\ 0.178 \\ 0.7516 \end{bmatrix};$$

Check for consistency (with $n = 3$)

$$\lambda_{\max} = \frac{\sum_{j=1}^n a_{ij} W_j}{W_i}$$

$$\begin{aligned} \text{So, } \lambda_{\max} &= \frac{\sum_{j=1}^3 a_{1j} W_j}{W_1} = \frac{a_{11} W_1 + a_{12} W_2 + a_{13} W_3}{W_1} \\ &= \{1 \times 0.0704 + (1/3) \times 0.1780 + (1/9) \times 0.7516\} / 0.0704 \\ &= 3.029 \end{aligned}$$

$$\text{Consistency index, } C. I. = \frac{\lambda_{\max} - n}{(n - 1)} = (3.029 - 3) / (3 - 1) = 0.0145$$

The consistency ratio is found out by,

$$C. R. = \frac{C. I.}{R. I.}, \text{ where, } R. I. = \text{Random index} = 0.58, \text{ for } n = 3$$

[Ref. Table 22 of Harker, P.T., 1989]

So, $C.R. = 0.025 < 0.1$ Hence o.k.

Hence, the relative weightages of the global, regional and local categories are: 0.0704, 0.1780 and 0.7516 respectively.

Under ‘Global’ category, the components are GWP and ODP and the relative weightages were considered to be 0.5 and 0.5 respectively.

As an example, the individual weightage of GWP found out from the weightages of the different tiers = $(0.0704 \times 0.5) = 0.0352$.

Under ‘local’ category, the pairwise comparison matrix of HTP, TTP and ATP with respect to the local perspective is shown in Table 6.37.

Table- 6.37: The pairwise comparison matrix of HTP, TTP and ATP with respect to the local perspective

	HTP	TTP	ATP
HTP	1	3	2
TTP	1/3	1	1/2
ATP	1/2	2	1

$$W^4 = A^4 e / e^T A^4 e \quad \text{or, } W^4 = \begin{bmatrix} 0.5396 \\ 0.1634 \\ 0.2970 \end{bmatrix};$$

$$\lambda_{\max} = 3.009; C.I. = 0.0045; C.R. = 0.0078 < 0.1 \text{ Hence o.k.}$$

Hence, the relative weightages of the HTP, TTP, and ATP are: 0.5396, 0.1634 and 0.2970 respectively.

As an example, the individual weightage of HTP found out from the weightages of the different tiers = $(0.7516 \times 0.5396) = 0.4056$

Similarly under ‘regional’ category, the components are AP and POCP and the *relative weightages* were found out to be 0.4 and 0.6, respectively.

Also under HTP, the components are HTPI and HTPE and their *relative weightages* were found out to be 0.5 and 0.5, respectively.

Under TTP, the components are TTPL and TTPG and their *relative weightages* were found out to be 0.6 and 0.4, respectively.

As an example, the individual weightage of HTPI found out from the *relative weightages* of the different tiers

$$W_{HTPI} = (0.7516 \times 0.5396 \times 0.5) = 0.2028$$

Similarly the weightages for the other eight sub-categories are found out and are shown in Table- 6.38, below.

Table- 6.38: Relative weightages of the impact categories in local perspective

Impact Category	Global		Regional		Local				
Sub-category	GWP	ODP	AP	POCP	HTPI	HTPE	TTPL	TTPG	ATP
Relative Weightages	0.0704		0.178		0.7516				
	0.0352	0.0352	0.0712	0.1068	0.2028	0.2028	0.07368	0.04912	0.2232

The weightage of global category is 7.04% which is equally divided into its sub-category Global Warming Potential (GWP) and Ozone Depletion Potential (ODP). The human toxicity potential has the largest weightage of 40.56% which is equally divided into its sub- categories Human Toxicity Potential by Ingestion (HTPI) and Human Toxicity Potential by Inhalation (HTPE). Aquatic Toxicity Potential (ATP) has the largest weightage of 22.32% among all the sub- categories. Weightage of global category is 7.04% which is small compare with the local category has the largest weightage of 75.16%. The weightages of all these categories are quite comparable with those derived in EPA report (1998) considering local perspectives.

b. Computation of equivalency factor for the municipal solid waste pollutants

Equivalency factors for an impact category can be evaluated based on level II (Equivalency assessment) or level III (Toxicity, Persistence and Bioaccumulation Profile, i.e. TPBP) impact assessment depending upon availability of data. Equivalency assessment includes approaches that translate inventory items into common units (via the use of equivalency factors) of impact that can either be evaluated to compare the

individual contributions of inventory items to impacts or resulting equivalency units to assess the collective contribution of items of impacts. Equivalency factor are based on mechanisms of impact that relate the group of inventory items to specific impacts.

Equivalency units can be aggregated within impact categories to provide an estimate of the total level of impact. This method essentially consists of multiplying the values for groups of inventory items (e.g., greenhouse gases) by the appropriate equivalency factors, thus expressing the inventory items in equivalency units (e.g., global warming potential). Toxicity, persistence, and bioaccumulation assessment includes those approaches that are more comprehensive than the Tier 2 (level II) assessment approach because they take into account not only hazard but also ecosystem and organism exposure information. Specifically, these models often focus on properties such as toxicity as an indicator of hazard; and persistence and bioaccumulation as indicators of exposure. The main premise of these models is to use information on the inherent properties of substances to assess the potential impacts of chemical substances on the environment (EPA 1995b). In this case, level II is used for GWP, AP, HTPI, HTPE, TTPL and TTPG, while level III is used for ATP. The choice is made based on availability of data.

Global category

Global Warming Potential (GWP)

The GWP of a substance is the ratio between the contribution to the heat radiation absorption resulting from the instantaneous release of 1 unit mass of a greenhouse gas and an equal amount of emission of CO₂ integrated over time.

Contributing chemical is CO₂ only and the heat radiation absorption of CO₂ with respective to CO₂ is 1. So equivalency factor of CO₂ for global warming potential is 1. Global Warming Potential relative to CO₂, with time horizon of 20, 100 and 500 years are given in Table 6.39.

This data is adapted from the IPCC Fifth Assessment Report, 2014 which is the latest assessment report and Heijungs (1992b).

Table- 6.39: Equivalency factor for global warming potential

Gases	EF (20 years)	EF (100 years)	EF (500 years)
CO ₂	1	1	1
CH ₄	84	28	6.5
CH ₂ Cl ₂	54	9	5

In the present system, Global Warming Potential (GWP) is calculated for 100 years. So, the value of Equivalency Factor (EF) of 100 years is taken for calculation of Global Warming Potential (GWP).

Ozone Depleting Potential (ODP)

The substances which contribute to the depletion of ozone layer parameters in a single effect score, they have been considered as Ozone Depletion Potential (ODP). The ODP is a relative parameter which uses CFC-11 as a reference. The steady state ozone depletion per unit mass of gas emitted to the atmosphere annually is calculated relative to that unit mass of CFC level. In the existing system of solid waste management of Kolkata, there are no such gases are generate which can cause the breakdown of ozone layer. So, ODP cannot be calculated.

Regional category

Acidification Potential (AP)

AP is defined as the ratio between the number of potential H⁺ equivalents per unit mass of substance release and the number of potential H⁺ equivalents per unit mass of SO₂. The contributing chemicals to AP are SO₂, NO₂ and NH₃. The equivalency factors for AP are shown in Table 6.40. This data is taken from Heijungs (1992b) and Hua Li et al, 2015.

Table- 6.40: Equivalency factor for acidification potential

Gases	Reaction Equation	No. of potential H ⁺	Mass (Kg/mole)	No. of potential H ⁺ per unit mass	Equivalency Factor (EF)
SO ₂	SO ₂ +H ₂ O+O ₃ = 2H ⁺ +SO ₄ ⁻ +O ₂	2	64	1/32	1
NO ₂	NO ₂ +1/2H ₂ O+1/4O ₂ = H ⁺ +NO ₃ ⁻	1	46	1/46	0.7
NH ₃	NH ₃ +2O ₂ = H ⁺ +NO ₃ ⁻ +H ₂ O	1	17	1/17	1.88

Photo- chemical Ozone Conversion Potential (POCP)

The POCP is relative to ethylene (C₂H₄). Contributing gases which are responsible for the changes of ozone concentration in the atmosphere are methane (CH₄), Dichloromethane (CH₂Cl₂) and Toluene (C₆H₅CH₃). As the amount of generation of other gases like acetone, benzene is less in the existing system, so, for calculation contribution of these gases is not considered.

Table- 6.41: Equivalency factor for photo- chemical ozone conversion potential

Gases	Equivalency Factor (EF)
CH ₄	0.007
CH ₂ Cl ₂	0.010
C ₆ H ₅ CH ₃	0.563

In this present study only contribution of CH₄ is considered as the generation of other gasses is very less. Data is taken from Heijungs (1992b).

Local category

In local category, consideration of human toxicity and terrestrial toxicity has been made in this study. Human toxicity is assessed correlating the emissions to the tolerable daily intake, acceptable daily intake, tolerable concentration in air, maximum tolerable risk level and air quality guidelines. Human toxicological classification depends on the substance and the environmental medium concerned e.g., for atmosphere (HTPE) and for water (HTPI). The assessment of ecotoxic substances on species in the ecosystem is based on maximum tolerable concentration. Terrestrial toxicological classification depends on

the substance and the environmental medium concerned e.g., for atmosphere (TTPG) and for water (TTPL).

Human toxicity potential by ingestion (HTPI) and terrestrial toxicity potential by liquids (TTPL)

The equivalency factors for HTPI and TTPL are the same (which is shown in table 6.42) as both are based on the LD₅₀ value (Young and Cabezas, 1999). LD₅₀ is the amount of a chemical that, when given orally as a single dose, will kill 50% of a group of rodents within 14 days. Dose is defined as the mass of the chemical per kilogram of the animal's body weight (i.e., rat). The information for the rat LD₅₀ has been obtained from several websites and is these are: Arsenic & Chloride: Whs.rocklinusd.org; The LD₅₀ of chloride is that for sodium chloride. Mercury & Cyanide: chem.libretexts.org; Lead: Inchem.org; Cadmium: Chemistry LibreTexts; Total Chromium: assets.publishing.service.gov.uk; Copper: Npic.orst.edu; The LD₅₀ of copper is that for copper sulphate pentahydrate and the average of 450 to 790 mg/kg is taken. Zinc: (Egorova & Ananikov, 2017); Nickel: pubmed.ncbi.nlm.nih.gov; Fluoride: Euro.who.int; Nitrate: Atsdr.cdc.gov; The LD₅₀ of nitrate is that for sodium nitrate. Sulphate: Finarchemicals.com; Phenolic Compounds: Ncbi.nlm.nih.gov; Ammoniacal Nitrogen: Rsc.aux.eng.ufl.edu.

Table 6.42: The equivalency factors for HTPI and TTPL

Chemical Components	LD₅₀ for rat, oral (mg/Kg body weight of rat)	Equivalency Factor (1/LD₅₀)
Arsenic (As)	15	0.0667
Mercury (Hg)	1	1
Lead (Pb)	1.2	0.8333
Cadmium (Cd)	7080	0.00014
Total Chromium (Cr)	399	0.0025
Copper (Cu)	620	0.0016
Zinc (Zn)	725	0.00138
Nickel (Ni)	705	0.00142
Cyanide (CN)	6.4	0.1563
Chloride (Cl)	3000	0.00033
Fluoride (F)	51.6	0.01938
Phenolic Compounds (Phn)	525	0.0019
Ammoniacal Nitrogen as (N)	350	0.00286

Human toxicity potential by inhalation (HTPE) and terrestrial toxicity potential by Gas (TTPG)

The equivalency factor of gases varies with different categories. The equivalency factors for HTPE and TTPG are the same (Table 6.43) as both are based on the TLV value (Young and Cabezas, 1999). TLV is the time weighted average of threshold limit value, which is the maximum amount of substance a worker can be exposed to over an 8 hour per day without any health damage. These data are taken from <http://www.cdc.gov/niosh/> (NIOSH); www.osha.gov (OSHA); www.omfra.gov.on.ca and <http://labor.ny.gov>. The TLV in mg/m^3 unit are the approximate value. The equivalency factors are shown in table below.

The TLV for chemical substances is defined as a concentration in air, typically for inhalation or skin exposure. Its units are in parts per million (ppm) for gases and in milligrams per cubic meter (mg/m^3) for particulates such as dust, smoke and mist. The basic formula for converting between ppm and mg/m^3 for gases is $\text{ppm} = [(\text{mg}/\text{m}^3) \times 24.45] / \text{molecular weight}$. This formula is not applicable to airborne particles.

Table 6.43: The equivalency factors for HTPE and TTPG

Chemical Compound	TLV (ppm)	TLV (mg/m^3)	Equivalency Factor (1/TLV)
Methane (CH_4)	1000	654.397	0.00153
Carbon Dioxide (CO_2)	5000	8997.955	0.000111
Sulphur Dioxide (SO_2)	5	13.0879	0.0764
Nitrogen Dioxide (NO_2)	5	9.407	0.10630
Ammonia (NH_3)	50	34.765	0.02876
Hydrogen Sulphide (H_2S)	10	13.9059	0.07191
Carbon Monoxide (CO)	50	57.2597	0.01746
Methylene Chloride (CH_2Cl_2)	25	86.912	0.01151
Toluene ($\text{C}_6\text{H}_5\text{CH}_3$)	200	752.556	0.001329
Acetone	1000	2372.188	0.00042
Benzene	1	3.19018	0.3135
Chloroform	50	244.376	0.00409
Ethyl Benzene	100	433.538	0.00231
Tetrachloroethylene	100	678.937	0.001473
Vinyl Chloride	1	2.55624	0.39120
Styrene	100	425.3579	0.00235
Vinyl Acetate	10	35.1738	0.02843

Aquatic Toxicity Potential (ATP)

The contributing chemicals and their aquatic toxicity potential values are shown in table 6.44. The aquatic toxicity potential of these chemicals calculated considering “Toxicity, Persistence and Bioaccumulation Profile (TPBP)” and required data are taken directly from table 4.1 of EPA 1998 document. The sample calculation for phenol has been discussed in annexure 6.7.

Table 6.44: The equivalency factors for ATP

Chemical Compound	Equivalency Factor
Arsenic (As)	16.78
Mercury (Hg)	29.8
Lead (Pb)	24.53
Cadmium (Cd)	36.25
Total Chromium (Cr)	16.386
Copper (Cu)	30
Zinc (Zn)	20.615
Nickel (Ni)	16.443
Cyanide (CN)	0
Chloride (Cl)	22.5
Fluoride (F)	5.718
Phenolic Compounds (Phn)	11.4
Ammoniacal Nitrogen as (N)	21.36

The equivalency factors of all the gaseous and liquid pollutants are tabulated below.

Table- 6.45: Equivalency factors (EF_{ij}) of gaseous pollutants

Impact Sub-category (j)	Gaseous Pollutants										
	CO ₂	CH ₄	SO ₂	NO ₂	NH ₃	H ₂ S	CO	HC	PM	BENZ	BUTDN
GWP	1	28									
AP			1	0.7	1.88						
POCP		0.007									
HTPE	0.000111	0.00153	0.0764	0.1063	0.02876	0.07191	0.01746	0.00153	0.00015	0.3135	0.500
TTPL											
TTPG	0.000111	0.00153	0.0764	0.1063	0.02876	0.07191	0.01746	0.00153	0.00015	0.3135	0.500

Table- 6.46: Equivalency factors (EF_{ij}) of liquid pollutants

Liquid Pollutants	Impact Sub- category		
	HTPI	ATP	TTPL
As	0.0667	16.78	0.0667
Hg	1.000	29.8	1.000
Pb	0.8333	24.53	0.8333
Cd	0.00014	36.25	0.00014
Cr	0.0025	16.386	0.0025
Cu	0.0016	30.00	0.0016
Zn	0.00138	20.615	0.00138
Ni	0.00142	16.443	0.00142
CN	0.1563	0	0.1563
F	0.01938	5.718	0.01938
Phn	0.0019	11.4	0.0019
Cl	0.00033	22.5	0.00033
NH₃-N	0.00286	21.36	0.00286

c. Computation of normalizing values for different impact categories

Equivalency factor (EF_{ij}) for a pollutant i and impact (sub) category j has already been estimated. The procedure for calculation of normalizing values has been presented along with sample calculations.

Global category:

Under global impact category, for all sub-category j, the normalizing value is given by

$$N_j = \sum_k (I_{kj} \times EF_{kj})$$

Where, I_{kj} is the global annual inventory of pollutant k with effect in global (sub) category j; and $\sum_k$ includes all pollutants for the global (sub) category j, whether included in this study or not.

Ozone Depleting Potential (ODP)

There are no such gases that can break down the ozone layer produced by current solid waste management system of kolkata. Therefore, ODP cannot be computed.

Regional category

Under regional impact category, for all sub-category j, the normalizing value is given by

$$N_j = \sum_k (I_{kj} \times \text{Regional scale factor} \times EF_{kj})$$

Where, I_{kj} is the maximum annual inventory of pollutant k in the region (state) responsible for impact (sub) category j; Regional scale factors are related to sensitivity of the region to the impact (sub) category. In the present work pertaining to India, since no such factors are yet defined, all regional scale factors are taken as unity; and $\sum_k$ denotes summation over all pollutants responsible for impact (sub) category j included in this study.

Acidification Potential (AP)

The region considered is the state of West Bengal. The gaseous pollutant SO₂, NO_x and NH₃ are responsible for acidification potential impact sub-category. Emission data for SO₂, NO_x and NH₃ in the West Bengal state are required as inventory of pollutants in the region.

As the emission data are not available directly, a calculated approach has been considered as described below. From the *Urbanemissions.info*, the annual emission of SO₂ from all sectors of Kolkata and Asansol in the year 2018 reported 10,400 and 12,700 MT respectively. And the annual emission of NO₂ from all sectors of Kolkata and Asansol in the year 2018 reported 1,43,650 and 1,60,350 MT respectively. Considering sector wise area of Kolkata and Asansol and their corresponding ambient air concentration calculating total emissions of West Bengal using weightage average method is justified. From 2020 onwards due to covid19 lockdown, various sectors was not operational so on an average of 7-10% increase of SO₂ emission in West Bengal region as on 2022 have been estimated. As the emission data is as on 2017-18, a 7.68% increased trend have been followed (STATE ENVIRONMENT PLAN: WEST BENGAL). Hence net calculated

SO₂ emission as on 2022 is 24.4×10^8 kg/year. The calculation is shown in *annexure 6.8*. As per the trend of growth in vehicle numbers from 2018-2022, it is increased by 14-27% (The Economic Times). However, from recent trends, percentage growth of NO₂ with respect to 2003 for West Bengal lies in between $3.37 \pm 1.18\%$ i.e., around 5%. So, for 2022 an increasing trend of 15-20% for NO₂ may be assumed. So, calculated NO₂ emission for West Bengal region is 40.1×10^{10} kg/year. The calculation is shown in *annexure 6.9*.

NH₃ generation from Dhapa landfill site in 2022 is 13244×10^3 kg/year. As the total solid waste generation in West Bengal is 3 times more than waste generated from Kolkata, NH₃ emission from all landfill of West Bengal can be estimated as 3 times NH₃ generation of Dhapa i.e., $(3 \times 13244 \times 10^3) = 39732 \times 10^3$ kg/yr. Considering other sources of NH₃ emission like agricultural field, industrial process and vehicular emission, the net NH₃ generation have been calculated by multiplying 2 times more than the amount which is emitting from the landfill. Net NH₃ generation = $(2 \times 39732 \times 10^3) = 0.79 \times 10^8$ kg/yr.

Table- 6.48: Normalizing value for acidification potential

Chemical	Max regional emission x scaling factor* (kg/yr.)	Acid rain equivalency factor	AP impact (Kg/Yr.)
SO ₂	24.4×10^8	1	24.4×10^8
NO _x as (NO ₂)	4.01×10^{10}	0.7	2.807×10^{10}
NH ₃	0.79×10^8	1.88	1.485×10^8
Normalizing value for AP = 3.066×10^{10} kg/year			

* All regional scale factors are taken as unity (Heijungs, 1992a)

Photo-chemical ozone conversion potential (POCP)

The region considered is the state of West Bengal. Methane (CH₄), Methylene Chloride (CH₂Cl₂) and Toluene (C₆H₅CH₃) are responsible for photo- chemical ozone conversion potential impact sub-category. Emission data for CH₄, CH₂Cl₂ and C₆H₅CH₃ in the West Bengal state are required as inventory of pollutants in the region. For West Bengal region maximum regional emission for CH₄ is not given directly. However, GHG emissions from the state of West Bengal grew from 114.5 Mt CO₂-e to 171.7 Mt CO₂-e at an estimated CAGR of 5.19% from 2005 to 2013. Assuming 80% CO₂ and 20% CH₄ as a major contributing GHG gas, calculated methane emission as on 2022 is 0.845×10^{10}

kg/year (GHG Platform, 2013), (Our World in Data). The detailed calculation is shown in annexure 6.10.

The maximum regional emission for CH_2Cl_2 and $\text{C}_6\text{H}_5\text{CH}_3$ are not given directly for West Bengal. CH_2Cl_2 and $\text{C}_6\text{H}_5\text{CH}_3$ emission from Dhapa landfill site in 2022 is 10921×10^3 kg/year and 15800×10^3 kg/year respectively. As the total solid waste generation in West Bengal is 3 times more than waste generated from Kolkata, CH_2Cl_2 emission from all landfill of West Bengal can be estimated as 3 times CH_2Cl_2 generation of Dhapa i.e., $(3 \times 10921 \times 10^{10}) = 32763 \times 10^3$. Considering other sources of CH_2Cl_2 emission like industrial process, energy sector, the net CH_2Cl_2 generation have been calculated by multiplying 2 times more than the amount which is emitting from the landfill. Net CH_2Cl_2 generation = $(2 \times 32763 \times 10^3) = 0.655 \times 10^8$ kg/yr. The same way, net $\text{C}_6\text{H}_5\text{CH}_3$ emission = $(3 \times 2 \times 15800 \times 10^3) = 0.948 \times 10^8$ kg/yr.

Table-6.49: Normalizing value for photo- chemical ozone conversion potential

Chemical	Max regional emission x scaling factor* (kg/yr)	POCP equivalency factor	POCP impact (kg/yr)
CH_4	84.5×10^8	0.007	59.15×10^6
CH_2Cl_2	0.655×10^8	0.01	0.655×10^6
$\text{C}_6\text{H}_5\text{CH}_3$	0.948×10^8	0.563	53.37×10^6
Normalizing value for POCP = 1.132×10^8 kg/year			

*All regional scale factors are taken as unity (Heijungs, 1992a)

Local category

Under local impact category, for all sub-category j, the normalizing value is given by

$$N_j = \sum_k (I_{kj} \times \text{Cluster multiplier} \times EF_{kj})$$

where I_{kj} is the largest annual facility emission of pollutant k responsible for impact (sub) category j in the region; Cluster multiplier is 1.5, to account for facility clustering effect; and $\sum_k$ denotes summation over all pollutants responsible for impact (sub) category j included in this study.

The local sub-categories are Human Toxicity Potential by Ingestion (HTPI), Human Toxicity Potential by Inhalation (HTPE), Terrestrial Toxicity Potential by Liquid (TTPL), Terrestrial Toxicity Potential by Gas (TTPG) and Aquatic Toxicity Potential (ATP). CO₂, CH₄, SO₂, NO₂, NH₃, H₂S, CH₂Cl₂, C₆H₅CH₃, CO, Acetone, benzene, chloroform, ethyl benzene, tetrachloroethylene, vinyl chloride, styrene and vinyl acetate contributes to HTPE and TTPG while Arsenic, Mercury, Lead, Cadmium, Total Chromium, Copper, Zinc, Nickel, Cyanide, Chloride, Fluoride, Nitrate, Sulphate, Ammoniacal Nitrogen and phenol contributes to HTPI, TTPL, and ATP.

Human Toxicity Potential by Ingestion (HTPI)

Kolkata and its surrounding area are considered as the Local category. The maximum facility discharge of chemicals contributing HTPI is not given directly. Dhapa landfill has been considered as a point source of maximum facility discharge of liquid pollutant. The contributing compounds responsible for this category are the chemicals including heavy metals which emitting from the landfill leachate shown in table 6.50. The maximum facility discharge calculation is shown in *annexure 6.11 (ref. table A.6.1)*.

Human Toxicity Potential by Inhalation (HTPE)

Farakka Thermal Power Plant is the largest emitter of SO₂, NO_x, and CO₂ with largest thermal power generation capacity of 2100 MW in the region (Wikipedia, 2020). Based on the coal consumption norm [specified by Minimal National Standards for Thermal Power Plant, India (CPCB, 1986)] and the composition of the coal used by above power plant [(Pit et al., 2016), (Composition-of-lignite-coal)], SO₂, NO_x and CO₂ emissions from the plant are estimated as 26488×10^3 , 28741×10^3 and 2.456×10^{10} kg/year, respectively. The detailed calculation is shown in *annexure 6.12*.

The normalizing value of contributing gases of human toxicity potential by inhalation is shown in Table 6.52. The emitting amount of all contributing gases except SO₂, NO₂ and CO₂ are taken from the landfill as max facility emission was not directly given for a particular industry.

Table-6.50: Normalizing value for human toxicity potential by ingestion (HTPI)

Contributing Chemicals	Max facility discharge (kg/yr)	HTPI Equivalency factor	Facility clustering multiplier	HTPI impact (kg/yr)
Arsenic (As)	8.94	0.0667	1.5	0.8944
Mercury (Hg)	343.2	1	1.5	514.8
Lead (Pb)	171.6	0.8333	1.5	214.49
Cadmium (Cd)	1.5	0.00014	1.5	0.00032
Total Chromium (Cr)	1288.8	0.0025	1.5	4.83
Copper (Cu)	98.4	0.0016	1.5	0.2362
Zink (Zn)	3158.4	0.00138	1.5	6.5379
Nickel (Ni)	120	0.00142	1.5	0.2556
Cyanide (CN)	7.08	0.1563	1.5	1.6599
Chloride (Cl)	1060560	0.00033	1.5	524.98
Fluoride (F)	312	0.01938	1.5	9.069
Nitrate (NO ₃)	2033.28	0.00079	1.5	2.4094
Sulphate (SO ₄)	95894.4	0.00078	1.5	112.196
Phenolic Compounds (Phn)	60	0.0019	1.5	0.171
Ammoniacal Nitrogen as (N)	525360	0.00286	1.5	2253.79
Normalizing value for HTPI = 3646.33 kg/year				

Table- 6.51: Normalizing value for human toxicity potential by inhalation (HTPE)

Contributing Gas	Max facility emission(kg/yr)	HTPE equivalency Factor	Facility clustering multiplier	HTPE impact (Kg/yr)
Methane (CH ₄)	5.927×10 ⁸	0.00153	1.5	1360246.5
Carbon Dioxide (CO ₂)	2.456 ×10 ¹⁰	0.000111	1.5	4089240
Sulphur Dioxide (SO ₂)	26.488 × 10 ⁶	0.0764	1.5	3035524.8
Nitrogen Dioxide (NO ₂)	28.741 ×10 ⁶	0.1063	1.5	4582752.45
Ammonia (NH ₃)	13.244 × 10 ⁶	0.02876	1.5	571346.16
Hydrogen Sulphide (H ₂ S)	0.233 × 10 ⁶	0.07191	1.5	25132.545
Carbon Monoxide (CO)	2.091 × 10 ⁶	0.01746	1.5	54763.29
Methylene Chloride (CH ₂ Cl ₂)	10.921 × 10 ⁶	0.01151	1.5	188551.065
Toluene (C ₆ H ₅ CH ₃)	15.8 × 10 ⁶	0.001329	1.5	31497.3
Acetone	2.091 × 10 ⁶	0.00042	1.5	1317.33
Benzene	0.929 × 10 ⁶	0.3135	1.5	436862.25
Chloroform	0.232 × 10 ⁶	0.00409	1.5	1423.32
Ethyl Benzene	3.95 × 10 ⁶	0.00231	1.5	13686.75
Tetrachloroethylene	4.415 × 10 ⁶	0.001473	1.5	9754.9425
Vinyl Chloride	1.162 × 10 ⁶	0.3912	1.5	681861.6
Styrene	0.697 × 10 ⁶	0.00235	1.5	2456.925
Vinyl Acetate	2.324 × 10 ⁶	0.02843	1.5	99106.98
Normalizing value for HTPE = 15.19 × 10 ⁶ Kg/yr.				

Terrestrial Toxicity Potential by Liquids (TTPL)

Normalizing value for TTPL of contributing chemicals are same as HTPI, because impact potentials of these chemicals are the same as HTPI (Ref. table- 6.50).

Terrestrial Toxicity Potential by Gas (TTPG)

The largest annual facility emission of the gases which are responsible for this category and the normalizing value of the sub category are same as HTPE (Ref. table- 6.51)

Aquatic Toxicity Potential (ATP)

ATP impact values for the contributing chemicals are shown in Table- 6.52. The calculation of maximum facility discharge is shown in *annexure 6.7*.

Table- 6.52: Normalizing value for aquatic toxicity potential (ATP)

Contributing Chemicals	Max facility discharge (kg/yr)	ATP equivalency factor	Facility clustering multiplier	ATP impact (kg/yr.)
Arsenic (As)	8.94	16.78	1.5	225.02
Mercury (Hg)	343.2	29.8	1.5	15341.04
Lead (Pb)	171.6	24.53	1.5	6314.02
Cadmium (Cd)	1.5	36.25	1.5	81.56
Total Chromium (Cr)	1288.8	16.386	1.5	31677.42
Copper (Cu)	98.4	30	1.5	4428
Zink (Zn)	3158.4	20.615	1.5	97665.6
Nickel (Ni)	120	16.443	1.5	2959.74
Cyanide (CN)	7.08	0	1.5	0
Chloride (Cl)	1060560	22.5	1.5	35793900
Fluoride (F)	312	5.718	1.5	2676.02
Nitrate (NO ₃)	2033.28	15.822	1.5	48255.83
Sulfate (SO ₄)	95894.4	15.054	1.5	2165391.45
Phenolic Compounds (Phn)	60	11.4	1.5	1026
Ammoniacal Nitrogen as (N)	525360	21.36	1.5	16832534
Normalizing value for ATP = 5.5×10^7 kg/yr				

The normalizing values of different sub- categories are shown in Table-

Table- 6.53: Normalizing values (Nj) for different Sub- categories

Impact Sub-Category	Normalizing Value (kg/yr)
GWP	5.77×10^{10}
ODP	-
AP	3.066×10^{10}
POCP	1.132×10^8
HTPE	15.19×10^6
HTPI	3646.33
TTPG	15.19×10^6
TTPL	3646.33
ATP	5.5×10^7

6.3.1.5 Potential environmental impact (PEI) in different category for existing MSW model in Kolkata

In this study, Potential Environmental Impact (PEI) is calculated based on LCIA approaches which are a part of LCA (Life Cycle Assessment). LCA is used to determine a product or process' overall environmental effect across all of the activities that take place during its life cycle. It offers a very efficient and useful tool that effectively supports the decision-making of a waste management policy, schemes, and practices.

The estimation of PEI based on LCIA approach incorporates interaction of both mass and energy flows to environment due to operations. It considers three impact categories (EPA, 1998): (1) global, (2) regional, and (3) local. Global category primarily refers to the concern of the whole world and appropriate worldwide pollutant inventories are considered for evaluating the PEI component from this impact category. Similarly, regional category refers to the region (state). Local category refers to the locality (Bandyopadhyay et. al., 2001, Dutta and Koshti, 2002).

The total PEI is 8.37×10^{-3} for the existing MSWM system. PEI is shown below in table 6.54 for various categories.

Table- 6.54: PEI contribution of gaseous pollutants of existing SWM system

Gaseous Pollutants (i)	Impact Sub- category (j)						Pollutant wise total PEI
	GWP	ODP	AP	POCP	HTPE	TTPG	
CO ₂	1.21×10^{-7}				4.01×10^{-4}	9.72×10^{-5}	4.98×10^{-4}
CH ₄	1.22×10^{-6}			4.72×10^{-4}	1.99×10^{-3}	4.82×10^{-4}	2.95×10^{-3}
SO ₂			2.40×10^{-9}		1.44×10^{-6}	3.49×10^{-7}	1.79×10^{-6}
NO _x			3.66×10^{-8}		4.36×10^{-5}	1.06×10^{-5}	5.42×10^{-5}
BENZ					9.82×10^{-8}	2.38×10^{-8}	1.22×10^{-7}
CO					4.03×10^{-6}	9.75×10^{-7}	5.00×10^{-6}
HC					9.64×10^{-8}	1.53×10^{-8}	1.12×10^{-7}
BUTDN					2.74×10^{-8}	6.64×10^{-9}	3.40×10^{-8}
PM					5.55×10^{-10}	1.35×10^{-10}	6.90×10^{-10}
Category wise total PEI	1.34×10^{-6}	0.00	3.90×10^{-8}	4.72×10^{-4}	2.44×10^{-3}	5.92×10^{-4}	3.51×10^{-3}

Table- 6.55: PEI contribution of liquid pollutants of existing SWM system

Liquid Pollutants (i)	Impact Sub- category (j)			Pollutant wise total PEI
	HTPI	TTPL	ATP	
Phenol	1.14×10^{-7}	4.14×10^{-8}	5.03×10^{-8}	2.05×10^{-7}
As	4.79×10^{-7}	1.74×10^{-7}	8.88×10^{-9}	6.62×10^{-7}
Cl	3.21×10^{-4}	1.17×10^{-4}	1.61×10^{-3}	2.05×10^{-3}
CN	1.12×10^{-4}	4.08×10^{-5}	0.00000	1.53×10^{-4}
Cr	1.93×10^{-6}	7.00×10^{-7}	9.30×10^{-7}	3.56×10^{-6}
Cu	1.23×10^{-7}	4.45×10^{-8}	1.69×10^{-7}	3.36×10^{-7}
Hg	2.08×10^{-4}	7.57×10^{-5}	4.57×10^{-7}	2.85×10^{-4}
Ni	1.73×10^{-7}	6.28×10^{-8}	1.47×10^{-7}	3.83×10^{-7}
Pb	1.20×10^{-4}	4.35×10^{-5}	2.59×10^{-7}	1.63×10^{-4}
Zn	2.51×10^{-6}	9.13×10^{-7}	2.77×10^{-6}	6.19×10^{-6}
NH ₃ -N	1.15×10^{-3}	4.18×10^{-4}	6.33×10^{-4}	2.20×10^{-3}
Category wise total PEI	1.92×10^{-3}	6.97×10^{-4}	2.24×10^{-3}	4.86×10^{-3}

In the existing system, PEI contribution of gaseous pollutant is ~42% and the liquid pollutant contributes the rest ~58% PEI. (Ref. table 6.54 and 6.55)

Category wise PEI contribution of different gaseous and liquid pollutants is depicted in figure 6.24 and 6.25.

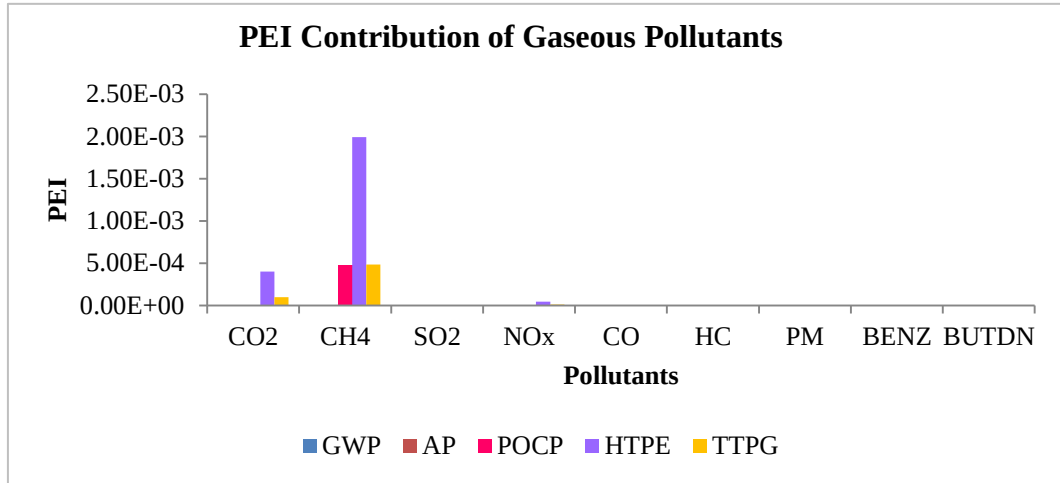


Figure- 6.24: Category wise PEI contribution of different gaseous pollutants in local perspective

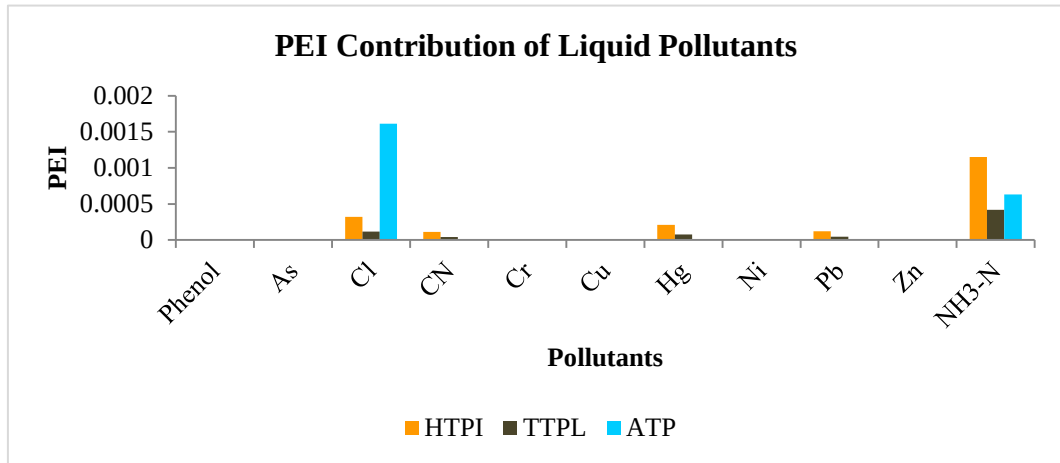


Figure- 6.25: Category wise PEI contribution of different liquid pollutants in local perspective

Figure 6.24 shows that among all gaseous pollutants, CH₄ contributes the most PEI, accounting for approximately ~84% of the total PEI contributed by the gaseous pollutants. CO₂, NO_x, and CO contributes ~14.2%, ~1.5%, and ~0.14%, respectively. Other gases contributed the remaining 0.16% of PEI w.r.t gaseous pollutants.

Figure 6.25 reveals that chloride contributes the most PEI to the ATP impact sub-category, whereas NH₃-N contributes the most to the HTPI impact sub-category.

Chlorides and $\text{NH}_3\text{-N}$ provide the most PEI of any liquid pollutants, accounting for 42.1% and 45.3%, respectively w.r.t. the total PEI contributed by the liquid pollutants. Other liquid pollutants such as As, CN, Cr, Cu, Hg, Ni, Pb, Zn, and Phenol contribute the remaining 12.6% PEI w.r.t. the same. Though their contribution is less than that of Cl and $\text{NH}_3\text{-N}$, the PEI contribution to distinct effect sub-categories is noteworthy due to their high toxicity.

The figure 6.26 depicts the PEI contribution of CO_2 and CH_4 to impact sub-category Global Warming Potential (GWP) in global category.

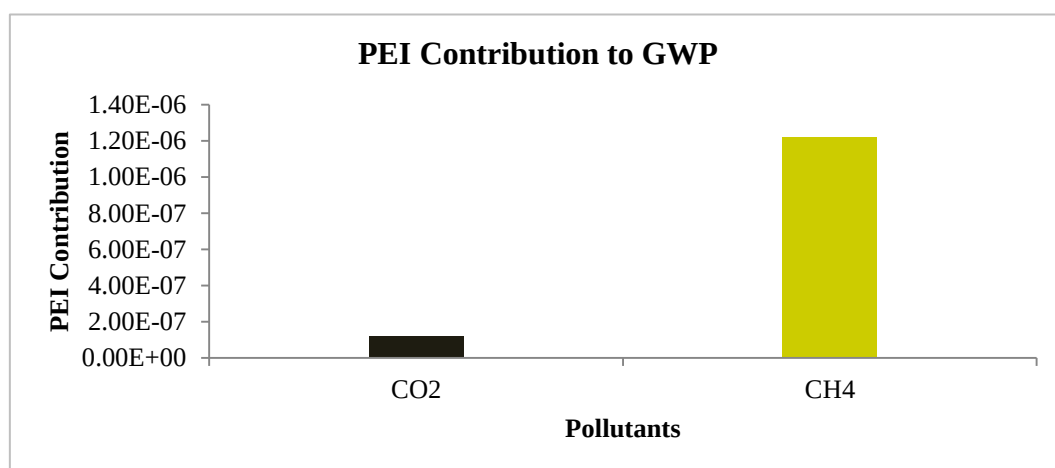


Figure- 6.26: PEI contribution of different gaseous pollutants to global category

Figure 6.26 show that CO_2 contributes 9% of the total PEI of GWP, while CH_4 contributes the remaining 91%. The CH_4 contribution is greater due to the massive emissions from the landfill site of the existing SWM system. There are no such gases generated in current solid waste management system that can cause the ozone layer to degrade. As a result, PEI contribution of ODP cannot be calculated.

Figure 6.27 show the contribution of SO_2 and NO_x to impact sub- category Acidification Potential (AP) in regional category.

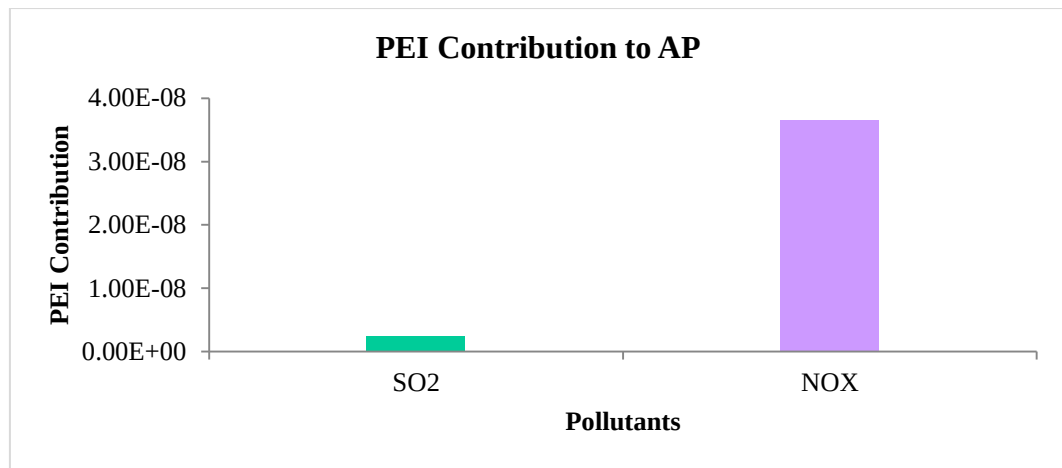


Figure- 6.27: PEI Contribution of different Gaseous Pollutants to Regional Category

As NO_x emissions are greater than SO_2 in the system, NO_x contributes 93.8% of the AP impact sub-category, while SO_2 contributes just 6.2%. As a result, the PEI caused by NO_x in AP is substantially higher than that caused by SO_2 . Another impact sub-category of regional category is Photochemical Ozone Conversion Potential (POCP) and the contributing chemical to POCP is only CH_4 . PEI due to CH_4 in POCP is 4.72×10^{-4} .

Human Toxicity Potential by Inhalation (HTPE), Terrestrial Toxicity Potential by Gas (TTPG), Human Toxicity Potential by Ingestion (HTPI), Terrestrial Toxicity Potential by Liquid (TTPL), and Aquatic Toxicity Potential (ATP) are considered in the local category, and the PEI contribution of various pollutants to these impact sub-categories is shown in the figures below.

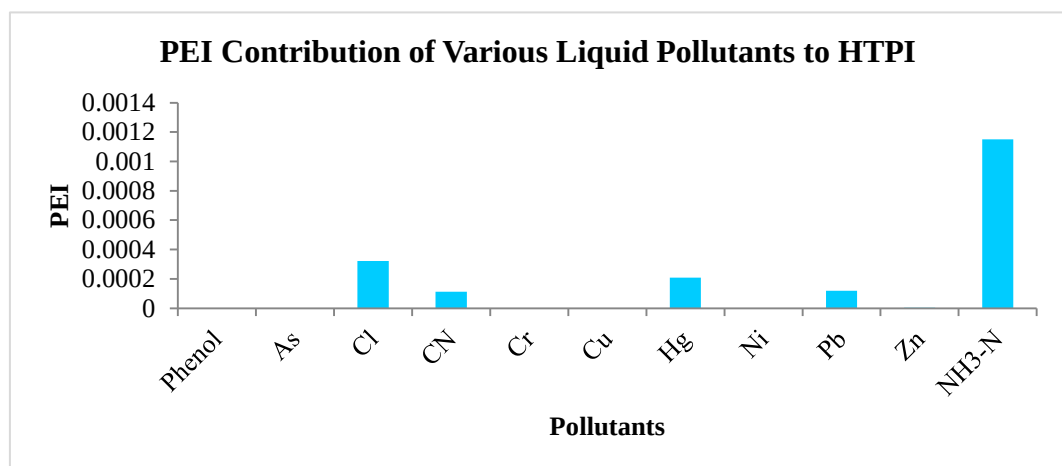


Figure- 6.28: PEI contribution of liquid pollutants to HTPI

According to figure 6.28, $\text{NH}_3\text{-N}$ has the highest contribution (60%) to the PEI of the HTPI impact sub-category in the local category, followed by Chloride (16.7%), Mercury (10.9%), and Lead (6.2%). In the existing system, the other pollutants, phenol, arsenic, chromium, copper, zinc, nickel, and cyanide, together add 6.2% of PEI to HTPI.

The figure 6.29 shows the PEI contribution of different gaseous pollutants to HTPE impact sub- category in local perspective.

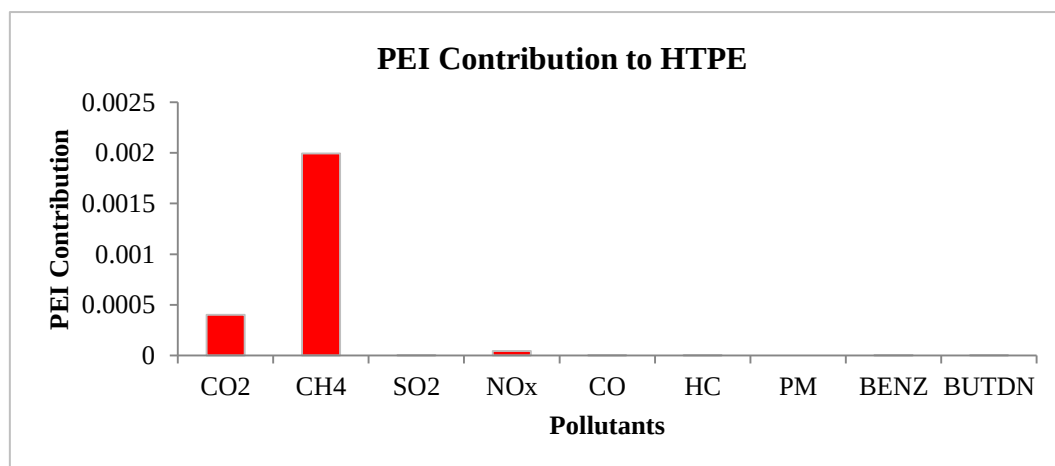


Figure- 6.29: PEI contribution of gaseous pollutants to HTPE

CH_4 contributes the most PEI in HTPE (~81.6%) followed by CO_2 (~16.4%) and NO_x (~1.8%). The contributions of CO, and SO_2 to PEI are visible, but the contributions of Butadiene, PM, HC, and Benzene are negligible.

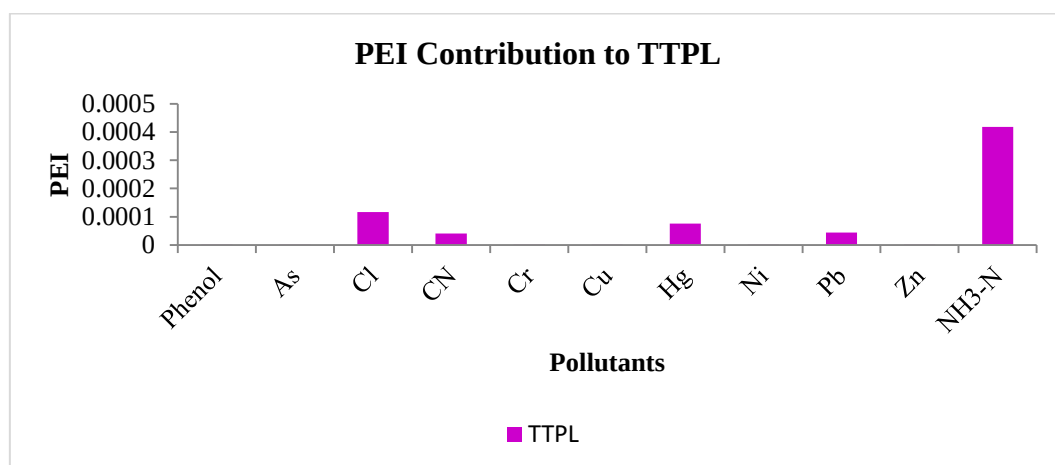


Figure- 6.30: PEI contribution of liquid pollutants to TTPL

Figure 6.30 shows that $\text{NH}_3\text{-N}$ contributes the most (60%) to the PEI of the TTPL impact sub-category in the local category, followed by Chloride (16.7%), Mercury (10.9%), and Lead (6.2%). The remaining pollutants, phenol, arsenic, chromium, copper, zinc, nickel, and cyanide, contribute 6.2% of PEI to TTPL in the existing system.

The figure 6.31 depicts the PEI contribution of different gaseous pollutants to impact sub-category TTPG in local category.

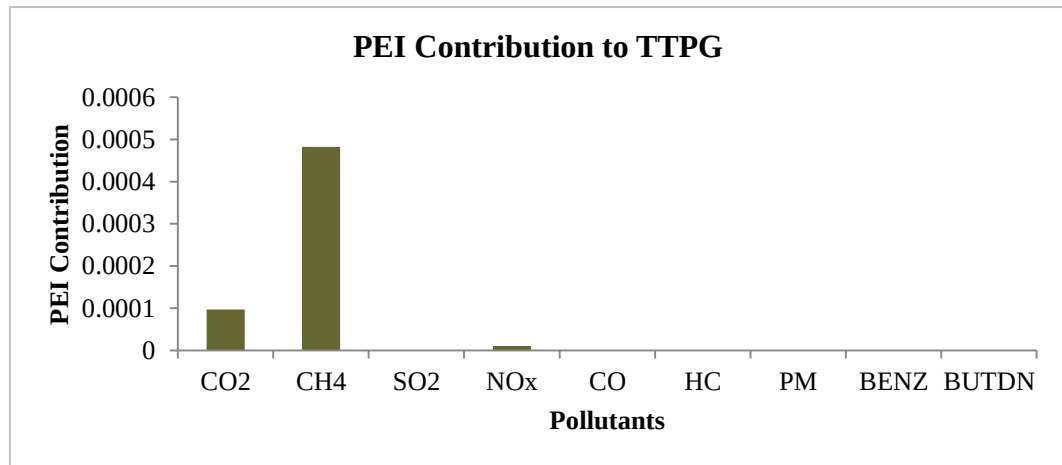


Figure- 6.31: PEI contribution of gaseous pollutants to TTPG

Of all contributing pollutants, CH_4 contributes the highest PEI in TTPG (81.6%). The contributions of CO_2 , CO, CH_4 , and SO_2 to PEI are obvious, whereas Butadiene, PM, HC, and Benzene are insignificant.

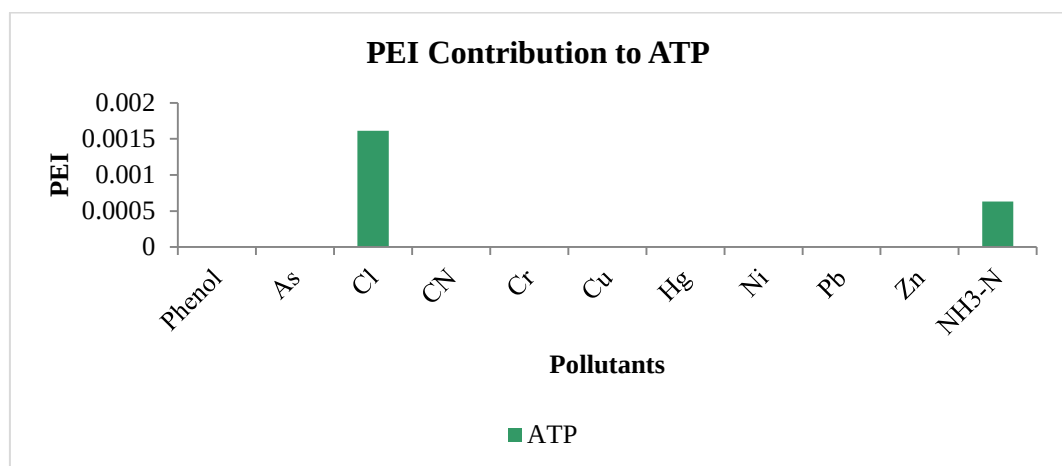


Figure- 6.32: PEI contribution of liquid Pollutants to ATP

Figure 6.32 shows that chloride contributes the highest (71.6%) to the PEI of the ATP impact sub-category in the local category, followed by $\text{NH}_3\text{-N}$ (28.2%). In the existing system, the remaining pollutants, phenol, arsenic, chromium, copper, zinc, nickel, cyanide, and lead, contribute a little amount of PEI (0.2%) to ATP.

The figure 6.33, below depicts the percent PEI contribution of different to impact sub-categories to the total PEI in local perspective.

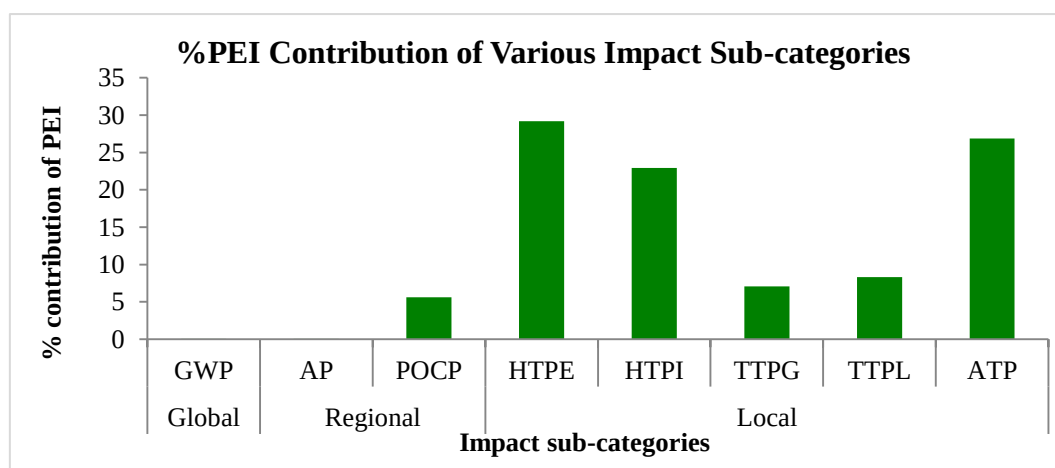


Figure- 6.33: Percent PEI contribution of different impact sub- categories to total PEI in local perspective

Figure 6.33 shows that, of all impact sub-categories, HTPE contributes the highest PEI value (~29%), followed by ATP (~27%), HTPI (~23%), TTPL (~8%), TTPG (~7%) and POCP (~5.6%) w.r.t. the total PEI. Leachate is responsible for increasing the impact value of HTPI, TTPL, and ATP and gaseous pollutants contributes most to the HTPE, TTPG and POCP. The PEI value of GWP and AP is less significant in a local perspective because the relative weightage value is lower compared to other impact sub-categories, but it is quite significant in a global and regional context. The impact of sub-category ODP did not provide any PEI value because no pollutant is produced in this system to deplete the ozone layer.

The figure 6.34, below present the percent PEI contribution of different to pollutants generated in existing SWM system to the total PEI in local perspective.

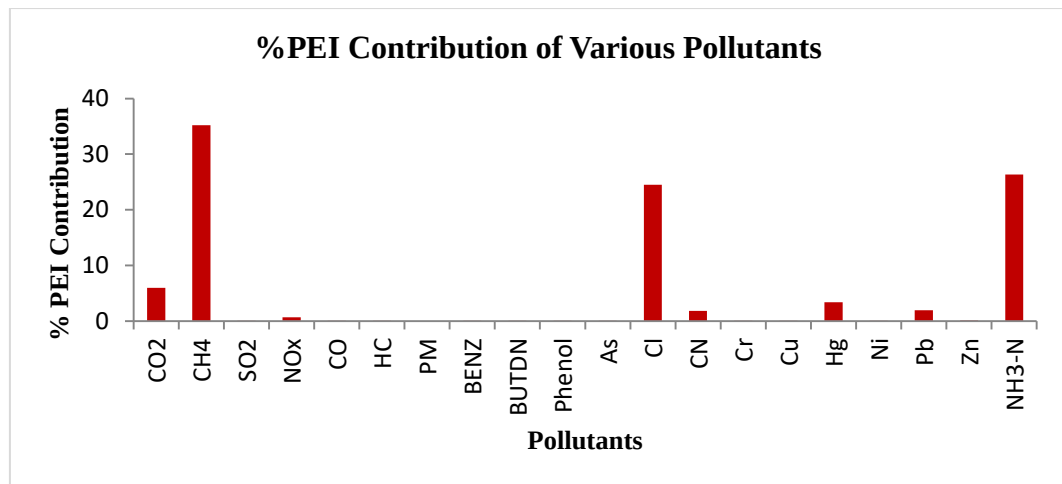


Figure- 6.34: Percent PEI contribution of different pollutants to total PEI in local perspective

Within all the pollutant present in the system, CH₄ has the highest impact in total PEI. It contributes ~35.2% of total PEI considering all categories followed by NH₃-N (~26.3%), Cl (~24.5%), CO₂ (~5.9%) NO_x (~1.4%) of total PEI. Other pollutants contribute only a little amount (~6.7%) of PEI to the total.

Figure 6.35 show the PEI contribution of transport sector and landfill in existing solid waste management system.

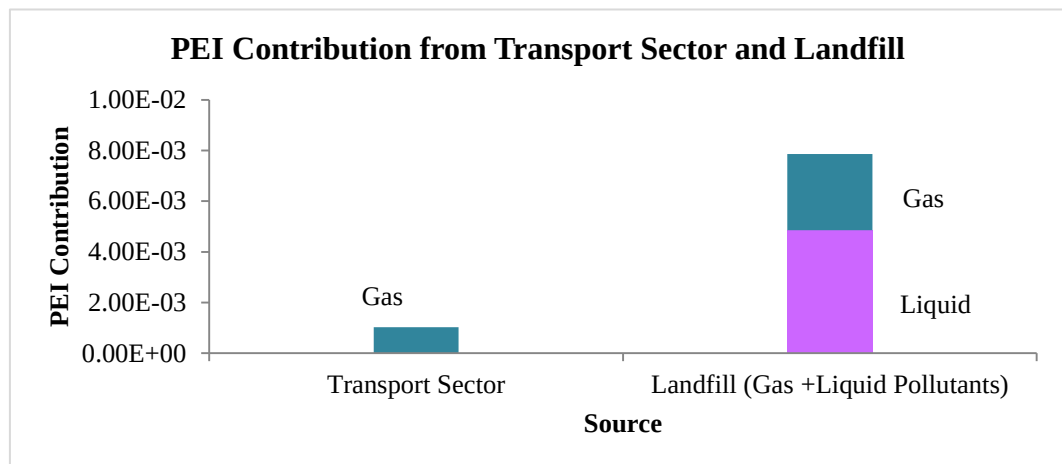


Figure- 6.35: PEI contribution of transport sector and landfill in existing SWM system

In the existing municipal SWM system, the results show that the transportation sector contributes only ~12.3% of total PEI, whereas landfill contributes ~87.7%. This is due to the huge quantity of gaseous pollutant generation from landfill and the presence of liquid

pollutants in landfill leachate, and the weightage of impact subcategories in local categories, such as HTPE, TTPG, HTPI, TTPL, and ATP. The PEI contribution of liquid pollutants is higher compared to the gaseous pollutants in landfill. Around 52% of total PEI is contributed by liquid pollutants and contribution of gaseous pollutants in total PEI from landfill is around 35.7%.

7 APPLICATION OF MODEL IN PROPOSED INTEGRATED SOLID WASTE MANAGEMENT (ISWM) SYSTEM OF KOLKATA

7.1 GENERAL DESCRIPTION

When all of the functional elements of the solid waste management system have been evaluated for use, and all of the interfaces and connections between elements have been matched for effectiveness and economy, the community has developed an integrated solid waste management system. In this context integrated solid waste management (ISWM) can be defined as the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals. Integrated solid waste management system are based on the concept of 3Rs i.e. reduction, reuse and recycling. Basic considerations of the integrated solid waste management are:

- Proper segregation should be done at source by providing two bins – one for biodegradable waste and the other for non-biodegradable waste.
- In no case solid waste should not touch the ground.
- For biodegradable waste, frequency of waste collection will be daily and for non-biodegradable waste, frequency of waste collection will be twice or thrice a week.
- Central or intermediate sorting facility to be provided from where recyclable material will be sent for recycling.
- Treatment and disposal of waste will be done as per its characteristics - like high calorific value of waste may go for incineration and biodegradable organic waste for composting.
- The pollutants generation from incinerators is considered after meeting the emission standard and pollutants emission from treated leachate are considered meeting the discharge standards as per SWM Rules, 2016.
- In all treatment facilities, pre-sorting facilities will be there for segregating the inert and recyclable from the processed waste. Inert and residues from treatment plant will go for sanitary landfill as in figure 7.1.

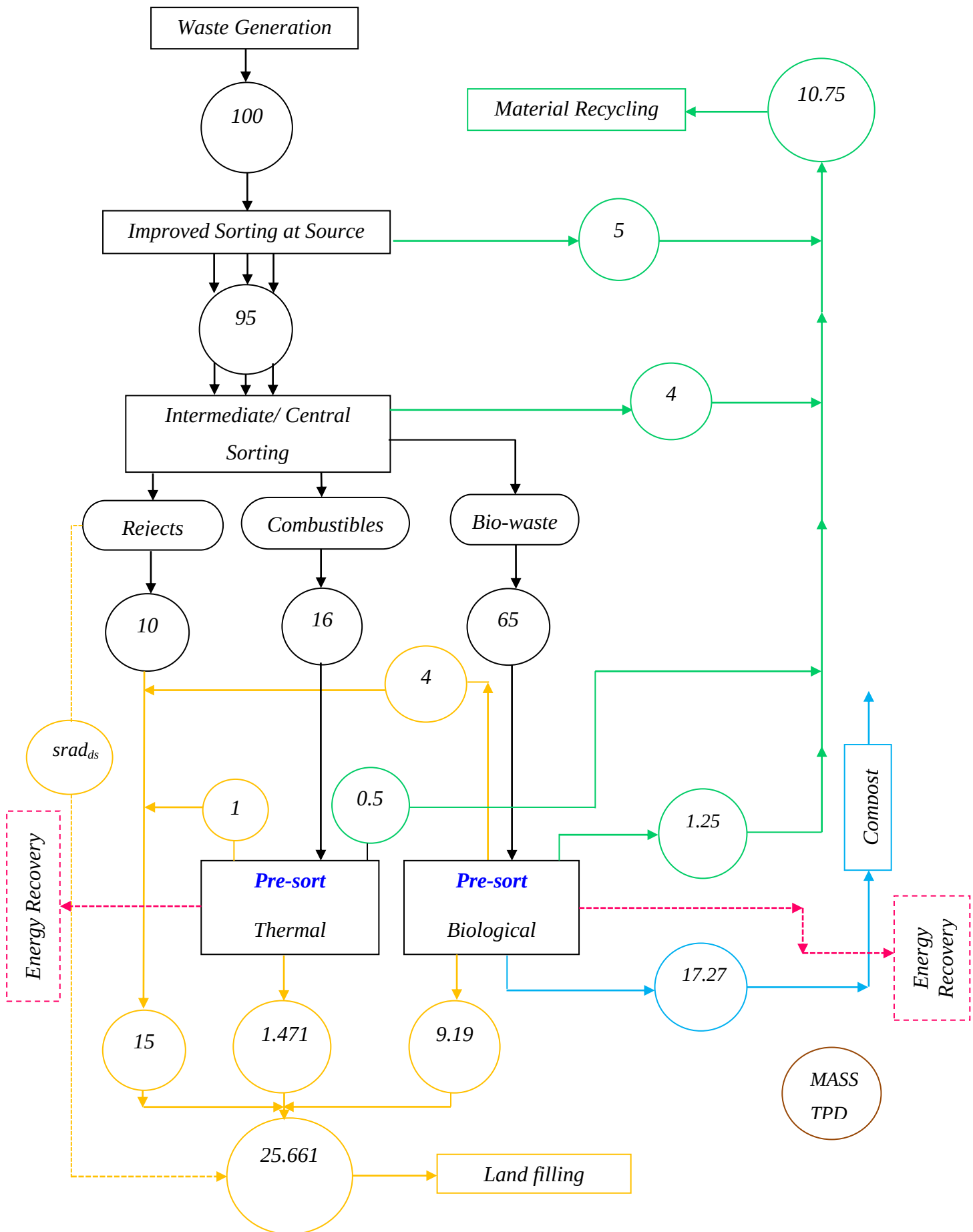


Figure- 7.1: Materials flow chart for garbage at a disposal site of ISWM System

From the previous chapter, it is identified that no incinerator/RDF-based plant is present in Kolkata in the present scenario. There is no waste segregation/sorting system exists currently. No sanitary/engineered landfill has been accomplished yet. At the Dhapa disposal site, a 700 MT/d compost plant is in operation, however it usually processes only 150 MT/d on an irregular basis. Although, it can be expected that SWM will be managed in a more modern and scientific way in the very near future with the propagation of the “Swachh Bharat Mission”. The mission proposes the capacity augmentation of urban local bodies (ULBs), 100% collection, transportation, and processing of solid waste, and public-private partnership (PPP) in setting up and operation of waste processing units which will require re-organizing and overhauling the entire MSWM system for Kolkata. To address this issue, effective planning and coordination of various functional elements through the use of an ISWM is important. Otherwise, the system is certain to be inefficient and fail. The chapter thus proposes the previously mentioned LP model for simulating such an ISWM system for Kolkata city with the same waste characteristics and waste transportation infrastructure as currently exists, with the ultimate goal of cost optimisation and minimization of Potential Environmental Impact (PEI) due to MSWM system pollution generation.

Considering the above, a study on pollution generation of Kolkata s being conducted based on its waste characteristics, using a 100 MT intake. The present fraction of recyclable materials in Kolkata is shown in Table 7.1, the total recyclable waste components in Table 7.2, and the overall input material composition for thermal processing is shown in Table 7.3. Table 7.4 illustrates the input material composition for biological processing.

Table- 7.1: Current proportion of recyclable materials in Kolkata

Materials/ components	Original composition	Recyclable Portion at Source and at Landfill
Paper	6.07	5.00 (82%)
Plastic	4.88	3.38 (70%)
Glass	0.34	0.27 (80%)
Metal	0.19	0.15 (80%)
Rubber & leather	0.68	0.41 (60%)
Total	12.16	9.21

In the present SWM system, around 5% of this 9.21% is recycled at household level and 4.21% is recycled by rag pickers.

Table- 7.2: Total recyclable waste components of garbage

Waste Components	Quantity (MT)
Paper	5.00
Rubber & leather	0.34
Plastic	4.88
Glass	0.34
Metal	0.19
Total Recycled	10.75

This recyclable amount (10.75 MT) is higher than the existing system (9.21 MT) because of proposed improved source segregation and sorting, but not too much as total amount of recyclable present in the garbage is less.

Table- 7.3: Input material composition for thermal processing

Waste Components	Quantity (MT)
Paper	1.07
Rubber & leather	0.34
Rags	1.87
Wooden matter	1.15
Coconut	4.50
Bones	0.16
Inert (for combustion)	2.41
Compostable portion	3.00
Inert	1.00
Recyclable materials	0.50
Total combustible	16.00

From physical and chemical composition of solid waste it is clear that amount of high calorific value materials in the garbage is not more after sorting of recyclable materials especially paper and plastics. Total input material composition for the incinerator is given in table 7.3. Some amount of inert and compostable materials are assumed to be mixed with remaining high calorific value materials as incinerator feed due to expected

inefficiency in sorting. Some amount of inert (1 MT) and recyclable (0.5 MT) will be separated out from the incinerator pre-sorter. Because of the presence of less amount of high calorific value materials, the amount of high quality incinerator feed is not much. Through mass burn incineration substantial volume reduction is possible which reduces the landfill area requirement. Incinerator generates high amount of air pollutants, so air pollution control equipment will have to be considered to minimize the air pollution.

Amount of organic material along with food waste is more in MSW in developing countries like India. Windrow composting is considered as biological processing rather than bio-methanation. Compost plant needs less capital cost and unskilled supervision. Compost enhances the natural fertilizing capacity of soil which is required in the developing countries having vast agricultural land. Table 7.4 shows total breakup of the input for composting plant. After sorted out of recyclable (1.25 MT) and inert (4 MT) by the compost plant pre-sorter and inert process reject (9.19 MT) from compost process, remaining 50.56 MT ($47.56 + 3$) will be converted to compost. Out of this, 30% (Flintoff, 1984) of compostable i.e, (47.56×0.3) MT along with 3 MT inert materials, 17.27 MT of compost product will be produced.

Table- 7.4: Composition of composting plant feed

Compostable	Recyclable	Inert			Total
$(50.56 - 3^*) = 47.56$	1.25 ^{**}	3 [#]	4.02 ^{\$}	9.193 ^{&}	65

* 3 tons of compostable material enters as incineration feed due to inefficiency of central sorter, ** Plastic recycled out of composting pre-sorter, [#]3 tons of inert present in composting product i.e. compost, ^{\$}4 tons of inert rejects at composting pre-sorter, [&]9.19 tons of inert rejects during composting process (Chattapadhyay et al., 2009; Paul et al., 2014).

Similar calculations for amount of recyclable materials sorted out from different processing techniques in a disposal site are shown in Table 7.5. Table 7.6 shows material balance of inert, originally present in the garbage.

Table- 7.5: Amount of recyclable material sorted out from different operation

Operations	Recycled quantity (MT)
Improved Sorting at Source	5.00
Intermediate Central Sorting	4.00
Pre-sorting in Thermal Processing	0.50
Pre-sorting in Composting	1.25
Total Recycled	10.75

Table- 7.6: Segregation of inert materials from different operations

Operations	Quantity (MT)
Reject from intermediate sorting	10.0
Pre-sorting from thermal processing	1.0
Pre-sorting from composting/ biological processing	4.0
In combustion	2.41
Residue from composting / biological processing	9.19
In composted material	3.0
Total	29.6

In integrated MSW management system engineered landfill is considered i.e. proper bottom liner with leachate collection system. Leachate will be collected and treated during active period as well as post closure period of landfill. A complete final cover will be provided after closure to minimize leachate generation i.e. to minimize ground water pollution. In this system silt or rubbish which is ~10% of the total waste and 25.661% inert (15% inert + 1.471 incinerator ash + 9.19 inorganic process reject from compost plant) from garbage, which is ~90% of the total waste, will be disposed in the engineered landfill. So, in this system $(10 + 25.661 \times 0.9) \%$ i.e. ~33% of the inert material of the total waste will be disposed in the engineered landfill. On the contrary at present in the existing MSW system 9.21% recyclable materials is taken out by the informal rag pickers and only around 5 to 6% of the garbage is converted to compost. So 85.79% of garbage i.e., $(85.79 \times 0.9) \%$ of the total waste and silt or rubbish (10% of the total waste) i.e., $(10 + 85.79 \times 0.9) \%$ or ~87 to 90% mixed waste (organic + inorganic) is being disposed.

7.2 CONSIDERATION OF DISPOSAL SITES

Considering the fact that landfill space for Dhapa has already got exhausted, the KMC-based model assumes three disposal sites at North (near Akandaberia, Haroa), South (near Kalicharanpur village, Nepalgunj) and East (near Noara, Bodura) of Kolkata (Paul et. al., 2014). A borough may find it economic to divert its waste to any of the North, South or East disposal sites as dictated by the model results. Each disposal site has a central sorting station, an incinerator, a composting plant and an Engineered Landfill Facility (ELF). The shortest path distance between each borough center (assumed to be waste source) and disposal site has been calculated using Network Analyst of ArcGIS (Paul et al., 2017). Figure 7.2 shows the borough divisions of KMC area, their centers and the three proposed disposal sites.

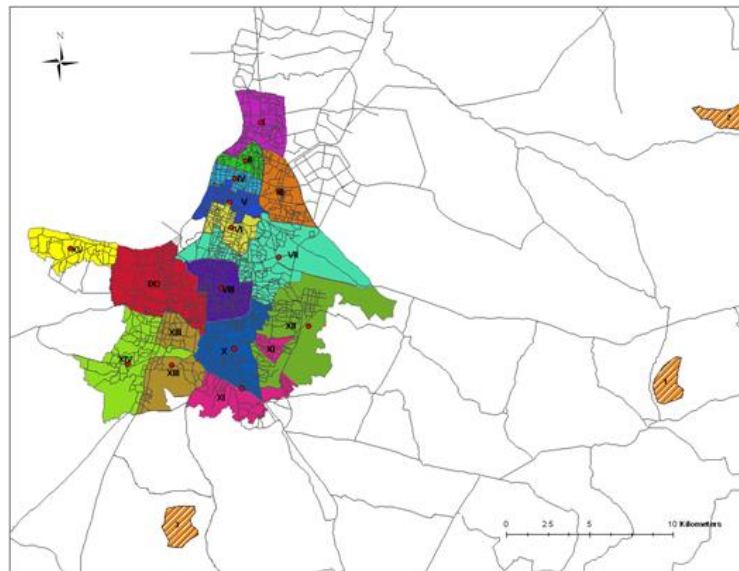


Figure- 7.2: Borough division of KMC and proposed disposal sites

Each disposal site is associated with zones. In this case, each of the three disposal sites has two zones. Zone 1 consists of boroughs near to that disposal site, while Zone 2 comprises of boroughs far away from that disposal site (Paul et al., 2014). The borough-zone divisions and the distances of the borough centres to the disposal sites are given in table 7.7 and 7.8.

Table- 7.7: Borough wise zone division for proposed landfill site

Dumpsite E		Dumpsite N		Dumpsite S	
Boroughs in Zone- 1	Boroughs in Zone- 2	Boroughs in Zone- 1	Boroughs in Zone- 2	Boroughs in Zone- 1	Boroughs in Zone- 2
3	1	1	8	8	1
4	2	2	9	9	2
5	9	3	10	10	3
6	11	4	11	11	4
7	13	5	12	12	5
8	14	6	13	13	6
10	15	7	14	14	7
12	16	-	15	16	15
-	-	-	16	-	-

Zone 1: Boroughs near to disposal site; Zone 2: Boroughs far from disposal site

Table- 7.8: Average distance from borough centre to proposed landfill site

Distance between borough centre and transfer station			
Borough	Disposal Site		
	East (E)	North (N)	South (S)
Borough 1	10.920	2.140	18.390
Borough 2	8.740	4.500	15.850
Borough 3	7.030	7.110	16.770
Borough 4	7.670	6.030	14.490
Borough 5	6.450	7.340	13.170
Borough 6	5.940	9.080	12.340
Borough 7	1.650	11.320	12.310
Borough 8	5.195	12.900	8.030
Borough 9	9.040	14.340	8.994
Borough 10	8.070	16.770	6.165
Borough 11	10.240	19.470	4.796
Borough 12	4.030	16.690	11.190
Borough 13	11.520	19.070	3.540
Borough 14	14.000	19.880	6.850
Borough 15	15.980	20.250	16.300
Borough 16	16.100	22.900	2.100

7.3 SORTING AND RECYCLING

In the integrated solid waste management system three ELF sites are considered in eastern site (D), northern site (N) and southern site (S) of Kolkata. In each ELF sites central sorting system, composting and incineration facilities are considered. In integrated system two bin system – one for bio-degradable waste and other for non-biodegradable waste is considered at household level. Non-biodegradable recyclable portions sorted at household level are ~ 5% of the total waste generation. Revenue from this 5% of recyclable portion has not considered in this model since this is sold at the household level without KMC getting any revenue. Rest 95% garbage, which is recorded by KMC reaches to the Intermediate /Central Sorting facility (ICS) for further management. After visual inspection at the ICS, 10% of waste (inert material) goes directly to the landfill site without unloading at ICS as direct dumpable inert portion from the garbage. Input/output stream at ICS is shown in Figure 7.3. Since 95% of the garbage reaches the ICS, to find out the percentages of the output streams from ICS, the mass values in Figure 7.1 are divided by 0.95.

If there is uneven distribution of waste among the three transfer station, one transfer station may get overloaded, rendering adjacent stations inoperable. Consequently, garbage is carried in vehicle-optimized condition in a 3:4:3 ratio to the North, East, and South transfer stations when all transfer sites are operational.

Transportation cost of incineration feed and compost feed from ICS to incineration and compost plant is considered within the operating cost of these two units. Cost of transportation from processing plants (sorter, incineration, composting) to recycling facility is assumed as Rs.55/MT. It is further assumed that sorter, incinerator, composting plant are within 2 km of each other.

7.4 BALANCE FOR INCINERATOR

Three Waste to Energy (WTE) incineration plants are considered at three disposal sites along with other facilities. Maximum incineration feed is 16.84% of respective ICS feed of that site only. Composition of incineration feed is shown in Table 7.3. Input and output streams of the incineration plans are given in Figure 7.4.

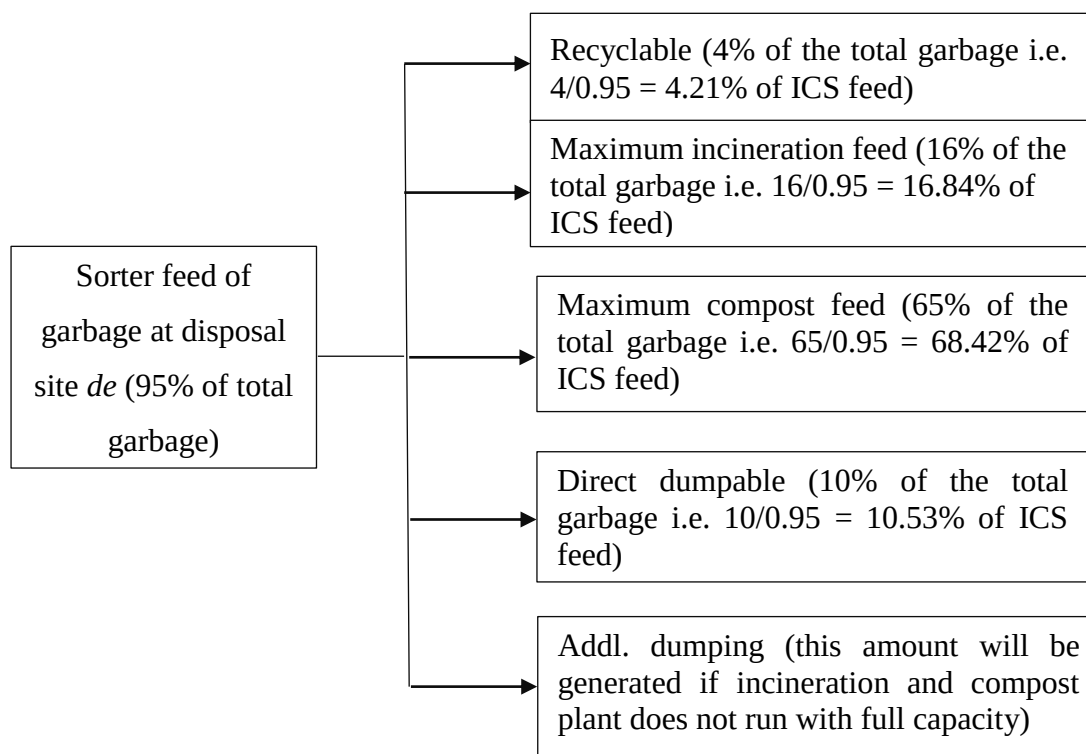


Figure- 7.3: Balance of intermediate central sorter (ICS)

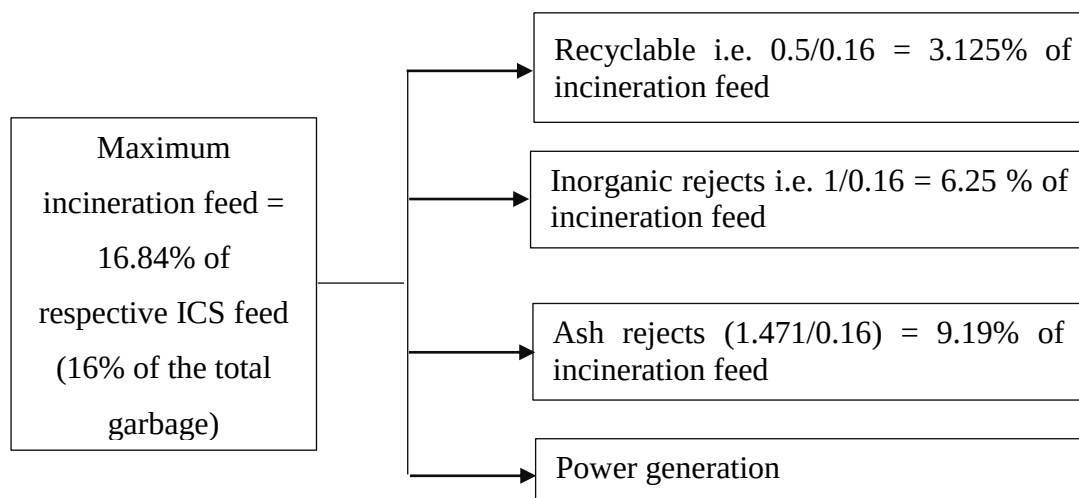


Figure- 7.4: Balance for incinerator

7.5 BALANCE FOR COMPOSTING

Three compost plants are considered adjacent to three ELF sites along with other facilities. Semi mechanized windrow composting is considered and the composition of composting feed is given in table 7.4. Maximum compost feed is 68.42% of the respective ICS feed of that ELF site only. Input and output streams of compost plants are

given in Figure 7.5. In the compost feed 47.56 units out of 65 units of total garbage is compostable. So, 30% of compostable (Flintoff, 1984) along with three units inert materials i.e. $[(47.56 \times 0.3) + 3] = 17.27$ units of compost is produced out of 65 unit of compostable materials.

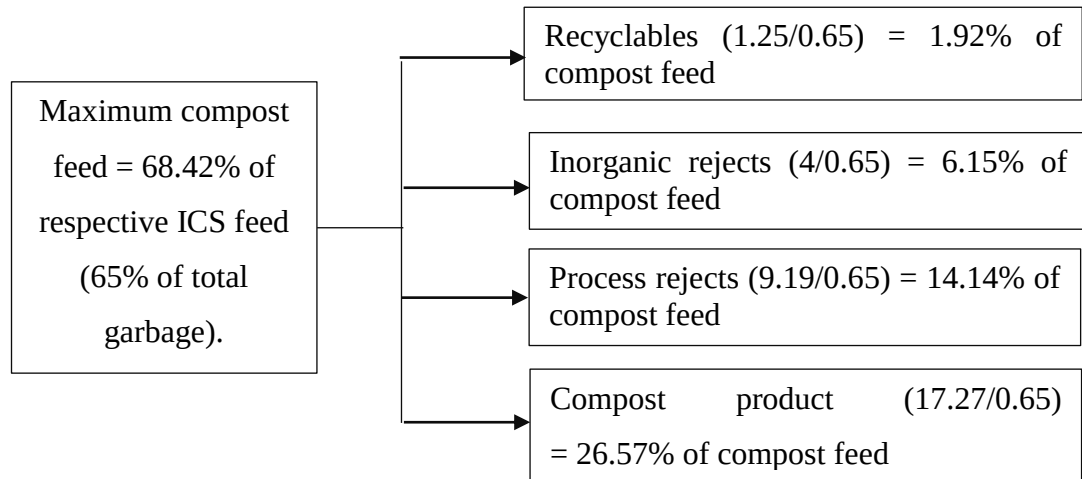


Figure- 7.5: Balance for composting

7.6 REVENUE FROM RECYCLABLE MATERIALS

To calculate the revenue for recyclable materials, recycling rate of paper, rubber & leather, plastic, glass, metal has been assumed as Rs.9.9/kg, Rs. 0.33/kg, Rs. 9.9/kg and Rs.1.1/kg and Rs. 55/kg respectively.

7.7 REVENUE FROM COMPOST

According to a validation report prepared by Det Norske Veritas (2010), in India, revenue from compost sale varied between Rs. 1741/MT to Rs. 2700/MT during the period 2006–2009 in Delhi. In this work, revenue from compost is assumed as Rs. 2750/MT, considering the present cost escalation.

7.8 COST OF COMPOSTING PLANT

Cost of composting facility including transportation cost from ICS to composting plant is taken as Rs. 295.9/MT (*Ref. annexure 7.1*).

7.9 COST OF INCINERATION PLANT

Cost of mass burn incineration plant including annualised capita cost, O & M cost and transportation cost from ICS to incineration plant is Rs. 757.9/MT of incineration feed (*Ref. annexure 7.2*).

7.10 COST OF ENGINEERED LANDFILL

The cost of landfills including cost of land are Rs. 217.25/MT for East (at Noara, Bodura), Rs. 224.554/MT for North (at Akandaberia village, Haroa/ Basirhat), and Rs. 212.938/MT for South (at Kalicharanpur village, Nepalgunj) (*Ref. annexure 7.3*).

7.11 INCORPORATING TRANSFER STATIONS IN THE PROPOSED ISWM

Three transfer stations are located in association with a particular disposal site. It is considered that these transfer stations are located very near or inside the KMC boundary as assumed that land is available. There will be sorter, incinerator and composting plant along with the transfer station located at the original disposal sites. No extra land cost is required for setting up of incinerator and composting plant, since it is already incorporated in the operational costs of processing plants - only their locations have shifted from disposal site to transfer station. Garbage portion from the city will enter the processing plants and then the disposable waste including process rejects/residues, ash, inert, etc. will be transferred from transfer station to disposal sites (landfill sites) for landfilling by TATA LPT 2518 Heavy Duty trucks. Silt/inert/rubbish may be directly loaded to TATA LPT 2518 trucks and transferred to landfill site. Total thirty number of heavy duty LPT trucks is assigned to carry the process rejects and silt from transfer station to the associated landfill site. Out of which twenty one numbers of trucks are considered for running condition and the rest nine trucks are in idle condition. The fixed running cost for each truck is Rs. 6,818.988, per day and the fixed idle cost is Rs. 3858.943 per day (*Ref. annexure 7.4*). The maximum number of trips assigned for heavy duty LPT trucks for east, north and south transfer station is four, three and five respectively.

Since, the incinerator plants generate electricity which is earning revenue in turn; locating the transfer station (along with incinerator) near KMC boundary will make power transmission / distribution to consumers much easier and cheaper as well. Similarly, placing the composting plant along with the transfer station will make effective for marketing and selling to the nearby agricultural areas. Again, if the transfer stations are at midway between KMC area and disposal sites (landfill sites), then impact of pollution, if any, from the processing plants on the city, will be less. Due to the introduction of the transfer station, the generic equations of the LP model need to be modified, since fuel cost, fixed running and fixed idle cost, pollution generation of the Heavy Duty Trucks have to be taken into account. Cost of transfer station is ignored, since no equipment or processing is expected there.

Equation (49) needs to be modified for transfer station.

Total cost of transportation of waste to all the disposal sites:

$$COSTRANSP - costran_{hv} - \sum_{DV=1}^{DV} costrandv_{dv} - costrantrucks = 0 \quad (206)$$

costrantrucks is the total cost of transporting disposable waste from transfer station to the disposal site by the heavy duty trucks.

The following equations need to be incorporated in association with the previous equations. Total cost of waste transportation from transfer station to the respective disposal site (landfill) *de* by the heavy duty trucks:

$$costantrucks - costfueltrucks - costfxdrtrucks - costfxdidltrucks = 0 \quad (207)$$

costfueltrucks is the fuel cost of the heavy duty trucks used for transporting disposable waste from transfer station to landfills. Similarly, *costfxdrtrucks* and *costfxdidltrucks* are the fixed running cost and idle cost respectively of the heavy duty trucks.

Total fuel cost of the heavy duty trucks:

$$costfueltrucks - \sum_{de=1}^{DE} xlf_{de} \times fcost\_trucks_{de} = 0 \quad (208)$$

$f_{cost\_truck_{de}}$ is the fuel cost per ton of waste transported by heavy duty trucks from transfer station associated with disposal site de to disposal site (landfill) de (Rs/MT).

Total fixed running cost of heavy duty trucks:

$$cost_{fxdtrucks} - truck_{na} \times r_{cost\_truck} = 0 \quad (209)$$

$truck_{na}$ is the number of heavy duty trucks actually running considering all the three disposal sites. r_{cost_truck} is the fixed running cost per truck.

Total fixed idle cost of heavy duty trucks:

$$cost_{fxdidltrucks} - (truck_{no} - truck_{na}) \times i_{cost\_truck} = 0 \quad (210)$$

$truck_{no}$ is the total number of heavy duty trucks considering all the three disposal sites. i_{cost_truck} is the fixed idle cost per truck.

Number of trips per day for each heavy duty truck associated with disposal site de :

$$x_{lf_{de}} \leq notrucks_{de} \times truck_{cap} \times trips_{truck_{de}} \quad \forall de = 1, 2, \dots, DE \quad (211)$$

$trips_{truck_{de}}$ is the number of trips per day each heavy duty truck associated with disposal site (and transfer station) de is required to make. $notrucks_{de}$ is the number of heavy duty trucks associated with disposal site (and transfer station) de . $truck_{cap}$ is the payload capacity of a heavy duty truck (MT).

Total number of running heavy duty trucks:

$$\sum_{de=1}^{DE} notrucks_{de} - truck_{na} = 0 \quad (212)$$

7.11.1 Pollution Generation Equation for Heavy Duty LPT Trucks

Total CO₂ generation from heavy duty trucks:

$$CO_{2\_emsntruck_{de}} - \sum_{de=1}^{DE} CO_{2\_er\_truck_{de}} \times x_{lf_{de}} = 0 \quad (213)$$

$CO_{2\_emsntruck_{de}}$ is the total emission of CO_2 from heavy duty LPT trucks. $CO_{2\_er\_truck_{de}}$ is the CO_2 emission rate from heavy duty trucks transporting waste from transfer station associated with disposal site de to disposal site (landfill) de per ton of waste per trip.

Total CO generation from heavy duty trucks:

$$CO_{emsntruck_{de}} - \sum_{de=1}^{DE} CO_{er\_truck_{de}} \times xlf_{de} = 0 \quad (214)$$

$CO_{emsntruck_{de}}$ is the total emission of CO from heavy duty LPT trucks. $CO_{er\_truck_{de}}$ is the CO emission rate from heavy duty trucks transporting waste from transfer station associated with disposal site de to disposal site (landfill) de per ton of waste per trip.

Total SO_2 generation from heavy duty trucks:

$$SO_{2\_emsntruck_{de}} - \sum_{de=1}^{DE} SO_{2\_er\_truck_{de}} \times xlf_{de} = 0 \quad (215)$$

$SO_{2\_emsntruck_{de}}$ is the total emission of SO_2 from heavy duty LPT trucks. $SO_{2\_er\_truck_{de}}$ is the SO_2 emission rate from heavy duty trucks transporting waste from transfer station associated with disposal site de to disposal site (landfill) de per ton of waste per trip.

Total HC generation from heavy duty trucks:

$$HC_{emsntruck_{de}} - \sum_{de=1}^{DE} HC_{er\_truck_{de}} \times xlf_{de} = 0 \quad (216)$$

$HC_{emsntruck_{de}}$ is the total emission of HC from heavy duty LPT trucks. $HC_{er\_truck_{de}}$ is the HC emission rate from heavy duty trucks transporting waste from transfer station associated with disposal site de to disposal site (landfill) de per ton of waste per trip.

Total PM generation from heavy duty trucks:

$$PM_{emsntruck_{de}} - \sum_{de=1}^{DE} PM_{er\_truck_{de}} \times xlf_{de} = 0 \quad (217)$$

$PM\_emsntruck_{de}$ is the total emission of PM from heavy duty LPT trucks. $PM\_er\_truck_{de}$ is the PM emission rate from heavy duty trucks transporting waste from transfer station associated with disposal site de to disposal site (landfill) de per ton of waste per trip.

Total NO_x generation from heavy duty trucks:

$$NO_{x\_emsntruck_{de}} - \sum_{de=1}^{DE} NO_{x\_er\_truck_{de}} \times xlf_{de} = 0 \quad (218)$$

$NO_{x\_emsntruck_{de}}$ is the total emission of NO_x from heavy duty LPT trucks. $NO_{x\_er\_truck_{de}}$ is the NO_x emission rate from heavy duty trucks transporting waste from transfer station associated with disposal site de to disposal site (landfill) de per ton of waste per trip.

Total benzene generation from heavy duty trucks:

$$BENZ\_emsntruck_{de} - \sum_{de=1}^{DE} BENZ\_er\_truck_{de} \times xlf_{de} = 0 \quad (219)$$

$BENZ\_emsntruck_{de}$ is the total emission of Benzene from heavy duty LPT trucks. $BENZ\_er\_truck_{de}$ is the Benzene emission rate from heavy duty trucks transporting waste from transfer station associated with disposal site de to disposal site (landfill) de per ton of waste per trip.

Total butadiene generation from heavy duty trucks:

$$BUTDN\_emsntruck_{de} - \sum_{de=1}^{DE} BUTDN\_er\_truck_{de} \times xlf_{de} = 0 \quad (220)$$

$BUTDN\_emsntruck_{de}$ is the total emission of Butadiene from heavy duty LPT trucks. $BUTDN\_er\_truck_{de}$ is the Butadiene emission rate from heavy duty trucks transporting waste from transfer station associated with disposal site de to disposal site (landfill) de per ton of waste per trip.

7.12 TRANSFER STATIONS LOCATED VERY NEAR / INSIDE KMC BOUNDARY

The transfer station located very near or inside the KMC boundary is the most cost effective condition (Paul et al., 2017). In this present study minimization of potential environmental impact along with cost is incorporated as there no such study yet done. The East transfer station is near Science City at Uttarpanchanna Gramme (22°32'02"N, 88°23'50"E), while the North and South transfer stations are on the Nepalgunje-Julpia Road at Ghughudanga-Pearabagan (22°37'11"N, 88°23'38"E) and Kabardanga, Ramchandrapur (22°27'39"N, 88°20'01"E), respectively (Paul et al., 2017) The conditions and other information are presented below.

7.12.1 Boroughs and Zones related to disposal sites or transfer stations

The KMC boroughs are distributed in Zone 1 and Zone 2. The borough-zone distribution and distance of transfer stations from borough centres are attributed in table 7.7 and Table 7.8.

7.12.2 Present generation of garbage and silt/rubbish by borough

Table 6.2 shows the average daily generation of garbage and silt/rubbish in each of the 16 boroughs in the KMC area as of the present time. While 5% of waste is recycled at the household level, KMC receives 95% of the total waste generated.

7.12.3 Vehicles types used by KMC at present for transportation of waste

The table 5.7 of chapter 5, table 6.32 and 6.33 of chapter 6 shows four different types of KMC vehicles associated with their capacity and characteristics.

7.12.4 Maximum and minimum fraction limits of waste carried by various types of KMC vehicles

Garbage disposal at the borough level is analyzed, taking into account the maximum and minimum amount of waste transported by departmental vehicles (DV1, DV2, DV3, DV4) and hired vehicles (HV type). Table 6.3 of sub-chapter 6.1.4 displays the minimum and

maximum waste-carrying quantity range (in fractions) for departmental and hired vehicles from each borough.

7.12.5 Maximum and minimum trip limitations for departmental vehicles

Table 6.4 of sub-chapter 6.1.5 shows the maximum and minimum trip limitations, as well as the incentives for departmental vehicles.

7.12.6 Transportation cost of KMC vehicles

In addition to the transportation costs depicted in chapter 6, the transportation costs for LPT trucks must be taken into account when using this ISWM system to carry garbage from transfer stations to the appropriate disposal sites.

7.12.6.1 Waste transportation cost for departmental vehicles

In previous Chapter, depending on the current scenario of diesel price and average load carrying capacity for departmental vehicles, fuel consumption for loaded and unloaded conditions or the various fuel costs (in Rs./km) for loaded and unloaded circumstances are shown. Tables 7.9, 7.10, 7.11, 7.12 respectively, present the fuel costs for moving garbage from each borough centre to the corresponding transfer stations (east, north, and south) by departmental vehicles. In *annexure 7.5*, sample calculations are displayed. In contrast, tables 7.13 indicates the fuel consumption and fuel charge of heavy duty trucks and cost for moving waste by heavy-duty LPT vehicles from transfer stations to disposal sites is presented in table 7.14. In *annexure 7.6.*, a sample fuel cost calculation for an LPT truck is presented.

Table- 7.9: Fuel Cost for transporting garbage from borough centre to transfer station by DV1 (Rs/MT)

Borough	E	N	S
1	148.76	29.150	250.51
2	119.06	61.300	215.91
3	95.760	96.850	228.45
4	104.48	82.140	197.39
5	87.860	99.990	179.41
6	80.920	123.69	168.10
7	22.480	154.20	167.69
8	70.770	175.73	109.39
9	123.15	195.34	122.52
10	109.93	228.45	83.980
11	139.49	265.23	65.33
12	54.900	227.36	152.43
13	156.93	259.78	48.220
14	190.71	270.81	93.310
15	217.68	275.85	222.04
16	219.32	311.95	28.610

Table- 7.10: Fuel cost for transporting garbage from borough centre to transfer station by DV2 (Rs/MT)

Borough	E	N	S
1	146.10	28.63	246.04
2	116.93	60.21	212.06
3	94.06	95.13	224.37
4	102.62	80.68	193.86
5	86.30	98.20	176.20
6	79.47	121.48	165.10
7	22.08	151.45	164.70
8	69.50	172.59	107.43
9	120.95	191.86	120.33
10	107.97	224.37	82.48
11	137.00	260.49	64.17
12	53.92	223.30	149.71
13	154.13	255.14	47.36
14	187.31	265.98	91.65
15	213.80	270.93	218.08
16	215.40	306.38	28.10

Table- 7.11: Fuel cost for transporting garbage from borough centre to transfer station by DV3 (Rs/MT)

Borough	E	N	S
1	202.69	39.72	341.34
2	162.23	83.53	294.20
3	130.49	131.97	311.27
4	142.37	111.93	268.95
5	119.72	136.24	244.45
6	110.25	168.54	229.05
7	30.63	210.11	228.49
8	96.43	239.44	149.05
9	167.79	266.17	166.94
10	149.79	311.27	114.43
11	190.07	361.39	89.02
12	74.80	309.79	207.70
13	213.83	353.97	65.71
14	259.86	369.00	127.15
15	296.61	375.87	302.55
16	298.84	425.06	38.98

Table- 7.12: Fuel cost for transporting garbage from borough centre to transfer station by DV4 (Rs/MT)

Borough	E	N	S
1	202.41	39.67	340.88
2	162.01	83.41	293.80
3	130.31	131.79	310.85
4	142.17	111.77	268.59
5	119.56	136.06	244.12
6	110.10	168.31	228.74
7	30.58	209.83	228.18
8	96.30	239.12	148.85
9	167.57	265.81	166.71
10	149.59	310.85	114.28
11	189.81	360.90	88.90
12	74.70	309.37	207.42
13	213.54	353.48	65.62
14	259.51	368.50	126.97
15	296.21	375.36	302.14
16	298.43	424.48	38.93

Table- 7.13: Average load capacity, fuel consumption and fuel charge in loaded and unloaded condition for heavy duty trucks

Vehicle type	Avg. load capacity (MT)	Fuel consumption (Km/lt.)		Fuel Charge (Rs./Km)	
		Loaded Condition	Unloaded Condition	Loaded Condition	Unloaded Condition
25 MT TATA LPT Heavy Duty Truck	20	7.0	8.3	13.071	11.175

Table- 7.14: Per MT cost of transportation by heavy duty trucks from transfer station to respective disposal site

Disposal Site	Fuel Charge (Rs./Km)		Distance (Km)	Cost (Rs.)	Cost/MT
	Loaded Condition	Unloaded Condition			
E	13.071	11.175	27.877	675.900	33.795
N			30.915	749.540	37.477
S			8.72	211.420	10.571

7.12.6.2 Waste transportation cost for hired vehicles

Since hired vehicles carry waste and silt/rubbish separately, the transportation cost (in Rs. per MT) for hired vehicles is considered when transporting garbage and silt/rubbish separately for different zones. Zone wise rate for transporting garbage and silt by hired vehicles to different transfer stations is shown in Table 7.15, whereas transportation costs for both garbage and silt carrying hired vehicles are shown in Table 7.16.

Table- 7.15: Zone wise rate for transporting garbage and silt by hired vehicles

Zone Division	Garbage Transport Rate of (Rs./MT)			Silt/Rubbish Transport Rate of (Rs./MT)			Distance of Zone Border from Borough Centre		
	E	N	S	E	N	S	E	N	S
1	418	429	429	399	396	396	<8.5 Km	<8.5 Km	<12 Km
2	504	515	515	486	478	478	≥8.5 Km	≥8.5 Km	≥12 Km

Table- 7.16: Fuel cost for transporting garbage and silt/ rubbish by hired Vehicles

Per ton garbage transportation cost from borough to transfer station (Rs/MT) by hired vehicles**				Per ton silt/ rubbish transportation cost from borough to transfer station (Rs/MT) by hired vehicles**			
Borough	East Dumpsite	North Dumpsite	South Dumpsite	Borough	East Dumpsite	North Dumpsite	South Dumpsite
1	504	429	515	1	486	396	478
2	504	429	515	2	486	396	478
3	418	429	515	3	399	396	478
4	418	429	515	4	399	396	478
5	418	429	515	5	399	396	478
6	418	429	515	6	399	396	478
7	418	429	515	7	399	396	478
8	418	515	429	8	399	478	396
9	504	515	429	9	486	478	396
10	418	515	429	10	399	478	396
11	504	515	429	11	486	478	396
12	418	515	429	12	399	478	396
13	504	515	429	13	486	478	396
14	504	515	429	14	486	478	396
15	504	515	515	15	486	478	478
16	504	515	429	16	486	478	396

7.13 AIR POLLUTION GENERATION FROM TRANSPORT SECTOR

The main purpose of this study is to analyze how numerous pollutants, described in the previous Chapter, are optimized by applying the parameters that contribute to pollution generation to the proposed ISWM sectors. Urban management strategies must address both traffic and pollution management in order to best paves the road for sustainable growth. Additionally, as shown in the tables from the preceding chapter, neither the weighted average emission factors for different pollutants nor the fuel consumption of departmental and hired vehicles have changed.

Table- 7.17: Pollutant emission rate by heavy duty truck (g/t/trip)

SO ₂			CO			CO ₂			HC		
E	N	S	E	N	S	E	N	S	E	N	S
0.209	0.232	0.07	6.272	6.956	1.962	943.34	1046.11	295.12	0.864	0.958	0.270
NO _x			PM			BENZENE			BUTADIENE		
E	N	S	E	N	S	E	N	S	E	N	S
5.492	6.090	1.718	0.056	0.062	0.017	0.0053	0.0059	0.0017	0.0004	0.0005	0.0001

The distance between different boroughs and disposal sites and transfer stations has varied in the case of the Integrated MSW system. The estimated density of the fuel is 820 kg/m³. Carbon and sulphur are anticipated to weigh 87% and 0.035% of the total mass, respectively. The calculated borough wise rate of pollutant emission by departmental and hired vehicles per MT of garbage per trip (g/t/trip) is shown in the following tables. This information was used as input data for the LP model in LINGO. All of these input data were entered into an excel spreadsheet to run the LINGO model. An example formula for figuring out the rate of pollutant emission is provided in the *annexure 7.7*.

The generated waste has been transported from borough centre to the east, north and south transfer station by the departmental and hired vehicles. Tables 7.18, 7.19, 7.20, 7.21, 7.22, and 7.23 show the calculated borough-wise rate of pollutant emission by departmental and hired vehicles per MT of garbage per trip (g/t/trip) that has been used as input data for running the LP model in LINGO. *Annexure 7.8* shows a sample calculation for determining the rate of pollutant emission of departmental vehicles.

Table- 7.18: Pollutant emission rate by departmental vehicle DV1 (g/t/trip)

Br No.	CO			HC			NO _x			PM		
	E	N	S	E	N	S	E	N	S	E	N	S
1	13.260	2.598	22.330	3.625	0.710	6.105	23.580	4.620	39.706	2.134	0.418	3.593
2	10.613	5.464	19.250	2.901	1.494	5.262	18.870	9.716	34.220	1.710	0.879	3.097
3	8.536	8.633	20.360	2.330	2.360	5.567	15.180	15.350	36.210	1.374	1.389	3.278
4	9.313	7.322	17.595	2.550	2.000	4.810	16.560	13.020	31.286	1.498	1.178	2.832
5	7.832	8.913	15.990	2.140	2.436	4.372	13.930	15.850	28.436	1.260	1.434	2.574
6	7.213	11.026	14.980	1.972	3.014	4.097	12.825	19.605	26.640	1.161	1.774	2.411
7	2.003	13.745	14.950	0.548	3.758	4.086	3.562	24.440	26.580	0.322	2.212	2.406
8	6.310	15.664	9.750	1.725	4.283	2.666	11.220	27.850	17.340	1.015	2.521	1.569
9	10.980	17.410	10.920	3.000	4.760	2.986	19.520	30.960	19.420	1.770	2.802	1.757
10	9.799	20.360	7.486	2.679	5.567	2.047	17.424	36.210	13.310	1.580	3.278	1.205
11	12.434	23.640	5.820	3.399	6.464	1.592	22.110	42.040	10.350	2.001	3.804	0.937
12	4.893	20.270	13.590	1.338	5.541	3.715	8.701	36.040	24.160	0.787	3.262	2.187
13	13.988	23.160	4.298	3.825	6.330	1.175	24.870	41.170	7.640	2.251	3.727	0.692
14	17.000	24.140	8.320	4.648	6.600	2.274	30.230	42.924	14.790	2.736	3.885	1.338
15	19.404	24.590	19.790	5.305	6.723	5.412	34.503	43.720	35.190	3.122	3.957	3.185
16	19.550	27.807	2.550	5.345	7.603	0.697	34.762	49.444	4.534	3.146	4.475	0.410
Br No.	SO ₂			BENZENE			BUTADIENE			CO ₂		
	E	N	S	E	N	S	E	N	S	E	N	S
1	0.895	0.175	1.508	0.018	0.004	0.030	0.003	0.001	0.006	4059.810	795.605	6836.990
2	0.717	0.369	1.299	0.014	0.008	0.026	0.003	0.001	0.005	3249.330	1672.990	5892.670
3	0.576	0.583	1.375	0.012	0.012	0.028	0.002	0.002	0.005	2613.590	2643.340	6234.710
4	0.629	0.494	1.188	0.013	0.010	0.024	0.002	0.002	0.005	2851.530	2241.820	5387.060
5	0.529	0.602	1.079	0.011	0.012	0.022	0.002	0.002	0.004	2397.960	2728.847	4896.310
6	0.487	0.744	1.012	0.010	0.015	0.020	0.002	0.003	0.004	2208.360	3375.740	4587.740
7	0.135	0.928	1.009	0.003	0.019	0.020	0.001	0.004	0.004	613.430	4208.520	4576.580
8	0.426	1.058	0.658	0.009	0.021	0.013	0.002	0.004	0.003	1931.380	4795.930	2985.370
9	0.741	1.176	0.737	0.015	0.024	0.015	0.003	0.005	0.003	3360.860	5331.290	3343.770
10	0.662	1.375	0.505	0.013	0.028	0.010	0.003	0.005	0.002	3000.245	6234.710	2292.000
11	0.839	1.596	0.393	0.017	0.032	0.008	0.003	0.006	0.002	3807.000	7238.510	1783.050
12	0.331	1.368	0.917	0.007	0.028	0.018	0.001	0.005	0.004	1498.260	6204.960	4160.190
13	0.945	1.564	0.290	0.019	0.032	0.006	0.004	0.006	0.001	4282.880	7089.790	1316.090
14	1.148	1.630	0.562	0.023	0.033	0.011	0.004	0.006	0.002	5204.890	7390.940	2546.670
15	1.310	1.660	1.340	0.026	0.034	0.027	0.005	0.006	0.005	5941.000	7528.490	6059.980
16	1.320	1.878	0.172	0.027	0.038	0.003	0.005	0.007	0.001	5985.619	8513.706	780.733

Table- 7.19: Pollutant emission rate by departmental vehicle DV2 (g/t/trip)

Br No.	CO			HC			NO _x			PM		
	E	N	S	E	N	S	E	N	S	E	N	S
1	10.686	2.094	17.997	2.950	0.578	4.969	19.040	3.731	32.059	1.876	0.368	3.159
2	8.550	4.404	15.510	2.360	1.216	4.283	15.240	7.845	27.632	1.501	0.773	2.723
3	6.879	6.958	16.410	1.899	1.921	4.532	12.260	12.395	29.236	1.207	1.221	2.881
4	7.506	5.901	14.180	2.073	1.629	3.915	13.370	10.510	25.261	1.317	1.035	2.489
5	6.312	7.183	12.890	1.743	1.983	3.559	11.240	12.796	22.959	1.108	1.261	2.262
6	5.813	8.886	12.076	1.605	2.454	3.334	10.350	15.829	21.512	1.020	1.559	2.119
7	1.615	11.080	12.047	0.446	3.059	3.326	2.880	19.734	21.460	0.283	1.944	2.114
8	5.084	12.624	7.858	1.404	3.486	2.169	9.060	22.489	13.990	0.892	2.216	1.379
9	8.850	14.030	8.802	2.443	3.875	2.430	15.760	24.990	15.680	1.553	2.463	1.545
10	7.897	16.410	6.033	2.181	4.532	1.666	14.069	29.236	10.750	1.386	2.881	1.059
11	10.020	19.050	4.693	2.767	5.261	1.296	17.852	33.940	8.361	1.759	3.344	0.824
12	3.944	16.330	10.951	1.089	4.510	3.024	7.026	29.096	19.510	0.692	2.867	1.922
13	11.274	18.660	3.464	3.112	5.153	0.956	20.080	33.240	6.171	1.978	3.276	0.608
14	13.701	19.450	6.704	3.783	5.372	1.851	24.410	34.657	11.940	2.405	3.415	1.176
15	15.640	19.820	15.952	4.318	5.472	4.405	27.860	35.300	28.420	2.745	3.478	2.799
16	15.756	22.411	2.0552	4.3506	6.1881	0.5675	28.068	39.922	3.6610	2.7656	3.9337	0.3607
Br No.	SO ₂			BENZENE			BUTADIENE			CO ₂		
	E	N	S	E	N	S	E	N	S	E	N	S
1	0.8980	0.1760	1.5130	0.0150	0.0029	0.0253	0.0027	0.0005	0.0045	4078.48	799.26	6868.43
2	0.7190	0.3700	1.3040	0.0120	0.0062	0.0220	0.0021	0.0011	0.0039	3264.28	1680.69	5919.77
3	0.5780	0.5850	1.3800	0.0097	0.0098	0.0230	0.0017	0.0017	0.0041	2625.62	2655.49	6263.38
4	0.6310	0.4960	1.1920	0.0106	0.0083	0.0190	0.0019	0.0015	0.0035	2864.65	2252.13	5411.83
5	0.5310	0.6040	1.0840	0.0089	0.0101	0.0180	0.0016	0.0018	0.0032	2408.99	2741.39	4918.82
6	0.4890	0.7470	1.0160	0.0082	0.0125	0.0170	0.0014	0.0022	0.0031	2218.51	3391.26	4608.83
7	0.1360	0.9310	1.0130	0.0023	0.0156	0.0169	0.0004	0.0027	0.0030	616.25	4227.87	4597.63
8	0.4270	1.0610	0.6610	0.0071	0.0178	0.0110	0.0013	0.0031	0.0020	1940.27	4817.98	2999.1
9	0.7440	1.1800	0.7400	0.0124	0.0197	0.0120	0.0022	0.0035	0.0022	3376.32	5355.81	3359.14
10	0.6640	1.3800	0.5070	0.0111	0.0230	0.0085	0.0020	0.0041	0.0015	3014.04	6263.38	2302.55
11	0.8430	1.6020	0.3940	0.0140	0.0270	0.0066	0.0025	0.0048	0.0012	3824.51	7271.8	1791.24
12	0.3320	1.3730	0.9210	0.0055	0.0220	0.0150	0.0010	0.0041	0.0027	1505.15	6233.51	4179.32
13	0.9480	1.5690	0.2910	0.0158	0.0260	0.0049	0.0028	0.0046	0.0009	4302.57	7122.4	1322.14
14	1.1520	1.6360	0.5640	0.0193	0.0270	0.0094	0.0034	0.0049	0.0017	5228.82	7424.93	2558.39
15	1.3150	1.6660	1.3410	0.0220	0.0280	0.0220	0.0039	0.0050	0.0039	5968.32	7563.11	6087.84
16	1.3249	1.8845	0.1728	0.0222	0.0316	0.0029	0.0039	0.0056	0.0005	6013.144	8552.857	784.323

Table- 7.20: Pollutant emission rate by departmental vehicle DV3 (g/t/trip)

Br No.	CO			HC			NO _x			PM		
	E	N	S	E	N	S	E	N	S	E	N	S
1	10.030	1.885	16.889	2.801	0.549	4.717	17.902	3.508	30.148	1.924	0.379	3.240
2	8.027	3.963	14.556	2.242	1.154	4.065	14.328	7.377	25.980	1.539	0.793	2.793
3	6.456	6.262	14.770	1.803	1.824	4.301	11.524	11.656	27.490	1.239	1.253	2.955
4	7.044	5.311	13.310	1.967	1.547	3.716	12.574	9.885	23.755	1.351	1.062	2.553
5	5.924	6.465	12.095	1.654	1.883	3.378	10.574	12.033	21.590	1.136	1.293	2.320
6	5.455	7.997	11.333	1.524	2.329	3.165	9.738	14.886	20.230	1.047	1.599	2.174
7	1.515	9.970	11.305	0.423	2.903	3.157	2.705	18.560	20.180	0.291	1.994	2.169
8	4.771	11.362	7.374	1.332	3.309	2.059	8.517	21.150	13.164	0.915	2.273	1.415
9	8.302	12.630	8.260	2.318	3.678	2.307	14.820	23.509	14.745	1.593	2.527	1.585
10	7.411	14.770	5.662	2.069	4.301	1.581	13.230	27.490	10.107	1.422	2.955	1.086
11	9.404	17.148	4.405	2.626	4.994	1.230	16.787	31.920	7.862	1.804	3.431	0.845
12	3.701	14.700	10.276	1.034	4.281	2.870	6.607	27.360	18.345	0.710	2.941	1.972
13	10.579	16.796	3.251	2.955	4.891	0.908	18.885	31.260	5.803	2.029	3.360	0.624
14	12.858	17.509	6.291	3.591	5.099	1.757	22.952	32.590	11.229	2.467	3.503	1.207
15	14.676	17.836	14.969	4.098	5.194	4.181	26.197	33.197	26.720	2.816	3.568	2.872
16	14.7862	21.0314	1.9286	4.1297	5.8739	0.5387	26.394	37.542	3.4427	2.8368	4.0350	0.3700
Br No.	SO ₂			BENZENE			BUTADIENE			CO ₂		
	E	N	S	E	N	S	E	N	S	E	N	S
1	1.2540	0.2456	2.1110	0.0146	0.0029	0.0250	0.0026	0.0005	0.0044	5697.14	1116.6	9594.372
2	1.0030	0.5170	1.8190	0.0117	0.0060	0.0210	0.0021	0.0011	0.0038	4559.8	2347.99	8269.21
3	0.8070	0.8160	1.9250	0.0094	0.0095	0.0220	0.0017	0.0017	0.0040	3667.67	3709.83	8750.18
4	0.8800	0.6920	1.6630	0.0103	0.0081	0.0190	0.0018	0.0014	0.0035	4001.57	3146.31	7559.67
5	0.7400	0.8430	1.5120	0.0086	0.0098	0.0176	0.0015	0.0018	0.0032	3365.07	3829.83	6871.01
6	0.6820	1.0420	1.4170	0.0079	0.0120	0.0165	0.0014	0.0022	0.0030	3098.99	4737.73	6437.98
7	0.1890	1.2990	1.4130	0.0022	0.0150	0.0164	0.0004	0.0027	0.0029	860.83	5906.5	6422.33
8	0.5960	1.4810	0.9220	0.0069	0.0170	0.0107	0.0013	0.0031	0.0019	2710.32	6730.91	4189.39
9	1.0380	1.6460	1.0320	0.0120	0.0190	0.0120	0.0022	0.0034	0.0022	4716.32	7482.27	4692.32
10	0.9260	1.9250	0.7080	0.0108	0.0220	0.0083	0.0019	0.0040	0.0015	4210.25	8750.18	3216.38
11	1.1750	2.2350	0.5505	0.0140	0.0260	0.0064	0.0024	0.0047	0.0012	5342.38	10158.98	2502.15
12	0.4630	1.9160	1.2850	0.0054	0.0223	0.0149	0.0010	0.0040	0.0027	2102.52	8708.44	5838.01
13	1.3220	2.1890	0.4060	0.0150	0.0250	0.0047	0.0028	0.0046	0.0009	6010.18	9950.267	1846.87
14	1.6070	2.2820	0.7860	0.0187	0.0270	0.0092	0.0034	0.0048	0.0016	7304.03	10372.91	3573.76
15	1.8340	2.3250	1.8710	0.0214	0.0271	0.0220	0.0038	0.0049	0.0039	8337.03	10565.96	8503.98
16	1.8309	2.6042	0.2388	0.0216	0.0307	0.0028	0.0039	0.0055	0.0005	8320.376	11834.57	1085.267

Table- 7.21: Pollutant emission rate by departmental vehicle DV4 (g/t/trip)

Br No.	CO			HC			NO _x			PM		
	E	N	S	E	N	S	E	N	S	E	N	S
1	13.837	2.711	23.302	3.828	0.750	6.447	24.656	4.832	41.520	2.465	0.483	4.151
2	11.075	5.702	20.084	3.064	1.577	5.556	19.734	10.160	35.787	1.973	1.016	3.577
3	8.908	9.009	21.249	2.464	2.492	5.879	15.873	16.053	37.865	1.587	1.605	3.785
4	9.719	7.641	18.360	2.689	2.114	5.079	17.318	13.615	32.717	1.731	1.361	3.271
5	8.173	9.301	16.688	2.261	2.573	4.617	14.563	16.573	29.736	1.456	1.657	2.973
6	7.527	11.506	15.640	2.082	3.183	4.326	13.412	20.502	27.862	1.341	2.049	2.785
7	2.091	14.344	15.598	0.578	3.968	4.315	3.725	25.560	27.794	0.372	2.555	2.778
8	6.583	16.346	10.175	1.821	4.522	2.815	11.729	29.127	18.131	1.172	2.912	1.812
9	11.455	18.171	11.397	3.169	5.027	3.153	20.410	32.378	20.307	2.040	3.237	2.030
10	10.226	21.249	7.812	2.829	5.879	2.161	18.220	37.865	13.920	1.821	3.785	1.391
11	12.975	24.670	6.077	3.589	6.826	1.681	23.121	43.961	10.829	2.311	4.395	1.082
12	5.106	21.149	14.179	1.413	5.851	3.923	9.099	37.684	25.266	0.910	3.767	2.526
13	14.597	24.164	4.486	4.038	6.685	1.241	26.011	43.058	7.993	2.600	4.304	0.799
14	17.740	25.191	8.679	4.908	6.969	2.401	31.610	44.887	15.466	3.160	4.487	1.546
15	20.249	25.659	20.654	5.602	7.099	5.714	36.081	45.720	36.803	3.607	4.571	3.679
16	20.401	29.018	2.661	5.644	8.028	0.736	36.352	51.706	4.742	3.634	5.169	0.474
Br No.	SO ₂			BENZENE			BUTADIENE			CO ₂		
	E	N	S	E	N	S	E	N	S	E	N	S
1	1.227	0.240	2.066	0.020	0.004	0.033	0.003	0.001	0.006	5568.180	1091.200	9377.190
2	0.982	0.505	1.780	0.016	0.008	0.028	0.003	0.001	0.005	4456.590	2294.580	8082.030
3	0.789	0.798	1.884	0.013	0.013	0.030	0.002	0.002	0.005	3584.650	3625.440	8551.140
4	0.861	0.677	1.627	0.014	0.011	0.026	0.002	0.002	0.005	3910.980	3074.780	7388.550
5	0.724	0.824	1.479	0.012	0.013	0.024	0.002	0.002	0.004	3288.900	3742.720	6715.470
6	0.667	1.019	1.386	0.011	0.016	0.022	0.002	0.003	0.004	3028.850	4629.950	6292.250
7	0.185	1.271	1.383	0.003	0.020	0.022	0.001	0.004	0.004	841.350	5772.150	6276.960
8	0.583	1.449	0.902	0.009	0.023	0.014	0.002	0.004	0.003	2648.970	6577.800	4094.550
9	1.015	1.611	1.010	0.016	0.026	0.016	0.003	0.005	0.003	4609.560	7312.070	4586.100
10	0.906	1.884	0.692	0.015	0.030	0.011	0.003	0.005	0.002	4114.950	8551.140	3143.580
11	1.150	2.187	0.539	0.018	0.035	0.009	0.003	0.006	0.002	5221.449	9927.890	2445.510
12	0.453	1.875	1.257	0.007	0.030	0.020	0.001	0.005	0.004	2054.930	8510.350	5705.860
13	1.294	2.142	0.397	0.021	0.034	0.006	0.004	0.006	0.001	5874.130	9723.930	1805.070
14	1.573	2.233	0.769	0.025	0.036	0.012	0.004	0.006	0.002	7138.690	10136.950	3492.860
15	1.795	2.275	1.831	0.029	0.036	0.029	0.005	0.006	0.005	8148.314	10325.620	8311.485
16	1.808	2.572	0.236	0.029	0.041	0.004	0.005	0.007	0.001	8209.503	11676.871	1070.805

Table- 7.22: Pollutant emission rate by hired vehicle HV per ton of garbage per trip
(g/t/trip)

Br No.	CO			HC			NO _x			PM		
	E	N	S	E	N	S	E	N	S	E	N	S
1	11.390	2.232	19.183	1.061	0.208	1.786	0.478	0.093	0.804	2.967	0.581	4.997
2	9.117	4.694	16.534	0.849	0.437	1.539	0.382	0.197	0.693	2.375	1.223	4.307
3	7.330	7.416	17.490	0.683	0.691	1.629	0.307	0.311	0.733	1.910	1.932	4.556
4	8.000	6.290	15.110	0.745	0.586	1.408	0.335	0.264	0.634	2.084	1.638	3.937
5	6.728	7.657	13.738	0.626	0.713	1.279	0.282	0.321	0.576	1.752	1.994	3.578
6	6.196	9.472	12.872	0.577	0.882	1.198	0.259	0.397	0.539	1.614	2.467	3.353
7	1.721	11.808	12.841	0.160	1.099	1.196	0.072	0.495	0.538	0.448	3.076	3.345
8	5.419	13.456	8.376	0.505	1.253	0.780	0.227	0.564	0.351	1.411	3.505	2.182
9	9.430	14.960	9.382	0.878	1.393	0.874	0.395	0.627	0.393	2.456	3.896	2.444
10	8.418	17.490	6.431	0.784	1.629	0.599	0.353	0.733	0.269	2.193	4.556	1.675
11	10.682	20.310	5.003	0.995	1.891	0.466	0.448	0.851	0.209	2.782	5.290	1.303
12	4.204	17.410	11.673	0.391	1.621	1.087	0.176	0.729	0.489	1.095	4.535	3.040
13	12.020	19.893	3.693	1.120	1.852	0.344	0.504	0.834	0.155	3.130	5.181	0.962
14	14.604	20.737	7.145	1.360	1.931	0.665	0.612	0.869	0.299	3.804	5.401	1.861
15	16.670	21.124	17.003	1.552	1.967	1.583	0.699	0.886	0.713	4.342	5.502	4.429
16	16.795	23.888	2.191	1.564	2.225	0.204	0.704	1.001	0.092	4.375	6.222	0.571
Br No.	SO ₂			BENZENE			BUTADIENE			CO ₂		
	E	N	S	E	N	S	E	N	S	E	N	S
1	0.478	0.093	0.804	0.013	0.003	0.022	0.002	0.000	0.003	2158.450	422.990	3634.960
2	0.382	0.197	0.693	0.011	0.005	0.019	0.002	0.001	0.003	1727.550	889.470	3132.910
3	0.307	0.311	0.733	0.008	0.009	0.020	0.001	0.001	0.003	1389.550	1405.360	3314.760
4	0.335	0.264	0.634	0.009	0.007	0.017	0.001	0.001	0.003	1516.050	1191.890	2864.090
5	0.282	0.321	0.576	0.008	0.009	0.016	0.001	0.001	0.002	1274.910	1450.820	2603.180
6	0.259	0.397	0.539	0.007	0.011	0.015	0.001	0.002	0.002	1174.090	1794.750	2439.120
7	0.072	0.495	0.538	0.002	0.014	0.015	0.000	0.002	0.002	326.140	2237.510	2433.190
8	0.227	0.564	0.351	0.006	0.016	0.010	0.001	0.002	0.002	1026.840	2549.810	1587.210
9	0.395	0.627	0.393	0.011	0.017	0.011	0.002	0.003	0.002	1786.840	2834.440	1777.750
10	0.353	0.733	0.269	0.010	0.020	0.007	0.002	0.003	0.001	1595.110	3314.760	1218.570
11	0.448	0.851	0.209	0.012	0.023	0.006	0.002	0.004	0.001	2024.040	3848.440	947.980
12	0.176	0.729	0.489	0.005	0.020	0.013	0.001	0.003	0.002	796.570	3298.940	2211.810
13	0.504	0.834	0.155	0.014	0.023	0.004	0.002	0.004	0.001	2277.040	3769.370	699.710
14	0.612	0.869	0.299	0.017	0.024	0.008	0.003	0.004	0.001	2767.240	3929.480	1353.970
15	0.699	0.886	0.713	0.019	0.024	0.020	0.003	0.004	0.003	3158.600	4002.610	3221.850
16	0.704	1.001	0.092	0.019	0.027	0.003	0.003	0.004	0.000	3182.323	4526.410	415.086

Table- 7.23: Pollutant emission rate by hired vehicle HV per ton of silt per trip (g/t/trip)

Br No.	CO			HC			NO _x			PM		
	E	N	S	E	N	S	E	N	S	E	N	S
1	8.859	1.736	14.920	2.308	0.452	3.887	15.618	3.061	26.304	0.825	0.162	1.389
2	7.091	3.651	12.860	1.847	0.951	3.350	12.502	6.437	22.672	0.660	0.340	1.197
3	5.701	5.768	13.603	1.486	1.503	3.544	10.056	10.170	23.988	0.531	0.537	1.267
4	6.222	4.892	11.752	1.621	1.274	3.062	10.971	8.626	20.727	0.579	0.456	1.095
5	5.233	5.955	10.685	1.363	1.551	2.783	9.226	10.499	18.838	0.487	0.555	0.995
6	4.819	7.367	10.012	1.255	1.919	2.608	8.496	12.981	17.652	0.449	0.686	0.932
7	1.339	9.184	9.987	0.348	2.392	2.602	2.360	16.193	17.609	0.124	0.855	0.930
8	4.215	10.466	6.515	1.097	2.726	1.697	7.431	18.453	11.486	0.393	0.975	0.607
9	7.334	11.636	7.297	1.910	3.030	1.901	12.927	20.512	12.865	0.683	1.083	0.680
10	6.547	13.603	5.002	1.706	3.544	1.303	11.544	23.988	8.818	0.610	1.267	0.466
11	8.308	15.797	3.891	2.164	4.114	1.013	14.646	27.851	6.860	0.774	1.471	0.362
12	3.270	13.541	9.079	0.852	3.527	2.364	5.765	23.874	16.007	0.304	1.261	0.845
13	9.349	15.472	2.872	2.434	4.030	0.748	16.479	27.277	5.063	0.871	1.440	0.268
14	11.359	16.129	5.557	2.959	4.201	1.447	20.028	28.436	9.798	1.058	1.502	0.517
15	12.966	16.430	13.225	3.377	4.279	3.445	22.859	28.967	23.316	1.207	1.530	1.231
16	13.062	18.580	1.704	3.402	4.840	0.444	23.030	32.757	3.004	1.216	1.730	0.159
Br No.	SO ₂			BENZENE			BUTADIENE			CO ₂		
	E	N	S	E	N	S	E	N	S	E	N	S
1	0.371	0.072	0.625	0.010	0.002	0.017	0.002	0.000	0.003	1678.794	328.992	2827.191
2	0.297	0.153	0.539	0.008	0.004	0.015	0.001	0.001	0.002	1343.650	691.810	2436.708
3	0.239	0.242	0.570	0.007	0.007	0.016	0.001	0.001	0.002	1080.761	1093.058	2578.147
4	0.261	0.205	0.493	0.007	0.006	0.014	0.001	0.001	0.002	1179.150	927.026	2227.626
5	0.219	0.250	0.448	0.006	0.007	0.012	0.001	0.001	0.002	991.597	1128.416	2024.696
6	0.201	0.309	0.419	0.006	0.009	0.012	0.001	0.001	0.002	913.181	1395.917	1897.093
7	0.056	0.385	0.418	0.001	0.011	0.011	0.000	0.002	0.002	253.664	1740.286	1892.481
8	0.177	0.439	0.273	0.005	0.012	0.007	0.001	0.002	0.001	798.653	1983.186	1234.497
9	0.307	0.488	0.306	0.008	0.013	0.008	0.001	0.002	0.001	1389.764	2204.564	1382.694
10	0.275	0.570	0.209	0.008	0.016	0.006	0.001	0.002	0.001	1240.641	2578.147	947.777
11	0.348	0.662	0.163	0.009	0.018	0.004	0.001	0.003	0.001	1574.253	2993.231	737.318
12	0.137	0.567	0.380	0.004	0.016	0.010	0.001	0.002	0.002	619.554	2565.842	1720.297
13	0.392	0.649	0.121	0.011	0.018	0.003	0.002	0.003	0.001	1771.031	2931.732	544.219
14	0.476	0.676	0.233	0.013	0.019	0.006	0.002	0.003	0.001	2152.298	3056.262	1053.088
15	0.544	0.689	0.555	0.015	0.019	0.015	0.002	0.003	0.002	2456.689	3113.141	2505.883
16	0.548	0.779	0.071	0.015	0.021	0.002	0.002	0.003	0.000	2475.140	3520.541	322.844

7.14 POLLUTION GENERATION FROM INCINERATION

The physical and chemical composition of solid waste makes it abundantly evident that, even after recyclables like paper and plastic are separated, there are still not more materials with a high calorific value in the trash. Table 7.3 provides the composition of the total input materials for thermal processing. Due to anticipated sorting inefficiencies, it is projected that some proportion of inert and biodegradable materials will be combined with the remaining high calorific value materials as incinerator feed. The incinerator pre-sorter will filter out some inert (1 MT) and recyclable (0.5 MT). Mass burn incineration allows for significant volume reduction, which lowers the need for landfill space. Because incinerators produce significant amounts of gases like CO₂, NO₂ and SO₂ that contribute to the rise in global temperatures, air pollution control equipment that complies with emission requirements must be taken into account to reduce the production of air pollution.

7.14.1 Gas Generation from 100MT of Garbage from Incineration in the Proposed ISWM System

Out of 100 MT of waste, 14.5 MT are incinerated directly after pre-sorting. The material balance, chemical and physical compositions of the incinerated waste (after presorting) is shown in table 7.24. (Tchobanoglous et.al., 1993)

Table- 7.24: Physical and chemical composition of incinerated waste (after presorting)

Waste Components	quantity (MT)	Total Combustible	Ultimate analysis on % dry basis					
			C	H	O	N	S	Ash
Paper	1.07	14.5 MT	43.5	6	44	0.3	0.2	6 [#]
Rubber & Leather	0.34		69	9	5.8	6	0.2	10
Rags	1.87		55	6.6	31.2	4.6	0.2	2.5
Wooden Matter	1.15		49.5	6	42.7	0.2	0.1	1.5
Coconut Shells [*]	4.5		49.6	6.1	43.2	0.1	0.1	0.9
Bones ^{**}	0.16		60	8	11.6	10	0.4	10
Inert in incineration feed	2.41		26.3	3	2	0.5	0.2	68
Compostable portion in incineration feed	3		48.6	6.4	37.6	2	0.4	5

Note: * ultimate analysis same as hard wood, ** ultimate analysis same as leather, # ultimate analysis average of rubber & leather.

Table 7.25 present the analysis of chemical composition of incinerated waste based on dry weight and ultimate analysis.

Table- 7.25: Analysis of chemical composition of incinerated waste

Waste Components	Quantity (MT)	Moisture Content (%)	Dry Mass (MT)	Ultimate analysis on % dry basis					
				C	H	O	N	S	Ash
Paper	1.07	6	1.06	0.44	0.062	0.44	0.003	0.002	0.063
Rubber & Leather	0.34	5	0.32	0.22	0.029	0.019	0.019	0.001	0.032
Rags	1.87	10	1.68	0.101	0.014	0.06	0.009	0	0.006
Wooden Matter	1.15	25	0.86	0.426	0.052	0.366	0.002	0.001	0.013
Coconut Shells*	4.5	40	2.70	1.34	0.165	1.166	0.003	0.003	0.023
Bones**	0.16	5	0.15	0.09	0.012	0.017	0.015	0.001	0.015
Inert in incineration feed	2.41	22	1.88	0.494	0.056	0.038	0.01	0.004	1.278
Compostable portion in incineration feed	3	72.5	0.825	0.401	0.053	0.31	0.017	0.003	0.041
Total	14.5		9.486	3.512	0.443	2.416	0.078	0.015	1.471

Amount of moisture = (moist mass - dry mass) = 5.014 ton

Hydrogen component from water = 0.557 ton

Oxygen from water = 4.457 ton

After availability of values of chemical components the approximate chemical formula can be determined and illustrated in Table 7.26.

Table- 7.26: Approximate chemical formula of incinerated waste

Component	Mass (MT)	Molecular Weight	Moles	Mole Ratio (S=1)
C	3.512	12.011	0.292	584
H	1.000	1.0079	0.992	1984
O	6.873	15.9994	0.430	860
N	0.078	14.0067	0.006	12
S	0.015	32.066	0.0005	1

The waste that will be burned has the chemical formula $C_{584}H_{1984}O_{860}N_{12}S$ according to the proposed system's study of the chemical composition of incinerated waste based on dry weight and ultimate analysis. In addition to the major gas, CO_2 , which is produced when MSW is burned in incinerators, this process can also produce NO_2 and SO_2 , as well as a number of other pollutants in various concentrations, such as CO, PM containing heavy metal compounds, and dioxins because of incomplete or partial combustion. Therefore, complete combustion is required, combined with air pollution management technology, to lower emission levels. The SWM Rules 2016 have been followed in maintaining the emission standards (CPHEEO, 2016).

7.14.2 Calculation of Gas Generation Rate from Incineration (Kg per MT of Waste)

The major gas emissions when incineration is taken into account are shown in below. These data have been entered into an excel spreadsheet as input for the model. The example calculation is also displayed below.

Amount of CO_2 generation from complete combustion is $[(44/12) \times 3.512]$ MT= 12.88 MT.

Amount of NO_2 generation from complete combustion is $[(46/14) \times 0.078]$ MT= 0.256 MT.

Amount of SO_2 generation from complete combustion is $[(64/32) \times 0.015]$ MT = 0.03 MT.

CO_2 generation rate per MT of waste= $[(12.88/14.5) \times 1000] = 888.3$ kg/MT of waste

NO_2 generation rate per MT of waste= $[(0.256/14.5) \times 1000] = 17.7$ kg/MT of waste

SO_2 generation rate per MT of waste= $[(0.03/14.5) \times 1000] = 2.1$ kg/MT of waste

The generation rate of gases from incineration for corresponding ELF is shown in Table 7.27.

Table- 7.27: Gas generation rate from incineration

Incineration (kg/ MT of waste)			
Dumpsite	CO₂	NO₂	SO₂
E	888.3	17.7	2.1
N	888.3	17.7	2.1
S	888.3	17.7	2.1

7.14.3 Calculation of Gas Generation Rate from Incineration Meeting the Emission Standards (Kg per MT of Waste)

The chemical formula for incineration fuel is $C_{584}H_{1984}O_{860}N_{12}S$. By weight % of different component of incineration fuel are C= 26.9%, H₂= 8.93%, O₂= 63.4%, N₂= 0.645%.

Different available component of fuel (Kg mole) are C= 26.9/12= 2.242 Kg mole, H₂= 8.93/2= 4.465 Kg mole, N₂= 0.645/28= 0.023 Kg mole and O₂= 63.4/32= 1.98 Kg mole. O₂ is required with 300% excess air for complete combustion of fuel.

C (1 mole) + O₂ (1 mole) = CO₂ (1 mole); H₂ (1 mole) + ½ O₂ (0.5 mole) = H₂O (1 mole)
O₂ required including 300% excess air = [(2.242×4) + (4.465×0.5×4)] = 17.898 Kg mole.
But already 1.98 Kg mole of O₂ is present in the fuel.

Then, O₂ required from the air = 17.898 – 1.98= 15.918 Kg mole ; Considering the other part as N₂ in the air i.e. 78.8% of N₂ and 21.2% of O₂ only, hence, N₂ present in the air along with O₂ = 78.8 × 15.918/21.2 = 59.17 Kg mol

Air requirement

(21.2 × 32/100) Kg of O₂ is equivalent to [(0.212 × 32) + (0.788 × 28)] = 28.848 Kg of air

Hence, (15.981 × 32) Kg of O₂ = (28.848 × 15.981 × 32) / (0.212 × 32) = 2174.62 Kg of air

Again, 21.2 gm mole of O₂ ≡ 100 mole of air

≡ 22.4 × 100 lt. of air

$$15.981 \text{ Kg mole of O}_2 \equiv (22.4 \times 100 \times 15.981 \times 1000) / (21.2 \times 1000) \text{ Nm}^3 \text{ of air}$$

$$\equiv 1688.56 \text{ Nm}^3 \text{ of air}$$

Table 7.28 shows the material balance for gas generation from incinerator.

Table- 7.28: Material balance for gas generation from incineration

Element/ Component		Input			Output	
		Kg	M.W.	Kg Mole	Kg Mole	Kg
Fuel	Carbon	26.9	12	2.242	-	-
	H ₂	8.93	2	4.465	-	-
	N ₂	0.645	28	0.023	0.023	0.644
	O ₂	63.4	32	1.981	-	-
Air with 300% Excess	O ₂	509.37	32	15.918	13.423	429.536
	N ₂	1656.76	28	59.17	59.17	1656.76
Fuel Gas	H ₂ O	-	18	-	4.465	80.37
	CO ₂	-	44	-	2.242	98.648
Total		2266.005 Kg			79.323	2265.958 Kg

Average molecular wt. of flue gas with 300% excess air= 2265.98/79.323 = 28.566

$$\begin{aligned}
 100 \text{ Kg of fuel generates } 2265.958 \text{ Kg of flue gas} &= 2265.958 \times 10^3 \text{ gm of flue gas} \\
 &= 2265.958 \times 10^3 / 28.566 \text{ mole} \\
 &= 79323.6 \text{ mole} \\
 &= 79323.6 \times 22.4 / 10^3 \text{ Nm}^3 \\
 &= 1776.85 \text{ Nm}^3
 \end{aligned}$$

$$\text{O}_2 \text{ concentration} = 429.536 \times 100 / 2265.958 = 18.96\%$$

But the emission standards are corrected to 11% O₂ correction on dry basis.

$$\text{Emission volume of flue gas to meet the standards} = 1776.85 / (18.96/11) \text{ Nm}^3 = 1030.87 \text{ Nm}^3$$

As CO₂ can't be regulated through these emission standards, we have only corrected the emission standards for SO₂ and NO₂ emission. Standards for incineration: The thermal technology and incineration emission regulations in solid waste treatment and disposal facilities must match the SO₂ criteria. = 200 mg/ Nm³ and for NO₂ = 400mg/ Nm³.

SO₂ generation rate per MT of waste = $200 \times 1030.87 \times 1000 / 100 \times 10^6 = 2.062$ g/ MT of waste

NO₂ generation rate per MT of waste = $400 \times 1030.87 \times 1000 / 100 \times 10^6 = 4.123$ g/ MT of waste.

Table 7.29 shows the gas generation rate from incineration meeting the emission standards for corresponding three dumpsites.

Table- 7.29: Gas generation rate from incineration meeting the emission

Incineration (kg/ MT of Waste)			
Dumpsite	CO ₂	NO ₂	SO ₂
E	888.3	4.123	2.062
N	888.3	4.123	2.062
S	888.3	4.123	2.062

7.15 POLLUTION GENERATION FROM COMPOSTING

For the proposed integrated MSW management system, the windrow composting method has been taken into account. The principal gases that windrow composting produces are CO₂, CH₄, N₂O, and NH₃, which are generated by microbial activity throughout the composting process. Methane is produced due to insufficient diffusion of O₂ into the core of the windrow (Font et al., 2011). N₂O after oxidation is converted to NO₂. Following are the generation rate of gases from windrow composting of MSW (Clemens and Cuhls, 2003; Shang et al., 2022).

CO₂ generation rate ranges from 0.63 to 413 kg/MT of waste. So, average CO₂ generation rate is 206.82 kg/MT of waste.

CH₄ generation rate ranges from 6 to 12 kg/MT of waste. So, average CH₄ generation rate is 9 kg/MT of waste.

NH₃ generation rate ranges from 0.018 to 0.115 kg/MT of waste. So, average NH₃ generation rate is 0.0665 kg/MT of waste.

N₂O generation rate ranges from 0.00144 to 0.378 kg/MT of waste. So, average N₂O generation rate is 0.19 kg/MT of waste.

After oxidation N₂O converted to NO₂ [N₂O → 2NO₂]. So, from 44 g of N₂O, 92 g of NO₂ is produced. So, average NO₂ generation rate is [0.19 × (92/44)] i.e., 0.4 kg/MT of waste.

Table 7.30 depicts the average values taken for the gas generation rate from composting plant of three respective dumpsites.

Table- 7.30: Gas generation rate from composting plant

Composting (kg/ MT of waste)				
Dumpsite	CO ₂	CH ₄	NO ₂	NH ₃
E	206.82	9	0.4	0.0665
N	206.82	9	0.4	0.0665
S	206.82	9	0.4	0.0665

7.16 GENERATION OF LIQUID POLLUTANTS FROM LANDFILL LEACHATE

Leachate from landfills and the production of heavy metals are described in detail in previous Chapter. The proposed ISWM system will include an engineered landfill with an appropriate bottom liner and a leachate collection facility. Leachate will be collected and treat during active and post-closure phases of landfill. After closure, a full final cover will be provided to minimize ground water pollution by reducing leachate generation. After sorting and treatment, just 33% of the total inert waste will be disposed in a designed landfill. According to EPACMTP (EPA Composite Model for Leachate Migration with Transformation Products), the majority of metal and organic contents in ground water will be within the permissible limit at this amount of leachate formation (Chattopadhyay, 2018). Thus, the direct reduction in leachate formation for the propose ISWM is 62%. As there is just inert material present, the quality of the leachate will also significantly improve. Despite the presence of leachate treatment facilities, a pollutant transport study conducted using the EPACMTP shows that all metals and organic pollutants will be substantially below the safe level in the nearby water resources. If a complete top cover system is used at post closure period, leachate generation will be reduced by 96% i.e. 43 L/m²/year.

7.16.1 Land requirement for Engineered Landfill site (CPHEEO, 2016)

Current generation of waste: 1000 MT/day

After 16 years, estimated waste generation: 1700 MT/day

In 16 years, the total waste generation: $[0.5 (1000+1700) \times 365 \times 16] = 7 \times 10^6$ MT

Total waste volume (assumed density 0.85 MT/m³): $[(7 \times 10^6) / 0.85] = 8.25 \times 10^6$ m³

Volume of daily cover: $[0.1 \times 8.25 \times 10^6] \text{ m}^3 = 0.825 \times 10^6 \text{ m}^3$

Volume of liner and cover systems: $[0.125 \times 8.25 \times 10^6] \text{ m}^3 = 1.03 \times 10^6 \text{ m}^3$

Estimate of landfill volume: $[(8.25 + 0.825 + 1.03 - 0.825) \times 10^6] \text{ m}^3 = 9.28 \times 10^6 \text{ m}^3$

Likely shape of a landfill: Rectangular in plan (length: width = 2:1)

Area restrictions: Nil

Possible maximum landfill height: 20 m

Dumping Area required: $[9.28 \times 10^6] / 20 = 4.6 \times 10^5 \text{ m}^2 = 46$ hectares

So for 1000 TPD ELF facility, dumping land area requirement will be 46 ha.

Table- 7.31: Landfill leachate characteristics for proposed landfill site meeting standards

Sl. No.	Parameter	Leachate standards for inland surface water (mg/L)	Heavy metal generation rate from leachate meeting with standards (Kg/MT)
1	NH ₃ -N	50	5.85×10^{-6}
2	TKN	100	1.17×10^{-5}
3	As	0.2	2.34×10^{-8}
4	Hg	0.01	1.17×10^{-9}
5	Pb	0.1	1.17×10^{-8}
6	Total Cr	2	2.34×10^{-7}
7	Cu	3	3.51×10^{-7}
8	Zn	5	5.85×10^{-7}
9	Ni	3	3.51×10^{-7}
10	CN	0.2	2.34×10^{-8}
11	Cl	1000	0.000117
12	Phenol	1	1.17×10^{-7}

For proposed system, rate of leachate generation is similar for east, north and south disposal sites. In table 7.31 the leachate characteristics and leachate generation rate for inland surface water discharge are shown. The emission standards are maintained as per SWM Rules 2016.

The following sub chapter 7.16.2 and 7.16.3 shows the sample calculation of leachate generation rate (kg/MT of waste). The values shown in Table 7.32 are fed as input data for the estimation of total heavy metal generation from three engineered landfill sites.

7.16.2 Calculation of Rate of Leachate Generation (L/MT of waste)

For proposed ISWM system, for 1000 MT/day capacity ELF, total disposable area is 46 ha. Average leachate generation = 43 L/m²/yr.

For 33% inert material going to ELF i.e. 330 MT/day capacity, area requirement = $[330 \times (46/1000)] = 15$ ha. For 4000 MT/day of total waste, only 33% i.e., 1320 MT/day of waste is going to dispose in ELF. Landfill area required per ton of waste = $[(15 \times 10^4)/(330 \times 365)] = 1.2$ m²/MT/day, which is assumed as 1 m²/MT/day considering practical situation.

Leachate generation rate per ton of waste = $[1 \times (43/365)] = 0.117$ L/MT of waste.

7.16.3 Sample Calculation of Rate of Heavy Metal Generation from Leachate (kg/MT of waste)

For NH₃-N, leachate generation rate for inland surface water = leachate characteristics x leachate generation rate per ton of waste. [Table 7.32]. Hence, Rate of generation = 50 x 0.117/1000000 = 5.85×10^{-6} kg/MT of waste.

Table- 7.32: Heavy metal generation rate from leachate meeting standards (Kg/MT)

Dumpsite	NH ₃ -N	TKN	As	Hg	Pb	Cr
E	5.85×10^{-6}	1.17×10^{-5}	2.34×10^{-8}	1.17×10^{-9}	1.17×10^{-8}	2.34×10^{-7}
N	5.85×10^{-6}	1.17×10^{-5}	2.34×10^{-8}	1.17×10^{-9}	1.17×10^{-8}	2.34×10^{-7}
S	5.85×10^{-6}	1.17×10^{-5}	2.34×10^{-8}	1.17×10^{-9}	1.17×10^{-8}	2.34×10^{-7}
Dumpsite	Cu	Zn	Ni	CN	Cl	Phenol
E	3.51×10^{-7}	5.85×10^{-7}	3.51×10^{-7}	2.34×10^{-8}	0.000117	1.17×10^{-7}
N	3.51×10^{-7}	5.85×10^{-7}	3.51×10^{-7}	2.34×10^{-8}	0.000117	1.17×10^{-7}
S	3.51×10^{-7}	5.85×10^{-7}	3.51×10^{-7}	2.34×10^{-8}	0.000117	1.17×10^{-7}

Table 7.32 depicts the average values taken for the leachate generation rate meeting the emission standards from three respective dumpsites.

7.17 IMPLEMENTING THE MODEL FOR PROPOSED ISWM SYSTEM WITH VEHICLE OPTIMISATION

In the proposed ISWM system concept of an intermediate transfer station with a central sorting facility, incineration, and composting are incorporated. A heavy-duty TATA LPT truck is engaged to transport the sorted waste to the appropriate ELF. The proposed ISWM model is implemented by optimizing the departmental vehicle. This leads to the reduction in overall cost. The number of running, idle, and total vehicles after optimization is shown in the table below.

Table- 7.33: Optimized data of departmental vehicle for proposed ISWM system

Vehicle type	Capacity (MT)	Vehicles in operation	Idle Vehicle	Total no of vehicles
DV1	7	14	10	24
DV2	9	70	47	117
DV3	10	20	14	34
DV4	7	2	1	3

7.18 OBSERVATION ON ABOVE PROPOSED STUDY

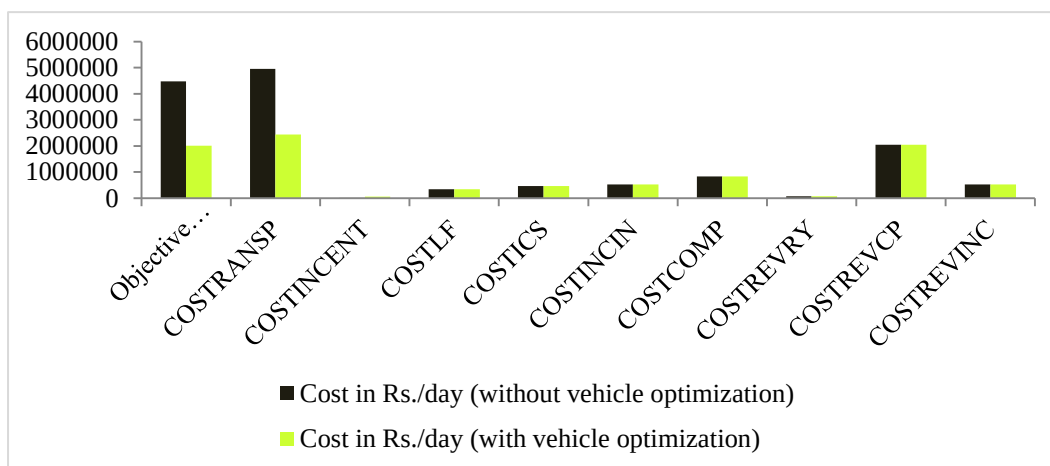
7.18.1 Cost Analysis

For the proposed ISWM system, transfer station case, it is estimated that each Heavy-Duty Truck will need to make a maximum of 10 trips to the east, 9 trips to the north, and 11 trips to the south to achieve the best possible cost efficiency. The total number of trucks thus operated is the input data, and the program can freely select the required number of trucks in the east, north, and south directions to optimize the total cost for a particular input of the total number of trucks. The cost of loading, process rejects and inert waste onto TATA LPT heavy duty trucks for transport from the transfer station to the landfill is included in the operation and maintenance costs of composting and incineration. Table 7.34 below summarizes the costs associated with the various variables of the proposed ISWM system with and without vehicle optimization.

Table- 7.34: Output summary of cost for proposed ISWM system

Items		Cost in Rs./day (without vehicle optimization)	Cost in Rs./day (with vehicle optimization)
Total SWM Cost	Objective Function	4469858	2007230
Transportation Cost	CTRANSP	4952360	2436537
Incentive Cost	CTINCENT	10160	61241
Landfilling cost	CTLF	341313	343427
Sorting Cost	CTICS	460604	460604
Incineration Cost	CTINCIN	524597	524597
Composting Cost	CTCOMP	833226	833226
Revenue from Recyclables	CTREVRV	74012	74012
Revenue from Composting	CTREVCV	2050194	2050194
Revenue from Incineration	CTREVINC	528194	528195

The cost of various components of the ISWM system, with and without vehicle optimization is depicted in the figure 7.6. The statistic shows that the cost of transportation exceeds the entire expense of solid waste management. As revenue is generated for composting, incineration, and recycling, the cost objective function becomes less. By selling the recyclables, compost and electricity produced, considerable revenue is generated which compensate about 37% of the total expenses in case of without vehicle optimization and 57% for vehicle optimization.

**Figure- 7.6:** Comparison of total cost for different variables of Proposed ISWM system.

The overall cost for two separate cases, with and without vehicle optimization, shows a large variation. It is observed from the above figure that the total cost is reduced by

55.1% and 50.8% transportation cost decrease found in vehicle optimization condition. However, the incentive cost was somewhat higher in the optimized condition due to the increased number of trips made by departmental vehicles. Since vehicle optimisation has no impact on other variables, all other expenses remain constant. A detail analysis of waste transportation from different borough centres by the KMC vehicles is shown in Table 7.35. Quantity of waste transported by individual KMC vehicle from different borough centres to the transfer stations/ disposal sites is illustrated in figure 7.7.

Table- 7.35: Analysis of waste transported by KMC vehicles in MT

Borough	DV1	DV2	DV3	DV4	HH_G	HH_S
1	37.41534	153.7873	69.01676	0	21.09887	30.25591
2	20.09913	165.7516	69.52975	0	20.70653	18.10195
3	39.59831	189.0292	48.7759	0	15.56316	30.2274
4	30.64023	156.5213	40.66973	0	18.4728	19.13389
5	40.47262	183.2857	51.11079	0	22.28668	25.7985
6	37.00011	242.5901	69.36284	0	20.30944	52.88692
7	27.56786	230.448	98.00553	0	24.75015	94.16452
8	25.99487	150.1937	65.30072	0	11.37908	60.31116
9	38.83356	276.5263	72.55642	0	31.45267	38.9884
10	1.38106	391.3994	98.55809	0	39.83826	46.58062
11	14.23647	49.1986	19.69629	12.43058	54.92931	2.708843
12	13.74963	86.30129	31.65048	0	0	3.38247
13	27.56903	105.3137	34.97365	7.068296	47.90932	5.3361
14	12.51355	57.19684	10.28258	0	21.9089	7.05159
15	0.349713	1.748565	0	0	32.87302	0.085995
16	15.01307	60.08946	20.51047	0	26.187	31.5
Total	382.43455	2499.3811	800	19.498876	409.66519	466.51427

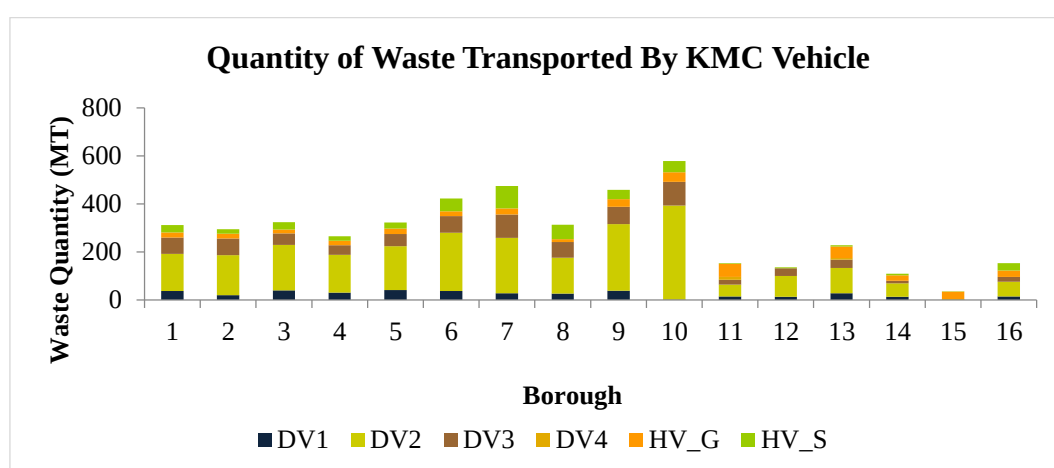


Figure- 7.7: Quantity of waste transported by individual KMC vehicle from different borough centres to the transfer stations/ ELF sites

Figure 7.7 shows that DV1, DV2, DV3, DV4 and HV carry 8.4%, 54.6%, 17.5%, 0.4% and 19.1% of the total waste. Although the hired vehicle takes away 19.1% of the total waste (garbage+ silt), DV2 shows the highest amount of transported waste because its number of vehicles and the range of waste carrying is high, while the hired vehicles transport the waste according to their minimum waste carrying range.

Table 7.36 illustrates the quantity of waste transported to different dumpsite or transfer station and undergoing processes in ISWM system.

Table- 7.36: Daily waste feed to transfer stations, different processes and ELF sites for restricted and unrestricted condition of proposed ISWM system

Transfer Station/ ELF	Transfer station/ELF feed unrestricted condition			Transfer station/ELF feed restricted condition		
	E	N	S	E	N	S
Central Sorter Feed (MT)	1805.910	785.237	1509.833	1640.392	1230.294	1230.294
Incinerator Feed (MT)	304.115	132.234	254.256	276.242	207.182	207.182
Composting Plant Feed (MT)	1235.604	537.259	1033.028	1122.356	841.761	841.761
Landfilling Quantity (inert + silt + process rejects) (MT)	710.033	260.470	603.785	629.715	472.286	472.286

Table 7.36 shows the daily waste feed to transfer stations, and its various waste processing units and total silt and rejects to engineered landfills site, for unrestricted and restricted condition, and figure 7.8 compares the same for various units. It can be seen that 44% of total garbage enters to the east transfer station, 19% enters to the north transfer station, and 37% enters to the south transfer station, respectively, for processing and disposal in unrestricted situation. While 45%, 17%, and 38% w.r.t the total landfill quantity (inert + process rejects + silt) goes to the east, north, and south ELF respectively. The percent is decreased as a result of various waste processing facilities.

For restricted condition 40% garbage enter to the east transfer station, 30% enter to the north transfer station and the rest 30% enter to the south transfer station. The same restricted percentage of landfill quantity goes to the east, north and south ELF.

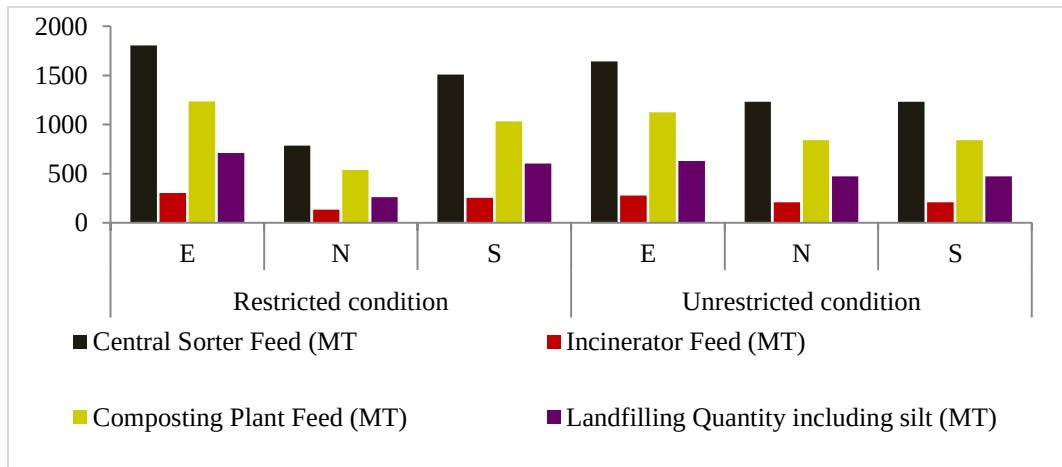


Figure- 7.8: Quantity of daily waste feed to different transfer stations, different process components and ELF sites

Figure 7.9 present the cost contribution of different KMC vehicles to the total cost transportation in proposed ISWM system.

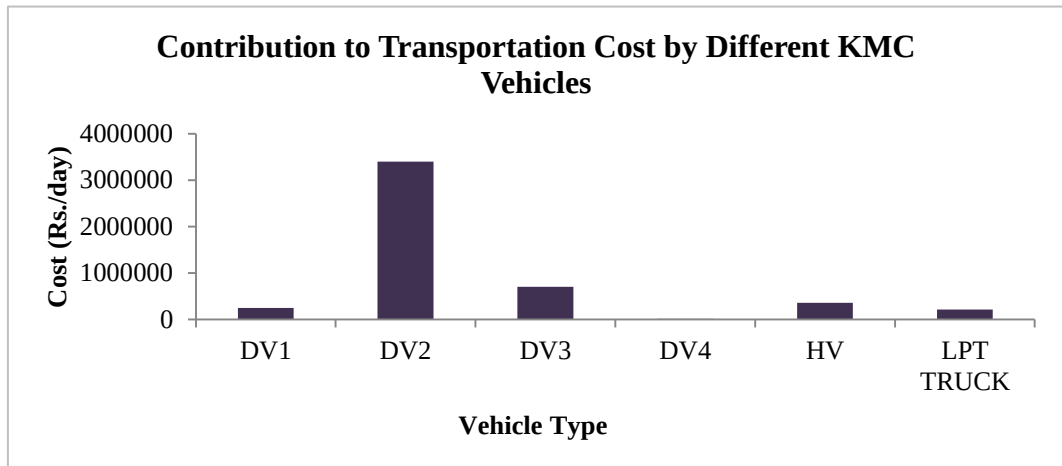


Figure- 7.9: Cost contribution of different vehicles to total transportation cost

The DV2 type vehicle contributes the most to the total transport costs, i.e. 68.6%, as can be seen from the above statistics, because they are more dominant. The costs of DV1 and DV3 are 5.1% and 14.2%, respectively. The DV4 shows a minimum contribution of 0.34%, while HV and LPT trucks each contribute 7.3% and 4.4%.

Figures 7.10, 7.11, and 7.12, respectively, demonstrate an analysis of waste transportation costs for various departments and hired vehicles, including fuel costs, fixed running costs, fixed idle costs, and incentive costs. In comparison to other KMC vehicles, the DV2 type have the highest fuel cost as a result of transporting the largest portion of waste from borough centres to the transfer station, i.e. 54.6%. Incentives are more expensive for DV4-type vehicles compared to other types, and only transportation costs have been taken into account for private hired cars and heavy-duty LPT trucks.

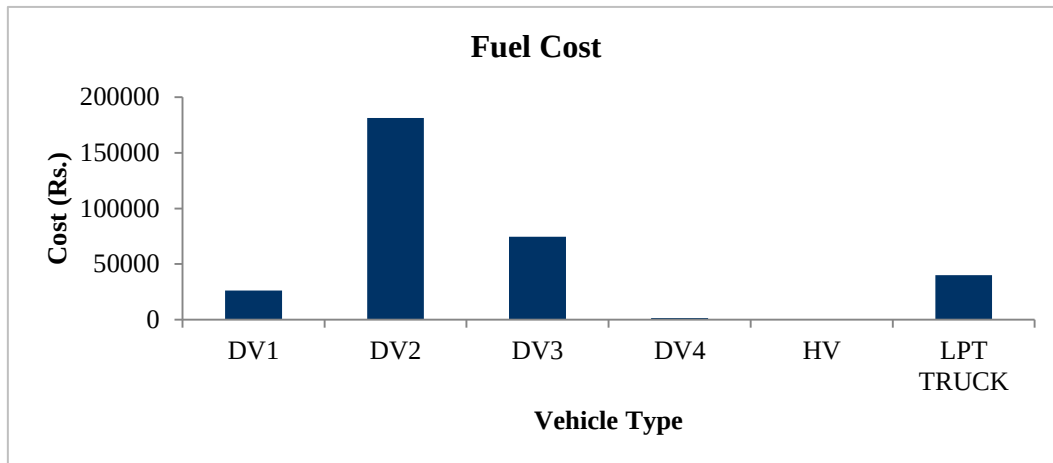


Figure- 7.10: Variation of fuel cost incurred by different KMC vehicles

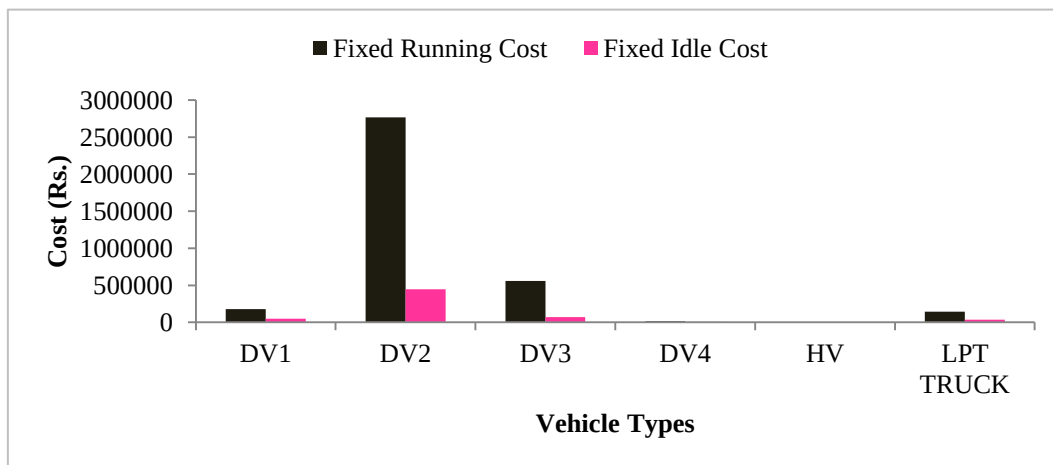


Figure- 7.11: Variation of fixed running and idle cost incurred by different KMC vehicles

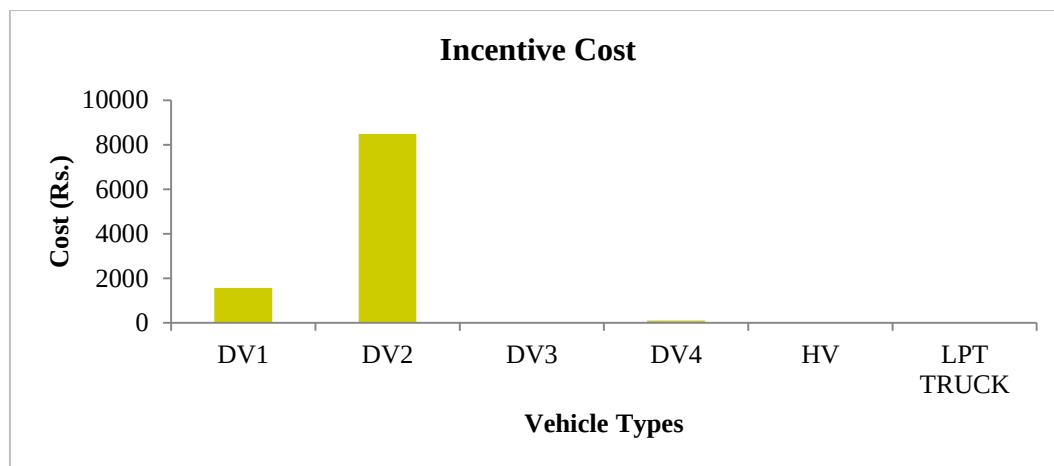


Figure- 7.12: Variation of incentive cost incurred by different KMC vehicles

7.18.2 Pollution Generation from Transport Sectors

The overall pollution generated by the transport sector in Kolkata under the planned ISWM system would be 3,543 MT per year in unrestricted transfer station feed condition and 3637 MT for restricted transfer station condition annually. The total contribution of CO₂ emission is the highest (99.09%) because of the high concentration of carbon in hydrocarbons that burns to produce CO₂ and it is one of the principal greenhouse gases in charge of causing global warming. The second-largest source of emissions after CO (0.294%) and HC (0.145%) is NO_x (0.409%). This occurs as a result of greater thermal NO_x production in addition to fuel NO_x during high temperature combustion in diesel engines. Acid rain and photochemical oxidants are produced by NO_x. Diesel fuel's restricted allowable sulphur level means that SO₂ emissions (0.022%) are far lower than NO_x emissions. PM has a significant influence on the respiratory system while having a lower emission percentage (0.040%) than other main pollutants due to its higher concentration of nanoparticles. The emission of benzene and butadiene is incredibly low in contrast to other pollutants.

7.18.2.1 Borough wise emission trend from departmental and private vehicles

Out of the 16 boroughs, boroughs 9 and 10 have the highest total pollutant emissions from the solid waste transport sector, with emissions of roughly 10% and 12.6%, respectively. This is due to waste generation, the distance to the landfill, and the fraction of the garbage component between departmental and private vehicles. The pollution

generation is less compared to waste carried from as the borough 1 is nearer to north transfer station and borough 7 is very close to east transfer station. Figure 7.13 displays a comparison of the total garbage generated by each borough and the total emissions caused by each pollutant. In comparison to other boroughs, borough 16 contributes a minimal amount of total pollutants (1.16%). Given that borough 15 is the farthest from the east and north disposal sites and transfer stations, KMC vehicles do not transport any waste to either the east or south transfer stations, causing the least amount of pollution compared to the other boroughs.

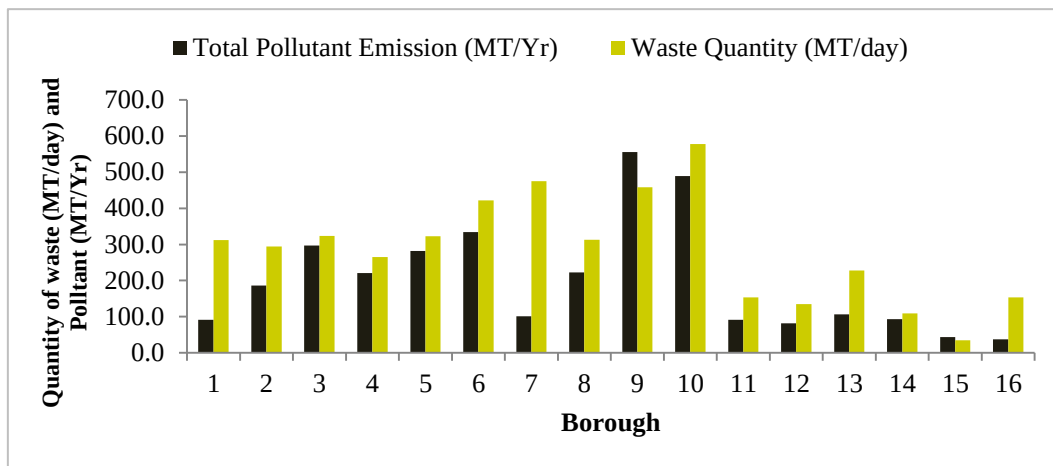


Figure- 7.13: Comparative representations of borough wise total waste generation and total pollutant emission

7.18.2.2 Contribution to total pollutant emissions from different boroughs

The borough-specific pollutant emissions are shown in the following graphs. It is seen that borough 9 and 10 emits the most, with borough 15 and 16 emitting the least. The CO and NO_x emission rates from various boroughs are shown in MT/Yr. in figure 7.14. The CO₂ emissions by various KMC vehicles are displayed in figure 7.15, from different borough. Boroughs 9 and 16 have CO₂ emission records of 17.18 and 1.16 percent, respectively. The emission trend (MT/Yr.) for the pollutants SO₂, Hydrocarbons (HC), Particulate Matter, Benzene, and Butadiene is shown in Figures 7.16 and 7.17. According to data from other boroughs, borough 9 emits these pollutants at rates of 17.18%, 16.87%, 17.22%, 16.71%, and 17.13%, respectively.

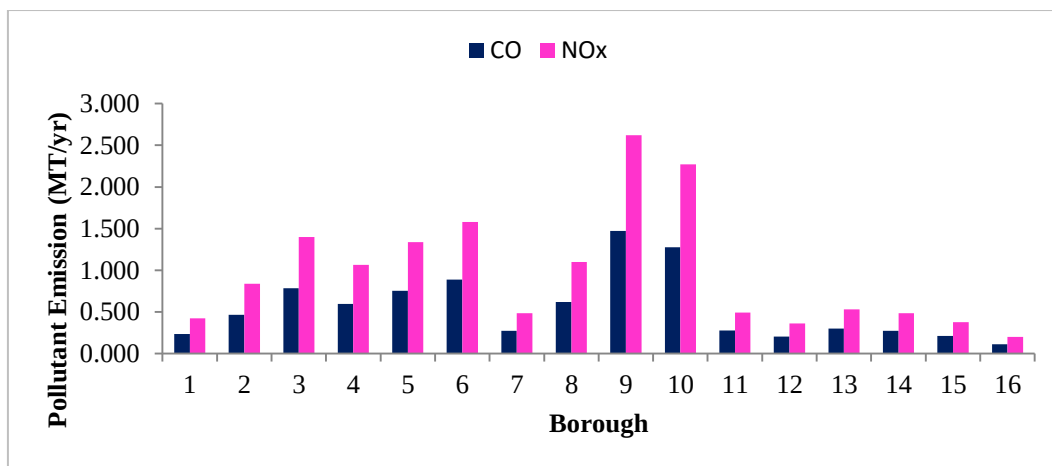


Figure- 7.14: Emission status of CO and NO_x from different borough

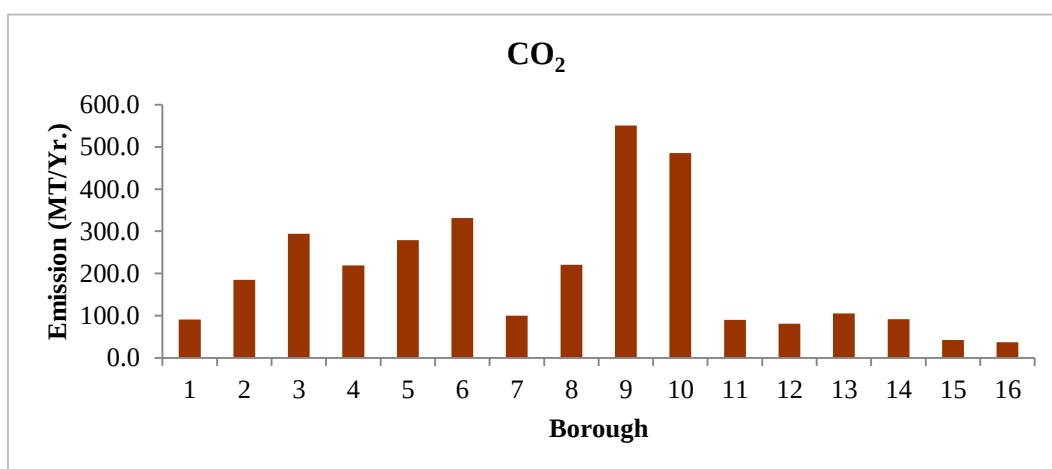


Figure- 7.15: CO₂ emission status of KMC vehicles from different borough

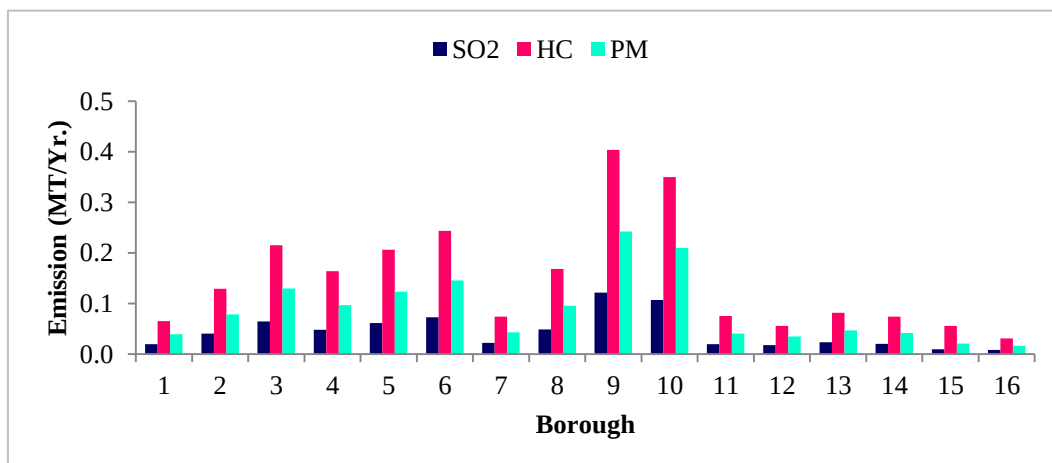


Figure- 7.16: Emission status of SO₂, HC and PM from different borough by KMC vehicles

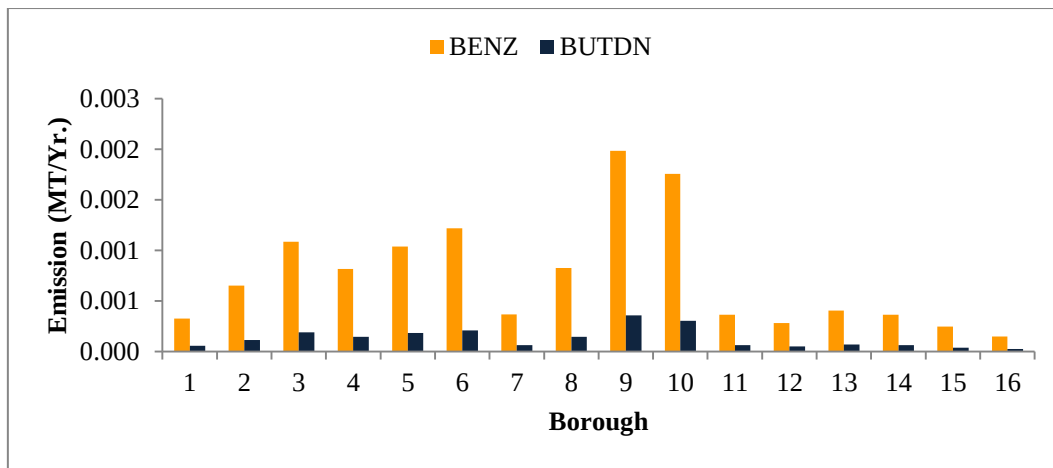


Figure- 7.17: Benzene and Butadiene emission from different borough by KMC vehicles

7.18.2.3 Pollutant contribution from departmental and private KMC vehicles

Figure 7.18 displays the proportion contributions of departmental and hired vehicles to the generation of all pollutants (CO_2 , PM, CO, SO_2 , NO_x , HC, Benzene, and Butadiene). The outcome suggests that the departmental vehicle's overall emission is 90%. Due to the addition of new compactor vehicles, the departmental vehicles now transport 80.9% of the total waste. Private vehicles that are hired have an overall emission rate of 10% and transport 19.1% of all garbage. In contrast to rented vehicles (HV), which carry less waste, Figure 7.18 shows that the majority of waste is transported by DV type vehicles, which produce the greatest amount of air pollutants.

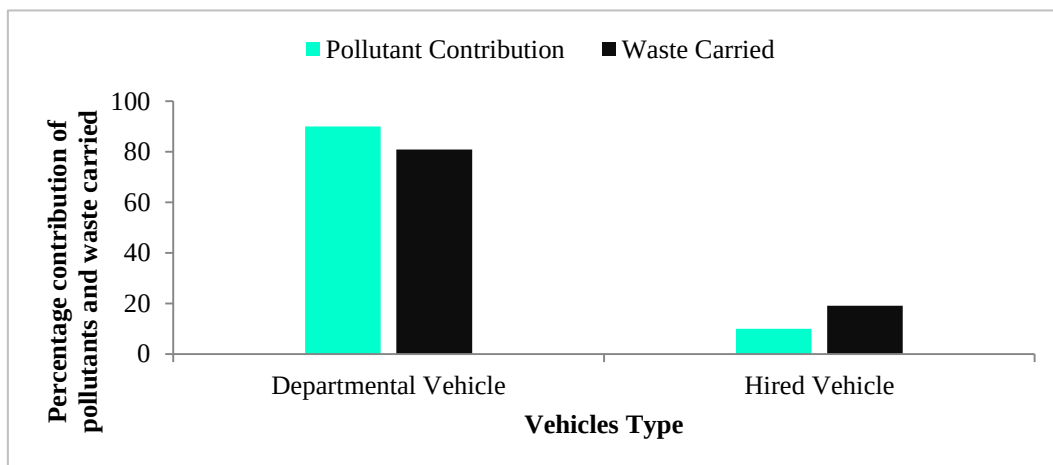


Figure- 7.18: Pollutant contribution and waste carried by departmental and private vehicles

Due to the greater distance travelled and waste carrying, departmental vehicle CO₂ emissions are 82.2% (2885.97 MT/Year) and private hired car CO₂ emissions are 9.1% (319.35 MT/Year). The remaining 8.7% (305.01 MT/Year) of CO₂ is contributed by a TATA LPT truck that transports silt and process wastes from transfer stations to the appropriate landfills. The variance in CO₂ contribution made by various KMC vehicles is shown in figure 7.19. The DV2 classes of vehicles have the highest emissions because, among other things, they carry the most garbage (54.6%) and travel furthest.

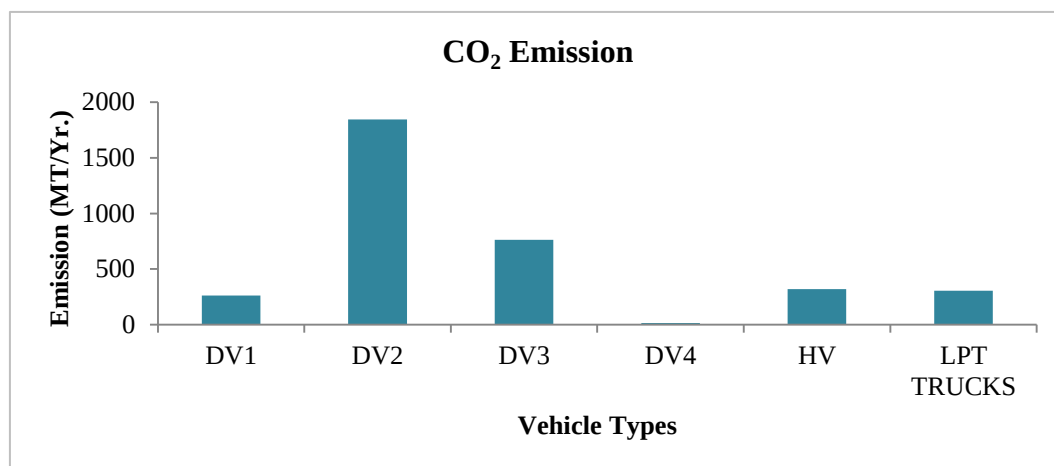


Figure- 7.19: CO₂ emission status by departmental and private vehicles

Departmental vehicles emit 67.9% (7.062 MT/yr), 74.6% (1.954 MT/yr), and 74% (12.061 MT/yr) of CO, HC, and NO_x, respectively, while hired vehicles emit 16.2%, 16.7%, and 17.5% of these pollutants. Departmental vehicles of the DV2 type have the highest level of coverage for the emission of these pollutants. When compared to rented vehicles, departmental vehicles' SO₂ and PM emissions are 82.1% and 87.9%, respectively, while hired vehicles' emissions are 9.12% and 11%. As more distance is travelled, departmental vehicles emit more benzene (75%) and butadiene (81.3%). Due to their carcinogenic nature, even though their number is lower than that of other pollutants, they continue to have a considerable negative influence on health. The emission of significant pollutants from individual departmental cars and private leased vehicles is depicted in Figure 7.20.

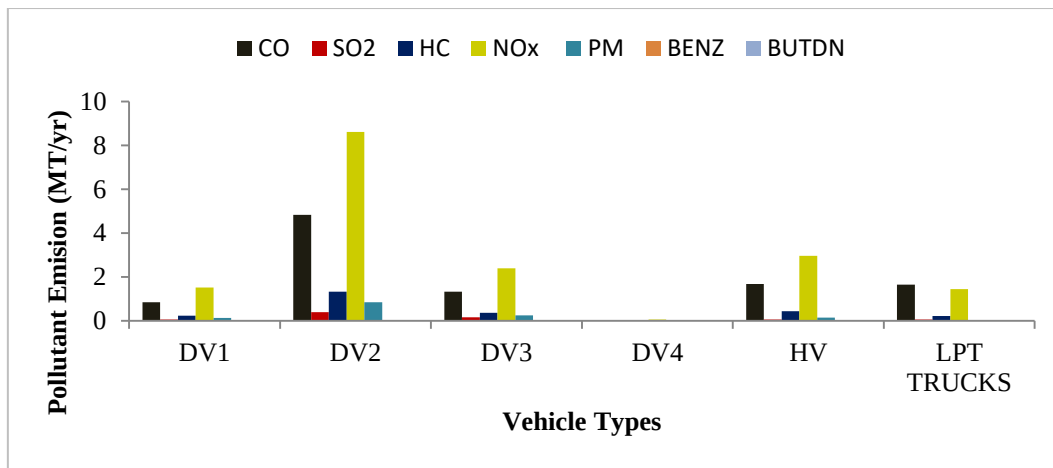


Figure- 7.20: Major pollutant emission status by departmental and private vehicles

7.18.3 Pollution Generation from Incineration Plant

Figure 7.21 illustrates various pollutant generation from the incineration plant. 2.255×10^5 MT of pollutants is released annually by the incinerator. CO₂ contributes the most to emissions of all pollutants, accounting for 99.31% (~223915 MT/yr). The contribution of NO_x and SO₂ is ~1039 MT/yr (0.46%) and ~520 MT/yr (0.23%) respectively, as significant pollutants as a percentage of total emissions. The main emission from waste-to-energy plants that is relevant to climate change is CO₂. Although CO₂ emissions cannot be minimized to meet emission regulations (SWM rule, 2016), while NO₂ and SO₂ is reduced to satisfy the limits are shown in Figure 7.22. It is feasible to reduce NO₂ emissions by 76.71% if the emission considered meeting the standards, as its generation is much higher than the standard. However SO₂ emissions can only be reduced by 1.83%.

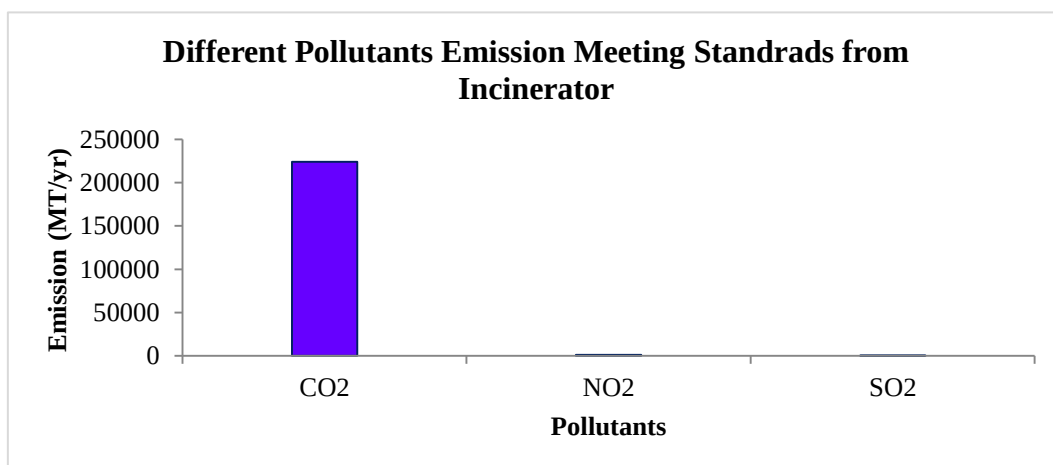


Figure- 7.21: Different pollutant generation from incineration

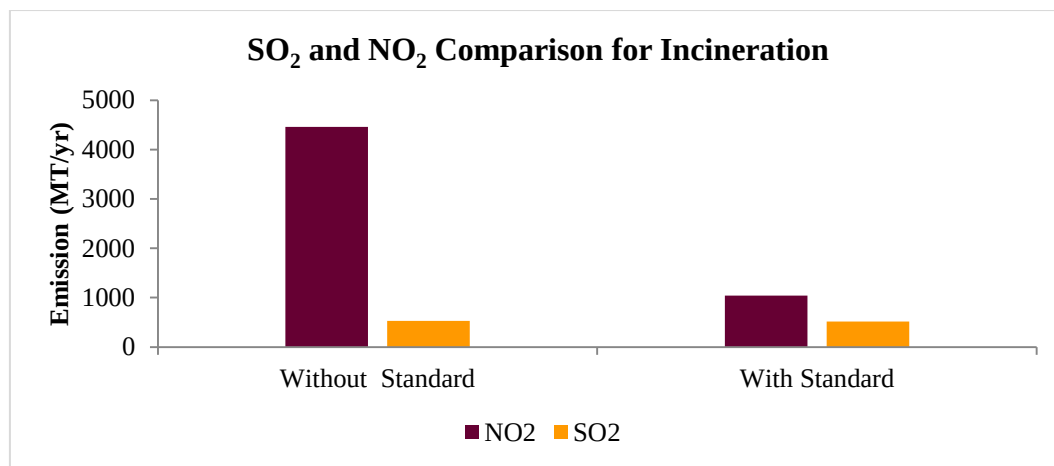


Figure- 7.22: Comparison of NO₂ and SO₂ emission from incinerator before and after meeting the emission standards

7.18.4 Pollution Generation from Composting Plant

The composting facility emits 2.22×10^5 MT pollutants per year. The emission of CO₂ is the highest, ~95.63% (211815 MT/yr) among all other pollutants. CH₄ emission is ~4.16% (9217.3 MT/yr), NO₂ and SO₂ emission are 0.18% (410 MT/yr), and 0.03% (68.1 MT/yr), respectively. Figures 7.23 show the generation of respective pollutant in biological processes i.e. composting.

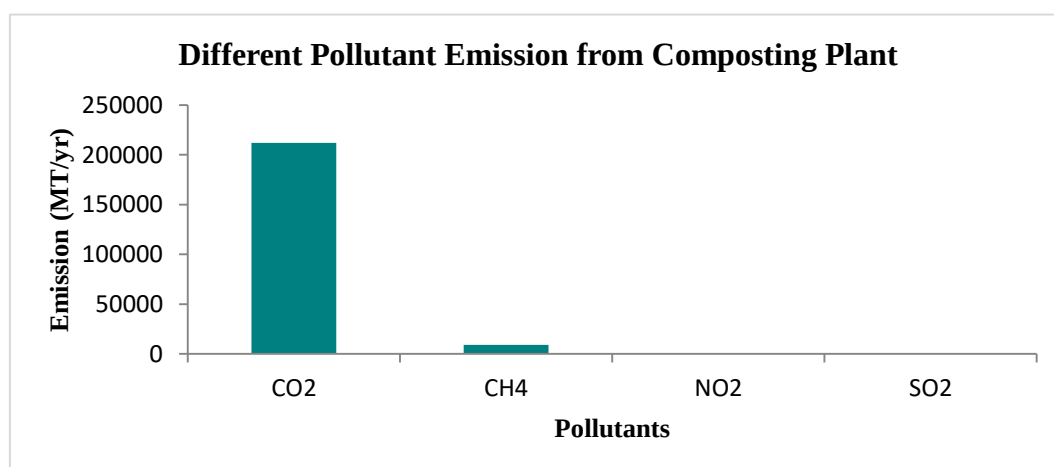


Figure- 7.23: Different pollutants generation from composting plant

7.18.5 Pollution Generation from ELF Sites for Proposed ISWM System

The pollution generation from engineered landfill sites is divided into two categories, gaseous and liquid. Although the total gas generation from landfills is thought to be zero due to the dumping of inert materials to the disposal ground.

Due to the presence of an engineered landfill, which includes a liner system, earth cover, and a leachate collection and treatment system, the proposed ISWM system will collect the 43 L/m² of leachate that each landfill site produces annually, treat it, and then discharge it into inland surface water conforming standards. The following figures illustrate how much heavy metal was generated by the leachate. The generation of Ammoniacal nitrogen (NH₃-N) and chloride (Cl) content is shown in Figure 7.24. Cl shows the highest emission ~93.9%, followed by NH₃-N ~4.7%.

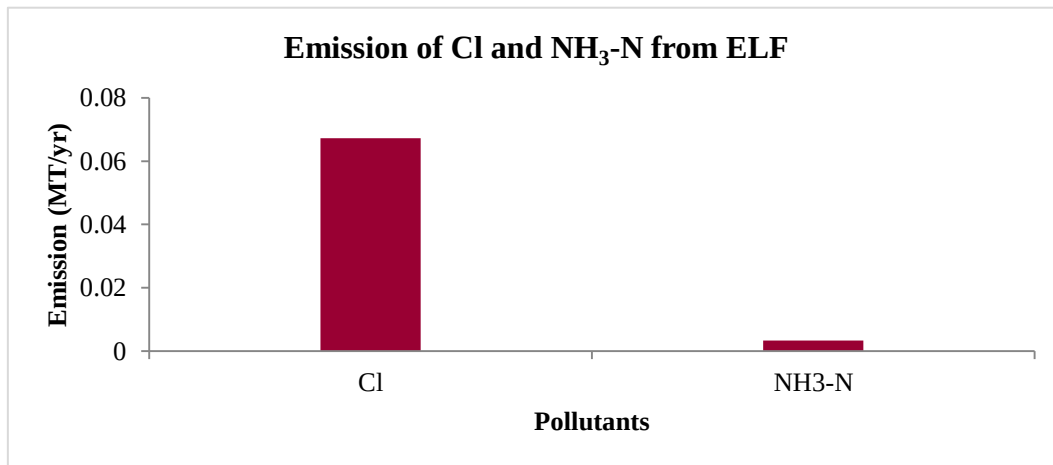


Figure- 7.24: Generation of NH₃-N and Cl from landfill leachate for ISWM

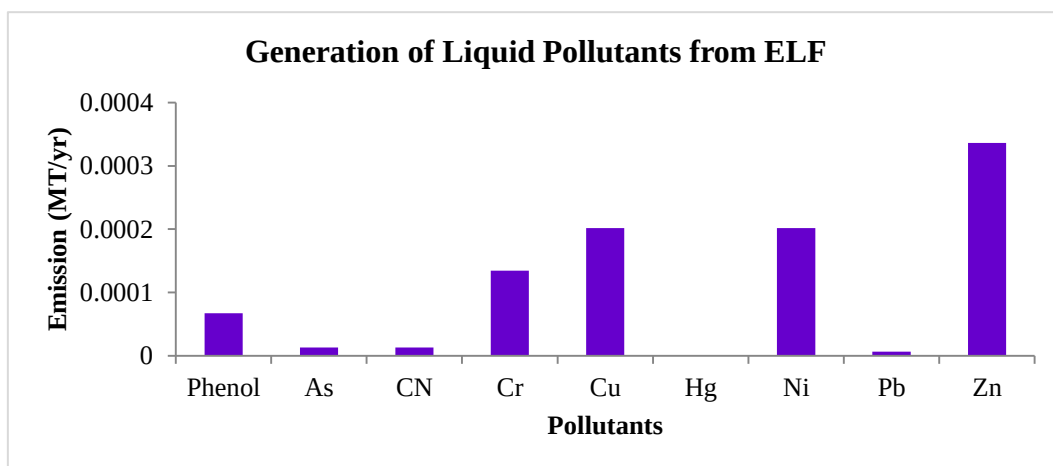


Figure- 7.25: Different pollutant generation from ELF leachate

The Figure 7.25 illustrates the production of arsenic, mercury, lead, chromium, copper, zinc, nickel, cyanide, and phenol and their emission is 1.4% of total liquid pollutants.

7.19 POTENTIAL ENVIRONMENTAL IMPACT (PEI) IN DIFFERENT CATEGORY FOR PROPOSED ISWM MODEL IN KOLKATA

7.19.1 Computation of Weightage for Different Impact Categories

The potential environmental impacts of the pollutant generated from the proposed integrated solid waste management system are calculated with respect to the local perspective. The relative weightages of the global, regional and local category with respect to local perspective are same as calculated for the existing system of solid waste management (Ref. table- 6.38).

7.19.2 Computation of Equivalency Factor for the Municipal Solid Waste Pollutants

The values of the equivalency factor of the pollutant generated from the integrated solid waste management system are same as in the existing system as the PEI contributing pollutants are same as previous system (Ref. table- 6.39 to table- 6.46).

7.19.3 Computation of Normalizing Values for Different Impact Categories

Equivalency factor (EF_{ij}) for a pollutant *i* and impact (sub) category *j* has already been consider same as estimated for the existing system of solid waste management. The normalizing values of different impact sub-categories such as GWP, AP, POCP, HTPE, HTPI, TTPG, TTPL and ATP are same as calculated in existing solid waste management system (Ref. table- 6.47 to 6.53).

7.19.4 Potential Environmental Impact (PEI) Value for proposed ISWM System

In the propose ISWM system, the total PEI comes out as 6.05×10^{-3} . The following table shows the PEI contribution of different gaseous and liquid pollutants generated from proposed ISWM system.

Table- 7.37: PEI contribution of gaseous pollutants of proposed ISWM system

Gaseous Pollutants (i)	Impact Sub- category (j)						Pollutant wise total PEI
	GWP	ODP	AP	POCP	HTPE	TPPG	
CO ₂	2.68×10^{-7}				8.89×10^{-4}	2.15×10^{-4}	1.10×10^{-3}
CH ₄	1.57×10^{-7}			6.09×10^{-5}	2.57×10^{-4}	6.23×10^{-5}	3.80×10^{-4}
SO ₂			1.37×10^{-6}		8.20×10^{-4}	1.99×10^{-4}	1.02×10^{-3}
NO _x			2.38×10^{-6}		2.84×10^{-3}	6.89×10^{-4}	3.53×10^{-3}
CO					3.46×10^{-6}	8.38×10^{-7}	4.30×10^{-6}
HC					7.59×10^{-8}	1.20×10^{-8}	8.79×10^{-8}
PM					3.97×10^{-10}	9.62×10^{-11}	4.93×10^{-10}
BENZ					7.89×10^{-8}	1.91×10^{-8}	9.80×10^{-8}
BUTDN					2.06×10^{-8}	4.99×10^{-9}	2.56×10^{-8}
Category wise total PEI	4.25×10^{-7}	0.00	3.75×10^{-6}	6.09×10^{-5}	4.81×10^{-3}	1.17×10^{-3}	6.04×10^{-3}

Table- 7.38: PEI contribution of liquid pollutants of proposed ISWM system

Liquid Pollutants (i)	Impact Sub- category (j)			Pollutant wise total PEI
	HTPI	TTPL	ATP	
Phenol	7.33×10^{-9}	2.66×10^{-9}	3.24×10^{-9}	1.32×10^{-8}
As	5.15×10^{-8}	1.87×10^{-8}	9.54×10^{-10}	7.12×10^{-8}
Cl	1.27×10^{-6}	4.63×10^{-7}	6.40×10^{-6}	8.13×10^{-6}
CN	1.21×10^{-7}	4.38×10^{-8}	0.00000	1.65×10^{-7}
Cr	1.93×10^{-8}	7.01×10^{-9}	9.32×10^{-9}	3.56×10^{-8}
Cu	1.85×10^{-8}	6.73×10^{-9}	2.56×10^{-8}	5.08×10^{-8}
Hg	3.86×10^{-8}	1.40×10^{-8}	8.47×10^{-11}	5.27×10^{-8}
Ni	1.64×10^{-8}	5.97×10^{-9}	1.40×10^{-8}	3.64×10^{-8}
Pb	3.22×10^{-7}	1.17×10^{-7}	6.97×10^{-10}	4.39×10^{-7}
Zn	2.66×10^{-8}	9.68×10^{-9}	2.93×10^{-8}	6.56×10^{-8}
NH ₃ -N	5.52×10^{-7}	2.01×10^{-7}	3.04×10^{-7}	1.06×10^{-6}
Category wise total PEI	2.45×10^{-6}	8.89×10^{-7}	6.78×10^{-6}	1.01×10^{-5}

The total PEI contribution of gaseous pollutants generated from the system is 99.83%, whereas the liquid pollutants contribute only 0.17% to total PEI, as in ISWM system, generation of leachate is much less and liquid pollutants are discharged after treatment conforming the standards.

Category wise PEI contribution of different gaseous and liquid pollutants in local perspective is depicted in figure 7.26 and 7.27.

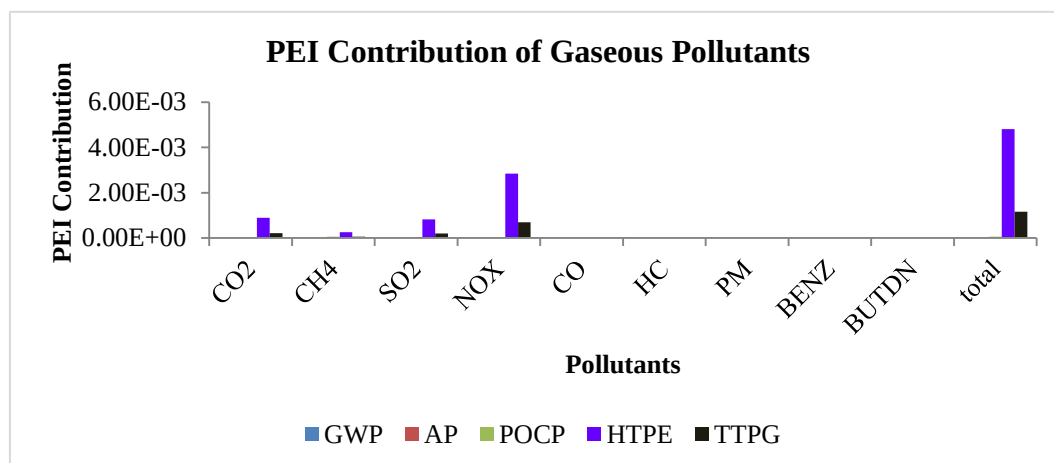


Figure- 7.26: Category wise PEI contribution of different gaseous pollutants

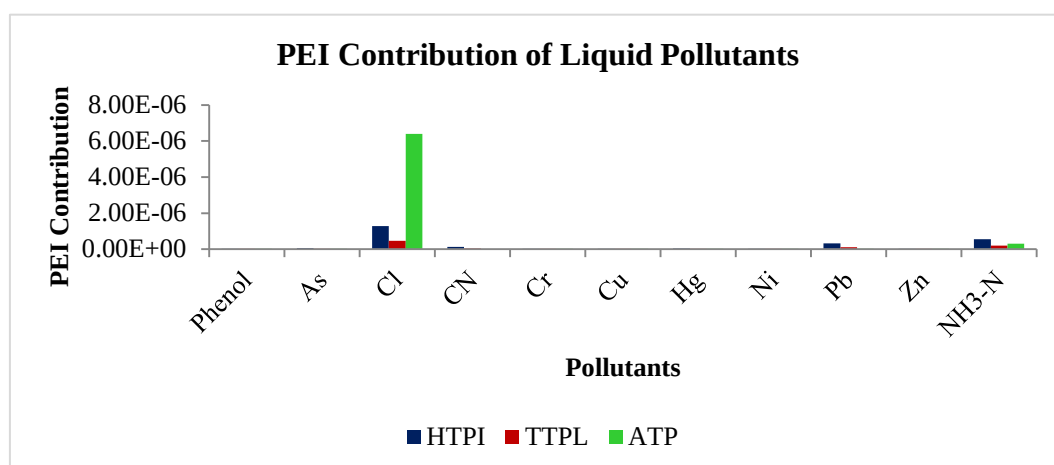


Figure- 7.27: Category wise PEI contribution of different gaseous pollutants

Figure 7.26 demonstrates that NO_x, which makes up around 58.4% of all gaseous pollutants, has the greatest impact on PEI. Contributions from CO₂, SO₂ and CH₄, are 18.3%, 16.9% and 6.28%, respectively w.r.t. the total PEI.

According to figure 7.27, chloride is the pollutant that contributes the most to the all three impact subcategories of liquid pollutants—HTPI, TTPL, and ATP. Chlorides provide 80.4% PEI w.r.t. the PEI of liquid pollutants and the same for NH₃-N is 10.4%, and Pb contributes 4.3%.

The contribution of CO₂ and CH₄ to impact sub-category Global Warming Potential (GWP) in global category is seen in the figure 7.28 for PEI. It is clearly shows that CO₂ and CH₄ are the main pollution contributors. The only source of CH₄ in the proposed ISWM system is a composting facility, but due to incineration procedures, the system produces more CO₂ overall. Therefore, contribution of PEI is higher for CO₂. While CH₄ contributes 37% of the GWP, CO₂ accounts for 63% of it.

The PEI value of GWP is less in local perspective as the relative weightage value is less compared to other impact sub- category but it is very significant in global perspective. The impact sub- category ODP did not contribute any PEI value as no pollutant is generated to breakdown the ozone layer in this system.

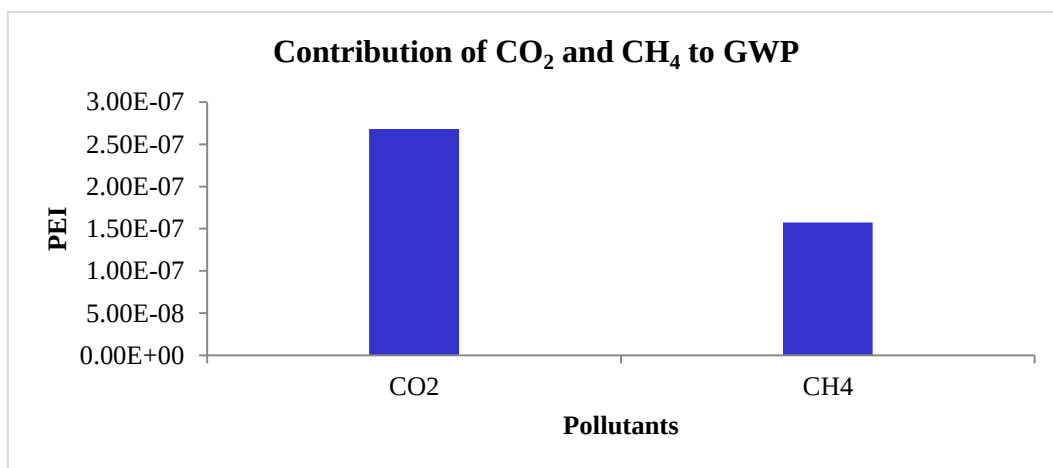


Figure- 7.28: PEI contribution of different gaseous pollutants to GWP

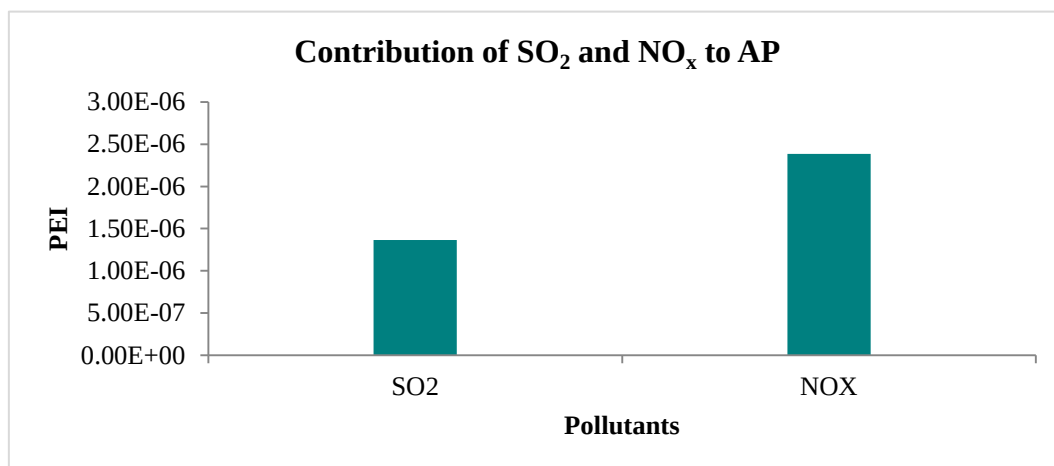


Figure- 7.29: PEI contribution of different gaseous pollutants to AP

PEI contribution of AP is present in the figure 7.28. In the regional category, the PEI contribution of NO_x is found to be highest in Acidification Potential (AP) followed by

SO₂. NO_x contributes ~64% and the contribution of SO₂ is ~36% to AP. The contribution of AP to total PEI is only 0.06%. Another impact sub-category of the regional category is POCP; the only contributory pollutant is CH₄. With respect to total PEI, 1% contribution comes from this sub-category, POCP.

In local category, the impact sub- categories considered are Human Toxicity Potential by Inhalation (HTPE), Terrestrial Toxicity Potential by Gas (TTPG), Human Toxicity Potential by Ingestion (HTPI), Terrestrial Toxicity Potential by Liquid (TTPL), and Aquatic Toxicity Potential (ATP). The contribution of PEI by various pollutants to these impact sub-categories is shown in the figures below.

Figures 7.30 show the contribution of PEI to the impact subcategories of HTPI and TTPG from various gaseous pollutants. It has been found that NO_x is the primary pollutant in both situations, contributing 59% in both the category HTPE and TTPG, followed by CO₂ (18.5%), SO₂ (17%) and CH₄ (5.3%). HTPE and TTPG each contribute 79.5% and 19.3% of the total PEI, respectively. The variation in contribution to total PEI is caused due to the major amount is contributed from the gaseous pollutants for incorporation of incineration and composting facility and meager amount of leachate generation from ELF and also the higher weightage assigned to the local impact sub-category.

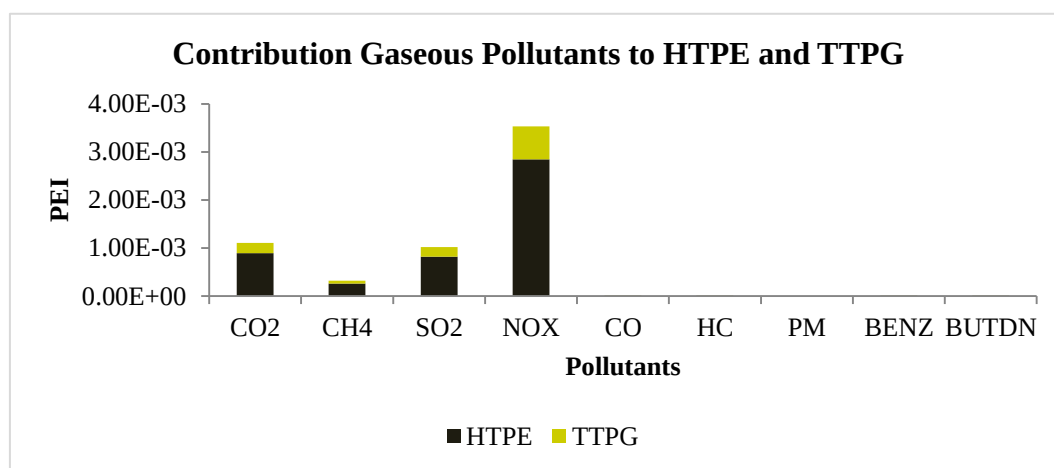


Figure- 7.30: PEI contribution of different gaseous pollutants to HTPE and TTPG

PEI contribution of Cl, lead, and NH₃-N to impact sub- category HTPI, TTPL, and ATP are depicted in figure 7.31. Chloride is the main contributor to each impact sub-category. The PEI contribution of chloride is 94.3% for ATP, 52% for TTPL and HTPI, w.r.t. to the PEI contribution of each impact sub-categories by liquid pollutants in total PEI. NH₃-N and lead contribution is 22.5% and 13.2% for each pollutant to HTPI and TTPL,

respectively with respect to the same. $\text{NH}_3\text{-N}$ contributes a small amount of PEI to ATP (4.5%). Figure 7.32 show the PEI contribution of other liquid pollutants to these impact sub-categories. Cyanide and mercury show some contributions to HTPI and TTPL. Due to their high level of toxicity, even though there are less of these pollutants on PEI than there are of other pollutants, their impact on human health and aquatic life is greater.

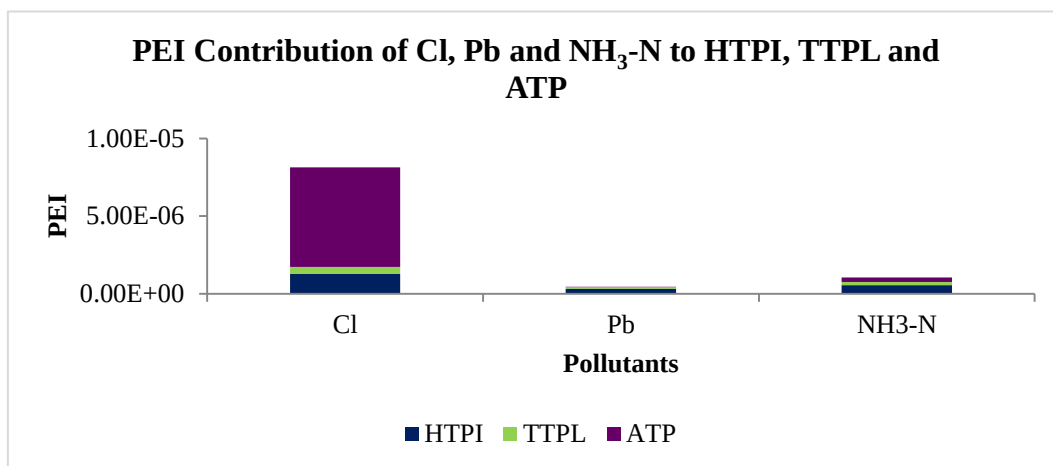


Figure- 7.31: PEI contribution of Cl, Pb and $\text{NH}_3\text{-N}$ to HTPI, TTPL and ATP

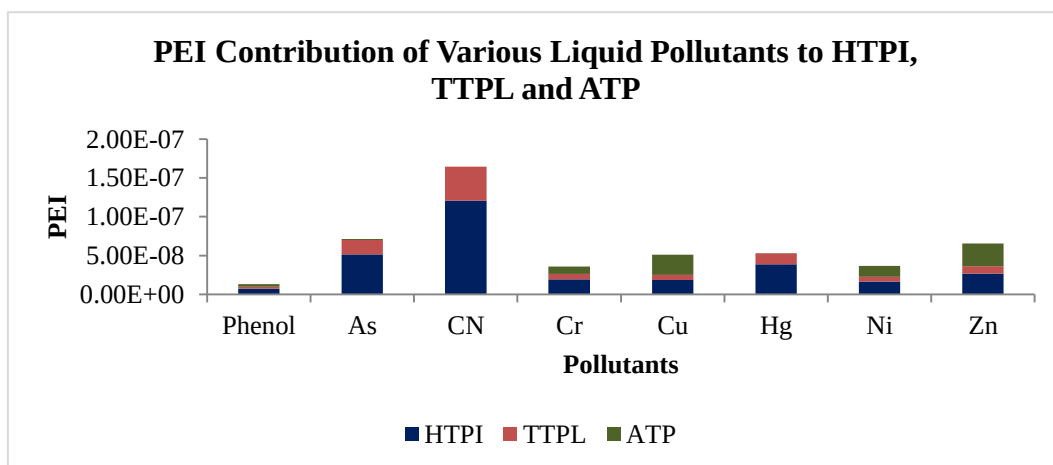


Figure- 7.32: PEI contribution of different liquid pollutant to HTPI, TTPL and ATP

According to figure 7.33, HTPE contributes the highest PEI value (79.5%) of all impact sub-categories, followed by TTPG (19.3%). This is because the impact value has increased as a result of increase in the generation of gaseous pollutants as incineration and composting process incorporated in proposed ISWM system. PEI contribution of POCP is 1% and the rest 0.2% PEI is contributes by ATP, AP, HTPI, TTPL and GWP together. Due to its relative weightage value being smaller than that of other impact sub-categories, the PEI value of GWP is less relevant from a local perspective, but it is highly significant from a global perspective. Due to the fact that no pollutants are produced in this system

that would deplete the ozone layer, the influence of subcategory ODP did not produce any PEI value.

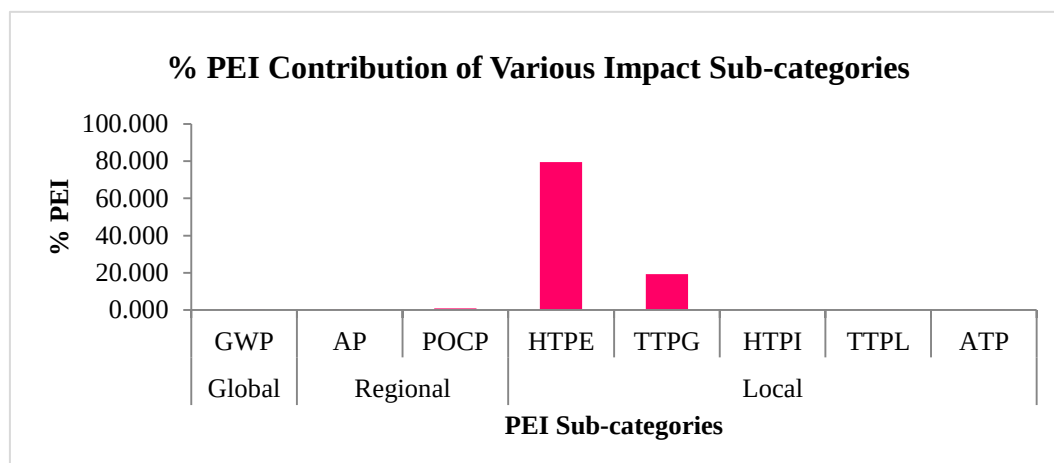


Figure- 7.33: Percent PEI contribution of different impact sub- categories to total PEI in local perspective

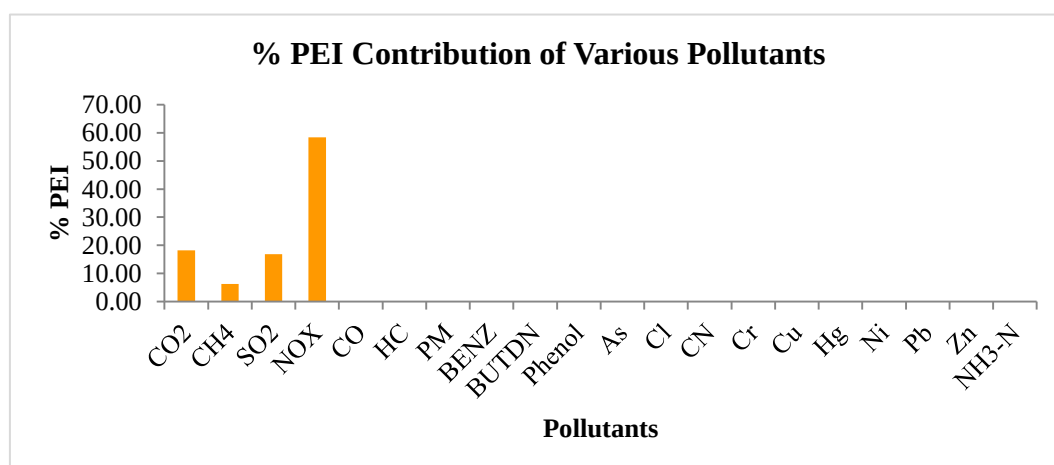


Figure- 7.34: Percent PEI contribution of different pollutants to total PEI in local perspective

Figure 7.34 shows the PEI contribution of different pollutants, gaseous and liquid, from various components of the proposed ISWM system. It is seen that PEI contribution is much more in gaseous pollutants than liquid pollutants as the gas generation is much more in the ISWM system compared to the liquid pollutants. Among all pollutants, NO_x contributes 58.37% PEI which is the highest. PEI contribution of CO₂, SO₂ and CH₄ is 18.25%, 16.85% and 6.28% respectively w.r.t. total PEI. Among all other liquid pollutants chloride has the highest PEI contribution, which is only 0.13%.

Figure 7.35 depicts the PEI contribution of the transport sector, incineration, composting, and ELF to the overall PEI of the proposed ISWM system under vehicle optimisation conditions with transfer station/ELF restricted situation. The incineration plants have the highest contribution to PEI at ~69.1%, followed by composting (~29.7%). Transportation sector and ELF contribute 1% and 0.2% respectively to the total PEI. The incinerators emit much higher quantities of gaseous pollutants compared to composting. Gaseous pollutants emissions from transport sector are least.

Gases are not produced in the landfill, as it only receives inert, processes rejects, and silt. So, the contribution of gaseous pollutants to the PEI from the landfill is zero. Also the leachate generation is significantly less (~95%) in ELF as it has liner system, and final top cover. Leachate is collected, treated and disposed meeting the standards as per SWM Rules, 2016. As a result the PEI contribution of liquid pollutants is also less in this case.

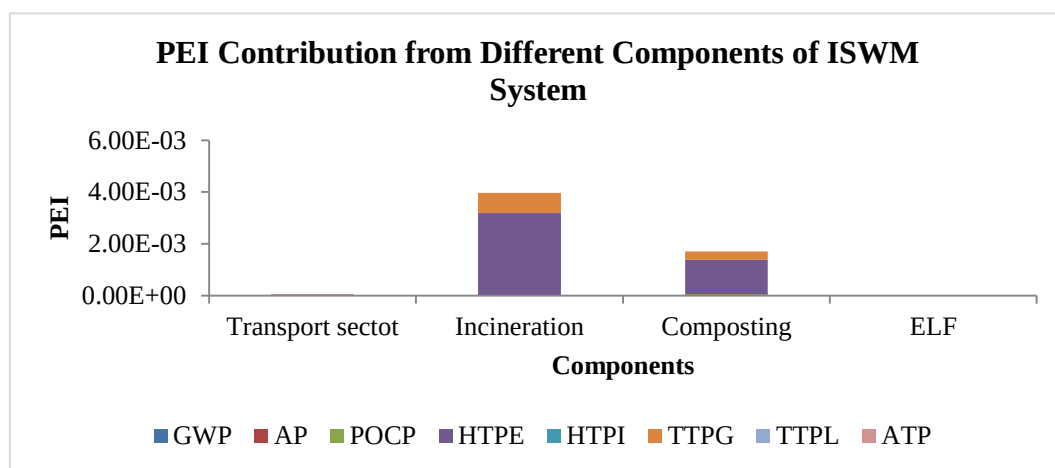


Figure- 7.35: Sector wise PEI contribution from different impact categories of ISWM system

Figure 7.36 shows the category wise contribution from different components of proposed ISWM. It is seen that HTPE and TTPG have ~70% PEI contribution from incineration, ~29% from composting and only ~1% from transportation sector. In impact sub- category HTPI, TTPL and ATP, landfill contributes 100% PEI, as no gaseous pollutants generated from landfill.

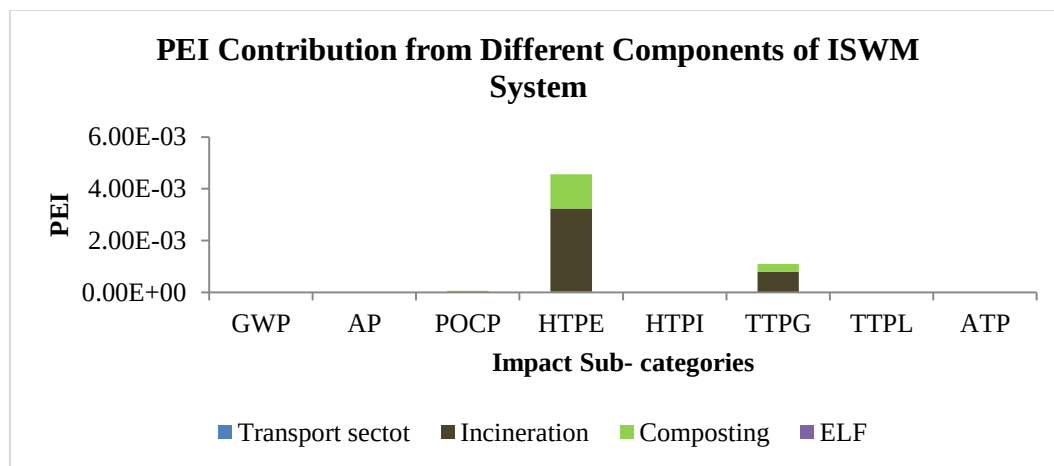


Figure- 7.36: Category wise PEI contribution from different sector of ISWM system

8 COMPARATIVE STUDY OF SOLID WASTE MANAGEMENT SYSTEM OF KOLKATA

8.1 GENERAL DESCRIPTION

The generalized SWM model from the previous chapters is run through various conditions simulating the existing and proposed integrated solid waste management in Kolkata. Analysis of cost, pollution generation, and PEI contribution of different pollutants using LCIA methodology, in each case, are discussed thoroughly in the previous chapters. This chapter presents a comparison of all these variables between the proposed ISWM system and the existing MSW management system as a result of model analysis. The first section of this chapter compares the existing SWM with the proposed ISWM system in free modes. The second section will compare both the systems under the cost minimization aspect (optimized vehicle condition) and subsequently pollution minimization aspect.

8.2 COMPARISON OF COST, POLLUTION GENERATION AND PEI FROM DIFFERENT SECTORS BETWEEN BOTH EXISTING AND PROPOSED ISWM SYSTEM IN VEHICLE UNOPTIMIZED CONDITIONS

The following analysis compares the cost, pollutant emissions, and total PEI from different sectors due to generated pollutants in the existing and proposed integrated system in the current BSIV standard. The comparative study starts with the cost analysis from different sectors of the SWM system followed by the pollutants emission from various sectors such as transportation, landfill, leachate, etc. Finally, the pollutants are used to compare the PEI of each system and discuss the cost and pollution optimization techniques.

8.2.1 Cost Analysis

The table 8.1 and figure 8.1, show the cost incurred from different aspects of the SWM system. The lack of any revenue generation system, like incineration or proper

compositing plant, in existing SWM increases the cost significantly. According to the analysis, the current total SWM cost for the existing system is 54,43,222 Rs/day, but the proposed integrated system has revealed a superior outcome that shows a net drop in overall SWM cost, 44,69,858 Rs/day. This suggests a net reduction in cost minimization of 17.88%. The transportation cost of ISWM is slightly reduced from 50,16,468 Rs/day in the existing system to 49,52,360 Rs/day in the proposed system by about 1.28%. This is due to the availability of three transfer stations in three extremities of Kolkata instead of a single dumpsite in Dhapa, which reduces the transport distance of waste and subsequently the cost. This cost also encompasses the cost of transportation of process rejects and silt from transfer stations to engineered landfill sites outside the city using heavy-duty LPT trucks which increases the transport cost. The ultimate results of these two are slight decrease in overall transport cost.

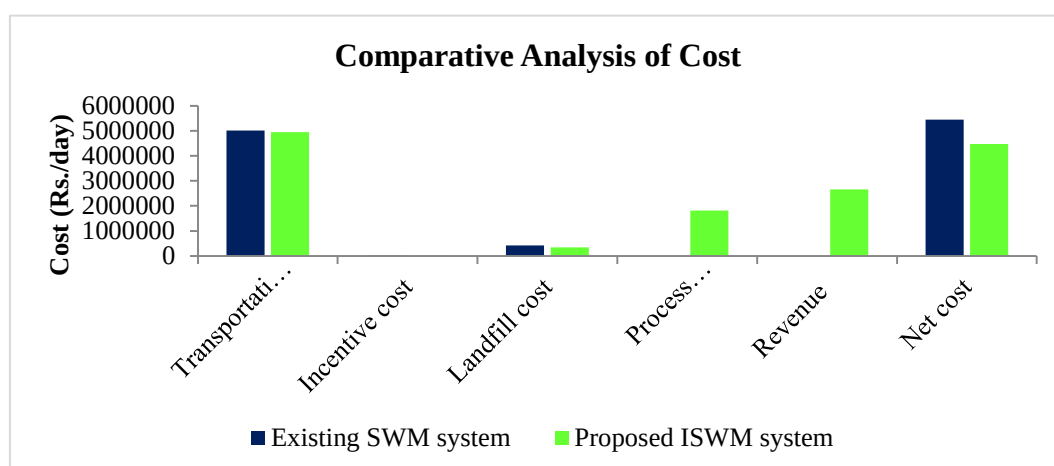
Though modern and sophisticated engineered landfill with leachate collection and liner systems are used in the proposed with a higher cost per MT of garbage, the cost of landfill is also reduced from 4,17,856 Rs/day to 3,41,313 Rs/day i.e. 18.32% reduction in the proposed system, as the quantity of waste i.e. only process rejects and silt, received by landfill is substantially less compare to existing system. The sorting and segregation of garbage with the practice of recycling, composting, and incineration of waste considerably reduced the quantity of waste being dumped in landfill.

Incentive cost has increased by around 12% in proposed ISWM system which amounts to only 0.02% of the total cost per day. There is an additional cost of sorting, composting, and incineration of the garbage around 41% of the net cost of the daily SWM cost of proposed ISWM system. The recyclables as well as compost and electricity produced are then sold and considerable revenue of 26,52,401 Rs/day is generated. It amounts to about 37% of the total cost generated to compensate for the expenditure of the MSWM systems.

Table- 8.1: Types of cost in existing and proposed ISWM system

Types of Cost (Rs.)	Existing SWM system	Proposed ISWM system
Transportation Cost	50,16,468	49,52,360
Incentive Cost	8,897	10,160
Landfill Cost	4,17,857	3,41,313
Sorting Cost	0	4,60,604
Incineration Cost	0	5,24,596
Composting Cost	0	8,33,226
Recycled Revenue	0	74,012
Compost Revenue	0	20,50,194
Incineration Revenue	0	5,28,195
Net Cost	54,43,222	44,69,858

The figure 8.1 shows the cost comparison between existing and proposed ISWM system.

**Figure- 8.1:** Cost analysis between existing SWM and proposed ISWM system

8.2.2 Pollution Emission by Different Sectors

Another aspect of the proposed ISWM system is to reduce the pollutant emission by different sectors of the SWM system. The pollutant emission sectors of the SWM system are:

1. **Transportation Sector-** Comprises of the emission of exhaust gases from the departmental vehicles and hired vehicles. In proposed ISWM, this sector also includes the exhaust gases from heavy duty LPT trucks.

2. **Composting and Incineration Plant (only in ISWM System)** - Gaseous emission from compost processing plant and incineration of dry waste.
3. **Landfill Gases (only in Existing SWM System)** - Gaseous emission due to decomposition of biodegradable waste in landfill.
4. **Leachate**- Leachate containing heavy metals are released from garbage at landfill.

The following study comprises of different pollutant minimization and a comparative study showing the difference in pollution emission from existing and proposed ISWM system.

The comparison of total pollutant emissions except CO₂ and CH₄ is shown in figure 8.2 below. CO₂ and CH₄ have been shown separately in figure 8.3, because of their significant emission quantity. By utilizing an ISWM system, every single pollutant emission has been reduced except CO₂, NO_x and SO₂, due the incorporation of incineration and composting facility. The following figures present a detailed comparison of emission of different gaseous pollutants between existing MSW management system and proposed ISWM systems.

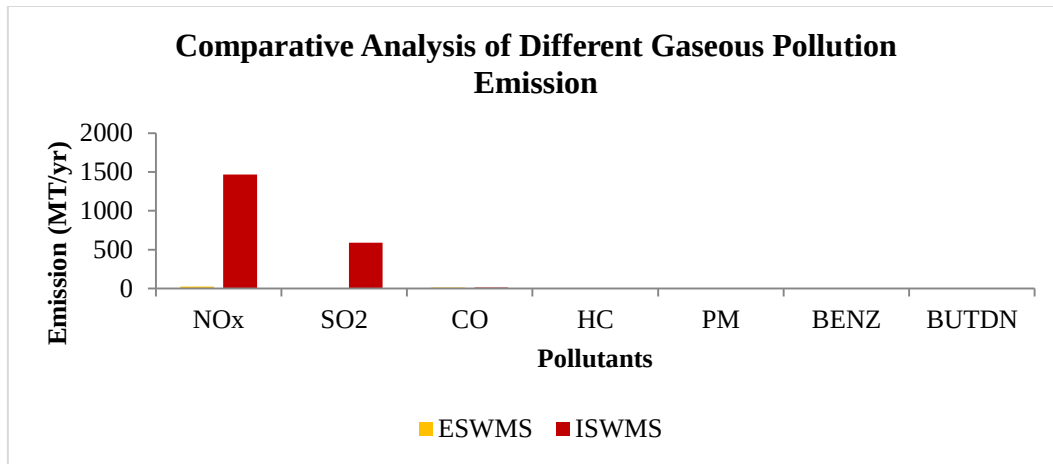


Figure- 8.2: Comparative analysis of different gaseous pollutants emission

Figure 8.2 show NO_x and SO₂ emission increased by huge amounts in proposed ISWM systems. Other gaseous pollutants, mentioned in figure 8.2, are reduced in the range of ~14% to ~25%.

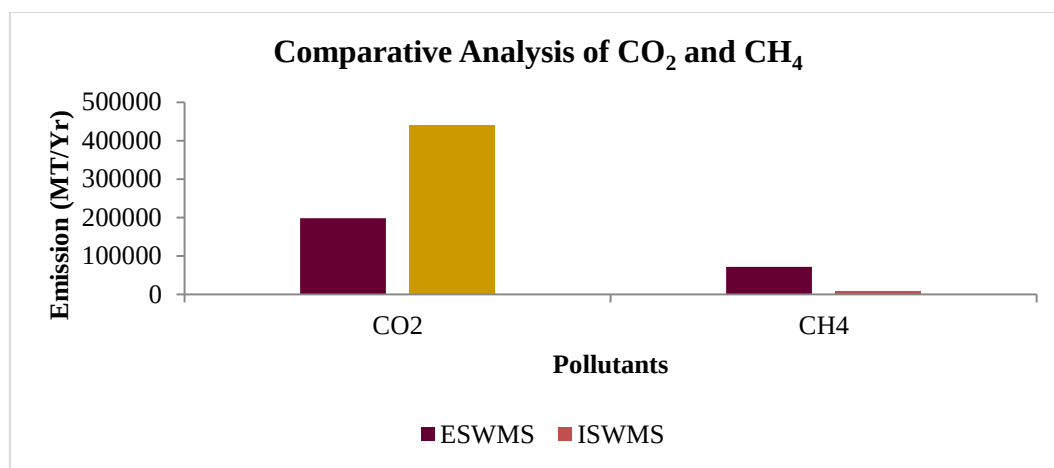


Figure- 8.3: Comparative analysis of CO₂ and CH₄ emission

Figure 8.3 show that among other gaseous pollutants, CH₄ exhibit a significant reduction in the emission from the ISWM system, with a value of 87.1% as inert and rejects are disposed in ELF in the ISWM system and is only generated from the composting plant. This reduction will help in the decrease of GWP as CH₄ is one of the main contributing pollutants of global warming. CO₂ emission is increased by 121% in proposed ISWM system due to huge quantities of CO₂ are released from incinerator and composting facility. The overall gaseous pollutants emission increased by 67% in ISWM system, compare to existing MSW management systems.

8.2.2.1 Pollution emission from transportation sectors

Figure 8.4 shows the emission of different gaseous pollutants from transport sector of both existing and proposed ISWM system and Figure 8.5 represent the CO₂ emission from transport sector of both the systems. Figure 8.6 shows the comparative analysis of total pollutant emission from different types of vehicles used in solid waste management systems, both existing and proposed ISWM systems.

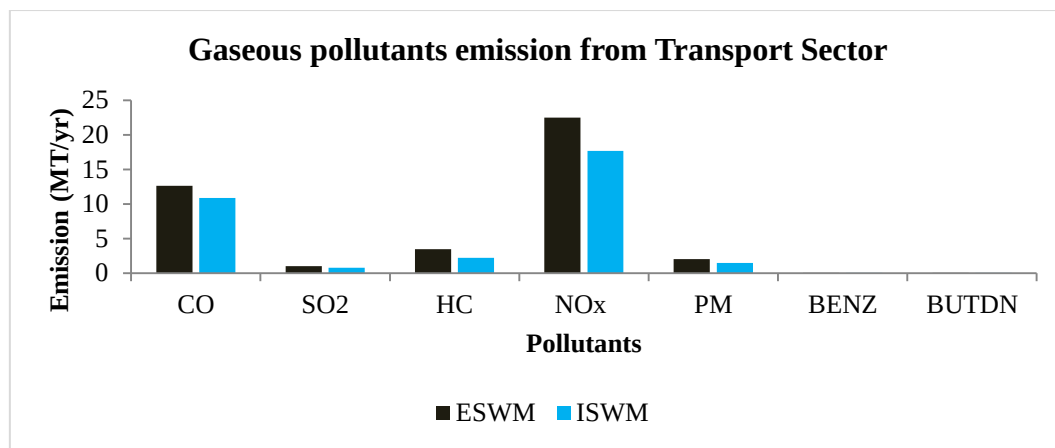


Figure- 8.4: Gaseous pollutant emissions from transportation sector

For transport sector, compared to current MSW management systems, an overall pollutant reduction of 23.2% can be obtained with the proposed ISWM system. There is about 14% decrease in the CO emission from ISWM system with respect to the existing system. Since the heavy-duty LPT trucks are used to transport sorted waste from the transfer station to the proper ELF site, it exhibits a considerable CO contribution to the pollution generation in the proposed ISWM system. In the existing system, this contribution is nonexistent. The percentage reductions in SO₂, NO_x, HC, PM, benzene and butadiene emissions from the transportation sector are 23.1%, 21.4%, 35.9%, 28.5%, 19.7% and 24.9%, respectively.

In comparison to the existing system, the ISWM system may cut overall CO₂ emissions by 23.2% in transport sector. The details are shown in figure 8.5. Departmental vehicles of the DV2 and DV3 types exhibit the greatest reduction in CO₂ emission of about ~21.9% and ~44.4% respectively.

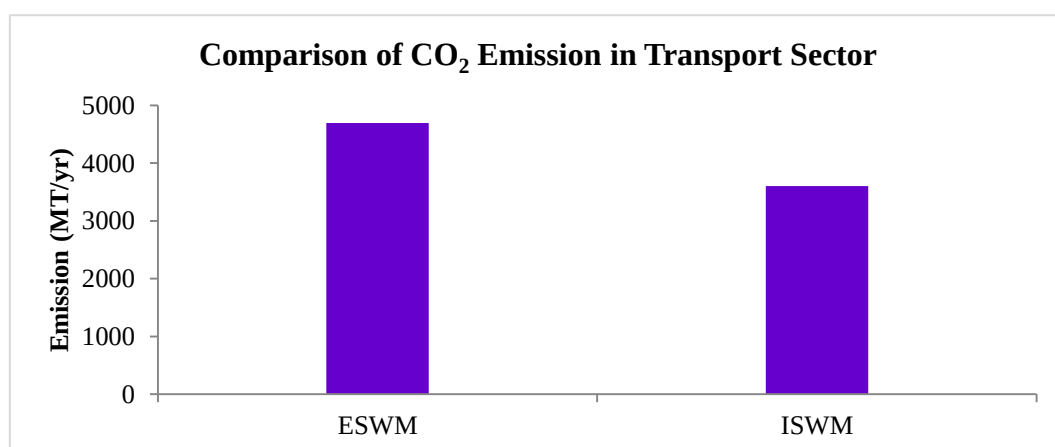


Figure- 8.5: CO₂ emissions from transportation sector for both SWM systems

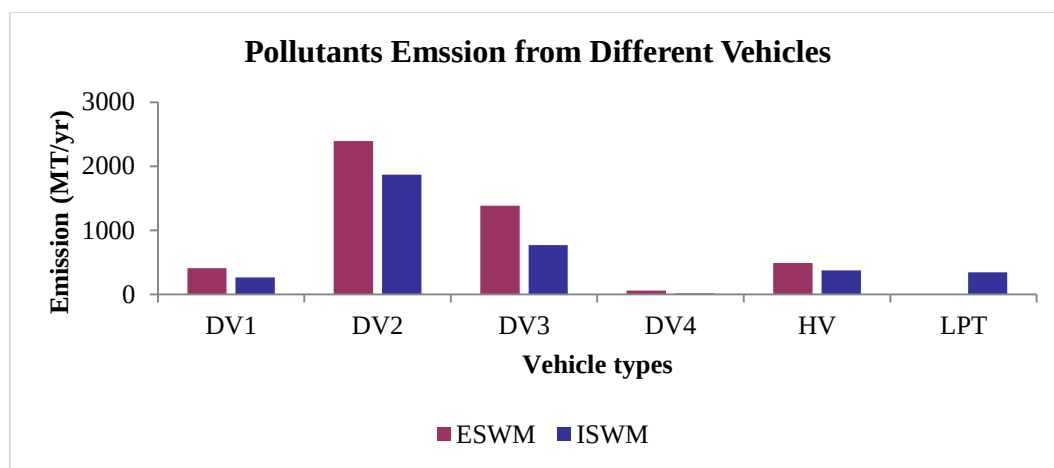


Figure- 8.6: Pollutant emissions from different types of vehicle

When a comparative analysis was done concerning various KMC vehicles used, most of the reduction in pollutant emission was incurred by DV2 and DV3 vehicles along with HV. The DV2 and DV3 show reduction about ~22% and ~44% respectively. The details are shown in figure 8.6. Individually DV2 and DV3 vehicles show the most reduction in CO emission of about 21.9% and 45% of CO respectively. Departmental vehicles of type DV2 demonstrate a 21.9% reduction of NO_x in ISWM systems over the existing MSWM systems. Additionally, there is a notable reduction in DV3 and HV of 44.4% and 33.6%, respectively.

8.2.2.2 Pollution emission from composting and incineration plant (ISWM only)

The composting and incineration facility is another possible source of pollution in the integrated MSW management system. The table 8.2 shows the pollutant contribution from composting and incineration plant to the pollution generation.

Table- 8.2: Pollutant emission from composting and incineration plant

Pollutant Sources	CO ₂ (MT/yr)	CH ₄ (MT/yr)	NO ₂ (MT/yr)	SO ₂ (MT/yr)
Composting Plant	211815	9217.3	410	68.1
Incineration Plant	223915	0	1039	520

The annual pollutant contribution from the composting facility is 221510 MT. The percentages of CO₂, CH₄, NO₂, and SO₂ are 95.63%, 4.16%, 0.18% and 0.03%, respectively.

The incinerator generates 225474 MT of pollutants annually, of which 99.3% of CO₂, 0.46% of NO₂, and 0.23% of SO₂.

8.2.2.3 Landfill gases (only in existing SWM system)

In existing SWM system, considerable amount of biodegradable waste reaches the landfill due to the absence of a proper sorting and segregation facility as well as a composting plant with intake capacity more than the generation rate of biodegradable waste in Kolkata. This biodegradable waste decomposes in the landfill (Dhapa) releasing considerable amount of CO₂ (~193499 MT/yr) and CH₄ of (~71408 MT/yr) respectively. This amount to about 97.63% of the total CO₂ and 100% of the total CH₄ emitted from the existing MSWM system.

After segregation and treatment, only inert MSW will be sent to an engineered landfill in the ISWM system. Only 33% of the total waste (inert, process reject and silt) is disposed off in the designed landfill under proposed ISWM system. As a result, there is no gas generation from ELF, which results total decrease in gas emissions.

8.2.2.4 Landfill leachates

The incorporation of an ISWM system has significantly altered the scenario of leachate pollution due to lesser amounts of leachate generation, collection and treatment. After collection the leachate will be treated before being discharged to inland surface water conforming to the standards. It is possible to reduce the liquid pollutants such as Ammoniacal Nitrogen (NH₃-N), Chloride, Arsenic, Mercury, lead, Copper, Nickel, Cyanide, Phenol, Total Chromium (Cr) and Zinc by 99.9%, 99.6%, 89.3%, 99.9%, 99.7%, 84.9%, 90.5%, 99.9%, 93.6%, 99% and 98.9% respectively. The figure 8.7 and 8.8 shows the comparative analysis of liquid pollutants for both existing and proposed ISWM systems.

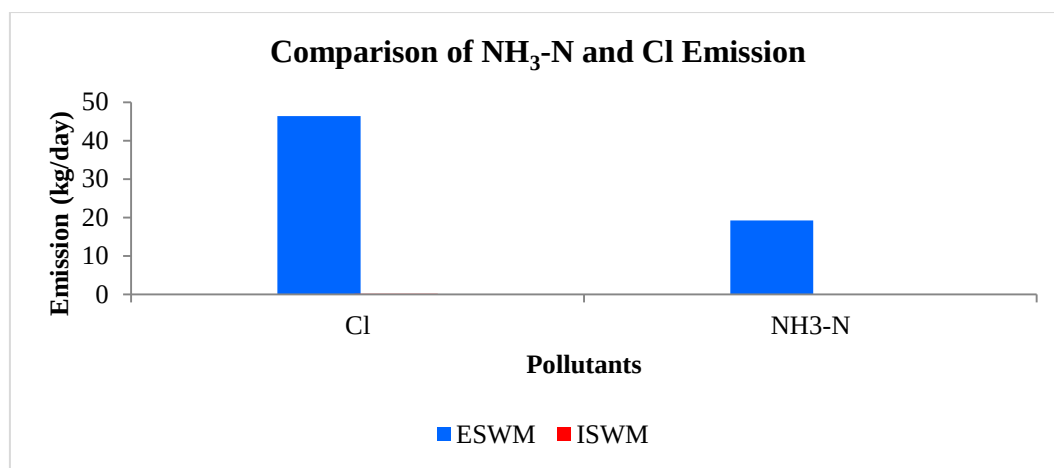


Figure- 8.7: Comparative NH₃-N emission and Chloride reduction between existing and proposed SWM system

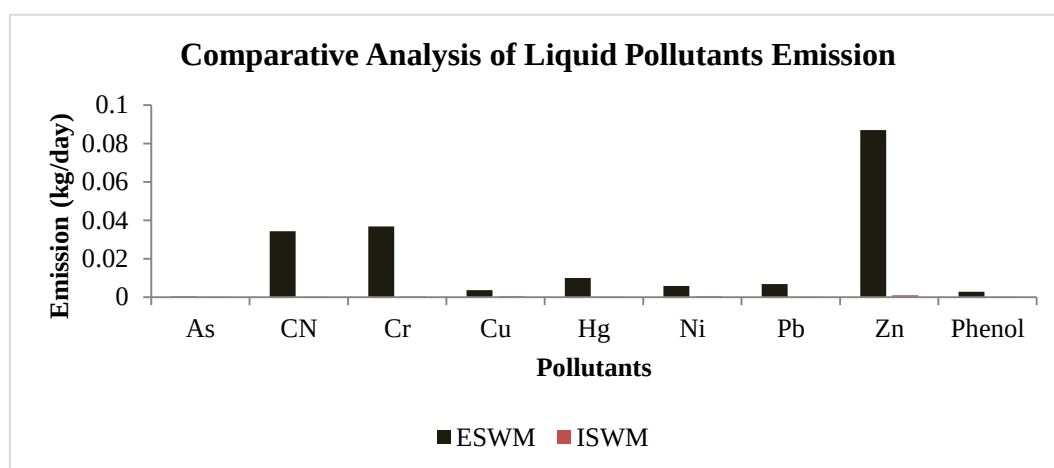


Figure- 8.8: Comparative As, Hg, Pb, Cr, Cu, Zn, Ni, CN and phenol reduction between existing and proposed SWM system

8.2.3 Comparative Analysis of PEI due to Pollutant Generation

The following study comprises the potential environmental impact and a comparative study showing the difference in PEI for different impact categories. In the present study, the estimation of PEI based on LCIA approach considering three impact categories (1) global, (2) regional and (3) local. Global category primarily refers to the concern of the whole world and appropriate worldwide pollutant inventories are considered for evaluating the PEI component from this impact category. Similarly, regional category refers to the region (state) in which landfill is situated. Local category refers to the locality.

The proposed ISWM system shows 27.7% reduction in PEI over the existing SWM system from 8.37×10^{-3} to 6.05×10^{-3} . HTPI and TTPL show ~99.9% reduction in PEI and ATP demonstrates the reduction of 99.7% PEI. The following table below shows the category wise PEI comparison of existing and integrated solid waste management systems.

Table- 8.3: Category-wise PEI comparison

PEI Category	Global	Regional		Local					Total
PEI Sub-category	GWP	AP	POCP	HTPE	HTPI	TTPG	TTPL	ATP	
Existing	1.34×10^{-06}	3.90×10^{-08}	4.72×10^{-04}	2.44×10^{-03}	1.92×10^{-03}	5.92×10^{-04}	6.97×10^{-04}	2.25×10^{-03}	8.37×10^{-03}
ISWM	4.25×10^{-07}	3.75×10^{-06}	6.09×10^{-05}	4.81×10^{-03}	4.81×10^{-03}	2.45×10^{-06}	1.17×10^{-03}	8.89×10^{-04}	6.05×10^{-03}

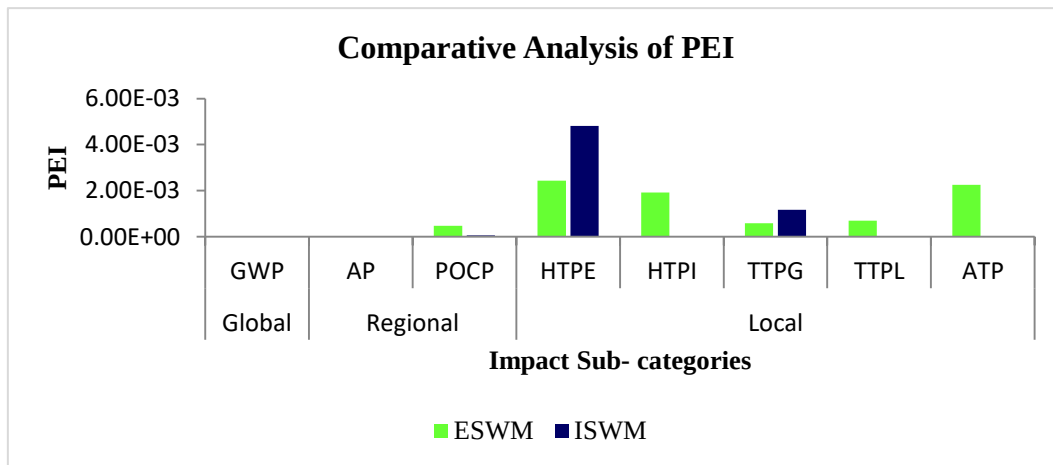


Figure- 8.9: Comparison of PEI of each category and subcategory for existing and proposed system

8.2.3.1 Global

Global warming potential (GWP)

In the proposed ISWM system about 68.3% reduction in GWP is achieved compared to the existing MSWM system which is mainly contributed by CO₂ and CH₄. CO₂ shows an increase of 121% contribution to PEI in proposed ISWM system, whereas CH₄ exhibit a reduction of about 87.1%. The reduction of CH₄ is the most as it only generates from the composting plant in the proposed ISWM system and not from ELF. The resultant

reduction is decrease in PEI of GWP impact sub- category in proposed ISWM systems as the GWP of CH₄ is 28 times higher than CO₂. The comparison of the PEI contributions of various GWP-responsible pollutants in the global category is shown in the figure 8.10.

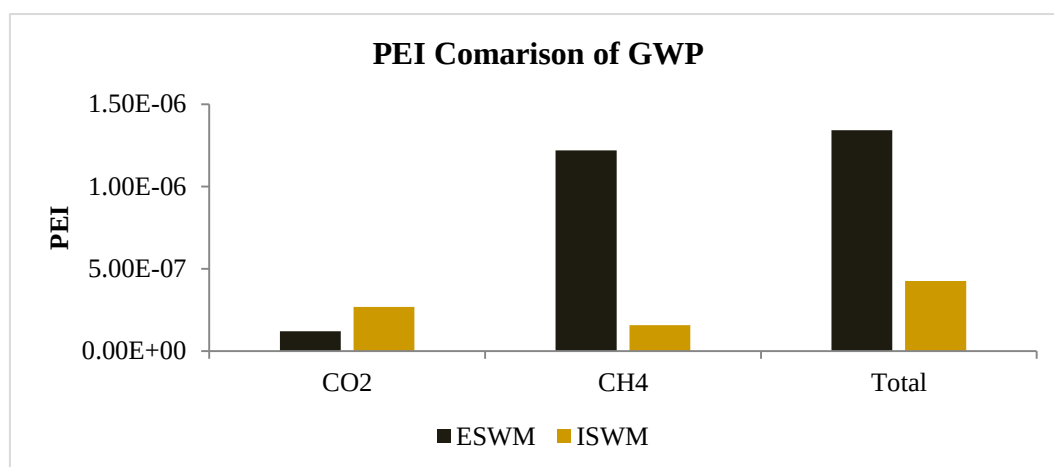


Figure- 8.10: Comparative study of GWP between existing and proposed system

8.2.3.2 Regional

Acidification potential (AP)

As the proposed ISWM system includes the incineration process, AP increases significantly as a result of the increased release of NO_x and SO₂ contribution mainly from incinerator and composting facility. The contribution of NO_x is much more than SO₂, (Ref. figure 8.11), as results the overall huge increment of acidification potential is found in proposed ISWM systems, though its impact on total PEI is less.

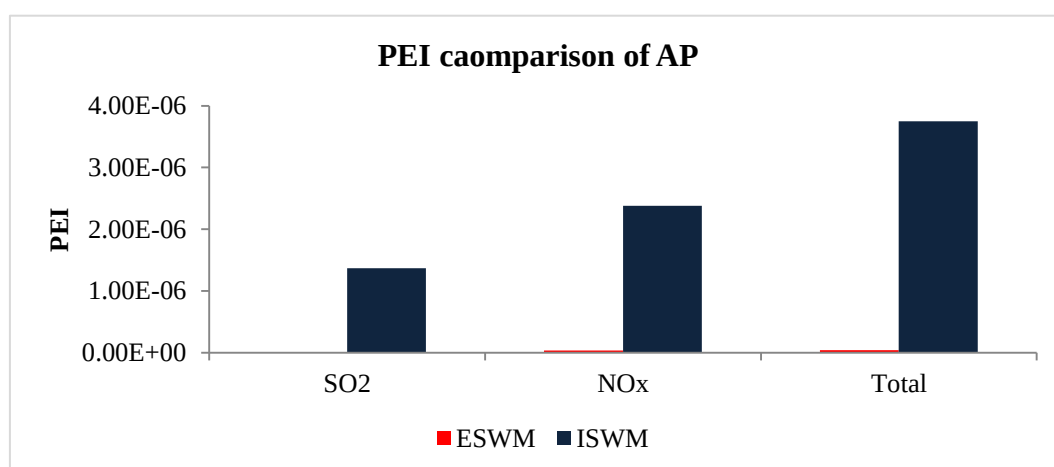


Figure- 8.11: Comparative study of AP between existing and proposed system

Photo-chemical ozone conversion potential (POCP)

The figure 8.12 shows the comparative study of POCP reduction between existing and proposed ISWM system. Only CH₄ contribute to the POCP in the SWM system and its emission is much less in ISWM system which is explained earlier. The POCP reduction of 87% is achieved in ISWM system.

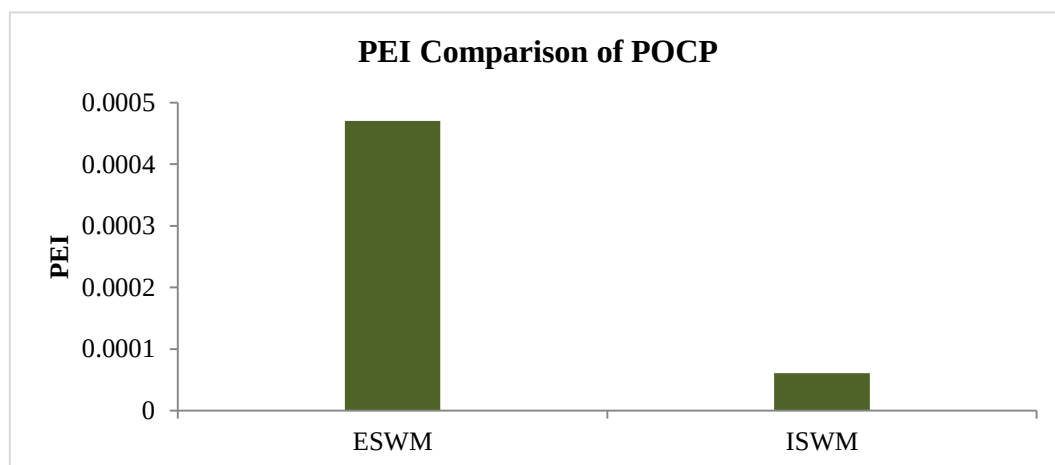


Figure- 8.12: Comparative study of POCP between existing and proposed system

8.2.3.3 Local

Human toxicity potential by ingestion (HTPI)

There is 99.87% reduction in the HTPI as compared to the existing SWM system. Cl, NH₃-N shows a reduction of 99.6%, and 99.9% respectively which contributes to most of HTPI. The results of the other pollutants follow similar trend with reduction varying from 85% to 99%. Figure 8.13 and 8.14 shows the comparative analysis of PEI by different pollutants in HTPI impact sub-category.

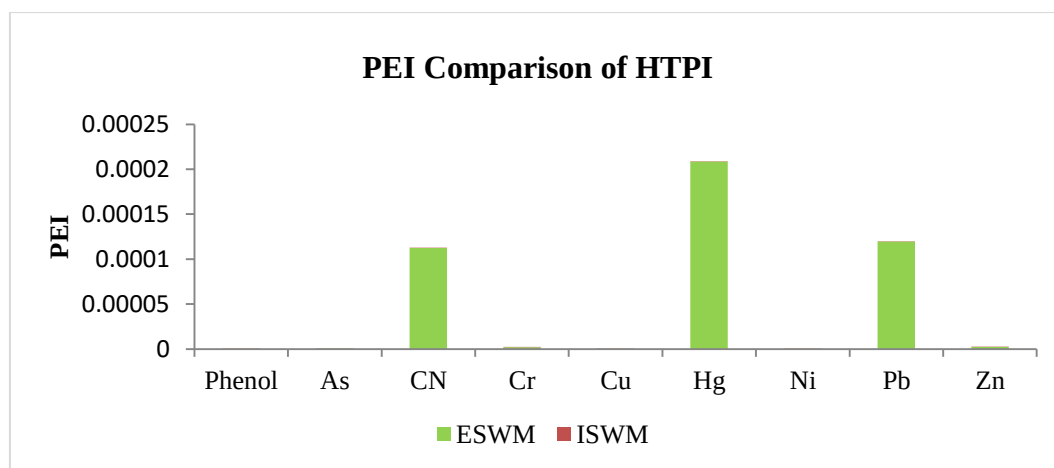


Figure- 8.13: PEI comparative study of HTPI

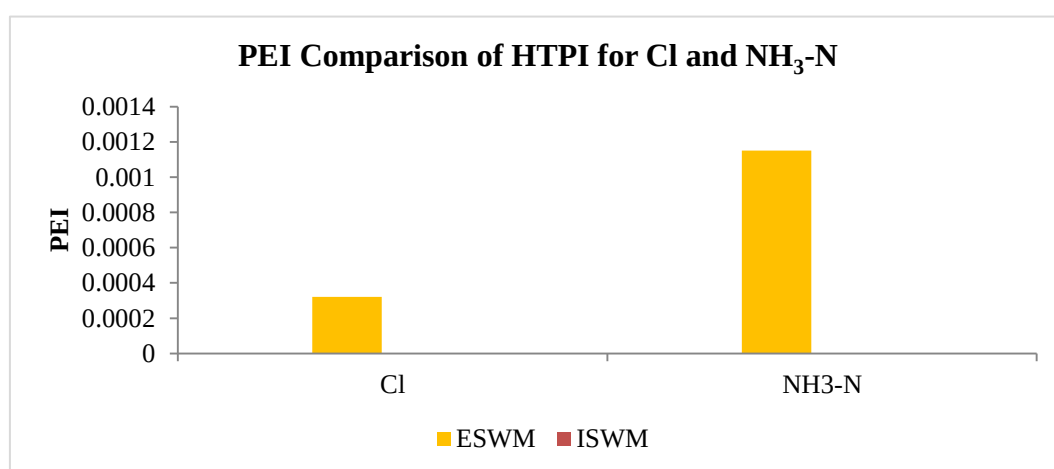


Figure- 8.14: Comparative study of HTPI between existing and proposed system for Cl and NH₃-N

Human toxicity potential by inhalation (HTPE)

In the proposed ISWM system, HTPE increased by 97% with respect to the existing system. Impact of NO_x, CO₂ and SO₂ increased significantly in the proposed ISWM system. CH₄ shows a reduction of about 87%. The impact of other pollutants is reduced by 14% to 29%. Figure 8.15 and 8.16 depicts the PEI comparison of HTPE for different pollutants.

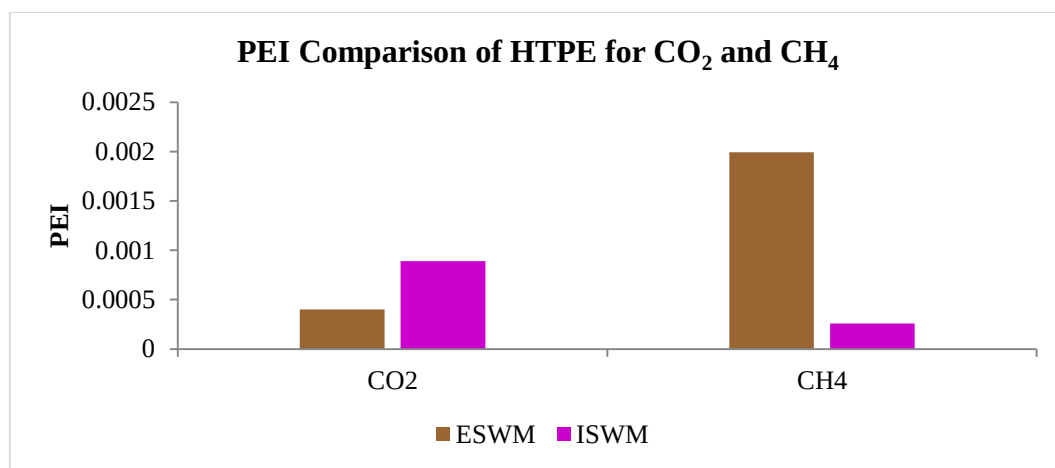


Figure- 8.15: Comparative study of HTPE for CO₂ and CH₄

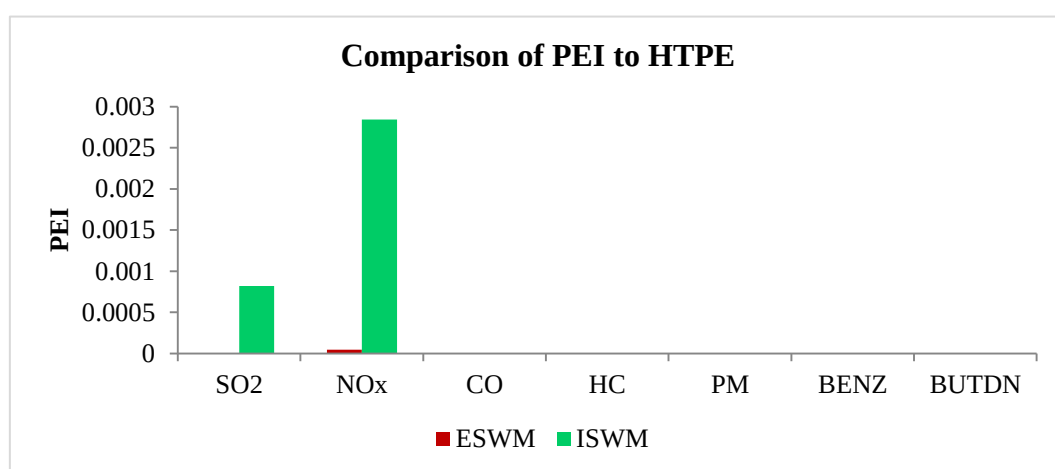


Figure- 8.16: Comparative study of HTPE between existing and proposed system

Terrestrial toxicity potential by gas (TTPG)

PEI is increased by 97% in the proposed ISWM system with respect to the existing MSWM systems. Figure 8.17 and 8.18 shows the comparison of PEI in existing system and proposed ISWM system.

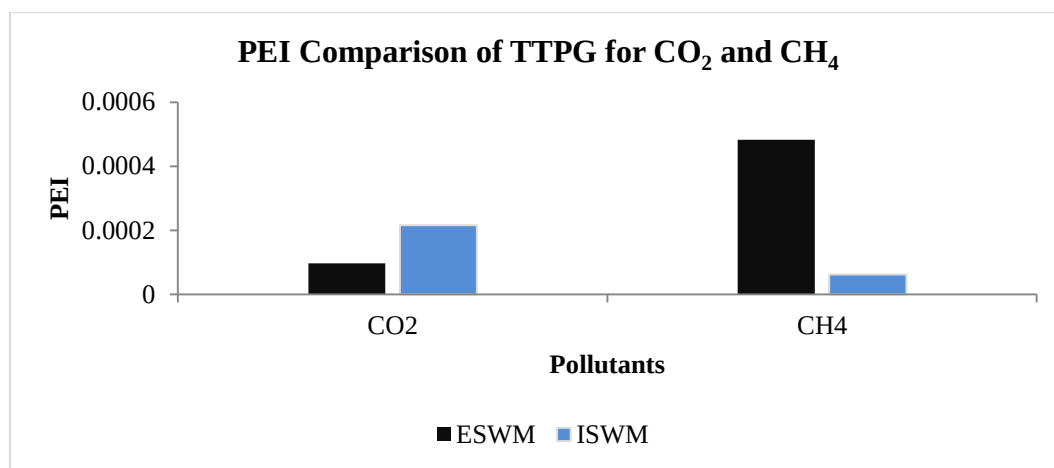


Figure- 8.17: Comparative study of TTPG for CO₂ and CH₄

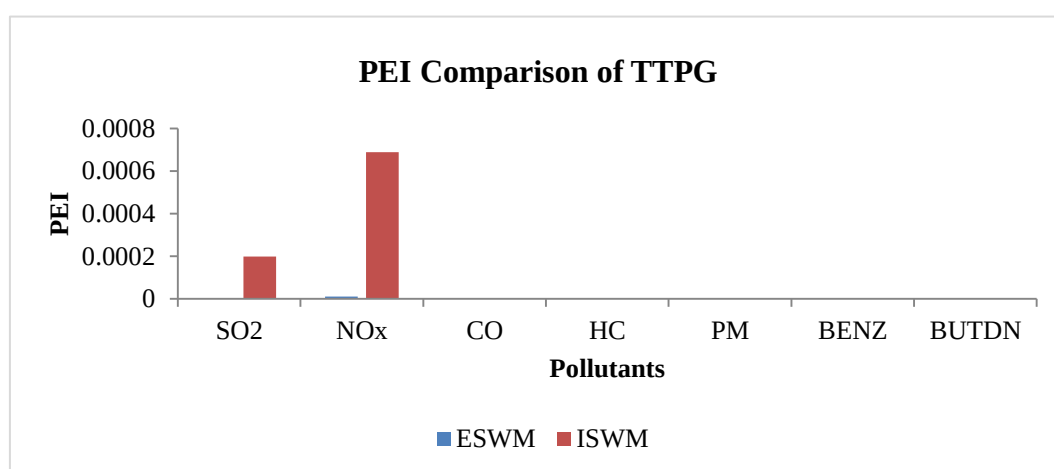


Figure- 8.18: Comparative study of TTPG reduction between existing and proposed system

Terrestrial toxicity potential by liquid (TTPL)

There is about 99.8% reduction in the TTPL for ISWM system with respect to the existing system. NH₃-N and Cl show the most reduction in TTPL of about 99.9% and 99.6%, respectively with respect to their contribution in existing MSWM system. PEI contribution of other pollutants reduces significantly within the range of 89% to 99% with respect to the same. The figure 8.19 shows the reduction of PEI in TTPL impact sub-category by Cl, and NH₃-N, whereas figure 8.20 shows the PEI reduction in TTPL by others liquid pollutant.

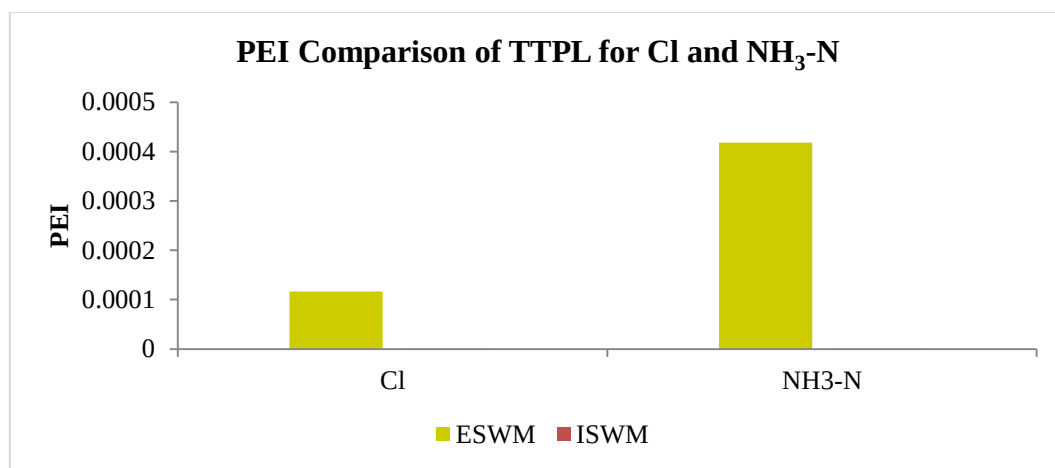


Figure- 8.19: Comparative study of TTPL reduction

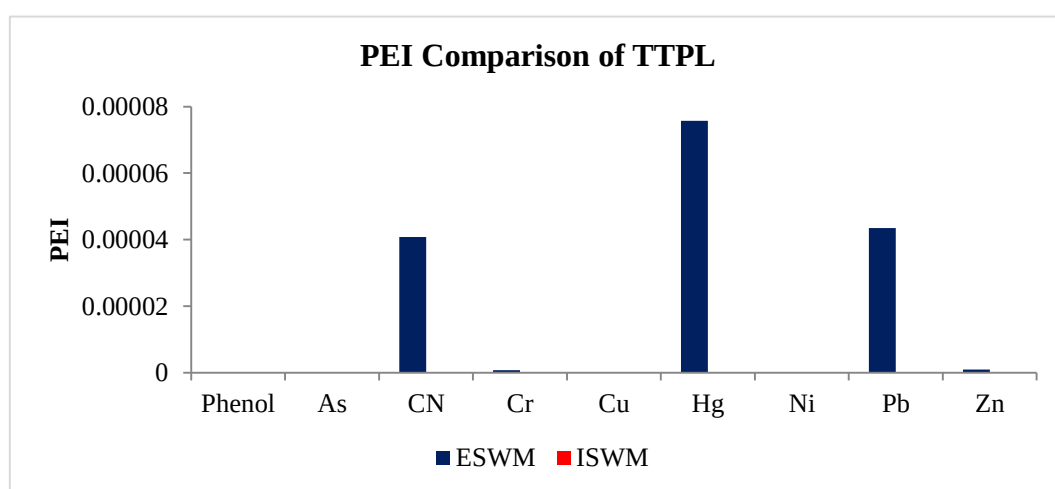


Figure- 8.20: Comparative study of TTPL reduction between existing and proposed system

Aquatic toxicity potential by liquid (ATP)

In the proposed ISWM system, 99.7% reduction is found in the ATP impact sub-category as compared to the existing MSWM system. Cl, and NH₃-N shows a reduction of 99.6% and 99.9%, respectively with respect to their contribution in existing MSWM system. The results of the other pollutants follow similar trend with reduction varying from 84% to 99%. The details are shown in figure 8.21 and 8.22.

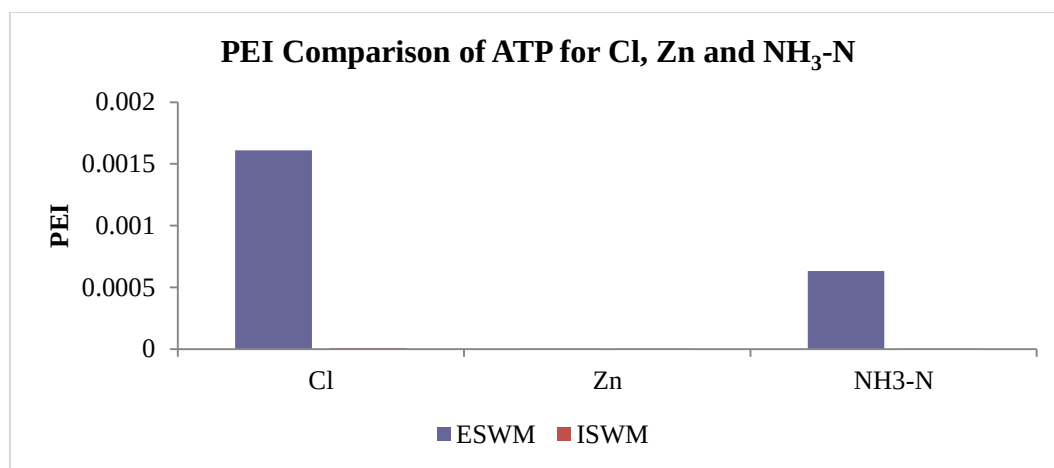


Figure- 8.21: PEI Comparative study of ATP reduction for Cl, Zn and NH₃-N

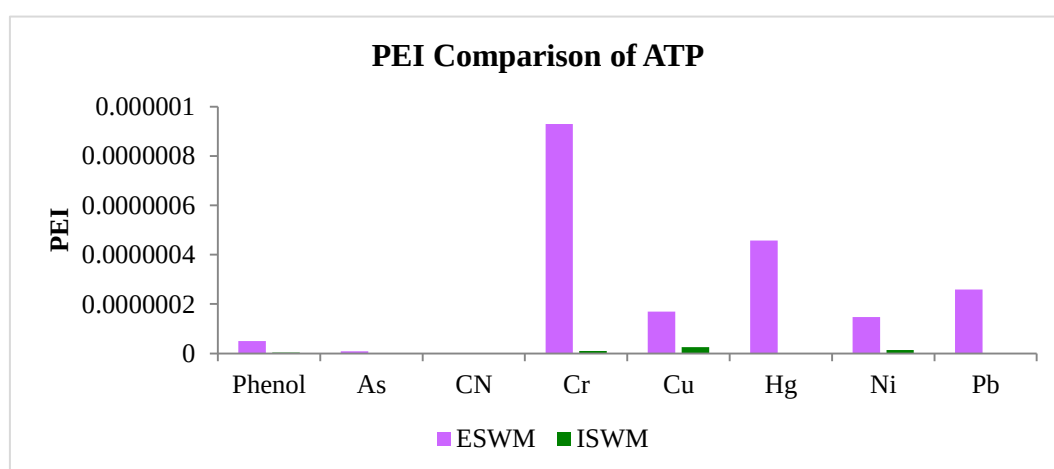


Figure- 8.22: Comparative study of ATP reduction between existing and proposed system

8.3 COMPARATIVE STUDY CONSIDERING APPLICATION OF OPTIMIZED VEHICLE BETWEEN EXISTING AND PROPOSED SWM SYSTEM

A comparison of operation costs between un-optimized (free mode) and vehicle optimized systems is illustrated in the table 8.4. As previously stated, local transit up to the transfer station becomes the most important component in minimizing SWM costs. Thus, optimizing the local transportation vehicles, namely DV1, DV2, DV3, and DV4, significantly decreases transportation costs and overall SWM costs. Another component for cost optimization in proposed SWM system is by optimization of the number of

operational LPT trucks transferring silt and process rejects from transfer stations to dumpsites outside the city.

Table- 8.4: Comparison of the operation cost and revenue by both SWM systems under vehicle optimization configuration

Types of Cost	Existing System		Proposed ISWM system with vehicle optimization
	Without vehicle optimization	With vehicle optimization	
Transportation Cost	5016468	2376101	2436537
Incentive Cost	8897	60150	61241
Landfill Cost	417857	417857	343427
Sorting Cost	0.00	0.00	460604
Incineration Cost	0.00	0.00	524597
Composting Cost	0.00	0.00	833226
Recycled Revenue	0.00	0.00	74012
Compost Revenue	0.00	0.00	2050194
Incineration Revenue	0.00	0.00	528195
Net Cost	5443222	2854108	2007230

A detailed examination of the cost analysis for both the systems indicates that there has been no change in the amount of garbage and silt transferred to various disposal locations and procedures. The quantity of waste transported by various types of vehicle from different boroughs varies almost similar. The entire transportation cost, however, has been lowered by 51.43% for the proposed system compare to existing SWM system without vehicle optimization. Fixed expenditures for departmental vehicles DV1, DV2, DV3 and DV4 have significantly dropped.

The overall operational cost of the vehicle optimized system for existing condition can be successfully reduced by 47.57% with respect existing SWM system without vehicle optimization. The chart below shows the net reduction in operational cost of each SWM system per day.

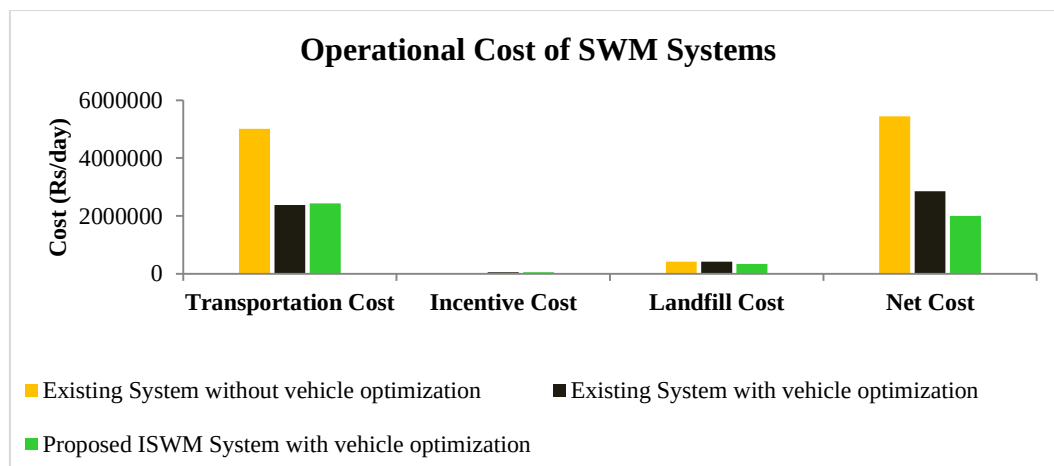


Figure- 8.23: Comparative study of Cost between ESWM systems (with and without vehicle optimization) and proposed system with vehicle optimization condition.

If vehicle optimization is done on the proposed ISWM system, the overall SWM cost may be reduced by 63.12% for un-optimized existing system and 29.67% for vehicle optimized existing system, which is a significant amount. However, an increase in incentive costs of 1.8% has been discovered. Additionally, transportation costs have also increased by 2.54% as silt and process rejects are being deposited far in dumpsites from the city. The landfill cost may be reduced by 17.81%, which is efficient. The existing SWM system has also been optimized for vehicle performance. It is feasible to lower the daily waste management cost by optimizing KMC vehicles in today's reality.

Pollution and PEI due to optimized and un-optimized system of existing are not comparable as the garbage produced, transported and deposited by both the systems are same. On vehicle optimization, the numbers of departmental vehicles transporting garbage from the borough to Dhapa are reduced such that the running vehicles work upto their given maximum trips per day. In return, the operators are paid incentives for each extra trip above their minimum trips. By this way, the number of required departmental vehicles can be reduced significantly, which in turn reduces the running and maintenance cost. The ratio of running to idle vehicles is kept at 3:2 to provide redundancy in the system in case of any unforeseen situations. Since the total trips of the vehicles remains same, the vehicular emissions by the system are identical for both cases. Additionally, the garbage dumped in landfill is identical causing same amount generation of leachate and landfill gases.

8.4 CONSIDERATION OF BS VI NORMS FOR THE STUDY OF ISWM SYSTEM

Only KMC vehicles are taken into account in the case study of the ISWM system, some of which are more than a decade old, meaning that their pollutant emissions are higher. In more recent years, KMC has incorporated certain compactors that also maintain BS IV standards. For the sake of estimation, all KMC vehicles are taken to operate to BS IV standards. However, incorporating the BS VI norms is extremely useful for the proposed model to determine how much further pollution may be reduced. The current effort to lower pollution levels by replacing the outdated BS IV standards with the Bharat Stage VI (BS VI) standards focuses on reducing SO_x emissions. Only the emission of pollutant would be affected by this consideration; it would not have an impact on the cost aspect.

Table- 8.5: Vehicle wise weighted average emission factor of different pollutants

Vehicle Type	Capacity (MT)	CO	HC	NO _x	PM	BENZ	BUTDN
DV1	7	0.74	0.09	0.125	0.005	0.00045	0.000085
DV2	9	0.74	0.09	0.125	0.005	0.00046	0.000081
DV3	10	2.25	0.09	0.258	0.006	0.00047	0.000084
DV4	7	2.25	0.09	0.258	0.006	0.00046	0.000081
HH_G	7	0.74	0.09	0.125	0.005	0.0004	0.00006
HH_S	9	0.74	0.09	0.125	0.006	0.0004	0.00006
TATA LPT 2518	20	2.25	0.09	0.258	0.006	0.00047	0.000084

With the aid of prior case studies, EURO 6 data, and an extrapolation method, the weighted average emission factors (g/km) for these particular pollutants are considered.

The calculated borough-wise rate of pollutant emission by departmental and hired vehicles per ton of waste per trip (g/t/trip) which has been fed as input data for running the LP model in LINGO is shown in the following Table 8.6, Table 8.7, Table 8.8, Table 8.9, Table 8.10, Table 8.11 and Table 8.12. The sample calculation for determining the rate of pollutant emission is shown in *annexure-8.1*.

Table- 8.6: Pollutant emission rate by DV1 per ton of waste per trip for BS VI (g/t/trip)

Br No.	CO			HC			NO _x			PM		
	E	N	S	E	N	S	E	N	S	E	N	S
1	2.309	0.452	3.888	0.281	0.055	0.473	0.390	0.076	0.657	0.016	0.003	0.026
2	1.848	0.951	3.352	0.225	0.116	0.408	0.312	0.161	0.566	0.013	0.006	0.023
3	1.486	1.503	3.545	0.180	0.183	0.431	0.251	0.254	0.599	0.010	0.010	0.024
4	1.622	1.275	3.064	0.198	0.155	0.373	0.274	0.215	0.518	0.011	0.009	0.021
5	1.364	1.552	2.784	0.166	0.189	0.339	0.230	0.262	0.470	0.009	0.010	0.019
6	1.256	1.920	2.608	0.153	0.233	0.317	0.212	0.324	0.441	0.008	0.013	0.018
7	0.349	2.393	2.603	0.042	0.291	0.316	0.059	0.404	0.440	0.002	0.016	0.018
8	1.099	2.727	1.698	0.134	0.332	0.206	0.186	0.461	0.287	0.007	0.018	0.011
9	1.912	3.031	1.901	0.232	0.369	0.231	0.323	0.512	0.321	0.013	0.020	0.013
10	1.706	3.545	1.303	0.207	0.431	0.159	0.288	0.599	0.220	0.012	0.024	0.009
11	2.165	4.116	1.013	0.263	0.501	0.123	0.366	0.695	0.171	0.015	0.028	0.007
12	0.852	3.529	2.366	0.104	0.429	0.288	0.144	0.596	0.400	0.006	0.024	0.016
13	2.436	4.033	0.748	0.296	0.490	0.091	0.411	0.681	0.126	0.016	0.027	0.005
14	2.960	4.203	1.449	0.360	0.511	0.176	0.500	0.710	0.245	0.020	0.028	0.010
15	3.379	4.282	3.446	0.411	0.521	0.419	0.571	0.723	0.582	0.023	0.029	0.023
16	3.404	4.842	0.444	0.414	0.5889	0.0540	0.575	0.8179	0.075	0.0230	0.0327	0.0030
Br No.	SO ₂			BENZENE			BUTADIENE			CO ₂		
	E	N	S	E	N	S	E	N	S	E	N	S
1	0.0256	0.005	0.0431	0.0014	0.0003	0.0024	0.0003	0.0001	0.0004	4077.019	798.977	6865.97
2	0.0205	0.0105	0.0371	0.0011	0.0006	0.0020	0.0002	0.0001	0.0004	3263.1034	1680.08	5917.653
3	0.0165	0.0167	0.0393	0.0009	0.0009	0.0022	0.0002	0.0002	0.0004	2624.668	2654.544	6261.134
4	0.0180	0.0141	0.0339	0.0010	0.0008	0.0019	0.0002	0.0001	0.0003	2863.6166	2251.323	5409.895
5	0.0151	0.0172	0.0308	0.0009	0.0009	0.0017	0.0002	0.0002	0.0003	2408.1245	2740.414	4917.062
6	0.0139	0.0213	0.0289	0.0008	0.0012	0.0016	0.0001	0.0002	0.0003	2217.7211	3390.050	4607.181
7	0.0039	0.0265	0.0288	0.0002	0.0015	0.0016	0.0000	0.0003	0.0003	616.02952	4226.358	4595.982
8	0.0122	0.0302	0.0188	0.0007	0.0016	0.0010	0.0001	0.0003	0.0002	1939.5692	4816.259	2998.024
9	0.0212	0.0336	0.0211	0.0012	0.0019	0.0012	0.0002	0.0003	0.0002	3375.11	5353.885	3357.942
10	0.0189	0.0393	0.0144	0.0010	0.0022	0.0008	0.0002	0.0004	0.0001	3012.9623	6261.134	2301.715
11	0.0240	0.0456	0.0112	0.0013	0.0025	0.0006	0.0002	0.0005	0.0001	3823.137	7269.190	1790.603
12	0.0094	0.0391	0.0262	0.0005	0.0022	0.0014	0.0001	0.0004	0.0003	1504.610	6231.267	4177.827
13	0.0270	0.0447	0.0083	0.0015	0.0025	0.0005	0.0003	0.0005	0.0001	4301.0338	7119.847	1321.668
14	0.0328	0.0466	0.0161	0.0018	0.0026	0.0009	0.0003	0.0005	0.0002	5226.9529	7422.269	2557.468
15	0.0374	0.0474	0.0383	0.0020	0.0026	0.0021	0.0004	0.0005	0.0004	5966.1828	7560.403	6085.664
16	1.3202	1.8778	0.1722	0.0021	0.0029	0.0003	0.0004	0.0006	0.0001	6010.9909	8549.794	784.0423

Table- 8.7: Pollutant emission rate by DV2 per ton of waste per trip for BS VI (g/t/trip)

Br No.	CO			HC			NO _x			PM		
	E	N	S	E	N	S	E	N	S	E	N	S
1	1.796	0.352	3.024	0.218	0.043	0.368	0.303	0.059	0.511	0.012	0.002	0.020
2	1.437	0.740	2.606	0.175	0.090	0.317	0.243	0.125	0.440	0.010	0.005	0.018
3	1.156	1.169	2.757	0.141	0.142	0.335	0.195	0.197	0.466	0.008	0.008	0.019
4	1.261	0.992	2.383	0.153	0.121	0.290	0.213	0.167	0.403	0.009	0.007	0.016
5	1.061	1.207	2.166	0.129	0.147	0.263	0.179	0.204	0.366	0.007	0.008	0.015
6	0.977	1.493	2.029	0.119	0.182	0.247	0.165	0.252	0.343	0.007	0.010	0.014
7	0.271	1.862	2.024	0.033	0.226	0.246	0.046	0.314	0.342	0.002	0.013	0.014
8	0.854	2.121	1.320	0.104	0.258	0.161	0.144	0.358	0.223	0.006	0.014	0.009
9	1.487	2.358	1.479	0.181	0.287	0.180	0.251	0.398	0.250	0.010	0.016	0.010
10	1.327	2.757	1.014	0.161	0.335	0.123	0.224	0.466	0.171	0.009	0.019	0.007
11	1.684	3.201	0.789	0.205	0.389	0.096	0.284	0.541	0.133	0.011	0.022	0.005
12	0.663	2.744	1.840	0.081	0.334	0.224	0.112	0.464	0.311	0.004	0.019	0.012
13	1.894	3.135	0.582	0.230	0.381	0.071	0.320	0.530	0.098	0.013	0.021	0.004
14	2.302	3.268	1.126	0.280	0.398	0.137	0.389	0.552	0.190	0.016	0.022	0.008
15	2.628	3.330	2.680	0.320	0.405	0.326	0.444	0.562	0.453	0.018	0.022	0.018
16	2.6476	3.7658	0.3453	0.3220	0.4580	0.0420	0.4472	0.6361	0.0583	0.0179	0.0254	0.0023
Br No.	SO ₂			BENZENE			BUTADIENE			CO ₂		
	E	N	S	E	N	S	E	N	S	E	N	S
1	0.0257	0.0050	0.0432	0.0011	0.0002	0.0019	0.0002	0.0000	0.0003	4092.4506	801.9977	6891.959
2	0.0205	0.0106	0.0373	0.0009	0.0005	0.0016	0.0002	0.0001	0.0003	3275.4581	1686.448	5940.047
3	0.0165	0.0167	0.0394	0.0007	0.0007	0.0017	0.0001	0.0001	0.0003	2634.6134	2664.587	6284.834
4	0.0180	0.0142	0.0341	0.0008	0.0006	0.0014	0.0001	0.0001	0.0003	2874.4632	2259.845	5430.369
5	0.0152	0.0173	0.0310	0.0007	0.0007	0.0013	0.0001	0.0001	0.0002	2417.2422	2750.781	4935.672
6	0.0140	0.0213	0.0290	0.0006	0.0009	0.0013	0.0001	0.0002	0.0002	2226.1098	3402.877	4624.618
7	0.0039	0.0266	0.0289	0.0002	0.0012	0.0013	0.0000	0.0002	0.0002	618.36141	4242.356	4613.38
8	0.0122	0.0303	0.0189	0.0005	0.0013	0.0008	0.0001	0.0002	0.0001	1946.9167	4834.484	3009.373
9	0.0213	0.0337	0.0211	0.0009	0.0015	0.0009	0.0002	0.0003	0.0002	3387.8903	5374.153	3370.648
10	0.0190	0.0394	0.0145	0.0008	0.0017	0.0006	0.0001	0.0003	0.0001	3024.3644	6284.834	2310.437
11	0.0241	0.0458	0.0113	0.0010	0.0020	0.0005	0.0002	0.0004	0.0001	3837.6099	7296.706	1797.376
12	0.0095	0.0392	0.0263	0.0004	0.0016	0.0011	0.0001	0.0003	0.0002	1510.3063	6254.860	4193.637
13	0.0271	0.0448	0.0083	0.0012	0.0019	0.0004	0.0002	0.0003	0.0001	4317.3094	7146.796	1326.669
14	0.0329	0.0467	0.0161	0.0014	0.0020	0.0007	0.0003	0.0004	0.0001	5246.7324	7450.359	2567.155
15	0.0376	0.0476	0.0383	0.0016	0.0021	0.0016	0.0003	0.0004	0.0003	5988.7674	7589.022	6108.695
16	1.3249	1.8845	0.1728	0.0016	0.0023	0.0002	0.0003	0.0004	0.0000	6033.7435	8582.157	787.0100

Table- 8.8: Pollutant emission rate by DV3 per ton of waste per trip for BS VI (g/t/trip)

Br No.	CO			HC			NO _x			PM		
	E	N	S	E	N	S	E	N	S	E	N	S
1	4.915	0.924	8.275	0.197	0.039	0.331	0.563	0.110	0.949	0.013	0.003	0.022
2	3.933	1.942	7.132	0.157	0.081	0.285	0.451	0.232	0.818	0.010	0.005	0.019
3	3.163	3.068	7.237	0.127	0.128	0.302	0.363	0.367	0.865	0.008	0.009	0.020
4	3.451	2.602	6.522	0.138	0.109	0.261	0.396	0.311	0.748	0.009	0.007	0.017
5	2.903	3.168	5.926	0.116	0.132	0.237	0.333	0.379	0.680	0.008	0.009	0.016
6	2.673	3.918	5.553	0.107	0.163	0.222	0.307	0.469	0.637	0.007	0.011	0.015
7	0.742	4.885	5.539	0.030	0.204	0.222	0.085	0.584	0.635	0.002	0.014	0.015
8	2.338	5.567	3.613	0.093	0.232	0.144	0.268	0.666	0.414	0.006	0.015	0.010
9	4.068	6.188	4.047	0.163	0.258	0.162	0.466	0.740	0.464	0.011	0.017	0.011
10	3.631	7.237	2.774	0.145	0.302	0.111	0.416	0.865	0.318	0.010	0.020	0.007
11	4.608	8.402	2.158	0.184	0.350	0.086	0.528	1.005	0.247	0.012	0.023	0.006
12	1.813	7.203	5.035	0.073	0.300	0.201	0.208	0.861	0.577	0.005	0.020	0.013
13	5.184	8.230	1.593	0.207	0.343	0.064	0.594	0.984	0.183	0.014	0.023	0.004
14	6.300	8.579	3.082	0.252	0.358	0.123	0.722	1.026	0.353	0.017	0.024	0.008
15	7.191	8.739	7.335	0.288	0.364	0.293	0.825	1.045	0.841	0.019	0.024	0.020
16	7.2450	10.3050	0.9450	0.2898	0.4122	0.0378	0.8308	1.1816	0.1084	0.0193	0.0275	0.0025
Br No.	SO ₂			BENZENE			BUTADIENE			CO ₂		
	E	N	S	E	N	S	E	N	S	E	N	S
1	0.0358	0.0070	0.0603	0.0010	0.0002	0.0018	0.0002	0.0000	0.0003	5705.179	1118.111	9607.908
2	0.0287	0.0148	0.0520	0.0008	0.0004	0.0015	0.0001	0.0001	0.0003	4566.233	2351.166	8280.876
3	0.0231	0.0233	0.0550	0.0007	0.0007	0.0015	0.0001	0.0001	0.0003	3672.844	3714.849	8762.018
4	0.0251	0.0198	0.0475	0.0007	0.0006	0.0013	0.0001	0.0001	0.0002	4007.215	3150.567	7570.337
5	0.0211	0.0241	0.0432	0.0006	0.0007	0.0012	0.0001	0.0001	0.0002	3369.818	3835.011	6880.704
6	0.0195	0.0298	0.0405	0.0006	0.0008	0.0012	0.0001	0.0002	0.0002	3103.362	4744.139	6447.063
7	0.0054	0.0371	0.0404	0.0002	0.0011	0.0012	0.0000	0.0002	0.0002	862.0442	5914.491	6431.39
8	0.0170	0.0423	0.0263	0.0005	0.0012	0.0008	0.0001	0.0002	0.0001	2714.144	6740.016	4195.3
9	0.0297	0.0470	0.0295	0.0008	0.0013	0.0008	0.0002	0.0002	0.0002	4722.974	7492.392	4698.94
10	0.0265	0.0550	0.0202	0.0008	0.0015	0.0006	0.0001	0.0003	0.0001	4216.19	8762.018	3220.918
11	0.0336	0.0639	0.0157	0.0010	0.0018	0.0005	0.0002	0.0003	0.0001	5349.917	10172.72	2505.68
12	0.0132	0.0547	0.0367	0.0004	0.0016	0.0010	0.0001	0.0003	0.0002	2105.486	8720.221	5846.246
13	0.0378	0.0625	0.0116	0.0011	0.0018	0.0003	0.0002	0.0003	0.0001	6018.659	9963.728	1849.476
14	0.0459	0.0652	0.0225	0.0013	0.0019	0.0006	0.0002	0.0003	0.0001	7314.335	10386.94	3578.802
15	0.0524	0.0664	0.0535	0.0015	0.0019	0.0015	0.0003	0.0003	0.0003	8348.792	10580.26	8515.977
16	1.8309	2.6042	0.2388	0.0015	0.0022	0.0002	0.0003	0.0004	0.0000	8332.2267	11851.42	1086.812

Table- 8.9: Pollutant emission rate by DV4 per ton of waste per trip for BS VI (g/t/trip)

Br No.	CO			HC			NO _x			PM		
	E	N	S	E	N	S	E	N	S	E	N	S
1	7.020	1.375	11.822	0.281	0.055	0.473	0.805	0.158	1.356	0.187	0.037	0.315
2	5.619	2.893	10.189	0.225	0.116	0.408	0.644	0.332	1.168	0.150	0.077	0.272
3	4.519	4.571	10.780	0.181	0.183	0.431	0.518	0.524	1.236	0.121	0.122	0.287
4	4.931	3.876	9.315	0.197	0.155	0.373	0.565	0.444	1.068	0.131	0.103	0.248
5	4.146	4.719	8.466	0.166	0.189	0.339	0.475	0.541	0.971	0.111	0.126	0.226
6	3.819	5.837	7.935	0.153	0.233	0.317	0.438	0.669	0.910	0.102	0.156	0.212
7	1.061	7.277	7.913	0.042	0.291	0.317	0.122	0.834	0.907	0.028	0.194	0.211
8	3.340	8.293	5.162	0.134	0.332	0.206	0.383	0.951	0.592	0.089	0.221	0.138
9	5.811	9.219	5.782	0.232	0.369	0.231	0.666	1.057	0.663	0.155	0.246	0.154
10	5.188	10.780	3.963	0.208	0.431	0.159	0.595	1.236	0.454	0.138	0.287	0.106
11	6.583	12.516	3.083	0.263	0.501	0.123	0.755	1.435	0.354	0.176	0.334	0.082
12	2.590	10.729	7.193	0.104	0.429	0.288	0.297	1.230	0.825	0.069	0.286	0.192
13	7.405	12.259	2.276	0.296	0.490	0.091	0.849	1.406	0.261	0.197	0.327	0.061
14	9.000	12.780	4.403	0.360	0.511	0.176	1.032	1.465	0.505	0.240	0.341	0.117
15	10.273	13.018	10.478	0.411	0.521	0.419	1.178	1.493	1.202	0.274	0.347	0.279
16	10.350	14.7214	1.3500	0.4140	0.5889	0.0540	1.1868	1.6881	0.1548	0.0276	0.0393	0.0036
Br No.	SO ₂			BENZENE			BUTADIENE			CO ₂		
	E	N	S	E	N	S	E	N	S	E	N	S
1	0.0351	0.0069	0.0590	0.0014	0.0003	0.0024	0.0003	0.0000	0.0004	5578.893	1093.299	9395.23
2	0.0281	0.0144	0.0509	0.0011	0.0006	0.0020	0.0002	0.0001	0.0004	4465.164	2298.995	8097.58
3	0.0225	0.0228	0.0538	0.0009	0.0009	0.0022	0.0002	0.0002	0.0004	3591.547	3632.415	8567.59
4	0.0246	0.0193	0.0465	0.0010	0.0008	0.0019	0.0002	0.0001	0.0003	3918.504	3080.696	7402.76
5	0.0207	0.0235	0.0423	0.0008	0.0010	0.0018	0.0001	0.0002	0.0003	3295.228	3749.921	6728.39
6	0.0191	0.0291	0.0396	0.0008	0.0012	0.0016	0.0001	0.0002	0.0003	3034.677	4638.858	6304.36
7	0.0053	0.0363	0.0395	0.0002	0.0015	0.0016	0.0000	0.0003	0.0003	842.9688	5783.255	6289.04
8	0.0167	0.0414	0.0258	0.0007	0.0017	0.0010	0.0001	0.0003	0.0002	2654.067	6590.455	4102.43
9	0.0290	0.0460	0.0289	0.0012	0.0019	0.0012	0.0002	0.0003	0.0002	4618.428	7326.138	4594.92
10	0.0259	0.0538	0.0198	0.0011	0.0022	0.0008	0.0002	0.0004	0.0001	4122.867	8567.591	3149.63
11	0.0329	0.0625	0.0154	0.0013	0.0026	0.0006	0.0002	0.0005	0.0001	5231.494	9946.990	2450.22
12	0.0129	0.0536	0.0359	0.0005	0.0022	0.0015	0.0001	0.0004	0.0003	2058.883	8526.724	5716.84
13	0.0370	0.0612	0.0113	0.0015	0.0025	0.0005	0.0003	0.0004	0.0001	5885.431	9742.638	1808.54
14	0.0449	0.0638	0.0220	0.0018	0.0026	0.0009	0.0003	0.0005	0.0002	7152.424	10156.45	3499.58
15	0.0513	0.0650	0.0523	0.0021	0.0027	0.0021	0.0004	0.0005	0.0004	8163.991	10345.49	8327.48
16	1.8085	2.5723	0.2359	0.0021	0.0030	0.0003	0.0004	0.0005	0.0000	8225.2974	11699.34	1072.87

Table- 8.10: Pollutant emission rate by HV per ton of waste per trip for BS VI (g/t/trip)

Br No.	CO			HC			NO _x			PM		
	E	N	S	E	N	S	E	N	S	E	N	S
1	2.309	0.452	3.888	0.281	0.055	0.473	0.390	0.076	0.657	0.016	0.003	0.026
2	1.848	0.951	3.351	0.225	0.116	0.408	0.312	0.161	0.566	0.012	0.006	0.023
3	1.486	1.503	3.545	0.181	0.183	0.431	0.251	0.254	0.599	0.010	0.010	0.024
4	1.621	1.275	3.063	0.197	0.155	0.373	0.274	0.215	0.517	0.011	0.009	0.021
5	1.364	1.552	2.784	0.166	0.189	0.339	0.230	0.262	0.470	0.009	0.010	0.019
6	1.256	1.920	2.609	0.153	0.233	0.317	0.212	0.324	0.441	0.008	0.013	0.018
7	0.349	2.393	2.603	0.042	0.291	0.317	0.059	0.404	0.440	0.002	0.016	0.018
8	1.098	2.727	1.698	0.134	0.332	0.206	0.186	0.461	0.287	0.007	0.018	0.011
9	1.911	3.032	1.902	0.232	0.369	0.231	0.323	0.512	0.321	0.013	0.020	0.013
10	1.706	3.545	1.303	0.208	0.431	0.159	0.288	0.599	0.220	0.012	0.024	0.009
11	2.165	4.117	1.014	0.263	0.501	0.123	0.366	0.695	0.171	0.015	0.028	0.007
12	0.852	3.529	2.366	0.104	0.429	0.288	0.144	0.596	0.400	0.006	0.024	0.016
13	2.436	4.032	0.749	0.296	0.490	0.091	0.411	0.681	0.126	0.016	0.027	0.005
14	2.960	4.203	1.448	0.360	0.511	0.176	0.500	0.710	0.245	0.020	0.028	0.010
15	3.379	4.282	3.446	0.411	0.521	0.419	0.571	0.723	0.582	0.023	0.029	0.023
16	3.404	4.8417	0.4440	0.4140	0.5889	0.0540	0.5750	0.8179	0.0750	0.0230	0.0327	0.0030
Br No.	SO ₂			BENZENE			BUTADIENE			CO ₂		
	E	N	S	E	N	S	E	N	S	E	N	S
1	0.0136	0.0027	0.0230	0.0012	0.0002	0.0021	0.0002	0.0000	0.0003	2172.72	425.7865	3658.9
2	0.0109	0.0056	0.0198	0.0010	0.0005	0.0018	0.0001	0.0001	0.0003	1738.97	895.3512	3153.6
3	0.0088	0.0089	0.0209	0.0008	0.0008	0.0019	0.0001	0.0001	0.0003	1398.73	1414.652	3336.7
4	0.0096	0.0075	0.0181	0.0009	0.0007	0.0017	0.0001	0.0001	0.0002	1526.07	1199.771	2883.0
5	0.0081	0.0092	0.0165	0.0007	0.0008	0.0015	0.0001	0.0001	0.0002	1283.34	1460.414	2620.4
6	0.0074	0.0113	0.0154	0.0007	0.0010	0.0014	0.0001	0.0002	0.0002	1181.85	1806.618	2455.3
7	0.0021	0.0141	0.0154	0.0002	0.0013	0.0014	0.0000	0.0002	0.0002	328.296	2252.305	2449.3
8	0.0065	0.0161	0.0100	0.0006	0.0015	0.0009	0.0001	0.0002	0.0001	1033.63	2566.669	1597.7
9	0.0113	0.0179	0.0112	0.0010	0.0016	0.0010	0.0002	0.0002	0.0002	1798.66	2853.184	1789.5
10	0.0101	0.0209	0.0077	0.0009	0.0019	0.0007	0.0001	0.0003	0.0001	1605.66	3336.674	1226.6
11	0.0128	0.0243	0.0060	0.0011	0.0022	0.0005	0.0002	0.0003	0.0001	2037.42	3873.887	954.25
12	0.0050	0.0208	0.0140	0.0005	0.0019	0.0013	0.0001	0.0003	0.0002	801.837	3320.753	2226.4
13	0.0144	0.0238	0.0044	0.0013	0.0022	0.0004	0.0002	0.0003	0.0001	2292.1	3794.294	704.34
14	0.0175	0.0248	0.0085	0.0016	0.0023	0.0008	0.0002	0.0003	0.0001	2785.54	3955.462	1362.9
15	0.0200	0.0253	0.0204	0.0018	0.0023	0.0019	0.0003	0.0003	0.0003	3179.49	4029.077	3243.1
16	0.7041	1.0015	0.0918	0.0018	0.0026	0.0002	0.0003	0.0004	0.0000	3203.37	4556.340	417.83

Table- 8.11: Pollutant emission rate by HV per ton of silt per trip for BS VI (g/t/trip)

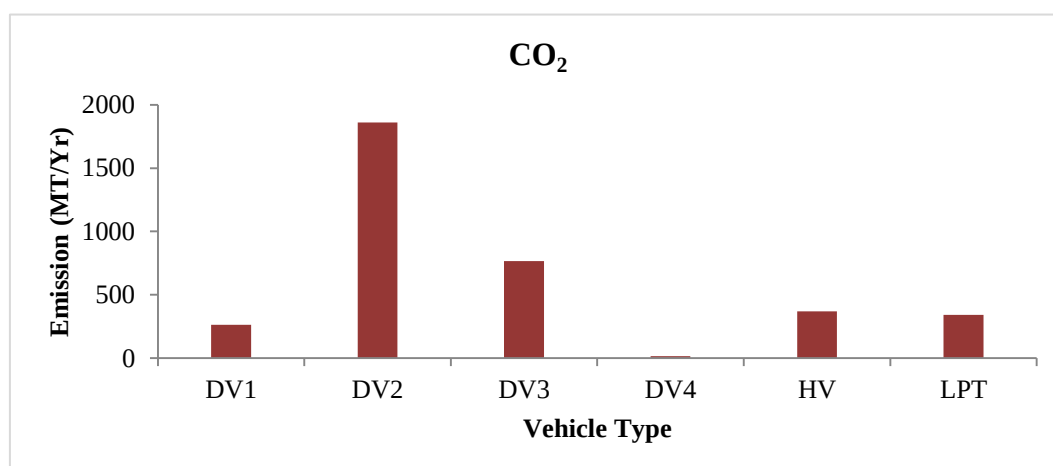
Br No.	CO			HC			NO_x			PM		
	E	N	S	E	N	S	E	N	S	E	N	S
1	1.796	0.352	3.024	0.218	0.043	0.368	0.303	0.059	0.511	0.012	0.002	0.020
2	1.437	0.740	2.606	0.175	0.090	0.317	0.243	0.125	0.440	0.010	0.005	0.018
3	1.156	1.169	2.757	0.141	0.142	0.335	0.195	0.197	0.466	0.008	0.008	0.019
4	1.261	0.992	2.382	0.153	0.121	0.290	0.213	0.167	0.402	0.009	0.007	0.016
5	1.061	1.207	2.166	0.129	0.147	0.263	0.179	0.204	0.366	0.007	0.008	0.015
6	0.977	1.493	2.029	0.119	0.182	0.247	0.165	0.252	0.343	0.007	0.010	0.014
7	0.271	1.861	2.024	0.033	0.226	0.246	0.046	0.314	0.342	0.002	0.013	0.014
8	0.854	2.121	1.320	0.104	0.258	0.161	0.144	0.358	0.223	0.006	0.014	0.009
9	1.487	2.358	1.479	0.181	0.287	0.180	0.251	0.398	0.250	0.010	0.016	0.010
10	1.327	2.757	1.014	0.161	0.335	0.123	0.224	0.466	0.171	0.009	0.019	0.007
11	1.684	3.202	0.789	0.205	0.389	0.096	0.284	0.541	0.133	0.011	0.022	0.005
12	0.663	2.745	1.840	0.081	0.334	0.224	0.112	0.464	0.311	0.004	0.019	0.012
13	1.895	3.136	0.582	0.230	0.381	0.071	0.320	0.530	0.098	0.013	0.021	0.004
14	2.302	3.269	1.126	0.280	0.398	0.137	0.389	0.552	0.190	0.016	0.022	0.008
15	2.628	3.330	2.680	0.320	0.405	0.326	0.444	0.563	0.453	0.018	0.022	0.018
16	2.6476	3.7658	0.3453	0.3220	0.4580	0.0420	0.9231	1.3129	0.1204	0.0179	0.025	0.0023
Br No.	SO₂			BENZENE			BUTADIENE			CO₂		
	E	N	S	E	N	S	E	N	S	E	N	S
1	0.0106	0.0021	0.0179	0.0010	0.0002	0.0016	0.0001	0.0000	0.0002	1689.8940	331.1673	2845.9
2	0.0085	0.0044	0.0154	0.0008	0.0004	0.0014	0.0001	0.0001	0.0002	1352.5345	696.3843	2452.8
3	0.0068	0.0069	0.0163	0.0006	0.0006	0.0015	0.0001	0.0001	0.0002	1087.9042	1100.285	2595.2
4	0.0074	0.0059	0.0141	0.0007	0.0005	0.0013	0.0001	0.0001	0.0002	1186.9460	933.1551	2242.4
5	0.0063	0.0071	0.0128	0.0006	0.0007	0.0012	0.0001	0.0001	0.0002	998.1531	1135.877	2038.1
6	0.0058	0.0088	0.0120	0.0005	0.0008	0.0011	0.0001	0.0001	0.0002	919.2191	1405.147	1909.6
7	0.0016	0.0110	0.0120	0.0001	0.0010	0.0011	0.0000	0.0002	0.0002	255.3416	1751.792	1904.7
8	0.0050	0.0125	0.0078	0.0005	0.0011	0.0007	0.0001	0.0002	0.0001	803.9341	1996.298	1242.7
9	0.0088	0.0139	0.0087	0.0008	0.0013	0.0008	0.0001	0.0002	0.0001	1398.9540	2219.143	1391.8
10	0.0078	0.0163	0.0060	0.0007	0.0015	0.0005	0.0001	0.0002	0.0001	1248.8444	2595.191	954.04
11	0.0100	0.0189	0.0046	0.0009	0.0017	0.0004	0.0001	0.0003	0.0001	1584.6629	3013.023	742.19
12	0.0039	0.0162	0.0109	0.0004	0.0015	0.0010	0.0001	0.0002	0.0001	623.6512	2582.808	1731.7
13	0.0112	0.0185	0.0034	0.0010	0.0017	0.0003	0.0002	0.0003	0.0000	1782.7446	2951.118	547.81
14	0.0136	0.0193	0.0066	0.0013	0.0018	0.0006	0.0002	0.0003	0.0001	2166.5293	3076.470	1060.1
15	0.0155	0.0197	0.0158	0.0014	0.0018	0.0015	0.0002	0.0003	0.0002	2472.9338	3133.726	2522.4
16	0.5476	0.7789	0.0714	0.0014	0.0020	0.0002	0.0002	0.0003	0.0000	2491.5065	3543.820	324.98

Table- 8.12: Pollutant emission rate by heavy duty LPT truck per ton of silt per trip for BS VI (g/t/trip)

SO ₂			CO			CO ₂			HC		
E	N	S	E	N	S	E	N	S	E	N	S
0.0034	0.0056	0.0023	2.936	4.843	1.962	541.52	893.23	361.87	0.1174	0.1945	0.0784
NO _x			PM			BENZENE			BUTADIENE		
E	N	S	E	N	S	E	N	S	E	N	S
0.3367	0.5553	0.2253	0.0078	0.0129	0.0051	0.0006	0.001	0.0004	0.0001	0.0002	0.0001

8.4.1 Total Pollutant Emissions from KMC Vehicles under BS VI norms

Figure 8.24 shows the Emission of CO₂ from departmental and hired vehicles along with heavy-duty TATA LPT trucks considering BS VI standards. It is seen that departmental vehicles contribute the most CO₂ 80.35% as they travel more. Emissions from hired vehicles is 10.22% and the remaining 9.43% is coming from heavy-duty TATA LPT trucks, which transport process reject and silt from transfer station to respective ELF sites. Among different departmental vehicles, the DV2 type is noted to have the highest emission due to the highest amount of garbage they carry (60.98%) and the greater distance they travel between others.

**Figure- 8.24:** Emission of CO₂ from departmental and hired vehicles under BS-VI

The emission patterns for CO and NO_x, SO₂ and PM, and butadiene and benzene are shown in Figures 8.25, 8.26, and 8.27, respectively. Except for CO, where LPT trucks emit more pollution than other vehicles, departmental vehicles had the greatest emissions

of all the pollutants. Departmental vehicles emit 42.23%, 48.10%, 80.19%, 55.87%, 56.22%, and 55.81% of CO, NO_x, SO₂, PM, butadiene, and benzene, respectively. Significant emissions of different pollutants are seen from heavy-duty LPT vehicles. Following are the emission percentages: CO (47.64%) and NO_x (27.82%). Benzene (28.50%), SO₂ (7.03%), PM (27.37%), and butadiene (30%). The remaining parts are coming from hired vehicles.

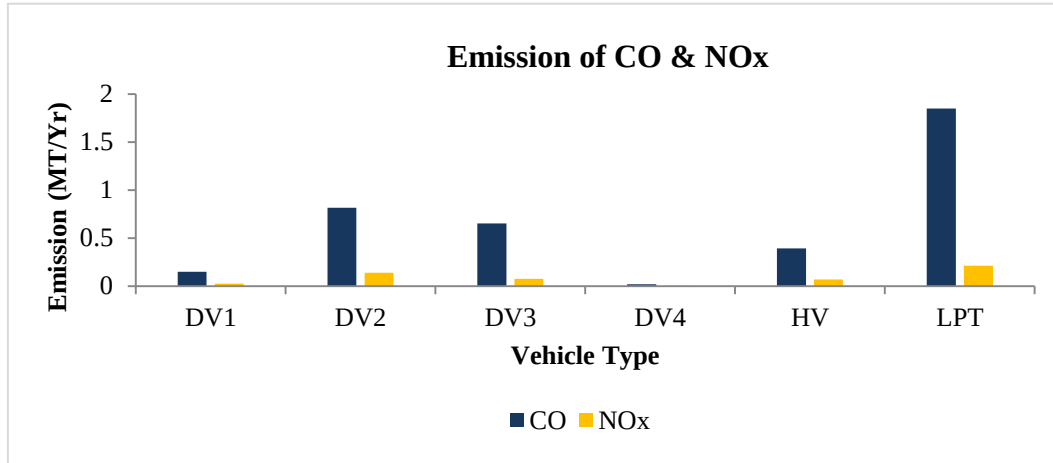


Figure- 8.25: Emission of CO and NO_x from departmental and hired vehicles under BS-VI

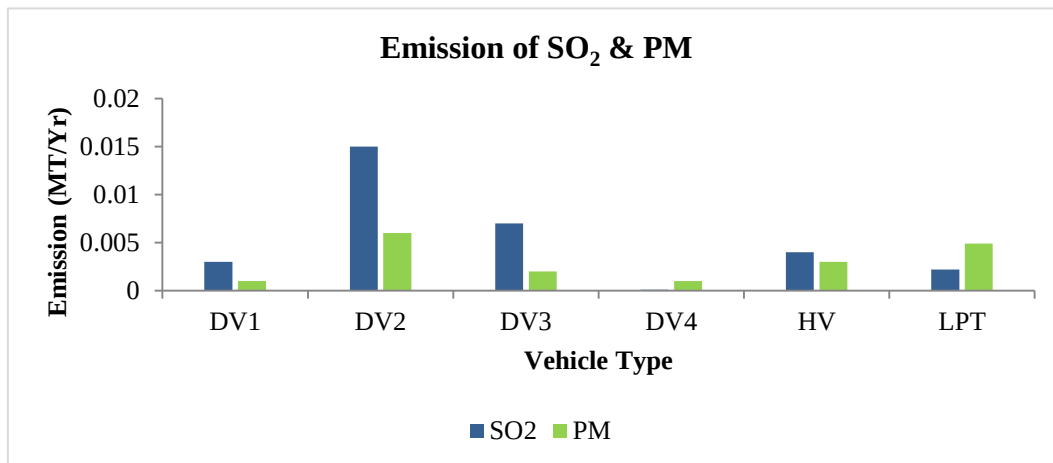


Figure- 8.26: Emission of SO₂ and PM from departmental and hired vehicles under BS-VI

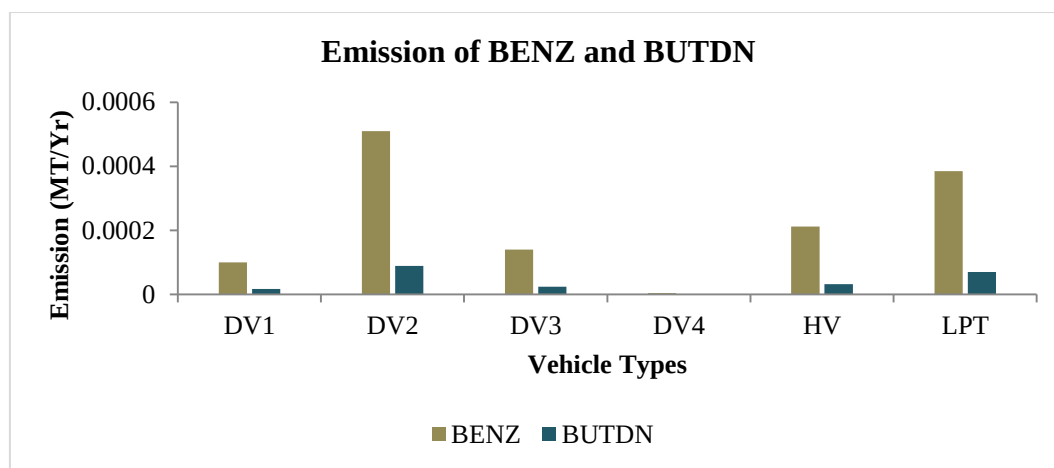


Figure- 8.27: Emission of benzene and butadiene from departmental and hired vehicles under BS-VI

8.5 COMPARATIVE ANALYSIS OF POLLUTANT EMISSION CONSIDERING BS-VI NORMS OVER BS-IV FOR PROPOSED ISWM SYSTEM

The ISWM systems run with two conditions. The Condition I is when all the vehicles (Departmental, Hired, Tata LPT) are BSIV and the Condition II is when all the vehicles (Departmental, Hired, Tata LPT) are BSVI. The incorporation of BS-VI norms, reduce the pollutant emission significantly from the transportation sector only. The emission of pollutants from other operations of proposed ISWM systems remains the same as BS-IV norms. Table 8.13 represents the emission of various pollutants for BS-IV and BS-VI accordingly.

Table- 8.13: Pollutant emission from transportation sector for BS-IV and BS-VI

<i>Pollutant</i>	<i>Emission (MT/Yr)</i>	
	<i>BS-IV</i>	<i>BS-VI</i>
<i>CO₂</i>	3603.82	3614.8
<i>CO</i>	10.869	3.878
<i>SO₂</i>	0.794	0.031
<i>NO_x</i>	17.68	0.520
<i>HC</i>	2.721	0.266
<i>PM</i>	1.452	0.016
<i>BENZ</i>	0.014	0.0013
<i>BUTDN</i>	0.0023	0.00023

In the proposed ISWM system, the vehicles used fuel with a sulphur level of 50 ppm that was reduced to 10 ppm using BS-VI fuel. The sulphur and nitrogen oxide contents of BS VI fuel and BS IV fuel are the main differences between them.

Figures 8.28, 8.29, and 8.30 below illustrate a comparison of total pollutant emissions of proposed ISWM system from transportation sector. In Figure 8.25, CO₂ has been depicted differently due to the substantial amount of emissions it produces. Every single pollutant emission has been decreased through the implementation of BS-VI standards in an integrated MSW management system, with the exception of CO₂, which could not be reduced to that amount due to no change in limit and little higher emission rate. The percentage reduction of these pollutant emissions is examined in depth in each of the following figures. The total emission of CO₂ increased by 0.3% only in BS-VI standards compared to BS-IV.

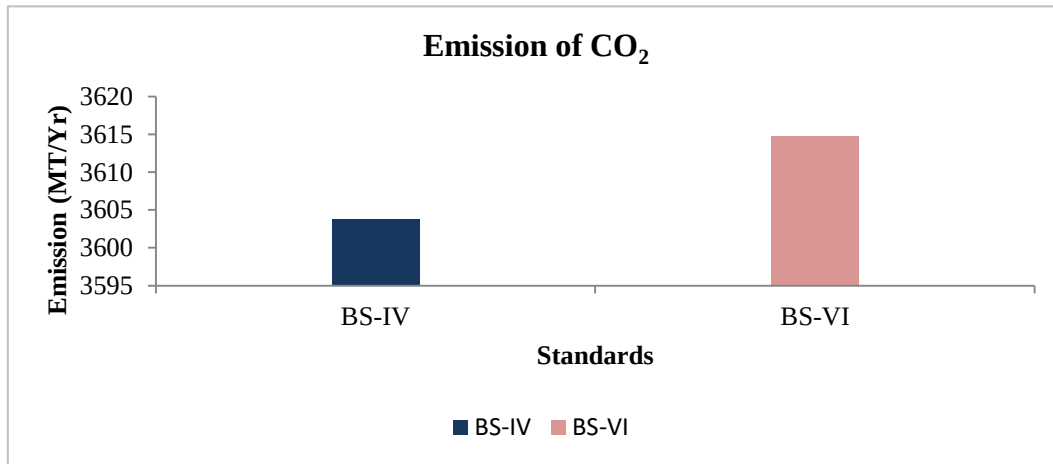


Figure- 8.28: Comparison of CO₂ Emission under BS-IV and BS-VI

Figure 8.26, shows the comparison of CO and SO₂ from both BS-IV & BS-VI Vehicular Emissions of the proposed ISWM system. In comparison to the BS-IV, the BS-VI cut overall CO and SO₂ emissions by 64.32% and 96.10% respectively. The departmental and hired vehicles exhibit the greatest reduction in CO and SO₂ emissions.

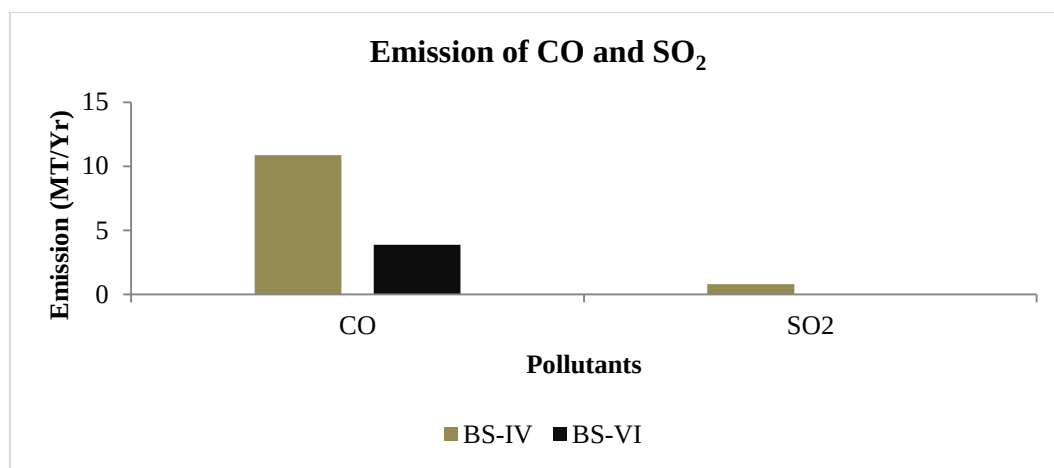


Figure- 8.29: Comparison of CO and SO₂ Emission under BS-IV and BS-VI

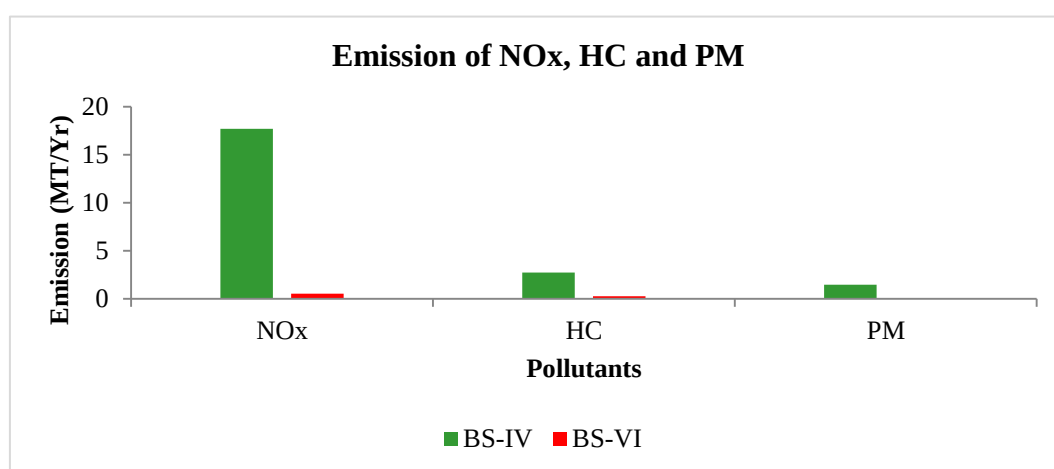


Figure- 8.30: Comparison of NO_x, HC and PM Emission under BS-IV and BS-VI

In comparison to the BS-IV, the BS-VI was able to reduce total PM emissions by 98.9%. While NO_x and HC emissions are reduced by 97.06% and 90.22%, respectively. The overall emission of benzene and butadiene is reduced by 90.71% and 90% respectively under BS-VI. The comparison is shown in Figure 8.31 below.

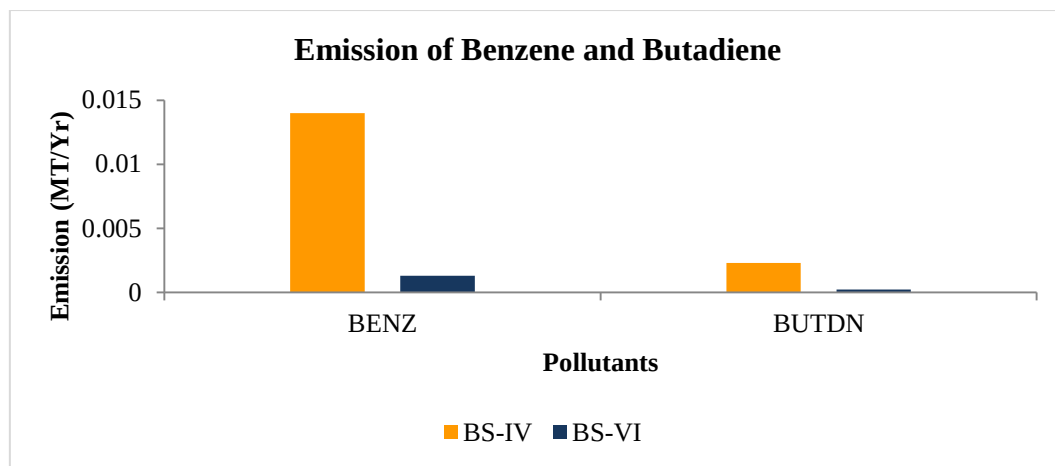


Figure- 8.31: Comparison of Benzene and Butadiene Emission under BS-IV and BS-VI

8.6 COMPARATIVE ANALYSIS OF POLLUTANT EMISSION FROM DIFFERENT VEHICLES USED CONSIDERING BS-VI NORMS OVER BS-IV FOR PROPOSED ISWM SYSTEM

The departmental and hired vehicles exhibit the greatest reduction in CO emissions. Emission from DV1 was reduced by 82.57%, while DV2 showed the highest reduction in CO emission by 83.19%. Reduction of CO found in DV3 and DV4 type vehicles are 50.98% and 48.72% respectively. DV4 showed the least reduction among others. Overall emission of HV cut by 79.72% and LPT shows same quantity of emission.

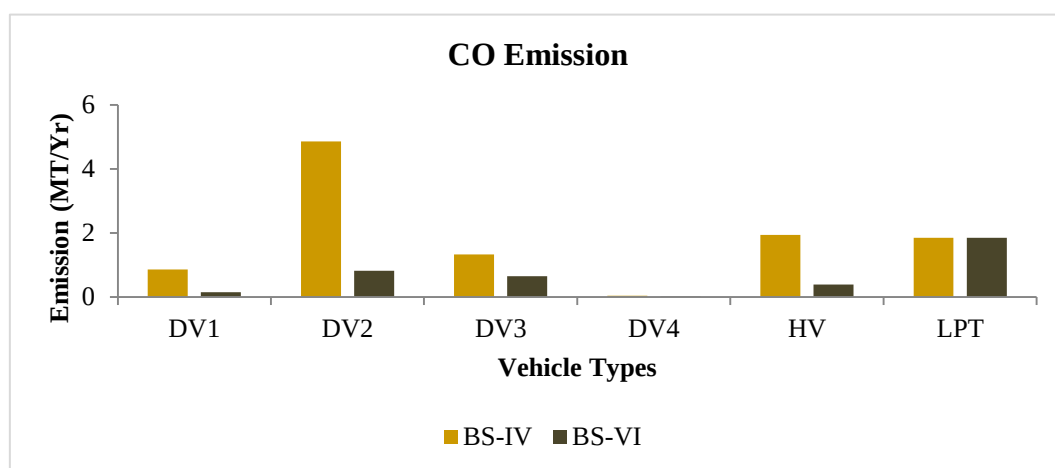


Figure- 8.32: Comparison of CO Emission under BS-IV and BS-VI for Different Types of Vehicles

The highest reduction of SO₂ emission found in DV4 by 97.17%, followed by LPT (97.09%). DV2 shows the reduction of 96.33%. Reduction of SO₂ is 94.83% for DV1, 95.83% for DV3 and 95.07% for HV.

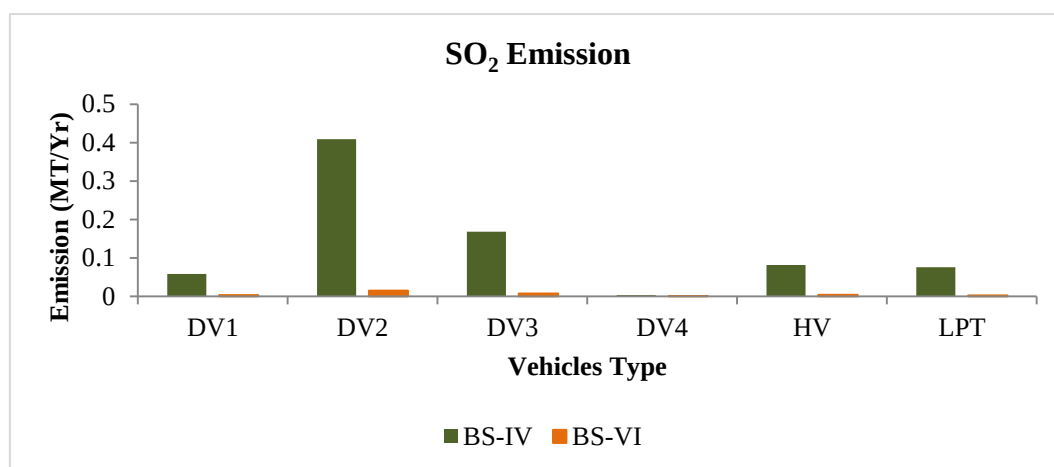


Figure- 8.33: Comparison of SO₂ Emission under BS-IV and BS-VI for Different Types of Vehicles

The emission of CO₂ from different types of departmental and hired vehicles and LPT trucks is shown in Figure 8.34. No significant reduction is found in CO₂ emission by introducing BS-VI standards over BS-IV.

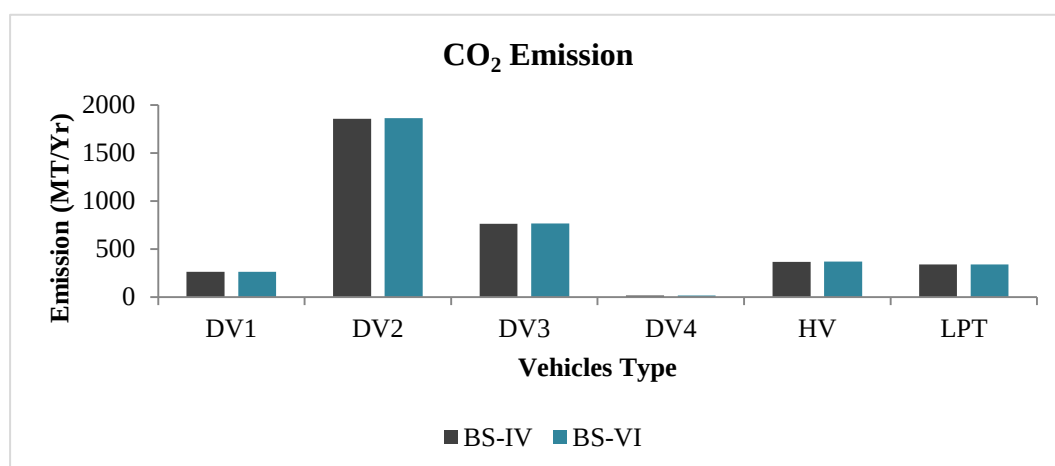


Figure- 8.34: Comparison of CO₂ Emission under BS-IV and BS-VI for Different Types of Vehicles

The emission of HC from different vehicles employed in the ISWM system is depicted in Figure 8.35 below. The greatest reduction, of 93.09%, is seen in DV3-type vehicles, followed by DV2, which exhibits a reduction of 92.62%. HC emissions are greatly

reduced by 92.31% and 90.5%, respectively, by DV1 and HV. The lowest reduction among them is seen by LPT which decreased by 70.98%, while DV4 emissions decreased by 92.73%.

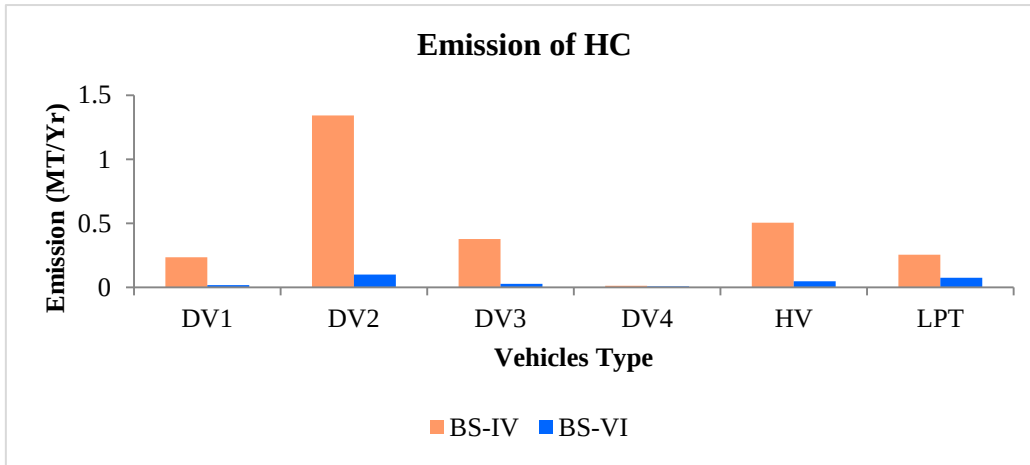


Figure- 8.35: Comparison of HC Emission under BS-IV and BS-VI for Different Types of Vehicles

The most significant reduction in all pollutants is shown for NO_x when BS-VI standards are introduced instead of BS-IV. Except for DV4, which shows a reduction of 97.14%, all departmental vehicles, including hired ones, show a reduction of NO_x above 98%. The emission of NO_x from LPT trucks was reduced by 86.90%.

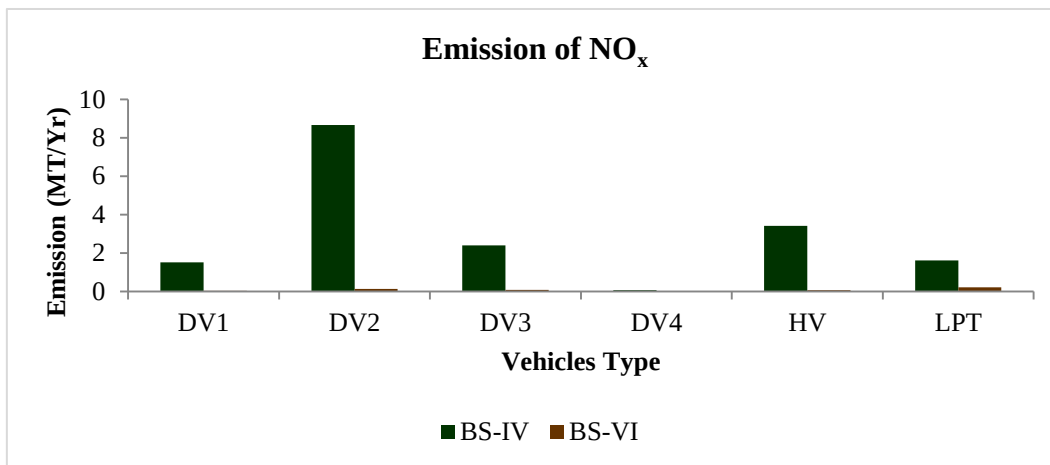


Figure- 8.36: Comparison of NO_x Emission under BS-IV and BS-VI for Different Types of Vehicles

For BS-VI standards over BS-IV, the largest reduction in PM emission was reported in DV2-type vehicles (99.30%), followed by DV1 (99.28%) and DV3 (99.22%). LPT shows a reduction of 69.33% whereas hired vehicles show a reduction of 98.33%.

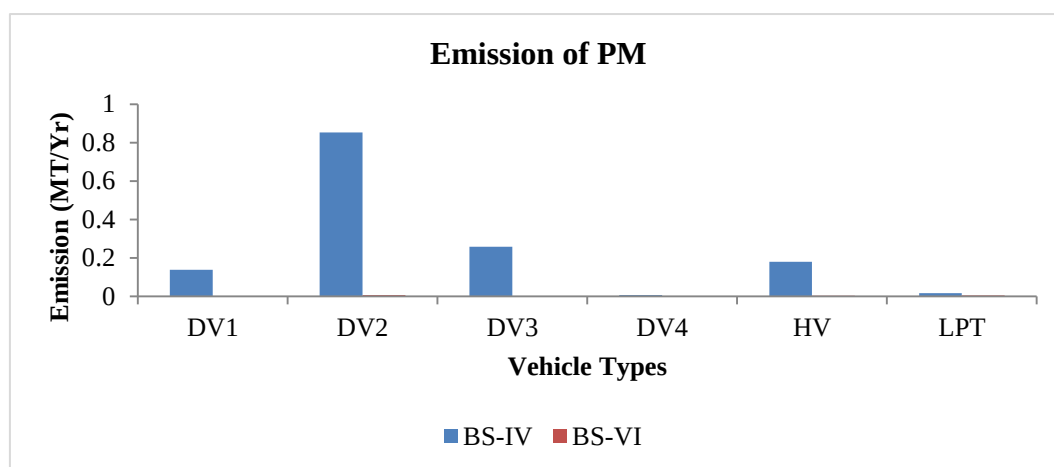


Figure- 8.37: Comparison of PM Emission under BS-IV and BS-VI for Different Types of Vehicles

In vehicles of the DV2-type, there is the greatest reduction in benzene and butadiene emissions. While hired vehicles have a decrease of 90%, departmental vehicles have reductions of 90% to 98% of benzene and butadiene. Benzene reduction for LPT trucks is 80%, and butadiene reduction is 42.33%.

8.7 COMPARATIVE ANALYSIS OF POTENTIAL ENVIRONMENTAL IMPACT (PEI) CONSIDERING BS-VI NORMS OVER BS-IV FOR PROPOSED ISWM SYSTEM

The overall PEI due to various pollutant emissions from different operation of proposed ISWM system by incorporating BS-VI standards over BS-IV shows a reduction of 0.66 %, i.e. from 6.05×10^{-3} to 6.01×10^{-3} .

The PEI comparison between BS-IV and BS-VI standards is shown in figure 8.38, for vehicle optimized ISWM systems transportation sector. It is seen from the figure that total 79.2% reduction can achieved in PEI contribution from transportation sector of proposed ISWM system, by introducing BS-VI standards in place of BS-IV. GWP is increased slightly (0.3%) due to the higher emission of CO₂. AP shows a reduction about 97%, HTPE and TTPG show reduction in PEI about 79.2% in BS-VI standards with respect to

PEI contribution from transportation sector mainly due to lower emission of SO₂ and NO_x.

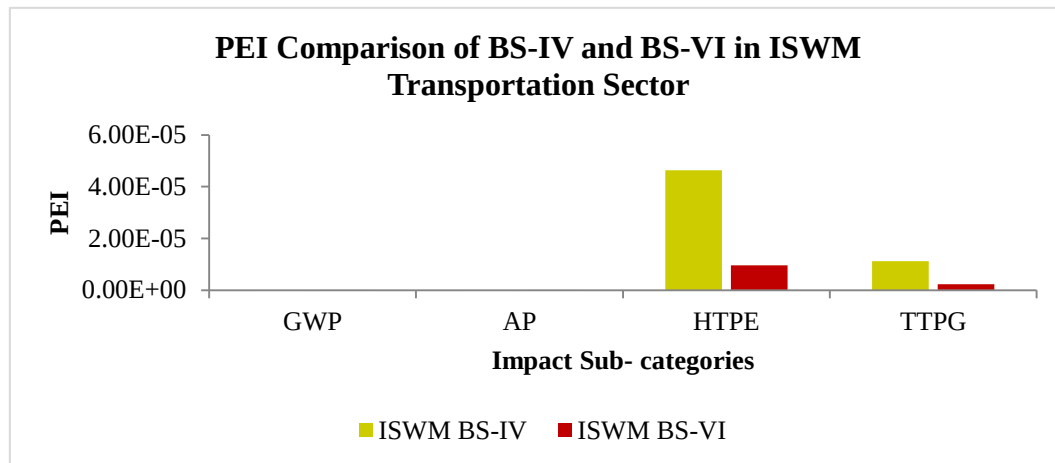


Figure- 8.38: PEI comparison between BS-IV and BS-VI Standards in vehicle optimized ISWM system transportation sector

9 MODEL ANALYSIS OF PROPOSED ISWM SYSTEM OF KOLKATA IN DIFFERENT OPERATING CONDITIONS

9.1 GENERAL DESCRIPTION

The previous chapter covered how the proposed ISWM system operated with three transfer stations and BS-IV type vehicles. Also, the ISWM system has been modeled in the previous chapter to operate with BS-VI type vehicles and compare the pollution potential of both vehicle types. This chapter compares the cost and PEI as well if two dumpsites are thought of for operation of the system compared to earlier studies. The comparative study starts with the pollution emission from various sectors such as transportation, landfill, leachate etc. Finally, the pollutants are used to compare the PEI of each system and discuss on the cost and pollution optimization techniques.

9.2 CASE STUDY: RUNNING WITH TWO OPERATIONAL DUMPSITE IN PROPOSED ISWM SYSTEM

Under free running condition of landfill sites, around 44% of the total garbage is being transfer to east transfer station, and 37% to the south transfer station. Only 19% of the garbage is being transported to north transfer station. This uneven dispersion of waste among the dumpsites may cause overloading on one of the transfer stations and leave other stations with un-operated plants. Thus, with all transfer sites operation, the garbage is transferred to North, East and South transfer stations in the ratio of 3:4:3 in vehicle optimized condition. This study is done to test the running efficacy of the proposed model under stress only two dumpsites are operational or an alternative idea of the operational requirement for an ISWM system with only two transfer stations and third one used for future sustainable project or under repair or temporarily closed due to some unavoidable circumstances. The model is turned to constrain free condition and allowed to run such that the garbage and silt of any one of the transfer stations is zero. Similar to the results of free run with three operational dumpsites, the quantity of silt and garbage transferred to each dumpsite are not isometric. North dumpsite is often unused under constrain free condition due to triangular shape of Kolkata and it is more costly to transfer waste to north from central or east Kolkata. East dumpsite being closely situated to heart of the

city is often preferred over other dumpsites. Thus, the garbage ratio and silt ratio between the dumpsites are maxed to 3:2 for proper use of the transfer stations and prevent overload or underutilization.

9.2.1 Cost Analysis

The cost analysis for each of the two-dumpsite configuration is shown in the table below. ES (East-South running), NS (North-South running) and NE (North-East running) are the three combinations of two dumpsites shown below with a comparative cost for each operation of the whole system. Transportation cost is the main differentiating factor between these conditions apart from the landfilling costs. Transportation cost included the cost of departmental vehicles transferring garbage, hired vehicle transferring garbage and silt as well as LPT trucks transferring silt and process rejects from transfer stations to dumpsites. Apart from that, landfilling cost of each dumpsite associated with the transfer stations varies as well due to acquisition and maintenance of the engineered landfill.

Table- 9.1: Types of cost in two dumpsite condition for proposed ISWM system

Types of Cost (Rs.)	ES (East-South Running)	NS (North-South Running)	NE(North-East Running)
Transportation Cost	24,78,285	25,21,016	25,60,156
Incentive Cost	61,241	61,241	61,241
Landfill Cost	3,39,299	3,42,540	3,46,614
Sorting Cost	4,60,604	4,60,604	4,60,604
Incineration Cost	5,24,596	5,24,596	5,24,596
Composting Cost	8,33,226	8,33,226	8,33,226
Recycled Revenue	74,012	74,012	74,012
Compost Revenue	20,50,194	20,50,194	20,50,194
Incineration Revenue	5,28,195	5,28,195	5,28,195
Net Cost	20,44,849	20,90,822	21,34,035

The overall costs for vehicle optimized SWM system with two operational dumpsites are only fractionally different from that of the three dumpsite of ISWM system. There is an increase in 1.87%, 4.16% and 6.32% for ES, NS and NE configurations respectively. There is only a marginal increase in cost in ES configuration cause the models heavily favors the east and south dumpsite due to their location and have relatively low effect due

to absence of north dumpsite. The landfilling cost has also varied by 2% to 1% of the normal vehicle optimized condition of the proposed ISWM system. Apart from that, the other costs and revenue remains the same as the cost of operation among all the transfer stations are identical and the amount of garbage produced and processed remains unchanged.

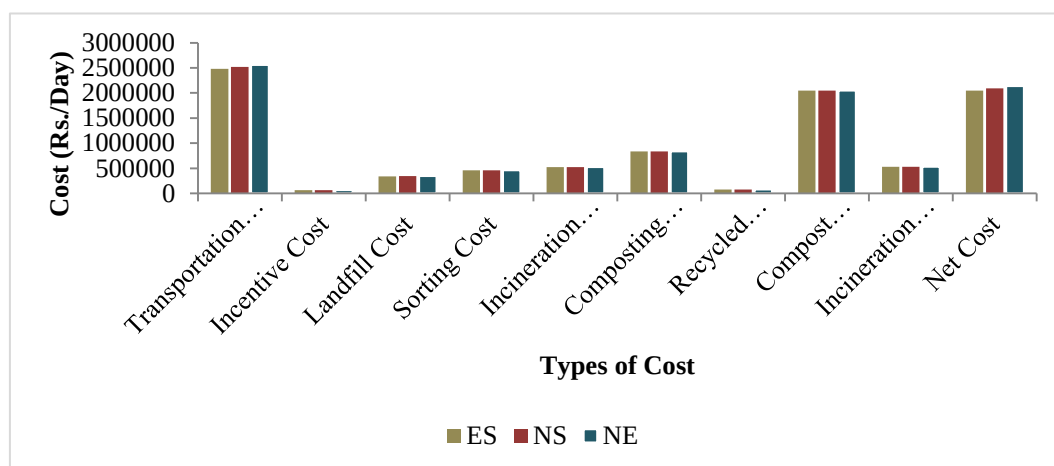


Figure- 9.1: Types of cost in proposed ISWM system in two dumpsite configurations

9.2.2 Pollution Generation

Optimizing the routes of departmental vehicles and hired vehicles from boroughs to transfer stations as well as change in the trips of LPT trucks has changed the pollutant emissions from transportation sector of the SWM system. As the operations and their efficiencies remain unchanged across the transfer stations, thus the total emissions produced during composting, incineration and liquid pollutants generated from leachate are same as that of vehicle optimized run of the proposed ISWM model. Below are the comparative charts of emissions for each pollutant from the transportation sector.

Figure 9.2 compares the CO emissions from the transportation sector of proposed ISWM system in two different dumpsite configurations. In comparison to the vehicle optimized ISWM system, each of the two dumpsite configurations results in a net increase in CO emission of 10% to 31%. With all dumpsites operating, the NE configuration emits the highest CO of any of the other configurations, roughly 18.42% more than the ES configuration and 31.22% more than the regular setup.

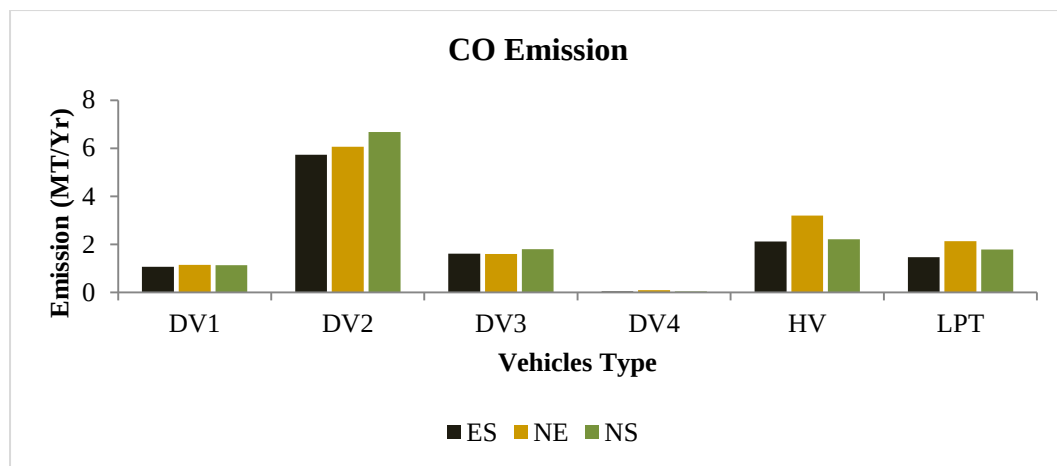


Figure- 9.2: Comparative emission of CO from transportation sector of proposed ISWM system in two dumpsite configuration

In the ES, NE, and NS configurations, the SO₂ emission increased by 14.05%, 28.54%, and 30.31%, respectively. The greatest significant increases in SO₂ emission in NS configurations are caused by DV2 and DV3 vehicles, with 37.41% and 35.71%, respectively. The ES and NE designs exhibit a similar pattern with increases in SO₂ emissions from DV2 of 17.6% and 24.7%, respectively.

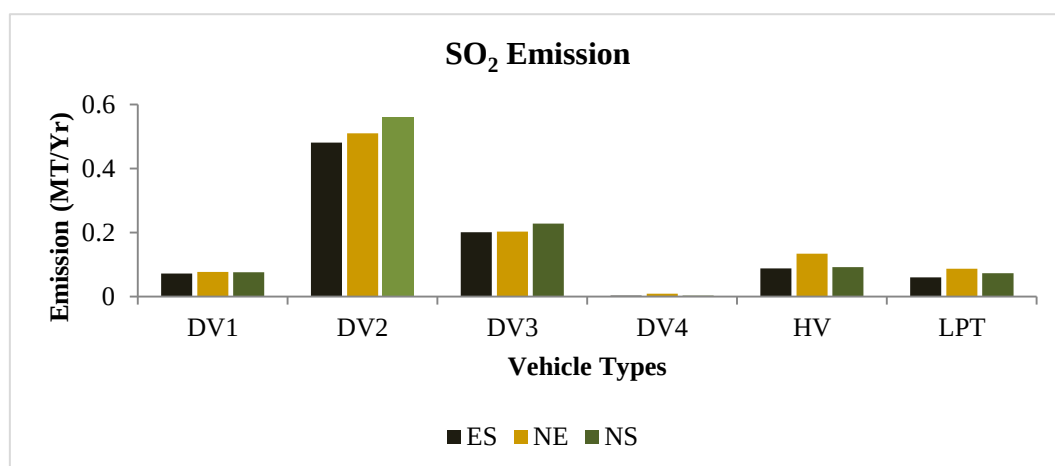


Figure- 9.3: Comparative emission of SO₂ from transportation sector of proposed ISWM system in two dumpsite configurations

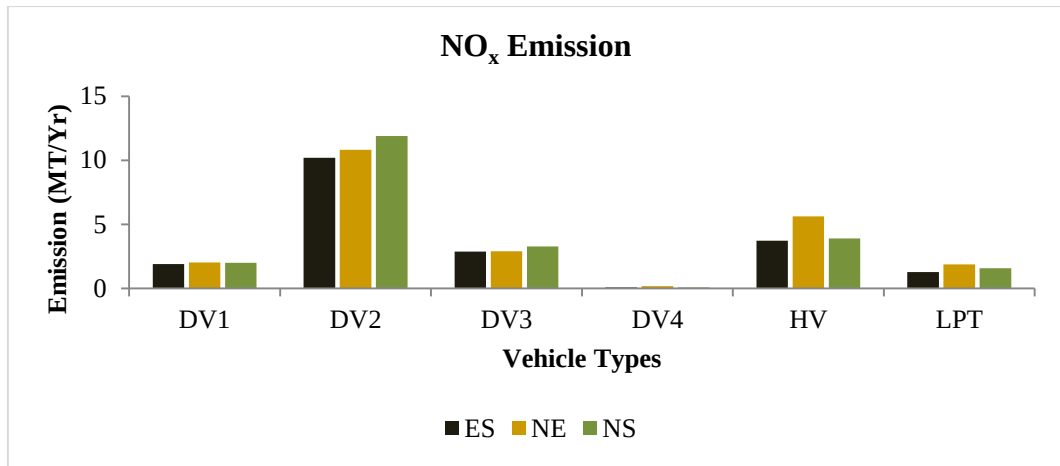


Figure- 9.4: Comparative emission of NO_x from transportation sector of proposed ISWM system in two dumpsite configurations

In comparison to three operational dumpsite conditions, the NO_x emission has increased by 13.67%, 32.70%, and 28.77% for the ES, NE, and NS configurations, respectively. While LPT truck emissions have fallen by 20.8%, DV2 and DV3 have had significant increases in NO_x emission in ES configuration of 17.85% and 19.83%, respectively. Along with DV2 and DV3, the emission from HV and LPT trucks in the NE configuration has increased significantly by 64.78% and 15.02%, respectively. With NS setup, the trend has persisted, with a rise in DV2 and DV3 emission of 37.5% and 35.9%, respectively.

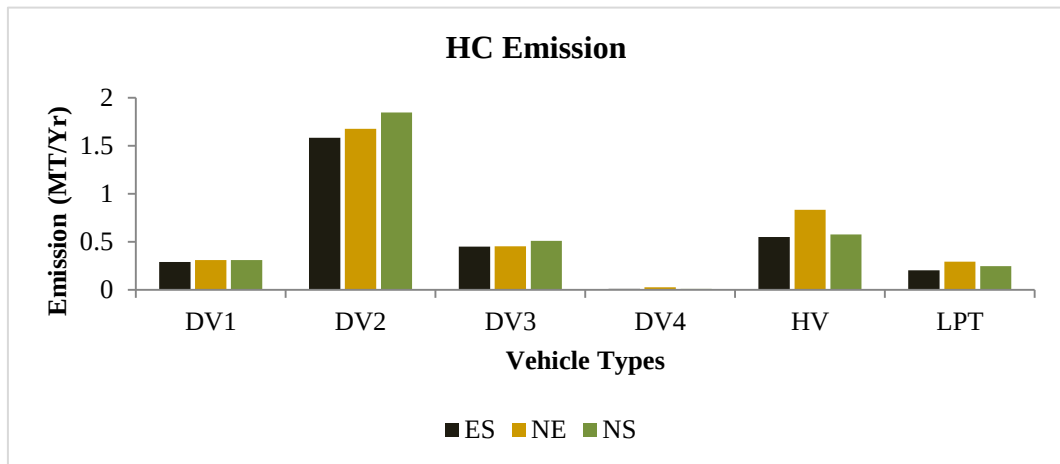


Figure- 9.5: Comparative emission of HC from transportation sector of proposed ISWM system in two dumpsite configurations

In comparison to three dumpsite configurations, the model forecasts an overall increase in HC emission in the configurations of ES, NE, and NS of 13.63%, 32.31%, and 28.85%. In all three combinations, DV2 exhibits the largest increase in HC emission, with increases of 17.81%, 24.81%, and 37.48%. In addition, emissions of LPT trucks in NE configuration have increased significantly by roughly 14.9% and decrease of 20.78% in ES setup.

The model forecasts an increase in PM emission of 17.46 %, 30.57%, and 33.54% in the ES, NE, and NS configurations compared to the three dumpsite configurations. In all three combinations of two dumpsites, DV2 had the highest increase in emission (17.82%, 24.85%, and 37.51%). Aside from that, LPT trucks have a 18.75% rise in emissions in NE configuration and decrease by the same percentage in ES configuration. Figure 9.6 shows the detail comparison of PM emission below.

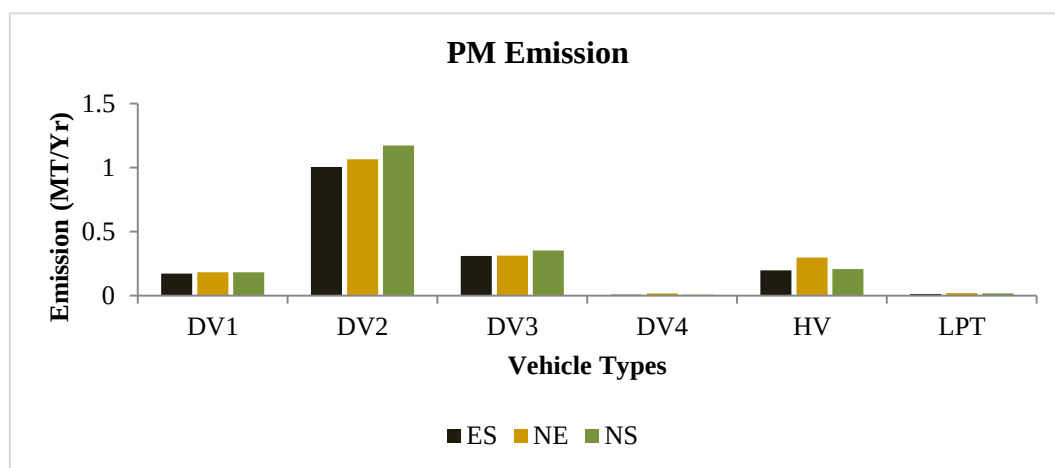


Figure- 9.6: Comparative emission of PM from transportation sector of proposed ISWM system in two dumpsite configurations

When compared to the three functioning dumpsite situations, the CO₂ emission rises by 14.24%, 28.42%, and 30.55% for the ES, NE, and NS configurations, respectively. While LPT truck emissions have increased by 20.52%, the ES configurations of DV2 and DV3 have shown considerable increases in CO₂ emissions of 17.84% and 19.79%, respectively. In NE design, HV and LPT truck emissions rise by 64.80% and 75.07%, respectively, along with DV2 and DV3. DV2 and DV3 emission have increased by 37.51% and 35.9%, respectively, in the NS setup.

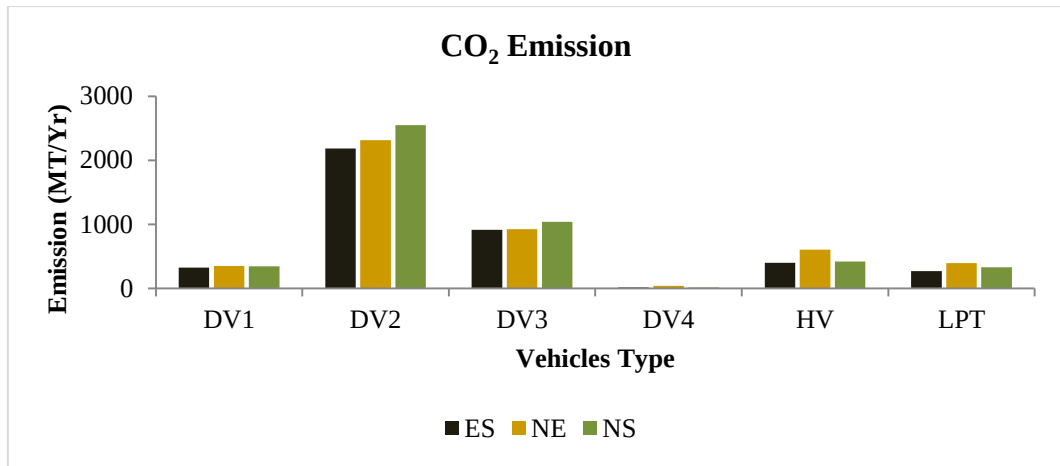


Figure- 9.7: Comparative emission of CO₂ from transportation sector of proposed ISWM system in two dumpsite configurations

Benzene emissions increased by 5.15%, 31.91%, and 29.71% in the ES, NE, and NS configurations, respectively. The DV2 and DV3 vehicles respectively account for 36.73% and 35.92% of the increase in Benzene emissions in NS setups. The ES and NE setups exhibit a similar pattern, with increases in benzene emissions.

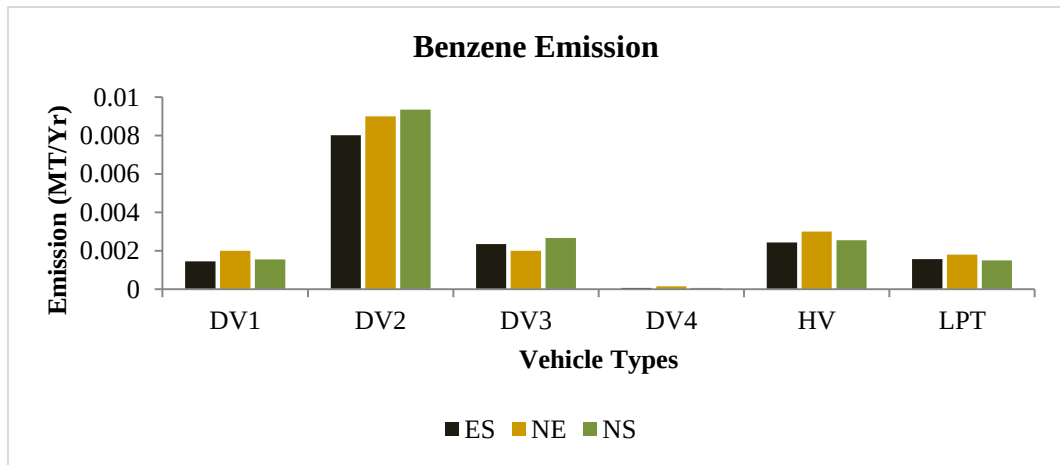


Figure- 9.8: Comparative emission of Benzene from transportation sector of proposed ISWM system in two dumpsite configurations

The model estimates that the ES, NE, and NS configurations will emit more butadiene than the three dumpsite options by 15.58%, 31.46%, and 31.32%, respectively. In all three pairings of two dumpsites, DV2 showed the most increase in emission (18.10%, 24.88%, and 38.12%). Aside from that, LPT trucks have a 15.35% increase in emissions in the NE configuration and a 20.00% drop in the ES configuration.

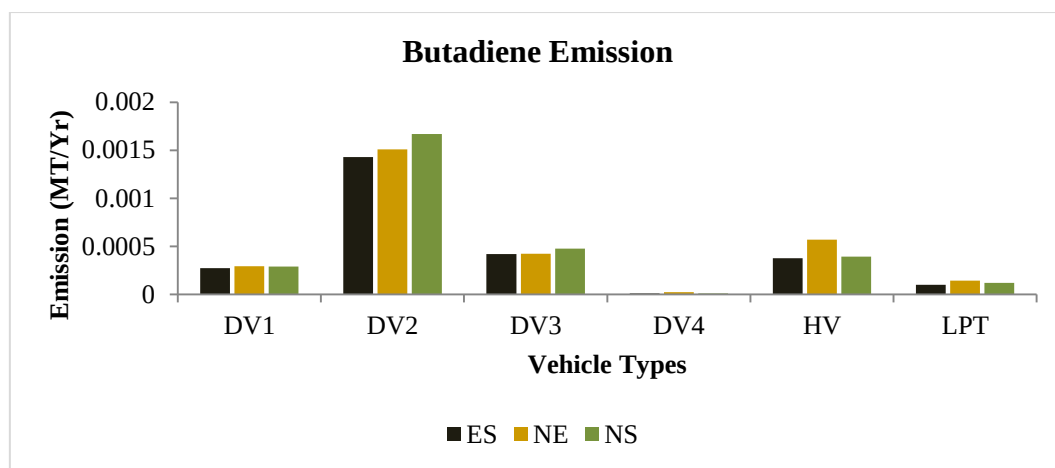


Figure- 9.9: Comparative emission of Butadiene from transportation sector of proposed ISWM system in two dumpsite configurations

9.3 PEI DUE TO POLLUTANTS

As departmental and hired vehicles travel more distance from boroughs to deposit waste and silt in transfer stations, the pollutant generation in the case of two dumpsite configurations is greater than that of three dumpsite designs. In addition, for the ES, NE, and NS configurations, the PEI increased very slightly from 0.17% to 0.33% as the effect of transport sector in total PEI is very less. The table 9.2 shows the PEI value of all the categories and sub-categories contributed by the pollutant emission from each combination of two dumpsites.

Table- 9.2: Comparison of PEI of each category and sub-category for all two dumpsite configurations

PEI Category	Global	Regional		Local					Total
PEI Sub-category	GWP	AP	POCP	HTPE	HTPI	TTPG	TTPL	ATP	
ES	4.26×10^{-07}	3.755×10^{-06}	6.09×10^{-05}	0.00482	2.45×10^{-06}	0.001167	8.9×10^{-07}	6.78×10^{-06}	6.06×10^{-03}
NS	4.26×10^{-07}	3.761×10^{-06}	6.09×10^{-05}	0.00483	2.45×10^{-06}	0.001169	8.9×10^{-07}	6.78×10^{-06}	6.07×10^{-03}
NE	4.26×10^{-07}	3.76×10^{-06}	6.09×10^{-05}	0.00483	2.45×10^{-09}	0.001169	8.9×10^{-10}	6.78×10^{-09}	6.06×10^{-03}

9.4 SENSITIVITY ANALYSIS OF PROPOSED ISWM SYSTEM

9.4.1 Effects on Variation of Waste Generation

Table 9.3 displays the variation in cost of the proposed ISWM system caused by an increase or decrease in waste generation of 1%. A 1% increase in waste generation causes a considerable change in the emissions of pollutants from various operations of SWM system, which subsequently shows changes in various impact sub-categories. The total PEI changes as $\pm 0.99\%$ for variation in waste generation by $\pm 1\%$. The impact for $\pm 1\%$ waste generation on other cost components like sorting cost to revenue from compost is same ($\sim \pm 0.99\%$) as all the components are proportional to waste generation. Emission of all the liquid pollutants varies in the range of $\pm 0.70\%$. Figure 9.10 shows the effect on cost for variation of $\pm 1\%$ waste generation.

Table- 9.3: Effects on cost components in percentage for variation of waste generation

Cost Parameter	Variation of cost for increase of 1% waste generation (%)	Variation of cost for decrease of 1% waste generation (%)
Total Cost	~ 0.48 (+ve)	~ 0.48 (-ve)
Transportation Cost	~ 0.64 (+ve)	~ 0.64 (-ve)
Incentive Cost	~ 0.05 (+ve)	~ 0.05 (-ve)
Landfill Cost	~ 0.99 (+ve)	~ 0.99 (-ve)
Sorting Cost	~ 0.99 (+ve)	~ 0.99 (-ve)
Incineration Cost	~ 0.99 (+ve)	~ 0.99 (-ve)
Composting Cost	~ 0.99 (+ve)	~ 0.99 (-ve)
Revenue from Recyclable	~ 0.99 (+ve)	~ 0.99 (-ve)
Revenue from Compost	~ 0.99 (+ve)	~ 0.99 (-ve)
Revenue from Incineration	~ 0.99 (+ve)	~ 0.99 (-ve)

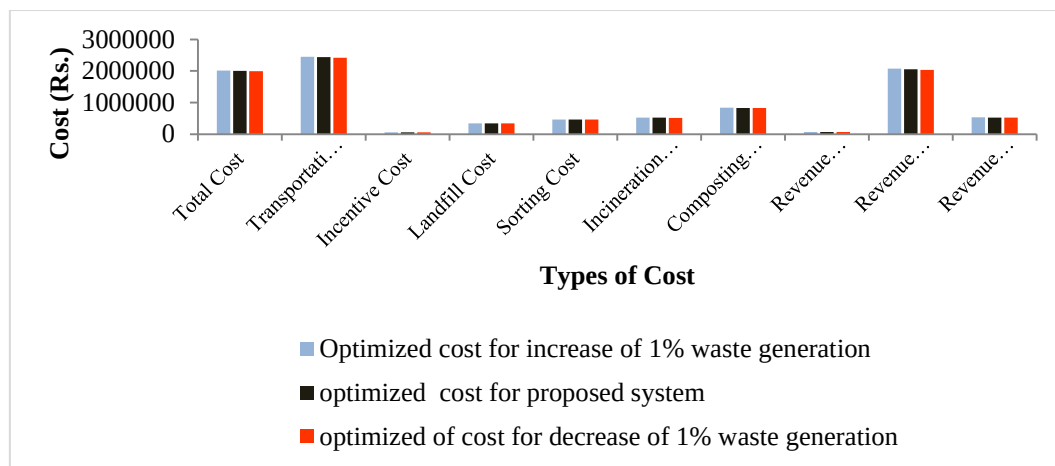


Figure- 9.10: Effects on cost for variation of waste generation

9.4.2 Effects on Variation of Fuel Cost

When fuel cost varies, it will affect the transportation cost of departmental vehicles. For hired vehicles, the transportation costs remain unchanged due to the variation in fuel cost as it is based on the payment of rate contracts including fuel. Transportation costs for departmental vehicles increase by $\sim 0.83\%$ for every 5% increase in fuel costs, and vice versa (Figure 9.21). Despite the fact that incentive costs remain constant; the overall SWM cost varies by only $\sim 0.86\%$ as a result of the impact of departmental transportation costs. The cost of transportation to transfer sorted waste from the sorting station to ELF by heavy-duty LPT trucks increases to $\sim 1\%$ for every increase in fuel cost by 5% and vice versa. There are no discernible impacts observed in PEI for variation of fuel cost by $\pm 5\%$.

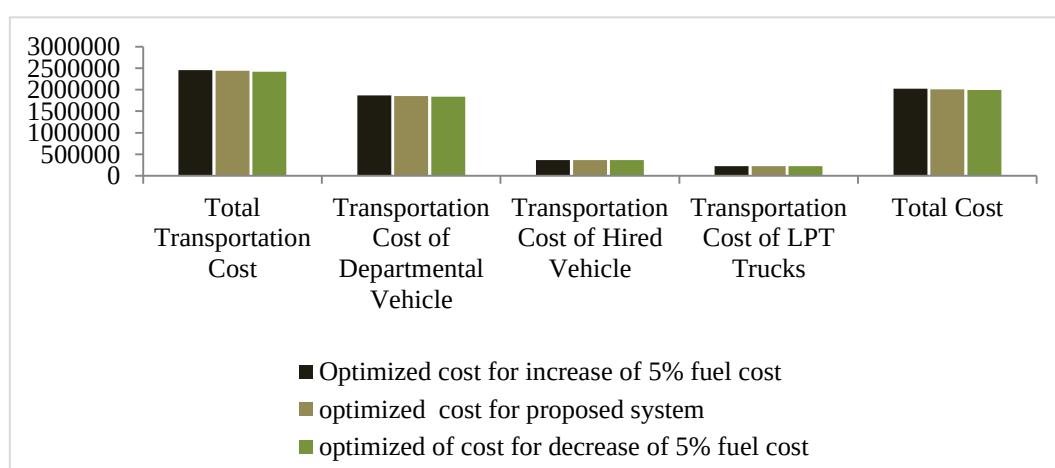


Figure- 9.11: Effects on cost for variation of fuel cost

9.4.3 Effects on Variation of Incentive Cost

Incentives are provided to the drivers and assistants of departmental vehicle in order to motivate them to routinely and efficiently remove solid waste from the primary collection stations. Total SWM cost is seen to vary by $\pm 0.15\%$ when incentive rates vary by $\pm 5\%$. Although incentives are crucial to SWM system, their impact on overall costs is minimal. Therefore, by raising the incentive rates to meet the demands of the drivers and assistants of the departmental vehicles, authorities can achieve effective SWM system. PEI remains unchanged for variation of incentive cost by $\pm 5\%$.

9.4.4 Effects of Individual Variation of Emission Rate of CO₂ and NO_x

For $\pm 10\%$ variation in CO₂, the total PEI varies as $\pm 1.8\%$. For every 10% change in the NO_x emission rate, the total PEI varies as $\pm 6\%$.

9.4.5 Effects of Individual Variation of Emission Rate of Chloride (Cl), Ammoniacal Nitrogen (NH₃-N) and Mercury (Hg)

Negligible variation is found in total PEI for every 10% variation in the emission rate of chloride, NH₃-N and Hg.

10 CONCLUSIONS

10.1 CONCLUSIONS

In many communities across the world, including India, managing municipal solid waste (MSW) is a major concern. The majority of Indian cities lack adequate waste management strategies due to unplanned urbanization and increased population demand. The significance and awareness of waste management has grown for megacities, though, as a result of poor waste collection systems, inadequate material recovery and processing facilities, mostly open and uncontrolled dumping of MSW pollutes the air, water and soil significantly. This environmental pollution of MSW is primarily caused by the emission of pollutants from vehicles and landfills. Increasingly, to manage MSW more effectively, more communities have adopted the idea of integrated solid waste management system. In order to meet the need for a sustainable environment, the SWM regulation 2016 mandates the implementation of an integrated SWM system to reduce cost and pollution impacts in a sustainable manner.

In this present study, the focus is made on the waste management system of Kolkata, one of the major metropolitan cities in India, to develop a sustainable municipal waste management strategy for the developing countries. At present, Kolkata municipal corporation (KMC), does not have any transfer station, central sorting system, proper material recovery facility, incineration plant and engineered landfill site. It has a small capacity composting plant which usually does not run on a regular basis. In addition to landfill gases, pollutants like CO, SO₂, NO_x, CO₂, PM, hydrocarbons, benzene, and butadiene are emitted to the environment by MSWM vehicular operations. These pollutants have the potential to impact on human health and cause environmental degradation. So, it is necessary to design and operate an efficient solid waste management system considering the waste characteristics, cost, and combined quantitative environmental impacts in all categories due to the pollutants generation from every component of the MSWM system.

It is challenging to evaluate the environmental impact quantitatively of municipal solid waste management systems. One of the most effective methods for assessing the

quantitative environmental impact of municipal SWM system is Life Cycle Impact Assessment (LCIA). A quantitative impact assessment is subsequently carried out, taking into account climate change, ozone depletion, acidification, photochemical ozone production, human, terrestrial and aquatic toxicity categories. LCIA assists in enabling the identification of potential for pollution prevention and resource consumption reductions based on the characteristics of solid wastes and the availability of treatment and disposal options.

The LCIA method has not yet been applied for pollutants generation and to evaluate the Potential Environmental Impact (PEI) of municipal solid waste management system of Kolkata. A generic MSWM linear programming (LP) model has been successfully developed considering pollutants generation and its potential environmental impact, apart from cost and all operational constraints.

The model has been validated using the 2022 KMC data set considering 85% of garbage carried by departmental vehicles and 15% of garbage and total silt/ rubbish transported by hired vehicles. The outcome of the model reveals that the total MSWM cost, excluding the cost of primary collection, provided by the optimization model is Rs. 55, 00,706 per day, and the same for actual situation is Rs. 57, 94,350 per day. The model result show potential drop of cost is around 5%, which indicate a well performance of the model. The total PEI value of the model for the existing MSWM system of Kolkata is 8.37×10^{-3} . So, this model has been used for further studies in different condition.

The model is then applied to the existing SWM system in free mode without vehicle optimization and also with vehicles optimization. The model results show that the departmental vehicle takes garbage around 90% and the rest of the garbage and total silt/ rubbish are taken by hired vehicles. The total cost of model implementation is further reduced to Rs. 54,43,222 per day, and with vehicle optimization, the cost is Rs. 28,54,108 per day. Vehicle optimization resulted in a 47.5% reduction in total costs. The transportation cost can be reduced by 52.6%. However, incentive costs increase in the optimization condition as the total number of trips per departmental vehicle increases. Vehicle optimization may significantly decrease costs, but emissions and PEI remain almost same as earlier in both situations.

The total generation of gaseous pollutants, including GHGs, for the existing MSW management system, is estimated to be ~269641 MT annually. The transport sector contributes around 4733 MT (~1.76%) of pollutants each year.

In transport sector, the total contribution of CO₂ emission is the highest (99.1%). NO_x generation is the second largest (0.475%) which is higher than CO (0.26%) and HC (0.073%). SO₂ emission (0.022%) is much less compared to NO_x due to the stringent permissible sulphur percentage in diesel fuel. The DV2 vehicle transports the highest proportion of waste from borough centers to disposal sites (~50% of total waste generated). So, of all the KMC vehicles, the DV2 has the highest fuel cost. In addition, DV2 is responsible for the largest pollutant emissions.

In the existing SWM system, the Dhapa landfill site in Kolkata generates around 264908 MT gaseous pollutants annually, of which 73% are provided by CO₂ and the remaining 27% by CH₄. The contributions of NH₃-N and Cl to the total generation of liquid pollutants from landfill leachate are 29.3% (~7 MT/yr) and 70.5% (17 MT/yr), respectively. Among all pollutants in the system, CH₄ has the highest impact on PEI. It contributes to ~35.2% of total PEI over all categories, followed by Ammoniacal Nitrogen (NH₃-N) (~26.3%), chloride (~24.5%), CO₂ (~5.9%) and NO_x (~1.4%). Among all impact sub-categories, HTPE has the highest PEI value (~29%), followed by ATP (~27%), HTPI (~23%), TTPL (~8%), TTPG (~7%) and POCP (~5.6%) w.r.t. the total PEI. Leachate is responsible for increasing the impact value of HTPI, TTPL, and ATP and gaseous pollutants contributes most to the HTPE, TTPG and POCP.

The PEI value of GWP and AP is less significant in a local perspective because the relative weightage value is lower compared to other impact sub-categories, but it is quite significant in a global and regional context. The impact of sub-category ODP did not provide any PEI value because no pollutant is produced in this system to deplete the ozone layer.

The contribution of transport sector and landfill in total PEI is ~12% and ~88% respectively. Liquid pollutants from landfill contribute the most ~52% of total PEI contributed by landfill and the rest ~36% coming from gaseous pollutants of landfill.

The proposed integrated MSW management system takes into account three engineered landfill (ELF) sites that are connected to three separate transfer station equipped with

sorting, incineration and composting facilities. The validated model is then used to simulate the proposed integrated MSW management system, with and without departmental vehicle optimization. According to the model output, the operational costs of the system without vehicle optimization is Rs. 44,69,858 per day, while the overall cost of integrated MSW management with vehicle optimization is Rs. 20,07,230 per day.

When compared to the cost of the existing MSW management system without vehicle optimization conditions, the overall cost in proposed ISWM system without vehicle optimization was reduced by 17.88%, and the cost of transportation showed a reduction of 1.28%. Landfill costs are also decreased by ~18%, though ELF includes leachate collection facility and liner system which increases the cost per MT of waste. However, without vehicle optimized ISWM condition resulted in a 12% rise in incentive costs.

The processes of waste sorting, composting, and incineration incur additional operating costs which is ~41% w.r.t net SWM cost for without vehicle optimization condition. By selling the recyclables, compost and electricity produced, considerable revenue is generated which compensate about 37% of the total expenses in case of without vehicle optimization and 57% for vehicle optimization of proposed ISWM systems.

~77% revenue is comes from the composting facility, whereas the electricity generate from the incinerator contribute ~20% to the total revenue. The contribution from selling recyclables is very less (~3%) as the quantity of recyclables is less in the MSW of the developing nations.

In the vehicle optimization condition in ISWM system, the overall cost is decreased ~55%, with ~50.8% decrease in transportation costs. Departmental vehicles generate ~90% of pollution w.r.t. the pollution contribution of transport sector and carried ~81% of waste. It is found that ~44% of total waste enters to the east transfer station, ~19% enters to the north transfer station, and ~37% enters to the south transfer station for processing without vehicle optimization unrestricted transfer station/ ELF feed condition.

To prevent the above disparity in distribution and reduce overload, waste is moved in a 3:4:3 ratios to the North, East, and South transfer stations in vehicle optimized condition of proposed ISWM system. In this condition 40% waste enter to the east transfer station, 30% enter to the north transfer station and the rest 30% enter to the south transfer station. By maintaining the same proportion, silt and rubbish is transferred directly to the

respective landfill through heavy duty LPT trucks. In vehicle optimization condition of proposed ISWM system, the overall SWM cost is reduced ~63% w.r.t. the un-optimized existing system and ~30% for the vehicle-optimized existing system. As only silt and process rejects are disposed of in the ELF which is far from the city, transportation costs increased by 2.54% in ISWM systems.

The proposed ISWM systems generate $\sim 4.5 \times 10^5$ MT of pollution from gaseous pollutants per year in total. A yearly total $\sim 2.25 \times 10^5$ MT (~50%) of pollutants are released by the incinerator, and $\sim 2.22 \times 10^5$ (~49.2%) by the composting facility. Transportation sector emit only 3637 MT (~0.8%) per year with respect to the total gaseous pollutants emission. With compared to the existing MSWM systems, the overall gaseous pollution emission is increased by ~67% in proposed ISWM system mainly due to emission from incineration and composting facilities.

In proposed ISWM system, only 33% of inert, process rejects and silt goes to ELF which having complete liner and top cover system. It is very significant that in ISWM systems the generation rate of leachate quality and quantity ($43\text{L}/\text{m}^2/\text{yr}$) is very less compared to the existing MSWM system ($1000\text{L}/\text{m}^2/\text{yr}$). As a result ~99.7% decreased in leachate quantity is achieved in case of proposed ISWM system w.r.t. existing MSWM system.

The total PEI for the proposed ISWM systems comes to 6.05×10^{-3} . PEI reduction achieved in proposed ISWM systems is 27.7% w.r.t existing MSWM systems. This has been achieved due to the resultant of gaseous pollutants increase and huge decrease of liquid pollutants in ISWM systems.

The most of the PEI contribution comes from local category (~98.9%). Among all other gaseous pollutants, NO_x contribute the most PEI (~58.37%). PEI contributions of CO_2 , SO_2 and CH_4 are 18.25%, 16.85% and 6.28% respectively w.r.t. total PEI. Among all other liquid pollutants chloride has the highest PEI contribution, which is only 0.13%.

The ISWM system shows a 68.3% reduction in GWP relative to the existing system, primarily from CO_2 and CH_4 . In the ISWM systems, CO_2 generation is increased by ~121%, mainly due to incineration. Whereas, the generation of CH_4 is decreased by ~87% due to no gas production from ELF in proposed ISWM systems and GWP of CH_4 is 28 times higher than CO_2 .

The PEI result of the proposed ISWM system shows that the incinerator contributes highest to PEI ~69.1% in vehicle-optimized conditions under transfer station/ELF feed-restricted situations, followed by composting ~29.7% and transportation sector ~1%. The contribution of ELF is very less ~0.2%. In impact sub- category HTPE and TTPG, main contributor of PEI is incineration (~70%), followed by composting (~29%).

The PEI comparison between BS-IV and BS-VI standards in the transport sector of vehicle-optimized ISWM system reveals that a total 79.2% reduction can achieved in the PEI contribution of the transportation sector. AP shows a reduction of about 97%, and HTPE and TTPG show a reduction in PEI of about 79.2% in BS-VI standards concerning PEI contribution from the transportation sector mainly due to lower emissions of SO₂ and NO_x. Implementing BS-VI standards over BS-IV, the vehicle-optimized proposed ISWM system, can reduce overall PEI from different operations by 0.66% only because the effects of transport sector emission in total PEI are less.

The model is implemented in the proposed ISWM system, taking into account two operating ELF simultaneously instead of three. In these cases, there are very little differences found in the overall costs when compared to the vehicle optimized ISWM system. In two ELF configurations over three ELF, the combination of ES, NE, and NS results in an increase in the overall SWM cost of 1.87%, 4.18%, and 6.32%, respectively. Additionally, there has been variation in the landfilling cost of the proposed ISWM system from 1% to 2%.

Two ELF configurations generate slightly more pollutants than three ELF configurations because departmental and hired vehicles have to cover more distance from boroughs to transfer station and respective ELF. The two ELF configurations result in a net increase in transport sector pollutant emission only. The maximum increase in emission from transport section is found for NS configuration (~30.3%), and the minimum increase is found in ES configuration (~14.1%). For NE configuration, the increase for the same is 28.3%.The generated pollutants result in increased the total PEI by 0.33%, 0.17%, and 0.17% for the NS, NE and ES configuration, respectively.

Sensitivity analysis has been carried out under various conditions. When total waste generation vary by $\pm 1\%$, the total SWM cost vary by $\pm 0.48\%$ and the total PEI varies by $\pm 0.99\%$. When fuel cost varies by $\pm 5\%$, the total SWM cost varies by $\pm 0.86\%$.

For $\pm 10\%$ variation in CO_2 , the total PEI varies as $\pm 1.8\%$. For every 10% change in the NO_x emission rate, the total PEI varies as $\pm 6\%$. The variation in emission of liquid pollutants has insignificant effects.

The model analysis shows that incorporation of multiple transfer stations and ELF in different direction of the city reduces both SWM cost and PEI.

To evaluate various waste management options and identify the optimal cost and eco-friendliness of the system for managing, processing, and ultimate disposal of municipal solid waste, the developed generic LP model, combined with the application of LCIA methodology of LCA, has been successfully used as a decision support tool. The model shows that an ISWM system is a better option for cost optimization along with PEI reduction. It is important to note that, though the datasets used in this study are specific to Kolkata, the generic model-based solutions can be successfully applied to any city in a developing country such as India.

10.2 FUTURE SCOPE OF WORK

The future scope of works is summarized below:

- A multi-objective optimization model that considers several objectives, such as the cost of solid waste management, emissions of pollutants, energy consumption in treatment facilities, etc. may be used in future studies.
- Social and environmental cost benefit analysis of MSW management can be done in future studies.
- The financial feasibility studies such as Net Present Value (NPV) and Internal Rate of Return (IRR) may be included in the future scope of work.
- The present model considers waste transportation from borough centres and the primary collection as a fixed cost. Ward-level primary collection optimization and borough-level optimization may be linked in the study in a future model.
- The waste composition variability on the model's prediction may be incorporated in the future scope of the study.
- In the future, MSW management may be combined with industrial, hazardous and biomedical waste management.

- The Waste Reduction Algorithm (WAR) approach can be used to quantify the potential environmental impact of all pollutants generated by the MSW management system and to compare the proposed system with the existing system.
- The optimal cost solution with minimum environmental impact considering other alternative treatments such as mechanical biological treatment (MBT), anaerobic digestion (CBG), hydrothermal carbonization, hydrothermal liquefaction, gasification, pyrolysis, plasma gasification may be introduced in the future scope of work.
- The sensitivity analysis for economic/policy changes may be added to the future scope the work.

BIBLIOGRAPHY

- Abdelli, I. S., Addou, F. Y., Dahmane, S., Abdelmalek, F., Addou, A., 2020. "Assessment of methane emission and evaluation of energy potential from the municipal solid waste landfills". *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 1–20. doi:10.1080/15567036.2020.1813221.
- Abdullah, M., Rahamat-Ullah, Z., Hosny, M., Alsmady, S., 2024. "Minimizing the environmental impacts of waste valorization systems using multi-criteria life cycle optimization". *Journal of Cleaner Production*, volume 449, 2024. <https://doi.org/10.1016/j.jclepro.2024.141619>.
- Abubakar, I.R., Maniruzzaman, K.M., Dano, U.L., AlShihri, F.S., AlShammari, M.S., Ahmed, S.M.S., Al-Gehlani, W.A.G., Alrawaf, T.I., 2022. "Environmental sustainability impacts of solid waste management practices in the global south". *International Journal of Environmental research and public health*. P- 3-26. 2022, 19, 12717. <https://doi.org/10.3390/ijerph191912717>.
- Abunama, T., Moodley, T., Abualqumboz, M., Kumari, S., & Bux, F., 2021. "Variability of leachate quality and polluting potentials in light of leachate pollution index (LPI) – A global perspective". *Chemosphere*, 282, 131119. doi:10.1016/j.chemosphere.2021.131119
- ADB (Asian Development Bank), 2005. *Kolkata Environmental Improvement Project*, Vol 1. Kolkata Municipal Corporation, India.
- Adeyemi, O., Oginni, O., Osabor, C. C., Adeyemi, O., Oloyede, O. B., Oladiji, A. T., Adebayo, E. A., 2009. "Effect of water contaminated with phthalate, benzene and cyclohexane on *Clarias gariepinus*' cellular system". *Food and Chemical Toxicology*, 47(8), 1941–1944. doi:10.1016/j.fct.2009.05.016
- Adhikari, B., Dahal, K.R., Khanal, S.N., 2014. "A review of factors affecting the composition of municipal solid waste landfill leachate". *International Journal of Engineering Science and Innovative Technology (IJESIT)* Volume 3, Issue 5, September 2014. P: 273-281.
- Ahsan, A., Alamgir, M., El-Sergany, M. M., Shams, S., Rowshon, M. K., NikDaud, N. N., 2014. "Assessment of municipal solid waste management system in a developing country". Hindawi Publishing Corporation, *Chinese Journal of Engineering*, Volume 2014, Article ID 561935, pages- 1-11 <http://dx.doi.org/10.1155/2014/561935>.

- Akhtar, M., Hannan, M. A., Basri, H., Scavino, E., 2015. “Solid Waste Generation and Collection Efficiencies: Issues and Challenges”. *Jurnal Teknologi*, 75(11). doi:10.11113/jt.v75.5331.41–49, www.jurnalteknologi.utm.my, eISSN 2180–3722.
- Akinbile C.O. and Yusoff Md. S., 2011. “Environmental impact of leachate pollution on groundwater supplies in akure, nigeria”. *International Journal of Environmental Science and Development*, Vol.2, No.1, P: 81-86. February 2011 ISSN: 2010-0264.
- Alam S., Kolekar K. A., Hazra T., Chakrabarty S.N., 2016. “Selection of suitable landfill site for municipal solid waste disposal: a fuzzy logic approach”. *Proceedings of 6th International Conference on Solid Waste Management (SWM). Waste Management and Resource Utilization*.
- Alam, R., Chowdhury, M.A.I., Hasan, G.M.J., Karanjit, B., Shrestha, L.R., 2008. “Generation, storage, collection and transportation of municipal solid waste – A case study in the city of Kathmandu, capital of Nepal”. *Waste Management*, Volume 28, Issue 6, 2008, Pages 1088-1097, ISSN 0956-053X, <https://doi.org/10.1016/j.wasman.2006.12.024>.
- Ali Md A., Hoque M.A., Kim P.J., 2012. “Mitigating global warming potentials of methane and nitrous oxide gases from rice paddies under different irrigation regimes”. *Royal Swedish Academy of Sciences, Springer. AMBIO* 2013, 42: 357–368 DOI 10.1007/s13280-012-0349-3.
- Ambade, B, Kumar, A., Kumar, A., Sahu L.K., 2022. “Temporal variability of atmospheric particulate-bound polycyclic aromatic hydrocarbons (PAHs) over central east India: sources and carcinogenic risk assessment”. *Air Qual Atmos Health*. 2022; 15(1): 115–130. doi: 10.1007/s11869-021-01089-5.
- Anderson, L. E., 1968. “A mathematical model for the optimization of a waste management system”. *SERPL Rep. No. 68-1. Sanitary Engineering Research Laboratory, University of California, Berkeley*.
- Annepu, R. K., 2012. “Sustainable solid waste management in India”. Submitted in partial fulfillment of the requirements for the degree of Master of Science in Earth Resources Engineering, Department of Earth and Environmental Engineering, Fu Foundation School of Engineering and Applied Science, Columbia University, New York. Sponsored by Waste-to-Energy Research and Technology Council (WTERTE).

- Aravind, J., Sudha, G., Kanmani, P., Devisri, A.J., Dhivyalakshmi, S., Raghavprasad M., 2015. "Equilibrium and kinetic study on chromium(VI) removal from simulated waste water using gooseberry seeds as a novel biosorbent". *Global J. Environ. Sci. Manage.*,1(3): 233-244, Summer 2015 ISSN 2383 – 3572.
- Aryan, S., Yadav, P., Samadder, S. R., 2018. "Life Cycle Assessment of the Existing and Proposed Plastic Waste Management Options in India: A Case Study". *Journal of Cleaner Production*, 2018, 11. DOI: 10.1016/j.jclepro.2018.11.236.
- Aziz, A.H., Adlan, M. N., Zahari, M. S. M., Alias, S., 2004. "Removal of ammoniacal nitrogen (N-NH₃) from municipal solid waste leachate by using activated carbon and limestone". *Waste Management & Research*, 22(5), 371–375. doi:10.1177/073.
- Babu, R., Prieto Veramendi, P. M. P., Rene, E. R., 2021. "Strategies for resource recovery from the organic fraction of municipal solid waste". *Case Studies in Chemical and Environmental Engineering*, 3, 100098, P-1-8. doi:10.1016/j.cscee.2021.100098.
- Badran, M. F., & El-Haggar, S. M, 2006. "Optimization of municipal solid waste management in Port Said-Egypt". *Waste Management*, 26, 534-545, doi: org/10.1016/j.wasman.2005.05.005.
- Bahukhandi, K. D. & Ollemman, S., 2022. "A review of municipal solid waste: its generation, composition, impacts, management and challenges in urban areas with special focus on India". *Environmental Pollution and Natural Resource Management*, pp 273–307. Part of the Springer Proceedings in Earth and Environmental Sciences book series (SPEES). DOI: 10.1007/978-3-031-05335-1_17.
- Baidya, R., Debnath, B., De, D., Ghosh, S. K., 2016. "Sustainability of modern scientific waste compacting station in the city of Kolkata". *Procedia of environmental sciences*, 31, 520-529. DOI: 10.1016/j.proenv.2016.02.072.
- Bala, G. P., Rajnoveanu, R. M., Tudorache, E., RaduMotișan, Oancea, C., 2021. "Air pollution exposure—the (in)visible risk factor for respiratory diseases". *Environmental Science and Pollution Research*, 2021, 28:19615–19628, <https://doi.org/10.1007/s11356-021-13208-x>.
- Banar, M., Cokaygil, Z., Ozkan, A., 2008. "Life cycle assessment of solid waste management options for Eskesehir, Turkey". *Journal of Waste Management*, 29, 54-62.
- Bandyopadhyay, M., Dutta, A., Dikshit, A. K., Ray, S., 2001. "Environment impact assessment and its minimization in a refinery for sustainable development".

- Interdisciplinary Environmental Review- Proceedings 2001, V.3, 2,2001 Indian Institute of Technology, Kharagpur, India. P 156-167.
- Banerjee, S., Chakraborty, S., Banerjee, S., Dutta, A., 2023. “Decision making and economical optimization of a city scale solid waste management system: An integrated model simulation on Kolkata, India”. *Materials Today: Proceedings*. DOI: 10.1016/j.matpr.2023.07.238.
 - Barma, M., Biniyamin, H. K., Modibbo, U. M. Gaya, H. M., 2022. “Mathematical model for the optimization of municipal solid waste management”. *Frontiers in Sustainability*, volume-3, Article No.: 880409. doi: 10.3389/frsus.2022.880409.
 - Barnthouse, L.W., Suter, G.W. II, Base, C.R. III, Bartell, S.M., Cavendish, M.G., Gardner, R.H., O'Neill, R.V., and Rosen, A.E., 1985a. “Environmental risk analysis for indirect coal liquefaction”. ORNL/TM-9120. Oak Ridge, TN: Oak Ridge National Laboratory.
 - Barnthouse, L.W., Suter, G.W. II, Base, C.R. III, Bartell, S.M., Gardner, R.H., Millemann, R.W., O'Neill, R.V., Powers, C.D., Rosen, A.E., Sigal, L.L., and Vaughan, D.S., 1985b. “Unit release risk analysis for environmental contaminants for potential concern in synthetic fuels technologies”. ORNL/TM-9070. Oak Ridge, TN: Oak Ridge National Laboratory.
 - Basak, S., 2011. “A study on estimation of leachate generation and its transport from municipal solid waste landfill — Kolkata perspective”. Masters Thesis, Jadavpur University, Civil Engineering Department, Kolkata.
 - Batista, M., Caiado. R. G. G., Quelhas, O. L. G., Lima, G. B. A., Filho, W. L., Yparraguirre, I. T. R., 2021. “A framework for sustainable and integrated municipal solid waste management: Barriers and critical factors to developing countries”. *Journal of Cleaner Production*, Volume 312, 20 August 2021, 127516. <https://doi.org/10.1016/j.jclepro.2021.127516>.
 - Batool, F., Kurinawan, T. A., Mohyuddin, A., Othman, M. H. D., Aziz, F., Al-Hazemi, H. E., Goh, H. W., Anouzla, A., 2023. “Environmental impacts of food waste management technologies: A critical review of life cycle assessment (LCA) studies”. *Trends in Food Science & Technology*, volume 143, 2024. DOI: <https://doi.org/10.1016/j.tifs.2023.104287>.

- Bishop, P. L., 2000. "Pollution prevention: Fundamental and practice". McGraw-Hill Higher Education, Singapore.
- Biswas, A. K., Kumar, S., Babu, S. S., Bhattacharyya, J. K., Chakrabarti, T., 2010. "Studies on environmental quality in and around municipal solid waste dumpsite". *Resources, Conservation and Recycling*, Volume 55, Issue 2, December 2010, Pages 129-134, doi:10.1016/j.resconrec.2010.08.003.
- Borisova, D., Kostadinova, G., Petkov, G., Dospatliev, L., Ivanova, M., Dermendzhieva, D., Beev, G., 2023. "Assessment of CH₄ and CO₂ emissions from a gas collection system of a regional non-hazardous waste landfill, Harmanli, Bulgaria, using the interrupted time series ARMA Model". *Atmosphere*, 2023, 14, 1089. <https://doi.org/10.3390/atmos14071089>.
- Bukowska, B., Mokra, K., Michałowicz, J., 2022. "Benzo[a]pyrene—environmental occurrence, human exposure, and mechanisms of toxicity". *International Journal of Molecular Sciences*, 23, 6348. Pages: 1-30. <https://doi.org/10.3390/ijms23116348>.
- Burgess, A.A., and Brennan, D.J., 2001. "Desulfurisation of gas oil: A case study in environmental and economic assessment". *Journal of Cleaner Production*, 9(5), 465-472. 10.1016/S0959-6526(01)00006-3.
- Buxton, A., Livingston A.G., and Pistikopoulos, E.N., 1997. "Reaction path synthesis for environmental impact minimization". *Computers and Chemical Engineering*, Volume 21, Supplement, 20 May 1997, Pages S959-S964. [https://doi.org/10.1016/S0098-1354\(97\)87626-0](https://doi.org/10.1016/S0098-1354(97)87626-0).
- Byakodi, A. S. and B.T. S. B., 2016. "A case study on existing solid waste collection system in ward no.53 of Belagavi city". *Journal of Emerging Technologies and Innovative Research (JETIR)*. Volume 3, Issue 7, P- 81-85. JETIR (ISSN-2349-5162).
- Cabezas, H., Bare J.C., Mallick, S. K., 1999. "Pollution prevention with chemical process simulators: the generalized waste reduction (WAR) algorithm- full version". *Computers and chemical Engineering*, 23, 623-634.
- Cabezas, H., Bare, J.C., Mallick, S.K., 1997. "Pollution prevention with chemical process simulators: the generalized waste reduction (WAR) algorithm". *Computers and Chemical Engineering*, 21, S305-S310. DOI:10.1016/S0098-1354(97)87519-9.

Bibliography

- Cave, S.R., and Edwards, D.W., 1997. “Chemical process route selection based on assessment of inherent environmental hazard”. *Computers and Chemical Engineering*, 21 (Suppl.), S965-S970.
- Census, 2011. Kolkata City Census 2011 data. <http://www.census2011.co.in/census/city/215-kolkata.html>. Accessed on 05.04.2021.
- CEQ (Council on Environmental Quality), 1989. “Risk analysis: A guide to principles and methods for analyzing health and environmental risks”. eds. Cohrssen, J.J., and Covello, V.T.
- Chandra, N., Venkataramani, S., Lal, S., Patra, P.K., Ramonet, M., Lin, X., Sharma, S.K., 2019. “Observational evidence of high methane emissions over a city in western India”. *Atmospheric Environment*, Volume 202, Pages 41-52. <https://doi.org/10.1016/j.atmosenv.2019.01.007>.
- Chattopadhyay, S., 2018. “Integrated solid waste management in a metropolitan city”. a thesis by Subhasish Chattopadhyay.
- Chattopadhyay, S., Dutta, A., Ray, S., 2007b. “Existing municipal solid waste management of Kolkata – Deficiencies and its solutions”. *Journal of Indian Association for Environmental Management*, 34 (3), 161–167.
- Chattopadhyay, S., Dutta, A., Ray, S., 2009. “Municipal solid waste management in Kolkata, India – A review”. *Waste Management*, 29 (4), 1449–1458. doi:10.1016/j.wasman.2008.08.030.
- Chattopadhyay, S., Dutta, A., Ray, S., 2009a. “Clean development mechanism benefit from municipal solid waste landfill gas – Kolkata”. 06-07 February, 2009, 7th All India People’s Technology Congress, Forum of Scientists, Engineers & Technologists, Kolkata, India 21, 350– 360.
- Chattopadhyay, S., Dutta, A., Ray, S., 2010b. “Energy recovery possibility from Dhapa landfill site, Kolkata – A case study”. *International Conference on Clean Energy Technologies and Energy Efficiency for Sustainable Development*, 27-29 December, 2010, Organized by Uttarakhand Technical University, Dehradun, India, Harcourt Butler Technological Institute, Kanpur, India, Shivalik College of Engineering, Dehradun, India.

- Chattopadhyay, S., Dutta, A., Ray, S., Roy, A., 2018. “Gas management and energy recovery from municipal solid waste landfill”. *International Journal of Research in Advent Technology*, Vol.6, No.5, May 2018, Page 730-745. E-ISSN: 2321-9637.
- Chen, H., Jiang, W., Yang, Y., Man, X., Tang, M., 2015. “A bibliometric analysis of waste management research during the period 1997-2014”. *Scientometrics*, volume; 105, pages: 1005-1018. DOI: 10.1007/s11192-015-1714-3.
- Cleary, J., 2009. “Life cycle assessments of municipal solid waste management systems: A comparative analysis of selected peer-reviewed literature”. *Environment International*, Volume 35, Issue 8, November 2009, Pages 1256-1266. <https://doi.org/10.1016/j.envint.2009.07.009>.
- Clemens, J. and Cuhls, C., 2003. “Greenhouse gas emissions from mechanical and biological waste treatment of municipal waste”. *Environmental Technology*, volume 24, 2003, issue 6, pages 745-754. <https://doi.org/10.1080/09593330309385611>.
- Clift, R., Doig A., Finnveden G., 2000. “The application of life cycle assessment to integrated solid waste management: Part 1 – methodology”. *Institute of Chemical Engineers*, volume 78, part B, 279-287.
- Cointreau, S., 2006. “Occupational and environmental health issues of solid waste management, special emphasis on middle- and lower-income countries”. World Bank Group, Urban Paper No. 2. <http://www.worldbank.org/urban/>.
- Consoli, F., Allen, D., Boustead, I., Fava, J.A., Franklin, W., Jensen, A., Oude, de N., Perrish, R., Perriman, R., Postlethwaite, D., Quay, B., Seguin, J., Vigon, B., 1993. “Guidelines for life-cycle assessment, A “Code of Practice””. Society of Environmental Toxicology and Chemistry (SETAC), Pensacola, FL.
- Costi, P., Minciardi, R., Robba, M., Rovatti, M., Sacile, R., 2004. “An environmentally sustainable decision model for urban solid waste management”. *Waste Management*, 24(3), 277-295. DOI: 10.1016/S0956-053X(03)00126-0.
- CPCB (Central Pollution Control Board), 2016. “Consolidated annual review report on implementation of solid waste management rules 2016”. Status report on municipal solid waste management. CPCB, Govt. of India, New Delhi.
- CPCB (Central Pollution Control Board, December). 2000a. “Transport fuel quality for year 2005: A study”.

- CPCB, 2021. “Annual report on solid waste management (2020-21) on implementation of solid waste management and rules 2016”. CPCB, Delhi.
- CPHEEO (Central Public Health and Environmental Engineering Organisation), 2000. “Manual on municipal solid waste management”. Ministry of Urban Development, Govt. of India, New Delhi.
- Curran, M. A., 2006. “Life cycle assessment: principle and practice. scientific applications International Corporation (SAIC)”. National Risk Management Research Laboratory. US EPA, Ohio.
- Cutshaw, A., Chou, J., Timothy J., P.E., Krynock, M., Jamieson, M. “Life cycle analysis of thermoelectric power generation in the United States”. United States: N. p., 2023. Web. doi:10.1016/B978-0-323-90386-8.00066-8.
- Dalal, D. H., 2017. “Energy generation opportunities from msw of ahmedabad city: A case study”. International Journal of Engineering Development and Research, Volume 5, P- 87-91, Issue 4, ISSN: 2321-9939.
- Dangi, M. B., Budhathoki, S., Malla, O. B., Cohen, R.R.H., Khatiwada, N. R., 2023. “Life cycle assessment of municipal solid waste management in Kathmandu city, Nepal – An impact of an incomplete data set”. Habitat International, Volume 139, September 2023, 102895. <https://doi.org/10.1016/j.habitatint.2023.102895>.
- Dangi, M.B., Cohen, R.R., Urynowicz, M.A., Poudyal, K.N., 2009. “Searching for a way to sustainability: technical and policy analyses of solid waste issues in Kathmandu”. Waste Manag & Research, volume-27, issue-3, doi: 10.1177/0734242X08094951.
- Das, S., Bhattacharya, B. K., 2014. “Estimation of municipal solid waste generation and future trends in greater metropolitan regions of Kolkata, India”. Journal of Industrial Engineering and Management Innovation, Vol. 1, No. 1, 31-38. DOI: 10.2991/jiemi.2014.1.1.3.
- Das, S., Dutta, A., Chakrabarty, S., 2019. “Assessment of potential environmental impact (PEI) of municipal solid waste management (MSWM) system practiced in Kolkata using life cycle assessment (LCA) methodology”. International Journal of Research and Analytical Reviews (IJRAR), June 2019, Volume 6, Issue 2, Page 375-384.

- Daskalopoulos, E., Badr, O., Probert, S. D., 1998. “An integrated approach to municipal solid waste management”. *Resources, Conservation and Recycling*, volume 24, issue 1, pages 33-50. [https://doi.org/10.1016/S0921-3449\(98\)00031-7](https://doi.org/10.1016/S0921-3449(98)00031-7).
- De, S., Maiti, S. K., Hazra, T., DebSarkar, A., Dutta, A., 2016. “Leachate characterization and identification of dominant pollutants using leachate pollution index for an uncontrolled landfill site”. *Global J. Environ. Sci. Manage.*, 2(2), 177-186. DOI: 10.7508/gjesm.2016.02.008.
- De, S., Maiti, S. K., Hazra, T., Debsarkar, A., Dutta, A., 2017. “Assessment of groundwater pollution by municipal solid waste (MSW) landfill leachate: A case study in Kolkata, India”. *Pollution*, 3(3): 443-452, Summer 2017 DOI: 10.7508/pj.2017.03.009 Print ISSN: 2383-451X Online ISSN: 2383-4501.
- Det Nortske Veritus, 2010. Validation report “Expansion of Nature and Waste Bhalaswa Composting Plant at Delhi” in India.
- Dey S., Mehta N.S., 2020. “Automobile pollution control using catalysis”. *Resources, Environment and Sustainability*, 2 (2020) 100006. <https://doi.org/10.1016/j.resenv.2020.100006>.
- Dutta, A., Koshti, M., 2002. “Estimating potential environmental impact of manufacturing processes using life cycle impact analysis approach”. International conference on advances in civil engineering, Organized by IITkgp, Dept of civil engg. January 3-5, 2002.
- Ejaz, N., Akhtar N., Nisar, H., Naeem, U. A., 2010. “Environmental impacts of improper solid waste management in developing countries: A case study of rawalpindi city”. *WIT Transactions on Ecology and the Environment*, Volume:142, Pages- 9, Page Range- 379 – 387, Paper DOI: 10.2495/SW100351. Copyright WIT Press
- Ekvall, T., Finnveden, G., 2000. “The application of life cycle assessment to integrated solid waste management: Part 2 – perspective on energy and material recovery from paper”. *Trans IChemE*, 78, part B, July, 288-294. <https://doi.org/10.1205/095758200530808>.
- EPA (Environmental Protection Agency), 1994a. “The hydrologic evaluation of landfill performance (HELP) model: Engineering documentation for version 3”. EPA/600/R-94/168b, September 1994.

Bibliography

- EPA (Environmental Protection Agency), 1994b. "The hydrologic evaluation of landfill performance (HELP) model: User's guide for version 3". EPA/600/R-94/168a, September 1994.
- EPA (U.S. Environmental Protection Agency), 1992a. "Facility pollution prevention guide". EPA/600/R-92/088, Office of Solid Waste, US EPA, Washington and Risk Reduction Engineering Laboratory, US EPA, Cincinnati, Ohio.
- EPA (U.S. Environmental Protection Agency), 1994a. "Life-cycle assessment: public sources of data for the lca practitioner". Final Report. Office of Solid Waste, Washington, D.C. Prepared by Battelle, Columbus, OH.
- EPA (U.S. Environmental Protection Agency), 1994b. "Guidelines for assessing the quality of life inventory data". Final Report. Office of Air Quality Planning and Standards, Research Triangle Park, NC. Prepared by Research Triangle Institute, Research Triangle Park, NC.
- EPA (U.S. Environmental Protection Agency), 1994c. "Chemical hazard evaluation management strategies: a method for ranking and scoring chemicals by potential human health and environmental impacts". EPA /600/R-94/177, Office of Research and Development, Washington, D.C.
- EPA (U.S. Environmental Protection Agency), 1995b. "Life cycle impact assessment: A conceptual framework, key issues, and summary of existing methods". EPA/452/R 95/002, Office of Air Quality Planning and Standards, NC.
- EPA (U.S. Environmental Protection Agency), 1996a. "Proposed guidelines for ecological risk assessment". Federal register 61:47552-47631. <http://www.epa.gov/ORD/WebPubs/ecorisk>.
- EPA (U.S. Environmental Protection Agency), 1998. "Life cycle impact assessment: demonstration for the GBU-24. EPA/ 600/R-98/070". Center for environmental Research Information, Cincinnati, Ohio.
- EPA (U.S. Environmental Protection Agency), Risk assessment Forum, 1992b. "Framework for ecological risk assessment". EPA/630/R-92/001, Washington, D.C.
- EPA (U.S. Environmental Protection Agency), Risk assessment Forum, 1992c. "Report on the ecological risk assessment guidelines strategic planning workshop". EPA/630/R-92/002, Washington, D.C.

- Fava, J., Consoli, F., Denison, R., Dickson, K., Mohin, T., Vigon, B., 1993. “A conceptual framework for life-cycle impact assessment”. Society of Environmental Toxicology and Chemistry (SETAC) and SETAC Foundation for Environmental Education, Inc. Pensacola, FL. USA.
- Fava, J., Jensen, A. A., Lindfors, L., Pomper, S., Smet, B. D., Warren, J., Vigon, B., 1994. “Life-cycle assessment data quality: a conceptual approach”. Society of Environmental Toxicology and Chemistry (SETAC), Pensacola, FL. USA.
- Fava, J.A., Denison, R., Mohin, T., and Parrish, R.. 1992. Life-Cycle Assessments Peer Review Framework. Society of Environmental Toxicology and Chemistry (SETAC), Life-Cycle Assessment Advisory Group. Pensacola, FL.
- Ferronato, N., and Torretta, V., 2019. “Waste mismanagement in developing countries: A review of global issues”. *International Journal of Environmental Research and Public Health*, 2019, 16, 1060; Pages: 1-28. doi:10.3390/ijerph16061060.
- Finnveden, G., 1999. “Methodological aspects of life cycle assessment of integrated solid waste management systems”. *Resources, Conservation and Recycling*, Volume 26, Issues 3–4, June 1999, Pages 173-187.
- Flintoff, F., 1984. “Management of solid wastes in developing countries”. World Health Organization, S F Asia, Series No.1.
- Ganesan, A. L., Matt, R., Mark, F. L., Robert, J. P., Hartmut, B. Goulding, N., Umezawa, T., Zahn, A., Chatterjee, A., Prinn, R. G., Tiwari, Y. K., Schoot, M. van der, Krummel, P. B., 2017. “Atmospheric observations show accurate reporting and little growth in India’s methane emissions”. *Nature Communications*. doi: 10.1038/s41467-017-00994-7.
- Gautam, S. P., Bundela, P. S., Pandey, A. K., Jamaluddin, Awasthi, M. K., Sarsaiya S., 2012. “Diversity of cellulolytic microbes and the biodegradation of municipal solid waste by a potential strain”. *International Journal of Microbiology* Volume 2012, Article ID 325907, 12 pages doi:10.1155/2012/325907, Hindawi Publishing Corporation.
- Gerlagh, R., Beukering, P.V., Verma, M., Yadav, P.P., 1999. “Integrated modeling of solid waste in India”. CREED working paper series 26, Amsterdam.
- Ghose, M. K, Dikshit, A K, Sharma, S. K., 2006. “A GIS based transportation model for solid waste disposal – A case study on Asansol municipality”. *Waste Management*, 26, 1287–1293, DOI:10.1016/j.wasman.2005.09.022.

Bibliography

- Giusti L., 2009. "A review of waste management practices and their impact on human health". *Waste Management*, 29(2009), 2227–2239, doi:10.1016/j.wasman.2009.03.028.
- Graedel, T.E., and Allenby, B.R., 1995. "Industrial ecology". Englewood Cliffs, Prentice Hall, NJ.
- Grimstead, B., Schaltegger, S., Stinson, C.H., Waldorn, C., 1993. "Methodology for assessing the environmental impacts of chemical emissions in the united states." Kirkland, WA: Pioneer Environmental Consulting.
- Grugnaletti, M., Pantini, S., Verginelli, I., Lombardi, F., 2016. "An easy-to-use tool for the evaluation of leachate production at landfill sites". *Waste Management*, 55, 204–219. doi:10.1016/j.wasman.2016.03.030
- Guerrero L. A., Maas G., Hogland W., 2013. "Solid waste management challenges for cities in developing countries". *Journal of Waste Management*, 33, 220–232. Doi: <http://dx.doi.org/10.1016/j.wasman.2012.09.008>
- Guinee, J.B., 1992a. "Headings for the impact analysis". SETAC European Workshop on Environmental Life Cycle Analysis of Products, Centre of Environmental Science, Leiden University.
- Guinee, J.B., 1992b. "LCA classification. draft report". Centre of Environmental Science, Leiden University.
- Guinee, J.B., and Heijungs, R., 1993. "A proposal for the classification of toxic substances within the framework of life-cycle assessment of products". *Chemosphere*, 26(10), 1925-1944.
- Gupta, A., Sharma, D.C., 2011. "Integer programming model for integrated planning of solid waste management in Jaipur". *International Journal of Scientific & Engineering Research*, Volume 2, Issue 3. ISSN 2229-5518.
- Gupta, A.K., Paul K. K., Ayooob, S., John, K., 2008. "Spatio-temporal characteristics of gaseous and particulate pollutants in an urban region of Kolkata, India". *Atmospheric Research*, Volume 87, Issue 2, February 2008, Pages 103-115. <https://doi.org/10.1016/j.atmosres.2007.07.008>.
- Gupta, N., Yadav, K. K., Kumar, V., 2015. "A review on current status of municipal solid waste management in India". *Journal of Environmental Sciences*, Vol. 37, P- 206-217, <https://doi.org/10.1016/j.jes.2015.01.034>.

- Gutberlet, J., and Uddin, S. M. N., 2018. "Household waste and health risks affecting waste pickers and the environment in low- and middleincome countries". *International Journal of Occupational and Environmental Health*, DOI: 10.1080/10773525.2018.1484996.
- Hajam, Y. A., Kumar, R., Kumar, A., 2023. "Environmental waste management strategies and vermi transformation for sustainable development". *Environmental Challenges*, 13(2023)100747. <https://doi.org/10.1016/j.envc.2023.100747>.
- Hanandeh, A. E., El-Zein, A., 2010. "Life-cycle assessment of municipal solid waste management alternatives with consideration of uncertainty: SIWMS development and application". *Waste Management*, Volume 30, Issue 5, May 2010, Pages 902-911. <https://doi.org/10.1016/j.wasman.2009.12.026>.
- Harshitha, A., Anitha, M. S., Jayanth, N., Govardhan, A., 2021. "A review on leachate treatment of solid waste dumping sites in Bangalore". *International Research Journal of Engineering and Technology (IRJET)*, Volume: 08 Issue: 01, P-942-945. e-ISSN: 2395-0056, p-ISSN: 2395-0072.
- He, R., Sandoval-Reyes, M., Scott, I., Semeano, R., Ferrao, P., Matthews, S., Small, M. J., 2022. "Global knowledge base for municipal solid waste management: Framework development and application in waste generation prediction". *Journal of Cleaner Production* 377(2022). <https://doi.org/10.1016/j.jclepro.2022.134501>.
- Heijungs R., Guinee J.B., Huppes G., Lankreijer R. M., Udo De Hayes H.A., Wegener Sleeswijk A., 1992. "Environmental life cycle assessment of products: Backgrounds". Centre of Environmental Science, Leiden.
- Heijungs, R., Guinee, J.B., Huppes, G., Lankreijer, R. M., Udo De Hayes, H. A., Wegener Sleeswijk, A., 1992a. "Environmental life cycle assessment of products guide LCA-October 1992". Centre of Environmental Science, Leiden.
- Heijungs, R., Guinee, J.B., Huppes, G., Lankreijer, R. M., Udo De Hayes, H. A., Wegener Sleeswijk, A., 1992b. "Environmental life cycle assessment of products: Backgrounds - October 1992". Centre of Environmental Science, Leiden.
- Hettiaratchi, J.P.A., 2003. "Bioreactor landfills: A comprehensive literature review, report to city of Calgary". *Solid Waste and Recycling Services Division*, Vol. 4(3): 160764.

- Hilaly, A.K., Sikdar, S.K., 1994. “Pollution balance: A new methodology for minimizing waste production in manufacturing processes”. *J. Air Waste Manage. Assoc.*, 44, 1303-1308.
- Hilaly, A.K., Sikdar, S.K., 1995. “Pollution balance method and the demonstration of its application to minimizing waste in a biochemical process”. *Ind. & Eng. Chem. Res.*, 34, 2051-2059.
- Ho, K.F., Lee, S.C., Ho, W.K., Blake, D.R., Cheng, Y., Li, Y.S., Ho, S.S.H., Fung, K., Louie, P.K.K., Park, D., 2009. “Vehicular emission of volatile organic compounds (VOCs) from a tunnel study in Hong Kong”. *Atmospheric Chemistry and Physics*, 9, 7491–7504, 2009.
- Hoa, L. T., Mai, N. T., 2016. “Community-based Solid Waste Management: The Case of Sai Son Commune, Quoc Oai District, Hanoi”. *Journal of Mekong Societies*, 12(1), 77–94. <https://so03.tci-thaijo.org/index.php/mekongjournal/article/view/55538>.
- Hoang, N.H., Fogarassy, C., 2020. “Sustainability Evaluation of Municipal Solid Waste Management System for Hanoi (Vietnam)—Why to Choose the ‘Waste-to-Energy’ Concept”. *Sustainability* 2020, 12, 1085. <https://doi.org/10.3390/su12031085>.
- Hoornweg, D., Bhada-Tata, Perinaz. 2012. What a waste : “A global review of solid waste management”. Urban development series, knowledge papers no. 15. World Bank, Washington, DC. <http://hdl.handle.net/10986/17388> License: CC BY 3.0 IGO.”
- https://www.kmcgov.in/KMCPortal/downloads/Public_domain_Statis_report_SWM_28_10_2019.pdf
- <https://www.newgeography.com/content/001689-how-much-world-covered-cities>
- Hussain, M. T. T., Behaylu, A., 2015. “Scenario of Present and Future of Solid Waste Generation in India: A Case Study of Delhi Mega City”. *Journal of Environment and Earth Science*, Vol.5, No.8, 2015, p-83-91. www.iiste.org.
- IEA, 2021. <https://www.iea.org/reports/methane-tracker-2021/methane-and-climate-change>. Accessed on 15.03.2022.
- ILCD, 2010. “International reference life cycle data system (ILCD) handbook: Framework and requirements for life cycle impact assessment models and indicators”. JRC, European Commission. Institute for Environment and Sustainability. First edition March 2010. EUR 24586 EN. Luxembourg. Publications Office of the European Union; 2010.

- ITA (International Trade Administration), 2023. Indian Solid Waste Management. <https://www.trade.gov/market-intelligence/india-solid-waste-management#:~:text=The%20Indian%20Central%20Pollution%20Control,ato%20increase%20proportionately%2C%20as%20well>. Accessed on.....
- Jie, L., 2011. “Environmental Effects of Vehicle Exhausts, Global and Local Effects – A Comparison between Gasoline and Diesel”. Master thesis of Applied Environmental Science (15 credits), School of Business and Engineering. Halmstad University.
- Jo, J. Y., Kwon, Y. S., Lee, J. W., Park, J. S., Rho, B. H., Choi, W., 2013. “Acute Respiratory Distress Due to Methane Inhalation. Tuberculosis and Respiratory Diseases”. Vol. 74. No. 3, Mar. 2013. <http://dx.doi.org/10.4046/trd.2013.74.3.120> ISSN: 1738-3536(Print)/2005-6184(Online).
- Jovicic, N. M., Boskovic, G.B., Vujic, G.V., Jovicic, G.R., Despotovic, M. Z., Milanovic, D.M., Gordic, D.R., 2011. “Route optimization to increase efficiency and reduce fuel consumption of communal vehicles”. Thermal Science, 14 (Suppl.), S67–S78.
- Kalyani K. A., Pandey K. K., 2014. “Waste To Energy Status in India: A Short Review”. Journal of Renewable and Sustainable Energy Reviews, 31, 113–120.
- Kamboj, N., Bisht, A., Kamboj, V., Bisht, A., 2020. “Leachate disposal induced groundwater pollution: A threat to drinking water scarcity and its management”. Advances in Environmental Pollution Management: Wastewater Impacts and Treatment Technologies. P: 54-76. DOI: 10.26832/aesa-2020-aepm-05.
- Kar, S., Chowdhury, S., Gupta, T., Hati, D., De, A., Ghatak, Z., Tinab, T., Rahman, I. T., Chatterjee, S., Roy Chowdhury, A., 2024. “A Study on the Impact of Air Pollution on Health Status of Traffic Police Personnel in Kolkata, India”. Air 2024, 2, 1–23. <https://doi.org/10.3390/air2010001>
- Karajgi, S.B., Kumar, U., Kamalapur, G.D., 2012. “Modeling of power generation using municipal solid waste in India”. International Journal of Electrical and Computer Engineering (IJECE), Vol.2, No.2, April 2012, pp. 197~202 ISSN: 2088-8708.
- Karuppannan, S., 2016. “Management of Solid Waste in Malaysia: A focus on Kuala Lumpur”. Malaysia Solid Waste Management and Environment (MSWME) 2016.

- Kathpalia, D., Alappat, B. J., 2003. “Monitoring Leachate Composition at a Municipal Landfill Site in New Delhi, India”. January 2003. International Journal of Environment and Pollution 19(5):454 – 465. DOI: 10.1504/IJEP.2003.004322
- Katre, N. H., Pandey, D., 2012. “Municipal Solid Waste Problem and Management in Gondia City in Indian Perspective (MS): A Case Study”. International journal of Life Sciences Biotechnology and Pharma Research, vol-I, No. 1, www.ijlbpr.com.
- Kaushal, R. K., Varghese, G. K., Chabukdhara, M., 2012. “Municipal Solid Waste Management in India-Current State and Future Challenges: A Review”. International Journal of Engineering Science and Technology (IJEST). ISSN : 0975-5462. Vol. 4 No.04 April 2012. P-1473-1489.
- Kawai, K., Tasaki, T., 2015. “Revisiting estimates of municipal solid waste generation per capita and their reliability”. Journal of Material Cycles and Waste Management, 18(1), 1–13. doi:10.1007/s10163-015-0355-1
- KEIP (Kolkata Environmental Improvement Project), 2005. “Rapid environmental impact assessment report and environmental management plan of engineered landfill at Dhapa”. Kolkata Municipal Corporation, India.
- Keiip, 2005. “Master Plan on Solid Waste Management”. http://www.keiip.in/bl333/pdfFiles/master_plan.pdf. Accessed on 27.05.2016.
- Khalaf, E. M., Mohammadi, J. M., Sulistiyani, S., Ramírez-Coronel, A. A., Kiani, F., Jalil, A.T., Almulla, A. F., Asban, P., Farhadi, M., Derikondi, M., 2022. “Effects of sulfur dioxide inhalation on human health: a review”. PMID: 36635910. DOI: 10.1515/reveh-2022-0237.
- Khan, D., Samadder, S. R., 2014. “Municipal solid waste management using Geographical Information System aided methods: A mini review”. Waste Management & Research, Vol. 32(11) 1049 –1062.
- Khandelwala, H., Thallaa, A. K., Kumar, S., Kumar, R., 2019. “Life cycle assessment of municipal solid waste management options for India”. Bioresource Technology, 288:121515. DOI: 10.1016/j.biortech.2019.121515.
- Khasreen, M. M., Banfill, P. F.G., Menzies, G. F., 2009. “Life-Cycle Assessment and the Environmental Impact of Buildings: A Review”. Sustainability 2009, 1, 674-701; doi:10.3390/su1030674.
- Kmcgov, 2016. <https://www.kmcgov.in/KMCPortal/jsp/KolkataStatistics.jsp>

- Kmcgov, 2016. Solid Waste Management Services. https://www.kmcgov.in/KMCPortal/jsp/Solid_Waste_Services.html, Accessed on 02.04.2016.
- Kolekar, K.A., Hazra, T., Chakrabarty, S.N., 2017. “Prediction of municipal solid waste generation for developing countries in temporal scale: A fuzzy inference system approach”. *Global NEST Journal*, Vol 19, No X, pp 1-10.
- Kumar, A., Agrawal, A., 2020. “Recent trends in solid waste management status, challenges, and potential for the future Indian cities—A review”. *Current Research in Environmental Sustainability*, 2, 100011. doi:10.1016/j.crsust.2020.100011.
- Kumar, D., Alappat, B. J., 2003. “Monitoring leachate composition at a municipal landfill site in New Delhi, India”. *International Journal of Environment and Pollution*, 19(5), 454. doi:10.1504/ijep.2003.004322
- Kumar, D., Alappat, B. J., 2005. “Evaluating leachate contamination potential of landfill sites using leachate pollution index”. *Clean Technologies and Environmental Policy*, 7(3), 190–197. doi:10.1007/s10098-004-0269-4.
- Kumar, S., Bhattacharyya, J.K., Vaidya, A.N., Chakrabarti, T., Devotta, S., Akolkar, A.B., 2009. “Assessment of The Status of Municipal Solid Waste Management in Metro Cities, State Capitals, Class I Cities, And Class II Towns in India: An Insight”. *Journal of Waste Management*, 29, 883–895. doi: 10.1016/j.wasman.200804.011.
- Kumar, S., Nimchuk, N., Kumar, R., Zietsman, J., Ramani, T., Spiegelman, C., Kenney, M., 2016. “Specific model for the estimation of methane emission from municipal solid waste landfills in India”. *Bioresource Technology*, 216, 981–987. doi:10.1016/j.biortech.2016.06.05.
- Kumar, S., Smith, S.R., Fowler, G., Velis, C., Kumar, S.J., Arya, S. R., Kumar, R., Cheeseman, C., 2017. “Challenges and opportunities associated with waste management in India”. *Royal Society Open Science*, 4: 160764. <http://dx.doi.org/10.1098/rsos.160764>, P- 1-10.
- Kumari, D. P., 2019. “Solid Waste Management in Indian Cities”. *Journal of Emerging Technologies and Innovative Research (JETIR)*, Volume 6, Issue 1, P- 194-200, (ISSN-2349-5162), www.jetir.org.
- Kurbatova, A. I., Abu-Qdais, H. A., Mikhaylichenko, K. Y., 2024. “Concentration and health risk assessment of volatile organic compounds from a closed solid waste landfill

- site: The role of flaring system”. *Atmospheric Pollution Research*, Volume 15, Issue 3, March 2024, 102010. <https://doi.org/10.1016/j.apr.2023.102010>.
- Kyung, S.Y., Jeong, S. H., 2020. “Particulate-Matter Related Respiratory Diseases”. *Tuberc Respir Dis (Seoul)*. 2020 Apr; 83(2): 116–121. doi: 10.4046/trd.2019.0025.
- Lagbas A. G. U., 2015. “The Theoretical Underpinnings of the Solid Waste Management Practices: A Proposed Blueprint Towards Government Action”. *European Scientific Journal*, August 2015 edition vol.11, No.23, P- 343-355. ISSN: 1857 – 7881 (Print) e - ISSN 1857- 7431.
- Laurent, A., Bakas, I., Clavreul, J., Bernstad, A., Niero, M., Gentil, E., Hauschild, M. Z., Christensen, T. H., 2014. “Review of LCA studies of solid waste management systems – Part I: Lessons learned and perspectives”. *Waste Management*, Volume 34, Issue 3, March 2014, Pages 573-588, <https://doi.org/10.1016/j.wasman.2013.10.045>.
- Lee, K., Inaba, A., 2004. “Life Cycle Assessment Best Practices of ISO 14040 Series”. Committee on Trade and Investment.
- LINDO Systems Inc., August 2004.LINGO User’s Guide. info@lindo.com.
- Lin, S. H., Shyu, C. T., 1999. “Performance characteristics and modeling of carbon dioxide absorption by amines in a packed column”. *Waste Management*, 19(4), 255–262. doi:10.1016/s0956-053x(99)00135-x.
- Lin, S.-L., Lee, W.-J., Lee, C. F., Wu, Y., 2012. “Reduction in emissions of nitrogen oxides, particulate matter, and polycyclic aromatic hydrocarbon by adding water-containing butanol into a diesel-fueled engine generator”. *Fuel*, 93, 364–372. doi:10.1016/j.fuel.2011.11.042
- Lindamulla, L.M.L.K.B, Jayawardene, N.K.R.N., Wijerathne, W.S.M.S.K., Nanayakkara, K.G.N., Jinadasa, K.B.S.N., Othman, M., Herath, G.B.B., Jegatheesan, V., 2022. “Treatment of mature landfill leachate in tropical climate using membrane bioreactors with different configurations”. *Chemosphere* Volume 307, Part 3. <https://doi.org/10.1016/j.chemosphere.2022.136013>.
- Lingan, B. A., Poyyamoli, G., 2014. “A Study on Current Status of Municipal Solid Waste Management Practices in Cuddalore Municipality, India”. *World Applied Sciences Journal* 31 (6): 1096-1103, 2014 ISSN 1818-4952 © IDOSI Publications, 2014 DOI: 10.5829/idosi.wasj.2014.31.06.415.

- Liu, M., Tan, Z., Fan, X., Chang, Y., Wang, L., Yin, X., 2021. “Application of life cycle assessment for municipal solid waste management options in Hohhot, People’s Republic of China”. *Waste Management & Research*, Vol. 39(1) 63 –72. DOI: 10.1177/0734242X20959709.
- Liu, Y., Li, S., Wang, Q., Zheng, X. Zhao, Y., Lu, W., 2023. “Occupational health risks of VOCs emitted from the working face of municipal solid waste landfill: Temporal variation and influencing factors”. *Waste Management*, Volume 160, 1 April 2023, Pages 173-181. <https://doi.org/10.1016/j.wasman.2023.02.001>.
- Mackay, D., 1979. “Finding Fugacity Feasible”. *Environmental Science and Technology*, 13(1), 218-223.
- Mackay, D., Paterson, S., 1981. “Calculating Fugacity”. *Environmental Science and Technology*, 15(1), 6-14.
- Mackay, D., Paterson, S., 1990. “Fugacity Models”. In *Practical Applications of quantitative Structure-Activity Relationships (QSAR) in Environmental Chemistry and Toxicology*, Karcher, W., and Devillers, J., eds., Kluwer, London.
- Majumdar, B. K., Dutta, A., Chakrabarty, S., Ray, S., 2008. “Correction Factors of CALINE 4: A Study of Automobile pollution in Kolkata”. *Indian Journal of Air pollution Control*, Volume VIII, No. I, March 2008, PP- 1-7.
- Mallick, S.K., Cabezas, H., Bare, J.C., Sikdar, S.K., 1996. “A Pollution Reduction Methodology for Chemical Process Simulators”. *Ind. and Eng. Chem. Res.*, 35, 4128.
- Manisalidis, I., Stavropoulou, E., Stavropoulos, A., Bezirtzoglou, E., 2020. “Environmental and Health Impacts of Air Pollution: A Review”. *Frontiers in Public Health*, 2020, Volume8, Article14, P: 1-13. doi:10.3389/fpubh.2020.00014.
- Meena M.D., Dotaniya, M.L., Meena, B.L., Rai, P.K., Antil, R.S., Meena, H.S., Meena, L.K., Dotaniya, C.K., Meena, V. S., Ghosh, A., Meena, K.N., Singh, A. K., Meena, V.D., Moharana, P.C., Meena, S. K., Srinivasarao, Ch., Meena, A.L., Chatterjee, S., Meena, D.K., Prajapat, M., Meena, R.B., 2023. “Municipal solid waste: Opportunities, challenges and management policies in India: A review”. *Waste Management Bulletin*, 1 (2023) 4–18, <https://doi.org/10.1016/j.wmb.2023.04.001>.
- Minghua, Z., Xiumin, F., Rovetta, A., Qichang, H., Vicentini, F., Bingkai, L., Yi, L., 2009. “Municipal solid waste management in Pudong New Area, China”. *Waste Management*, 29(3), 1227–1233, doi:10.1016/j.wasman.2008.07.016.

Bibliography

- Mir, I. S., Cheema, P. P. S., Singh, S. P., 2021. “Implementation analysis of solid waste management in Ludhiana city of Punjab”. *Environmental Challenges*, Volume 2, January 2021, 100023. <https://doi.org/10.1016/j.envc.2021.100023>.
- Mishra S., 2013. “A Geographical Interrogation of Solid Waste Management : A Case Study of Puri town, Odisha Review”. <http://magazines.odisha.gov.in/Orissareview/2013/aug-sept/engpdf/67-73.pdf>. Accessed 12.02.2018.
- Mishra, S., Tiwary, D., Ohri, A., Agnihotri, A. K., 2019. “Impact of Municipal Solid Waste Landfill Leachate on Groundwater Quality in Varanasi, India.” *Groundwater for Sustainable Development*, Volume 9, October 2019, 100230. <https://doi.org/10.1016/j.gsd.2019.100230>.
- Mohajan H. K., 2012. “Dangerous Effects of Methane Gas in Atmosphere”. *International Journal of Economic and Political Integration*, 2(1): 3–10. Munich Personal RePEc Archive.
- Mohanty, S., Saha, S., Santra, G.H., Kumari, A., 2021. “Future Perspective of Solid Waste Management Strategy in India”. In: Baskar, C., Ramakrishna, S., Baskar, S., Sharma, R., Chinnappan, A., Sehrawat, R. (eds) *Handbook of Solid Waste Management*. Springer, Singapore. https://doi.org/10.1007/978-981-15-7525-9_10-1
- Mor, S., Khairwal, R., Dahiya, R.P., Chandra, A., 2006. “Leachate Characterization and Assessment of Groundwater Pollution Near Municipal Solid Waste Landfill Site”. *Environmental Monitoring and Assessment* (2006) 118: 435–456 DOI: 10.1007/s10661-006-1505-7 ©Springer 2006
- Motling et al, 2013. “Leachate Characteristics of Municipal Solid Waste Landfill Site in Kolkata.” Volume 2013-14. Number 3. October 2013.
- Mukherjee, S., Mukhopadhyay, S., Hashim, M. A., Sen Gupta, B., 2014. “Contemporary environmental issues of landfill leachate: assessment & remedies”. *Critical Reviews in Environmental Science and Technology*, 00-00.
- Naghibzadeh, J.S., Khorasani, S. N., Javad, Y., Mousavi, B. S., Badehian, Z., 2014. “Life Cycle Assessment of Municipal Waste Management System (Case Study: Karaj, Iran)”. *Journal of Applied Science and Environmental Management*, December, 2014 Vol. 18 (4) 559-565. Doi: 10.4314/jasem.v18i4.1.

- Najm, A. M., El-Fadel, M., Ayoub, G., El-Taha, M., Al-Awar, F., 2002. "An optimisation model for regional integrated solid waste management I. Model formulation". *Waste Management & Research*, 20, 37-45.
- Narayana T., 2009. "Municipal Solid Waste Management in India: From Waste Disposal to Recovery of Resources?" *Journal of Waste Management*, 29, 1163-1166.
- National Research Council, 1983. "Risk Assessment in the Federal Government: Managing the Process". National Academy Press, Washington, D.C.
- Nayak, A., 2022. "A Review of Industrial Waste Management to Conserve Marine Ecology: A Case of Coastal Industrial Cluster". *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, Volume 10 Issue I Jan 2022, P-879-887, ISSN: 2321-9653; www.ijraset.com.
- Noche B., Rhoma F. A., Chinakupt T., Jawale M., 2010. "Optimization model for solid waste management system network design case study". The 2nd International Conference on Computer and Automation Engineering (ICCAE), Singapore, 2010, pp. 230-236, doi: 10.1109/ICCAE.2010.5451476.
- Oakley, S. M., Jimenez, R., 2012. "Sustainable sanitary landfills for neglected small cities in developing countries: The semi-mechanized trench method from Villanueva, Honduras". *Waste Management* Volume 32, Issue 12, December 2012, Pages 2535-2551, <https://doi.org/10.1016/j.wasman.2012.07.030>.
- Ohri, A., Singh, P. K., 2010. "Development of Decision Support System for Municipal Solid Waste Management in India: A Review". *International Journal of Environmental Sciences*, Volume 1, No 4, 2010.
- Omran, A., Mahmood, A., Aziz, H. A., 2007. "Current Practice of Solid Waste Management In Malaysia and Its Disposal". *Environmental Engineering and Management Journal*, Vol. 6, No. 4, 295-300.
- Ouedraogo, A. S., Kumar, A., Fraizer, R., Sallam, K.A., 2024. "Comparative Life Cycle Assessment of Landfilling with Sustainable Waste Management Methods for Municipal Solid Wastes". *Environments*, 2024, 11(11), 248; <https://doi.org/10.3390/environments11110248>.
- Ozeler. D., U. Yetis., G.N. Demirer. 2006. "Life Cycle Assessment of MSW Management Methods: Ankara Case Study". *Environmental International*. Volume 32, Issue 3, April 2006, Pages 405-411. <https://doi.org/10.1016/j.envint.2005.10.002>

- Partha, V., Murthy, N.N., Saxena, P. R., 2011. “Assessment of heavy metal contamination in soil around hazardous waste disposal sites in Hyderabad city (India): natural and anthropogenic implications”. *Journal of Environmental Research and Management*, Vol.2(2). pp. 027-034, August, 2011.
- Patel, V., Meka, S.R., 2013. “Forecasting of municipal solid waste generation for medium scale towns located in the state of Gujarat, India”. *International Journal of Innovative Research in Science, Engineering and Technology*, volume- 2, P: 4707–4716, ISSN: 2319-8753.
- Pati, R.K., Vrat, P., Kumar, P., 2008. “A goal programming model for paper recycling system”. *Omega, The International Journal of Management Science*, 36, 405–417. DOI: 10.1016/j.omega.2006.04.014.
- Paul, A., Roy, P., 2020. “Fuzzy Logic and Statistical Based Modelling to Predict Rural Solid Waste Generation of West Bengal”. *International Journal of Innovative Technology and Exploring Technology*. Volume-9 Issue-9, July 2020, ISSN: 2278-3075 (Online).
- Paul, K., Dutta, A., Krishna, A.P., 2014. “A comprehensive study on landfill site selection for Kolkata City, India”. *Journal of the Air & Waste Management Association*, 64:7, 846-861, DOI: 10.1080/10962247.2014.896834.
- Paul, K., Dutta, A., Krishna, A.P., 2017. “Using GIS to Locate Waste Bins: a Case Study on Kolkata City, India”. *Journal of Environmental Science and Management* 20-1: 95-105 (June 2017) ISSN 0119-1144.
- Paul, K., Chattopadhyay, S., Dutta, A., Krishna, A. P., Ray S., 2020. “Developing and Optimising an Urban Integrated Solid Waste Management Model: Effect of Transfer Stations”. *Journal of Urban and Environmental Engineering*, v.14, n.1, p.119-131, ISSN 1982-3932 doi: 10.4090/juee.2020.v14n1.119131.
- Paul, K., Chattopadhyay, S., Dutta, A., Krishna, A. P., Ray, S., 2018. “A comprehensive optimization model for integrated solid waste management system: A case study”. *Environmental Engineering Research* 2019; 24(2): 220-237. DOI: <https://doi.org/10.4491/eer.2018.132>
- Peavy, H. S., Rowe, D. R., Tchobanoglous, G., 1979. “Environmental Engineering”. McGraw Hill, New York.

- Pistikopoulos, E.N., Stefanis, S.K., 1998. “Optimal solvent design for environmental impact minimization”. *Computers and Chemical Engineering*, 22(6), 717-733.
- Pokhrel, D., Viraraghavan, T., 2005. “Municipal solid waste management in Nepal: practices and challenges”. *Waste Management*, Volume 25, Issue 5, 2005, Pages 555-562, ISSN 0956-053X, <https://doi.org/10.1016/j.wasman.2005.01.020>.
- Postlethwaite, D., de Oude, N.T., 1996. “European Perspective”. In *Environmental Life-Cycle Assessment*, Curran, M.A., ed., McGraw_hill, New York. 9.1-9.13.
- Prodhan, A. H. M. S. U., Kaesar, A., 2020. “Solid waste Management in Dhaka City”. *Nature Study Society of Bangladesh*, April, 2020.
- Raju, M.V., Kumari, G. V. R., Mariadas, K., Palivela, H., Babu, S. R., 2018. “Evaluation and Remediation of Sludge from Municipal Solid Waste Dumping Sites: A Model Study”. *International Journal of Civil Engineering and Technology (IJCET)* Volume 9, Issue 10, October 2018, pp. 591–599, Article ID: IJCET_09_10_061 Available online at <http://iaeme.com/Home/issue/IJCET?Volume=9&Issue=10> ISSN Print: 0976-6308 and ISSN Online: 0976-6316.
- Ramachandra T.V., 2011. “Integrated Management of Municipal Solid Waste, Chapter 30”. *Environmental Security : Human & Animal Health.*, Pages: 465-484.
- Rathi, S., 2007. “Optimisation model for integrated municipal solid waste management in Mumbai, India”. *Environment and Development Economics*, 12, 105-121, doi:10.1017/S1355770X0600341X.
- Raza, S.T., Hafeez, S., Ali, Z., Nasir, Z. A., Saleem, I., Wu, J., Chen, Z., Xu, Y., 2021. “An Assessment of Air Quality within Facilities of Municipal Solid Waste Management (MSWM) Sites in Lahore, Pakistan”. *MDPI*, 9, 1604. <https://doi.org/10.3390/pr9091604>.
- Renou, S., Givaudan, J.G., Poulain, S., Dirassouyan, F., Moulin, P., 2008. “Landfill leachate treatment: Review and opportunity”. *Journal of Hazardous Materials* 150 (2008) 468–493. doi:10.1016/j.jhazmat.2007.09.077.
- Rodrigues, A.P., Fernandes M.L., Rodrigues M.F.F., Bortoluzzi, S. C., Costa, S. E. G. da, Lima, E. P. de, 2018. “Developing criteria for performance assessment in municipal solid waste management”. *Journal of Cleaner Production*, 186, DOI: 10.1016/j.jclepro.2018.03.067

Bibliography

- Roy P., Daisuke N., Takahiro O., Qingyi X., Hiroshi O., Nobutaka N., Takeo S., 2009. “A review of life cycle assessment (LCA) on some food products”. *Journal of Food Engineering* 90 (2009) 1–10.
- Saaty, T.L., 1977. “A Scaling Method for Priorities in Hierarchical Structures.” *Journal of Mathematical Psychology*.15, 234-281.
- Saaty, T.L., 1980. “The Analytic Hierarchy Process”. McGraw-Hill, New York.
- Saaty, T.L., 1990. “The Analytic Hierarchy Process”. RWS Publication, Pittsburg, PA.
- Saba, N., Balwan, W. K., Rasool, N., Kour, S., 2022. “Future Perspective for Utilization of Municipal Solid Waste (MSW) in India: A Review”. *Scholars Academic Journal of Biosciences*, 2022 Sep 10(9): 199-204. DOI: 10.36347/sajb.2022.v10i09.001.
- Sabahi, E. A., Samsuddin, A. R., Yaacob, W. Z., Nozaily, F. A., Alshaebi, F., 2009. “The Characteristics of Leachate and Groundwater Pollution at Municipal Solid Waste Landfill of Ibb City, Yemen”. *American Journal of Environmental Sciences* 5 (3): 256-266, 2009 ISSN 1553-345X.
- Saha, R., Chattopadhyay, A., Naidu, B.R., 2003. “Pollution potential of leachate from East Kolkata solid waste dumpsite”. *Workshop on Sustainable Landfill Management*, 3–5 December, 2003, Chennai, India, 303-307.
- Salam, M., Nilza, N., 2021. “Hazardous Components of Landfill Leachates and Its Bioremediation”. *Soil Contamination*, IntechOpen, P: 1-10.
- Sankoh, F. P., Yan, X., Tran, Q., 2013. “Environmental and Health Impact of Solid Waste Disposal in Developing Cities: A Case Study of Granville Brook Dumpsite, Freetown, Sierra Leone”. *Journal of Environmental Protection*, 2013, 4, 665-670 <http://dx.doi.org/10.4236/jep.2013.47076>.
- Statista, 2022. <https://www.statista.com/statistics/271312/urbanization-in-india/> accessed on 12.04.2022
- Saxena, S., Rajendran, C., Sanjeevi V., Shahabudeen P., 2021. “Optimization of solid waste management in a metropolitan city”. *Materialstoday Proceedings*, Volume- 46, Part-17, 2021, P- 8231-8238. <https://doi.org/10.1016/j.matpr.2021.03.219>.
- Schaltegger, S.C., Sturn, J.A., 1993. “Eco-Controlling: An Integrated Economic Ecological Management Tool”. In *Green Business Opportunities*, Financial Times, Pitman Publishing.

- Schaltegger, S.C., Sturn, J.A., 1994. “Okolo-gieorientierte Entscheidungen in Unternehmen”. 2nd ed., Univ. of Basel, Basel Switzerland.
- Schaltegger, S.C., Sturn, J.A., 1996. “Eco-controlling for Environmental Management”. Asian Institute of Technology, School of management, Pathumthani, Thailand.
- SERI (Swedish Environmental Research Institute), 1991. “A System of Calculating Environmental Impact”. Technical report prepared for the Swedish Waste Research Council, Goteborg Sweden.
- SERI (Swedish Environmental Research Institute), 1992. “The EPS Enviro-Accounting Method”. Technical report prepared for the Swedish Waste Research Council, Goteborg Sweden.
- SERI (Swedish Environmental Research Institute), 1993. “Recent Development in methodologies for Impact Assessment in the Context of Life Cycle Assessment”. Paper presented in the 14th annual meeting of SETAC in Houston, TX, November 14-18,1993.
- SETAC (Society of Environmental Toxicology and Chemistry), 1997a. “Ecological Risk Assessment Technical Issue Paper”. Pensacola, FL.
- Shaban, A. Zaki, F.-E. Afefy, I.H. Di Gravio, G. Falegnami, A. Patriarca, R., 2022. “An Optimization Model for the Design of a Sustainable Municipal Solid Waste Management System”. Sustainability, 2022, 14, 6345. <https://doi.org/10.3390/su14106345>.
- Shaban, A., Kourtiti, K., Nijkamp, P., 2020. “India’s Urban System: Sustainability and Imbalanced Growth of Cities”. Sustainability, MDPI, 12, 2941; doi:10.3390/su12072941 www.mdpi.com/journal/sustainability.
- Shafya, A. H. I., Mansour, M. S. M., 2018. “Solid waste issue: Sources, composition, disposal, recycling, and valorization”. Egyptian Journal of Petroleum, 27 (2018), 1275–1290, <https://doi.org/10.1016/j.ejpe.2018.07.003>.
- Shahab, S., Anjum, M., 2022. “Solid Waste Management Scenario in India and Illegal Dump Detection Using Deep Learning: An AI Approach towards the Sustainable Waste Management”. Sustainability 2022, 14, 15896. <https://doi.org/10.3390/su142315896>
- Shang, B., Zhou, T., Tao, X., Chen, Y., 2022. “Greenhouse Gas Emissions From Biofilters for Composting Exhaust Ammonia Removal”. Frontiers in Bioengineering and Biotechnology 10:918365. doi: 10.3389/fbioe.2022.918365.

Bibliography

- Sharholly, M., Ahmad, K., Mahmood, G., Trivedi, R.C., 2008. “Municipal solid waste management in Indian cities – A review”. *Journal of Waste Management*, 28, Issue 2, 459–467.
- Sharma, A., Ganguly, R., Gupta, A. K., 2023. “Life cycle assessment of municipal solid waste generated from hilly cities in India – A case study”. *Helyon* 9 2023 e21575, P- 1-22. <https://doi.org/10.1016/j.heliyon.2023.e21575>,
- Sharma, A., Gupta, A. K., Ganguly, R., 2018. “Impact of open dumping of municipal solid waste on soil properties in mountainous region”. *Journal of Rock Mechanics and Geotechnical Engineering*, 10 (2018), 725-739, <https://doi.org/10.1016/j.jrmge.2017.12.009>.
- Sharma, K. D., Jain, S., 2020. “Municipal solid waste generation, composition, and management: the global scenario”. *Social Responsibility Journal*, ahead-of-print(ahead-of-print). doi:10.1108/srj-06-2019-0210
- Sharma, K. K., 2018. “Solid Waste Management in India”. *International Journal of Research in Social Sciences* Vol. 8 Issue 7, July 2018, ISSN: 2249-2496 Impact Factor: 7.081. P-672-690.
- Sharma, S. B., Jain, S., Khirwadkar, P., Kulkarni, S., 2013. “The Effects of Air Pollution on the Environment and Human Health”. *Indian Journal of Research in Pharmacy and Biotechnology*, Volume 1(3) May-June 2013, Page: 391-396.
- Shrestha, P.P., Ghimire, A., Dangi, M.B., Urynowicz, M.A., 2023. “Development of a Municipal Solid Waste Management Life Cycle Assessment Tool for Banepa Municipality, Nepal”. *Sustainability* , 15, 9954. <https://doi.org/10.3390/su15139954>,MDPI.
- Shruti, S., Singh, P. K., Ohri, A., Singh, R.S., 2022. “Development of environmental decision support system for sustainable smart cities in India”. *Environmental Progress and Sustainable Energy*. <https://doi.org/10.1002/ep.13817>.
- Siddiqua, A., Hahladakis, J. N., Al-Attiya, W. A. K. A., 2022. “An overview of the environmental pollution and health effects associated with waste landfilling and open dumping”. *Environmental Science and Pollution Research* (2022) 29:58514–58536 <https://doi.org/10.1007/s11356-022-21578-z>,

- Singh, A., Agrawal, M., 2008. “Acid rain and its ecological consequences”. *Journal of Environmental Biology*, January 2008, 29(1) 15-24.
- Singh, C. K., Kumar, A., Roy, S. S., 2018. “Quantitative analysis of the methane gas emissions from municipal solid waste in India”. *SCIENTIFIC RepoRtS* |(2018) 8:2913, DOI:10.1038/s41598-018-21326-9.
- Smith, A., Brown, K., Ogilvie, S., Rushton, K., and Bates, J., 2001. “Waste Management Options and Climate Change, Final Report to the European Commission”. Amsterdam: AEA Technology Environment.
- Somani P, Navaneethan R D, Thangaiyan S, 2021. “Integrated solid waste management in urban India: A mini review”. *International Conference on Research Frontiers in Sciences (ICRFS 2021) Journal of Physics: Conference Series* 1913 (2021) 012084 IOP Publishing doi:10.1088/1742-6596/1913/1/012084.
- Sridevi V., Modi, M., Lakshmi M.V.V.C., Kesavarao, L., 2012. “A Review on Integrated Solid Waste Management”. *International Journal of Engineering Science & Advanced Technology*, Volume-2, Issue-5, 1491 – 1499, ISSN: 2250–3676.
- Srivastava, V., Ismail, S. A., Singh, P., Singh, R. P., 2014. “Urban solid waste management in the developing world with emphasis on India: challenges and opportunities”. *Rev Environ Sci Biotechnol*. DOI 10.1007/s11157-014-9352-4.
- Stefanis, S.K., Livingston, A.G., Pistikopoulos, E.N., 1997. “Environmental impact considerations in the optimal design and scheduling of batch processes”. *Computers and Chemical Engineering*, 21(10), 1073-1094.
- Sufian M.A., Bala B.K., 2007. “Modeling of urban solid waste management system: The case of Dhaka city”. *Journal of Waste Management*, 27, 858–868.
- Suter, G.W. II, Barnthouse, L.W., Base, C.R. III, Bartell, S.M., Cavendish, M.G., Gardner, R.H., O'Neill, R.V., and Rosen, A.E., 1984. “Environmental Risk Analysis for Indirect Coal Liquefaction”. ORNL/TM-9074. Oak Ridge, TN: Oak Ridge National Laboratory.
- Suter, G.W. II, Barnthouse, L.W., Kraemer, S.R., Grismer, M.E., Durnford, D.S., McWhorter, D.B., O'Donnell, F.R., Base, C.R. III, R.V., and Rosen, A.E., 1985. “Environmental Risk Analysis for Oil from Shale”. ORNL/TM-9074. Oak Ridge, TN: Oak Ridge National Laboratory.

- Talyan, V., Dahiya, R.P., Sreekrishnan, T.R., 2008. “State of Municipal Solid Waste Management in Delhi, the Capital of India”. *Journal of Waste management*, Volume 28, Issue 7, 2008, Pages 1276-1287. <https://doi.org/10.1016/j.wasman.2007.05.017>.
- Talyan, V., Dahiya, R.P., Anand, S., Sreekrishnan, T.R., 2007. “Quantification of methane emission from municipal solid waste disposal in Delhi”. *Resources, Conservation and Recycling*, Volume 50, Issue 3, May 2007, Pages 240-259. <https://doi.org/10.1016/j.resconrec.2006.06.002>.
- Tchobanoglous G., Theisen H., Vigil S., 1997. “Integrated Solid Waste Management: Engineering Principles and Management Issues”. McGraw hill, Inc., New York.
- Tchobanoglous, G., Theisen, H., Eliassen, R., 1993. “Integrated Solid Waste Management Engineering”. P, McGraw-Hill, INC.
- Tellus Institute, 1992a. “CSG/Tellus Packaging Study, Report #5: Executive Summary”. Report prepared for the Council of State Governments, Lexington, KY, and U.S. Environmental Protection Agency, Boston, MA: Tellus Institute.
- Tellus Institute, 1992b. “CSG/Tellus Packaging Study, Volume I”. Report prepared for the Council of State Governments, Lexington, KY, and U.S. Environmental Protection Agency, Boston, MA: Tellus Institute.
- Tellus Institute, 1992c. “CSG/Tellus Packaging Study, Volume II”. Report prepared for the Council of State Governments, Lexington, KY, and U.S. Environmental Protection Agency, Boston, MA: Tellus Institute.
- Thanh, H.T., Yabar, H., Higano, Y., 2015. “Analysis of the environmental benefits of introducing municipal organic waste recovery in Hanoi city, Vietnam”. *Procedia Environmental Sciences* 28 (2015) 185 – 194. doi: 10.1016/j.proenv.2015.07.025.
- Thompson S., Tanapat S., 2005. “Modeling Waste Management Options for Greenhouse Gas Reduction”. *Journal of Environmental Informatics* 6 (1) 16-24 (2005).
- Thushari, I., Vicheanteab, J., Janjaroen, Dao., 2020. “Material flow analysis and life cycle assessment of solid waste management in urban green areas, Thailand”. *Sustainable Environment Research* (2020) 30: P-1-1721 <https://doi.org/10.1186/s42834-020-00057-5>,
- Tiwari, M.K., Bajpai, S., Dewangan, U.K., 2012. “Prediction of industrial solid waste with ANFIS model and its comparison with ANN model—a case study of Durg-Bhilai

- Twin city India”. *International Journal of Engineering and Innovative Technology (IJEIT)*, Volume 2, Issue 6, ISSN: 2277-3754.
- Traboulsi, H., Guerrina, N., Iu, M., Maysinger, D., Ariya, P., Baglole, C. J., 2017. “Inhaled Pollutants: The Molecular Scene behind Respiratory and Systemic Diseases Associated with Ultrafine Particulate Matter”. *International Journal of Molecular Sciences*, 18, 243, Pages: 1-19; doi:10.3390/ijms18020243.
 - Trankler J., Manandhar, D.R., Xiaoning, Q., Sivapornpun, V., Scholl W., 2001. “Effects of Monsooning Conditions on the Management of Landfill Leachate in Tropical Countries”. *Proceedings Sardinia 2001, Eighth International Waste management and Landfill Symposium*, Pula, Cagliari, Italy , Vol II, pp. 59-68.
 - Tsatsarelis T., Karagiannidis A., 2009. “Estimation of Future Methane Production from Hellenic Landfills”. *Global NEST Journal*, Vol 11, No 2, pp 162-171.
 - UNCHS, 1994. “A reference handbook for trainers on promotion of solid waste recycling and reuse in the developing countries of Asia United Nations Center for Human Settlements (Habitat), Nairobi, Kenya”.
 - Uredy, D. C. F., 1994. “Solid waste in the Waste Economy Socio-Cultural aspects”. *Workshop on "The Waste Economy" Sponsored by National Institute for Scientific and Technical Forecasting and Strategy Studies, Hanoi; University of Toronto; International Development Research Centre, Ottawa Hanoi, August 22-25, 1994.*
 - Vaverkova, M. D., 2019. “Landfill Impacts on the Environment—Review”. *Geosciences* 2019, 9, 431; P- 9-16. doi:10.3390/geosciences9100431.
 - Vignes, R.P., 1999. “Limited Life Cycle Analysis: A Tool for the Environmental Decision-Making Toolbox”. *Strategic Environmental Management*, 1(4), 297-332.
 - Vignes, R.P., 2001. “Use Limited Life-Cycle Analysis for Environmental Decision Making”. *Chemical Engineering progress*, 97(2), 40-54.
 - Vigon, B.W., Jensen, A.A., 1992. “Lifecycle Assessment Data Quality and Databases Practitioner Survey”. Discussion initiation paper presented at the Society of Environmental Toxicology and Chemistry Lifecycle Assessment Data Quality Workshop, Wintergreen, Virginia.
 - Vilms, M., Voronova, V., Loigu, E., 2015. “Proceedings Sardinia 2015, 15th International Waste Management and Landfill Symposium S. Margherita di Pula, Cagliari, Italy”; 5 – 9 October 2015, CISA Publisher, Italy.

- Wdowczyk, A., Szymanska-Pulikowska, A., 2020. "Differences in the Composition of Leachate from Active and Non-Operational Municipal Waste Landfills in Poland". *Water* 2020, 12, 3129; P-1-15. doi:10.3390/w12113129.
- WHO (World Health Organization), 2005. "WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: global update 2005". 1–21. 10.1016/0004-6981(88)90109-6.
- Wikidedia, 2020. https://en.wikipedia.org/wiki/Farakka_Super_Thermal_Power_Station. Accessed On 12.03.2020.
- Wikipedia, 2011. 2011 Census of India. https://en.wikipedia.org/wiki/2011_Census_of_India, Accessed on 05.04.2018.
- Wilson, DC, Velis, CA and Rodic, L, 2013. "Integrated sustainable waste management in developing countries". *Proceedings of the Institution of Civil Engineers: Waste and Resource Management*, 166 (2). 52 - 68.
- World Bank, 2012. https://datatopics.worldbank.org/what-a_waste/trends_in_solid_waste_management.html, Accessed on 02.04.2018.
- World Bank, 2016. Population Growth (Annual %) <http://data.worldbank.org/indicator/SP.POP.GROW>. Accessed 28.04.2018.
- World Bank, 2018. "What A Waste 2.0, A Global Snapshot of Solid Waste Management to 2050".
- World Bank, 2018. [https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS ? locations=IN](https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=IN). Accessed on 10.06.2020.
- World Bank, 2019. "Urban population (% of total) Data". data.worldbank.org. Retrieved 17 January 2019.
- Yadav, P., Samadder, S. R., 2014."Life cycle assessment of solid waste management options: A Review". *Recent Research in Science and Technology*, 6(1): 113-116 ISSN: 2076-5061, <http://recent-science.com>.
- Yang, N., Damgaard, A., Kjeldsen, P., Shao, L.-M., He, P.-J., 2015. "Quantification of regional leachate variance from municipal solid waste landfills in China". *Waste Management*, 46, 362–372. doi:10.1016/j.wasman.2015.09.016
- Yasmin, S., Rahman, Md. I., 2017. "A Review of Solid Waste Management Practice in Dhaka City, Bangladesh". *International Journal of Environmental Protection and Policy*. Vol. 5, No. 2, 2017, pp. 19-25. doi: 10.11648/j.ijepp.20170502.11.

- Yedla, S., Parikh, J. K., 2001. “Economic evaluation of landfill system with gas recovery for MSW- A case study”. *International journal of environment and pollution*, 15(4), 433-47.
- Young, D. M., and Cabezas, H., 1999. Designing sustainable processes with simulation: the waste reduction (WAR) algorithm. *Computers and Chemical Engineering*, 23, 1477-1491.
- Young, D. M., Scharp R., Cabezas, H., 2000. “The waste reduction (WAR) algorithm: environmental impacts, energy consumption, and engineering economics”. *Journal of Waste Management*, 20, 605-615.
- Zaeimi, M. B., Rassafi, A. A., 2021. “Optimization Model for Integrated Municipal Solid Waste System Using Stochastic Chance-Constraint Programming under Uncertainty: A Case Study in Qazvin, Iran”. *Journal of Advanced Transportation*, Volume 2021, Article ID 9994853, 16 pages, Hindawi, <https://doi.org/10.1155/2021/9994853>.
- Zainu, Z. A., Songip, A. R., 2017. “Policies, Challenges and Strategies for Municipal Waste Management in Malaysia”. *JOSTIP*, Volume 3, No. 1.
- Zainu, Z. A., Syukri, W. Md., Ali, W. M., Songip, A. R., 2015. “Present and Future Innovations in Solid Waste Management in Malaysia”. *Int'l Conference on Waste Management, Ecology and Biological Sciences (WMEBS'15)* May 13-14, 2015 Kuala Lumpur, Malaysia. <http://dx.doi.org/10.17758/ER1515220>.
- Zaks, D. P. M., Winchester, N., Kucharik, C. J., Barford, C. C., Paltsev, S., Reilly, J. M., 2011. “Contribution of Anaerobic Digesters to Emissions Mitigation and Electricity Generation Under U.S. Climate Policy”. *Environmental Science Technology* 2011, 45, 6735–6742. [dx.doi.org/10.1021/es104227y](https://doi.org/10.1021/es104227y). American Chemical Society.
- Zhang, Q., Yang, L., Ma, C., Zhang, Y., Wu, L., Mao, H., 2020. “Emission characteristics and chemical composition of particulate matter emitted by typical non-road construction machinery”. *Atmospheric Pollution Research*, 11 (2020) 679-685. DOI: 10.1016/j.apr.2019.12.018
- Zhao Y., Hu J., Tan Z., Liu T., Zeng W., Li X., Ma W. , 2019. “Ambient carbon monoxide and increased risk of daily hospital outpatient visits for respiratory diseases in Dongguan, China”. *Science of The Total Environment*. 668 (2019), 254-260. doi:10.1016/j.scitotenv.2019.02.3.

ANNEXURE 6.1: FIXED COST FOR RUNNING AND IDLE DEPARTMENTAL VEHICLES

A.6.1.1 Fixed Cost per Vehicle (for running condition) for 11 m³ Pay-Loader Loaded Tipper Trucks:

Number of Tipper truck of 11 m³ in total = 28; in operation vehicle = 20; Number of Pay loader in total = 10. Pay loader to Tipper truck Ratio = 10:28 i.e. (10/28) = 0.35

Pay loaders are used for each Tipper Truck is 0.4 (Assumed).

- (A) Depreciation (10% of the capital cost is assumed for scrap value) = Rs [0.4 (50,00,000 – 5,00,000) + (20,00,000 – 2,00,000)] / 10 = Rs 3,82,000. [Vehicle life is considered to be ten years.].
- (B) Interest @ 10% on reducing loan = [(50,00,000 x 0.1 x 0.4) / (1 + 0.1)¹⁰-1] + [(22,00,000 x 0.1) / (1 + 0.1)¹⁰-1] = Rs 2,63,508.
- (C) Wages for 1.4 drivers and 1.4 assistants (40% from payloader) = 1.3 x {0.4 (27000 + 18000) + (27000 + 18000)} x 12 = Rs 9,82,800. [30% overtime allowances are represented by the multiplication ratio of 1.3] [Working time (6.00 A.M. to 4.00 P.M); regular duty 8 hrs + 2 to 2.5 hrs extra i.e. 30% overtime]
- (D) Wages of garage staff including managerial and administrative = 2 (numbers per vehicle) x 1.4 (40% increase due to Pay loader) x Rs 27000 x 12 = Rs 9,07,200. [Two numbers of personnel includes managerial and administrative staff, standby drivers and contractual labour force (if any)]
- (E) Annual operational and maintenance (O&M) cost = 10% of capital cost = Rs 4,20,000 [Rs (22,00,000 + 50,00,000 x 0.4) x 0.1] [40% due to Pay loader]
- (F) Total cost per annum (including depreciation and interest) per running vehicle = [(A) + (B) + (C) + (D) + (E)] = Rs. 29,55,508.
- (G) Consider the uncertainty factor as 1.1 for futuristic and realistic consideration.
- (H) Total cost per day per running vehicle = Rs [(29,55,508 x 1.1)/ 365] = Rs 8,907.01/-

A.6.1.2 Fixed Cost per Vehicle (for idle condition) for 11 m³ Pay-loader Loaded Tipper Trucks:

Number of Tipper truck of 11 m³ in total = 28; in operation vehicle = 20; Number of Pay loader in total = 10. Pay loader to Tipper truck Ratio = 10:28 i.e. (10/28) = 0.35

Pay loaders are used for each Tipper Truck is 0.4 (Assumed).

- (A) Depreciation (10% of the capital cost is assumed for scrap value) = Rs [0.4 (50,00,000 – 5,00,000) + (20,00,000 – 2,00,000)] / 10 = Rs 3,82,000. [Vehicle life is considered to be ten years].
- (B) Interest @ 10% on reducing loan = [(50,00,000 x 0.1 x 0.4) / (1 + 0.1)¹⁰-1] + [(22,00,000 x 0.1) / (1 + 0.1)¹⁰-1] = Rs 2,63,508.
- (C) Wages for 1.4 drivers and 1.4 assistants (40% from payloader) = 1.3 x {0.4 (27000 + 18000) + (27000 + 18000)} x 12 = Rs 9,82,800. [30% overtime allowances are represented by the multiplication ratio of 1.3] [Working time (6.00 A.M. to 4.00 P.M); regular duty 8 hrs + 2 to 2.5 hrs extra i.e. 30% overtime]
- (D) Wages of garage staff including managerial and administrative = 2 (numbers per vehicle) x 1.4 (40% increase due to Pay loader) x Rs 27000 x 12 = Rs 9,07,200. [Two numbers of personnel includes managerial and administrative staff, standby drivers and contractual labour force (if any)]
- (E) Annual operational and maintenance (O&M) cost = 10% of capital cost = Rs 4,20,000 [Rs (22,00,000 + 50,00,000 x 0.4) x 0.1] [40% due to Pay loader]
- (F) Total cost per annum (including depreciation and interest) per running vehicle = [(A) + (B) + (C) + (D) + (E) – (C)] = Rs. 19,72,708.
- (G) Consider the uncertainty factor as 1.1 for futuristic and realistic consideration.
- (H) Total cost per day per running vehicle = Rs [(19,72,708 x 1.1)/ 365] = Rs 5,945.15/-

A.6.1.3 Fixed Cost per Vehicle (for running condition) for 10.5 m³ Stationary Compactor:

245 numbers of stationery compactors to be placed at 131 compactor station. Each compactor reduces 30% waste volume by applying 140 bar pressure. The cost of each compactor is Rs. 17,00,000. In order to transport these stationary compactors to Dhapa,

KMC is also obtaining 80 hook loaders. Each hook loader costs Rs. 30,00,000 and can only move one stationary compactor at a time. A maximum of 4 stationary compactors can be hauled to the disposal site each day by one hook loader. This type of stationary compactor-hook loader combo requires one driver, one helper, one security staff member, and one operator-cum-sweeper (the latter two are contractual labour forces assigned to a compactor station). 18 hook-loaders are idle and 62 are in operation at any given time. Similarly, 60 containers are idle and 240 are in use at any given time.

- (A) Depreciation (10% of the capital cost is assumed for scrap value) = Rs $[(30,00,000 - 3,00,000) + 4 (17,00,000 - 1,70,000)] / 10$ = Rs 8,82,000 [Vehicle life is considered to be ten years].
- (B) Interest @ 10% on reducing loan = $[(30,00,000 \times 0.1) / (1 + 0.1)^{10} - 1] + [(17,00,000 \times 0.1 \times 4) / (1 + 0.1)^{10} - 1]$ = Rs 6,14,852.
- (C) Wages of 1 driver and 1 helper = $1.3 \times (27000 + 18000) \times 12$ = Rs 7,02,000. [30% overtime allowances are represented by the multiplication ratio of 1.3] [Working time (6.00 A.M. to 4.00 P.M); regular duty 8 hrs + 2 to 2.5 hrs extra i.e. 30% overtime]
- (D) Wages of garage staff including managerial and administrative = 2 (numbers per vehicle) $\times$ Rs 27000 $\times$ 12 = Rs 6,48,000. [Two numbers of personnel includes managerial and administrative staff, standby drivers and contractual labour force (if any)]
- (E) Annual operational and maintenance (O&M) cost = 10% of capital cost = Rs 9,80,000 [Rs $(30,00,000 + 17,00,000 \times 4) \times 0.1$]
- (F) Total cost per annum (including depreciation and interest) per running vehicle = $[(A) + (B) + (C) + (D) + (E)]$ = Rs 38,26,852.
- (G) Consider the uncertainty factor as 1.1 for futuristic and realistic consideration.
- (H) Total cost per day per running vehicle = Rs $[(38,26,852 \times 1.1) / 365]$ = Rs 11,532.98/-

A.6.1.4 Fixed Cost per Vehicle (for idle condition) for 10.5 m³ Stationary Compactor:

- (A) Depreciation (10% of the capital cost is assumed for scrap value) = Rs $[(30,00,000 - 3,00,000) + 2.5 (17,00,000 - 1,70,000)] / 10 = \text{Rs } 6,52,500$ [Vehicle life is considered to be ten years].
- (B) Interest @ 10% on reducing loan = $[(30,00,000 \times 0.1) / (1 + 0.1)^{10} - 1] + [(17,00,000 \times 0.1 \times 2.5) / (1 + 0.1)^{10} - 1] = \text{Rs } 4,55,975$.
- (C) Wages of 1 driver and 1 helper = $1.3 \times (27000 + 18000) \times 12 = \text{Rs } 7,02,000$. [30% overtime allowances are represented by the multiplication ratio of 1.3] [Working time (6.00 A.M. to 4.00 P.M); regular duty 8 hrs + 2 to 2.5 hrs extra i.e. 30% overtime]
- (D) Wages of garage staff including managerial and administrative = 2 (numbers per vehicle) $\times \text{Rs } 27000 \times 12 = \text{Rs } 6,48,000$. [Two numbers of personnel includes managerial and administrative staff, standby drivers and contractual labour force (if any)]
- (E) Annual operational and maintenance (O&M) cost = 10% of capital cost = Rs 7,25,000 [Rs $(30,00,000 + 17,00,000 \times 2.5) \times 0.1$]
- (F) Total cost per annum (including depreciation and interest) per running vehicle = $[(A) + (B) + (C) + (D) + (E) - (C)] = \text{Rs } 24,81,475$.
- (G) Consider the uncertainty factor as 1.1 for futuristic and realistic consideration.
- (H) Total cost per day per running vehicle = Rs $[(24,81,475 \times 1.1) / 365] = \text{Rs } 7,478.42/-$

A.6.1.5 Fixed Cost per Vehicle (for running condition) for 14 m³ Movable Compactor:

KMC is now operating 95 Movable Compactors with a capacity of 14 m³ (10 MT), 80 of which run daily and 15 on standby. Compactors can reduce waste volume by 30% at 140 bar pressure. Waste from handcarts/skips is deposited into these compactors, which then transport the waste to the disposal site. In the Trip Cart system, the compactor collects waste from six 4.5 m³ capacity skips; in the Bin Cart system, rubbish is collected from any roadside bin/handcart. Each movable compactor costs Rs. 38,00,000, and requires one driver and one assistant.

- (A) Depreciation (Assume scrap value 10% of capital cost) = Rs $[(38,00,000 - 3,80,000)] / 10$ = Rs 3,42,000 [Life of vehicle is considered as 10 years].
- (B) Interest @ 10% on reducing loan = $[(38,00,000 \times 0.1) / (1 + 0.1)^{10} - 1]$ = Rs 2,38,412
- (C) Wages of 1 driver and 1 helper = $1.3 \times (27000 + 18000) \times 12$ = Rs 7,02,000
[Multiplication factor 1.3 means 30% overtime allowances] [Working time (6.00 A.M. to 4.00 P.M); regular duty 8 hrs + 2 to 2.5 hrs extra i.e. 30% overtime]
- (D) Wages of garage staff including managerial and administrative = 2 (numbers per vehicle) $\times$ Rs 27000 $\times$ 12 = Rs 6,48,000 [Two numbers of personnel includes managerial and administrative staff, standby drivers and contractual labour force (if any)]
- (E) Annual operational and maintenance (O&M) cost = 10% of capital cost = Rs. 3,80,000.
- (F) Total cost per annum (including depreciation and interest) per running vehicle = [(A) + (B) + (C) + (D) + (E)] = Rs 23,10,412
- (G) Consider the uncertainty factor as 1.1 for futuristic and realistic consideration.
- (H) Total cost per day per running vehicle = Rs $[(23,10,412 \times 1.1) / 365]$ = Rs 6,962.89/-

A.6.1.6 Fixed Cost per Vehicle (for idle condition) for 14 m³ Movable Compactor:

- (A) Depreciation (Assume scrap value 10% of capital cost) = Rs. $[(38,00,000 - 3,80,000)] / 10$ = Rs. 3,42,000 [Life of vehicle is considered as 10 years].
- (B) Interest @ 10% on reducing loan = $[(38,00,000 \times 0.1) / (1 + 0.1)^{10} - 1]$ = Rs. 2,38,412
- (C) Wages of 1 driver and 1 helper = $1.3 \times (27000 + 18000) \times 12$ = Rs. 7,02,000
[Multiplication factor 1.3 means 30% overtime allowances] [Working time (6.00 A.M. to 4.00 P.M); regular duty 8 hrs + 2 to 2.5 hrs extra i.e. 30% overtime]
- (D) Wages of garage staff including managerial and administrative = 2 (numbers per vehicle) $\times$ Rs 27000 $\times$ 12 = Rs. 6,48,000 [Two numbers of personnel includes managerial and administrative staff, standby drivers and contractual labour force (if any)]
- (E) Annual operational and maintenance (O&M) cost = 10% of capital cost = Rs. 3,80,000.

- (F) Total cost per annum (including depreciation and interest) per running vehicle = [(A) + (B) + (C) + (D) + (E) - (C)] = Rs. 16,08,412
- (G) Consider the uncertainty factor as 1.1 for futuristic and realistic consideration.
- (H) Total cost per day per running vehicle = Rs. [(16,08,412 x 1.1) / 365] = Rs. 4,847.26/-

A.6.1.7 Fixed Cost per Vehicle (for running condition) for 8 m³ Movable Compactor:

KMC is now operating three Movable Compactors with a capacity of 8 m³ (7 MT), two of which are operational and one is idle. When operated at 140 bar pressure, these compactors may reduce waste volume by 30%. Handcart/skip garbage is disposed of into these compactors, which then transport the compacted waste to the landfill. Each moveable compactor costs Rs. 30,00,000 and requires 1 driver and 1 assistant. This movable compactor is capable of collecting waste from narrow roads and alleys.

- (A) Depreciation (10% of the capital cost is assumed for scrap value) = Rs. [(30,00,000 – 3,00,000)] / 10 = Rs. 2,70,000 [Vehicle life is considered to be ten years].
- (B) Interest @ 10% on reducing loan = [(30,00,000 x 0.1) / (1 + 0.1)¹⁰ - 1] = Rs. 1,88,236
- (C) Wages of 1 driver and 1 helper = 1.3 x (27000 + 18000) x 12 = Rs. 7,02,000 [Multiplication factor 1.3 means 30% overtime allowances] [Working time (6.00 A.M. to 4.00 P.M); regular duty 8 hrs + 2 to 2.5 hrs extra i.e. 30% overtime]
- (D) Wages of garage staff including managerial and administrative = 2 (numbers per vehicle) x Rs 27000 x 12 = Rs. 6,48,000 [Two numbers of personnel includes managerial and administrative staff, standby drivers and contractual labour force (if any)]
- (E) Annual operational and maintenance (O&M) cost = 10% of capital cost = Rs. 3,00,000
- (F) Total cost per annum (including depreciation and interest) per running vehicle = [(A) + (B) + (C) + (D) + (E)] = Rs. 21,08,236
- (G) Consider the uncertainty factor as 1.1 for futuristic and realistic consideration.
- (H) Total cost per day per running vehicle = Rs. [(21,08,236 x 1.1) / 365] = Rs. 6,353.49/-

A.6.1.8 Fixed Cost per Vehicle (for idle condition) for 8 m³ Movable Compactor:

- (A) Depreciation (10% of the capital cost is assumed for scrap value) = Rs. $[(30,00,000 - 3,00,000)] / 10$ = Rs. 2,70,000 [Vehicle life is considered to be ten years].
- (B) Interest @ 10% on reducing loan = $[(30,00,000 \times 0.1) / (1 + 0.1)^{10} - 1]$ = Rs. 1,88,236
- (C) Wages of 1 driver and 1 helper = $1.3 \times (27000 + 18000) \times 12$ = Rs. 7,02,000
[Multiplication factor 1.3 means 30% overtime allowances] [Working time (6.00 A.M. to 4.00 P.M); regular duty 8 hrs + 2 to 2.5 hrs extra i.e. 30% overtime]
- (D) Wages of garage staff including managerial and administrative = 2 (numbers per vehicle) $\times$ Rs 27000 $\times$ 12 = Rs. 6,48,000 [Two numbers of personnel includes managerial and administrative staff, standby drivers and contractual labour force (if any)]
- (E) Annual operational and maintenance (O&M) cost = 10% of capital cost = Rs. 3,00,000
- (F) Total cost per annum (including depreciation and interest) per running vehicle = $[(A) + (B) + (C) + (D) + (E) - (C)]$ = Rs. 14,06,236
- (G) Consider the uncertainty factor as 1.1 for futuristic and realistic consideration.
- (H) Total cost per day per running vehicle = Rs. $[(14,06,236 \times 1.1) / 365]$ = Rs. 4,237.97/-

ANNEXURE 6.2: SAMPLE CALCULATION FOR FUEL COST OF DEPARTMENTAL VEHICLES

Annexure 6.2.1: Sample Calculation for Fuel Cost of Departmental Vehicle, DV1 type, Carrying Waste from Borough 1 to Dhapa Landfill site:

Distance of Dhapa landfill site from Borough-I is 10.92 km (Table 6.1).

Average waste carrying capacity of DV1 type vehicle is 7 MT (Table 6.6).

Fuel consumption in loaded and unloaded condition of DV1 vehicle is 1.67 km/L and 2.33 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

Therefore, Fuel charge per km for loaded and unloaded condition:

For loaded condition = $(1/1.67) \times 92.76 = \text{Rs. } 55.545$ (Table 6.6); and

For unloaded condition = $(1/2.33) \times 92.76 = \text{Rs. } 39.811$ (Table 6.6)

The total distance travelled by DV1 type vehicle per trip = $10.92 \times 2 = 21.84$ km.

Average fuel charge for total distance per trip = $[(55.545 + 39.811)/2] = 47.678$ Rs./km

Hence, Fuel cost of DV1 per MT of waste = $[(47.678 \times 21.84)/7] = 148.755$ Rs./MT of waste (Table 6.7)

Annexure 6.2.2: Sample Calculation for Fuel Cost of Departmental Vehicle, DV2 type, Carrying Waste from Borough 2 to Dhapa Landfill site:

Distance of Dhapa landfill site from Borough 2 is 8.74 km (Table 6.1).

Average waste carrying capacity of DV2 type vehicle is 9 MT (Table 6.6).

Fuel consumption in loaded and unloaded condition of DV2 vehicle is 1.43 km/L and 1.67 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

Therefore, Fuel charge per km for loaded and unloaded condition:

For loaded condition = $(1/1.43) \times 92.76 = \text{Rs. } 64.867$ (Table 6.6); and

For unloaded condition = $(1/1.67) \times 92.76 = \text{Rs. } 55.545$ (Table 6.6)

The total distance travelled by DV2 type vehicle per trip = $8.74 \times 2 = 17.48$ km.

Average fuel charge for total distance per trip = $[(64.867 + 55.545)/2] = 60.205$ Rs./km

Hence, Fuel cost of DV2 per MT of waste = $[(60.205 \times 17.48)/9] = 116.933$ Rs./MT of waste (Table 6.7)

Annexure 6.2.3: Sample Calculation for Fuel Cost of Departmental Vehicle, DV3 type, Carrying Waste from Borough 3 to Dhapa Landfill site:

Distance of Dhapa landfill site from Borough 3 is 7.03 km (Table 6.1).

Average waste carrying capacity of DV3 type vehicle is 10 MT (Table 6.6).

Fuel consumption in loaded and unloaded condition of DV3 vehicle is 0.909 km/L and 1.11 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

Therefore, Fuel charge per km for loaded and unloaded condition:

For loaded condition = $(1/0.909) \times 92.76 = \text{Rs. } 102.046$ (Table 6.6); and

For unloaded condition = $(1/1.11) \times 92.76 = \text{Rs. } 83.568$ (Table 6.6)

The total distance travelled by DV3 type vehicle per trip = $7.03 \times 2 = 14.06$ km.

Average fuel charge for total distance per trip = $[(102.046 + 83.568)/2] = 92.807$ Rs./km

Hence, Fuel cost of DV3 per MT of waste = $[(92.807 \times 14.06)/10] = 130.486$ Rs./MT of waste (Table 6.7)

Annexure 6.2.4: Sample Calculation for Fuel Cost of Departmental Vehicle, DV4 type, Carrying Waste from Borough 4 to Dhapa Landfill site:

Distance of Dhapa landfill site from Borough 4 is 7.67 km (Table 6.1).

Average waste carrying capacity of DV4 type vehicle is 7 MT (Table 6.6).

Fuel consumption in loaded and unloaded condition of DV4 vehicle is 1.25 km/L and 1.67 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

Therefore, Fuel charge per km for loaded and unloaded condition:

For loaded condition = $(1/1.25) \times 92.76 = \text{Rs. } 74.208$ (Table 6.6); and

For unloaded condition = $(1/1.67) \times 92.76 = \text{Rs. } 55.545$ (Table 6.6)

The total distance travelled by DV4 type vehicle per trip = $7.67 \times 2 = 15.34$ km.

Average fuel charge for total distance per trip = $[(74.208 + 55.545)/2] = 64.877$ Rs./km

Hence, Fuel cost of DV4 per MT of waste = $[(64.877 \times 15.34)/7] = 142.172$ Rs./MT of waste (Table 6.7)

ANNEXURE 6.3: SAMPLE CALCULATION FOR POLLUTANT EMISSION BY DEPARTMENTAL VEHICLE DV1 PER TON OF GARBAGE PER TRIP TO DHAPA LANDFILL (G/T/TRIP)

Annexure 6.3.1: Sample Calculation for CO Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to Dhapa Landfill (g/t/trip)

Weighted average emission factor for CO = 4.25 g/km (Table 6.11); Distance of Dhapa landfill site from Borough 1 is 10.92 km (Table 6.1).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km. Hence, CO generation = $4.25 \times 21.84 = 92.82$ g/trip

CO generation rate per MT of waste = $92.82 / 7 = 13.260$ g/t/trip (Table 6.12)

Annexure 6.3.2: Sample Calculation for CO₂ Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to Dhapa Landfill (g/t/trip)

From Annexure 6.3.1, Total distance travelled per trip = $10.92 \times 2 = 21.84$ km and average fuel consumption of DV1 type vehicle is 2 km/L.

Total fuel consumption = $[21.84 / (2 \times 7)] = 1.56$ L/trip/MT; Fuel density is 820 kg/m³ and % carbon present in fuel = 87%.

Therefore, total fuel consumption = $[(1.56 \times 820) / 1000] = 1.2792$ kg/MT of waste/trip = 1279.2 g/t/trip

Carbon in CO = $13.26 \times 12/28 = 5.683$ g/t/trip

Carbon remaining = $(1279.2 \times 0.87) - 5.683 = 1107.221$ g/t/trip

CO₂ emission rate per MT of waste per trip = $1107.221 \times 44/12 = 4059.810$ g/t/trip
(Table 6.12)

Annexure 6.3.3: Sample Calculation for SO₂ Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to Dhapa Landfill (g/t/trip)

From Annexure 6.3.1, Total distance travelled per trip = $10.92 \times 2 = 21.84$ km and average fuel consumption of DV1 type vehicle is 2 km/L.

Total fuel consumption = $[21.84 / (2 \times 7)] = 1.56$ L/trip/MT; Fuel density is 820 kg/m³ and % sulphur present in fuel = 0.035%.

Therefore, total fuel consumption = $[(1.56 \times 820) / 1000] = 1.2792$ kg/MT of waste/trip
= 1279.2 g/t/trip

SO₂ emission rate per MT of waste per trip = $[(1279.2 \times 0.035 \times 64) / (100 \times 32)] = 0.895$ g/t/trip (Table 6.12)

Annexure 6.3.4: Sample Calculation for NO_x Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to Dhapa Landfill (g/t/trip)

Weighted average emission factor for NO_x = 7.557 g/km (Table 6.11); Distance of Dhapa landfill site from Borough 1 is 10.92 km (Table 6.1).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km. Hence, NO_x generation = $7.557 \times 21.84 = 165.045$ g/trip

NO_x generation rate per MT of waste = $165.045/7 = 23.580$ g/t/trip (Table 6.12)

Annexure 6.3.5: Sample Calculation for HC Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to Dhapa Landfill (g/t/trip)

Weighted average emission factor for HC = 1.162 g/km (Table 6.11); Distance of Dhapa landfill site from Borough 1 is 10.92 km (Table 6.1).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km. Hence, HC generation = $1.162 \times 21.84 = 25.378$ g/trip

HC generation rate per MT of waste = $25.378/7 = 3.625$ g/t/trip (Table 6.12)

Annexure 6.3.6: Sample Calculation for PM Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to Dhapa Landfill (g/t/trip)

Weighted average emission factor for PM = 0.684 g/km (Table 6.11); Distance of Dhapa landfill site from Borough 1 is 10.92 km (Table 6.1).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km. Hence, PM generation = $0.684 \times 21.84 = 14.939$ g/trip

PM generation rate per MT of waste = $14.939/7 = 2.134$ g/t/trip (Table 6.12)

Annexure 6.3.7: Sample Calculation for Benzene Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to Dhapa Landfill (g/t/trip)

Weighted average emission factor for BENZ = 0.0058 g/km (Table 6.11); Distance of Dhapa landfill site from Borough 1 is 10.92 km (Table 6.1).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km. Hence, benzene generation = $0.0058 \times 21.84 = 0.1267$ g/trip

Benzene generation rate per MT of waste = $0.1267/7 = 0.0018$ g/t/trip (Table 6.12)

Annexure 6.3.8: Sample Calculation for Butadiene Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to Dhapa Landfill (g/t/trip)

Weighted average emission factor for BUTDN = 0.0011 g/km (Table 6.11); Distance of Dhapa landfill site from Borough 1 is 10.92 km (Table 6.1).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km. Hence, butadiene generation = $0.0011 \times 21.84 = 0.024$ g/trip

Butadiene generation rate per MT of waste = $0.024/7 = 0.003$ g/t/trip (Table 6.12)

ANNEXURE 6.4: CALCULATION FOR THE VOLUME OF DIFFERENT GASES GENERATED FROM DEGRADATION OF WASTE

Organic materials present in municipal solid wastes of Kolkata can be divided into two parts (1) rapidly bio-degradable materials (three months to five years) and (2) slowly bio degradable materials (up to fifty years or more).

Annexure 6.4.1: Sample Calculation for the Volume of Different Gases Generated from Degradation of RBW and Percentage of Generated Gases

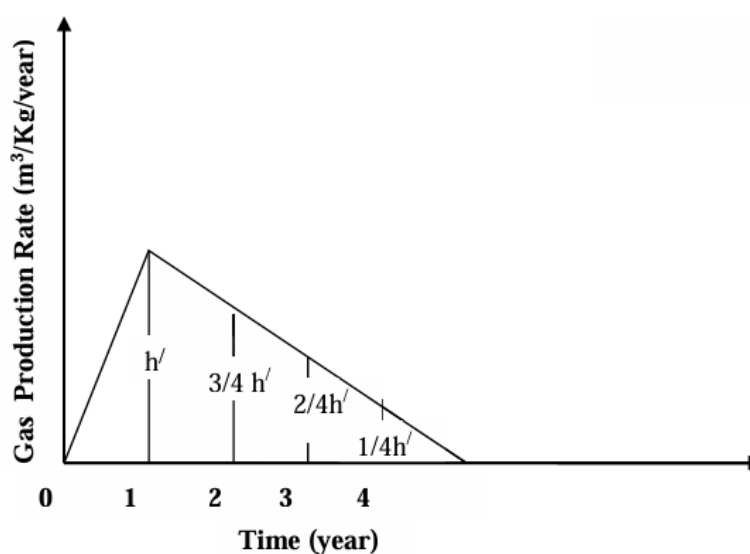


Figure- A-6.1: Gas production over five year period from RBW

For RBW, the volume of different gases generated from degradation of RBW is as follows: At 25°C, volume of CH_4 = $[(256.42 \times 14.91) / (0.7167 \times 706.83)] \times [(273 + 25) / 273] = 8.25 \text{ m}^3$

At 25°C, volume of CO₂ = $[(612.645 \times 14.91) / (1.9768 \times 706.83)] \times [(273 + 25) / 273] = 7.15 \text{ m}^3$

At 25°C, volume of NH₃ = $[(17 \times 14.91) / (0.7708 \times 706.83)] \times [(273 + 25) / 273] = 0.509 \text{ m}^3$

At 25°C, volume of H₂S = $[(3.06 \times 14.91) / (1.5392 \times 706.83)] \times [(273 + 25) / 273] = 0.046 \text{ m}^3$

Total volume of gas from RBW = 15.955 m³

Volume of gas per Kg dry weight of RBW = $15.955 / 14.91 = 1.07 \text{ m}^3/\text{Kg}$ of dry wt. of RBW

Annexure 6.4.2: Sample Calculation for the Volume of Different Gases Generated from Degradation of SBW And Percentage Of Generated Gases

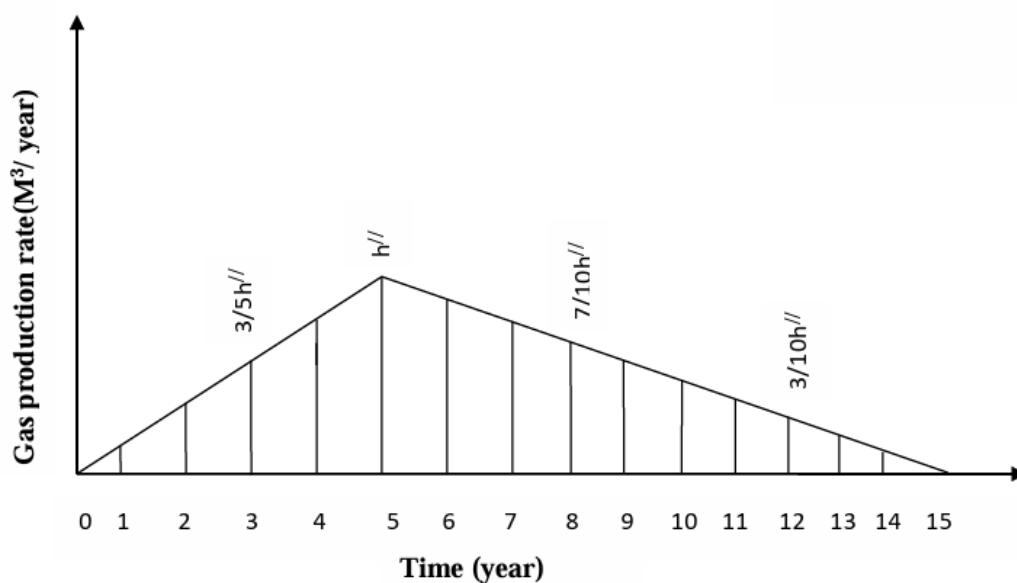


Figure- A-6.2: Gas production over fifteen year period from SBW

For SBW, the volume of different gases generated from degradation of SBW is as follows: At 25°C, volume of CH₄ = $[(296.16 \times 5.503) / (0.7167 \times 781.10)] \times [(273 + 25) / 273] = 3.18 \text{ m}^3$

At 25°C, volume of CO₂ = $[(708.84 \times 5.503) / (1.9768 \times 781.1)] \times [(273 + 25) / 273] = 2.76 \text{ m}^3$

At 25°C, volume of NH₃ = $[(17 \times 5.503) / (0.7708 \times 781.10)] \times [(273 + 25) / 273] = 0.170 \text{ m}^3$

At 25°C, volume of H₂S = $[(3.06 \times 5.503) / (1.5392 \times 781.10)] \times [(273 + 25) / 273] = 0.005 \text{ m}^3$

Total volume of gas from RBW = 6.115 m³

Volume of gas per Kg dry weight of RBW = $6.115 / 5.503 = 1.11 \text{ m}^3/\text{Kg}$ of dry wt. of SBW

ANNEXURE 6.5: SAMPLE CALCULATION FOR CUMULATIVE CH₄ GAS GENERATION, OVER A PERIOD OF 35 YEARS

Total Gas generation rate in the year 1988 = 0.024368 m³/ kg of total waste

Total waste generation in the year 1988 = $8.23 \times 10^5 \text{ MT}$

Total gas generation in the year 1988 = $(8.23 \times 10^8 \text{ kg} \times 0.024368 \text{ m}^3/\text{kg}) = 20054864 \text{ m}^3$

Total methane generation = $(20054864 \text{ m}^3 \times 0.5) = 10027432 \text{ m}^3/\text{year}$

$1 \text{ m}^3/\text{year} = 6.67148 \times 10^{-4} \text{ MT}/\text{year}$

Total methane generation in the year 1988 = $(10027432 \times 6.67148 \times 10^{-4}) = 6689.8 \text{ MT}/\text{year}$. So, total methane generation from the year 1987 to 2011 = 12, 27,014 MT,

Total methane entrapment from the year 1987 to 2011 = 1, 73.871 MT

Considering 50% recovery for open disposal site, total 86,936 MT can be recovered upto year 2021 i.e. 10 years post closure.

ANNEXURE 6.6: CALCULATION FOR LEACHATE GENERATION PER TON OF WASTE

Considering total waste generation as 4000 MT/day and total disposable area is 34.47 ha. Assume, average leachate generation = 1000 L/m²/yr and the compacted density of waste is 1000 kg/m³.

Assuming that the total waste generated in a year is uniformly spread over the entire area. Therefore, landfill area required = $[(34.47 \times 10^4) / (4000 \times 365)] = 0.236 \text{ m}^2/\text{MT}/\text{day}$.

Considering temporary road material for landfill, uneven landfill height and poor solid waste management in the dumpsite, area required per ton of waste is 1 m²/MT/day.

Leachate generation rate per ton of waste = $(1000 \times 1) / 365 = 2.734 \text{ L}/\text{MT}$ of waste

ANNEXURE 6.7: CALCULATION FOR EQUIVALENCY FACTOR OF PHENOL FOR ATP

Sample Calculation:

Equivalency factor based on TPBP (EPA, 1998) is defined as:

$$EF = HV_{\text{toxicity}} \times (HV_{\text{BOD}} + HV_{\text{HYD}} + HV_{\text{BCF}})$$

Where, HV_{toxicity} is toxicity hazard value for LC₅₀ or LD₅₀ whichever is applicable, calculated following the procedural steps shown in figure 6.4;

HV_{BOD} is biological oxygen demand hazard value, calculated from BOD half-life following the procedural steps shown in figure 6.5. The BOD half-life is the number of days needed for a chemical to biodegrade to the point where its BOD in water is reduced to half of what it was initially.

HV_{HYD} is hydrolysis hazard value, calculated from Hydrolysis half-life following the procedural steps shown in figure 6.6. Hydrolysis half-life is the time required in days for the amount of substance to decrease to half of the original amount through hydrolysis reaction in water at pH 7.

HV_{BCF} is bio-concentration factor hazard value, calculated from Aquatic Bio-concentration factor following the procedural steps shown in figure 6.7. Bio-concentration factor is a measure of a chemical's ability to bio-accumulate and is defined as the ratio of a chemical in fish to its concentration in water at steady state condition.

ATP of phenol considering "Toxicity, Persistence and Bioaccumulation Profile" can be estimated as follows:

LC_{50} fish for phenol = 34 mg/l (EPA, 1994c)

So, $HV_{\text{toxicity}} = -1.67 \times \log LC_{50} + 5.0 = -1.67 \times \log (34) + 5.0 = 2.4$

BOD half-life = 9 days (EPA, 1994c)

So, $HV_{BOD} = 0.311 \times \ln (\text{BOD half life}) + 0.568 = 0.311 \times \ln (9) + 0.568 = 1.25$

Hydrolysis half-life = 1000 days > 500 days (EPA, 1994c)

So, $HV_{HYD} = 2.5$

$\log BCF = 0.6 < 1.0$ (EPA, 1994c)

So, $HV_{BCF} = 1.0$

So, ATP of phenol: $ATP_{\text{PHENOL}} = HV_{\text{toxicity}} \times (HV_{BOD} + HV_{HYD} + HV_{BCF})$

$$= 2.4 \times (1.25 + 2.5 + 1.0) = 11.4$$

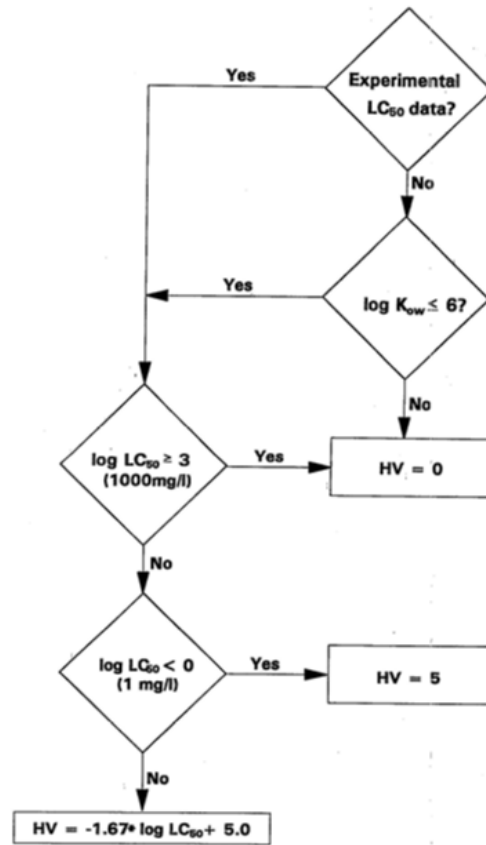


Figure- A.6.3: Decision tree for aquatic LC₅₀ hazard value (EPA, 1994c)

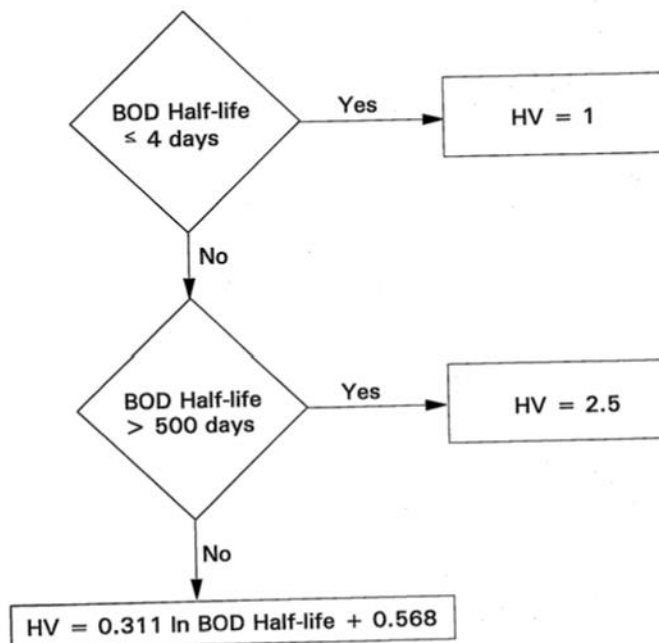


Figure- A.6.4: Decision tree for BOD half-life hazard value (EPA, 1994c)

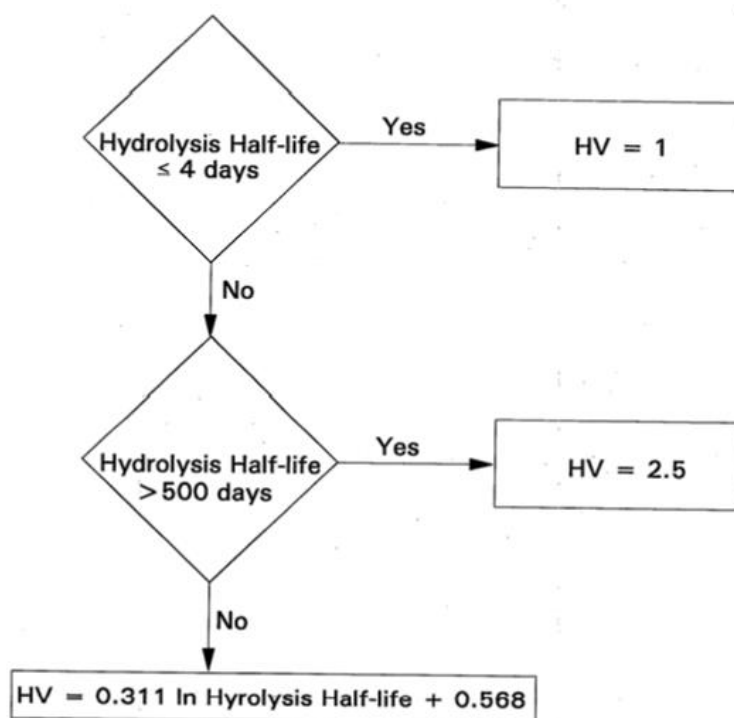


Figure- A.6.5: Decision tree for hydrolysis half-life hazard value (EPA, 1994c)

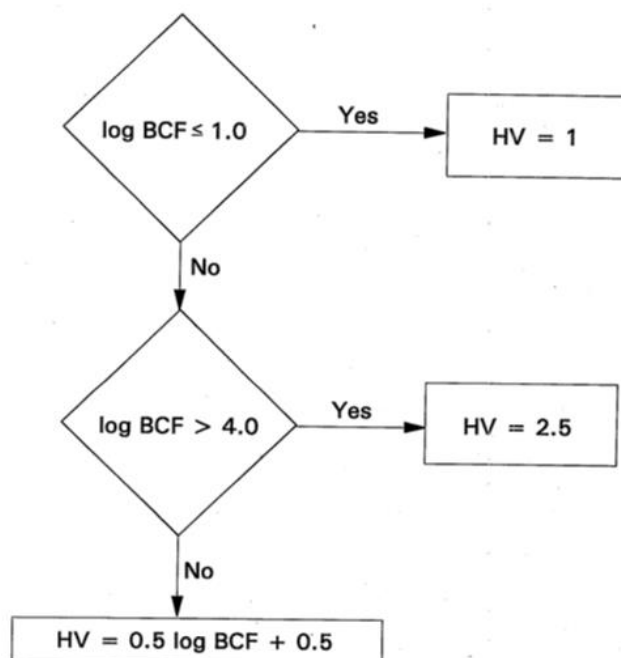


Figure- A.6.6: Decision tree for BCF hazard value (EPA, 1994c)

source: Chemical Hazard Evaluation Management Strategies: A Method For Ranking and Scoring Chemicals By Potential Human Health and Environmental Impacts.1994c, EPA /600/R-94/177, Office of Research and Development, Washington DC.

ANNEXURE 6.8: CALCULATION FOR EMISSION OF SO₂ IN WEST BENGAL REGION

From the *Urbanemissions.info*, the annual emission of SO₂ from all sectors of Kolkata and Asansol in the year 2018 reported 10,400 MT and 12700 MT respectively.

Ambient air concentration of SO₂ in Kolkata (K_a) = 8 ug/m³

Ambient air concentration of SO₂ in Asansol (A_a) = 13.5 ug/m³

Ref. (STATE ENVIRONMENT PLAN: WEST BENGAL)

Weightage Average of ambient air concentration = $[(K_A * K_a + A_A * A_a) / (K_A + A_A)]$
 $= [(185 * 8 + 326 * 13.6) / (185 + 326)] = 11.5 \dots (\text{Say X})$

Where, K_A and A_A are the area of Kolkata and Asansol respectively in km².

The same way, weightage avg. of all districts except Kolkata and Asansol = $(571710.5 / 81000) = 7.06 \dots (\text{Say Y})$

Where, 81,000 is the sum of area of all district except Kolkata and Asansol. From $(185 + 326)$ km² area, total emission is $(10400 + 12700)$ MT.

From total area 81000 km² area, total emission would be = $[(10400 + 12700) / (185 + 326)] \times 81000 \times (7.06 / 11.5) = 2248249$ MT

Total SO₂ emission from West Bengal = $(2248249 + 10400 + 12700)$ Mt/yr. = 22.7×10^8 kg/yr. From the emission data as on 2017-18, a 7.68% increased trend have been followed from all district in West Bengal (STATE ENVIRONMENT PLAN: WEST BENGAL). So, net SO₂ emission in 2022 = $22.7 \times 10^8 \times 1.0768 = 24.4 \times 10^8$ kg/yr.

ANNEXURE 6.9: CALCULATION FOR EMISSION OF NO₂ IN WEST BENGAL REGION

Region from the *Urbanemissions.info*, the annual emission of NO₂ from all sectors of Kolkata and Asansol in the year 2018 reported 143650 and 160350 MT respectively.

Ambient air concentration of NO₂ in Kolkata (K_a) = 42 ug/m³

Ambient air concentration of NO₂ in Asansol (A_a) = 41 ug/m³

Ref. (STATE ENVIRONMENT PLAN: WEST BENGAL)

Weightage Average of ambient air concentration = $[(K_A * K_a + A_A * A_a)/(K_A + A_A)]$
 $=[(185*42+326*41)/(185+326)]=41.36 \dots(\text{Say X})$

Where, K_A and A_A are the area of Kolkata and Asansol respectively in km^2 .

The same way, weightage avg. of all districts except Kolkata and Asansol = $(2479230.5/81000)=30.6 \dots\dots(\text{Say Y})$

Where, 81,000 is the sum of area of all district except Kolkata and Asansol. From $(185+326) \text{ km}^2$ area, total emission is $(143650+160350) \text{ MT}$.

From total area 81000 km^2 area, total emission would be = $[(143650+160350)/(185+326)] \times 81000 \times (30.6/41.36) = 34936203 \text{ MT}$

Total NO_2 emission from West Bengal = $(34936203+143650+160350) \text{ Mt/yr}$.
 $= 3.52 \times 10^{10} \text{ kg/yr}$.

From the vehicular growth data in West Bengal from 2018-22, a 15% increased trend have been followed. So, net NO_2 emission in 2022 = $3.52 \times 10^{10} \times 1.15 = 4.01 \times 10^{10} \text{ kg/yr}$.

ANNEXURE 6.10: CALCULATION FOR EMISSION OF CH_4 IN WEST BENGAL REGION

GHG emissions in the state of West Bengal estimated 171.7 Mt $\text{CO}_2\text{-e}$ in the year 2013 (GHG Platform, 2013). Assume 80% CO_2 and 20% CH_4 present in total GHG gas (Our World in Data).

Let, the amount of CO_2 is $x \text{ MT}$

So, $0.80x + 28x * 0.20 = 171.7$; (28= GWP of Methane) $x = 26.8 \text{ MT}$;

$\text{CH}_4 = 26.8 \times 0.20 = 5.36 \text{ MT}$

Growth rate of GHG emission is 5.19% CAGR

Time $n = 9$ years (from 2013 to 2022)

CH_4 emission in 2022 = $5.36(1+0.0519)^9 \text{ MT} = 0.845 \times 10^{10} \text{ kg}$

ANNEXURE 6.11: MAXIMUM FACILITY DISCHARGE CALCULATION FOR HTPI

The maximum and minimum concentrations of contributing chemicals are derived from De et. al., 2015), with the exception of sulphate, nitrate, fluoride, and cadmium. Sulphate, nitrate, fluoride, and cadmium concentrations are extracted from Dhapa landfill's on-site

leachate characterization data. It is assumed that the Dhapa landfill generates 1000 L/m²/yr of leachate. There are 24 hectares of area. The maximum facility discharge is computed and displayed in table A.6.1. The computation example is displayed below.

Table- A.6.1: Maximum facility discharge of liquid pollutants

Parameter	Conc. (mg/L)	Avg. Conc. (mg/L)	Leachate generation Rate (L/m ² /yr.)	Area (m ²)	Max. facility emission (kg/yr)
Cl	2103-6735	4419	1000	240000	1060560
NO ₃	8.472	8.472	1000	240000	2033.28
SO ₄	399.56	399.56	1000	240000	95894.4
Phenol	0.16-0.34	0.25	1000	240000	60
As	0.0045-0.07	0.03725	1000	240000	8.94
Cd	0.00625	0.00625	1000	240000	1.5
Cr	0.31-10.43	5.37	1000	240000	1288.8
Cu	0.14-0.68	0.41	1000	240000	98.4
Hg	0.21-2.65	1.43	1000	240000	343.2
Ni	0.23-0.77	0.5	1000	240000	120
Pb	0.37-1.06	0.715	1000	240000	171.6
Zn	1.18-25.14	13.16	1000	240000	3158.4
CN	0.024-0.035	0.0295	1000	240000	7.08
F	1.3	1.3	1000	240000	312
NH ₃ -N	168-4210	2189	1000	240000	525360

Sample Calculation: Maximum facility discharge for cadmium = (0.00625 x 1000 x 240000) x 10⁻⁶ kg/yr. = 1.5 kg/yr.

ANNEXURE 6.12: MAXIMUM FACILITY DISCHARGE CALCULATION OF SO₂, NO₂, AND CO₂ IN FARAKKA THERMAL POWER PLANT FOR HTPE.

Farakka is a 3-stage thermal generating facility powered by lignite that has a capacity of 2100 MW. The elements that make up lignite coal are as follows: 35% moisture, 0.54% sulphur, 41.7% carbon, 9.47% ash 2.61% hydrogen, 0.79% nitrogen and 9.9% oxygen.

Different available components of coal (Kg mole) are C= $41.7/12 = 3.475$ Kg mole, H₂= $2.61/2 = 1.305$ Kg mole, N₂= $0.79/28 = 0.028$ Kg mole, O₂= $9.90/32 = 0.309$ Kg mole.

O₂ is required with 20% excess air for coal combustion. (Ref: Optimal Combustion Processes - Fuel vs. Excess Air)

C (1 mole) + O₂ (1 mole) = CO₂ (1 mole)

H₂ (1 mole) + $\frac{1}{2}$ O₂ (0.5 mole) = H₂O (1 mole)

O₂ required including 20% excess air = $[(3.475 \times 1.2) + (1.305 \times 0.5 \times 1.2)] = 4.953$ Kg mole But already 0.309 Kg mole of O₂ is present in the fuel.

Then, O₂ required from the air= $4.953 - 0.309 = 4.644$ Kg mole

Considering the other part as N₂ in the air i.e., 78.8% of N₂ and 21.2% of O₂ only.

Hence, N₂ present in the air along with O₂= $78.8 \times (4.644/21.2) = 17.26$ Kg mole.

Air requirement:

$(21.2 \times 32/100)$ Kg of O₂ is equivalent to $[(0.212 \times 32) + (0.788 \times 28)] = 28.848$ Kg of air

Hence, (4.644×32) Kg of O₂ = $(28.848 \times 4.644 \times 32) / (0.212 \times 32) = 631.93$ Kg of air.

Again, 21.2 gm mole of O₂ = 100 mole of air = 22.4 x100 litre of air

4.644 Kg mole of O₂ equivalent to $(22.4 \times 100 \times 4.644 \times 100) / (21.2 \times 100) \text{ Nm}^3$ of air
= 490.69 Nm³ of air

Material Balance:

Table- A.6.2: Material balance for gas generation

Element/ component		Input			Output	
		Kg	M.W	Kg mole	Kg mole	Kg
Fuel	C	41.7	12	3.475	-	-
	H ₂	2.61	2	1.305	-	-
	N ₂	0.79	28	0.028	0.028	0.784
	O ₂	9.9	32	0.309	-	-
Air with 20% excess	O ₂	148.6	32	4.644	0.774	24.768
	N ₂	483.2	28	17.26	17.26	483.2
Flue Gas	H ₂ O	-	18	-	1.305	23.49
	CO ₂	-	44	-	3.475	152.9
Total		686.18 Kg			685.222	

Avg. molecular wt. of the flue gas with 20% excess air = $(685.222/22.843) = 29.99$

100 Kg of coal generates 685.222 Kg of flue gas = 685.222×10^3 gm of flue gas = $(685.222 \times 10^3/29.99)$ mole = 22848.3 mole = $(22848.3 \times 22.4/1000)$ Nm³ = 511.8 Nm³

Table- A.6.3: Farakka coal consumption and emission data (Pit et al., 2016).

Stage	Coal Consumption (MT)	Emission (mg/m ³)	
		SO _x	NO _x
1 st	6888666	303.7	331.3
2 nd	6888666	332.8	358.7
3 rd	2282719	346.3	377.7

100 Kg of coal generates 511.8 Nm³ of flue gas

6888666 MT of coal generates $= 3.526 \times 10^{10}$ Nm³ of flue gas

2282719 MT of coal generates $= 1.168 \times 10^{10}$ Nm³ of flue gas

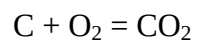
Total SO_x emission = $(3.526 \times 10^{10} \times 303.7 + 3.526 \times 10^{10} \times 332.8 + 1.168 \times 10^{10} \times 346.3) \times 10^{-6} = 26487774$ kg

$$\begin{aligned}\text{Total NO}_x \text{ emission} &= (3.526 \times 331.3 + 3.526 \times 358.7 + 1.168 \times 377.7) \times 10^4 \text{ kg} \\ &= 28740936 \text{ kg}\end{aligned}$$

$$\text{Total coal consumption} = (6888666 + 6888666 + 2282719) = 16060051 \text{ MT}$$

Carbon percentage in coal 41.7%

$$\text{Total Carbon in coal} = (160600051 \times 0.417) \text{ MT} = 6697041.3 \text{ MT}$$



$$\text{Total CO}_2 \text{ emission} = 6697041.3 \times (44/12) \text{ MT} = 2.456 \times 10^{10} \text{ kg}$$

ANNEXURE 7.1: OPERATIONAL AND MAINTENANCE COST OF COMPOSTING PLANT OF CAPACITY 700 TPD

Sl. No	Particulars	Quantity	Rate (Rs.)	Cost (Rs.) in lakh
1.	Cost of land (on lease basis)	25 acres (101171.5 m ²)	Rs. 1.1 per m ² /year rent	1.112/yr
2.	For machinery and plants		LS	770
3.	Civil works			
	For development of land including access road facility			39.6
	Shed for processing of waste			154
	Concrete yard			154
	For leachate collection and drainage for storm water			16.5
	For development of buffer zone and green and environmental requirements			22
	Store and office			55
	For water source and supply system including overhead reservoir etc.			11
			Sub total	452.1
4.	Fixed cost (Miscellaneous)			
	For commissioning, erection of plant and machinery			38.5
	For connection of power, electrical fittings and transformers			44
	For laboratory setup			16.5
	For office furniture and accessories			22
			Sub total	121
5.	Total capital cost of the project			1343.1
6.	MoEF can provide upto 50% subsidy on capital cost	Consider subsidy as 40%	(-)	537.24
7.	60% as bank loan			805.86
8.	Annualised capital cost considering 14% interest on loan amount yearly and 20 years tenure of repayment			

Sl. No	Particulars	Quantity	Rate (Rs.)	Cost (Rs.) in lakh
1.	Annual average O & M cost:			
	For culture			83.16
	Packing material			132.57
	Power			23.95
	Fuel			66.54
	Water			6.6
	Wages and salary			111.94
	Expenses for selling and marketing			55.24
	Expenses for administration			11.06
	Expenses for taxes, rent and insurance			55.25
	Maintenance and repair			33.14
	Rent for lease land			1.112
	Cost of transportation of process rejects etc. to landfill site			7.05
			Sub total	587.57

1.	Manpower required:			
	Manager	3	22000	0.66
	Marketing Officer	2	18700	0.374
	Clerk/Accountant	7	11000	0.77
	Plant Operator/Drivers	40	9350	3.74
	Mechanics/Electrician	10	9350	0.935
	Supervisor	5	7700	0.385
	Security	7	6600	0.462
	Skilled labourers	14	275	0.77
	Unskilled labourers	28	220	1.232
			Sub total	9.328

Annualised capital cost considering 14% interest on loan amount yearly and 20 years tenure of repayment	Rs. 1,21,67,358.00
Average annual maintenance and operation cost	Rs. 5,87,57,000.00
Average depreciation considering 5% on building, 10% on plant and machinery and 10% on fixed miscellaneous assets. Design period of the composting plant is 20 years, as considered.	Rs. 46,78,100.00
Cost of composting per MT of waste	Rs. 295.90

(Paul et al., 2019; Paul et al., 2020; Paul et al., 2018; Chattopadhyay, 2018)

ANNEXURE 7.2: OPERATIONAL AND MAINTENANCE COST OF INCINERATION PLANT

- Assumption and technical input:

Particulars	Values
Treatment capacity of MSW (TPD)	600
Design life of plant (years)	20
Requirement of land (acres)	9-10 / MW
Capacity of power generation	6 MW
Plant Load Factor (PLF) %	70%
Capital cost	Rs. 66 crores (Rs 10 million / MW)
Cost of land (assumed)	Rs. 0.44 crores
Operation and Maintenance (O & M) including cost of emission control	5 % of project cost per year with an escalation of 5.72 % per annum
Debt-Equity ratio	70:30 (based on financing norms given by IREDA)
Rate of interest	14
Repayment period (years)	20
Capital Subsidy from Ministry of New & Renewable Energy, (MNRE), Govt of India Minimum Rs 2 Crore, Maximum Rs. 10 Crore per project ²	10

Capital cost of the 600 TPD incinerator plant (including land) =	Rs. 60.44 Cr
MNRE subsidy =	Rs. 5 Cr
Bank loan =	Rs. 38.81 Cr
Promoter/ ULB investment (Equity) =	Rs. 16.63 Cr
Annualised capital cost considering 14% interest on loan amount yearly and 20 years tenure of repayment	Rs. 8.316 Cr

The following table provides an overview of the levelized cost of power generation for the Waste-to-Energy Mass-Burn Incinerator facility, depending on the inputs mentioned above:

Plant capacity	Annualised capital cost (including land cost)	Annual O & M cost (including rent, insurance premium, etc.)	Total levelised cost	Electric units (kWh) generated (assuming 6500 work-hours of operation per year i.e. 270 days)	Levelised unit cost of electricity (LUCE) generation	Tariff at which the power is being sold
	Rs. Cr	Rs. Cr	Rs. Cr	kwh	Rs. / kWh	Rs. / kWh
6.0 MW 600 TPD	8.316	3.96	12.276	$6.0 \times 1000 \times 6500 \times 0.70 = 27300000$	4.499	4.499

Total cost of waste-to-energy recovery in a mass-burn incinerator facility

$$= \text{Rs. } [(12.276 \times 10^7) / (600 \times 270)] = \text{Rs. } 757.9/\text{MT}$$

Total revenue obtained from the sale of electricity

$$= \text{Rs. } [(27300000 \times 4.499) / (600 \times 270)] = \text{Rs. } 757.9/\text{MT}$$

$$f = \text{kWh of electricity is generated by burning 1 MT of MSW} = [27300000 / (600 \times 270)]$$

$$= 170 \text{ (approx.)}$$

(Paul et al., 2019; Paul et al., 2020; Paul et al., 2018; Chattopadhyay, 2018)

ANNEXURE 7.3: OPERATIONAL AND MAINTENANCE COST OF ENGINEERED LANDFILL

Landfill site location	Type of land	Cost of land per acre (Rs./acre)	Total cost of 270 acres land for landfilling (Rs.)	Land cost per MT of waste (Rs./MT)	Capital cost (Rs./MT)	O & M cost (Rs./MT)	Total cost (Rs./MT)
East (at Noara, Bodura)	Double crop / Multicrop	9,68,032	26,13,68,640	13.75	165	38.5	217.25
North (at Akandaberia village, Haroa / Basirhat)	Double Crop / Multicrop + Rural Settlement	$0.5 \times (9,68,032 + 19,84,874) = 14,76,453$	39,86,42,310	21.054	165	38.5	224.554
South (at Kalicharanpur village, Nepalgunj)	Primarily agricultural, single crop	6,61,890	17,87,10,300	9.435	165	38.5	212.935

It assumed that waste generation is 5100 MT per day and the silt quantity is 500 MT (9.8%) of total waste, goes straight to the land fill. 27.02% of remaining waste goes to landfill after processing. Design period of the landfill considers as 30 years and the land requirement for 5100 MT/day is 270 acre. Cost of land is increased by 10% by considering the futuristic and realistic condition.

Classification of land	Approved Rate (Rs per acre)
Sali land (lowly irrigated single cropped land)	6,01,718
Sona land (highly irrigated double/multi-cropped land)	8,80,029
Homestead	18,04,431
Shop or cold storage	14,43,545
Bamboo garden	7,04,023
Temple	6,01,718
Burial ground	6,01,718
Canal	3,61,030

(Paul et al., 2019; Paul et al., 2020; Paul et al., 2018; Chattopadhyay, 2018)

ANNEXURE 7.4: FIXED COST FOR RUNNING AND IDLE HEAVY DUTY LPT TRUCKS

Fixed Cost (For Running Condition) Per Heavy Duty LPT Trucks

Description	Cost (Rs.)
Capital cost	27,50,000
Depreciation @ 10% of capital cost (scrap value is considered 10% of capital cost and the life of vehicle is 10 years).	2,47,000
Interest @10% on reducing loan	1,72,550
Wages for drivers and helpers with 30% overtime allowance. (1 driver and 2 helper per vehicle)	10,81,080
Wages of garage staff including managerial and administrative (2 numbers of personnel per vehicle).	7,12,800
Annual operational and maintenance (O&M) cost @10% of capital cost.	2,75,000
Total cost per running vehicles per annum (including depreciation and interest).	24,88,930
Total cost per running vehicle per day	6818.988

Fixed Cost (For Idle Condition) Per Heavy Duty LPT Trucks

Description	Cost (Rs.)
Capital cost	27,50,000
Depreciation @ 10% of capital cost (scrap value is considered 10% of capital cost and the life of vehicle is 10 years).	2,47,500
Interest @10% on reducing loan	1,72,550
Wages of garage staff including managerial and administrative (2 numbers of personnel per vehicle).	7,12,800
Annual operational and maintenance (O&M) cost @10% of capital cost.	2,75,000
Total cost per running vehicles per annum (including depreciation and interest).	14,07,851
Total cost per running vehicle per day	3858.943

ANNEXURE 7.5: SAMPLE CALCULATION FOR FUEL COST OF DEPARTMENTAL VEHICLES

Annexure 7.5.1: Sample Calculation for Fuel Cost of Departmental Vehicle, DV1 Type, Carrying Waste from Borough 1 to East Transfer Station:

Distance of East transfer station from Borough-I is 10.92 km (Table 7.8).

Average waste carrying capacity of DV1 type vehicle is 7 MT (Table 6.4).

Fuel consumption in loaded and unloaded condition of DV1 vehicle is 1.67 km/L and 2.33 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

Therefore, Fuel charge per km for loaded and unloaded condition:

For loaded condition = $(1/1.67) \times 92.76 = \text{Rs. } 55.545$ (Table 6.6); and

For unloaded condition = $(1/2.33) \times 92.76 = \text{Rs. } 39.811$ (Table 6.6)

The total distance travelled by DV1 type vehicle per trip = $10.92 \times 2 = 21.84$ km.

Average fuel charge for total distance per trip = $[(55.545 + 39.811)/2] = 47.678 \text{ Rs./km}$

Hence, Fuel cost of DV1 per MT of waste = $[(47.678 \times 21.84)/7] = 148.755 \text{ Rs./MT of waste (Table 7.9)}$

Annexure 7.5.2: Sample Calculation for Fuel Cost of Departmental Vehicle, DV1 Type, Carrying Waste from Borough 1 to North Transfer Station:

Distance of North transfer station from Borough-I is 2.14 km (Table 7.8).

Average waste carrying capacity of DV1 type vehicle is 7 MT (Table 6.4).

Fuel consumption in loaded and unloaded condition of DV1 vehicle is 1.67 km/L and 2.33 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

The total distance travelled by DV1 type vehicle per trip = $2.14 \times 2 = 4.28 \text{ km}$.

Average fuel charge for total distance per trip = $[(55.545 + 39.811)/2] = 47.678 \text{ Rs./km}$

Hence, Fuel cost of DV1 per MT of waste = $[(47.678 \times 4.28)/7] = 29.150 \text{ Rs./MT of waste (Table 7.9)}$

Annexure 7.5.3: Sample Calculation for Fuel Cost of Departmental Vehicle, DV1 Type, Carrying Waste from Borough 1 to South Transfer Station:

Distance of South transfer station from Borough-I is 18.390 km (Table 7.8).

Average waste carrying capacity of DV1 type vehicle is 7 MT (Table 6.4).

Fuel consumption in loaded and unloaded condition of DV1 vehicle is 1.67 km/L and 2.33 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

The total distance travelled by DV1 type vehicle per trip = $18.390 \times 2 = 36.78 \text{ km}$.

Average fuel charge for total distance per trip = $[(55.545 + 39.811)/2] = 47.678 \text{ Rs./km}$

Hence, Fuel cost of DV1 per MT of waste = $[(47.678 \times 36.78)/7] = 250.51$ Rs./MT of waste (Table 7.9)

Annexure 7.5.4: Sample Calculation for Fuel Cost of Departmental Vehicle, DV2 Type, Carrying Waste from Borough 2 to East Transfer Station:

Distance of East transfer station from Borough 2 is 8.740 km (Table 7.8).

Average waste carrying capacity of DV2 type vehicle is 9 MT (Table 6.4).

Fuel consumption in loaded and unloaded condition of DV2 vehicle is 1.43 km/L and 1.67 km/L respectively. (Table 6.7); Fuel cost is Rs. 92.76/L as on 10.07.2022.

Therefore, Fuel charge per km for loaded and unloaded condition:

For loaded condition = $(1/1.43) \times 92.76 = \text{Rs. } 64.867$ (Table 6.6); and

For unloaded condition = $(1/1.67) \times 92.76 = \text{Rs. } 55.545$ (Table 6.6)

The total distance travelled by DV2 type vehicle per trip = $8.740 \times 2 = 17.48$ km.

Average fuel charge for total distance per trip = $[(64.867 + 55.545)/2] = 60.205$ Rs./km

Hence, Fuel cost of DV2 per MT of waste = $[(60.205 \times 17.48)/9] = 116.93$ Rs./MT of waste (Table 7.10)

Annexure 7.5.5: Sample Calculation for Fuel Cost of Departmental Vehicle, DV2 Type, Carrying Waste from Borough 2 to North Transfer Station:

Distance of North transfer station from Borough 2 is 4.500 km (Table 7.8).

Average waste carrying capacity of DV2 type vehicle is 9 MT (Table 6.4).

Fuel consumption in loaded and unloaded condition of DV2 vehicle is 1.43 km/L and 1.67 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

The total distance travelled by DV2 type vehicle per trip = $4.500 \times 2 = 9.00$ km.

Average fuel charge for total distance per trip = $[(64.867 + 55.545)/2] = 60.205$ Rs./km

Hence, Fuel cost of DV2 per MT of waste = $[(60.205 \times 9)/9] = 60.21$ Rs./MT of waste
(Table 7.10)

Annexure 7.5.6: Sample Calculation for Fuel Cost of Departmental Vehicle, DV2 Type, Carrying Waste from Borough 2 to South Transfer Station:

Distance of South transfer station from Borough 2 is 15.850 km (Table 7.8).

Average waste carrying capacity of DV2 type vehicle is 9 MT (Table 6.4).

Fuel consumption in loaded and unloaded condition of DV2 vehicle is 1.43 km/L and 1.67 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

The total distance travelled by DV2 type vehicle per trip = $15.850 \times 2 = 31.700$ km.

Average fuel charge for total distance per trip = $[(64.867 + 55.545)/2] = 60.205$ Rs./km

Hence, Fuel cost of DV2 per MT of waste = $[(60.205 \times 31.70)/9] = 212.06$ Rs./MT of waste (Table 7.10)

Annexure 7.5.7: Sample Calculation for Fuel Cost of Departmental Vehicle, DV3 Type, Carrying Waste from Borough 3 to East Transfer Station:

Distance of East transfer station from Borough 3 is 7.03 km (Table 7.8).

Average waste carrying capacity of DV3 type vehicle is 10 MT (Table 6.4).

Fuel consumption in loaded and unloaded condition of DV3 vehicle is 0.909 km/L and 1.11 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

Therefore, Fuel charge per km for loaded and unloaded condition:

For loaded condition = $(1/0.909) \times 92.76 = \text{Rs. } 102.046$ (Table 6.6); and

For unloaded condition = $(1/1.11) \times 92.76 = \text{Rs. } 83.568$ (Table 6.6)

The total distance travelled by DV3 type vehicle per trip = $7.03 \times 2 = 14.06 \text{ km}$.

Average fuel charge for total distance per trip = $[(102.046 + 83.568)/2] = 92.807 \text{ Rs./km}$

Hence, Fuel cost of DV3 per MT of waste = $[(92.807 \times 14.06)/10] = 130.49 \text{ Rs./MT of waste}$ (Table 7.11)

Annexure 7.5.8: Sample Calculation for Fuel Cost of Departmental Vehicle, DV3 Type, Carrying Waste from Borough 3 to North Transfer Station:

Distance of North transfer station from Borough 3 is 7.110 km (Table 7.8).

Average waste carrying capacity of DV3 type vehicle is 10 MT (Table 6.4).

Fuel consumption in loaded and unloaded condition of DV3 vehicle is 0.909 km/L and 1.11 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

The total distance travelled by DV3 type vehicle per trip = $7.110 \times 2 = 14.22 \text{ km}$.

Average fuel charge for total distance per trip = $[(102.046 + 83.568)/2] = 92.807 \text{ Rs./km}$

Hence, Fuel cost of DV3 per MT of waste = $[(92.807 \times 14.22)/10] = 131.97 \text{ Rs./MT of waste}$ (Table 7.11)

Annexure 7.5.9: Sample Calculation for Fuel Cost of Departmental Vehicle, DV3 Type, Carrying Waste from Borough 3 to South Transfer Station:

Distance of South transfer station from Borough 3 is 16.770 km (Table 7.8).

Average waste carrying capacity of DV3 type vehicle is 10 MT (Table 6.4).

Fuel consumption in loaded and unloaded condition of DV3 vehicle is 0.909 km/L and 1.11 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

The total distance travelled by DV3 type vehicle per trip = $16.770 \times 2 = 33.54$ km.

Average fuel charge for total distance per trip = $[(102.046 + 83.568)/2] = 92.807$ Rs./km

Hence, Fuel cost of DV3 per MT of waste = $[(92.807 \times 33.54)/10] = 311.27$ Rs./MT of waste (Table 7.11)

Annexure 7.5.10: Sample Calculation for Fuel Cost of Departmental Vehicle, DV4 Type, Carrying Waste from Borough 4 to East Transfer Station:

Distance of East transfer station from Borough 4 is 7.67 km (Table 7.8).

Average waste carrying capacity of DV4 type vehicle is 7 MT (Table 6.4).

Fuel consumption in loaded and unloaded condition of DV4 vehicle is 1.25 km/L and 1.67 km/L respectively. (Table 6.7); Fuel cost is Rs. 92.76/L as on 10.07.2022.

Therefore, Fuel charge per km for loaded and unloaded condition:

For loaded condition = $(1/1.25) \times 92.76 = \text{Rs. } 74.208$ (Table 6.6); and

For unloaded condition = $(1/1.67) \times 92.76 = \text{Rs. } 55.545$ (Table 6.6)

The total distance travelled by DV4 type vehicle per trip = $7.67 \times 2 = 15.34$ km.

Average fuel charge for total distance per trip = $[(74.208 + 55.545)/2] = 64.877$ Rs./km

Hence, Fuel cost of DV4 per MT of waste = $[(64.877 \times 15.34)/7] = 142.17$ Rs./MT of waste (Table 7.12)

Annexure 7.5.11: Sample Calculation for Fuel Cost of Departmental Vehicle, DV4 Type, Carrying Waste from Borough 4 to North Transfer Station:

Distance of North transfer station from Borough 4 is 6.030 km (Table 7.8).

Average waste carrying capacity of DV4 type vehicle is 7 MT (Table 6.4).

Fuel consumption in loaded and unloaded condition of DV4 vehicle is 1.25 km/L and 1.67 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

The total distance travelled by DV4 type vehicle per trip = $6.030 \times 2 = 12.060$ km.

Average fuel charge for total distance per trip = $[(74.208 + 55.545)/2] = 64.877$ Rs./km

Hence, Fuel cost of DV4 per MT of waste = $[(64.877 \times 12.06)/7] = 111.77$ Rs./MT of waste (Table 7.12)

Annexure 7.5.12: Sample Calculation for Fuel Cost of Departmental Vehicle, DV4 Type, Carrying Waste from Borough 4 to North Transfer Station:

Distance of North transfer station from Borough 4 is 14.490 km (Table 7.8).

Average waste carrying capacity of DV4 type vehicle is 7 MT (Table 6.4).

Fuel consumption in loaded and unloaded condition of DV4 vehicle is 1.25 km/L and 1.67 km/L respectively. (Table 6.6); Fuel cost is Rs. 92.76/L as on 10.07.2022.

The total distance travelled by DV4 type vehicle per trip = $14.490 \times 2 = 28.980$ km.

Average fuel charge for total distance per trip = $[(74.208 + 55.545)/2] = 64.877$ Rs./km

Hence, Fuel cost of DV4 per MT of waste = $[(64.877 \times 28.98)/7] = 268.59$ Rs./MT of waste (Table 7.12)

ANNEXURE 7.6: SAMPLE CALCULATION FOR FUEL COST OF HEAVY DUTY LPT TRUCKS

Annexure 7.6.1: Sample Calculation for Fuel Cost of Heavy Duty Trucks, Carrying Waste to East Landfill Site from Associated Transfer Station:

Distance of East landfill site from associated transfer station is 22.443 km (Table 7.14).

Average waste carrying capacity of heavy duty truck is 20 MT (Table 7.13).

Fuel consumption in loaded and unloaded condition of heavy duty truck is 5.5 km/L and 7 km/L respectively. (Table 7.13); Fuel cost is Rs. 92.76/L as on 10.07.2022.

Therefore, Fuel charge per km for loaded and unloaded condition:

For loaded condition = $(1/5.5) \times 92.76 = \text{Rs. } 16.865$ (Table 7.13); and

For unloaded condition = $(1/7) \times 92.76 = \text{Rs. } 13.251$ (Table 7.13)

The total distance travelled by heavy duty truck per trip = $22.443 \times 2 = 44.886$ km.

Average fuel charge for total distance per trip = $[(16.865 + 13.251)/2] = 15.058$ Rs./km

Hence, Fuel cost of DV4 per MT of waste = $[(15.058 \times 44.886)/20] = 33.795$ Rs./MT of waste (Table 7.14)

Annexure 7.6.2: Sample Calculation for Fuel Cost of Heavy Duty Trucks, Carrying Waste to North Landfill Site from Associated Transfer Station:

Distance of North landfill site from associated transfer station is 24.890 km (Table 7.14).

Average waste carrying capacity of heavy duty truck is 20 MT (Table 7.13).

Fuel consumption in loaded and unloaded condition of heavy duty truck is 5.5 km/L and 7 km/L respectively. (Table 7.13); Fuel cost is Rs. 92.76/L as on 10.07.2022.

The total distance travelled by heavy duty truck per trip = $24.890 \times 2 = 49.780$ km.

Average fuel charge for total distance per trip = $[(16.865 + 13.251)/2] = 15.058 \text{ Rs./km}$

Hence, Fuel cost of DV4 per MT of waste = $[(15.058 \times 49.780)/20] = 37.477 \text{ Rs./MT of waste (Table 7.14)}$

Annexure 7.6.3: Sample Calculation for Fuel Cost of Heavy Duty Trucks, Carrying Waste to South Landfill Site from Associated Transfer Station:

Distance of South landfill site from associated transfer station is 7.02 km (Table 7.14).

Average waste carrying capacity of heavy duty truck is 20 MT (Table 7.13).

Fuel consumption in loaded and unloaded condition of heavy duty truck is 5.5 km/L and 7 km/L respectively. (Table 7.13); Fuel cost is Rs. 92.76/L as on 10.07.2022.

The total distance travelled by heavy duty truck per trip = $7.02 \times 2 = 14.04 \text{ km}$.

Average fuel charge for total distance per trip = $[(16.865 + 13.251)/2] = 15.058 \text{ Rs./km}$

Hence, Fuel cost of DV4 per MT of waste = $[(15.058 \times 14.04)/20] = 10.570 \text{ Rs./MT of waste (Table 7.14)}$

ANNEXURE 7.7: SAMPLE CALCULATION FOR POLLUTANT EMISSION BY HEAVY DUTY LPT TRUCKS

Annexure 7.7.1: Sample Calculation for CO Emission Rate by Heavy Duty LPT Trucks per Ton per Trip from East Transfer Station to ELF (g/t/trip)

Weighted average emission factor for CO = 2.250 g/km (Table 6.11); Distance of East transfer station from Borough 1 is 27.877 km (Table 7.14).

Total distance travelled per trip = $27.877 \times 2 = 55.754 \text{ km}$.

Hence, CO generation rate = $(2.25 \times 55.754)/20 = 6.272 \text{ g/trip (Table 7.17)}$

Annexure 7.7.2: Sample Calculation for CO Emission Rate by Heavy Duty LPT Trucks per Ton per Trip from North Transfer Station to ELF (g/t/trip)

Weighted average emission factor for CO = 2.250 g/km (Table 6.11); Distance of East transfer station from Borough 1 is 30.915 km (Table 7.14).

Total distance travelled per trip = $30.915 \times 2 = 61.83$ km.

Hence, CO generation rate = $(2.25 \times 61.83)/20 = 6.956$ g/trip (Table 7.17)

Annexure 7.7.3: Sample Calculation for CO Emission Rate by Heavy Duty LPT Trucks per Ton per Trip from North Transfer Station to ELF (g/t/trip)

Weighted average emission factor for CO = 2.250 g/km (Table 6.11); Distance of East transfer station from Borough 1 is 8.72 km (Table 7.14).

Total distance travelled per trip = $8.72 \times 2 = 17.44$ km.

Hence, CO generation rate = $(2.25 \times 17.44)/20 = 1.962$ g/trip (Table 7.17)

ANNEXURE 7.8: SAMPLE CALCULATION FOR POLLUTANT EMISSION BY DEPARTMENTAL VEHICLE

Annexure 7.8.1: Sample Calculation for CO Emission Rate by DV2 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

Weighted average emission factor for CO = 4.4039 g/km (Table 6.11); Distance of east transfer station from borough 1 is 10.92 km (Table 7.8).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km. Hence, CO generation = $4.4039 \times 21.84 = 96.18$ g/trip

CO generation rate per MT of waste = $96.18 / 9 = 10.686$ g/t/trip (Table 7.19)

Annexure 7.8.2: Sample Calculation for CO₂ Emission Rate by DV2 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

From Annexure 7.8.1, Total distance travelled per trip = $10.92 \times 2 = 21.84$ km and average fuel consumption of DV2 type vehicle is 1.55 km/L.

Total fuel consumption = $[21.84 / (1.55 \times 9)] = 1.566$ L/trip/MT; Fuel density is 820 kg/m³ and % carbon present in fuel = 87%.

Therefore, total fuel consumption = $[(1.566 \times 820) / 1000] = 1.28378$ kg/MT of waste/trip = 1283.78 g/t/trip

Carbon in CO = $10.686 \times 12/28 = 4.5797$ g/t/trip

Carbon remaining = $(1283.78 \times 0.87) - 4.5797 = 1112.3089$ g/t/trip

CO₂ emission rate per MT of waste per trip = $1112.3089 \times 44/12 = 4078.48$ g/t/trip (Table 7.19)

Annexure 7.8.3: Sample Calculation for SO₂ Emission Rate by DV2 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

From Annexure 7.8.1, Total distance travelled per trip = $10.92 \times 2 = 21.84$ km and average fuel consumption of DV2 type vehicle is 1.55 km/L.

Total fuel consumption = $[21.84 / (1.55 \times 9)] = 1.566$ L/trip/MT; Fuel density is 820 kg/m³ and % sulphur present in fuel = 0.035%.

Therefore, total fuel consumption = $[(1.566 \times 820) / 1000] = 1.28378$ kg/MT of waste/trip = 1283.78 g/t/trip

SO₂ emission rate per MT of waste per trip = $[(1283.78 \times 0.035 \times 64) / (100 \times 32)] = 0.898$ g/t/trip (Table 7.19)

Annexure 7.8.4: Sample Calculation for NO_x Emission Rate by DV2 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

Weighted average emission factor for NO_x = 7.845 g/km (Table 6.11); Distance of east transfer station from borough 1 is 10.92 km (Table 7.8).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km.

Hence, NO_x generation rate per MT of waste = $(7.845 \times 21.84)/9 = 19.040$ g/t/trip (table 7.19)

Annexure 7.8.5: Sample Calculation for HC Emission Rate by DV2 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

Weighted average emission factor for HC = 1.216 g/km (Table 6.11); Distance of east transfer station from borough 1 is 10.92 km (Table 7.8).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km.

Hence, HC generation rate per MT of waste = $(1.216 \times 21.84)/9 = 2.950$ g/t/trip (table 7.19)

Annexure 7.8.6: Sample Calculation for PM Emission Rate by DV2 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

Weighted average emission factor for PM = 0.773 g/km (Table 6.11); Distance of east transfer station from borough 1 is 10.92 km (Table 7.8).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km.

Hence, PM generation rate per MT of waste = $(0.773 \times 21.84)/9 = 1.876$ g/t/trip (table 7.19)

Annexure 7.8.7: Sample Calculation for Benzene Emission Rate by DV2 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

Weighted average emission factor for BENZ = 0.0062 g/km (Table 6.11); Distance of east transfer station from borough 1 is 10.92 km (Table 7.8).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km.

Hence, benzene generation rate per MT of waste = $(0.0062 \times 21.84)/9 = 0.015$ g/t/trip (table 7.19)

Annexure 7.8.8: Sample Calculation for Butadiene Emission Rate by DV2 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

Weighted average emission factor for BUTDN = 0.0011 g/km (Table 6.11); Distance of east transfer station from borough 1 is 10.92 km (Table 7.8).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km.

Hence, butadiene generation rate per MT of waste = $(0.0011 \times 21.84)/9 = 0.003$ g/t/trip (table 7.19)

ANNEXURE 8.1: SAMPLE CALCULATION FOR POLLUTANT EMISSION BY DEPARTMENTAL VEHICLES FOR BS-VI**Annexure 8.1.1: Sample Calculation for CO Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)**

Weighted average emission factor for CO = 0.74 g/km (Table 8.5); Distance of east transfer station from borough 1 is 10.92 km (Table 7.8).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km. Hence, CO generation = $0.74 \times 21.84 = 16.162$ g/trip

CO generation rate per MT of waste = $16.162 / 7 = 2.309$ g/t/trip (Table 8.6)

Annexure 8.1.2: Sample Calculation for CO₂ Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

From Annexure 8.1.1, Total distance travelled per trip = $10.92 \times 2 = 21.84$ km and average fuel consumption of DV1 type vehicle is 2.0 km/L (Table 6.6)

Total fuel consumption = $[21.84 / (2 \times 7)] = 1.56$ L/trip/MT; Fuel density is 820 kg/m^3 and % carbon present in fuel = 87%.

Therefore, total fuel consumption = $[(1.56 \times 820) / 1000] = 1.2792$ kg/MT of waste/trip = 1279.2 g/t/trip

Carbon in CO = $2.309 \times 12/28 = 0.9896$ g/t/trip

Carbon remaining = $(1279.2 \times 0.87) - 0.9896 = 1111.914$ g/t/trip

CO₂ emission rate per MT of waste per trip = $1111.914 \times 44/12 = 4077.019$ g/t/trip
(Table 8.6)

Annexure 8.1.3: Sample Calculation for SO₂ Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

From Annexure 8.1.1, Total distance travelled per trip = $10.92 \times 2 = 21.84$ km and average fuel consumption of DV1 type vehicle is 2.0 km/L.

Total fuel consumption = $[21.84 / (2 \times 7)] = 1.56$ L/trip/MT; Fuel density is 820 kg/m³ and % sulphur present in fuel = 0.001%.

Therefore, total fuel consumption = $[(1.56 \times 820) / 1000] = 1.2792$ kg/MT of waste/trip = 1279.2 g/t/trip

SO₂ emission rate per MT of waste per trip = $[(1279.2 \times 0.001 \times 64) / (100 \times 32)] = 0.0256$ g/t/trip (Table 8.6)

Annexure 8.1.4: Sample Calculation for NO_x Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

Weighted average emission factor for NO_x = 0.125 g/km (Table 8.5); Distance of east transfer station from borough 1 is 10.92 km (Table 7.8).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km. Hence, NO_x generation rate per MT of waste = $(0.125 \times 21.84)/7 = 0.39$ g/t/trip (Table 8.6)

Annexure 8.1.5: Sample Calculation for HC Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

Weighted average emission factor for HC = 0.09 g/km (Table 8.5); Distance of east transfer station from borough 1 is 10.92 km (Table 7.8).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km.

Hence, HC generation rate per MT of waste = $(0.09 \times 21.84)/7 = 0.281$ g/t/trip (Table 8.6)

Annexure 8.1.6: Sample Calculation for PM Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

Weighted average emission factor for PM = 0.005 g/km (Table 8.5); Distance of east transfer station from borough 1 is 10.92 km (Table 7.8).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km.

Hence, PM generation rate per MT of waste = $(0.005 \times 21.84)/7 = 0.016$ g/t/trip (table 8.6)

Annexure 8.1.7: Sample Calculation for Benzene Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

Weighted average emission factor for BENZ = 0.00045 g/km (Table 8.5); Distance of east transfer station from borough 1 is 10.92 km (Table 7.8).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km.

Hence, benzene generation rate per MT of waste = $(0.00045 \times 21.84)/7 = 0.0014$ g/t/trip (Table 8.6)

Annexure 8.1.8: Sample Calculation for Butadiene Emission Rate by DV1 Type Vehicle per Ton of Garbage per Trip to East Transfer Station from Borough 1 (g/t/trip)

Weighted average emission factor for BUTDN = 0.000085 g/km (Table 8.5); Distance of east transfer station from borough 1 is 10.92 km (Table 7.8).

Total distance travelled per trip = $10.92 \times 2 = 21.84$ km.

Hence, butadiene generation rate per MT of waste = $(0.000085 \times 21.84)/7 = 0.0003$
g/t/trip (Table 8.6)

Model;

[1] MIN = CTTRANSP + CTINCENT + CTICS + CTINCIN + CTCOMP + CTLF - CTREVVY - CTREVCVP - CTREVINC;
 [2] Q_BH_D_HV_S_1_E + Q_BH_D_HV_S_1_N + Q_BH_D_HV_S_1_S = 30.2559075;
 [3] Q_BH_D_HV_S_2_E + Q_BH_D_HV_S_2_N + Q_BH_D_HV_S_2_S = 18.1019475;
 [4] Q_BH_D_HV_S_3_E + Q_BH_D_HV_S_3_N + Q_BH_D_HV_S_3_S = 30.2272425;
 [5] Q_BH_D_HV_S_4_E + Q_BH_D_HV_S_4_N + Q_BH_D_HV_S_4_S = 19.1338875;
 [6] Q_BH_D_HV_S_5_E + Q_BH_D_HV_S_5_N + Q_BH_D_HV_S_5_S = 25.7985;
 [7] Q_BH_D_HV_S_6_E + Q_BH_D_HV_S_6_N + Q_BH_D_HV_S_6_S = 52.886925;
 [8] Q_BH_D_HV_S_7_E + Q_BH_D_HV_S_7_N + Q_BH_D_HV_S_7_S = 94.164525;
 [9] Q_BH_D_HV_S_8_E + Q_BH_D_HV_S_8_N + Q_BH_D_HV_S_8_S = 60.31116;
 [10] Q_BH_D_HV_S_9_E + Q_BH_D_HV_S_9_N + Q_BH_D_HV_S_9_S = 38.9844;
 [11] Q_BH_D_HV_S_10_E + Q_BH_D_HV_S_10_N + Q_BH_D_HV_S_10_S = 46.580625;
 [12] Q_BH_D_HV_S_11_E + Q_BH_D_HV_S_11_N + Q_BH_D_HV_S_11_S = 2.7088425;
 [13] Q_BH_D_HV_S_12_E + Q_BH_D_HV_S_12_N + Q_BH_D_HV_S_12_S = 3.38247;
 [14] Q_BH_D_HV_S_13_E + Q_BH_D_HV_S_13_N + Q_BH_D_HV_S_13_S = 5.3361;
 [15] Q_BH_D_HV_S_14_E + Q_BH_D_HV_S_14_N + Q_BH_D_HV_S_14_S = 7.05159;
 [16] Q_BH_D_HV_S_15_E + Q_BH_D_HV_S_15_N + Q_BH_D_HV_S_15_S = 0.85995E-01;
 [17] Q_BH_D_HV_S_16_E + Q_BH_D_HV_S_16_N + Q_BH_D_HV_S_16_S = 31.5;
 [18] Q_BH_D_HV_G_1_E + Q_BH_D_HV_G_1_N + Q_BH_D_HV_G_1_S + Q_BH_D_DV_G_1_E_DV1 + Q_BH_D_DV_G_1_E_DV2 + Q_BH_D_DV_G_1_E_DV3 + Q_BH_D_DV_G_1_E_DV4 + Q_BH_D_DV_G_1_N_DV1 + Q_BH_D_DV_G_1_N_DV2 + Q_BH_D_DV_G_1_N_DV3 + Q_BH_D_DV_G_1_N_DV4 + Q_BH_D_DV_G_1_S_DV1 + Q_BH_D_DV_G_1_S_DV2 + Q_BH_D_DV_G_1_S_DV3 + Q_BH_D_DV_G_1_S_DV4 = 281.31831;
 [19] Q_BH_D_HV_G_2_E + Q_BH_D_HV_G_2_N + Q_BH_D_HV_G_2_S + Q_BH_D_DV_G_2_E_DV1 + Q_BH_D_DV_G_2_E_DV2 + Q_BH_D_DV_G_2_E_DV3 + Q_BH_D_DV_G_2_E_DV4 + Q_BH_D_DV_G_2_N_DV1 + Q_BH_D_DV_G_2_N_DV2 + Q_BH_D_DV_G_2_N_DV3 + Q_BH_D_DV_G_2_N_DV4 + Q_BH_D_DV_G_2_S_DV1 + Q_BH_D_DV_G_2_S_DV2 + Q_BH_D_DV_G_2_S_DV3 + Q_BH_D_DV_G_2_S_DV4 = 276.087;
 [20] Q_BH_D_HV_G_3_E + Q_BH_D_HV_G_3_N + Q_BH_D_HV_G_3_S + Q_BH_D_DV_G_3_E_DV1 + Q_BH_D_DV_G_3_E_DV2 + Q_BH_D_DV_G_3_E_DV3 + Q_BH_D_DV_G_3_E_DV4 + Q_BH_D_DV_G_3_N_DV1 + Q_BH_D_DV_G_3_N_DV2 + Q_BH_D_DV_G_3_N_DV3 + Q_BH_D_DV_G_3_N_DV4 + Q_BH_D_DV_G_3_S_DV1 + Q_BH_D_DV_G_3_S_DV2 + Q_BH_D_DV_G_3_S_DV3 + Q_BH_D_DV_G_3_S_DV4 = 282.9666;
 [21] Q_BH_D_HV_G_4_E + Q_BH_D_HV_G_4_N + Q_BH_D_HV_G_4_S + Q_BH_D_DV_G_4_E_DV1 + Q_BH_D_DV_G_4_E_DV2 + Q_BH_D_DV_G_4_E_DV3 + Q_BH_D_DV_G_4_E_DV4 + Q_BH_D_DV_G_4_N_DV1 + Q_BH_D_DV_G_4_N_DV2 + Q_BH_D_DV_G_4_N_DV3 + Q_BH_D_DV_G_4_N_DV4 + Q_BH_D_DV_G_4_S_DV1 + Q_BH_D_DV_G_4_S_DV2 + Q_BH_D_DV_G_4_S_DV3 + Q_BH_D_DV_G_4_S_DV4 = 246.304065;
 [22] Q_BH_D_HV_G_5_E + Q_BH_D_HV_G_5_N + Q_BH_D_HV_G_5_S + Q_BH_D_DV_G_5_E_DV1 + Q_BH_D_DV_G_5_E_DV2 + Q_BH_D_DV_G_5_E_DV3 + Q_BH_D_DV_G_5_E_DV4 + Q_BH_D_DV_G_5_N_DV1 + Q_BH_D_DV_G_5_N_DV2 + Q_BH_D_DV_G_5_N_DV3 + Q_BH_D_DV_G_5_N_DV4 + Q_BH_D_DV_G_5_S_DV1 + Q_BH_D_DV_G_5_S_DV2 + Q_BH_D_DV_G_5_S_DV3 + Q_BH_D_DV_G_5_S_DV4 = 297.155775;
 [23] Q_BH_D_HV_G_6_E + Q_BH_D_HV_G_6_N + Q_BH_D_HV_G_6_S + Q_BH_D_DV_G_6_E_DV1 + Q_BH_D_DV_G_6_E_DV2 + Q_BH_D_DV_G_6_E_DV3 + Q_BH_D_DV_G_6_E_DV4 + Q_BH_D_DV_G_6_N_DV1 + Q_BH_D_DV_G_6_N_DV2 + Q_BH_D_DV_G_6_N_DV3 + Q_BH_D_DV_G_6_N_DV4 + Q_BH_D_DV_G_6_S_DV1 + Q_BH_D_DV_G_6_S_DV2 + Q_BH_D_DV_G_6_S_DV3 + Q_BH_D_DV_G_6_S_DV4 = 369.26253;
 [24] Q_BH_D_HV_G_7_E + Q_BH_D_HV_G_7_N + Q_BH_D_HV_G_7_S + Q_BH_D_DV_G_7_E_DV1 + Q_BH_D_DV_G_7_E_DV2 + Q_BH_D_DV_G_7_E_DV3 + Q_BH_D_DV_G_7_E_DV4 + Q_BH_D_DV_G_7_N_DV1 + Q_BH_D_DV_G_7_N_DV2 + Q_BH_D_DV_G_7_N_DV3 + Q_BH_D_DV_G_7_N_DV4 + Q_BH_D_DV_G_7_S_DV1 + Q_BH_D_DV_G_7_S_DV2 + Q_BH_D_DV_G_7_S_DV3 + Q_BH_D_DV_G_7_S_DV4 = 380.77158;
 [25] Q_BH_D_HV_G_8_E + Q_BH_D_HV_G_8_N + Q_BH_D_HV_G_8_S + Q_BH_D_DV_G_8_E_DV1 + Q_BH_D_DV_G_8_E_DV2 + Q_BH_D_DV_G_8_E_DV3 + Q_BH_D_DV_G_8_E_DV4 + Q_BH_D_DV_G_8_N_DV1 + Q_BH_D_DV_G_8_N_DV2 + Q_BH_D_DV_G_8_N_DV3 + Q_BH_D_DV_G_8_N_DV4 + Q_BH_D_DV_G_8_S_DV1 + Q_BH_D_DV_G_8_S_DV2 + Q_BH_D_DV_G_8_S_DV3 + Q_BH_D_DV_G_8_S_DV4 = 252.86835;
 [26] Q_BH_D_HV_G_9_E + Q_BH_D_HV_G_9_N + Q_BH_D_HV_G_9_S + Q_BH_D_DV_G_9_E_DV1 + Q_BH_D_DV_G_9_E_DV2 + Q_BH_D_DV_G_9_E_DV3 + Q_BH_D_DV_G_9_E_DV4 + Q_BH_D_DV_G_9_N_DV1 + Q_BH_D_DV_G_9_N_DV2 + Q_BH_D_DV_G_9_N_DV3 + Q_BH_D_DV_G_9_N_DV4 + Q_BH_D_DV_G_9_S_DV1 + Q_BH_D_DV_G_9_S_DV2 + Q_BH_D_DV_G_9_S_DV3 + Q_BH_D_DV_G_9_S_DV4 = 419.36895;
 [27] Q_BH_D_HV_G_10_E + Q_BH_D_HV_G_10_N + Q_BH_D_HV_G_10_S + Q_BH_D_DV_G_10_E_DV1 + Q_BH_D_DV_G_10_E_DV2 + Q_BH_D_DV_G_10_E_DV3 + Q_BH_D_DV_G_10_E_DV4 + Q_BH_D_DV_G_10_N_DV1 + Q_BH_D_DV_G_10_N_DV2 + Q_BH_D_DV_G_10_N_DV3 + Q_BH_D_DV_G_10_N_DV4 + Q_BH_D_DV_G_10_S_DV1 + Q_BH_D_DV_G_10_S_DV2 + Q_BH_D_DV_G_10_S_DV3 + Q_BH_D_DV_G_10_S_DV4 = 531.176835;
 [28] Q_BH_D_HV_G_11_E + Q_BH_D_HV_G_11_N + Q_BH_D_HV_G_11_S + Q_BH_D_DV_G_11_E_DV1 + Q_BH_D_DV_G_11_E_DV2 + Q_BH_D_DV_G_11_E_DV3 + Q_BH_D_DV_G_11_E_DV4 + Q_BH_D_DV_G_11_N_DV1 + Q_BH_D_DV_G_11_N_DV2 + Q_BH_D_DV_G_11_N_DV3 + Q_BH_D_DV_G_11_N_DV4 + Q_BH_D_DV_G_11_S_DV1 + Q_BH_D_DV_G_11_S_DV2 + Q_BH_D_DV_G_11_S_DV3 + Q_BH_D_DV_G_11_S_DV4 = 150.49125;
 [29] Q_BH_D_HV_G_12_E + Q_BH_D_HV_G_12_N + Q_BH_D_HV_G_12_S + Q_BH_D_DV_G_12_E_DV1 + Q_BH_D_DV_G_12_E_DV2 + Q_BH_D_DV_G_12_E_DV3 + Q_BH_D_DV_G_12_E_DV4 + Q_BH_D_DV_G_12_N_DV1 + Q_BH_D_DV_G_12_N_DV2 + Q_BH_D_DV_G_12_N_DV3 + Q_BH_D_DV_G_12_N_DV4 + Q_BH_D_DV_G_12_S_DV1 + Q_BH_D_DV_G_12_S_DV2 + Q_BH_D_DV_G_12_S_DV3 + Q_BH_D_DV_G_12_S_DV4 = 131.701395;
 [30] Q_BH_D_HV_G_13_E + Q_BH_D_HV_G_13_N + Q_BH_D_HV_G_13_S + Q_BH_D_DV_G_13_E_DV1 + Q_BH_D_DV_G_13_E_DV2 + Q_BH_D_DV_G_13_E_DV3 + Q_BH_D_DV_G_13_E_DV4 + Q_BH_D_DV_G_13_N_DV1 + Q_BH_D_DV_G_13_N_DV2 + Q_BH_D_DV_G_13_N_DV3 + Q_BH_D_DV_G_13_N_DV4 + Q_BH_D_DV_G_13_S_DV1 + Q_BH_D_DV_G_13_S_DV2 + Q_BH_D_DV_G_13_S_DV3 + Q_BH_D_DV_G_13_S_DV4 = 222.834045;
 [31] Q_BH_D_HV_G_14_E + Q_BH_D_HV_G_14_N + Q_BH_D_HV_G_14_S + Q_BH_D_DV_G_14_E_DV1 + Q_BH_D_DV_G_14_E_DV2 + Q_BH_D_DV_G_14_E_DV3 + Q_BH_D_DV_G_14_E_DV4 + Q_BH_D_DV_G_14_N_DV1 + Q_BH_D_DV_G_14_N_DV2 + Q_BH_D_DV_G_14_N_DV3 + Q_BH_D_DV_G_14_N_DV4 + Q_BH_D_DV_G_14_S_DV1 + Q_BH_D_DV_G_14_S_DV2 + Q_BH_D_DV_G_14_S_DV3 + Q_BH_D_DV_G_14_S_DV4 = 222.834045;

Annexure 9

2+Q_BH_D_DV_G_14_N_DV3+Q_BH_D_DV_G_14_N_DV4+Q_BH_D_DV_G_14_S_DV1+Q_BH_D_DV_G_14_S_DV2+
Q_BH_D_DV_G_14_S_DV3+Q_BH_D_DV_G_14_S_DV4 = 101.90187;
[32]Q_BH_D_HV_G_15_E+Q_BH_D_HV_G_15_N+Q_BH_D_HV_G_15_S+Q_BH_D_DV_G_15_E_DV1+Q_BH_D_DV_G_15
_E_DV2+Q_BH_D_DV_G_15_E_DV3+Q_BH_D_DV_G_15_E_DV4+Q_BH_D_DV_G_15_N_DV1+Q_BH_D_DV_G_15_N_DV
2+Q_BH_D_DV_G_15_N_DV3+Q_BH_D_DV_G_15_N_DV4+Q_BH_D_DV_G_15_S_DV1+Q_BH_D_DV_G_15_S_DV2+Q_B
H_D_DV_G_15_S_DV3+Q_BH_D_DV_G_15_S_DV4= 34.9713;
[33]Q_BH_D_HV_G_16_E+Q_BH_D_HV_G_16_N+Q_BH_D_HV_G_16_S+Q_BH_D_DV_G_16_E_DV1+Q_BH_D_DV_G_16
_E_DV2+Q_BH_D_DV_G_16_E_DV3+Q_BH_D_DV_G_16_E_DV4+Q_BH_D_DV_G_16_N_DV1+Q_BH_D_DV_G_16_N_DV
2+Q_BH_D_DV_G_16_N_DV3+Q_BH_D_DV_G_16_N_DV4+Q_BH_D_DV_G_16_S_DV1+Q_BH_D_DV_G_16_S_DV2+Q_B
H_D_DV_G_16_S_DV3+Q_BH_D_DV_G_16_S_DV4= 121.8;
[34]Q_BH_D_DV_G_1_E_DV1+Q_BH_D_DV_G_1_N_DV1+Q_BH_D_DV_G_1_S_DV1 <= 37.41533523;
[35]Q_BH_D_DV_G_1_E_DV2+Q_BH_D_DV_G_1_N_DV2+Q_BH_D_DV_G_1_S_DV2 <= 204.7059569;
[36]Q_BH_D_DV_G_1_E_DV3+Q_BH_D_DV_G_1_N_DV3+Q_BH_D_DV_G_1_S_DV3 <= 69.01675872;
[37]Q_BH_D_DV_G_1_E_DV4+Q_BH_D_DV_G_1_N_DV4+Q_BH_D_DV_G_1_S_DV4 <= 0;
[38]Q_BH_D_DV_G_2_E_DV1+Q_BH_D_DV_G_2_N_DV1+Q_BH_D_DV_G_2_S_DV1 <= 20.0991336;
[39]Q_BH_D_DV_G_2_E_DV2+Q_BH_D_DV_G_2_N_DV2+Q_BH_D_DV_G_2_S_DV2 <= 205.7842063;
[40]Q_BH_D_DV_G_2_E_DV3+Q_BH_D_DV_G_2_N_DV3+Q_BH_D_DV_G_2_S_DV3 <= 69.52975008;
[41]Q_BH_D_DV_G_2_E_DV4+Q_BH_D_DV_G_2_N_DV4+Q_BH_D_DV_G_2_S_DV4 <= 0;
[42]Q_BH_D_DV_G_3_E_DV1+Q_BH_D_DV_G_3_N_DV1+Q_BH_D_DV_G_3_S_DV1 <= 29.59830636;
[43]Q_BH_D_DV_G_3_E_DV2+Q_BH_D_DV_G_3_N_DV2+Q_BH_D_DV_G_3_S_DV2 <= 218.9746466;
[44]Q_BH_D_DV_G_3_E_DV3+Q_BH_D_DV_G_3_N_DV3+Q_BH_D_DV_G_3_S_DV3 <= 74.00897101;
[45]Q_BH_D_DV_G_3_E_DV4+Q_BH_D_DV_G_3_N_DV4+Q_BH_D_DV_G_3_S_DV4 <= 0;
[46]Q_BH_D_DV_G_4_E_DV1+Q_BH_D_DV_G_4_N_DV1+Q_BH_D_DV_G_4_S_DV1 <= 30.64022569;
[47]Q_BH_D_DV_G_4_E_DV2+Q_BH_D_DV_G_4_N_DV2+Q_BH_D_DV_G_4_S_DV2 <= 178.2124852;
[48]Q_BH_D_DV_G_4_E_DV3+Q_BH_D_DV_G_4_N_DV3+Q_BH_D_DV_G_4_S_DV3 <= 60.11132808;
[49]Q_BH_D_DV_G_4_E_DV4+Q_BH_D_DV_G_4_N_DV4+Q_BH_D_DV_G_4_S_DV4 <= 0;
[50]Q_BH_D_DV_G_5_E_DV1+Q_BH_D_DV_G_5_N_DV1+Q_BH_D_DV_G_5_S_DV1 <= 40.47261656;
[51]Q_BH_D_DV_G_5_E_DV2+Q_BH_D_DV_G_5_N_DV2+Q_BH_D_DV_G_5_S_DV2 <= 201.1467251;
[52]Q_BH_D_DV_G_5_E_DV3+Q_BH_D_DV_G_5_N_DV3+Q_BH_D_DV_G_5_S_DV3 <= 67.71982008;
[53]Q_BH_D_DV_G_5_E_DV4+Q_BH_D_DV_G_5_N_DV4+Q_BH_D_DV_G_5_S_DV4 <= 0;
[54]Q_BH_D_DV_G_6_E_DV1+Q_BH_D_DV_G_6_N_DV1+Q_BH_D_DV_G_6_S_DV1 <= 37.00010551;
[55]Q_BH_D_DV_G_6_E_DV2+Q_BH_D_DV_G_6_N_DV2+Q_BH_D_DV_G_6_S_DV2 <= 263.4958944;
[56]Q_BH_D_DV_G_6_E_DV3+Q_BH_D_DV_G_6_N_DV3+Q_BH_D_DV_G_6_S_DV3 <= 89.07596924;
[57]Q_BH_D_DV_G_6_E_DV4+Q_BH_D_DV_G_6_N_DV4+Q_BH_D_DV_G_6_S_DV4 <= 0;
[58]Q_BH_D_DV_G_7_E_DV1+Q_BH_D_DV_G_7_N_DV1+Q_BH_D_DV_G_7_S_DV1 <= 27.56786239;
[59]Q_BH_D_DV_G_7_E_DV2+Q_BH_D_DV_G_7_N_DV2+Q_BH_D_DV_G_7_S_DV2 <= 289.4676321;
[60]Q_BH_D_DV_G_7_E_DV3+Q_BH_D_DV_G_7_N_DV3+Q_BH_D_DV_G_7_S_DV3 <= 98.00552774;
[61]Q_BH_D_DV_G_7_E_DV4+Q_BH_D_DV_G_7_N_DV4+Q_BH_D_DV_G_7_S_DV4 <= 0;
[62]Q_BH_D_DV_G_8_E_DV1+Q_BH_D_DV_G_8_N_DV1+Q_BH_D_DV_G_8_S_DV1 <= 25.99486638;
[63]Q_BH_D_DV_G_8_E_DV2+Q_BH_D_DV_G_8_N_DV2+Q_BH_D_DV_G_8_S_DV2 <= 192.9284363;
[64]Q_BH_D_DV_G_8_E_DV3+Q_BH_D_DV_G_8_N_DV3+Q_BH_D_DV_G_8_S_DV3 <= 65.3007227;
[65]Q_BH_D_DV_G_8_E_DV4+Q_BH_D_DV_G_8_N_DV4+Q_BH_D_DV_G_8_S_DV4 <= 0;
[66]Q_BH_D_DV_G_9_E_DV1+Q_BH_D_DV_G_9_N_DV1+Q_BH_D_DV_G_9_S_DV1 <= 38.83356477;
[67]Q_BH_D_DV_G_9_E_DV2+Q_BH_D_DV_G_9_N_DV2+Q_BH_D_DV_G_9_S_DV2 <= 312.6199817;
[68]Q_BH_D_DV_G_9_E_DV3+Q_BH_D_DV_G_9_N_DV3+Q_BH_D_DV_G_9_S_DV3 <= 105.6586091;
[69]Q_BH_D_DV_G_9_E_DV4+Q_BH_D_DV_G_9_N_DV4+Q_BH_D_DV_G_9_S_DV4 <= 0;
[70]Q_BH_D_DV_G_10_E_DV1+Q_BH_D_DV_G_10_N_DV1+Q_BH_D_DV_G_10_S_DV1 <= 1.381059771;
[71]Q_BH_D_DV_G_10_E_DV2+Q_BH_D_DV_G_10_N_DV2+Q_BH_D_DV_G_10_S_DV2 <= 414.2754372;
[72]Q_BH_D_DV_G_10_E_DV3+Q_BH_D_DV_G_10_N_DV3+Q_BH_D_DV_G_10_S_DV3 <= 140.4856493;
[73]Q_BH_D_DV_G_10_E_DV4+Q_BH_D_DV_G_10_N_DV4+Q_BH_D_DV_G_10_S_DV4 <= 0;
[74]Q_BH_D_DV_G_11_E_DV1+Q_BH_D_DV_G_11_N_DV1+Q_BH_D_DV_G_11_S_DV1 <= 14.23647225;
[75]Q_BH_D_DV_G_11_E_DV2+Q_BH_D_DV_G_11_N_DV2+Q_BH_D_DV_G_11_S_DV2 <= 61.6893732;
[76]Q_BH_D_DV_G_11_E_DV3+Q_BH_D_DV_G_11_N_DV3+Q_BH_D_DV_G_11_S_DV3 <= 19.6962948;
[77]Q_BH_D_DV_G_11_E_DV4+Q_BH_D_DV_G_11_N_DV4+Q_BH_D_DV_G_11_S_DV4 <= 27.78068475;
[78]Q_BH_D_DV_G_12_E_DV1+Q_BH_D_DV_G_12_N_DV1+Q_BH_D_DV_G_12_S_DV1 <= 13.74962564;
[79]Q_BH_D_DV_G_12_E_DV2+Q_BH_D_DV_G_12_N_DV2+Q_BH_D_DV_G_12_S_DV2 <= 113.9585831;
[80]Q_BH_D_DV_G_12_E_DV3+Q_BH_D_DV_G_12_N_DV3+Q_BH_D_DV_G_12_S_DV3 <= 31.65047925;
[81]Q_BH_D_DV_G_12_E_DV4+Q_BH_D_DV_G_12_N_DV4+Q_BH_D_DV_G_12_S_DV4 <= 0;
[82]Q_BH_D_DV_G_13_E_DV1+Q_BH_D_DV_G_13_N_DV1+Q_BH_D_DV_G_13_S_DV1 <= 27.56902805;
[83]Q_BH_D_DV_G_13_E_DV2+Q_BH_D_DV_G_13_N_DV2+Q_BH_D_DV_G_13_S_DV2 <= 107.319253;
[84]Q_BH_D_DV_G_13_E_DV3+Q_BH_D_DV_G_13_N_DV3+Q_BH_D_DV_G_13_S_DV3 <= 34.97365481;
[85]Q_BH_D_DV_G_13_E_DV4+Q_BH_D_DV_G_13_N_DV4+Q_BH_D_DV_G_13_S_DV4 <= 29.7973685;
[86]Q_BH_D_DV_G_14_E_DV1+Q_BH_D_DV_G_14_N_DV1+Q_BH_D_DV_G_14_S_DV1 <= 12.51354964;
[87]Q_BH_D_DV_G_14_E_DV2+Q_BH_D_DV_G_14_N_DV2+Q_BH_D_DV_G_14_S_DV2 <= 71.06228806;
[88]Q_BH_D_DV_G_14_E_DV3+Q_BH_D_DV_G_14_N_DV3+Q_BH_D_DV_G_14_S_DV3 <= 18.3260323;
[89]Q_BH_D_DV_G_14_E_DV4+Q_BH_D_DV_G_14_N_DV4+Q_BH_D_DV_G_14_S_DV4 <= 0;
[90]Q_BH_D_DV_G_15_E_DV1+Q_BH_D_DV_G_15_N_DV1+Q_BH_D_DV_G_15_S_DV1 <= 0.349713;
[91]Q_BH_D_DV_G_15_E_DV2+Q_BH_D_DV_G_15_N_DV2+Q_BH_D_DV_G_15_S_DV2 <= 1.748565;
[92]Q_BH_D_DV_G_15_E_DV3+Q_BH_D_DV_G_15_N_DV3+Q_BH_D_DV_G_15_S_DV3 <= 0;
[93]Q_BH_D_DV_G_15_E_DV4+Q_BH_D_DV_G_15_N_DV4+Q_BH_D_DV_G_15_S_DV4 <= 0;
[94]Q_BH_D_DV_G_16_E_DV1+Q_BH_D_DV_G_16_N_DV1+Q_BH_D_DV_G_16_S_DV1 <= 15.013068;
[95]Q_BH_D_DV_G_16_E_DV2+Q_BH_D_DV_G_16_N_DV2+Q_BH_D_DV_G_16_S_DV2 <= 79.9428616;
[96]Q_BH_D_DV_G_16_E_DV3+Q_BH_D_DV_G_16_N_DV3+Q_BH_D_DV_G_16_S_DV3 <= 20.5104704;
[97]Q_BH_D_DV_G_16_E_DV4+Q_BH_D_DV_G_16_N_DV4+Q_BH_D_DV_G_16_S_DV4 <= 0;
[98]Q_BH_D_DV_G_1_E_DV1+Q_BH_D_DV_G_1_N_DV1+Q_BH_D_DV_G_1_S_DV1 >= 8.664603948;
[99]Q_BH_D_DV_G_1_E_DV2+Q_BH_D_DV_G_1_N_DV2+Q_BH_D_DV_G_1_S_DV2 >= 134.0087902;
[100]Q_BH_D_DV_G_1_E_DV3+Q_BH_D_DV_G_1_N_DV3+Q_BH_D_DV_G_1_S_DV3 >= 46.09119191;
[101]Q_BH_D_DV_G_1_E_DV4+Q_BH_D_DV_G_1_N_DV4+Q_BH_D_DV_G_1_S_DV4 >= 0;

[_102] Q_BH_D_DV_G_2_E_DV1+Q_BH_D_DV_G_2_N_DV1+Q_BH_D_DV_G_2_S_DV1 >= 0.2208696;
 [_103] Q_BH_D_DV_G_2_E_DV2+Q_BH_D_DV_G_2_N_DV2+Q_BH_D_DV_G_2_S_DV2 >= 138.4005725;
 [_104] Q_BH_D_DV_G_2_E_DV3+Q_BH_D_DV_G_2_N_DV3+Q_BH_D_DV_G_2_S_DV3 >= 47.73728288;
 [_105] Q_BH_D_DV_G_2_E_DV4+Q_BH_D_DV_G_2_N_DV4+Q_BH_D_DV_G_2_S_DV4 >= 0;
 [_106] Q_BH_D_DV_G_3_E_DV1+Q_BH_D_DV_G_3_N_DV1+Q_BH_D_DV_G_3_S_DV1 >= 0.50933988;
 [_107] Q_BH_D_DV_G_3_E_DV2+Q_BH_D_DV_G_3_N_DV2+Q_BH_D_DV_G_3_S_DV2 >= 141.7172191;
 [_108] Q_BH_D_DV_G_3_E_DV3+Q_BH_D_DV_G_3_N_DV3+Q_BH_D_DV_G_3_S_DV3 >= 48.77589606;
 [_109] Q_BH_D_DV_G_3_E_DV4+Q_BH_D_DV_G_3_N_DV4+Q_BH_D_DV_G_3_S_DV4 >= 0;
 [_110] Q_BH_D_DV_G_4_E_DV1+Q_BH_D_DV_G_4_N_DV1+Q_BH_D_DV_G_4_S_DV1 >= 5.517211056;
 [_111] Q_BH_D_DV_G_4_E_DV2+Q_BH_D_DV_G_4_N_DV2+Q_BH_D_DV_G_4_S_DV2 >= 118.0978731;
 [_112] Q_BH_D_DV_G_4_E_DV3+Q_BH_D_DV_G_4_N_DV3+Q_BH_D_DV_G_4_S_DV3 >= 40.66972721;
 [_113] Q_BH_D_DV_G_4_E_DV4+Q_BH_D_DV_G_4_N_DV4+Q_BH_D_DV_G_4_S_DV4 >= 0;
 [_114] Q_BH_D_DV_G_5_E_DV1+Q_BH_D_DV_G_5_N_DV1+Q_BH_D_DV_G_5_S_DV1 >= 10.6976079;
 [_115] Q_BH_D_DV_G_5_E_DV2+Q_BH_D_DV_G_5_N_DV2+Q_BH_D_DV_G_5_S_DV2 >= 147.983576;
 [_116] Q_BH_D_DV_G_5_E_DV3+Q_BH_D_DV_G_5_N_DV3+Q_BH_D_DV_G_5_S_DV3 >= 51.1107933;
 [_117] Q_BH_D_DV_G_5_E_DV4+Q_BH_D_DV_G_5_N_DV4+Q_BH_D_DV_G_5_S_DV4 >= 0;
 [_118] Q_BH_D_DV_G_6_E_DV1+Q_BH_D_DV_G_6_N_DV1+Q_BH_D_DV_G_6_S_DV1 >= 0;
 [_119] Q_BH_D_DV_G_6_E_DV2+Q_BH_D_DV_G_6_N_DV2+Q_BH_D_DV_G_6_S_DV2 >= 197.432366;
 [_120] Q_BH_D_DV_G_6_E_DV3+Q_BH_D_DV_G_6_N_DV3+Q_BH_D_DV_G_6_S_DV3 >= 68.43665556;
 [_121] Q_BH_D_DV_G_6_E_DV4+Q_BH_D_DV_G_6_N_DV4+Q_BH_D_DV_G_6_S_DV4 >= 0;
 [_122] Q_BH_D_DV_G_7_E_DV1+Q_BH_D_DV_G_7_N_DV1+Q_BH_D_DV_G_7_S_DV1 >= 0.152308632;
 [_123] Q_BH_D_DV_G_7_E_DV2+Q_BH_D_DV_G_7_N_DV2+Q_BH_D_DV_G_7_S_DV2 >= 196.5339818;
 [_124] Q_BH_D_DV_G_7_E_DV3+Q_BH_D_DV_G_7_N_DV3+Q_BH_D_DV_G_7_S_DV3 >= 67.94995769;
 [_125] Q_BH_D_DV_G_7_E_DV4+Q_BH_D_DV_G_7_N_DV4+Q_BH_D_DV_G_7_S_DV4 >= 0;
 [_126] Q_BH_D_DV_G_8_E_DV1+Q_BH_D_DV_G_8_N_DV1+Q_BH_D_DV_G_8_S_DV1 >= 0.20229468;
 [_127] Q_BH_D_DV_G_8_E_DV2+Q_BH_D_DV_G_8_N_DV2+Q_BH_D_DV_G_8_S_DV2 >= 131.211701;
 [_128] Q_BH_D_DV_G_8_E_DV3+Q_BH_D_DV_G_8_N_DV3+Q_BH_D_DV_G_8_S_DV3 >= 45.34098094;
 [_129] Q_BH_D_DV_G_8_E_DV4+Q_BH_D_DV_G_8_N_DV4+Q_BH_D_DV_G_8_S_DV4 >= 0;
 [_130] Q_BH_D_DV_G_9_E_DV1+Q_BH_D_DV_G_9_N_DV1+Q_BH_D_DV_G_9_S_DV1 >= 0.25162137;
 [_131] Q_BH_D_DV_G_9_E_DV2+Q_BH_D_DV_G_9_N_DV2+Q_BH_D_DV_G_9_S_DV2 >= 210.2659999;
 [_132] Q_BH_D_DV_G_9_E_DV3+Q_BH_D_DV_G_9_N_DV3+Q_BH_D_DV_G_9_S_DV3 >= 72.55641994;
 [_133] Q_BH_D_DV_G_9_E_DV4+Q_BH_D_DV_G_9_N_DV4+Q_BH_D_DV_G_9_S_DV4 >= 0;
 [_134] Q_BH_D_DV_G_10_E_DV1+Q_BH_D_DV_G_10_N_DV1+Q_BH_D_DV_G_10_S_DV1 >= 0.318706101;
 [_135] Q_BH_D_DV_G_10_E_DV2+Q_BH_D_DV_G_10_N_DV2+Q_BH_D_DV_G_10_S_DV2 >= 284.6328776;
 [_136] Q_BH_D_DV_G_10_E_DV3+Q_BH_D_DV_G_10_N_DV3+Q_BH_D_DV_G_10_S_DV3 >= 98.55809114;
 [_137] Q_BH_D_DV_G_10_E_DV4+Q_BH_D_DV_G_10_N_DV4+Q_BH_D_DV_G_10_S_DV4 >= 0;
 [_138] Q_BH_D_DV_G_11_E_DV1+Q_BH_D_DV_G_11_N_DV1+Q_BH_D_DV_G_11_S_DV1 >= 0.39127725;
 [_139] Q_BH_D_DV_G_11_E_DV2+Q_BH_D_DV_G_11_N_DV2+Q_BH_D_DV_G_11_S_DV2 >= 30.77847045;
 [_140] Q_BH_D_DV_G_11_E_DV3+Q_BH_D_DV_G_11_N_DV3+Q_BH_D_DV_G_11_S_DV3 >= 9.8240688;
 [_141] Q_BH_D_DV_G_11_E_DV4+Q_BH_D_DV_G_11_N_DV4+Q_BH_D_DV_G_11_S_DV4 >= 12.43057725;
 [_142] Q_BH_D_DV_G_12_E_DV1+Q_BH_D_DV_G_12_N_DV1+Q_BH_D_DV_G_12_S_DV1 >= 0.316083348;
 [_143] Q_BH_D_DV_G_12_E_DV2+Q_BH_D_DV_G_12_N_DV2+Q_BH_D_DV_G_12_S_DV2 >= 68.64452309;
 [_144] Q_BH_D_DV_G_12_E_DV3+Q_BH_D_DV_G_12_N_DV3+Q_BH_D_DV_G_12_S_DV3 >= 21.25484913;
 [_145] Q_BH_D_DV_G_12_E_DV4+Q_BH_D_DV_G_12_N_DV4+Q_BH_D_DV_G_12_S_DV4 >= 0;
 [_146] Q_BH_D_DV_G_13_E_DV1+Q_BH_D_DV_G_13_N_DV1+Q_BH_D_DV_G_13_S_DV1 >= 4.839955457;
 [_147] Q_BH_D_DV_G_13_E_DV2+Q_BH_D_DV_G_13_N_DV2+Q_BH_D_DV_G_13_S_DV2 >= 53.37855848;
 [_148] Q_BH_D_DV_G_13_E_DV3+Q_BH_D_DV_G_13_N_DV3+Q_BH_D_DV_G_13_S_DV3 >= 17.38462085;
 [_149] Q_BH_D_DV_G_13_E_DV4+Q_BH_D_DV_G_13_N_DV4+Q_BH_D_DV_G_13_S_DV4 >= 7.068295907;
 [_150] Q_BH_D_DV_G_14_E_DV1+Q_BH_D_DV_G_14_N_DV1+Q_BH_D_DV_G_14_S_DV1 >= 2.119558896;
 [_151] Q_BH_D_DV_G_14_E_DV2+Q_BH_D_DV_G_14_N_DV2+Q_BH_D_DV_G_14_S_DV2 >= 36.00125133;
 [_152] Q_BH_D_DV_G_14_E_DV3+Q_BH_D_DV_G_14_N_DV3+Q_BH_D_DV_G_14_S_DV3 >= 10.28257803;
 [_153] Q_BH_D_DV_G_14_E_DV4+Q_BH_D_DV_G_14_N_DV4+Q_BH_D_DV_G_14_S_DV4 >= 0;
 [_154] Q_BH_D_DV_G_15_E_DV1+Q_BH_D_DV_G_15_N_DV1+Q_BH_D_DV_G_15_S_DV1 >= 0;
 [_155] Q_BH_D_DV_G_15_E_DV2+Q_BH_D_DV_G_15_N_DV2+Q_BH_D_DV_G_15_S_DV2 >= 0.8742825;
 [_156] Q_BH_D_DV_G_15_E_DV3+Q_BH_D_DV_G_15_N_DV3+Q_BH_D_DV_G_15_S_DV3 >= 0;
 [_157] Q_BH_D_DV_G_15_E_DV4+Q_BH_D_DV_G_15_N_DV4+Q_BH_D_DV_G_15_S_DV4 >= 0;
 [_158] Q_BH_D_DV_G_16_E_DV1+Q_BH_D_DV_G_16_N_DV1+Q_BH_D_DV_G_16_S_DV1 >= 2.589468;
 [_159] Q_BH_D_DV_G_16_E_DV2+Q_BH_D_DV_G_16_N_DV2+Q_BH_D_DV_G_16_S_DV2 >= 38.0355416;
 [_160] Q_BH_D_DV_G_16_E_DV3+Q_BH_D_DV_G_16_N_DV3+Q_BH_D_DV_G_16_S_DV3 >= 10.8963904;
 [_161] Q_BH_D_DV_G_16_E_DV4+Q_BH_D_DV_G_16_N_DV4+Q_BH_D_DV_G_16_S_DV4 >= 0;
 [_162] Q_BH_D_HV_G_1_E+Q_BH_D_HV_G_1_N+Q_BH_D_HV_G_1_S <= 42.1977465;
 [_163] Q_BH_D_HV_G_2_E+Q_BH_D_HV_G_2_N+Q_BH_D_HV_G_2_S <= 41.41305;
 [_164] Q_BH_D_HV_G_3_E+Q_BH_D_HV_G_3_N+Q_BH_D_HV_G_3_S <= 36.785658;
 [_165] Q_BH_D_HV_G_4_E+Q_BH_D_HV_G_4_N+Q_BH_D_HV_G_4_S <= 36.94560975;
 [_166] Q_BH_D_HV_G_5_E+Q_BH_D_HV_G_5_N+Q_BH_D_HV_G_5_S <= 44.57336625;
 [_167] Q_BH_D_HV_G_6_E+Q_BH_D_HV_G_6_N+Q_BH_D_HV_G_6_S <= 48.0041289;
 [_168] Q_BH_D_HV_G_7_E+Q_BH_D_HV_G_7_N+Q_BH_D_HV_G_7_S <= 53.3080212;
 [_169] Q_BH_D_HV_G_8_E+Q_BH_D_HV_G_8_N+Q_BH_D_HV_G_8_S <= 30.344202;
 [_170] Q_BH_D_HV_G_9_E+Q_BH_D_HV_G_9_N+Q_BH_D_HV_G_9_S <= 62.9053425;
 [_171] Q_BH_D_HV_G_10_E+Q_BH_D_HV_G_10_N+Q_BH_D_HV_G_10_S <= 79.67652525;
 [_172] Q_BH_D_HV_G_11_E+Q_BH_D_HV_G_11_N+Q_BH_D_HV_G_11_S <= 66.21615;
 [_173] Q_BH_D_HV_G_12_E+Q_BH_D_HV_G_12_N+Q_BH_D_HV_G_12_S <= 9.21909765;
 [_174] Q_BH_D_HV_G_13_E+Q_BH_D_HV_G_13_N+Q_BH_D_HV_G_13_S <= 64.62187305;
 [_175] Q_BH_D_HV_G_14_E+Q_BH_D_HV_G_14_N+Q_BH_D_HV_G_14_S <= 29.5515423;
 [_176] Q_BH_D_HV_G_15_E+Q_BH_D_HV_G_15_N+Q_BH_D_HV_G_15_S <= 33.222735;
 [_177] Q_BH_D_HV_G_16_E+Q_BH_D_HV_G_16_N+Q_BH_D_HV_G_16_S <= 35.322;
 [_178] Q_BH_D_HV_G_1_E+Q_BH_D_HV_G_1_N+Q_BH_D_HV_G_1_S >= 21.09887325;
 [_179] Q_BH_D_HV_G_2_E+Q_BH_D_HV_G_2_N+Q_BH_D_HV_G_2_S >= 20.706525;

Annexure 9

[_180] Q_BH_D_HV_G_3_E+Q_BH_D_HV_G_3_N+Q_BH_D_HV_G_3_S >= 15.563163;
[_181] Q_BH_D_HV_G_4_E+Q_BH_D_HV_G_4_N+Q_BH_D_HV_G_4_S >= 18.47280488;
[_182] Q_BH_D_HV_G_5_E+Q_BH_D_HV_G_5_N+Q_BH_D_HV_G_5_S >= 22.28668313;
[_183] Q_BH_D_HV_G_6_E+Q_BH_D_HV_G_6_N+Q_BH_D_HV_G_6_S >= 20.30943915;
[_184] Q_BH_D_HV_G_7_E+Q_BH_D_HV_G_7_N+Q_BH_D_HV_G_7_S >= 24.7501527;
[_185] Q_BH_D_HV_G_8_E+Q_BH_D_HV_G_8_N+Q_BH_D_HV_G_8_S >= 11.37907575;
[_186] Q_BH_D_HV_G_9_E+Q_BH_D_HV_G_9_N+Q_BH_D_HV_G_9_S >= 31.45267125;
[_187] Q_BH_D_HV_G_10_E+Q_BH_D_HV_G_10_N+Q_BH_D_HV_G_10_S >= 39.83826263;
[_188] Q_BH_D_HV_G_11_E+Q_BH_D_HV_G_11_N+Q_BH_D_HV_G_11_S >= 54.92930625;
[_189] Q_BH_D_HV_G_12_E+Q_BH_D_HV_G_12_N+Q_BH_D_HV_G_12_S >= 0;
[_190] Q_BH_D_HV_G_13_E+Q_BH_D_HV_G_13_N+Q_BH_D_HV_G_13_S >= 47.90931968;
[_191] Q_BH_D_HV_G_14_E+Q_BH_D_HV_G_14_N+Q_BH_D_HV_G_14_S >= 21.90890205;
[_192] Q_BH_D_HV_G_15_E+Q_BH_D_HV_G_15_N+Q_BH_D_HV_G_15_S >= 31.9987395;
[_193] Q_BH_D_HV_G_16_E+Q_BH_D_HV_G_16_N+Q_BH_D_HV_G_16_S >= 26.187;
[_194] AT_DV_D_Z_DV1_E_1 <= 56;
[_195] AT_DV_D_Z_DV1_E_2 <= 28;
[_196] AT_DV_D_Z_DV1_N_1 <= 56;
[_197] AT_DV_D_Z_DV1_N_2 <= 28;
[_198] AT_DV_D_Z_DV1_S_1 <= 56;
[_199] AT_DV_D_Z_DV1_S_2 <= 28;
[_200] AT_DV_D_Z_DV2_E_1 <= 280;
[_201] AT_DV_D_Z_DV2_E_2 <= 140;
[_202] AT_DV_D_Z_DV2_N_1 <= 280;
[_203] AT_DV_D_Z_DV2_N_2 <= 140;
[_204] AT_DV_D_Z_DV2_S_1 <= 280;
[_205] AT_DV_D_Z_DV2_S_2 <= 140;
[_206] AT_DV_D_Z_DV3_E_1 <= 80;
[_207] AT_DV_D_Z_DV3_E_2 <= 40;
[_208] AT_DV_D_Z_DV3_N_1 <= 80;
[_209] AT_DV_D_Z_DV3_N_2 <= 40;
[_210] AT_DV_D_Z_DV3_S_1 <= 80;
[_211] AT_DV_D_Z_DV3_S_2 <= 40;
[_212] AT_DV_D_Z_DV4_E_1 <= 8;
[_213] AT_DV_D_Z_DV4_E_2 <= 4;
[_214] AT_DV_D_Z_DV4_N_1 <= 8;
[_215] AT_DV_D_Z_DV4_N_2 <= 4;
[_216] AT_DV_D_Z_DV4_S_1 <= 8;
[_217] AT_DV_D_Z_DV4_S_2 <= 4;
[_218] AT_DV_D_Z_DV1_E_1+AT_DV_D_Z_DV1_E_2+AT_DV_D_Z_DV1_N_1+AT_DV_D_Z_DV1_N_2+AT_DV_D_Z_DV1_S_1+AT_DV_D_Z_DV1_S_2 <= 56;
[_219] AT_DV_D_Z_DV2_E_1+AT_DV_D_Z_DV2_E_2+AT_DV_D_Z_DV2_N_1+AT_DV_D_Z_DV2_N_2+AT_DV_D_Z_DV2_S_1+AT_DV_D_Z_DV2_S_2 <= 280;
[_220] AT_DV_D_Z_DV3_E_1+AT_DV_D_Z_DV3_E_2+AT_DV_D_Z_DV3_N_1+AT_DV_D_Z_DV3_N_2+AT_DV_D_Z_DV3_S_1+AT_DV_D_Z_DV3_S_2 <= 80;
[_221] AT_DV_D_Z_DV4_E_1+AT_DV_D_Z_DV4_E_2+AT_DV_D_Z_DV4_N_1+AT_DV_D_Z_DV4_N_2+AT_DV_D_Z_DV4_S_1+AT_DV_D_Z_DV4_S_2 <= 8;
[_222] AT_DV_D_Z_DV1_E_1+AT_DV_D_Z_DV1_E_2+AT_DV_D_Z_DV1_N_1+AT_DV_D_Z_DV1_N_2+AT_DV_D_Z_DV1_S_1+AT_DV_D_Z_DV1_S_2 >= 28;
[_223] AT_DV_D_Z_DV2_E_1+AT_DV_D_Z_DV2_E_2+AT_DV_D_Z_DV2_N_1+AT_DV_D_Z_DV2_N_2+AT_DV_D_Z_DV2_S_1+AT_DV_D_Z_DV2_S_2 >= 70;
[_224] AT_DV_D_Z_DV3_E_1+AT_DV_D_Z_DV3_E_2+AT_DV_D_Z_DV3_N_1+AT_DV_D_Z_DV3_N_2+AT_DV_D_Z_DV3_S_1+AT_DV_D_Z_DV3_S_2 >= 20;
[_225] AT_DV_D_Z_DV4_E_1+AT_DV_D_Z_DV4_E_2+AT_DV_D_Z_DV4_N_1+AT_DV_D_Z_DV4_N_2+AT_DV_D_Z_DV4_S_1+AT_DV_D_Z_DV4_S_2 >= 2;
[_226] DGHV_E_1-Q_BH_D_HV_G_3_E-Q_BH_D_HV_G_4_E-Q_BH_D_HV_G_5_E-Q_BH_D_HV_G_6_E-Q_BH_D_HV_G_7_E-Q_BH_D_HV_G_8_E-Q_BH_D_HV_G_10_E-Q_BH_D_HV_G_12_E=0;
[_227] DGHV_E_2-Q_BH_D_HV_G_1_E-Q_BH_D_HV_G_2_E-Q_BH_D_HV_G_9_E-Q_BH_D_HV_G_11_E-Q_BH_D_HV_G_13_E-Q_BH_D_HV_G_14_E-Q_BH_D_HV_G_15_E-Q_BH_D_HV_G_16_E=0;
[_228] DGHV_N_1-Q_BH_D_HV_G_1_N-Q_BH_D_HV_G_2_N-Q_BH_D_HV_G_3_N-Q_BH_D_HV_G_4_N-Q_BH_D_HV_G_5_N-Q_BH_D_HV_G_6_N-Q_BH_D_HV_G_7_N=0;
[_229] DGHV_N_2-Q_BH_D_HV_G_8_N-Q_BH_D_HV_G_9_N-Q_BH_D_HV_G_10_N-Q_BH_D_HV_G_11_N-Q_BH_D_HV_G_12_N-Q_BH_D_HV_G_13_N-Q_BH_D_HV_G_14_N-Q_BH_D_HV_G_15_N-Q_BH_D_HV_G_16_N=0;
[_230] DGHV_S_1-Q_BH_D_HV_G_8_S-Q_BH_D_HV_G_9_S-Q_BH_D_HV_G_10_S-Q_BH_D_HV_G_11_S-Q_BH_D_HV_G_12_S-Q_BH_D_HV_G_13_S-Q_BH_D_HV_G_14_S-Q_BH_D_HV_G_16_S=0;
[_231] DGHV_S_2-Q_BH_D_HV_G_1_S-Q_BH_D_HV_G_2_S-Q_BH_D_HV_G_3_S-Q_BH_D_HV_G_4_S-Q_BH_D_HV_G_5_S-Q_BH_D_HV_G_6_S-Q_BH_D_HV_G_7_S-Q_BH_D_HV_G_15_S=0;
[_232] DGDV_DV1_E_1+Q_BH_D_DV_G_3_E_DV1+Q_BH_D_DV_G_4_E_DV1+Q_BH_D_DV_G_5_E_DV1+Q_BH_D_DV_G_6_E_DV1+Q_BH_D_DV_G_7_E_DV1+Q_BH_D_DV_G_8_E_DV1+Q_BH_D_DV_G_10_E_DV1+Q_BH_D_DV_G_12_E_DV1=0;
[_233] DGDV_DV2_E_1+Q_BH_D_DV_G_3_E_DV2+Q_BH_D_DV_G_4_E_DV2+Q_BH_D_DV_G_5_E_DV2+Q_BH_D_DV_G_6_E_DV2+Q_BH_D_DV_G_7_E_DV2+Q_BH_D_DV_G_8_E_DV2+Q_BH_D_DV_G_10_E_DV2+Q_BH_D_DV_G_12_E_DV2=0;
[_234] DGDV_DV3_E_1+Q_BH_D_DV_G_3_E_DV3+Q_BH_D_DV_G_4_E_DV3+Q_BH_D_DV_G_5_E_DV3+Q_BH_D_DV_G_6_E_DV3+Q_BH_D_DV_G_7_E_DV3+Q_BH_D_DV_G_8_E_DV3+Q_BH_D_DV_G_10_E_DV3+Q_BH_D_DV_G_12_E_DV3=0;
[_235] DGDV_DV4_E_1+Q_BH_D_DV_G_3_E_DV4+Q_BH_D_DV_G_4_E_DV4+Q_BH_D_DV_G_5_E_DV4+Q_BH_D_DV_G_6_E_DV4+Q_BH_D_DV_G_7_E_DV4+Q_BH_D_DV_G_8_E_DV4+Q_BH_D_DV_G_10_E_DV4+Q_BH_D_DV_G_12_E_DV4=0;

[236]-DGDV_DV1_E_2+Q_BH_D_DV_G_1_E_DV1+Q_BH_D_DV_G_2_E_DV1+Q_BH_D_DV_G_9_E_DV1+Q_BH_D_DV_G_11_E_DV1+Q_BH_D_DV_G_13_E_DV1+Q_BH_D_DV_G_14_E_DV1+Q_BH_D_DV_G_15_E_DV1+Q_BH_D_DV_G_16_E_DV1 = 0;

[237]-DGDV_DV2_E_2+Q_BH_D_DV_G_1_E_DV2+Q_BH_D_DV_G_2_E_DV2+Q_BH_D_DV_G_9_E_DV2+Q_BH_D_DV_G_11_E_DV2+Q_BH_D_DV_G_13_E_DV2+Q_BH_D_DV_G_14_E_DV2+Q_BH_D_DV_G_15_E_DV2+Q_BH_D_DV_G_16_E_DV2 = 0;

[238]- DGDV_DV3_E_2+Q_BH_D_DV_G_1_E_DV3+Q_BH_D_DV_G_2_E_DV3+Q_BH_D_DV_G_9_E_DV3+Q_BH_D_DV_G_11_E_DV3+Q_BH_D_DV_G_13_E_DV3+Q_BH_D_DV_G_14_E_DV3+Q_BH_D_DV_G_15_E_DV3+Q_BH_D_DV_G_16_E_DV3 = 0;

[239]-DGDV_DV4_E_2+ Q_BH_D_DV_G_1_E_DV4+Q_BH_D_DV_G_2_E_DV4+Q_BH_D_DV_G_9_E_DV4+Q_BH_D_DV_G_11_E_DV4+Q_BH_D_DV_G_13_E_DV4+Q_BH_D_DV_G_14_E_DV4+Q_BH_D_DV_G_15_E_DV4+Q_BH_D_DV_G_16_E_DV4 = 0;

[240]-DGDV_DV1_N_1+Q_BH_D_DV_G_1_N_DV1+Q_BH_D_DV_G_2_N_DV1+Q_BH_D_DV_G_3_N_DV1+Q_BH_D_DV_G_4_N_DV1+Q_BH_D_DV_G_5_N_DV1+Q_BH_D_DV_G_6_N_DV1+Q_BH_D_DV_G_7_N_DV1 = 0;

[241]-DGDV_DV2_N_1+Q_BH_D_DV_G_1_N_DV2+Q_BH_D_DV_G_2_N_DV2+Q_BH_D_DV_G_3_N_DV2+Q_BH_D_DV_G_4_N_DV2 +Q_BH_D_DV_G_5_N_DV2+Q_BH_D_DV_G_6_N_DV2+Q_BH_D_DV_G_7_N_DV2 = 0;

[242]-DGDV_DV3_N_1+Q_BH_D_DV_G_1_N_DV3+Q_BH_D_DV_G_2_N_DV3+Q_BH_D_DV_G_3_N_DV3+Q_BH_D_DV_G_4_N_DV3+Q_BH_D_DV_G_5_N_DV3+Q_BH_D_DV_G_6_N_DV3+Q_BH_D_DV_G_7_N_DV3 = 0;

[243]-DGDV_DV4_N_1+Q_BH_D_DV_G_1_N_DV4+Q_BH_D_DV_G_2_N_DV4+Q_BH_D_DV_G_3_N_DV4+Q_BH_D_DV_G_4_N_DV4+Q_BH_D_DV_G_5_N_DV4+Q_BH_D_DV_G_6_N_DV4+Q_BH_D_DV_G_7_N_DV4 = 0;

[244]-DGDV_DV1_N_2+Q_BH_D_DV_G_8_N_DV1+Q_BH_D_DV_G_9_N_DV1+Q_BH_D_DV_G_10_N_DV1+Q_BH_D_DV_G_11_N_DV1+Q_BH_D_DV_G_12_N_DV1+Q_BH_D_DV_G_13_N_DV1+Q_BH_D_DV_G_14_N_DV1+Q_BH_D_DV_G_15_N_DV1+ Q_BH_D_DV_G_16_N_DV1 = 0;

[245]-DGDV_DV2_N_2+Q_BH_D_DV_G_8_N_DV2+Q_BH_D_DV_G_9_N_DV2+Q_BH_D_DV_G_10_N_DV2+Q_BH_D_DV_G_11_N_DV2+Q_BH_D_DV_G_12_N_DV2+Q_BH_D_DV_G_13_N_DV2+Q_BH_D_DV_G_14_N_DV2+Q_BH_D_DV_G_15_N_DV2+ Q_BH_D_DV_G_16_N_DV2 = 0;

[246]-DGDV_DV3_N_2+Q_BH_D_DV_G_8_N_DV3+Q_BH_D_DV_G_9_N_DV3+Q_BH_D_DV_G_10_N_DV3+Q_BH_D_DV_G_11_N_DV3+Q_BH_D_DV_G_12_N_DV3+Q_BH_D_DV_G_13_N_DV3+Q_BH_D_DV_G_14_N_DV3+Q_BH_D_DV_G_15_N_DV3+ Q_BH_D_DV_G_16_N_DV3 = 0;

[247]-DGDV_DV4_N_2+Q_BH_D_DV_G_8_N_DV4+Q_BH_D_DV_G_9_N_DV4+Q_BH_D_DV_G_10_N_DV4+Q_BH_D_DV_G_11_N_DV4+Q_BH_D_DV_G_12_N_DV4+Q_BH_D_DV_G_13_N_DV4+Q_BH_D_DV_G_14_N_DV4+Q_BH_D_DV_G_15_N_DV4+ Q_BH_D_DV_G_16_N_DV4 = 0;

[248]-DGDV_DV1_S_1+Q_BH_D_DV_G_8_S_DV1+Q_BH_D_DV_G_9_S_DV1+Q_BH_D_DV_G_10_S_DV1+Q_BH_D_DV_G_11_S_DV1+Q_BH_D_DV_G_12_S_DV1+Q_BH_D_DV_G_13_S_DV1+Q_BH_D_DV_G_14_S_DV1+Q_BH_D_DV_G_16_S_DV1= 0;

[249]-DGDV_DV2_S_1+Q_BH_D_DV_G_8_S_DV2+Q_BH_D_DV_G_9_S_DV2+Q_BH_D_DV_G_10_S_DV2+Q_BH_D_DV_G_11_S_DV2+Q_BH_D_DV_G_12_S_DV2+Q_BH_D_DV_G_13_S_DV2+Q_BH_D_DV_G_14_S_DV2+Q_BH_D_DV_G_16_S_DV2 = 0;

[250]-DGDV_DV3_S_1+Q_BH_D_DV_G_8_S_DV3+Q_BH_D_DV_G_9_S_DV3+Q_BH_D_DV_G_10_S_DV3+Q_BH_D_DV_G_11_S_DV3+Q_BH_D_DV_G_12_S_DV3+Q_BH_D_DV_G_13_S_DV3+Q_BH_D_DV_G_14_S_DV3+Q_BH_D_DV_G_16_S_DV3 = 0;

[251]-DGDV_DV4_S_1+Q_BH_D_DV_G_8_S_DV4+Q_BH_D_DV_G_9_S_DV4+Q_BH_D_DV_G_10_S_DV4+Q_BH_D_DV_G_11_S_DV4+Q_BH_D_DV_G_12_S_DV4+Q_BH_D_DV_G_13_S_DV4+Q_BH_D_DV_G_14_S_DV4+Q_BH_D_DV_G_16_S_DV4 = 0;

[252]-DGDV_DV1_S_2+Q_BH_D_DV_G_1_S_DV1+Q_BH_D_DV_G_2_S_DV1+Q_BH_D_DV_G_3_S_DV1+Q_BH_D_DV_G_4_S_DV1+Q_BH_D_DV_G_5_S_DV1+Q_BH_D_DV_G_6_S_DV1+Q_BH_D_DV_G_7_S_DV1+Q_BH_D_DV_G_15_S_DV1 = 0;

[253]-DGDV_DV2_S_2+Q_BH_D_DV_G_1_S_DV2+Q_BH_D_DV_G_2_S_DV2+Q_BH_D_DV_G_3_S_DV2+Q_BH_D_DV_G_4_S_DV2+Q_BH_D_DV_G_5_S_DV2+Q_BH_D_DV_G_6_S_DV2+Q_BH_D_DV_G_7_S_DV2+Q_BH_D_DV_G_15_S_DV2 = 0;

[254]-DGDV_DV3_S_2+Q_BH_D_DV_G_1_S_DV3+Q_BH_D_DV_G_2_S_DV3+Q_BH_D_DV_G_3_S_DV3+Q_BH_D_DV_G_4_S_DV3+Q_BH_D_DV_G_5_S_DV3+Q_BH_D_DV_G_6_S_DV3+Q_BH_D_DV_G_7_S_DV3+Q_BH_D_DV_G_15_S_DV3 = 0;

[255]-DGDV_DV4_S_2+Q_BH_D_DV_G_1_S_DV4+Q_BH_D_DV_G_2_S_DV4+Q_BH_D_DV_G_3_S_DV4+Q_BH_D_DV_G_4_S_DV4+Q_BH_D_DV_G_5_S_DV4+Q_BH_D_DV_G_6_S_DV4+Q_BH_D_DV_G_7_S_DV4+Q_BH_D_DV_G_15_S_DV4 = 0;

[256]-DSHV_E_1-Q_BH_D_HV_S_3_E-Q_BH_D_HV_S_4_E-Q_BH_D_HV_S_5_E-Q_BH_D_HV_S_6_E-Q_BH_D_HV_S_7_E-Q_BH_D_HV_S_8_E-Q_BH_D_HV_S_10_E-Q_BH_D_HV_S_12_E = 0;

[257]-DSHV_E_2-Q_BH_D_HV_S_1_E-Q_BH_D_HV_S_2_E-Q_BH_D_HV_S_9_E-Q_BH_D_HV_S_11_E-Q_BH_D_HV_S_13_E-Q_BH_D_HV_S_14_E-Q_BH_D_HV_S_15_E-Q_BH_D_HV_S_16_E = 0;

[258]-DSHV_N_1-Q_BH_D_HV_S_1_N-Q_BH_D_HV_S_2_N-Q_BH_D_HV_S_3_N-Q_BH_D_HV_S_4_N-Q_BH_D_HV_S_5_N-Q_BH_D_HV_S_6_N-Q_BH_D_HV_S_7_N = 0;

[259]-DSHV_N_2-Q_BH_D_HV_S_8_N-Q_BH_D_HV_S_9_N-Q_BH_D_HV_S_10_N-Q_BH_D_HV_S_11_N-Q_BH_D_HV_S_12_N-Q_BH_D_HV_S_13_N-Q_BH_D_HV_S_14_N-Q_BH_D_HV_S_15_N-Q_BH_D_HV_S_16_N = 0;

[260]-DSHV_S_1-Q_BH_D_HV_S_8_S-Q_BH_D_HV_S_9_S-Q_BH_D_HV_S_10_S-Q_BH_D_HV_S_11_S-Q_BH_D_HV_S_12_S-Q_BH_D_HV_S_13_S-Q_BH_D_HV_S_14_S-Q_BH_D_HV_S_16_S = 0;

[261]-DSHV_S_2-Q_BH_D_HV_S_1_S-Q_BH_D_HV_S_2_S-Q_BH_D_HV_S_3_S-Q_BH_D_HV_S_4_S-Q_BH_D_HV_S_5_S-Q_BH_D_HV_S_6_S-Q_BH_D_HV_S_7_S-Q_BH_D_HV_S_15_S = 0;

[262]- 7 * AT_DV_D_Z_DV1_E_1+Q_BH_D_DV_G_3_E_DV1+Q_BH_D_DV_G_4_E_DV1+Q_BH_D_DV_G_5_E_DV1+Q_BH_D_DV_G_6_E_DV1+Q_BH_D_DV_G_7_E_DV1+Q_BH_D_DV_G_8_E_DV1+Q_BH_D_DV_G_10_E_DV1+Q_BH_D_DV_G_12_E_DV1 = 0;

[263]- 9 * AT_DV_D_Z_DV2_E_1+Q_BH_D_DV_G_3_E_DV2+Q_BH_D_DV_G_4_E_DV2+Q_BH_D_DV_G_5_E_DV2+Q_BH_D_DV_G_6_E_DV2+Q_BH_D_DV_G_7_E_DV2+Q_BH_D_DV_G_8_E_DV2+Q_BH_D_DV_G_10_E_DV2+Q_BH_D_DV_G_12_E_DV2 = 0;

[264]- 10 * AT_DV_D_Z_DV3_E_1+Q_BH_D_DV_G_3_E_DV3+Q_BH_D_DV_G_4_E_DV3+Q_BH_D_DV_G_5_E_DV3+Q_BH_D_DV_G_6_E_DV3+Q_BH_D_DV_G_7_E_DV3+Q_BH_D_DV_G_8_E_DV3+Q_BH_D_DV_G_10_E_DV3+Q_BH_D_DV_G_12_E_DV3 = 0;

Annexure 9

[265]- 7 * AT_DV_D_Z_DV4_E_1+Q_BH_D_DV_G_3_E_DV4+Q_BH_D_DV_G_4_E_DV4+Q_BH_D_DV_G_5_E_DV4+Q_BH_D_DV_G_6_E_DV4+Q_BH_D_DV_G_7_E_DV4+Q_BH_D_DV_G_8_E_DV4+Q_BH_D_DV_G_10_E_DV4+Q_BH_D_DV_G_12_E_DV4=0;

[266]- 7 * AT_DV_D_Z_DV1_E_2+ Q_BH_D_DV_G_1_E_DV1+Q_BH_D_DV_G_2_E_DV1+Q_BH_D_DV_G_9_E_DV1+Q_BH_D_DV_G_11_E_DV1+Q_BH_D_DV_G_13_E_DV1+Q_BH_D_DV_G_14_E_DV1+Q_BH_D_DV_G_15_E_DV1+Q_BH_D_DV_G_16_E_DV1=0;

[267]- 9 * AT_DV_D_Z_DV2_E_2+Q_BH_D_DV_G_1_E_DV2+Q_BH_D_DV_G_2_E_DV2+Q_BH_D_DV_G_9_E_DV2+Q_BH_D_DV_G_11_E_DV2+Q_BH_D_DV_G_13_E_DV2+Q_BH_D_DV_G_14_E_DV2+Q_BH_D_DV_G_15_E_DV2+Q_BH_D_DV_G_16_E_DV2=0;

[268]- 10 * AT_DV_D_Z_DV3_E_2+Q_BH_D_DV_G_1_E_DV3+Q_BH_D_DV_G_2_E_DV3+Q_BH_D_DV_G_9_E_DV3+Q_BH_D_DV_G_11_E_DV3+Q_BH_D_DV_G_13_E_DV3+Q_BH_D_DV_G_14_E_DV3+Q_BH_D_DV_G_15_E_DV3+Q_BH_D_DV_G_16_E_DV3=0;

[269]- 7 * AT_DV_D_Z_DV4_E_2+Q_BH_D_DV_G_1_E_DV4+Q_BH_D_DV_G_2_E_DV4+Q_BH_D_DV_G_9_E_DV4+Q_BH_D_DV_G_11_E_DV4+Q_BH_D_DV_G_13_E_DV4+Q_BH_D_DV_G_14_E_DV4+Q_BH_D_DV_G_15_E_DV4+Q_BH_D_DV_G_16_E_DV4=0;

[270]- 7 * AT_DV_D_Z_DV1_N_1+Q_BH_D_DV_G_1_N_DV1+Q_BH_D_DV_G_2_N_DV1+Q_BH_D_DV_G_3_N_DV1+Q_BH_D_DV_G_4_N_DV1+Q_BH_D_DV_G_5_N_DV1+Q_BH_D_DV_G_6_N_DV1+Q_BH_D_DV_G_7_N_DV1=0;

[271]- 9 * AT_DV_D_Z_DV2_N_1+Q_BH_D_DV_G_1_N_DV2+Q_BH_D_DV_G_2_N_DV2+Q_BH_D_DV_G_3_N_DV2+Q_BH_D_DV_G_4_N_DV2+Q_BH_D_DV_G_5_N_DV2+Q_BH_D_DV_G_6_N_DV2+Q_BH_D_DV_G_7_N_DV2=0;

[272]- 10 * AT_DV_D_Z_DV3_N_1+Q_BH_D_DV_G_1_N_DV3+Q_BH_D_DV_G_2_N_DV3+Q_BH_D_DV_G_3_N_DV3+Q_BH_D_DV_G_4_N_DV3+Q_BH_D_DV_G_5_N_DV3+Q_BH_D_DV_G_6_N_DV3+Q_BH_D_DV_G_7_N_DV3=0;

[273]- 7 * AT_DV_D_Z_DV4_N_1+Q_BH_D_DV_G_1_N_DV4+Q_BH_D_DV_G_2_N_DV4+Q_BH_D_DV_G_3_N_DV4+Q_BH_D_DV_G_4_N_DV4+Q_BH_D_DV_G_5_N_DV4+Q_BH_D_DV_G_6_N_DV4+Q_BH_D_DV_G_7_N_DV4=0;

[274]- 7 * AT_DV_D_Z_DV1_N_2+Q_BH_D_DV_G_8_N_DV1+Q_BH_D_DV_G_9_N_DV1+Q_BH_D_DV_G_10_N_DV1+Q_BH_D_DV_G_11_N_DV1+Q_BH_D_DV_G_12_N_DV1+Q_BH_D_DV_G_13_N_DV1+Q_BH_D_DV_G_14_N_DV1+Q_BH_D_DV_G_15_N_DV1+Q_BH_D_DV_G_16_N_DV1=0;

[275]- 9 * AT_DV_D_Z_DV2_N_2+Q_BH_D_DV_G_8_N_DV2+Q_BH_D_DV_G_9_N_DV2+Q_BH_D_DV_G_10_N_DV2+Q_BH_D_DV_G_11_N_DV2+Q_BH_D_DV_G_12_N_DV2+Q_BH_D_DV_G_13_N_DV2+Q_BH_D_DV_G_14_N_DV2+Q_BH_D_DV_G_15_N_DV2+Q_BH_D_DV_G_16_N_DV2=0;

[276]- 10 * AT_DV_D_Z_DV3_N_2+Q_BH_D_DV_G_8_N_DV3+Q_BH_D_DV_G_9_N_DV3+Q_BH_D_DV_G_10_N_DV3+Q_BH_D_DV_G_11_N_DV3+Q_BH_D_DV_G_12_N_DV3+Q_BH_D_DV_G_13_N_DV3+Q_BH_D_DV_G_14_N_DV3+Q_BH_D_DV_G_15_N_DV3+Q_BH_D_DV_G_16_N_DV3=0;

[277]- 7 * AT_DV_D_Z_DV4_N_2+Q_BH_D_DV_G_8_N_DV4+Q_BH_D_DV_G_9_N_DV4+Q_BH_D_DV_G_10_N_DV4+Q_BH_D_DV_G_11_N_DV4+Q_BH_D_DV_G_12_N_DV4+Q_BH_D_DV_G_13_N_DV4+Q_BH_D_DV_G_14_N_DV4+Q_BH_D_DV_G_15_N_DV4+Q_BH_D_DV_G_16_N_DV4=0;

[278]- 7 * AT_DV_D_Z_DV1_S_1+Q_BH_D_DV_G_8_S_DV1+Q_BH_D_DV_G_9_S_DV1+Q_BH_D_DV_G_10_S_DV1+Q_BH_D_DV_G_11_S_DV1+Q_BH_D_DV_G_12_S_DV1+Q_BH_D_DV_G_13_S_DV1+Q_BH_D_DV_G_14_S_DV1+Q_BH_D_DV_G_16_S_DV1=0;

[279]- 9 * AT_DV_D_Z_DV2_S_1+Q_BH_D_DV_G_8_S_DV2+Q_BH_D_DV_G_9_S_DV2+Q_BH_D_DV_G_10_S_DV2+Q_BH_D_DV_G_11_S_DV2+Q_BH_D_DV_G_12_S_DV2+Q_BH_D_DV_G_13_S_DV2+Q_BH_D_DV_G_14_S_DV2+Q_BH_D_DV_G_16_S_DV2=0;

[280]- 10 * AT_DV_D_Z_DV3_S_1+Q_BH_D_DV_G_8_S_DV3+Q_BH_D_DV_G_9_S_DV3+Q_BH_D_DV_G_10_S_DV3+Q_BH_D_DV_G_11_S_DV3+Q_BH_D_DV_G_12_S_DV3+Q_BH_D_DV_G_13_S_DV3+Q_BH_D_DV_G_14_S_DV3+Q_BH_D_DV_G_16_S_DV3=0;

[281]- 7 * AT_DV_D_Z_DV4_S_1+Q_BH_D_DV_G_8_S_DV4+Q_BH_D_DV_G_9_S_DV4+Q_BH_D_DV_G_10_S_DV4+Q_BH_D_DV_G_11_S_DV4+Q_BH_D_DV_G_12_S_DV4+Q_BH_D_DV_G_13_S_DV4+Q_BH_D_DV_G_14_S_DV4+Q_BH_D_DV_G_16_S_DV4=0;

[282]- 7 * AT_DV_D_Z_DV1_S_2+Q_BH_D_DV_G_1_S_DV1+Q_BH_D_DV_G_2_S_DV1+Q_BH_D_DV_G_3_S_DV1+Q_BH_D_DV_G_4_S_DV1+Q_BH_D_DV_G_5_S_DV1+Q_BH_D_DV_G_6_S_DV1+Q_BH_D_DV_G_7_S_DV1+Q_BH_D_DV_G_15_S_DV1=0;

[283]- 9 * AT_DV_D_Z_DV2_S_2+Q_BH_D_DV_G_1_S_DV2+Q_BH_D_DV_G_2_S_DV2+Q_BH_D_DV_G_3_S_DV2+Q_BH_D_DV_G_4_S_DV2+Q_BH_D_DV_G_5_S_DV2+Q_BH_D_DV_G_6_S_DV2+Q_BH_D_DV_G_7_S_DV2+Q_BH_D_DV_G_15_S_DV2=0;

[284]- 10 * AT_DV_D_Z_DV3_S_2+Q_BH_D_DV_G_1_S_DV3+Q_BH_D_DV_G_2_S_DV3+Q_BH_D_DV_G_3_S_DV3+Q_BH_D_DV_G_4_S_DV3+Q_BH_D_DV_G_5_S_DV3+Q_BH_D_DV_G_6_S_DV3+Q_BH_D_DV_G_7_S_DV3+Q_BH_D_DV_G_15_S_DV3=0;

[285]- 7 * AT_DV_D_Z_DV4_S_2+Q_BH_D_DV_G_1_S_DV4+Q_BH_D_DV_G_2_S_DV4+Q_BH_D_DV_G_3_S_DV4+Q_BH_D_DV_G_4_S_DV4+Q_BH_D_DV_G_5_S_DV4+Q_BH_D_DV_G_6_S_DV4+Q_BH_D_DV_G_7_S_DV4+Q_BH_D_DV_G_15_S_DV4=0;

[286]- 7 * AT_HVG_D_Z_E_1+Q_BH_D_HV_G_3_E+Q_BH_D_HV_G_4_E+Q_BH_D_HV_G_5_E+Q_BH_D_HV_G_6_E+Q_BH_D_HV_G_7_E+Q_BH_D_HV_G_8_E+Q_BH_D_HV_G_10_E+Q_BH_D_HV_G_12_E=0;

[287]- 7 * AT_HVG_D_Z_E_2+Q_BH_D_HV_G_1_E+Q_BH_D_HV_G_2_E+Q_BH_D_HV_G_9_E+Q_BH_D_HV_G_11_E+Q_BH_D_HV_G_13_E+Q_BH_D_HV_G_14_E+Q_BH_D_HV_G_15_E+Q_BH_D_HV_G_16_E=0;

[288] - 7 * AT_HVG_D_Z_N_1 + Q_BH_D_HV_G_1_N + Q_BH_D_HV_G_2_N + Q_BH_D_HV_G_3_N + Q_BH_D_HV_G_4_N+Q_BH_D_HV_G_5_N+Q_BH_D_HV_G_6_N+Q_BH_D_HV_G_7_N=0;

[289] - 7 * AT_HVG_D_Z_N_2 + Q_BH_D_HV_G_8_N + Q_BH_D_HV_G_9_N + Q_BH_D_HV_G_10_N + Q_BH_D_HV_G_11_N+Q_BH_D_HV_G_12_N+Q_BH_D_HV_G_13_N+Q_BH_D_HV_G_14_N+Q_BH_D_HV_G_15_N+Q_BH_D_HV_G_16_N=0;

[290] - 7 * AT_HVG_D_Z_S_1 + Q_BH_D_HV_G_8_S + Q_BH_D_HV_G_9_S + Q_BH_D_HV_G_10_S + Q_BH_D_HV_G_11_S+Q_BH_D_HV_G_12_S+Q_BH_D_HV_G_13_S+Q_BH_D_HV_G_14_S+Q_BH_D_HV_G_16_S=0;

[291] - 7 * AT_HVG_D_Z_S_2 + Q_BH_D_HV_G_1_S + Q_BH_D_HV_G_2_S + Q_BH_D_HV_G_3_S + Q_BH_D_HV_G_4_S+Q_BH_D_HV_G_5_S+Q_BH_D_HV_G_6_S+Q_BH_D_HV_G_7_S+Q_BH_D_HV_G_15_S=0;

[292] - 9 * AT_HVS_D_Z_E_1 + Q_BH_D_HV_S_3_E + Q_BH_D_HV_S_4_E + Q_BH_D_HV_S_5_E + Q_BH_D_HV_S_6_E+Q_BH_D_HV_S_7_E+Q_BH_D_HV_S_8_E+Q_BH_D_HV_S_10_E+Q_BH_D_HV_S_12_E=0;

[293] - 9 * AT_HVS_D_Z_E_2 + Q_BH_D_HV_S_1_E + Q_BH_D_HV_S_2_E + Q_BH_D_HV_S_9_E + Q_BH_D_HV_S_11_E+Q_BH_D_HV_S_13_E+Q_BH_D_HV_S_14_E+Q_BH_D_HV_S_15_E+Q_BH_D_HV_S_16_E=0;

```
[_294] - 9 * AT_HVS_D_Z_N_1 + Q_BH_D_HV_S_1_N + Q_BH_D_HV_S_2_N + Q_BH_D_HV_S_3_N +
Q_BH_D_HV_S_4_N+Q_BH_D_HV_S_5_N+ Q_BH_D_HV_S_6_N+ Q_BH_D_HV_S_7_N=0;
[_295] - 9 * AT_HVS_D_Z_N_2 + Q_BH_D_HV_S_8_N + Q_BH_D_HV_S_9_N + Q_BH_D_HV_S_10_N +
Q_BH_D_HV_S_11_N+ Q_BH_D_HV_S_12_N+ Q_BH_D_HV_S_13_N+ Q_BH_D_HV_S_14_N+ Q_BH_D_HV_S_15_N+
Q_BH_D_HV_S_16_N=0;
[_296] - 9 * AT_HVS_D_Z_S_1 + Q_BH_D_HV_S_8_S + Q_BH_D_HV_S_9_S + Q_BH_D_HV_S_10_S +
Q_BH_D_HV_S_11_S+Q_BH_D_HV_S_12_S+ Q_BH_D_HV_S_13_S+ Q_BH_D_HV_S_14_S+Q_BH_D_HV_S_16_S=0;
[_297] - 9 * AT_HVS_D_Z_S_2 + Q_BH_D_HV_S_1_S + Q_BH_D_HV_S_2_S + Q_BH_D_HV_S_3_S +
Q_BH_D_HV_S_4_S+Q_BH_D_HV_S_5_S+ Q_BH_D_HV_S_6_S+ Q_BH_D_HV_S_7_S+ Q_BH_D_HV_S_15_S=0;
[_298] Q_BH_D_HV_G_1_E + Q_BH_D_HV_G_2_E + Q_BH_D_HV_G_3_E + Q_BH_D_HV_G_4_E +
Q_BH_D_HV_G_5_E + Q_BH_D_HV_G_6_E + Q_BH_D_HV_G_7_E + Q_BH_D_HV_G_8_E + Q_BH_D_HV_G_9_E +
Q_BH_D_HV_G_10_E + Q_BH_D_HV_G_11_E + Q_BH_D_HV_G_12_E + Q_BH_D_HV_G_13_E + Q_BH_D_HV_G_14_E +
Q_BH_D_HV_G_15_E +Q_BH_D_HV_G_16_E+Q_BH_D_DV_G_1_E_DV1 +Q_BH_D_DV_G_1_E_DV2 +
Q_BH_D_DV_G_1_E_DV3 + Q_BH_D_DV_G_1_E_DV4 + Q_BH_D_DV_G_2_E_DV1 +Q_BH_D_DV_G_2_E_DV2 +
Q_BH_D_DV_G_2_E_DV3 + Q_BH_D_DV_G_2_E_DV4 +Q_BH_D_DV_G_3_E_DV1 + Q_BH_D_DV_G_3_E_DV2 +
Q_BH_D_DV_G_3_E_DV3 + Q_BH_D_DV_G_3_E_DV4 +Q_BH_D_DV_G_4_E_DV1 + Q_BH_D_DV_G_4_E_DV2 +
Q_BH_D_DV_G_4_E_DV3 + Q_BH_D_DV_G_4_E_DV4 +Q_BH_D_DV_G_5_E_DV1 + Q_BH_D_DV_G_5_E_DV2 +
Q_BH_D_DV_G_5_E_DV3 + Q_BH_D_DV_G_5_E_DV4 +Q_BH_D_DV_G_6_E_DV1 + Q_BH_D_DV_G_6_E_DV2 +
Q_BH_D_DV_G_6_E_DV3 + Q_BH_D_DV_G_6_E_DV4 +Q_BH_D_DV_G_7_E_DV1 + Q_BH_D_DV_G_7_E_DV2 +
Q_BH_D_DV_G_7_E_DV3 + Q_BH_D_DV_G_7_E_DV4 +Q_BH_D_DV_G_8_E_DV1 + Q_BH_D_DV_G_8_E_DV2 +
Q_BH_D_DV_G_8_E_DV3 + Q_BH_D_DV_G_8_E_DV4 +Q_BH_D_DV_G_9_E_DV1 + Q_BH_D_DV_G_9_E_DV2 +
Q_BH_D_DV_G_9_E_DV3 + Q_BH_D_DV_G_9_E_DV4 + Q_BH_D_DV_G_10_E_DV1 + Q_BH_D_DV_G_10_E_DV2 +
Q_BH_D_DV_G_10_E_DV3 + Q_BH_D_DV_G_10_E_DV4 + Q_BH_D_DV_G_11_E_DV1 + Q_BH_D_DV_G_11_E_DV2 +
Q_BH_D_DV_G_11_E_DV3 + Q_BH_D_DV_G_11_E_DV4 + Q_BH_D_DV_G_12_E_DV1 + Q_BH_D_DV_G_12_E_DV2 +
Q_BH_D_DV_G_12_E_DV3 + Q_BH_D_DV_G_12_E_DV4 + Q_BH_D_DV_G_13_E_DV1 + Q_BH_D_DV_G_13_E_DV2 +
Q_BH_D_DV_G_13_E_DV3 + Q_BH_D_DV_G_13_E_DV4 + Q_BH_D_DV_G_14_E_DV1 + Q_BH_D_DV_G_14_E_DV2 +
Q_BH_D_DV_G_14_E_DV3 + Q_BH_D_DV_G_14_E_DV4 + Q_BH_D_DV_G_15_E_DV1 + Q_BH_D_DV_G_15_E_DV2 +
Q_BH_D_DV_G_15_E_DV3 + Q_BH_D_DV_G_15_E_DV4 + Q_BH_D_DV_G_16_E_DV1 + Q_BH_D_DV_G_16_E_DV2 +
Q_BH_D_DV_G_16_E_DV3 + Q_BH_D_DV_G_16_E_DV4- SGF_E=0;
[_299] Q_BH_D_HV_G_1_N + Q_BH_D_HV_G_2_N + Q_BH_D_HV_G_3_N + Q_BH_D_HV_G_4_N +
Q_BH_D_HV_G_5_N + Q_BH_D_HV_G_6_N+ Q_BH_D_HV_G_7_N + Q_BH_D_HV_G_8_N + Q_BH_D_HV_G_9_N +
Q_BH_D_HV_G_10_N+ Q_BH_D_HV_G_11_N+ Q_BH_D_HV_G_12_N+ Q_BH_D_HV_G_13_N+ Q_BH_D_HV_G_14_N
+ Q_BH_D_HV_G_15_N+Q_BH_D_HV_G_16_N +Q_BH_D_DV_G_1_N_DV1 +Q_BH_D_DV_G_1_N_DV2
+Q_BH_D_DV_G_1_N_DV3 + Q_BH_D_DV_G_1_N_DV4 +Q_BH_D_DV_G_2_N_DV1 + Q_BH_D_DV_G_2_N_DV2 +
Q_BH_D_DV_G_2_N_DV3 + Q_BH_D_DV_G_2_N_DV4 +Q_BH_D_DV_G_3_N_DV1 + Q_BH_D_DV_G_3_N_DV2 +
Q_BH_D_DV_G_3_N_DV3 + Q_BH_D_DV_G_3_N_DV4+Q_BH_D_DV_G_4_N_DV1 + Q_BH_D_DV_G_4_N_DV2 +
Q_BH_D_DV_G_4_N_DV3 + Q_BH_D_DV_G_4_N_DV4+Q_BH_D_DV_G_5_N_DV1 + Q_BH_D_DV_G_5_N_DV2 +
Q_BH_D_DV_G_5_N_DV3 + Q_BH_D_DV_G_5_N_DV4+Q_BH_D_DV_G_6_N_DV1 + Q_BH_D_DV_G_6_N_DV2 +
Q_BH_D_DV_G_6_N_DV3 + Q_BH_D_DV_G_6_N_DV4+Q_BH_D_DV_G_7_N_DV1 + Q_BH_D_DV_G_7_N_DV2 +
Q_BH_D_DV_G_7_N_DV3 + Q_BH_D_DV_G_7_N_DV4+Q_BH_D_DV_G_8_N_DV1 + Q_BH_D_DV_G_8_N_DV2 +
Q_BH_D_DV_G_8_N_DV3 + Q_BH_D_DV_G_8_N_DV4+Q_BH_D_DV_G_9_N_DV1 + Q_BH_D_DV_G_9_N_DV2 +
Q_BH_D_DV_G_9_N_DV3 + Q_BH_D_DV_G_9_N_DV4+Q_BH_D_DV_G_10_N_DV1 + Q_BH_D_DV_G_10_N_DV2 +
Q_BH_D_DV_G_10_N_DV3 + Q_BH_D_DV_G_10_N_DV4+Q_BH_D_DV_G_11_N_DV1 + Q_BH_D_DV_G_11_N_DV2 +
Q_BH_D_DV_G_11_N_DV3 + Q_BH_D_DV_G_11_N_DV4+Q_BH_D_DV_G_12_N_DV1 + Q_BH_D_DV_G_12_N_DV2 +
Q_BH_D_DV_G_12_N_DV3 + Q_BH_D_DV_G_12_N_DV4+Q_BH_D_DV_G_13_N_DV1 + Q_BH_D_DV_G_13_N_DV2 +
Q_BH_D_DV_G_13_N_DV3 + Q_BH_D_DV_G_13_N_DV4+Q_BH_D_DV_G_14_N_DV1 + Q_BH_D_DV_G_14_N_DV2 +
Q_BH_D_DV_G_14_N_DV3 + Q_BH_D_DV_G_14_N_DV4+Q_BH_D_DV_G_15_N_DV1 + Q_BH_D_DV_G_15_N_DV2 +
Q_BH_D_DV_G_15_N_DV3 + Q_BH_D_DV_G_15_N_DV4+Q_BH_D_DV_G_16_N_DV1 + Q_BH_D_DV_G_16_N_DV2 +
Q_BH_D_DV_G_16_N_DV3 + Q_BH_D_DV_G_16_N_DV4- SGF_N=0;
[_300] Q_BH_D_HV_G_1_S+ Q_BH_D_HV_G_2_S+ Q_BH_D_HV_G_3_S+ Q_BH_D_HV_G_4_S+ Q_BH_D_HV_G_5_S
+ Q_BH_D_HV_G_6_S+Q_BH_D_HV_G_7_S+ Q_BH_D_HV_G_8_S+ Q_BH_D_HV_G_9_S+Q_BH_D_HV_G_10_S +
Q_BH_D_HV_G_11_S+Q_BH_D_HV_G_12_S+Q_BH_D_HV_G_13_S+ Q_BH_D_HV_G_14_S+ Q_BH_D_HV_G_15_S+
Q_BH_D_HV_G_16_S+Q_BH_D_DV_G_1_S_DV1+Q_BH_D_DV_G_1_S_DV2+Q_BH_D_DV_G_1_S_DV3+
Q_BH_D_DV_G_1_S_DV4 +Q_BH_D_DV_G_2_S_DV1 + Q_BH_D_DV_G_2_S_DV2 +Q_BH_D_DV_G_2_S_DV3 +
Q_BH_D_DV_G_2_S_DV4 +Q_BH_D_DV_G_3_S_DV1 + Q_BH_D_DV_G_3_S_DV2 +Q_BH_D_DV_G_3_S_DV3 +
Q_BH_D_DV_G_3_S_DV4 + Q_BH_D_DV_G_4_S_DV1 + Q_BH_D_DV_G_4_S_DV2 + Q_BH_D_DV_G_4_S_DV3 +
Q_BH_D_DV_G_4_S_DV4 + Q_BH_D_DV_G_5_S_DV1 + Q_BH_D_DV_G_5_S_DV2 + Q_BH_D_DV_G_5_S_DV3 +
Q_BH_D_DV_G_5_S_DV4 + Q_BH_D_DV_G_6_S_DV1 + Q_BH_D_DV_G_6_S_DV2 + Q_BH_D_DV_G_6_S_DV3 +
Q_BH_D_DV_G_6_S_DV4 + Q_BH_D_DV_G_7_S_DV1 + Q_BH_D_DV_G_7_S_DV2 + Q_BH_D_DV_G_7_S_DV3 +
Q_BH_D_DV_G_7_S_DV4 + Q_BH_D_DV_G_8_S_DV1 + Q_BH_D_DV_G_8_S_DV2 + Q_BH_D_DV_G_8_S_DV3 +
Q_BH_D_DV_G_8_S_DV4 + Q_BH_D_DV_G_9_S_DV1 + Q_BH_D_DV_G_9_S_DV2 + Q_BH_D_DV_G_9_S_DV3 +
Q_BH_D_DV_G_9_S_DV4 + Q_BH_D_DV_G_10_S_DV1 + Q_BH_D_DV_G_10_S_DV2 + Q_BH_D_DV_G_10_S_DV3 +
Q_BH_D_DV_G_10_S_DV4 + Q_BH_D_DV_G_11_S_DV1 + Q_BH_D_DV_G_11_S_DV2 + Q_BH_D_DV_G_11_S_DV3 +
Q_BH_D_DV_G_11_S_DV4 + Q_BH_D_DV_G_12_S_DV1 + Q_BH_D_DV_G_12_S_DV2 + Q_BH_D_DV_G_12_S_DV3 +
Q_BH_D_DV_G_12_S_DV4 + Q_BH_D_DV_G_13_S_DV1 + Q_BH_D_DV_G_13_S_DV2 + Q_BH_D_DV_G_13_S_DV3 +
Q_BH_D_DV_G_13_S_DV4 + Q_BH_D_DV_G_14_S_DV1 + Q_BH_D_DV_G_14_S_DV2 + Q_BH_D_DV_G_14_S_DV3 +
Q_BH_D_DV_G_14_S_DV4 + Q_BH_D_DV_G_15_S_DV1 + Q_BH_D_DV_G_15_S_DV2 + Q_BH_D_DV_G_15_S_DV3 +
Q_BH_D_DV_G_15_S_DV4 + Q_BH_D_DV_G_16_S_DV1 + Q_BH_D_DV_G_16_S_DV2 + Q_BH_D_DV_G_16_S_DV3 +
Q_BH_D_DV_G_16_S_DV4- SGF_S=0;
[_301] SGF_E - SR_E - SDV_E - SIF_E - SCF_E =0;
[_302] SGF_N - SR_N - SDV_N - SIF_N - SCF_N =0;
[_303] SGF_S - SR_S - SDV_S - SIF_S - SCF_S =0;
[_304] -0.421E-01 *SGF_E + SR_E <=0;
[_305] -0.421E-01 *SGF_N + SR_N <=0;
[_306] -0.421E-01 *SGF_S + SR_S <=0;
[_307] -0.1053 *SGF_E + SDV_E <=0;
[_308] -0.1053 *SGF_N + SDV_N <=0;
[_30
```

Annexure 9

```

[_310] - 0.1684 * SGF_E + SIF_E <= 0;
[_311] - 0.1684 * SGF_N + SIF_N <= 0;
[_312] - 0.1684 * SGF_S + SIF_S <= 0;
[_313] - 0.6842 * SGF_E + SCF_E <= 0;
[_314] - 0.6842 * SGF_N + SCF_N <= 0;
[_315] - 0.6842 * SGF_S + SCF_S <= 0;
[_316] - 0.3125E-01 * SIF_E + IR_E = 0;
[_317] - 0.3125E-01 * SIF_N + IR_N = 0;
[_318] - 0.3125E-01 * SIF_S + IR_S = 0;
[_319] - 0.625E-01 * SIF_E + IIR_E = 0;
[_320] - 0.625E-01 * SIF_N + IIR_N = 0;
[_321] - 0.625E-01 * SIF_S + IIR_S = 0;
[_322] - 0.919E-01 * SIF_E + IAR_E = 0;
[_323] - 0.919E-01 * SIF_N + IAR_N = 0;
[_324] - 0.919E-01 * SIF_S + IAR_S = 0;
[_325] - 170 * SIF_E + IP_E = 0;
[_326] - 170 * SIF_N + IP_N = 0;
[_327] - 170 * SIF_S + IP_S = 0;
[_328] - 0.192E-01 * SCF_E + CR_E = 0;
[_329] - 0.192E-01 * SCF_N + CR_N = 0;
[_330] - 0.192E-01 * SCF_S + CR_S = 0;
[_331] - 0.615E-01 * SCF_E + CIR_E = 0;
[_332] - 0.615E-01 * SCF_N + CIR_N = 0;
[_333] - 0.615E-01 * SCF_S + CIR_S = 0;
[_334] - 0.1414 * SCF_E + CPR_E = 0;
[_335] - 0.1414 * SCF_N + CPR_N = 0;
[_336] - 0.1414 * SCF_S + CPR_S = 0;
[_337] - 0.2657 * SCF_E + CPD_E = 0;
[_338] - 0.2657 * SCF_N + CPD_N = 0;
[_339] - 0.2657 * SCF_S + CPD_S = 0;
[_340] XF_E - XSILT_E - XFG_E - XFRJ_E = 0;
[_341] XF_N - XSILT_N - XFG_N - XFRJ_N = 0;
[_342] XF_S - XSILT_S - XFG_S - XFRJ_S = 0;
[_343] Q_BH_D_HV_S_1_E + Q_BH_D_HV_S_2_E + Q_BH_D_HV_S_3_E + Q_BH_D_HV_S_4_E + Q_BH_D_HV_S_5_E +
Q_BH_D_HV_S_6_E + Q_BH_D_HV_S_7_E + Q_BH_D_HV_S_8_E + Q_BH_D_HV_S_9_E + Q_BH_D_HV_S_10_E +
Q_BH_D_HV_S_11_E + Q_BH_D_HV_S_12_E + Q_BH_D_HV_S_13_E + Q_BH_D_HV_S_14_E + Q_BH_D_HV_S_15_E +
Q_BH_D_HV_S_16_E - XSILT_E = 0;
[_344] Q_BH_D_HV_S_1_N + Q_BH_D_HV_S_2_N + Q_BH_D_HV_S_3_N + Q_BH_D_HV_S_4_N + Q_BH_D_HV_S_5_N +
Q_BH_D_HV_S_6_N + Q_BH_D_HV_S_7_N + Q_BH_D_HV_S_8_N + Q_BH_D_HV_S_9_N + Q_BH_D_HV_S_10_N +
Q_BH_D_HV_S_11_N + Q_BH_D_HV_S_12_N + Q_BH_D_HV_S_13_N + Q_BH_D_HV_S_14_N + Q_BH_D_HV_S_15_N +
Q_BH_D_HV_S_16_N - XSILT_N = 0;
[_345] Q_BH_D_HV_S_1_S + Q_BH_D_HV_S_2_S + Q_BH_D_HV_S_3_S + Q_BH_D_HV_S_4_S + Q_BH_D_HV_S_5_S +
Q_BH_D_HV_S_6_S + Q_BH_D_HV_S_7_S + Q_BH_D_HV_S_8_S + Q_BH_D_HV_S_9_S + Q_BH_D_HV_S_10_S +
Q_BH_D_HV_S_11_S + Q_BH_D_HV_S_12_S + Q_BH_D_HV_S_13_S + Q_BH_D_HV_S_14_S + Q_BH_D_HV_S_15_S +
Q_BH_D_HV_S_16_S - XSILT_S = 0;
[_346] - SDV_E + XFG_E = 0;
[_347] - SDV_N + XFG_N = 0;
[_348] - SDV_S + XFG_S = 0;
[_349] - IIR_E - IAR_E - CIR_E - CPR_E + XFRJ_E = 0;
[_350] - IIR_N - IAR_N - CIR_N - CPR_N + XFRJ_N = 0;
[_351] - IIR_S - IAR_S - CIR_S - CPR_S + XFRJ_S = 0;
[_352] SGF_E <= 5000;
[_353] SGF_N <= 5000;
[_354] SGF_S <= 5000;
[_355] SGF_E >= 0;
[_356] SGF_N >= 0;
[_357] SGF_S >= 0;
[_358] SIF_E <= 5000;
[_359] SIF_N <= 5000;
[_360] SIF_S <= 5000;
[_361] SIF_E >= 0;
[_362] SIF_N >= 0;
[_363] SIF_S >= 0;
[_364] XF_E <= 5000;
[_365] XF_N <= 5000;
[_366] XF_S <= 5000;
[_367] SCF_E <= 5000;
[_368] SCF_N <= 5000;
[_369] SCF_S <= 5000;
[_370] SCF_E >= 0;
[_371] SCF_N >= 0;
[_372] SCF_S >= 0;
[_373] - CTCX + 217.25 * XF_E + 224.554 * XF_N + 212.938 * XF_S = 0;
[_374] CTCX - 110 * SGF_E - 55 * SR_E - 110 * SGF_N - 55 * SR_N - 110 * SGF_S - 55 * SR_S = 0;
[_375] - CTCI + 757.9 * SIF_E + 55 * IR_E + 757.9 * SIF_N + 55 * IR_N + 757.9 * SIF_S + 55 * IR_S = 0;
[_376] - CTCC + 295.9 * SCF_E + 55 * CR_E + 295.9 * SCF_N + 55 * CR_N + 295.9 * SCF_S + 55 * CR_S = 0;
[_377] - CTREVC + 2750 * CPD_E + 2750 * CPD_N + 2750 * CPD_S = 0;
[_378] - CTREVI + 4.499 * IP_E + 4.499 * IP_N + 4.499 * IP_S = 0;

```

[_379] - CTREVR + 404.64446 * SR_E + 55 * IR_E + 55 * CR_E + 404.64446 * SR_N + 55 * IR_N + 55 * CR_N + 404.64446 * SR_S + 55 * IR_S + 55 * CR_S = 0;

[_380] CTRANSP - CTCHV - CTCTRUCKS - CTC_DV1 - CTC_DV2 - CTC_DV3 - CTC_DV4 = 0;

[_381] CTCHV - CTCGHV - CTCSHV = 0;

[_382] - CTCGHV + 504 * Q_BH_D_HV_G_1_E + 429 * Q_BH_D_HV_G_1_N + 515 * Q_BH_D_HV_G_1_S + 504 * Q_BH_D_HV_G_2_E + 429 * Q_BH_D_HV_G_2_N + 515 * Q_BH_D_HV_G_2_S + 418 * Q_BH_D_HV_G_3_E + 429 * Q_BH_D_HV_G_3_N + 515 * Q_BH_D_HV_G_3_S + 418 * Q_BH_D_HV_G_4_E + 429 * Q_BH_D_HV_G_4_N + 515 * Q_BH_D_HV_G_4_S + 418 * Q_BH_D_HV_G_5_E + 429 * Q_BH_D_HV_G_5_N + 515 * Q_BH_D_HV_G_5_S + 418 * Q_BH_D_HV_G_6_E + 429 * Q_BH_D_HV_G_6_N + 515 * Q_BH_D_HV_G_6_S + 418 * Q_BH_D_HV_G_7_E + 429 * Q_BH_D_HV_G_7_N + 515 * Q_BH_D_HV_G_7_S + 418 * Q_BH_D_HV_G_8_E + 515 * Q_BH_D_HV_G_8_N + 429 * Q_BH_D_HV_G_8_S + 504 * Q_BH_D_HV_G_9_E + 515 * Q_BH_D_HV_G_9_N + 429 * Q_BH_D_HV_G_9_S + 418 * Q_BH_D_HV_G_10_E + 515 * Q_BH_D_HV_G_10_N + 429 * Q_BH_D_HV_G_10_S + 504 * Q_BH_D_HV_G_11_E + 515 * Q_BH_D_HV_G_11_N + 429 * Q_BH_D_HV_G_11_S + 418 * Q_BH_D_HV_G_12_E + 515 * Q_BH_D_HV_G_12_N + 429 * Q_BH_D_HV_G_12_S + 504 * Q_BH_D_HV_G_13_E + 515 * Q_BH_D_HV_G_13_N + 429 * Q_BH_D_HV_G_13_S + 504 * Q_BH_D_HV_G_14_E + 515 * Q_BH_D_HV_G_14_N + 429 * Q_BH_D_HV_G_14_S + 504 * Q_BH_D_HV_G_15_E + 515 * Q_BH_D_HV_G_15_N + 515 * Q_BH_D_HV_G_15_S + 504 * Q_BH_D_HV_G_16_E + 515 * Q_BH_D_HV_G_16_N + 429 * Q_BH_D_HV_G_16_S = 0;

[_383] - CTCSHV + 486 * Q_BH_D_HV_S_1_E + 396 * Q_BH_D_HV_S_1_N + 478 * Q_BH_D_HV_S_1_S + 486 * Q_BH_D_HV_S_2_E + 396 * Q_BH_D_HV_S_2_N + 478 * Q_BH_D_HV_S_2_S + 399 * Q_BH_D_HV_S_3_E + 396 * Q_BH_D_HV_S_3_N + 478 * Q_BH_D_HV_S_3_S + 399 * Q_BH_D_HV_S_4_E + 396 * Q_BH_D_HV_S_4_N + 478 * Q_BH_D_HV_S_4_S + 399 * Q_BH_D_HV_S_5_E + 396 * Q_BH_D_HV_S_5_N + 478 * Q_BH_D_HV_S_5_S + 399 * Q_BH_D_HV_S_6_E + 396 * Q_BH_D_HV_S_6_N + 478 * Q_BH_D_HV_S_6_S + 399 * Q_BH_D_HV_S_7_E + 396 * Q_BH_D_HV_S_7_N + 478 * Q_BH_D_HV_S_7_S + 399 * Q_BH_D_HV_S_8_E + 478 * Q_BH_D_HV_S_8_N + 396 * Q_BH_D_HV_S_8_S + 486 * Q_BH_D_HV_S_9_E + 478 * Q_BH_D_HV_S_9_N + 396 * Q_BH_D_HV_S_9_S + 399 * Q_BH_D_HV_S_10_E + 478 * Q_BH_D_HV_S_10_N + 396 * Q_BH_D_HV_S_10_S + 486 * Q_BH_D_HV_S_11_E + 478 * Q_BH_D_HV_S_11_N + 396 * Q_BH_D_HV_S_11_S + 399 * Q_BH_D_HV_S_12_E + 478 * Q_BH_D_HV_S_12_N + 396 * Q_BH_D_HV_S_12_S + 486 * Q_BH_D_HV_S_13_E + 478 * Q_BH_D_HV_S_13_N + 396 * Q_BH_D_HV_S_13_S + 486 * Q_BH_D_HV_S_14_E + 478 * Q_BH_D_HV_S_14_N + 396 * Q_BH_D_HV_S_14_S + 486 * Q_BH_D_HV_S_15_E + 478 * Q_BH_D_HV_S_15_N + 478 * Q_BH_D_HV_S_15_S + 486 * Q_BH_D_HV_S_16_E + 478 * Q_BH_D_HV_S_16_N + 396 * Q_BH_D_HV_S_16_S = 0;

[_384] CTC_DV1 - CFUEL_DV1 = 184149.592;

[_385] CTC_DV2 - CFUEL_DV2 = 1158793.592;

[_386] CTC_DV3 - CFUEL_DV3 = 207119.44;

[_387] CTC_DV4 - CFUEL_DV4 = 16944.95;

[_388] - Q_BH_D_DV1_G_1_E + Q_BH_D_DV_G_1_E_DV1 = 0;

[_389] - Q_BH_D_DV1_G_1_N + Q_BH_D_DV_G_1_N_DV1 = 0;

[_390] - Q_BH_D_DV1_G_1_S + Q_BH_D_DV_G_1_S_DV1 = 0;

[_391] - Q_BH_D_DV1_G_2_E + Q_BH_D_DV_G_2_E_DV1 = 0;

[_392] - Q_BH_D_DV1_G_2_N + Q_BH_D_DV_G_2_N_DV1 = 0;

[_393] - Q_BH_D_DV1_G_2_S + Q_BH_D_DV_G_2_S_DV1 = 0;

[_394] - Q_BH_D_DV1_G_3_E + Q_BH_D_DV_G_3_E_DV1 = 0;

[_395] - Q_BH_D_DV1_G_3_N + Q_BH_D_DV_G_3_N_DV1 = 0;

[_396] - Q_BH_D_DV1_G_3_S + Q_BH_D_DV_G_3_S_DV1 = 0;

[_397] - Q_BH_D_DV1_G_4_E + Q_BH_D_DV_G_4_E_DV1 = 0;

[_398] - Q_BH_D_DV1_G_4_N + Q_BH_D_DV_G_4_N_DV1 = 0;

[_399] - Q_BH_D_DV1_G_4_S + Q_BH_D_DV_G_4_S_DV1 = 0;

[_400] - Q_BH_D_DV1_G_5_E + Q_BH_D_DV_G_5_E_DV1 = 0;

[_401] - Q_BH_D_DV1_G_5_N + Q_BH_D_DV_G_5_N_DV1 = 0;

[_402] - Q_BH_D_DV1_G_5_S + Q_BH_D_DV_G_5_S_DV1 = 0;

[_403] - Q_BH_D_DV1_G_6_E + Q_BH_D_DV_G_6_E_DV1 = 0;

[_404] - Q_BH_D_DV1_G_6_N + Q_BH_D_DV_G_6_N_DV1 = 0;

[_405] - Q_BH_D_DV1_G_6_S + Q_BH_D_DV_G_6_S_DV1 = 0;

[_406] - Q_BH_D_DV1_G_7_E + Q_BH_D_DV_G_7_E_DV1 = 0;

[_407] - Q_BH_D_DV1_G_7_N + Q_BH_D_DV_G_7_N_DV1 = 0;

[_408] - Q_BH_D_DV1_G_7_S + Q_BH_D_DV_G_7_S_DV1 = 0;

[_409] - Q_BH_D_DV1_G_8_E + Q_BH_D_DV_G_8_E_DV1 = 0;

[_410] - Q_BH_D_DV1_G_8_N + Q_BH_D_DV_G_8_N_DV1 = 0;

[_411] - Q_BH_D_DV1_G_8_S + Q_BH_D_DV_G_8_S_DV1 = 0;

[_412] - Q_BH_D_DV1_G_9_E + Q_BH_D_DV_G_9_E_DV1 = 0;

[_413] - Q_BH_D_DV1_G_9_N + Q_BH_D_DV_G_9_N_DV1 = 0;

[_414] - Q_BH_D_DV1_G_9_S + Q_BH_D_DV_G_9_S_DV1 = 0;

[_415] - Q_BH_D_DV1_G_10_E + Q_BH_D_DV_G_10_E_DV1 = 0;

[_416] - Q_BH_D_DV1_G_10_N + Q_BH_D_DV_G_10_N_DV1 = 0;

[_417] - Q_BH_D_DV1_G_10_S + Q_BH_D_DV_G_10_S_DV1 = 0;

[_418] - Q_BH_D_DV1_G_11_E + Q_BH_D_DV_G_11_E_DV1 = 0;

[_419] - Q_BH_D_DV1_G_11_N + Q_BH_D_DV_G_11_N_DV1 = 0;

[_420] - Q_BH_D_DV1_G_11_S + Q_BH_D_DV_G_11_S_DV1 = 0;

[_421] - Q_BH_D_DV1_G_12_E + Q_BH_D_DV_G_12_E_DV1 = 0;

[_422] - Q_BH_D_DV1_G_12_N + Q_BH_D_DV_G_12_N_DV1 = 0;

[_423] - Q_BH_D_DV1_G_12_S + Q_BH_D_DV_G_12_S_DV1 = 0;

[_424] - Q_BH_D_DV1_G_13_E + Q_BH_D_DV_G_13_E_DV1 = 0;

[_425] - Q_BH_D_DV1_G_13_N + Q_BH_D_DV_G_13_N_DV1 = 0;

[_426] - Q_BH_D_DV1_G_13_S + Q_BH_D_DV_G_13_S_DV1 = 0;

[_427] - Q_BH_D_DV1_G_14_E + Q_BH_D_DV_G_14_E_DV1 = 0;

Annexure 9

[_428] - Q_BH_D_DV1_G_14_N + Q_BH_D_DV_G_14_N_DV1 = 0;
[_429] - Q_BH_D_DV1_G_14_S + Q_BH_D_DV_G_14_S_DV1 = 0;
[_430] - Q_BH_D_DV1_G_15_E + Q_BH_D_DV_G_15_E_DV1 = 0;
[_431] - Q_BH_D_DV1_G_15_N + Q_BH_D_DV_G_15_N_DV1 = 0;
[_432] - Q_BH_D_DV1_G_15_S + Q_BH_D_DV_G_15_S_DV1 = 0;
[_433] - Q_BH_D_DV1_G_16_E + Q_BH_D_DV_G_16_E_DV1 = 0;
[_434] - Q_BH_D_DV1_G_16_N + Q_BH_D_DV_G_16_N_DV1 = 0;
[_435] - Q_BH_D_DV1_G_16_S + Q_BH_D_DV_G_16_S_DV1 = 0;
[_436] - Q_BH_D_DV2_G_1_E + Q_BH_D_DV_G_1_E_DV2 = 0;
[_437] - Q_BH_D_DV2_G_1_N + Q_BH_D_DV_G_1_N_DV2 = 0;
[_438] - Q_BH_D_DV2_G_1_S + Q_BH_D_DV_G_1_S_DV2 = 0;
[_439] - Q_BH_D_DV2_G_2_E + Q_BH_D_DV_G_2_E_DV2 = 0;
[_440] - Q_BH_D_DV2_G_2_N + Q_BH_D_DV_G_2_N_DV2 = 0;
[_441] - Q_BH_D_DV2_G_2_S + Q_BH_D_DV_G_2_S_DV2 = 0;
[_442] - Q_BH_D_DV2_G_3_E + Q_BH_D_DV_G_3_E_DV2 = 0;
[_443] - Q_BH_D_DV2_G_3_N + Q_BH_D_DV_G_3_N_DV2 = 0;
[_444] - Q_BH_D_DV2_G_3_S + Q_BH_D_DV_G_3_S_DV2 = 0;
[_445] - Q_BH_D_DV2_G_4_E + Q_BH_D_DV_G_4_E_DV2 = 0;
[_446] - Q_BH_D_DV2_G_4_N + Q_BH_D_DV_G_4_N_DV2 = 0;
[_447] - Q_BH_D_DV2_G_4_S + Q_BH_D_DV_G_4_S_DV2 = 0;
[_448] - Q_BH_D_DV2_G_5_E + Q_BH_D_DV_G_5_E_DV2 = 0;
[_449] - Q_BH_D_DV2_G_5_N + Q_BH_D_DV_G_5_N_DV2 = 0;
[_450] - Q_BH_D_DV2_G_5_S + Q_BH_D_DV_G_5_S_DV2 = 0;
[_451] - Q_BH_D_DV2_G_6_E + Q_BH_D_DV_G_6_E_DV2 = 0;
[_452] - Q_BH_D_DV2_G_6_N + Q_BH_D_DV_G_6_N_DV2 = 0;
[_453] - Q_BH_D_DV2_G_6_S + Q_BH_D_DV_G_6_S_DV2 = 0;
[_454] - Q_BH_D_DV2_G_7_E + Q_BH_D_DV_G_7_E_DV2 = 0;
[_455] - Q_BH_D_DV2_G_7_N + Q_BH_D_DV_G_7_N_DV2 = 0;
[_456] - Q_BH_D_DV2_G_7_S + Q_BH_D_DV_G_7_S_DV2 = 0;
[_457] - Q_BH_D_DV2_G_8_E + Q_BH_D_DV_G_8_E_DV2 = 0;
[_458] - Q_BH_D_DV2_G_8_N + Q_BH_D_DV_G_8_N_DV2 = 0;
[_459] - Q_BH_D_DV2_G_8_S + Q_BH_D_DV_G_8_S_DV2 = 0;
[_460] - Q_BH_D_DV2_G_9_E + Q_BH_D_DV_G_9_E_DV2 = 0;
[_461] - Q_BH_D_DV2_G_9_N + Q_BH_D_DV_G_9_N_DV2 = 0;
[_462] - Q_BH_D_DV2_G_9_S + Q_BH_D_DV_G_9_S_DV2 = 0;
[_463] - Q_BH_D_DV2_G_10_E + Q_BH_D_DV_G_10_E_DV2 = 0;
[_464] - Q_BH_D_DV2_G_10_N + Q_BH_D_DV_G_10_N_DV2 = 0;
[_465] - Q_BH_D_DV2_G_10_S + Q_BH_D_DV_G_10_S_DV2 = 0;
[_466] - Q_BH_D_DV2_G_11_E + Q_BH_D_DV_G_11_E_DV2 = 0;
[_467] - Q_BH_D_DV2_G_11_N + Q_BH_D_DV_G_11_N_DV2 = 0;
[_468] - Q_BH_D_DV2_G_11_S + Q_BH_D_DV_G_11_S_DV2 = 0;
[_469] - Q_BH_D_DV2_G_12_E + Q_BH_D_DV_G_12_E_DV2 = 0;
[_470] - Q_BH_D_DV2_G_12_N + Q_BH_D_DV_G_12_N_DV2 = 0;
[_471] - Q_BH_D_DV2_G_12_S + Q_BH_D_DV_G_12_S_DV2 = 0;
[_472] - Q_BH_D_DV2_G_13_E + Q_BH_D_DV_G_13_E_DV2 = 0;
[_473] - Q_BH_D_DV2_G_13_N + Q_BH_D_DV_G_13_N_DV2 = 0;
[_474] - Q_BH_D_DV2_G_13_S + Q_BH_D_DV_G_13_S_DV2 = 0;
[_475] - Q_BH_D_DV2_G_14_E + Q_BH_D_DV_G_14_E_DV2 = 0;
[_476] - Q_BH_D_DV2_G_14_N + Q_BH_D_DV_G_14_N_DV2 = 0;
[_477] - Q_BH_D_DV2_G_14_S + Q_BH_D_DV_G_14_S_DV2 = 0;
[_478] - Q_BH_D_DV2_G_15_E + Q_BH_D_DV_G_15_E_DV2 = 0;
[_479] - Q_BH_D_DV2_G_15_N + Q_BH_D_DV_G_15_N_DV2 = 0;
[_480] - Q_BH_D_DV2_G_15_S + Q_BH_D_DV_G_15_S_DV2 = 0;
[_481] - Q_BH_D_DV2_G_16_E + Q_BH_D_DV_G_16_E_DV2 = 0;
[_482] - Q_BH_D_DV2_G_16_N + Q_BH_D_DV_G_16_N_DV2 = 0;
[_483] - Q_BH_D_DV2_G_16_S + Q_BH_D_DV_G_16_S_DV2 = 0;
[_484] - Q_BH_D_DV3_G_1_E + Q_BH_D_DV_G_1_E_DV3 = 0;
[_485] - Q_BH_D_DV3_G_1_N + Q_BH_D_DV_G_1_N_DV3 = 0;
[_486] - Q_BH_D_DV3_G_1_S + Q_BH_D_DV_G_1_S_DV3 = 0;
[_487] - Q_BH_D_DV3_G_2_E + Q_BH_D_DV_G_2_E_DV3 = 0;
[_488] - Q_BH_D_DV3_G_2_N + Q_BH_D_DV_G_2_N_DV3 = 0;
[_489] - Q_BH_D_DV3_G_2_S + Q_BH_D_DV_G_2_S_DV3 = 0;
[_490] - Q_BH_D_DV3_G_3_E + Q_BH_D_DV_G_3_E_DV3 = 0;
[_491] - Q_BH_D_DV3_G_3_N + Q_BH_D_DV_G_3_N_DV3 = 0;
[_492] - Q_BH_D_DV3_G_3_S + Q_BH_D_DV_G_3_S_DV3 = 0;
[_493] - Q_BH_D_DV3_G_4_E + Q_BH_D_DV_G_4_E_DV3 = 0;
[_494] - Q_BH_D_DV3_G_4_N + Q_BH_D_DV_G_4_N_DV3 = 0;
[_495] - Q_BH_D_DV3_G_4_S + Q_BH_D_DV_G_4_S_DV3 = 0;
[_496] - Q_BH_D_DV3_G_5_E + Q_BH_D_DV_G_5_E_DV3 = 0;
[_497] - Q_BH_D_DV3_G_5_N + Q_BH_D_DV_G_5_N_DV3 = 0;
[_498] - Q_BH_D_DV3_G_5_S + Q_BH_D_DV_G_5_S_DV3 = 0;
[_499] - Q_BH_D_DV3_G_6_E + Q_BH_D_DV_G_6_E_DV3 = 0;
[_500] - Q_BH_D_DV3_G_6_N + Q_BH_D_DV_G_6_N_DV3 = 0;
[_501] - Q_BH_D_DV3_G_6_S + Q_BH_D_DV_G_6_S_DV3 = 0;
[_502] - Q_BH_D_DV3_G_7_E + Q_BH_D_DV_G_7_E_DV3 = 0;
[_503] - Q_BH_D_DV3_G_7_N + Q_BH_D_DV_G_7_N_DV3 = 0;
[_504] - Q_BH_D_DV3_G_7_S + Q_BH_D_DV_G_7_S_DV3 = 0;
[_505] - Q_BH_D_DV3_G_8_E + Q_BH_D_DV_G_8_E_DV3 = 0;

[_506] - Q_BH_D_DV3_G_8_N + Q_BH_D_DV_G_8_N_DV3 = 0;
 [_507] - Q_BH_D_DV3_G_8_S + Q_BH_D_DV_G_8_S_DV3 = 0;
 [_508] - Q_BH_D_DV3_G_9_E + Q_BH_D_DV_G_9_E_DV3 = 0;
 [_509] - Q_BH_D_DV3_G_9_N + Q_BH_D_DV_G_9_N_DV3 = 0;
 [_510] - Q_BH_D_DV3_G_9_S + Q_BH_D_DV_G_9_S_DV3 = 0;
 [_511] - Q_BH_D_DV3_G_10_E + Q_BH_D_DV_G_10_E_DV3 = 0;
 [_512] - Q_BH_D_DV3_G_10_N + Q_BH_D_DV_G_10_N_DV3 = 0;
 [_513] - Q_BH_D_DV3_G_10_S + Q_BH_D_DV_G_10_S_DV3 = 0;
 [_514] - Q_BH_D_DV3_G_11_E + Q_BH_D_DV_G_11_E_DV3 = 0;
 [_515] - Q_BH_D_DV3_G_11_N + Q_BH_D_DV_G_11_N_DV3 = 0;
 [_516] - Q_BH_D_DV3_G_11_S + Q_BH_D_DV_G_11_S_DV3 = 0;
 [_517] - Q_BH_D_DV3_G_12_E + Q_BH_D_DV_G_12_E_DV3 = 0;
 [_518] - Q_BH_D_DV3_G_12_N + Q_BH_D_DV_G_12_N_DV3 = 0;
 [_519] - Q_BH_D_DV3_G_12_S + Q_BH_D_DV_G_12_S_DV3 = 0;
 [_520] - Q_BH_D_DV3_G_13_E + Q_BH_D_DV_G_13_E_DV3 = 0;
 [_521] - Q_BH_D_DV3_G_13_N + Q_BH_D_DV_G_13_N_DV3 = 0;
 [_522] - Q_BH_D_DV3_G_13_S + Q_BH_D_DV_G_13_S_DV3 = 0;
 [_523] - Q_BH_D_DV3_G_14_E + Q_BH_D_DV_G_14_E_DV3 = 0;
 [_524] - Q_BH_D_DV3_G_14_N + Q_BH_D_DV_G_14_N_DV3 = 0;
 [_525] - Q_BH_D_DV3_G_14_S + Q_BH_D_DV_G_14_S_DV3 = 0;
 [_526] - Q_BH_D_DV3_G_15_E + Q_BH_D_DV_G_15_E_DV3 = 0;
 [_527] - Q_BH_D_DV3_G_15_N + Q_BH_D_DV_G_15_N_DV3 = 0;
 [_528] - Q_BH_D_DV3_G_15_S + Q_BH_D_DV_G_15_S_DV3 = 0;
 [_529] - Q_BH_D_DV3_G_16_E + Q_BH_D_DV_G_16_E_DV3 = 0;
 [_530] - Q_BH_D_DV3_G_16_N + Q_BH_D_DV_G_16_N_DV3 = 0;
 [_531] - Q_BH_D_DV3_G_16_S + Q_BH_D_DV_G_16_S_DV3 = 0;
 [_532] - Q_BH_D_DV4_G_1_E + Q_BH_D_DV_G_1_E_DV4 = 0;
 [_533] - Q_BH_D_DV4_G_1_N + Q_BH_D_DV_G_1_N_DV4 = 0;
 [_534] - Q_BH_D_DV4_G_1_S + Q_BH_D_DV_G_1_S_DV4 = 0;
 [_535] - Q_BH_D_DV4_G_2_E + Q_BH_D_DV_G_2_E_DV4 = 0;
 [_536] - Q_BH_D_DV4_G_2_N + Q_BH_D_DV_G_2_N_DV4 = 0;
 [_537] - Q_BH_D_DV4_G_2_S + Q_BH_D_DV_G_2_S_DV4 = 0;
 [_538] - Q_BH_D_DV4_G_3_E + Q_BH_D_DV_G_3_E_DV4 = 0;
 [_539] - Q_BH_D_DV4_G_3_N + Q_BH_D_DV_G_3_N_DV4 = 0;
 [_540] - Q_BH_D_DV4_G_3_S + Q_BH_D_DV_G_3_S_DV4 = 0;
 [_541] - Q_BH_D_DV4_G_4_E + Q_BH_D_DV_G_4_E_DV4 = 0;
 [_542] - Q_BH_D_DV4_G_4_N + Q_BH_D_DV_G_4_N_DV4 = 0;
 [_543] - Q_BH_D_DV4_G_4_S + Q_BH_D_DV_G_4_S_DV4 = 0;
 [_544] - Q_BH_D_DV4_G_5_E + Q_BH_D_DV_G_5_E_DV4 = 0;
 [_545] - Q_BH_D_DV4_G_5_N + Q_BH_D_DV_G_5_N_DV4 = 0;
 [_546] - Q_BH_D_DV4_G_5_S + Q_BH_D_DV_G_5_S_DV4 = 0;
 [_547] - Q_BH_D_DV4_G_6_E + Q_BH_D_DV_G_6_E_DV4 = 0;
 [_548] - Q_BH_D_DV4_G_6_N + Q_BH_D_DV_G_6_N_DV4 = 0;
 [_549] - Q_BH_D_DV4_G_6_S + Q_BH_D_DV_G_6_S_DV4 = 0;
 [_550] - Q_BH_D_DV4_G_7_E + Q_BH_D_DV_G_7_E_DV4 = 0;
 [_551] - Q_BH_D_DV4_G_7_N + Q_BH_D_DV_G_7_N_DV4 = 0;
 [_552] - Q_BH_D_DV4_G_7_S + Q_BH_D_DV_G_7_S_DV4 = 0;
 [_553] - Q_BH_D_DV4_G_8_E + Q_BH_D_DV_G_8_E_DV4 = 0;
 [_554] - Q_BH_D_DV4_G_8_N + Q_BH_D_DV_G_8_N_DV4 = 0;
 [_555] - Q_BH_D_DV4_G_8_S + Q_BH_D_DV_G_8_S_DV4 = 0;
 [_556] - Q_BH_D_DV4_G_9_E + Q_BH_D_DV_G_9_E_DV4 = 0;
 [_557] - Q_BH_D_DV4_G_9_N + Q_BH_D_DV_G_9_N_DV4 = 0;
 [_558] - Q_BH_D_DV4_G_9_S + Q_BH_D_DV_G_9_S_DV4 = 0;
 [_559] - Q_BH_D_DV4_G_10_E + Q_BH_D_DV_G_10_E_DV4 = 0;
 [_560] - Q_BH_D_DV4_G_10_N + Q_BH_D_DV_G_10_N_DV4 = 0;
 [_561] - Q_BH_D_DV4_G_10_S + Q_BH_D_DV_G_10_S_DV4 = 0;
 [_562] - Q_BH_D_DV4_G_11_E + Q_BH_D_DV_G_11_E_DV4 = 0;
 [_563] - Q_BH_D_DV4_G_11_N + Q_BH_D_DV_G_11_N_DV4 = 0;
 [_564] - Q_BH_D_DV4_G_11_S + Q_BH_D_DV_G_11_S_DV4 = 0;
 [_565] - Q_BH_D_DV4_G_12_E + Q_BH_D_DV_G_12_E_DV4 = 0;
 [_566] - Q_BH_D_DV4_G_12_N + Q_BH_D_DV_G_12_N_DV4 = 0;
 [_567] - Q_BH_D_DV4_G_12_S + Q_BH_D_DV_G_12_S_DV4 = 0;
 [_568] - Q_BH_D_DV4_G_13_E + Q_BH_D_DV_G_13_E_DV4 = 0;
 [_569] - Q_BH_D_DV4_G_13_N + Q_BH_D_DV_G_13_N_DV4 = 0;
 [_570] - Q_BH_D_DV4_G_13_S + Q_BH_D_DV_G_13_S_DV4 = 0;
 [_571] - Q_BH_D_DV4_G_14_E + Q_BH_D_DV_G_14_E_DV4 = 0;
 [_572] - Q_BH_D_DV4_G_14_N + Q_BH_D_DV_G_14_N_DV4 = 0;
 [_573] - Q_BH_D_DV4_G_14_S + Q_BH_D_DV_G_14_S_DV4 = 0;
 [_574] - Q_BH_D_DV4_G_15_E + Q_BH_D_DV_G_15_E_DV4 = 0;
 [_575] - Q_BH_D_DV4_G_15_N + Q_BH_D_DV_G_15_N_DV4 = 0;
 [_576] - Q_BH_D_DV4_G_15_S + Q_BH_D_DV_G_15_S_DV4 = 0;
 [_577] - Q_BH_D_DV4_G_16_E + Q_BH_D_DV_G_16_E_DV4 = 0;
 [_578] - Q_BH_D_DV4_G_16_N + Q_BH_D_DV_G_16_N_DV4 = 0;
 [_579] - Q_BH_D_DV4_G_16_S + Q_BH_D_DV_G_16_S_DV4 = 0;
 [_580] 148.7554676 * Q_BH_D_DV1_G_1_E + 29.15171252 * Q_BH_D_DV1_G_1_N + 250.5140155 * Q_BH_D_DV1_G_1_S +
 119.0588633 * Q_BH_D_DV1_G_2_E + 61.30033006 *
 Q_BH_D_DV1_G_2_N + 215.9133848 * Q_BH_D_DV1_G_2_S + 95.76473784 * Q_BH_D_DV1_G_3_E + 96.85452149 *
 Q_BH_D_DV1_G_3_N + 228.4458967 * Q_BH_D_DV1_G_3_S + 104.483007 * Q_BH_D_DV1_G_4_E + 82.14244228 *

Annexure 9

Q_BH_D_DV1_G_4_N + 197.3870628 * Q_BH_D_DV1_G_4_S + 87.86380642 * Q_BH_D_DV1_G_5_E + 99.98764947 *
 Q_BH_D_DV1_G_5_N + 179.4056326 * Q_BH_D_DV1_G_5_S + 80.91643568 * Q_BH_D_DV1_G_6_E + 123.6904438 *
 Q_BH_D_DV1_G_6_N + 168.0991273 * Q_BH_D_DV1_G_6_S + 22.47678769 * Q_BH_D_DV1_G_7_E + 154.2043858 *
 Q_BH_D_DV1_G_7_N + 167.6904584 * Q_BH_D_DV1_G_7_S + 70.76782548 * Q_BH_D_DV1_G_8_E + 175.7276128 *
 Q_BH_D_DV1_G_8_N + 109.3870334 * Q_BH_D_DV1_G_8_S + 123.1455519 * Q_BH_D_DV1_G_9_E + 195.3437184 *
 Q_BH_D_DV1_G_9_N + 122.5189263 * Q_BH_D_DV1_G_9_S + 109.9319252 * Q_BH_D_DV1_G_10_E + 228.4458967 *
 Q_BH_D_DV1_G_10_N + 83.98145218 * Q_BH_D_DV1_G_10_S + 139.4923066 * Q_BH_D_DV1_G_11_E + 265.2260947 *
 Q_BH_D_DV1_G_11_N + 65.33252955 * Q_BH_D_DV1_G_11_S + 54.89785114 * Q_BH_D_DV1_G_12_E + 227.356113 *
 Q_BH_D_DV1_G_12_N + 152.4334874 * Q_BH_D_DV1_G_12_S + 156.9288449 * Q_BH_D_DV1_G_13_E + 259.7771765 *
 Q_BH_D_DV1_G_13_N + 48.22292631 * Q_BH_D_DV1_G_13_S + 190.712138 * Q_BH_D_DV1_G_14_E + 270.8112359 *
 Q_BH_D_DV1_G_14_N + 93.31272464 * Q_BH_D_DV1_G_14_S + 217.6842832 * Q_BH_D_DV1_G_15_E + 275.8514853 *
 Q_BH_D_DV1_G_15_N + 222.0434178 * Q_BH_D_DV1_G_15_S + 219.3189586 * Q_BH_D_DV1_G_16_E + 311.9505685 *
 Q_BH_D_DV1_G_16_N + 28.60682069 * Q_BH_D_DV1_G_16_S - CFUEL_DV1 = 0;
 [_581] 146.0999456 * Q_BH_D_DV2_G_1_E + 28.63130801 * Q_BH_D_DV2_G_1_N + 246.0419413 * Q_BH_D_DV2_G_1_S
 + 116.9334729 * Q_BH_D_DV2_G_2_E + 60.20602152 * Q_BH_D_DV2_G_2_N + 212.0589869 * Q_BH_D_DV2_G_2_S +
 94.05518474 * Q_BH_D_DV2_G_3_E + 95.12551401 * Q_BH_D_DV2_G_3_N + 224.3677735 * Q_BH_D_DV2_G_3_S +
 102.6178189 * Q_BH_D_DV2_G_4_E + 80.67606884 * Q_BH_D_DV2_G_4_N + 193.8633893 * Q_BH_D_DV2_G_4_S
 + 86.29529752 * Q_BH_D_DV2_G_5_E + 98.20271066 * Q_BH_D_DV2_G_5_N + 176.2029563 * Q_BH_D_DV2_G_5_S +
 79.47194841 * Q_BH_D_DV2_G_6_E + 121.4823723 * Q_BH_D_DV2_G_6_N + 165.0982901 * Q_BH_D_DV2_G_6_S +
 22.07554123 * Q_BH_D_DV2_G_7_E + 151.4515919 * Q_BH_D_DV2_G_7_N + 164.6969167 * Q_BH_D_DV2_G_7_S
 + 69.50450707 * Q_BH_D_DV2_G_8_E + 172.590595 * Q_BH_D_DV2_G_8_N + 107.4343006 * Q_BH_D_DV2_G_8_S +
 120.9472077 * Q_BH_D_DV2_G_9_E + 191.8565219 * Q_BH_D_DV2_G_9_N + 120.3317684 * Q_BH_D_DV2_G_9_S +
 107.9694653 * Q_BH_D_DV2_G_10_E + 224.3677735 * Q_BH_D_DV2_G_10_N + 82.48224949 * Q_BH_D_DV2_G_10_S
 + 137.0021468 * Q_BH_D_DV2_G_11_E + 260.4913865 * Q_BH_D_DV2_G_11_N + 64.16623983 * Q_BH_D_DV2_G_11_S +
 53.91783705 * Q_BH_D_DV2_G_12_E + 223.2974443 * Q_BH_D_DV2_G_12_N + 149.7123069 * Q_BH_D_DV2_G_12_S +
 154.1274151 * Q_BH_D_DV2_G_13_E + 255.1397401 * Q_BH_D_DV2_G_13_N + 47.36207027 * Q_BH_D_DV2_G_13_S
 + 187.3076225 * Q_BH_D_DV2_G_14_E + 265.976824 * Q_BH_D_DV2_G_14_N + 91.64694387 * Q_BH_D_DV2_G_14_S +
 213.798272 * Q_BH_D_DV2_G_15_E + 270.9270969 * Q_BH_D_DV2_G_15_N + 218.0795891 * Q_BH_D_DV2_G_15_S +
 215.4037659 * Q_BH_D_DV2_G_16_E + 306.381754 * Q_BH_D_DV2_G_16_N + 28.09614338 * Q_BH_D_DV2_G_16_S -
 CFUEL_DV2 = 0;
 [_582] 202.6902392 * Q_BH_D_DV3_G_1_E + 39.72134725 * Q_BH_D_DV3_G_1_N + 341.3437271 * Q_BH_D_DV3_G_1_S
 + 162.2264369 * Q_BH_D_DV3_G_2_E + 83.52619748 * Q_BH_D_DV3_G_2_N + 294.1978289 * Q_BH_D_DV3_G_2_S +
 130.4864818 * Q_BH_D_DV3_G_3_E + 131.971392 * Q_BH_D_DV3_G_3_N + 311.274296 * Q_BH_D_DV3_G_3_S +
 142.3657633 * Q_BH_D_DV3_G_4_E + 111.9251046 * Q_BH_D_DV3_G_4_N + 268.9543559 * Q_BH_D_DV3_G_4_S +
 119.7208831 * Q_BH_D_DV3_G_5_E + 136.2405088 * Q_BH_D_DV3_G_5_N + 244.453338 * Q_BH_D_DV3_G_5_S +
 110.2545807 * Q_BH_D_DV3_G_6_E + 168.5373051 * Q_BH_D_DV3_G_6_N + 229.0473949 * Q_BH_D_DV3_G_6_S +
 30.62627241 * Q_BH_D_DV3_G_7_E + 210.1147901 * Q_BH_D_DV3_G_7_N + 228.4905536 * Q_BH_D_DV3_G_7_S +
 96.42635465 * Q_BH_D_DV3_G_8_E + 239.4417661 * Q_BH_D_DV3_G_8_N + 149.0478591 * Q_BH_D_DV3_G_8_S +
 167.7948501 * Q_BH_D_DV3_G_9_E + 266.1701493 * Q_BH_D_DV3_G_9_N + 166.9410267 * Q_BH_D_DV3_G_9_S +
 149.7903142 * Q_BH_D_DV3_G_10_E + 311.274296 * Q_BH_D_DV3_G_10_N + 114.4308906 * Q_BH_D_DV3_G_10_S +
 190.0685027 * Q_BH_D_DV3_G_11_E + 361.3900145 * Q_BH_D_DV3_G_11_N + 89.02036514 * Q_BH_D_DV3_G_11_S +
 74.80235019 * Q_BH_D_DV3_G_12_E + 309.7893858 * Q_BH_D_DV3_G_12_N + 207.7018111 * Q_BH_D_DV3_G_12_S +
 213.8270656 * Q_BH_D_DV3_G_13_E + 353.9654636 * Q_BH_D_DV3_G_13_N + 65.70727535 * Q_BH_D_DV3_G_13_S +
 259.8592811 * Q_BH_D_DV3_G_14_E + 369.0001791 * Q_BH_D_DV3_G_14_N + 127.1454339 * Q_BH_D_DV3_G_14_S +
 296.610808 * Q_BH_D_DV3_G_15_E + 375.8678887 * Q_BH_D_DV3_G_15_N + 302.5504487 * Q_BH_D_DV3_G_15_S +
 298.8381732 * Q_BH_D_DV3_G_16_E + 425.0555383 * Q_BH_D_DV3_G_16_N + 38.97889216 * Q_BH_D_DV3_G_16_S -
 CFUEL_DV3 = 0;
 [_583] 202.4145399 * Q_BH_D_DV4_G_1_E + 39.66731825 * Q_BH_D_DV4_G_1_N + 340.8794312 * Q_BH_D_DV4_G_1_S
 + 162.0057764 * Q_BH_D_DV4_G_2_E + 83.41258512 * Q_BH_D_DV4_G_2_N + 293.7976609 * Q_BH_D_DV4_G_2_S +
 130.3089941 * Q_BH_D_DV4_G_3_E + 131.7918845 * Q_BH_D_DV4_G_3_N + 310.8509005 * Q_BH_D_DV4_G_3_S +
 142.1721173 * Q_BH_D_DV4_G_4_E + 111.7728641 * Q_BH_D_DV4_G_4_N + 268.5885241 * Q_BH_D_DV4_G_4_S
 + 119.5580387 * Q_BH_D_DV4_G_5_E + 136.0551944 * Q_BH_D_DV4_G_5_N + 244.1208324 * Q_BH_D_DV4_G_5_S +
 110.1046124 * Q_BH_D_DV4_G_6_E + 168.3080606 * Q_BH_D_DV4_G_6_N + 228.7358445 * Q_BH_D_DV4_G_6_S +
 30.58461454 * Q_BH_D_DV4_G_7_E + 209.8289919 * Q_BH_D_DV4_G_7_N + 228.1797606 * Q_BH_D_DV4_G_7_S
 + 96.29519548 * Q_BH_D_DV4_G_8_E + 239.1160773 * Q_BH_D_DV4_G_8_N + 148.8451241 * Q_BH_D_DV4_G_8_S +
 167.5666154 * Q_BH_D_DV4_G_9_E + 265.8081046 * Q_BH_D_DV4_G_9_N + 166.7139535 * Q_BH_D_DV4_G_9_S +
 149.5865693 * Q_BH_D_DV4_G_10_E + 310.8509005 * Q_BH_D_DV4_G_10_N + 114.2752416 * Q_BH_D_DV4_G_10_S +
 189.8099715 * Q_BH_D_DV4_G_11_E + 360.8984516 * Q_BH_D_DV4_G_11_N + 88.8992796 * Q_BH_D_DV4_G_11_S +
 74.700604 * Q_BH_D_DV4_G_12_E + 309.3680101 * Q_BH_D_DV4_G_12_N + 207.419295 * Q_BH_D_DV4_G_12_S +
 213.5362179 * Q_BH_D_DV4_G_13_E + 353.4839996 * Q_BH_D_DV4_G_13_N + 65.61790029 * Q_BH_D_DV4_G_13_S +
 259.5058204 * Q_BH_D_DV4_G_14_E + 368.4982649 * Q_BH_D_DV4_G_14_N + 126.9724907 * Q_BH_D_DV4_G_14_S +
 296.2073578 * Q_BH_D_DV4_G_15_E + 375.356633 * Q_BH_D_DV4_G_15_N + 302.1389194 * Q_BH_D_DV4_G_15_S +
 298.4316934 * Q_BH_D_DV4_G_16_E + 424.4773776 * Q_BH_D_DV4_G_16_N + 38.92587305 * Q_BH_D_DV4_G_16_S -
 CFUEL_DV4 = 0;
 [_592] 17 * DGDV_DV1_E_1 + 17 * DGDV_DV1_E_2 + 17 * DGDV_DV1_N_1 + 17 * DGDV_DV1_N_2 + 17 *
 DGDV_DV1_S_1 + 17 * DGDV_DV1_S_2 - CINC_DV1 = 3332;
 [_593] 25 * DGDV_DV2_E_1 + 25 * DGDV_DV2_E_2 + 25 * DGDV_DV2_N_1 + 25 * DGDV_DV2_N_2 + 25 *
 DGDV_DV2_S_1 + 25 * DGDV_DV2_S_2 - CINC_DV2 = 15750; [_594] 19 * DGDV_DV3_E_1 + 19 * DGDV_DV3_E_2 + 19 *
 DGDV_DV3_N_1 + 19 * DGDV_DV3_N_2 + 19 * DGDV_DV3_S_1 + 19 *
 DGDV_DV3_S_2 - CINC_DV3 = 3800;
 [_595] 19 * DGDV_DV4_E_1 + 19 * DGDV_DV4_E_2 + 19 * DGDV_DV4_N_1 + 19 * DGDV_DV4_N_2 + 19 *
 DGDV_DV4_S_1 + 19 * DGDV_DV4_S_2 - CINC_DV4 = 266;
 [_596] CINCT - CINC_DV1 - CINC_DV2 - CINC_DV3 - CINC_DV4 = 0;
 [_597] CTCTRUCKS - CFUELTRUCKSTOTAL = 177929.235;
 [_598] CFUELTRUCKSTOTAL - 33.7953 * XF_E - 37.477 * XF_N - 10.571 * XF_S = 0;
 [_604] XF_E - 80 * NOOFTRUCKSPERDUMPSITE_E <= 0;
 [_605] XF_N - 60 * NOOFTRUCKSPERDUMPSITE_N <= 0;
 [_606] XF_S - 100 * NOOFTRUCKSPERDUMPSITE_S <= 0;

[_607] NOOFTRUCKSPERDUMPSITE_E + NOOFTRUCKSPERDUMPSITE_N + NOOFTRUCKSPERDUMPSITE_S = 21;

[_608] 13.26 * Q_BH_D_DV1_G_1_E + 2.598 * Q_BH_D_DV1_G_1_N + 22.33 * Q_BH_D_DV1_G_1_S + 10.613 * Q_BH_D_DV1_G_2_E + 5.464 * Q_BH_D_DV1_G_2_N + 19.25 * Q_BH_D_DV1_G_2_S + 8.536 * Q_BH_D_DV1_G_3_E + 8.633 * Q_BH_D_DV1_G_3_N + 20.36 * Q_BH_D_DV1_G_3_S + 9.313 * Q_BH_D_DV1_G_4_E + 7.322 * Q_BH_D_DV1_G_4_N + 17.595 * Q_BH_D_DV1_G_4_S + 7.832 * Q_BH_D_DV1_G_5_E + 8.913 * Q_BH_D_DV1_G_5_N + 15.99 * Q_BH_D_DV1_G_5_S + 7.213 * Q_BH_D_DV1_G_6_E + 11.026 * Q_BH_D_DV1_G_6_N + 14.98 * Q_BH_D_DV1_G_6_S + 2.003 * Q_BH_D_DV1_G_7_E + 13.745 * Q_BH_D_DV1_G_7_N + 14.95 * Q_BH_D_DV1_G_7_S + 6.31 * Q_BH_D_DV1_G_8_E + 15.664 * Q_BH_D_DV1_G_8_N + 9.75 * Q_BH_D_DV1_G_8_S + 10.98 * Q_BH_D_DV1_G_9_E + 17.41 * Q_BH_D_DV1_G_9_N + 10.92 * Q_BH_D_DV1_G_9_S + 9.799 * Q_BH_D_DV1_G_10_E + 20.36 * Q_BH_D_DV1_G_10_N + 7.486 * Q_BH_D_DV1_G_10_S + 12.434 * Q_BH_D_DV1_G_11_E + 23.64 * Q_BH_D_DV1_G_11_N + 5.82 * Q_BH_D_DV1_G_11_S + 4.893 * Q_BH_D_DV1_G_12_E + 20.27 * Q_BH_D_DV1_G_12_N + 13.59 * Q_BH_D_DV1_G_12_S + 13.988 * Q_BH_D_DV1_G_13_E + 23.16 * Q_BH_D_DV1_G_13_N + 4.298 * Q_BH_D_DV1_G_13_S + 17 * Q_BH_D_DV1_G_14_E + 24.14 * Q_BH_D_DV1_G_14_N + 8.32 * Q_BH_D_DV1_G_14_S + 19.404 * Q_BH_D_DV1_G_15_E + 24.59 * Q_BH_D_DV1_G_15_N + 19.79 * Q_BH_D_DV1_G_15_S + 19.55 * Q_BH_D_DV1_G_16_E + 27.80714286 * Q_BH_D_DV1_G_16_N + 2.55 * Q_BH_D_DV1_G_16_S - CO_EMSN_DV1 = 0;

[_609] 4059.81 * Q_BH_D_DV1_G_1_E + 795.605 * Q_BH_D_DV1_G_1_N + 6836.99 * Q_BH_D_DV1_G_1_S + 3249.33 * Q_BH_D_DV1_G_2_E + 1672.99 * Q_BH_D_DV1_G_2_N + 5892.67 * Q_BH_D_DV1_G_2_S + 2613.59 * Q_BH_D_DV1_G_3_E + 2643.34 * Q_BH_D_DV1_G_3_N + 6234.71 * Q_BH_D_DV1_G_3_S + 2851.53 * Q_BH_D_DV1_G_4_E + 2241.82 * Q_BH_D_DV1_G_4_N + 5387.06 * Q_BH_D_DV1_G_4_S + 2397.96 * Q_BH_D_DV1_G_5_E + 2728.847 * Q_BH_D_DV1_G_5_N + 4896.31 * Q_BH_D_DV1_G_5_S + 2208.36 * Q_BH_D_DV1_G_6_E + 3375.74 * Q_BH_D_DV1_G_6_N + 4587.74 * Q_BH_D_DV1_G_6_S + 613.43 * Q_BH_D_DV1_G_7_E + 4208.52 * Q_BH_D_DV1_G_7_N + 4576.58 * Q_BH_D_DV1_G_7_S + 1931.38 * Q_BH_D_DV1_G_8_E + 4795.93 * Q_BH_D_DV1_G_8_N + 2985.37 * Q_BH_D_DV1_G_8_S + 3360.86 * Q_BH_D_DV1_G_9_E + 5331.29 * Q_BH_D_DV1_G_9_N + 3343.77 * Q_BH_D_DV1_G_9_S + 3000.245 * Q_BH_D_DV1_G_10_E + 6234.71 * Q_BH_D_DV1_G_10_N + 2292 * Q_BH_D_DV1_G_10_S + 3807 * Q_BH_D_DV1_G_11_E + 7238.51 * Q_BH_D_DV1_G_11_N + 1783.05 * Q_BH_D_DV1_G_11_S + 1498.26 * Q_BH_D_DV1_G_12_E + 6204.96 * Q_BH_D_DV1_G_12_N + 4160.19 * Q_BH_D_DV1_G_12_S + 4282.88 * Q_BH_D_DV1_G_13_E + 7089.79 * Q_BH_D_DV1_G_13_N + 1316.09 * Q_BH_D_DV1_G_13_S + 5204.89 * Q_BH_D_DV1_G_14_E + 7390.94 * Q_BH_D_DV1_G_14_N + 2546.67 * Q_BH_D_DV1_G_14_S + 5941 * Q_BH_D_DV1_G_15_E + 7528.49 * Q_BH_D_DV1_G_15_N + 6059.98 * Q_BH_D_DV1_G_15_S + 5985.618571 * Q_BH_D_DV1_G_16_E + 8513.705918 * Q_BH_D_DV1_G_16_N + 780.7328571 * Q_BH_D_DV1_G_16_S - CO2_EMSN_DV1 = 0;

[_610] 0.895 * Q_BH_D_DV1_G_1_E + 0.175 * Q_BH_D_DV1_G_1_N + 1.508 * Q_BH_D_DV1_G_1_S + 0.717 * Q_BH_D_DV1_G_2_E + 0.369 * Q_BH_D_DV1_G_2_N + 1.299 * Q_BH_D_DV1_G_2_S + 0.576 * Q_BH_D_DV1_G_3_E + 0.583 * Q_BH_D_DV1_G_3_N + 1.375 * Q_BH_D_DV1_G_3_S + 0.629 * Q_BH_D_DV1_G_4_E + 0.494 * Q_BH_D_DV1_G_4_N + 1.188 * Q_BH_D_DV1_G_4_S + 0.529 * Q_BH_D_DV1_G_5_E + 0.602 * Q_BH_D_DV1_G_5_N + 1.079 * Q_BH_D_DV1_G_5_S + 0.487 * Q_BH_D_DV1_G_6_E + 0.744 * Q_BH_D_DV1_G_6_N + 1.012 * Q_BH_D_DV1_G_6_S + 0.135 * Q_BH_D_DV1_G_7_E + 0.928 * Q_BH_D_DV1_G_7_N + 1.009 * Q_BH_D_DV1_G_7_S + 0.426 * Q_BH_D_DV1_G_8_E + 1.058 * Q_BH_D_DV1_G_8_N + 0.658 * Q_BH_D_DV1_G_8_S + 0.741 * Q_BH_D_DV1_G_9_E + 1.176 * Q_BH_D_DV1_G_9_N + 0.737 * Q_BH_D_DV1_G_9_S + 0.662 * Q_BH_D_DV1_G_10_E + 1.375 * Q_BH_D_DV1_G_10_N + 0.505 * Q_BH_D_DV1_G_10_S + 0.839 * Q_BH_D_DV1_G_11_E + 1.596 * Q_BH_D_DV1_G_11_N + 0.393 * Q_BH_D_DV1_G_11_S + 0.3305 * Q_BH_D_DV1_G_12_E + 1.368 * Q_BH_D_DV1_G_12_N + 0.917 * Q_BH_D_DV1_G_12_S + 0.945 * Q_BH_D_DV1_G_13_E + 1.564 * Q_BH_D_DV1_G_13_N + 0.29 * Q_BH_D_DV1_G_13_S + 1.148 * Q_BH_D_DV1_G_14_E + 1.63 * Q_BH_D_DV1_G_14_N + 0.562 * Q_BH_D_DV1_G_14_S + 1.31 * Q_BH_D_DV1_G_15_E + 1.66 * Q_BH_D_DV1_G_15_N + 1.34 * Q_BH_D_DV1_G_15_S + 1.3202 * Q_BH_D_DV1_G_16_E + 1.8778 * Q_BH_D_DV1_G_16_N + 0.1722 * Q_BH_D_DV1_G_16_S - SO2_EMSN_DV1 = 0;

[_611] 3.625 * Q_BH_D_DV1_G_1_E + 0.71 * Q_BH_D_DV1_G_1_N + 6.105 * Q_BH_D_DV1_G_1_S + 2.901 * Q_BH_D_DV1_G_2_E + 1.494 * Q_BH_D_DV1_G_2_N + 5.262 * Q_BH_D_DV1_G_2_S + 2.33 * Q_BH_D_DV1_G_3_E + 2.36 * Q_BH_D_DV1_G_3_N + 5.567 * Q_BH_D_DV1_G_3_S + 2.55 * Q_BH_D_DV1_G_4_E + 2 * Q_BH_D_DV1_G_4_N + 4.81 * Q_BH_D_DV1_G_4_S + 2.14 * Q_BH_D_DV1_G_5_E + 2.436 * Q_BH_D_DV1_G_5_N + 4.372 * Q_BH_D_DV1_G_5_S + 1.972 * Q_BH_D_DV1_G_6_E + 3.014 * Q_BH_D_DV1_G_6_N + 4.097 * Q_BH_D_DV1_G_6_S + 0.548 * Q_BH_D_DV1_G_7_E + 3.758 * Q_BH_D_DV1_G_7_N + 4.086 * Q_BH_D_DV1_G_7_S + 1.725 * Q_BH_D_DV1_G_8_E + 4.283 * Q_BH_D_DV1_G_8_N + 2.666 * Q_BH_D_DV1_G_8_S + 3 * Q_BH_D_DV1_G_9_E + 4.76 * Q_BH_D_DV1_G_9_N + 2.986 * Q_BH_D_DV1_G_9_S + 2.679 * Q_BH_D_DV1_G_10_E + 5.567 * Q_BH_D_DV1_G_10_N + 2.047 * Q_BH_D_DV1_G_10_S + 3.399 * Q_BH_D_DV1_G_11_E + 6.464 * Q_BH_D_DV1_G_11_N + 1.592 * Q_BH_D_DV1_G_11_S + 1.338 * Q_BH_D_DV1_G_12_E + 5.541 * Q_BH_D_DV1_G_12_N + 3.715 * Q_BH_D_DV1_G_12_S + 3.825 * Q_BH_D_DV1_G_13_E + 6.33 * Q_BH_D_DV1_G_13_N + 1.175 * Q_BH_D_DV1_G_13_S + 4.648 * Q_BH_D_DV1_G_14_E + 6.6 * Q_BH_D_DV1_G_14_N + 2.274 * Q_BH_D_DV1_G_14_S + 5.305 * Q_BH_D_DV1_G_15_E + 6.723 * Q_BH_D_DV1_G_15_N + 5.412 * Q_BH_D_DV1_G_15_S + 5.3452 * Q_BH_D_DV1_G_16_E + 7.6028 * Q_BH_D_DV1_G_16_N + 0.6972 * Q_BH_D_DV1_G_16_S - HC_EMSN_DV1 = 0;

[_612] 23.58 * Q_BH_D_DV1_G_1_E + 4.62 * Q_BH_D_DV1_G_1_N + 39.706 * Q_BH_D_DV1_G_1_S + 18.87 * Q_BH_D_DV1_G_2_E + 9.716 * Q_BH_D_DV1_G_2_N + 34.22 * Q_BH_D_DV1_G_2_S + 15.18 * Q_BH_D_DV1_G_3_E + 15.35 * Q_BH_D_DV1_G_3_N + 36.21 * Q_BH_D_DV1_G_3_S + 16.56 * Q_BH_D_DV1_G_4_E + 13.02 * Q_BH_D_DV1_G_4_N + 31.286 * Q_BH_D_DV1_G_4_S + 13.93 * Q_BH_D_DV1_G_5_E + 15.85 * Q_BH_D_DV1_G_5_N + 28.436 * Q_BH_D_DV1_G_5_S + 12.825 * Q_BH_D_DV1_G_6_E + 19.605 * Q_BH_D_DV1_G_6_N + 26.64 * Q_BH_D_DV1_G_6_S + 3.562 * Q_BH_D_DV1_G_7_E + 24.44 * Q_BH_D_DV1_G_7_N + 26.58 * Q_BH_D_DV1_G_7_S + 11.22 * Q_BH_D_DV1_G_8_E + 27.85 * Q_BH_D_DV1_G_8_N + 17.34 * Q_BH_D_DV1_G_8_S + 19.52 * Q_BH_D_DV1_G_9_E + 30.96 * Q_BH_D_DV1_G_9_N + 19.42 * Q_BH_D_DV1_G_9_S + 17.424 * Q_BH_D_DV1_G_10_E + 36.21 * Q_BH_D_DV1_G_10_N + 13.31 * Q_BH_D_DV1_G_10_S + 22.11 * Q_BH_D_DV1_G_11_E + 42.04 * Q_BH_D_DV1_G_11_N + 10.35 * Q_BH_D_DV1_G_11_S + 8.701 * Q_BH_D_DV1_G_12_E + 36.04 * Q_BH_D_DV1_G_12_N + 24.16 * Q_BH_D_DV1_G_12_S + 24.87 * Q_BH_D_DV1_G_13_E + 41.17 * Q_BH_D_DV1_G_13_N + 7.64 * Q_BH_D_DV1_G_13_S + 30.23 * Q_BH_D_DV1_G_14_E + 42.924 * Q_BH_D_DV1_G_14_N + 14.79 * Q_BH_D_DV1_G_14_S + 34.503 * Q_BH_D_DV1_G_15_E + 43.72 * Q_BH_D_DV1_G_15_N + 35.19 * Q_BH_D_DV1_G_15_S + 34.7622 * Q_BH_D_DV1_G_16_E + 49.44437143 * Q_BH_D_DV1_G_16_N + 4.5342 * Q_BH_D_DV1_G_16_S - NOX_EMSN_DV1 = 0;

[_613] 2.134 * Q_BH_D_DV1_G_1_E + 0.418 * Q_BH_D_DV1_G_1_N + 3.593 * Q_BH_D_DV1_G_1_S + 1.71 * Q_BH_D_DV1_G_2_E + 0.879 * Q_BH_D_DV1_G_2_N + 3.097 * Q_BH_D_DV1_G_2_S + 1.374 * Q_BH_D_DV1_G_3_E + 1.389 * Q_BH_D_DV1_G_3_N + 3.278 * Q_BH_D_DV1_G_3_S + 1.498 * Q_BH_D_DV1_G_4_E + 1.178 * Q_BH_D_DV1_G_4_N + 2.832 * Q_BH_D_DV1_G_4_S + 1.26 * Q_BH_D_DV1_G_5_E + 1.434 * Q_BH_D_DV1_G_5_N +

Annexure 9

2.574 * Q_BH_D_DV1_G_5_S + 1.161 * Q_BH_D_DV1_G_6_E + 1.774 * Q_BH_D_DV1_G_6_N + 2.411 * Q_BH_D_DV1_G_6_S + 0.322 * Q_BH_D_DV1_G_7_E + 2.212 * Q_BH_D_DV1_G_7_N + 2.406 * Q_BH_D_DV1_G_7_S + 1.015 * Q_BH_D_DV1_G_8_E + 2.521 * Q_BH_D_DV1_G_8_N + 1.569 * Q_BH_D_DV1_G_8_S + 1.77 * Q_BH_D_DV1_G_9_E + 2.802 * Q_BH_D_DV1_G_9_N + 1.757 * Q_BH_D_DV1_G_9_S + 1.58 * Q_BH_D_DV1_G_10_E + 3.278 * Q_BH_D_DV1_G_10_N + 1.205 * Q_BH_D_DV1_G_10_S + 2.001 * Q_BH_D_DV1_G_11_E + 3.804 * Q_BH_D_DV1_G_11_N + 0.937 * Q_BH_D_DV1_G_11_S + 0.787 * Q_BH_D_DV1_G_12_E + 3.262 * Q_BH_D_DV1_G_12_N + 2.187 * Q_BH_D_DV1_G_12_S + 2.251 * Q_BH_D_DV1_G_13_E + 3.727 * Q_BH_D_DV1_G_13_N + 0.692 * Q_BH_D_DV1_G_13_S + 2.736 * Q_BH_D_DV1_G_14_E + 3.885 * Q_BH_D_DV1_G_14_N + 1.338 * Q_BH_D_DV1_G_14_S + 3.122 * Q_BH_D_DV1_G_15_E + 3.957 * Q_BH_D_DV1_G_15_N + 3.185 * Q_BH_D_DV1_G_15_S + 3.1464 * Q_BH_D_DV1_G_16_E + 4.475314286 * Q_BH_D_DV1_G_16_N + 0.4104 * Q_BH_D_DV1_G_16_S - PM_EMSN_DV1 = 0;

[_614] 0.18E-01 * Q_BH_D_DV1_G_1_E + 0.35E-02 * Q_BH_D_DV1_G_1_N + 0.304E-01 * Q_BH_D_DV1_G_1_S + 0.14E-01 * Q_BH_D_DV1_G_2_E + 0.75E-02 * Q_BH_D_DV1_G_2_N + 0.26E-01 * Q_BH_D_DV1_G_2_S + 0.12E-01 * Q_BH_D_DV1_G_3_E + 0.12E-01 * Q_BH_D_DV1_G_3_N + 0.28E-01 * Q_BH_D_DV1_G_3_S + 0.13E-01 * Q_BH_D_DV1_G_4_E + 0.99E-02 * Q_BH_D_DV1_G_4_N + 0.24E-01 * Q_BH_D_DV1_G_4_S + 0.11E-01 * Q_BH_D_DV1_G_5_E + 0.122E-01 * Q_BH_D_DV1_G_5_N + 0.22E-01 * Q_BH_D_DV1_G_5_S + 0.98E-02 * Q_BH_D_DV1_G_6_E + 0.15E-01 * Q_BH_D_DV1_G_6_N + 0.2E-01 * Q_BH_D_DV1_G_6_S + 0.27E-02 * Q_BH_D_DV1_G_7_E + 0.187E-01 * Q_BH_D_DV1_G_7_N + 0.204E-01 * Q_BH_D_DV1_G_7_S + 0.86E-02 * Q_BH_D_DV1_G_8_E + 0.21E-01 * Q_BH_D_DV1_G_8_N + 0.13E-01 * Q_BH_D_DV1_G_8_S + 0.15E-01 * Q_BH_D_DV1_G_9_E + 0.24E-01 * Q_BH_D_DV1_G_9_N + 0.15E-01 * Q_BH_D_DV1_G_9_S + 0.13E-01 * Q_BH_D_DV1_G_10_E + 0.28E-01 * Q_BH_D_DV1_G_10_N + 0.1E-01 * Q_BH_D_DV1_G_10_S + 0.17E-01 * Q_BH_D_DV1_G_11_E + 0.32E-01 * Q_BH_D_DV1_G_11_N + 0.79E-02 * Q_BH_D_DV1_G_11_S + 0.67E-02 * Q_BH_D_DV1_G_12_E + 0.28E-01 * Q_BH_D_DV1_G_12_N + 0.18E-01 * Q_BH_D_DV1_G_12_S + 0.19E-01 * Q_BH_D_DV1_G_13_E + 0.32E-01 * Q_BH_D_DV1_G_13_N + 0.59E-02 * Q_BH_D_DV1_G_13_S + 0.23E-01 * Q_BH_D_DV1_G_14_E + 0.33E-01 * Q_BH_D_DV1_G_14_N + 0.11E-01 * Q_BH_D_DV1_G_14_S + 0.26E-01 * Q_BH_D_DV1_G_15_E + 0.34E-01 * Q_BH_D_DV1_G_15_N + 0.27E-01 * Q_BH_D_DV1_G_15_S + 0.2668E-01 * Q_BH_D_DV1_G_16_E + 0.3794857143E-01 * Q_BH_D_DV1_G_16_N + 0.348E-02 * Q_BH_D_DV1_G_16_S - BENZ_EMSN_DV1 = 0;

[_615] 0.34E-02 * Q_BH_D_DV1_G_1_E + 0.67E-03 * Q_BH_D_DV1_G_1_N + 0.58E-02 * Q_BH_D_DV1_G_1_S + 0.275E-02 * Q_BH_D_DV1_G_2_E + 0.14E-02 * Q_BH_D_DV1_G_2_N + 0.49E-02 * Q_BH_D_DV1_G_2_S + 0.22E-02 * Q_BH_D_DV1_G_3_E + 0.22E-02 * Q_BH_D_DV1_G_3_N + 0.53E-02 * Q_BH_D_DV1_G_3_S + 0.24E-02 * Q_BH_D_DV1_G_4_E + 0.189E-02 * Q_BH_D_DV1_G_4_N + 0.45E-02 * Q_BH_D_DV1_G_4_S + 0.202E-02 * Q_BH_D_DV1_G_5_E + 0.23E-02 * Q_BH_D_DV1_G_5_N + 0.41E-02 * Q_BH_D_DV1_G_5_S + 0.187E-02 * Q_BH_D_DV1_G_6_E + 0.28E-02 * Q_BH_D_DV1_G_6_N + 0.387E-02 * Q_BH_D_DV1_G_6_S + 0.52E-03 * Q_BH_D_DV1_G_7_E + 0.36E-02 * Q_BH_D_DV1_G_7_N + 0.386E-02 * Q_BH_D_DV1_G_7_S + 0.163E-02 * Q_BH_D_DV1_G_8_E + 0.4E-02 * Q_BH_D_DV1_G_8_N + 0.25E-02 * Q_BH_D_DV1_G_8_S + 0.284E-02 * Q_BH_D_DV1_G_9_E + 0.45E-02 * Q_BH_D_DV1_G_9_N + 0.28E-02 * Q_BH_D_DV1_G_9_S + 0.254E-02 * Q_BH_D_DV1_G_10_E + 0.53E-02 * Q_BH_D_DV1_G_10_N + 0.19E-02 * Q_BH_D_DV1_G_10_S + 0.322E-02 * Q_BH_D_DV1_G_11_E + 0.61E-02 * Q_BH_D_DV1_G_11_N + 0.15E-02 * Q_BH_D_DV1_G_11_S + 0.13E-02 * Q_BH_D_DV1_G_12_E + 0.52E-02 * Q_BH_D_DV1_G_12_N + 0.35E-02 * Q_BH_D_DV1_G_12_S + 0.36E-02 * Q_BH_D_DV1_G_13_E + 0.59E-02 * Q_BH_D_DV1_G_13_N + 0.11E-02 * Q_BH_D_DV1_G_13_S + 0.44E-02 * Q_BH_D_DV1_G_14_E + 0.62E-02 * Q_BH_D_DV1_G_14_N + 0.21E-02 * Q_BH_D_DV1_G_14_S + 0.502E-02 * Q_BH_D_DV1_G_15_E + 0.64E-02 * Q_BH_D_DV1_G_15_N + 0.51E-02 * Q_BH_D_DV1_G_15_S + 0.506E-02 * Q_BH_D_DV1_G_16_E + 0.7197142857E-02 * Q_BH_D_DV1_G_16_N + 0.66E-03 * Q_BH_D_DV1_G_16_S - BUTDN_EMSN_DV1 = 0;

[_616] 10.686 * Q_BH_D_DV2_G_1_E + 2.094 * Q_BH_D_DV2_G_1_N + 17.997 * Q_BH_D_DV2_G_1_S + 8.55 * Q_BH_D_DV2_G_2_E + 4.4039 * Q_BH_D_DV2_G_2_N + 15.51 * Q_BH_D_DV2_G_2_S + 6.879 * Q_BH_D_DV2_G_3_E + 6.958 * Q_BH_D_DV2_G_3_N + 16.41 * Q_BH_D_DV2_G_3_S + 7.506 * Q_BH_D_DV2_G_4_E + 5.901 * Q_BH_D_DV2_G_4_N + 14.18 * Q_BH_D_DV2_G_4_S + 6.312 * Q_BH_D_DV2_G_5_E + 7.183 * Q_BH_D_DV2_G_5_N + 12.89 * Q_BH_D_DV2_G_5_S + 5.813 * Q_BH_D_DV2_G_6_E + 8.886 * Q_BH_D_DV2_G_6_N + 12.076 * Q_BH_D_DV2_G_6_S + 1.615 * Q_BH_D_DV2_G_7_E + 11.08 * Q_BH_D_DV2_G_7_N + 12.047 * Q_BH_D_DV2_G_7_S + 5.084 * Q_BH_D_DV2_G_8_E + 12.624 * Q_BH_D_DV2_G_8_N + 7.858 * Q_BH_D_DV2_G_8_S + 8.85 * Q_BH_D_DV2_G_9_E + 14.03 * Q_BH_D_DV2_G_9_N + 8.802 * Q_BH_D_DV2_G_9_S + 7.897 * Q_BH_D_DV2_G_10_E + 16.41 * Q_BH_D_DV2_G_10_N + 6.033 * Q_BH_D_DV2_G_10_S + 10.02 * Q_BH_D_DV2_G_11_E + 19.05 * Q_BH_D_DV2_G_11_N + 4.693 * Q_BH_D_DV2_G_11_S + 3.944 * Q_BH_D_DV2_G_12_E + 16.33 * Q_BH_D_DV2_G_12_N + 10.951 * Q_BH_D_DV2_G_12_S + 11.274 * Q_BH_D_DV2_G_13_E + 18.66 * Q_BH_D_DV2_G_13_N + 3.464 * Q_BH_D_DV2_G_13_S + 13.701 * Q_BH_D_DV2_G_14_E + 19.45 * Q_BH_D_DV2_G_14_N + 6.704 * Q_BH_D_DV2_G_14_S + 15.64 * Q_BH_D_DV2_G_15_E + 19.82 * Q_BH_D_DV2_G_15_N + 15.952 * Q_BH_D_DV2_G_15_S + 15.75617556 * Q_BH_D_DV2_G_16_E + 22.41095778 * Q_BH_D_DV2_G_16_N + 2.055153333 * Q_BH_D_DV2_G_16_S - CO_EMSN_DV2 = 0;

[_617] 4078.48 * Q_BH_D_DV2_G_1_E + 799.26 * Q_BH_D_DV2_G_1_N + 6868.43 * Q_BH_D_DV2_G_1_S + 3264.28 * Q_BH_D_DV2_G_2_E + 1680.69 * Q_BH_D_DV2_G_2_N + 5919.77 * Q_BH_D_DV2_G_2_S + 2625.62 * Q_BH_D_DV2_G_3_E + 2655.49 * Q_BH_D_DV2_G_3_N + 6263.38 * Q_BH_D_DV2_G_3_S + 2864.65 * Q_BH_D_DV2_G_4_E + 2252.13 * Q_BH_D_DV2_G_4_N + 5411.83 * Q_BH_D_DV2_G_4_S + 2408.99 * Q_BH_D_DV2_G_5_E + 2741.39 * Q_BH_D_DV2_G_5_N + 4918.82 * Q_BH_D_DV2_G_5_S + 2218.51 * Q_BH_D_DV2_G_6_E + 3391.26 * Q_BH_D_DV2_G_6_N + 4608.83 * Q_BH_D_DV2_G_6_S + 616.25 * Q_BH_D_DV2_G_7_E + 4227.87 * Q_BH_D_DV2_G_7_N + 4597.63 * Q_BH_D_DV2_G_7_S + 1940.27 * Q_BH_D_DV2_G_8_E + 4817.98 * Q_BH_D_DV2_G_8_N + 2999.1 * Q_BH_D_DV2_G_8_S + 3376.32 * Q_BH_D_DV2_G_9_E + 5355.81 * Q_BH_D_DV2_G_9_N + 3359.14 * Q_BH_D_DV2_G_9_S + 3014.04 * Q_BH_D_DV2_G_10_E + 6263.38 * Q_BH_D_DV2_G_10_N + 2302.55 * Q_BH_D_DV2_G_10_S + 3824.51 * Q_BH_D_DV2_G_11_E + 7271.8 * Q_BH_D_DV2_G_11_N + 1791.24 * Q_BH_D_DV2_G_11_S + 1505.15 * Q_BH_D_DV2_G_12_E + 6233.51 * Q_BH_D_DV2_G_12_N + 4179.32 * Q_BH_D_DV2_G_12_S + 4302.57 * Q_BH_D_DV2_G_13_E + 7122.4 * Q_BH_D_DV2_G_13_N + 1322.14 * Q_BH_D_DV2_G_13_S + 5228.82 * Q_BH_D_DV2_G_14_E + 7424.93 * Q_BH_D_DV2_G_14_N + 2558.39 * Q_BH_D_DV2_G_14_S + 5968.32 * Q_BH_D_DV2_G_15_E + 7563.11 * Q_BH_D_DV2_G_15_N + 6087.84 * Q_BH_D_DV2_G_15_S + 6013.144238 * Q_BH_D_DV2_G_16_E + 8552.857333 * Q_BH_D_DV2_G_16_N + 784.3231615 * Q_BH_D_DV2_G_16_S - CO2_EMSN_DV2 = 0;

[_618] 0.898 * Q_BH_D_DV2_G_1_E + 0.176 * Q_BH_D_DV2_G_1_N + 1.513 * Q_BH_D_DV2_G_1_S + 0.719 * Q_BH_D_DV2_G_2_E + 0.37 * Q_BH_D_DV2_G_2_N + 1.304 * Q_BH_D_DV2_G_2_S + 0.578 * Q_BH_D_DV2_G_3_E + 0.585 * Q_BH_D_DV2_G_3_N + 1.38 * Q_BH_D_DV2_G_3_S + 0.631 * Q_BH_D_DV2_G_4_E + 0.496 *

Q_BH_D_DV2_G_4_N + 1.192 * Q_BH_D_DV2_G_4_S + 0.531 * Q_BH_D_DV2_G_5_E + 0.604 * Q_BH_D_DV2_G_5_N + 1.084 * Q_BH_D_DV2_G_5_S + 0.489 * Q_BH_D_DV2_G_6_E + 0.747 * Q_BH_D_DV2_G_6_N + 1.016 * Q_BH_D_DV2_G_6_S + 0.136 * Q_BH_D_DV2_G_7_E + 0.931 * Q_BH_D_DV2_G_7_N + 1.013 * Q_BH_D_DV2_G_7_S + 0.427 * Q_BH_D_DV2_G_8_E + 1.061 * Q_BH_D_DV2_G_8_N + 0.661 * Q_BH_D_DV2_G_8_S + 0.744 * Q_BH_D_DV2_G_9_E + 1.18 * Q_BH_D_DV2_G_9_N + 0.74 * Q_BH_D_DV2_G_9_S + 0.664 * Q_BH_D_DV2_G_10_E + 1.38 * Q_BH_D_DV2_G_10_N + 0.507 * Q_BH_D_DV2_G_10_S + 0.843 * Q_BH_D_DV2_G_11_E + 1.602 * Q_BH_D_DV2_G_11_N + 0.394 * Q_BH_D_DV2_G_11_S + 0.332 * Q_BH_D_DV2_G_12_E + 1.373 * Q_BH_D_DV2_G_12_N + 0.921 * Q_BH_D_DV2_G_12_S + 0.948 * Q_BH_D_DV2_G_13_E + 1.569 * Q_BH_D_DV2_G_13_N + 0.291 * Q_BH_D_DV2_G_13_S + 1.152 * Q_BH_D_DV2_G_14_E + 1.636 * Q_BH_D_DV2_G_14_N + 0.564 * Q_BH_D_DV2_G_14_S + 1.315 * Q_BH_D_DV2_G_15_E + 1.666 * Q_BH_D_DV2_G_15_N + 1.341 * Q_BH_D_DV2_G_15_S + 1.3249319 * Q_BH_D_DV2_G_16_E + 1.884530466 * Q_BH_D_DV2_G_16_N + 0.1728172043 * Q_BH_D_DV2_G_16_S - SO2_EMSN_DV2 = 0;

[_619] 2.95 * Q_BH_D_DV2_G_1_E + 0.578 * Q_BH_D_DV2_G_1_N + 4.969 * Q_BH_D_DV2_G_1_S + 2.36 * Q_BH_D_DV2_G_2_E + 1.216 * Q_BH_D_DV2_G_2_N + 4.283 * Q_BH_D_DV2_G_2_S + 1.899 * Q_BH_D_DV2_G_3_E + 1.921 * Q_BH_D_DV2_G_3_N + 4.532 * Q_BH_D_DV2_G_3_S + 2.073 * Q_BH_D_DV2_G_4_E + 1.629 * Q_BH_D_DV2_G_4_N + 3.915 * Q_BH_D_DV2_G_4_S + 1.743 * Q_BH_D_DV2_G_5_E + 1.983 * Q_BH_D_DV2_G_5_N + 3.559 * Q_BH_D_DV2_G_5_S + 1.605 * Q_BH_D_DV2_G_6_E + 2.454 * Q_BH_D_DV2_G_6_N + 3.334 * Q_BH_D_DV2_G_6_S + 0.446 * Q_BH_D_DV2_G_7_E + 3.059 * Q_BH_D_DV2_G_7_N + 3.326 * Q_BH_D_DV2_G_7_S + 1.404 * Q_BH_D_DV2_G_8_E + 3.486 * Q_BH_D_DV2_G_8_N + 2.169 * Q_BH_D_DV2_G_8_S + 2.443 * Q_BH_D_DV2_G_9_E + 3.875 * Q_BH_D_DV2_G_9_N + 2.43 * Q_BH_D_DV2_G_9_S + 2.181 * Q_BH_D_DV2_G_10_E + 4.532 * Q_BH_D_DV2_G_10_N + 1.666 * Q_BH_D_DV2_G_10_S + 2.767 * Q_BH_D_DV2_G_11_E + 5.261 * Q_BH_D_DV2_G_11_N + 1.296 * Q_BH_D_DV2_G_11_S + 1.089 * Q_BH_D_DV2_G_12_E + 4.51 * Q_BH_D_DV2_G_12_N + 3.024 * Q_BH_D_DV2_G_12_S + 3.112 * Q_BH_D_DV2_G_13_E + 5.153 * Q_BH_D_DV2_G_13_N + 0.956 * Q_BH_D_DV2_G_13_S + 3.783 * Q_BH_D_DV2_G_14_E + 5.372 * Q_BH_D_DV2_G_14_N + 1.851 * Q_BH_D_DV2_G_14_S + 4.318 * Q_BH_D_DV2_G_15_E + 5.472 * Q_BH_D_DV2_G_15_N + 4.405 * Q_BH_D_DV2_G_15_S + 4.350577778 * Q_BH_D_DV2_G_16_E + 6.188088889 * Q_BH_D_DV2_G_16_N + 0.5674666667 * Q_BH_D_DV2_G_16_S - HC_EMSN_DV2 = 0;

[_620] 19.04 * Q_BH_D_DV2_G_1_E + 3.731 * Q_BH_D_DV2_G_1_N + 32.059 * Q_BH_D_DV2_G_1_S + 15.24 * Q_BH_D_DV2_G_2_E + 7.845 * Q_BH_D_DV2_G_2_N + 27.632 * Q_BH_D_DV2_G_2_S + 12.26 * Q_BH_D_DV2_G_3_E + 12.395 * Q_BH_D_DV2_G_3_N + 29.236 * Q_BH_D_DV2_G_3_S + 13.37 * Q_BH_D_DV2_G_4_E + 10.51 * Q_BH_D_DV2_G_4_N + 25.261 * Q_BH_D_DV2_G_4_S + 11.24 * Q_BH_D_DV2_G_5_E + 12.796 * Q_BH_D_DV2_G_5_N + 22.959 * Q_BH_D_DV2_G_5_S + 10.35 * Q_BH_D_DV2_G_6_E + 15.829 * Q_BH_D_DV2_G_6_N + 21.512 * Q_BH_D_DV2_G_6_S + 2.88 * Q_BH_D_DV2_G_7_E + 19.734 * Q_BH_D_DV2_G_7_N + 21.46 * Q_BH_D_DV2_G_7_S + 9.06 * Q_BH_D_DV2_G_8_E + 22.489 * Q_BH_D_DV2_G_8_N + 13.99 * Q_BH_D_DV2_G_8_S + 15.76 * Q_BH_D_DV2_G_9_E + 24.99 * Q_BH_D_DV2_G_9_N + 15.68 * Q_BH_D_DV2_G_9_S + 14.069 * Q_BH_D_DV2_G_10_E + 29.236 * Q_BH_D_DV2_G_10_N + 10.75 * Q_BH_D_DV2_G_10_S + 17.852 * Q_BH_D_DV2_G_11_E + 33.94 * Q_BH_D_DV2_G_11_N + 8.361 * Q_BH_D_DV2_G_11_S + 7.026 * Q_BH_D_DV2_G_12_E + 29.096 * Q_BH_D_DV2_G_12_N + 19.51 * Q_BH_D_DV2_G_12_S + 20.08 * Q_BH_D_DV2_G_13_E + 33.24 * Q_BH_D_DV2_G_13_N + 6.171 * Q_BH_D_DV2_G_13_S + 24.41 * Q_BH_D_DV2_G_14_E + 34.657 * Q_BH_D_DV2_G_14_N + 11.94 * Q_BH_D_DV2_G_14_S + 27.86 * Q_BH_D_DV2_G_15_E + 35.3 * Q_BH_D_DV2_G_15_N + 28.42 * Q_BH_D_DV2_G_15_S + 28.06766667 * Q_BH_D_DV2_G_16_E + 39.92233333 * Q_BH_D_DV2_G_16_N + 3.661 * Q_BH_D_DV2_G_16_S - NOX_EMSN_DV2 = 0;

[_621] 1.876 * Q_BH_D_DV2_G_1_E + 0.368 * Q_BH_D_DV2_G_1_N + 3.159 * Q_BH_D_DV2_G_1_S + 1.501 * Q_BH_D_DV2_G_2_E + 0.773 * Q_BH_D_DV2_G_2_N + 2.723 * Q_BH_D_DV2_G_2_S + 1.207 * Q_BH_D_DV2_G_3_E + 1.221 * Q_BH_D_DV2_G_3_N + 2.881 * Q_BH_D_DV2_G_3_S + 1.317 * Q_BH_D_DV2_G_4_E + 1.035 * Q_BH_D_DV2_G_4_N + 2.489 * Q_BH_D_DV2_G_4_S + 1.108 * Q_BH_D_DV2_G_5_E + 1.261 * Q_BH_D_DV2_G_5_N + 2.262 * Q_BH_D_DV2_G_5_S + 1.02 * Q_BH_D_DV2_G_6_E + 1.559 * Q_BH_D_DV2_G_6_N + 2.119 * Q_BH_D_DV2_G_6_S + 0.283 * Q_BH_D_DV2_G_7_E + 1.944 * Q_BH_D_DV2_G_7_N + 2.114 * Q_BH_D_DV2_G_7_S + 0.892 * Q_BH_D_DV2_G_8_E + 2.216 * Q_BH_D_DV2_G_8_N + 1.379 * Q_BH_D_DV2_G_8_S + 1.553 * Q_BH_D_DV2_G_9_E + 2.463 * Q_BH_D_DV2_G_9_N + 1.545 * Q_BH_D_DV2_G_9_S + 1.386 * Q_BH_D_DV2_G_10_E + 2.881 * Q_BH_D_DV2_G_10_N + 1.059 * Q_BH_D_DV2_G_10_S + 1.759 * Q_BH_D_DV2_G_11_E + 3.344 * Q_BH_D_DV2_G_11_N + 0.824 * Q_BH_D_DV2_G_11_S + 0.692 * Q_BH_D_DV2_G_12_E + 2.867 * Q_BH_D_DV2_G_12_N + 1.922 * Q_BH_D_DV2_G_12_S + 1.978 * Q_BH_D_DV2_G_13_E + 3.276 * Q_BH_D_DV2_G_13_N + 0.608 * Q_BH_D_DV2_G_13_S + 2.405 * Q_BH_D_DV2_G_14_E + 3.415 * Q_BH_D_DV2_G_14_N + 1.176 * Q_BH_D_DV2_G_14_S + 2.745 * Q_BH_D_DV2_G_15_E + 3.478 * Q_BH_D_DV2_G_15_N + 2.799 * Q_BH_D_DV2_G_15_S + 2.765622222 * Q_BH_D_DV2_G_16_E + 3.933711111 * Q_BH_D_DV2_G_16_N + 0.3607333333 * Q_BH_D_DV2_G_16_S - PM_EMSN_DV2 = 0;

[_622] 0.15E-01 * Q_BH_D_DV2_G_1_E + 0.29E-02 * Q_BH_D_DV2_G_1_N + 0.253E-01 * Q_BH_D_DV2_G_1_S + 0.12E-01 * Q_BH_D_DV2_G_2_E + 0.62E-02 * Q_BH_D_DV2_G_2_N + 0.22E-01 * Q_BH_D_DV2_G_2_S + 0.97E-02 * Q_BH_D_DV2_G_3_E + 0.98E-02 * Q_BH_D_DV2_G_3_N + 0.23E-01 * Q_BH_D_DV2_G_3_S + 0.106E-01 * Q_BH_D_DV2_G_4_E + 0.83E-02 * Q_BH_D_DV2_G_4_N + 0.19E-01 * Q_BH_D_DV2_G_4_S + 0.89E-02 * Q_BH_D_DV2_G_5_E + 0.101E-01 * Q_BH_D_DV2_G_5_N + 0.18E-01 * Q_BH_D_DV2_G_5_S + 0.82E-02 * Q_BH_D_DV2_G_6_E + 0.125E-01 * Q_BH_D_DV2_G_6_N + 0.17E-01 * Q_BH_D_DV2_G_6_S + 0.23E-02 * Q_BH_D_DV2_G_7_E + 0.156E-01 * Q_BH_D_DV2_G_7_N + 0.169E-01 * Q_BH_D_DV2_G_7_S + 0.71E-02 * Q_BH_D_DV2_G_8_E + 0.178E-01 * Q_BH_D_DV2_G_8_N + 0.11E-01 * Q_BH_D_DV2_G_8_S + 0.124E-01 * Q_BH_D_DV2_G_9_E + 0.197E-01 * Q_BH_D_DV2_G_9_N + 0.12E-01 * Q_BH_D_DV2_G_9_S + 0.111E-01 * Q_BH_D_DV2_G_10_E + 0.23E-01 * Q_BH_D_DV2_G_10_N + 0.85E-02 * Q_BH_D_DV2_G_10_S + 0.14E-01 * Q_BH_D_DV2_G_11_E + 0.27E-01 * Q_BH_D_DV2_G_11_N + 0.66E-02 * Q_BH_D_DV2_G_11_S + 0.55E-02 * Q_BH_D_DV2_G_12_E + 0.22E-01 * Q_BH_D_DV2_G_12_N + 0.15E-01 * Q_BH_D_DV2_G_12_S + 0.158E-01 * Q_BH_D_DV2_G_13_E + 0.26E-01 * Q_BH_D_DV2_G_13_N + 0.49E-02 * Q_BH_D_DV2_G_13_S + 0.193E-01 * Q_BH_D_DV2_G_14_E + 0.27E-01 * Q_BH_D_DV2_G_14_N + 0.94E-02 * Q_BH_D_DV2_G_14_S + 0.22E-01 * Q_BH_D_DV2_G_15_E + 0.28E-01 * Q_BH_D_DV2_G_15_N + 0.22E-01 * Q_BH_D_DV2_G_15_S + 0.2218222222E-01 * Q_BH_D_DV2_G_16_E + 0.3155111111E-01 * Q_BH_D_DV2_G_16_N + 0.2893333333E-02 * Q_BH_D_DV2_G_16_S - BENZ_EMSN_DV2 = 0;

[_623] 0.27E-02 * Q_BH_D_DV2_G_1_E + 0.52E-03 * Q_BH_D_DV2_G_1_N + 0.45E-02 * Q_BH_D_DV2_G_1_S + 0.21E-02 * Q_BH_D_DV2_G_2_E + 0.11E-02 * Q_BH_D_DV2_G_2_N + 0.39E-02 * Q_BH_D_DV2_G_2_S + 0.17E-02 * Q_BH_D_DV2_G_3_E + 0.17E-02 * Q_BH_D_DV2_G_3_N + 0.41E-02 * Q_BH_D_DV2_G_3_S + 0.19E-02 * Q_BH_D_DV2_G_4_E + 0.15E-02 * Q_BH_D_DV2_G_4_N + 0.35E-02 * Q_BH_D_DV2_G_4_S + 0.16E-02 *

Annexure 9

Q_BH_D_DV2_G_5_E + 0.18E-02 * Q_BH_D_DV2_G_5_N + 0.32E-02 * Q_BH_D_DV2_G_5_S + 0.14E-02 *
 Q_BH_D_DV2_G_6_E + 0.22E-02 * Q_BH_D_DV2_G_6_N + 0.31E-02 * Q_BH_D_DV2_G_6_S + 0.4E-03 *
 Q_BH_D_DV2_G_7_E + 0.27E-02 * Q_BH_D_DV2_G_7_N + 0.3E-02 * Q_BH_D_DV2_G_7_S + 0.13E-02 *
 Q_BH_D_DV2_G_8_E + 0.31E-02 * Q_BH_D_DV2_G_8_N + 0.196E-02 * Q_BH_D_DV2_G_8_S + 0.22E-02 *
 Q_BH_D_DV2_G_9_E + 0.35E-02 * Q_BH_D_DV2_G_9_N + 0.22E-02 * Q_BH_D_DV2_G_9_S + 0.197E-02 *
 Q_BH_D_DV2_G_10_E + 0.41E-02 * Q_BH_D_DV2_G_10_N + 0.15E-02 * Q_BH_D_DV2_G_10_S + 0.25E-02 *
 Q_BH_D_DV2_G_11_E + 0.476E-02 * Q_BH_D_DV2_G_11_N + 0.12E-02 * Q_BH_D_DV2_G_11_S + 0.98E-03 *
 Q_BH_D_DV2_G_12_E + 0.41E-02 * Q_BH_D_DV2_G_12_N + 0.27E-02 * Q_BH_D_DV2_G_12_S + 0.282E-02 *
 Q_BH_D_DV2_G_13_E + 0.46E-02 * Q_BH_D_DV2_G_13_N + 0.86E-03 * Q_BH_D_DV2_G_13_S + 0.34E-02 *
 Q_BH_D_DV2_G_14_E + 0.486E-02 * Q_BH_D_DV2_G_14_N + 0.17E-02 * Q_BH_D_DV2_G_14_S + 0.39E-02 *
 Q_BH_D_DV2_G_15_E + 0.495E-02 * Q_BH_D_DV2_G_15_N + 0.39E-02 * Q_BH_D_DV2_G_15_S + 0.393555556E-02 *
 Q_BH_D_DV2_G_16_E + 0.5597777778E-02 * Q_BH_D_DV2_G_16_N + 0.5133333333E-03 * Q_BH_D_DV2_G_16_S -
 BUTDN_EMSN_DV2 = 0;
 [_624] 10.03 * Q_BH_D_DV3_G_1_E + 1.885 * Q_BH_D_DV3_G_1_N + 16.889 * Q_BH_D_DV3_G_1_S + 8.027 *
 Q_BH_D_DV3_G_2_E + 3.963 * Q_BH_D_DV3_G_2_N + 14.556 * Q_BH_D_DV3_G_2_S + 6.456 * Q_BH_D_DV3_G_3_E +
 6.262 * Q_BH_D_DV3_G_3_N + 14.77 * Q_BH_D_DV3_G_3_S + 7.044 * Q_BH_D_DV3_G_4_E + 5.311 *
 Q_BH_D_DV3_G_4_N + 13.31 * Q_BH_D_DV3_G_4_S + 5.924 * Q_BH_D_DV3_G_5_E + 6.465 * Q_BH_D_DV3_G_5_N +
 12.095 * Q_BH_D_DV3_G_5_S + 5.455 * Q_BH_D_DV3_G_6_E + 7.997 * Q_BH_D_DV3_G_6_N + 11.333 *
 Q_BH_D_DV3_G_6_S + 1.515 * Q_BH_D_DV3_G_7_E + 9.97 * Q_BH_D_DV3_G_7_N + 11.305 * Q_BH_D_DV3_G_7_S +
 4.771 * Q_BH_D_DV3_G_8_E + 11.362 * Q_BH_D_DV3_G_8_N + 7.374 * Q_BH_D_DV3_G_8_S + 8.302 *
 Q_BH_D_DV3_G_9_E + 12.63 * Q_BH_D_DV3_G_9_N + 8.26 * Q_BH_D_DV3_G_9_S + 7.411 * Q_BH_D_DV3_G_10_E +
 14.77 * Q_BH_D_DV3_G_10_N + 5.662 * Q_BH_D_DV3_G_10_S + 9.404 * Q_BH_D_DV3_G_11_E + 17.148 *
 Q_BH_D_DV3_G_11_N + 4.405 * Q_BH_D_DV3_G_11_S + 3.701 * Q_BH_D_DV3_G_12_E + 14.7 * Q_BH_D_DV3_G_12_N +
 10.276 * Q_BH_D_DV3_G_12_S + 10.579 * Q_BH_D_DV3_G_13_E + 16.796 * Q_BH_D_DV3_G_13_N + 3.251 *
 Q_BH_D_DV3_G_13_S + 12.858 * Q_BH_D_DV3_G_14_E + 17.509 * Q_BH_D_DV3_G_14_N + 6.291 *
 Q_BH_D_DV3_G_14_S + 14.676 * Q_BH_D_DV3_G_15_E + 17.836 * Q_BH_D_DV3_G_15_N + 14.969 *
 Q_BH_D_DV3_G_15_S + 14.78624 * Q_BH_D_DV3_G_16_E + 21.03136 * Q_BH_D_DV3_G_16_N + 1.92864 *
 Q_BH_D_DV3_G_16_S - CO_EMSN_DV3 = 0;
 [_625] 5697.14 * Q_BH_D_DV3_G_1_E + 1116.6 * Q_BH_D_DV3_G_1_N + 9594.372 * Q_BH_D_DV3_G_1_S + 4559.8 *
 Q_BH_D_DV3_G_2_E + 2347.99 * Q_BH_D_DV3_G_2_N + 8269.21 * Q_BH_D_DV3_G_2_S + 3667.67 *
 Q_BH_D_DV3_G_3_E + 3709.83 * Q_BH_D_DV3_G_3_N + 8750.18 * Q_BH_D_DV3_G_3_S + 4001.57 *
 Q_BH_D_DV3_G_4_E + 3146.31 * Q_BH_D_DV3_G_4_N + 7559.67 * Q_BH_D_DV3_G_4_S + 3365.07 *
 Q_BH_D_DV3_G_5_E + 3829.83 * Q_BH_D_DV3_G_5_N + 6871.01 * Q_BH_D_DV3_G_5_S + 3098.99 *
 Q_BH_D_DV3_G_6_E + 4737.73 * Q_BH_D_DV3_G_6_N + 6437.98 * Q_BH_D_DV3_G_6_S + 860.83 * Q_BH_D_DV3_G_7_E +
 5906.5 * Q_BH_D_DV3_G_7_N + 6422.33 * Q_BH_D_DV3_G_7_S + 2710.32 * Q_BH_D_DV3_G_8_E + 6730.91 *
 Q_BH_D_DV3_G_8_N + 4189.39 * Q_BH_D_DV3_G_8_S + 4716.32 * Q_BH_D_DV3_G_9_E + 7482.27 *
 Q_BH_D_DV3_G_9_N + 4692.32 * Q_BH_D_DV3_G_9_S + 4210.25 * Q_BH_D_DV3_G_10_E + 8750.18 *
 Q_BH_D_DV3_G_10_N + 3216.38 * Q_BH_D_DV3_G_10_S + 5342.38 * Q_BH_D_DV3_G_11_E + 10158.98 *
 Q_BH_D_DV3_G_11_N + 2502.15 * Q_BH_D_DV3_G_11_S + 2102.52 * Q_BH_D_DV3_G_12_E + 8708.44 *
 Q_BH_D_DV3_G_12_N + 5838.01 * Q_BH_D_DV3_G_12_S + 6010.18 * Q_BH_D_DV3_G_13_E + 9950.267 *
 Q_BH_D_DV3_G_13_N + 1846.87 * Q_BH_D_DV3_G_13_S + 7304.03 * Q_BH_D_DV3_G_14_E + 10372.91 *
 Q_BH_D_DV3_G_14_N + 3573.76 * Q_BH_D_DV3_G_14_S + 8337.03 * Q_BH_D_DV3_G_15_E + 10565.96 *
 Q_BH_D_DV3_G_15_N + 8503.98 * Q_BH_D_DV3_G_15_S + 8320.376169 * Q_BH_D_DV3_G_16_E + 11834.57231 *
 Q_BH_D_DV3_G_16_N + 1085.266457 * Q_BH_D_DV3_G_16_S - CO2_EMSN_DV3 = 0;
 [_626] 1.254 * Q_BH_D_DV3_G_1_E + 0.2456 * Q_BH_D_DV3_G_1_N + 2.111 * Q_BH_D_DV3_G_1_S + 1.003 *
 Q_BH_D_DV3_G_2_E + 0.517 * Q_BH_D_DV3_G_2_N + 1.819 * Q_BH_D_DV3_G_2_S + 0.807 * Q_BH_D_DV3_G_3_E +
 0.816 * Q_BH_D_DV3_G_3_N + 1.925 *
 Q_BH_D_DV3_G_3_S + 0.88 * Q_BH_D_DV3_G_4_E + 0.692 * Q_BH_D_DV3_G_4_N + 1.663 * Q_BH_D_DV3_G_4_S + 0.74
 * Q_BH_D_DV3_G_5_E + 0.843 * Q_BH_D_DV3_G_5_N + 1.512 * Q_BH_D_DV3_G_5_S + 0.682 * Q_BH_D_DV3_G_6_E +
 1.042 * Q_BH_D_DV3_G_6_N + 1.417 * Q_BH_D_DV3_G_6_S + 0.189 * Q_BH_D_DV3_G_7_E + 1.299 *
 Q_BH_D_DV3_G_7_N + 1.413 * Q_BH_D_DV3_G_7_S + 0.596 * Q_BH_D_DV3_G_8_E + 1.481 * Q_BH_D_DV3_G_8_N +
 0.922 * Q_BH_D_DV3_G_8_S + 1.038 * Q_BH_D_DV3_G_9_E + 1.646 * Q_BH_D_DV3_G_9_N + 1.032 *
 Q_BH_D_DV3_G_9_S + 0.926 * Q_BH_D_DV3_G_10_E + 1.925 * Q_BH_D_DV3_G_10_N + 0.708 * Q_BH_D_DV3_G_10_S +
 1.175 * Q_BH_D_DV3_G_11_E + 2.235 * Q_BH_D_DV3_G_11_N + 0.5505 * Q_BH_D_DV3_G_11_S + 0.463 *
 Q_BH_D_DV3_G_12_E + 1.916 * Q_BH_D_DV3_G_12_N + 1.285 * Q_BH_D_DV3_G_12_S + 1.322 * Q_BH_D_DV3_G_13_E +
 2.189 * Q_BH_D_DV3_G_13_N + 0.406 * Q_BH_D_DV3_G_13_S + 1.607 * Q_BH_D_DV3_G_14_E + 2.282 *
 Q_BH_D_DV3_G_14_N + 0.786 * Q_BH_D_DV3_G_14_S + 1.834 * Q_BH_D_DV3_G_15_E + 2.325 * Q_BH_D_DV3_G_15_N +
 1.871 * Q_BH_D_DV3_G_15_S + 1.830886578 * Q_BH_D_DV3_G_16_E + 2.604180287 * Q_BH_D_DV3_G_16_N +
 0.2388112927 * Q_BH_D_DV3_G_16_S - SO2_EMSN_DV3 = 0;
 [_627] 2.801 * Q_BH_D_DV3_G_1_E + 0.549 * Q_BH_D_DV3_G_1_N + 4.717 * Q_BH_D_DV3_G_1_S + 2.242 *
 Q_BH_D_DV3_G_2_E + 1.154 * Q_BH_D_DV3_G_2_N + 4.065 * Q_BH_D_DV3_G_2_S + 1.803 * Q_BH_D_DV3_G_3_E +
 1.824 * Q_BH_D_DV3_G_3_N + 4.301 * Q_BH_D_DV3_G_3_S + 1.967 * Q_BH_D_DV3_G_4_E + 1.547 *
 Q_BH_D_DV3_G_4_N + 3.716 * Q_BH_D_DV3_G_4_S + 1.654 * Q_BH_D_DV3_G_5_E + 1.883 * Q_BH_D_DV3_G_5_N +
 3.378 * Q_BH_D_DV3_G_5_S + 1.524 * Q_BH_D_DV3_G_6_E + 2.329 * Q_BH_D_DV3_G_6_N + 3.165 *
 Q_BH_D_DV3_G_6_S + 0.423 * Q_BH_D_DV3_G_7_E + 2.903 * Q_BH_D_DV3_G_7_N + 3.157 * Q_BH_D_DV3_G_7_S +
 1.332 * Q_BH_D_DV3_G_8_E + 3.309 * Q_BH_D_DV3_G_8_N + 2.059 * Q_BH_D_DV3_G_8_S + 2.318 *
 Q_BH_D_DV3_G_9_E + 3.678 * Q_BH_D_DV3_G_9_N + 2.307 * Q_BH_D_DV3_G_9_S + 2.069 * Q_BH_D_DV3_G_10_E +
 4.301 * Q_BH_D_DV3_G_10_N + 1.581 * Q_BH_D_DV3_G_10_S + 2.626 * Q_BH_D_DV3_G_11_E + 4.994 *
 Q_BH_D_DV3_G_11_N + 1.23 * Q_BH_D_DV3_G_11_S + 1.034 * Q_BH_D_DV3_G_12_E + 4.281 * Q_BH_D_DV3_G_12_N +
 2.87 * Q_BH_D_DV3_G_12_S + 2.955 * Q_BH_D_DV3_G_13_E + 4.891 * Q_BH_D_DV3_G_13_N + 0.908 *
 Q_BH_D_DV3_G_13_S + 3.591 * Q_BH_D_DV3_G_14_E + 5.099 * Q_BH_D_DV3_G_14_N + 1.757 * Q_BH_D_DV3_G_14_S +
 4.098 * Q_BH_D_DV3_G_15_E + 5.194 * Q_BH_D_DV3_G_15_N + 4.181 * Q_BH_D_DV3_G_15_S + 4.12965 *
 Q_BH_D_DV3_G_16_E + 5.87385 * Q_BH_D_DV3_G_16_N + 0.53865 * Q_BH_D_DV3_G_16_S - HC_EMSN_DV3 = 0;
 [_628] 17.902 * Q_BH_D_DV3_G_1_E + 3.508 * Q_BH_D_DV3_G_1_N + 30.148 * Q_BH_D_DV3_G_1_S + 14.328 *
 Q_BH_D_DV3_G_2_E + 7.377 * Q_BH_D_DV3_G_2_N + 25.98 * Q_BH_D_DV3_G_2_S + 11.524 * Q_BH_D_DV3_G_3_E +
 11.656 * Q_BH_D_DV3_G_3_N + 27.49 * Q_BH_D_DV3_G_3_S + 12.574 * Q_BH_D_DV3_G_4_E + 9.885 *
 Q_BH_D_DV3_G_4_N + 23.755 * Q_BH_D_DV3_G_4_S + 10.574 * Q_BH_D_DV3_G_5_E + 12.033 * Q_BH_D_DV3_G_5_N +
 21.59 * Q_BH_D_DV3_G_5_S + 9.738 * Q_BH_D_DV3_G_6_E + 14.886 * Q_BH_D_DV3_G_6_N + 20.23 *

$Q\_BH\_D\_DV3\_G\_6\_S + 2.705 * Q\_BH\_D\_DV3\_G\_7\_E + 18.56 * Q\_BH\_D\_DV3\_G\_7\_N + 20.18 * Q\_BH\_D\_DV3\_G\_7\_S +$
 $8.517 * Q\_BH\_D\_DV3\_G\_8\_E + 21.15 * Q\_BH\_D\_DV3\_G\_8\_N + 13.164 * Q\_BH\_D\_DV3\_G\_8\_S + 14.82 * Q\_BH\_D\_DV3\_G\_9\_E +$
 $23.509 * Q\_BH\_D\_DV3\_G\_9\_N + 14.745 * Q\_BH\_D\_DV3\_G\_9\_S + 13.23 * Q\_BH\_D\_DV3\_G\_10\_E + 27.49 * Q\_BH\_D\_DV3\_G\_10\_N +$
 $10.107 * Q\_BH\_D\_DV3\_G\_10\_S + 16.787 * Q\_BH\_D\_DV3\_G\_11\_E + 31.92 * Q\_BH\_D\_DV3\_G\_11\_N + 7.862 * Q\_BH\_D\_DV3\_G\_11\_S +$
 $6.607 * Q\_BH\_D\_DV3\_G\_12\_E + 27.36 * Q\_BH\_D\_DV3\_G\_12\_N + 18.345 * Q\_BH\_D\_DV3\_G\_12\_S + 18.885 * Q\_BH\_D\_DV3\_G\_13\_E + 31.26 * Q\_BH\_D\_DV3\_G\_13\_N + 5.803 * Q\_BH\_D\_DV3\_G\_13\_S +$
 $22.952 * Q\_BH\_D\_DV3\_G\_14\_E + 32.59 * Q\_BH\_D\_DV3\_G\_14\_N + 11.229 * Q\_BH\_D\_DV3\_G\_14\_S + 26.197 * Q\_BH\_D\_DV3\_G\_15\_E + 33.197 * Q\_BH\_D\_DV3\_G\_15\_N + 26.72 * Q\_BH\_D\_DV3\_G\_15\_S +$
 $26.39434 * Q\_BH\_D\_DV3\_G\_16\_E + 37.54226 * Q\_BH\_D\_DV3\_G\_16\_N + 3.44274 * Q\_BH\_D\_DV3\_G\_16\_S -$
 $NOX\_EMSN\_DV3 = 0;$
 $[\_629] 1.924 * Q\_BH\_D\_DV3\_G\_1\_E + 0.379 * Q\_BH\_D\_DV3\_G\_1\_N + 3.24 * Q\_BH\_D\_DV3\_G\_1\_S + 1.539 * Q\_BH\_D\_DV3\_G\_2\_E + 0.793 * Q\_BH\_D\_DV3\_G\_2\_N + 2.793 * Q\_BH\_D\_DV3\_G\_2\_S + 1.239 * Q\_BH\_D\_DV3\_G\_3\_E + 1.253 * Q\_BH\_D\_DV3\_G\_3\_N + 2.955 * Q\_BH\_D\_DV3\_G\_3\_S + 1.351 * Q\_BH\_D\_DV3\_G\_4\_E + 1.062 * Q\_BH\_D\_DV3\_G\_4\_N + 2.553 * Q\_BH\_D\_DV3\_G\_4\_S + 1.136 * Q\_BH\_D\_DV3\_G\_5\_E + 1.293 * Q\_BH\_D\_DV3\_G\_5\_N + 2.32 * Q\_BH\_D\_DV3\_G\_5\_S + 1.047 * Q\_BH\_D\_DV3\_G\_6\_E + 1.599 * Q\_BH\_D\_DV3\_G\_6\_N + 2.174 * Q\_BH\_D\_DV3\_G\_6\_S + 0.291 * Q\_BH\_D\_DV3\_G\_7\_E + 1.994 * Q\_BH\_D\_DV3\_G\_7\_N + 2.169 * Q\_BH\_D\_DV3\_G\_7\_S + 0.915 * Q\_BH\_D\_DV3\_G\_8\_E + 2.273 * Q\_BH\_D\_DV3\_G\_8\_N + 1.415 * Q\_BH\_D\_DV3\_G\_8\_S + 1.593 * Q\_BH\_D\_DV3\_G\_9\_E + 2.527 * Q\_BH\_D\_DV3\_G\_9\_N + 1.585 * Q\_BH\_D\_DV3\_G\_9\_S + 1.422 * Q\_BH\_D\_DV3\_G\_10\_E + 2.955 * Q\_BH\_D\_DV3\_G\_10\_N + 1.086 * Q\_BH\_D\_DV3\_G\_10\_S + 1.804 * Q\_BH\_D\_DV3\_G\_11\_E + 3.431 * Q\_BH\_D\_DV3\_G\_11\_N + 0.845 * Q\_BH\_D\_DV3\_G\_11\_S + 0.71 * Q\_BH\_D\_DV3\_G\_12\_E + 2.941 * Q\_BH\_D\_DV3\_G\_12\_N + 1.972 * Q\_BH\_D\_DV3\_G\_12\_S + 2.029 * Q\_BH\_D\_DV3\_G\_13\_E + 3.36 * Q\_BH\_D\_DV3\_G\_13\_N + 0.624 * Q\_BH\_D\_DV3\_G\_13\_S + 2.467 * Q\_BH\_D\_DV3\_G\_14\_E + 3.503 * Q\_BH\_D\_DV3\_G\_14\_N + 1.207 * Q\_BH\_D\_DV3\_G\_14\_S + 2.816 * Q\_BH\_D\_DV3\_G\_15\_E + 3.568 * Q\_BH\_D\_DV3\_G\_15\_N + 2.872 * Q\_BH\_D\_DV3\_G\_15\_S + 2.83682 * Q\_BH\_D\_DV3\_G\_16\_E + 4.03498 * Q\_BH\_D\_DV3\_G\_16\_N + 0.37002 * Q\_BH\_D\_DV3\_G\_16\_S - PM\_EMSN\_DV3 = 0;$
 $[\_630] 0.146E-01 * Q\_BH\_D\_DV3\_G\_1\_E + 0.29E-02 * Q\_BH\_D\_DV3\_G\_1\_N + 0.25E-01 * Q\_BH\_D\_DV3\_G\_1\_S + 0.117E-01 * Q\_BH\_D\_DV3\_G\_2\_E + 0.6E-02 * Q\_BH\_D\_DV3\_G\_2\_N + 0.21E-01 * Q\_BH\_D\_DV3\_G\_2\_S + 0.94E-02 * Q\_BH\_D\_DV3\_G\_3\_E + 0.95E-02 * Q\_BH\_D\_DV3\_G\_3\_N + 0.22E-01 * Q\_BH\_D\_DV3\_G\_3\_S + 0.103E-01 * Q\_BH\_D\_DV3\_G\_4\_E + 0.81E-02 * Q\_BH\_D\_DV3\_G\_4\_N + 0.19E-01 * Q\_BH\_D\_DV3\_G\_4\_S + 0.86E-02 * Q\_BH\_D\_DV3\_G\_5\_E + 0.98E-02 * Q\_BH\_D\_DV3\_G\_5\_N + 0.176E-01 * Q\_BH\_D\_DV3\_G\_5\_S + 0.79E-02 * Q\_BH\_D\_DV3\_G\_6\_E + 0.12E-01 * Q\_BH\_D\_DV3\_G\_6\_N + 0.165E-01 * Q\_BH\_D\_DV3\_G\_6\_S + 0.22E-02 * Q\_BH\_D\_DV3\_G\_7\_E + 0.15E-01 * Q\_BH\_D\_DV3\_G\_7\_N + 0.164E-01 * Q\_BH\_D\_DV3\_G\_7\_S + 0.69E-02 * Q\_BH\_D\_DV3\_G\_8\_E + 0.17E-01 * Q\_BH\_D\_DV3\_G\_8\_N + 0.107E-01 * Q\_BH\_D\_DV3\_G\_8\_S + 0.12E-01 * Q\_BH\_D\_DV3\_G\_9\_E + 0.19E-01 * Q\_BH\_D\_DV3\_G\_9\_N + 0.12E-01 * Q\_BH\_D\_DV3\_G\_9\_S + 0.108E-01 * Q\_BH\_D\_DV3\_G\_10\_E + 0.22E-01 * Q\_BH\_D\_DV3\_G\_10\_N + 0.83E-02 * Q\_BH\_D\_DV3\_G\_10\_S + 0.14E-01 * Q\_BH\_D\_DV3\_G\_11\_E + 0.26E-01 * Q\_BH\_D\_DV3\_G\_11\_N + 0.643E-02 * Q\_BH\_D\_DV3\_G\_11\_S + 0.54E-02 * Q\_BH\_D\_DV3\_G\_12\_E + 0.223E-01 * Q\_BH\_D\_DV3\_G\_12\_N + 0.149E-01 * Q\_BH\_D\_DV3\_G\_12\_S + 0.15E-01 * Q\_BH\_D\_DV3\_G\_13\_E + 0.25E-01 * Q\_BH\_D\_DV3\_G\_13\_N + 0.47E-02 * Q\_BH\_D\_DV3\_G\_13\_S + 0.187E-01 * Q\_BH\_D\_DV3\_G\_14\_E + 0.27E-01 * Q\_BH\_D\_DV3\_G\_14\_N + 0.92E-02 * Q\_BH\_D\_DV3\_G\_14\_S + 0.214E-01 * Q\_BH\_D\_DV3\_G\_15\_E + 0.271E-01 * Q\_BH\_D\_DV3\_G\_15\_N + 0.22E-01 * Q\_BH\_D\_DV3\_G\_15\_S + 0.21574E-01 * Q\_BH\_D\_DV3\_G\_16\_E + 0.30686E-01 * Q\_BH\_D\_DV3\_G\_16\_N + 0.2814E-02 * Q\_BH\_D\_DV3\_G\_16\_S - BENZ\_EMSN\_DV3 = 0;$
 $[\_631] 0.26E-02 * Q\_BH\_D\_DV3\_G\_1\_E + 0.51E-03 * Q\_BH\_D\_DV3\_G\_1\_N + 0.44E-02 * Q\_BH\_D\_DV3\_G\_1\_S + 0.21E-02 * Q\_BH\_D\_DV3\_G\_2\_E + 0.11E-02 * Q\_BH\_D\_DV3\_G\_2\_N + 0.38E-02 * Q\_BH\_D\_DV3\_G\_2\_S + 0.17E-02 * Q\_BH\_D\_DV3\_G\_3\_E + 0.17E-02 * Q\_BH\_D\_DV3\_G\_3\_N + 0.4E-02 * Q\_BH\_D\_DV3\_G\_3\_S + 0.18E-02 * Q\_BH\_D\_DV3\_G\_4\_E + 0.14E-02 * Q\_BH\_D\_DV3\_G\_4\_N + 0.35E-02 * Q\_BH\_D\_DV3\_G\_4\_S + 0.15E-02 * Q\_BH\_D\_DV3\_G\_5\_E + 0.176E-02 * Q\_BH\_D\_DV3\_G\_5\_N + 0.32E-02 * Q\_BH\_D\_DV3\_G\_5\_S + 0.14E-02 * Q\_BH\_D\_DV3\_G\_6\_E + 0.22E-02 * Q\_BH\_D\_DV3\_G\_6\_N + 0.296E-02 * Q\_BH\_D\_DV3\_G\_6\_S + 0.39E-03 * Q\_BH\_D\_DV3\_G\_7\_E + 0.27E-02 * Q\_BH\_D\_DV3\_G\_7\_N + 0.29E-02 * Q\_BH\_D\_DV3\_G\_7\_S + 0.125E-02 * Q\_BH\_D\_DV3\_G\_8\_E + 0.31E-02 * Q\_BH\_D\_DV3\_G\_8\_N + 0.193E-02 * Q\_BH\_D\_DV3\_G\_8\_S + 0.217E-02 * Q\_BH\_D\_DV3\_G\_9\_E + 0.34E-02 * Q\_BH\_D\_DV3\_G\_9\_N + 0.216E-02 * Q\_BH\_D\_DV3\_G\_9\_S + 0.194E-02 * Q\_BH\_D\_DV3\_G\_10\_E + 0.4E-02 * Q\_BH\_D\_DV3\_G\_10\_N + 0.15E-02 * Q\_BH\_D\_DV3\_G\_10\_S + 0.24E-02 * Q\_BH\_D\_DV3\_G\_11\_E + 0.47E-02 * Q\_BH\_D\_DV3\_G\_11\_N + 0.115E-02 * Q\_BH\_D\_DV3\_G\_11\_S + 0.97E-03 * Q\_BH\_D\_DV3\_G\_12\_E + 0.4E-02 * Q\_BH\_D\_DV3\_G\_12\_N + 0.268E-02 * Q\_BH\_D\_DV3\_G\_12\_S + 0.276E-02 * Q\_BH\_D\_DV3\_G\_13\_E + 0.46E-02 * Q\_BH\_D\_DV3\_G\_13\_N + 0.85E-03 * Q\_BH\_D\_DV3\_G\_13\_S + 0.34E-02 * Q\_BH\_D\_DV3\_G\_14\_E + 0.48E-02 * Q\_BH\_D\_DV3\_G\_14\_N + 0.16E-02 * Q\_BH\_D\_DV3\_G\_14\_S + 0.38E-02 * Q\_BH\_D\_DV3\_G\_15\_E + 0.49E-02 * Q\_BH\_D\_DV3\_G\_15\_N + 0.39E-02 * Q\_BH\_D\_DV3\_G\_15\_S + 0.3864E-02 * Q\_BH\_D\_DV3\_G\_16\_E + 0.5496E-02 * Q\_BH\_D\_DV3\_G\_16\_N + 0.504E-03 * Q\_BH\_D\_DV3\_G\_16\_S - BUTDN\_EMSN\_DV3 = 0;$
 $[\_632] 13.837 * Q\_BH\_D\_DV4\_G\_1\_E + 2.711 * Q\_BH\_D\_DV4\_G\_1\_N + 23.302 * Q\_BH\_D\_DV4\_G\_1\_S + 11.075 * Q\_BH\_D\_DV4\_G\_2\_E + 5.702 * Q\_BH\_D\_DV4\_G\_2\_N + 20.084 * Q\_BH\_D\_DV4\_G\_2\_S + 8.908 * Q\_BH\_D\_DV4\_G\_3\_E + 9.009 * Q\_BH\_D\_DV4\_G\_3\_N + 21.249 * Q\_BH\_D\_DV4\_G\_3\_S + 9.719 * Q\_BH\_D\_DV4\_G\_4\_E + 7.641 * Q\_BH\_D\_DV4\_G\_4\_N + 18.36 * Q\_BH\_D\_DV4\_G\_4\_S + 8.173 * Q\_BH\_D\_DV4\_G\_5\_E + 9.301 * Q\_BH\_D\_DV4\_G\_5\_N + 16.688 * Q\_BH\_D\_DV4\_G\_5\_S + 7.527 * Q\_BH\_D\_DV4\_G\_6\_E + 11.506 * Q\_BH\_D\_DV4\_G\_6\_N + 15.64 * Q\_BH\_D\_DV4\_G\_6\_S + 2.091 * Q\_BH\_D\_DV4\_G\_7\_E + 14.344 * Q\_BH\_D\_DV4\_G\_7\_N + 15.598 * Q\_BH\_D\_DV4\_G\_7\_S + 6.583 * Q\_BH\_D\_DV4\_G\_8\_E + 16.346 * Q\_BH\_D\_DV4\_G\_8\_N + 10.175 * Q\_BH\_D\_DV4\_G\_8\_S + 11.455 * Q\_BH\_D\_DV4\_G\_9\_E + 18.171 * Q\_BH\_D\_DV4\_G\_9\_N + 11.397 * Q\_BH\_D\_DV4\_G\_9\_S + 10.226 * Q\_BH\_D\_DV4\_G\_10\_E + 21.249 * Q\_BH\_D\_DV4\_G\_10\_N + 7.812 * Q\_BH\_D\_DV4\_G\_10\_S + 12.975 * Q\_BH\_D\_DV4\_G\_11\_E + 24.67 * Q\_BH\_D\_DV4\_G\_11\_N + 6.077 * Q\_BH\_D\_DV4\_G\_11\_S + 5.106 * Q\_BH\_D\_DV4\_G\_12\_E + 21.149 * Q\_BH\_D\_DV4\_G\_12\_N + 14.179 * Q\_BH\_D\_DV4\_G\_12\_S + 14.597 * Q\_BH\_D\_DV4\_G\_13\_E + 24.164 * Q\_BH\_D\_DV4\_G\_13\_N + 4.486 * Q\_BH\_D\_DV4\_G\_13\_S + 17.74 * Q\_BH\_D\_DV4\_G\_14\_E + 25.191 * Q\_BH\_D\_DV4\_G\_14\_N + 8.679 * Q\_BH\_D\_DV4\_G\_14\_S + 20.249 * Q\_BH\_D\_DV4\_G\_15\_E + 25.659 * Q\_BH\_D\_DV4\_G\_15\_N + 20.654 * Q\_BH\_D\_DV4\_G\_15\_S + 20.401 * Q\_BH\_D\_DV4\_G\_16\_E + 29.01757143 * Q\_BH\_D\_DV4\_G\_16\_N + 2.661 * Q\_BH\_D\_DV4\_G\_16\_S - CO\_EMSN\_DV4 = 0;$
 $[\_633] 5568.18 * Q\_BH\_D\_DV4\_G\_1\_E + 1091.2 * Q\_BH\_D\_DV4\_G\_1\_N + 9377.19 * Q\_BH\_D\_DV4\_G\_1\_S + 4456.59 * Q\_BH\_D\_DV4\_G\_2\_E + 2294.58 * Q\_BH\_D\_DV4\_G\_2\_N + 8082.03 * Q\_BH\_D\_DV4\_G\_2\_S + 3584.65 * Q\_BH\_D\_DV4\_G\_3\_E + 3625.44 * Q\_BH\_D\_DV4\_G\_3\_N + 8551.14 * Q\_BH\_D\_DV4\_G\_3\_S + 3910.98 * Q\_BH\_D\_DV4\_G\_4\_E + 3074.78 * Q\_BH\_D\_DV4\_G\_4\_N + 7388.55 * Q\_BH\_D\_DV4\_G\_4\_S + 3288.9 * Q\_BH\_D\_DV4\_G\_5\_E + 3742.72 * Q\_BH\_D\_DV4\_G\_5\_N + 6715.47 * Q\_BH\_D\_DV4\_G\_5\_S + 3028.85 * Q\_BH\_D\_DV4\_G\_6\_E + 4629.95 *$

Annexure 9

$Q_{BH\_D\_DV4\_G\_6\_N} + 6292.25 * Q_{BH\_D\_DV4\_G\_6\_S} + 841.35 * Q_{BH\_D\_DV4\_G\_7\_E} + 5772.15 * Q_{BH\_D\_DV4\_G\_7\_N}$
 $+ 6276.96 * Q_{BH\_D\_DV4\_G\_7\_S} + 2648.97 * Q_{BH\_D\_DV4\_G\_8\_E} + 6577.8 * Q_{BH\_D\_DV4\_G\_8\_N} + 4094.55 * Q_{BH\_D\_DV4\_G\_8\_S}$
 $+ 4609.56 * Q_{BH\_D\_DV4\_G\_9\_E} + 7312.07 * Q_{BH\_D\_DV4\_G\_9\_N} + 4586.1 * Q_{BH\_D\_DV4\_G\_9\_S}$
 $+ 4114.95 * Q_{BH\_D\_DV4\_G\_10\_E} + 8551.14 * Q_{BH\_D\_DV4\_G\_10\_N} + 3143.58 * Q_{BH\_D\_DV4\_G\_10\_S} + 5221.449 * Q_{BH\_D\_DV4\_G\_11\_E}$
 $+ 9927.89 * Q_{BH\_D\_DV4\_G\_11\_N} + 2445.51 * Q_{BH\_D\_DV4\_G\_11\_S} + 2054.93 * Q_{BH\_D\_DV4\_G\_12\_E}$
 $+ 8510.35 * Q_{BH\_D\_DV4\_G\_12\_N} + 5705.86 * Q_{BH\_D\_DV4\_G\_12\_S} + 5874.13 * Q_{BH\_D\_DV4\_G\_13\_E}$
 $+ 9723.93 * Q_{BH\_D\_DV4\_G\_13\_N} + 1805.07 * Q_{BH\_D\_DV4\_G\_13\_S} + 7138.69 * Q_{BH\_D\_DV4\_G\_14\_E}$
 $+ 10136.95 * Q_{BH\_D\_DV4\_G\_14\_N} + 3492.86 * Q_{BH\_D\_DV4\_G\_14\_S} + 8148.314 * Q_{BH\_D\_DV4\_G\_15\_E}$
 $+ 10325.62 * Q_{BH\_D\_DV4\_G\_15\_N} + 8311.485 * Q_{BH\_D\_DV4\_G\_15\_S} + 8209.50293 * Q_{BH\_D\_DV4\_G\_16\_E}$
 $+ 11676.87063 * Q_{BH\_D\_DV4\_G\_16\_N} + 1070.80473 * Q_{BH\_D\_DV4\_G\_16\_S} - CO2\_EMSN\_DV4 = 0;$
 $[\_634] 1.227 * Q_{BH\_D\_DV4\_G\_1\_E} + 0.24 * Q_{BH\_D\_DV4\_G\_1\_N} + 2.066 * Q_{BH\_D\_DV4\_G\_1\_S} + 0.982 * Q_{BH\_D\_DV4\_G\_2\_E}$
 $+ 0.505 * Q_{BH\_D\_DV4\_G\_2\_N} + 1.7804 * Q_{BH\_D\_DV4\_G\_2\_S} + 0.789 * Q_{BH\_D\_DV4\_G\_3\_E} + 0.798 * Q_{BH\_D\_DV4\_G\_3\_N}$
 $+ 1.884 * Q_{BH\_D\_DV4\_G\_3\_S} + 0.861 * Q_{BH\_D\_DV4\_G\_4\_E} + 0.677 * Q_{BH\_D\_DV4\_G\_4\_N} + 1.627 * Q_{BH\_D\_DV4\_G\_4\_S}$
 $+ 0.724 * Q_{BH\_D\_DV4\_G\_5\_E} + 0.824 * Q_{BH\_D\_DV4\_G\_5\_N} + 1.479 * Q_{BH\_D\_DV4\_G\_5\_S} + 0.667 * Q_{BH\_D\_DV4\_G\_6\_E}$
 $+ 1.019 * Q_{BH\_D\_DV4\_G\_6\_N} + 1.386 * Q_{BH\_D\_DV4\_G\_6\_S} + 0.185 * Q_{BH\_D\_DV4\_G\_7\_E}$
 $+ 1.271 * Q_{BH\_D\_DV4\_G\_7\_N} + 1.383 * Q_{BH\_D\_DV4\_G\_7\_S} + 0.583 * Q_{BH\_D\_DV4\_G\_8\_E} + 1.449 * Q_{BH\_D\_DV4\_G\_8\_N}$
 $+ 0.902 * Q_{BH\_D\_DV4\_G\_8\_S} + 1.015 * Q_{BH\_D\_DV4\_G\_9\_E} + 1.611 * Q_{BH\_D\_DV4\_G\_9\_N}$
 $+ 1.01 * Q_{BH\_D\_DV4\_G\_9\_S} + 0.906 * Q_{BH\_D\_DV4\_G\_10\_E} + 1.884 * Q_{BH\_D\_DV4\_G\_10\_N}$
 $+ 0.692 * Q_{BH\_D\_DV4\_G\_10\_S} + 1.15 * Q_{BH\_D\_DV4\_G\_11\_E} + 2.187 * Q_{BH\_D\_DV4\_G\_11\_N}$
 $+ 0.539 * Q_{BH\_D\_DV4\_G\_11\_S} + 0.453 * Q_{BH\_D\_DV4\_G\_12\_E} + 1.875 * Q_{BH\_D\_DV4\_G\_12\_N}$
 $+ 1.257 * Q_{BH\_D\_DV4\_G\_12\_S} + 1.294 * Q_{BH\_D\_DV4\_G\_13\_E} + 2.142 * Q_{BH\_D\_DV4\_G\_13\_N} + 0.397 * Q_{BH\_D\_DV4\_G\_13\_S}$
 $+ 1.573 * Q_{BH\_D\_DV4\_G\_14\_E} + 2.233 * Q_{BH\_D\_DV4\_G\_14\_N} + 0.769 * Q_{BH\_D\_DV4\_G\_14\_S} + 1.795 * Q_{BH\_D\_DV4\_G\_15\_E}$
 $+ 2.275 * Q_{BH\_D\_DV4\_G\_15\_N} + 1.831 * Q_{BH\_D\_DV4\_G\_15\_S} + 1.808493151 * Q_{BH\_D\_DV4\_G\_16\_E}$
 $+ 2.572328767 * Q_{BH\_D\_DV4\_G\_16\_N} + 0.235890411 * Q_{BH\_D\_DV4\_G\_16\_S} - SO2\_EMSN\_DV4 = 0;$
 $[\_635] 3.828 * Q_{BH\_D\_DV4\_G\_1\_E} + 0.75 * Q_{BH\_D\_DV4\_G\_1\_N} + 6.447 * Q_{BH\_D\_DV4\_G\_1\_S} + 3.064 * Q_{BH\_D\_DV4\_G\_2\_E}$
 $+ 1.577 * Q_{BH\_D\_DV4\_G\_2\_N} + 5.556 * Q_{BH\_D\_DV4\_G\_2\_S} + 2.464 * Q_{BH\_D\_DV4\_G\_3\_E} + 2.492 * Q_{BH\_D\_DV4\_G\_3\_N}$
 $+ 5.879 * Q_{BH\_D\_DV4\_G\_3\_S} + 2.689 * Q_{BH\_D\_DV4\_G\_4\_E} + 2.114 * Q_{BH\_D\_DV4\_G\_4\_N} + 5.079 * Q_{BH\_D\_DV4\_G\_4\_S}$
 $+ 2.261 * Q_{BH\_D\_DV4\_G\_5\_E} + 2.573 * Q_{BH\_D\_DV4\_G\_5\_N} + 4.617 * Q_{BH\_D\_DV4\_G\_5\_S} + 2.082 * Q_{BH\_D\_DV4\_G\_6\_E}$
 $+ 3.183 * Q_{BH\_D\_DV4\_G\_6\_N} + 4.326 * Q_{BH\_D\_DV4\_G\_6\_S} + 0.578 * Q_{BH\_D\_DV4\_G\_7\_E}$
 $+ 3.968 * Q_{BH\_D\_DV4\_G\_7\_N} + 4.315 * Q_{BH\_D\_DV4\_G\_7\_S} + 1.821 * Q_{BH\_D\_DV4\_G\_8\_E} + 4.522 * Q_{BH\_D\_DV4\_G\_8\_N}$
 $+ 2.815 * Q_{BH\_D\_DV4\_G\_8\_S} + 3.169 * Q_{BH\_D\_DV4\_G\_9\_E} + 5.027 * Q_{BH\_D\_DV4\_G\_9\_N}$
 $+ 3.153 * Q_{BH\_D\_DV4\_G\_9\_S} + 2.829 * Q_{BH\_D\_DV4\_G\_10\_E} + 5.879 * Q_{BH\_D\_DV4\_G\_10\_N}$
 $+ 2.161 * Q_{BH\_D\_DV4\_G\_10\_S} + 3.589 * Q_{BH\_D\_DV4\_G\_11\_E} + 6.826 * Q_{BH\_D\_DV4\_G\_11\_N}$
 $+ 1.681 * Q_{BH\_D\_DV4\_G\_11\_S} + 1.413 * Q_{BH\_D\_DV4\_G\_12\_E} + 5.851 * Q_{BH\_D\_DV4\_G\_12\_N}$
 $+ 3.923 * Q_{BH\_D\_DV4\_G\_12\_S} + 4.038 * Q_{BH\_D\_DV4\_G\_13\_E} + 6.685 * Q_{BH\_D\_DV4\_G\_13\_N} + 1.241 * Q_{BH\_D\_DV4\_G\_13\_S}$
 $+ 4.908 * Q_{BH\_D\_DV4\_G\_14\_E} + 6.969 * Q_{BH\_D\_DV4\_G\_14\_N} + 2.401 * Q_{BH\_D\_DV4\_G\_14\_S} + 5.602 * Q_{BH\_D\_DV4\_G\_15\_E}$
 $+ 7.099 * Q_{BH\_D\_DV4\_G\_15\_N} + 5.714 * Q_{BH\_D\_DV4\_G\_15\_S} + 5.6442 * Q_{BH\_D\_DV4\_G\_16\_E}$
 $+ 8.028085714 * Q_{BH\_D\_DV4\_G\_16\_N} + 0.7362 * Q_{BH\_D\_DV4\_G\_16\_S} - HC\_EMSN\_DV4 = 0;$
 $[\_636] 24.656 * Q_{BH\_D\_DV4\_G\_1\_E} + 4.832 * Q_{BH\_D\_DV4\_G\_1\_N} + 41.52 * Q_{BH\_D\_DV4\_G\_1\_S} + 19.734 * Q_{BH\_D\_DV4\_G\_2\_E}$
 $+ 10.16 * Q_{BH\_D\_DV4\_G\_2\_N} + 35.787 * Q_{BH\_D\_DV4\_G\_2\_S} + 15.873 * Q_{BH\_D\_DV4\_G\_3\_E} + 16.053 * Q_{BH\_D\_DV4\_G\_3\_N}$
 $+ 37.865 * Q_{BH\_D\_DV4\_G\_3\_S} + 17.318 * Q_{BH\_D\_DV4\_G\_4\_E} + 13.615 * Q_{BH\_D\_DV4\_G\_4\_N} + 32.717 * Q_{BH\_D\_DV4\_G\_4\_S}$
 $+ 14.563 * Q_{BH\_D\_DV4\_G\_5\_E} + 16.573 * Q_{BH\_D\_DV4\_G\_5\_N} + 29.736 * Q_{BH\_D\_DV4\_G\_5\_S} + 13.412 * Q_{BH\_D\_DV4\_G\_6\_E}$
 $+ 20.502 * Q_{BH\_D\_DV4\_G\_6\_N} + 27.862 * Q_{BH\_D\_DV4\_G\_6\_S} + 3.725 * Q_{BH\_D\_DV4\_G\_7\_E}$
 $+ 25.56 * Q_{BH\_D\_DV4\_G\_7\_N} + 27.794 * Q_{BH\_D\_DV4\_G\_7\_S} + 11.729 * Q_{BH\_D\_DV4\_G\_8\_E} + 29.127 * Q_{BH\_D\_DV4\_G\_8\_N}$
 $+ 18.131 * Q_{BH\_D\_DV4\_G\_8\_S} + 20.41 * Q_{BH\_D\_DV4\_G\_9\_E} + 32.378 * Q_{BH\_D\_DV4\_G\_9\_N}$
 $+ 20.307 * Q_{BH\_D\_DV4\_G\_9\_S} + 18.22 * Q_{BH\_D\_DV4\_G\_10\_E} + 37.865 * Q_{BH\_D\_DV4\_G\_10\_N}$
 $+ 13.92 * Q_{BH\_D\_DV4\_G\_10\_S} + 23.121 * Q_{BH\_D\_DV4\_G\_11\_E} + 43.961 * Q_{BH\_D\_DV4\_G\_11\_N}$
 $+ 10.829 * Q_{BH\_D\_DV4\_G\_11\_S} + 9.099 * Q_{BH\_D\_DV4\_G\_12\_E} + 37.684 * Q_{BH\_D\_DV4\_G\_12\_N}$
 $+ 25.266 * Q_{BH\_D\_DV4\_G\_12\_S} + 26.011 * Q_{BH\_D\_DV4\_G\_13\_E} + 43.058 * Q_{BH\_D\_DV4\_G\_13\_N}$
 $+ 7.993 * Q_{BH\_D\_DV4\_G\_13\_S} + 31.61 * Q_{BH\_D\_DV4\_G\_14\_E} + 44.887 * Q_{BH\_D\_DV4\_G\_14\_N} + 15.466 * Q_{BH\_D\_DV4\_G\_14\_S}$
 $+ 36.081 * Q_{BH\_D\_DV4\_G\_15\_E} + 45.72 * Q_{BH\_D\_DV4\_G\_15\_N} + 36.803 * Q_{BH\_D\_DV4\_G\_15\_S}$
 $+ 36.35196 * Q_{BH\_D\_DV4\_G\_16\_E} + 51.70558286 * Q_{BH\_D\_DV4\_G\_16\_N} + 4.74156 * Q_{BH\_D\_DV4\_G\_16\_S} - NOX\_EMSN\_DV4 = 0;$
 $[\_637] 2.465 * Q_{BH\_D\_DV4\_G\_1\_E} + 0.483 * Q_{BH\_D\_DV4\_G\_1\_N} + 4.151 * Q_{BH\_D\_DV4\_G\_1\_S} + 1.973 * Q_{BH\_D\_DV4\_G\_2\_E}$
 $+ 1.016 * Q_{BH\_D\_DV4\_G\_2\_N} + 3.577 * Q_{BH\_D\_DV4\_G\_2\_S} + 1.587 * Q_{BH\_D\_DV4\_G\_3\_E} + 1.605 * Q_{BH\_D\_DV4\_G\_3\_N}$
 $+ 3.785 * Q_{BH\_D\_DV4\_G\_3\_S} + 1.731 * Q_{BH\_D\_DV4\_G\_4\_E} + 1.361 * Q_{BH\_D\_DV4\_G\_4\_N} + 3.271 * Q_{BH\_D\_DV4\_G\_4\_S}$
 $+ 1.456 * Q_{BH\_D\_DV4\_G\_5\_E} + 1.657 * Q_{BH\_D\_DV4\_G\_5\_N} + 2.973 * Q_{BH\_D\_DV4\_G\_5\_S} + 1.341 * Q_{BH\_D\_DV4\_G\_6\_E}$
 $+ 2.049 * Q_{BH\_D\_DV4\_G\_6\_N} + 2.785 * Q_{BH\_D\_DV4\_G\_6\_S} + 0.372 * Q_{BH\_D\_DV4\_G\_7\_E}$
 $+ 2.555 * Q_{BH\_D\_DV4\_G\_7\_N} + 2.778 * Q_{BH\_D\_DV4\_G\_7\_S} + 1.172 * Q_{BH\_D\_DV4\_G\_8\_E} + 2.912 * Q_{BH\_D\_DV4\_G\_8\_N}$
 $+ 1.812 * Q_{BH\_D\_DV4\_G\_8\_S} + 2.04 * Q_{BH\_D\_DV4\_G\_9\_E} + 3.237 * Q_{BH\_D\_DV4\_G\_9\_N}$
 $+ 2.03 * Q_{BH\_D\_DV4\_G\_9\_S} + 1.821 * Q_{BH\_D\_DV4\_G\_10\_E} + 3.785 * Q_{BH\_D\_DV4\_G\_10\_N}$
 $+ 1.391 * Q_{BH\_D\_DV4\_G\_10\_S} + 2.311 * Q_{BH\_D\_DV4\_G\_11\_E} + 4.395 * Q_{BH\_D\_DV4\_G\_11\_N}$
 $+ 1.082 * Q_{BH\_D\_DV4\_G\_11\_S} + 0.9096 * Q_{BH\_D\_DV4\_G\_12\_E} + 3.767 * Q_{BH\_D\_DV4\_G\_12\_N}$
 $+ 2.526 * Q_{BH\_D\_DV4\_G\_12\_S} + 2.6 * Q_{BH\_D\_DV4\_G\_13\_E} + 4.304 * Q_{BH\_D\_DV4\_G\_13\_N} + 0.799 * Q_{BH\_D\_DV4\_G\_13\_S}$
 $+ 3.16 * Q_{BH\_D\_DV4\_G\_14\_E} + 4.487 * Q_{BH\_D\_DV4\_G\_14\_N} + 1.546 * Q_{BH\_D\_DV4\_G\_14\_S} + 3.607 * Q_{BH\_D\_DV4\_G\_15\_E}$
 $+ 4.571 * Q_{BH\_D\_DV4\_G\_15\_N} + 3.679 * Q_{BH\_D\_DV4\_G\_15\_S} + 3.634 * Q_{BH\_D\_DV4\_G\_16\_E}$
 $+ 5.168857143 * Q_{BH\_D\_DV4\_G\_16\_N} + 0.474 * Q_{BH\_D\_DV4\_G\_16\_S} - PM\_EMSN\_DV4 = 0;$
 $[\_638] 0.196E-01 * Q_{BH\_D\_DV4\_G\_1\_E} + 0.38E-02 * Q_{BH\_D\_DV4\_G\_1\_N} + 0.33E-01 * Q_{BH\_D\_DV4\_G\_1\_S} + 0.157E-01$
 $* Q_{BH\_D\_DV4\_G\_2\_E} + 0.81E-02 * Q_{BH\_D\_DV4\_G\_2\_N} + 0.28E-01 * Q_{BH\_D\_DV4\_G\_2\_S} + 0.126E-01 * Q_{BH\_D\_DV4\_G\_3\_E}$
 $+ 0.128E-01 * Q_{BH\_D\_DV4\_G\_3\_N} + 0.302E-01 * Q_{BH\_D\_DV4\_G\_3\_S} + 0.138E-01 * Q_{BH\_D\_DV4\_G\_4\_E}$
 $+ 0.11E-01 * Q_{BH\_D\_DV4\_G\_4\_N} + 0.26E-01 * Q_{BH\_D\_DV4\_G\_4\_S} + 0.116E-01 * Q_{BH\_D\_DV4\_G\_5\_E}$
 $+ 0.132E-01 * Q_{BH\_D\_DV4\_G\_5\_N} + 0.24E-01 * Q_{BH\_D\_DV4\_G\_5\_S} + 0.106E-01 * Q_{BH\_D\_DV4\_G\_6\_E}$
 $+ 0.163E-01 * Q_{BH\_D\_DV4\_G\_6\_N} + 0.22E-01 * Q_{BH\_D\_DV4\_G\_6\_S} + 0.297E-02 * Q_{BH\_D\_DV4\_G\_7\_E}$
 $+ 0.203E-01 * Q_{BH\_D\_DV4\_G\_7\_N} + 0.221E-01 * Q_{BH\_D\_DV4\_G\_7\_S} + 0.93E-02 * Q_{BH\_D\_DV4\_G\_8\_E}$
 $+ 0.23E-01 * Q_{BH\_D\_DV4\_G\_8\_N} + 0.14E-01 * Q_{BH\_D\_DV4\_G\_8\_S} + 0.163E-01 * Q_{BH\_D\_DV4\_G\_9\_E}$
 $+ 0.26E-01 * Q_{BH\_D\_DV4\_G\_9\_N} + 0.162E-01 * Q_{BH\_D\_DV4\_G\_9\_S} + 0.145E-01$

Annexure 9

$Q\_BH\_D\_HV\_G\_13\_E + 35.07 * Q\_BH\_D\_HV\_G\_13\_N + 6.51 * Q\_BH\_D\_HV\_G\_13\_S + 25.75 * Q\_BH\_D\_HV\_G\_14\_E + 36.56 * Q\_BH\_D\_HV\_G\_14\_N + 12.598 * Q\_BH\_D\_HV\_G\_14\_S + 29.39 * Q\_BH\_D\_HV\_G\_15\_E + 37.243 * Q\_BH\_D\_HV\_G\_15\_N + 29.978 * Q\_BH\_D\_HV\_G\_15\_S + 29.6102 * Q\_BH\_D\_HV\_G\_16\_E + 42.11637143 * Q\_BH\_D\_HV\_G\_16\_N + 3.8622 * Q\_BH\_D\_HV\_G\_16\_S - NOX\_EMSN\_HV\_G\_HV = 0;$
 $[\_644] 2.967 * Q\_BH\_D\_HV\_G\_1\_E + 0.581 * Q\_BH\_D\_HV\_G\_1\_N + 4.997 * Q\_BH\_D\_HV\_G\_1\_S + 2.375 * Q\_BH\_D\_HV\_G\_2\_E + 1.223 * Q\_BH\_D\_HV\_G\_2\_N + 4.307 * Q\_BH\_D\_HV\_G\_2\_S + 1.91 * Q\_BH\_D\_HV\_G\_3\_E + 1.932 * Q\_BH\_D\_HV\_G\_3\_N + 4.556 * Q\_BH\_D\_HV\_G\_3\_S + 2.084 * Q\_BH\_D\_HV\_G\_4\_E + 1.638 * Q\_BH\_D\_HV\_G\_4\_N + 3.937 * Q\_BH\_D\_HV\_G\_4\_S + 1.752 * Q\_BH\_D\_HV\_G\_5\_E + 1.994 * Q\_BH\_D\_HV\_G\_5\_N + 3.578 * Q\_BH\_D\_HV\_G\_5\_S + 1.614 * Q\_BH\_D\_HV\_G\_6\_E + 2.467 * Q\_BH\_D\_HV\_G\_6\_N + 3.353 * Q\_BH\_D\_HV\_G\_6\_S + 0.448 * Q\_BH\_D\_HV\_G\_7\_E + 3.076 * Q\_BH\_D\_HV\_G\_7\_N + 3.345 * Q\_BH\_D\_HV\_G\_7\_S + 1.411 * Q\_BH\_D\_HV\_G\_8\_E + 3.505 * Q\_BH\_D\_HV\_G\_8\_N + 2.182 * Q\_BH\_D\_HV\_G\_8\_S + 2.456 * Q\_BH\_D\_HV\_G\_9\_E + 3.896 * Q\_BH\_D\_HV\_G\_9\_N + 2.444 * Q\_BH\_D\_HV\_G\_9\_S + 2.193 * Q\_BH\_D\_HV\_G\_10\_E + 4.556 * Q\_BH\_D\_HV\_G\_10\_N + 1.675 * Q\_BH\_D\_HV\_G\_10\_S + 2.782 * Q\_BH\_D\_HV\_G\_11\_E + 5.29 * Q\_BH\_D\_HV\_G\_11\_N + 1.303 * Q\_BH\_D\_HV\_G\_11\_S + 1.095 * Q\_BH\_D\_HV\_G\_12\_E + 4.535 * Q\_BH\_D\_HV\_G\_12\_N + 3.04 * Q\_BH\_D\_HV\_G\_12\_S + 3.13 * Q\_BH\_D\_HV\_G\_13\_E + 5.181 * Q\_BH\_D\_HV\_G\_13\_N + 0.962 * Q\_BH\_D\_HV\_G\_13\_S + 3.804 * Q\_BH\_D\_HV\_G\_14\_E + 5.401 * Q\_BH\_D\_HV\_G\_14\_N + 1.861 * Q\_BH\_D\_HV\_G\_14\_S + 4.342 * Q\_BH\_D\_HV\_G\_15\_E + 5.502 * Q\_BH\_D\_HV\_G\_15\_N + 4.429 * Q\_BH\_D\_HV\_G\_15\_S + 4.3746 * Q\_BH\_D\_HV\_G\_16\_E + 6.22257143 * Q\_BH\_D\_HV\_G\_16\_N + 0.5706 * Q\_BH\_D\_HV\_G\_16\_S - HC\_EMSN\_HV\_G\_HV = 0;$
 $[\_645] 1.061 * Q\_BH\_D\_HV\_G\_1\_E + 0.208 * Q\_BH\_D\_HV\_G\_1\_N + 1.786 * Q\_BH\_D\_HV\_G\_1\_S + 0.849 * Q\_BH\_D\_HV\_G\_2\_E + 0.437 * Q\_BH\_D\_HV\_G\_2\_N + 1.539 * Q\_BH\_D\_HV\_G\_2\_S + 0.683 * Q\_BH\_D\_HV\_G\_3\_E + 0.691 * Q\_BH\_D\_HV\_G\_3\_N + 1.629 * Q\_BH\_D\_HV\_G\_3\_S + 0.745 * Q\_BH\_D\_HV\_G\_4\_E + 0.586 * Q\_BH\_D\_HV\_G\_4\_N + 1.408 * Q\_BH\_D\_HV\_G\_4\_S + 0.626 * Q\_BH\_D\_HV\_G\_5\_E + 0.713 * Q\_BH\_D\_HV\_G\_5\_N + 1.279 * Q\_BH\_D\_HV\_G\_5\_S + 0.577 * Q\_BH\_D\_HV\_G\_6\_E + 0.882 * Q\_BH\_D\_HV\_G\_6\_N + 1.198 * Q\_BH\_D\_HV\_G\_6\_S + 0.16 * Q\_BH\_D\_HV\_G\_7\_E + 1.099 * Q\_BH\_D\_HV\_G\_7\_N + 1.196 * Q\_BH\_D\_HV\_G\_7\_S + 0.505 * Q\_BH\_D\_HV\_G\_8\_E + 1.253 * Q\_BH\_D\_HV\_G\_8\_N + 0.78 * Q\_BH\_D\_HV\_G\_8\_S + 0.878 * Q\_BH\_D\_HV\_G\_9\_E + 1.393 * Q\_BH\_D\_HV\_G\_9\_N + 0.874 * Q\_BH\_D\_HV\_G\_9\_S + 0.784 * Q\_BH\_D\_HV\_G\_10\_E + 1.629 * Q\_BH\_D\_HV\_G\_10\_N + 0.599 * Q\_BH\_D\_HV\_G\_10\_S + 0.995 * Q\_BH\_D\_HV\_G\_11\_E + 1.891 * Q\_BH\_D\_HV\_G\_11\_N + 0.466 * Q\_BH\_D\_HV\_G\_11\_S + 0.391 * Q\_BH\_D\_HV\_G\_12\_E + 1.621 * Q\_BH\_D\_HV\_G\_12\_N + 1.087 * Q\_BH\_D\_HV\_G\_12\_S + 1.12 * Q\_BH\_D\_HV\_G\_13\_E + 1.852 * Q\_BH\_D\_HV\_G\_13\_N + 0.344 * Q\_BH\_D\_HV\_G\_13\_S + 1.36 * Q\_BH\_D\_HV\_G\_14\_E + 1.931 * Q\_BH\_D\_HV\_G\_14\_N + 0.665 * Q\_BH\_D\_HV\_G\_14\_S + 1.552 * Q\_BH\_D\_HV\_G\_15\_E + 1.967 * Q\_BH\_D\_HV\_G\_15\_N + 1.583 * Q\_BH\_D\_HV\_G\_15\_S + 1.564 * Q\_BH\_D\_HV\_G\_16\_E + 2.224571429 * Q\_BH\_D\_HV\_G\_16\_N + 0.204 * Q\_BH\_D\_HV\_G\_16\_S - PM\_EMSN\_HV\_G\_HV = 0;$
 $[\_646] 0.13E-01 * Q\_BH\_D\_HV\_G\_1\_E + 0.26E-02 * Q\_BH\_D\_HV\_G\_1\_N + 0.22E-01 * Q\_BH\_D\_HV\_G\_1\_S + 0.105E-01 * Q\_BH\_D\_HV\_G\_2\_E + 0.54E-02 * Q\_BH\_D\_HV\_G\_2\_N + 0.19E-01 * Q\_BH\_D\_HV\_G\_2\_S + 0.84E-02 * Q\_BH\_D\_HV\_G\_3\_E + 0.85E-02 * Q\_BH\_D\_HV\_G\_3\_N + 0.201E-01 * Q\_BH\_D\_HV\_G\_3\_S + 0.92E-02 * Q\_BH\_D\_HV\_G\_4\_E + 0.72E-02 * Q\_BH\_D\_HV\_G\_4\_N + 0.174E-01 * Q\_BH\_D\_HV\_G\_4\_S + 0.77E-02 * Q\_BH\_D\_HV\_G\_5\_E + 0.88E-02 * Q\_BH\_D\_HV\_G\_5\_N + 0.158E-01 * Q\_BH\_D\_HV\_G\_5\_S + 0.71E-02 * Q\_BH\_D\_HV\_G\_6\_E + 0.11E-01 * Q\_BH\_D\_HV\_G\_6\_N + 0.148E-01 * Q\_BH\_D\_HV\_G\_6\_S + 0.19E-02 * Q\_BH\_D\_HV\_G\_7\_E + 0.136E-01 * Q\_BH\_D\_HV\_G\_7\_N + 0.147E-01 * Q\_BH\_D\_HV\_G\_7\_S + 0.62E-02 * Q\_BH\_D\_HV\_G\_8\_E + 0.155E-01 * Q\_BH\_D\_HV\_G\_8\_N + 0.96E-02 * Q\_BH\_D\_HV\_G\_8\_S + 0.108E-01 * Q\_BH\_D\_HV\_G\_9\_E + 0.172E-01 * Q\_BH\_D\_HV\_G\_9\_N + 0.108E-01 * Q\_BH\_D\_HV\_G\_9\_S + 0.97E-02 * Q\_BH\_D\_HV\_G\_10\_E + 0.201E-01 * Q\_BH\_D\_HV\_G\_10\_N + 0.74E-02 * Q\_BH\_D\_HV\_G\_10\_S + 0.12E-01 * Q\_BH\_D\_HV\_G\_11\_E + 0.233E-01 * Q\_BH\_D\_HV\_G\_11\_N + 0.57E-02 * Q\_BH\_D\_HV\_G\_11\_S + 0.48E-02 * Q\_BH\_D\_HV\_G\_12\_E + 0.2E-01 * Q\_BH\_D\_HV\_G\_12\_N + 0.134E-01 * Q\_BH\_D\_HV\_G\_12\_S + 0.14E-01 * Q\_BH\_D\_HV\_G\_13\_E + 0.23E-01 * Q\_BH\_D\_HV\_G\_13\_N + 0.425E-02 * Q\_BH\_D\_HV\_G\_13\_S + 0.17E-01 * Q\_BH\_D\_HV\_G\_14\_E + 0.238E-01 * Q\_BH\_D\_HV\_G\_14\_N + 0.82E-02 * Q\_BH\_D\_HV\_G\_14\_S + 0.19E-01 * Q\_BH\_D\_HV\_G\_15\_E + 0.243E-01 * Q\_BH\_D\_HV\_G\_15\_N + 0.196E-01 * Q\_BH\_D\_HV\_G\_15\_S + 0.1932E-01 * Q\_BH\_D\_HV\_G\_16\_E + 0.2748E-01 * Q\_BH\_D\_HV\_G\_16\_N + 0.252E-02 * Q\_BH\_D\_HV\_G\_16\_S - BENZ\_EMSN\_HV\_G\_HV = 0;$
 $[\_647] 0.203E-02 * Q\_BH\_D\_HV\_G\_1\_E + 0.397E-03 * Q\_BH\_D\_HV\_G\_1\_N + 0.34E-02 * Q\_BH\_D\_HV\_G\_1\_S + 0.162E-02 * Q\_BH\_D\_HV\_G\_2\_E + 0.83E-03 * Q\_BH\_D\_HV\_G\_2\_N + 0.29E-02 * Q\_BH\_D\_HV\_G\_2\_S + 0.13E-02 * Q\_BH\_D\_HV\_G\_3\_E + 0.13E-02 * Q\_BH\_D\_HV\_G\_3\_N + 0.31E-02 * Q\_BH\_D\_HV\_G\_3\_S + 0.14E-02 * Q\_BH\_D\_HV\_G\_4\_E + 0.12E-02 * Q\_BH\_D\_HV\_G\_4\_N + 0.27E-02 * Q\_BH\_D\_HV\_G\_4\_S + 0.12E-02 * Q\_BH\_D\_HV\_G\_5\_E + 0.136E-02 * Q\_BH\_D\_HV\_G\_5\_N + 0.24E-02 * Q\_BH\_D\_HV\_G\_5\_S + 0.11E-02 * Q\_BH\_D\_HV\_G\_6\_E + 0.17E-02 * Q\_BH\_D\_HV\_G\_6\_N + 0.23E-02 * Q\_BH\_D\_HV\_G\_6\_S + 0.31E-03 * Q\_BH\_D\_HV\_G\_7\_E + 0.21E-02 * Q\_BH\_D\_HV\_G\_7\_N + 0.228E-02 * Q\_BH\_D\_HV\_G\_7\_S + 0.96E-03 * Q\_BH\_D\_HV\_G\_8\_E + 0.24E-02 * Q\_BH\_D\_HV\_G\_8\_N + 0.15E-02 * Q\_BH\_D\_HV\_G\_8\_S + 0.17E-02 * Q\_BH\_D\_HV\_G\_9\_E + 0.266E-02 * Q\_BH\_D\_HV\_G\_9\_N + 0.17E-02 * Q\_BH\_D\_HV\_G\_9\_S + 0.15E-02 * Q\_BH\_D\_HV\_G\_10\_E + 0.31E-02 * Q\_BH\_D\_HV\_G\_10\_N + 0.11E-02 * Q\_BH\_D\_HV\_G\_10\_S + 0.19E-02 * Q\_BH\_D\_HV\_G\_11\_E + 0.36E-02 * Q\_BH\_D\_HV\_G\_11\_N + 0.89E-03 * Q\_BH\_D\_HV\_G\_11\_S + 0.75E-03 * Q\_BH\_D\_HV\_G\_12\_E + 0.31E-02 * Q\_BH\_D\_HV\_G\_12\_N + 0.208E-02 * Q\_BH\_D\_HV\_G\_12\_S + 0.21E-02 * Q\_BH\_D\_HV\_G\_13\_E + 0.35E-02 * Q\_BH\_D\_HV\_G\_13\_N + 0.66E-03 * Q\_BH\_D\_HV\_G\_13\_S + 0.26E-02 * Q\_BH\_D\_HV\_G\_14\_E + 0.37E-02 * Q\_BH\_D\_HV\_G\_14\_N + 0.13E-02 * Q\_BH\_D\_HV\_G\_14\_S + 0.29E-02 * Q\_BH\_D\_HV\_G\_15\_E + 0.376E-02 * Q\_BH\_D\_HV\_G\_15\_N + 0.303E-02 * Q\_BH\_D\_HV\_G\_15\_S + 0.299E-02 * Q\_BH\_D\_HV\_G\_16\_E + 0.4252857143E-02 * Q\_BH\_D\_HV\_G\_16\_N + 0.39E-03 * Q\_BH\_D\_HV\_G\_16\_S - BUTDN\_EMSN\_HV\_G\_HV = 0;$
 $[\_648] 8.858888889 * Q\_BH\_D\_HV\_S\_1\_E + 1.736 * Q\_BH\_D\_HV\_S\_1\_N + 14.92011111 * Q\_BH\_D\_HV\_S\_1\_S + 7.091 * Q\_BH\_D\_HV\_S\_2\_E + 3.650888889 * Q\_BH\_D\_HV\_S\_2\_N + 12.85977778 * Q\_BH\_D\_HV\_S\_2\_S + 5.701111111 * Q\_BH\_D\_HV\_S\_3\_E + 5.768 * Q\_BH\_D\_HV\_S\_3\_N + 13.60333333 * Q\_BH\_D\_HV\_S\_3\_S + 6.222222222 * Q\_BH\_D\_HV\_S\_4\_E + 4.892222222 * Q\_BH\_D\_HV\_S\_4\_N + 11.75222222 * Q\_BH\_D\_HV\_S\_4\_S + 5.232888889 * Q\_BH\_D\_HV\_S\_5\_E + 5.955444444 * Q\_BH\_D\_HV\_S\_5\_N + 10.68511111 * Q\_BH\_D\_HV\_S\_5\_S + 4.819111111 * Q\_BH\_D\_HV\_S\_6\_E + 7.367111111 * Q\_BH\_D\_HV\_S\_6\_N + 10.01155556 * Q\_BH\_D\_HV\_S\_6\_S + 1.338555556 * Q\_BH\_D\_HV\_S\_7\_E + 9.184 * Q\_BH\_D\_HV\_S\_7\_N + 9.987444444 * Q\_BH\_D\_HV\_S\_7\_S + 4.214777778 * Q\_BH\_D\_HV\_S\_8\_E + 10.46577778 * Q\_BH\_D\_HV\_S\_8\_N + 6.514666667 * Q\_BH\_D\_HV\_S\_8\_S + 7.334444444 * Q\_BH\_D\_HV\_S\_9\_E + 11.63555556 * Q\_BH\_D\_HV\_S\_9\_N + 7.297111111 * Q\_BH\_D\_HV\_S\_9\_S + 6.547333333 * Q\_BH\_D\_HV\_S\_10\_E + 13.60333333 * Q\_BH\_D\_HV\_S\_10\_N + 5.001888889 * Q\_BH\_D\_HV\_S\_10\_S + 8.308222222 * Q\_BH\_D\_HV\_S\_11\_E + 15.79666667 * Q\_BH\_D\_HV\_S\_11\_N + 3.891222222 * Q\_BH\_D\_HV\_S\_11\_S + 3.269777778 * Q\_BH\_D\_HV\_S\_12\_E + 13.54111111 * Q\_BH\_D\_HV\_S\_12\_N + 9.079 * Q\_BH\_D\_HV\_S\_12\_S + 9.348888889 * Q\_BH\_D\_HV\_S\_13\_E + 15.47233333 * Q\_BH\_D\_HV\_S\_13\_N + 2.872333333 * Q\_BH\_D\_HV\_S\_13\_S + 11.35866667 * Q\_BH\_D\_HV\_S\_14\_E + 16.12877778 * Q\_BH\_D\_HV\_S\_14\_N + 5.557222222 * Q\_BH\_D\_HV\_S\_14\_S + 12.96555556 *$

$Q\_BH\_D\_HV\_S\_15\_E + 16.42977778 * Q\_BH\_D\_HV\_S\_15\_N + 13.22455556 * Q\_BH\_D\_HV\_S\_15\_S + 13.06246667 * Q\_BH\_D\_HV\_S\_16\_E + 18.57953333 * Q\_BH\_D\_HV\_S\_16\_N + 1.7038 * Q\_BH\_D\_HV\_S\_16\_S - CO\_EMSN\_HV\_S\_HV = 0;$
 $[\_649] 1678.794444 * Q\_BH\_D\_HV\_S\_1\_E + 328.9922222 * Q\_BH\_D\_HV\_S\_1\_N + 2827.191111 * Q\_BH\_D\_HV\_S\_1\_S + 1343.65 * Q\_BH\_D\_HV\_S\_2\_E + 691.81 * Q\_BH\_D\_HV\_S\_2\_N + 2436.707778 * Q\_BH\_D\_HV\_S\_2\_S + 1080.761111 * Q\_BH\_D\_HV\_S\_3\_E + 1093.057778 * Q\_BH\_D\_HV\_S\_3\_N + 2578.146667 * Q\_BH\_D\_HV\_S\_3\_S + 1179.15 * Q\_BH\_D\_HV\_S\_4\_E + 927.025556 * Q\_BH\_D\_HV\_S\_4\_N + 2227.625556 * Q\_BH\_D\_HV\_S\_4\_S + 991.596667 * Q\_BH\_D\_HV\_S\_5\_E + 1128.415556 * Q\_BH\_D\_HV\_S\_5\_N + 2024.695556 * Q\_BH\_D\_HV\_S\_5\_S + 913.181111 * Q\_BH\_D\_HV\_S\_6\_E + 1395.916667 * Q\_BH\_D\_HV\_S\_6\_N + 1897.093333 * Q\_BH\_D\_HV\_S\_6\_S + 253.664444 * Q\_BH\_D\_HV\_S\_7\_E + 1740.285556 * Q\_BH\_D\_HV\_S\_7\_N + 1892.481111 * Q\_BH\_D\_HV\_S\_7\_S + 798.653333 * Q\_BH\_D\_HV\_S\_8\_E + 1983.185556 * Q\_BH\_D\_HV\_S\_8\_N + 1234.496667 * Q\_BH\_D\_HV\_S\_8\_S + 1389.764444 * Q\_BH\_D\_HV\_S\_9\_E + 2204.564444 * Q\_BH\_D\_HV\_S\_9\_N + 1382.694444 * Q\_BH\_D\_HV\_S\_9\_S + 1240.641111 * Q\_BH\_D\_HV\_S\_10\_E + 2578.146667 * Q\_BH\_D\_HV\_S\_10\_N + 947.776667 * Q\_BH\_D\_HV\_S\_10\_S + 1574.253333 * Q\_BH\_D\_HV\_S\_11\_E + 2993.231111 * Q\_BH\_D\_HV\_S\_11\_N + 737.317778 * Q\_BH\_D\_HV\_S\_11\_S + 619.554444 * Q\_BH\_D\_HV\_S\_12\_E + 2565.842222 * Q\_BH\_D\_HV\_S\_12\_N + 1720.296667 * Q\_BH\_D\_HV\_S\_12\_S + 1771.031111 * Q\_BH\_D\_HV\_S\_13\_E + 2931.732222 * Q\_BH\_D\_HV\_S\_13\_N + 544.218889 * Q\_BH\_D\_HV\_S\_13\_S + 2152.297778 * Q\_BH\_D\_HV\_S\_14\_E + 3056.262222 * Q\_BH\_D\_HV\_S\_14\_N + 1053.087778 * Q\_BH\_D\_HV\_S\_14\_S + 2456.688889 * Q\_BH\_D\_HV\_S\_15\_E + 3113.141111 * Q\_BH\_D\_HV\_S\_15\_N + 2505.883333 * Q\_BH\_D\_HV\_S\_15\_S + 2475.14023 * Q\_BH\_D\_HV\_S\_16\_E + 3520.541072 * Q\_BH\_D\_HV\_S\_16\_N + 322.8443778 * Q\_BH\_D\_HV\_S\_16\_S - CO2\_EMSN\_HV\_S\_HV = 0;$
 $[\_650] 0.3713888889 * Q\_BH\_D\_HV\_S\_1\_E + 0.7233333333E-01 * Q\_BH\_D\_HV\_S\_1\_N + 0.6253333333 * Q\_BH\_D\_HV\_S\_1\_S + 0.2971111111 * Q\_BH\_D\_HV\_S\_2\_E + 0.1532222222 * Q\_BH\_D\_HV\_S\_2\_N + 0.539 * Q\_BH\_D\_HV\_S\_2\_S + 0.2387777778 * Q\_BH\_D\_HV\_S\_3\_E + 0.2418888889 * Q\_BH\_D\_HV\_S\_3\_N + 0.5701111111 * Q\_BH\_D\_HV\_S\_3\_S + 0.2605555556 * Q\_BH\_D\_HV\_S\_4\_E + 0.2053333333 * Q\_BH\_D\_HV\_S\_4\_N + 0.4931111111 * Q\_BH\_D\_HV\_S\_4\_S + 0.2193333333 * Q\_BH\_D\_HV\_S\_5\_E + 0.2496666667 * Q\_BH\_D\_HV\_S\_5\_N + 0.448 * Q\_BH\_D\_HV\_S\_5\_S + 0.2014444444 * Q\_BH\_D\_HV\_S\_6\_E + 0.3087777778 * Q\_BH\_D\_HV\_S\_6\_N + 0.4192222222 * Q\_BH\_D\_HV\_S\_6\_S + 0.56E-01 * Q\_BH\_D\_HV\_S\_7\_E + 0.385 * Q\_BH\_D\_HV\_S\_7\_N + 0.4184444444 * Q\_BH\_D\_HV\_S\_7\_S + 0.1765555556 * Q\_BH\_D\_HV\_S\_8\_E + 0.4386666667 * Q\_BH\_D\_HV\_S\_8\_N + 0.273 * Q\_BH\_D\_HV\_S\_8\_S + 0.3072222222 * Q\_BH\_D\_HV\_S\_9\_E + 0.4876666667 * Q\_BH\_D\_HV\_S\_9\_N + 0.3056666667 * Q\_BH\_D\_HV\_S\_9\_S + 0.2745555556 * Q\_BH\_D\_HV\_S\_10\_E + 0.5701111111 * Q\_BH\_D\_HV\_S\_10\_N + 0.2092222222 * Q\_BH\_D\_HV\_S\_10\_S + 0.3484444444 * Q\_BH\_D\_HV\_S\_11\_E + 0.6618888889 * Q\_BH\_D\_HV\_S\_11\_N + 0.1625555556 * Q\_BH\_D\_HV\_S\_11\_S + 0.1368888889 * Q\_BH\_D\_HV\_S\_12\_E + 0.567 * Q\_BH\_D\_HV\_S\_12\_N + 0.3803333333 * Q\_BH\_D\_HV\_S\_12\_S + 0.392 * Q\_BH\_D\_HV\_S\_13\_E + 0.6486666667 * Q\_BH\_D\_HV\_S\_13\_N + 0.1205555556 * Q\_BH\_D\_HV\_S\_13\_S + 0.476 * Q\_BH\_D\_HV\_S\_14\_E + 0.6758888889 * Q\_BH\_D\_HV\_S\_14\_N + 0.2325555556 * Q\_BH\_D\_HV\_S\_14\_S + 0.5436666667 * Q\_BH\_D\_HV\_S\_15\_E + 0.6891111111 * Q\_BH\_D\_HV\_S\_15\_N + 0.5545555556 * Q\_BH\_D\_HV\_S\_15\_S + 0.5476385185 * Q\_BH\_D\_HV\_S\_16\_E + 0.7789392593 * Q\_BH\_D\_HV\_S\_16\_N + 0.7143111111E-01 * Q\_BH\_D\_HV\_S\_16\_S - SO2\_EMSN\_HV\_S\_HV = 0;$
 $[\_651] 15.61777778 * Q\_BH\_D\_HV\_S\_1\_E + 3.061333333 * Q\_BH\_D\_HV\_S\_1\_N + 26.30444444 * Q\_BH\_D\_HV\_S\_1\_S + 12.502 * Q\_BH\_D\_HV\_S\_2\_E + 6.436888889 * Q\_BH\_D\_HV\_S\_2\_N + 22.67222222 * Q\_BH\_D\_HV\_S\_2\_S + 10.05588889 * Q\_BH\_D\_HV\_S\_3\_E + 10.17022222 * Q\_BH\_D\_HV\_S\_3\_N + 23.98822222 * Q\_BH\_D\_HV\_S\_3\_S + 10.97133333 * Q\_BH\_D\_HV\_S\_4\_E + 8.62555556 * Q\_BH\_D\_HV\_S\_4\_N + 20.727 * Q\_BH\_D\_HV\_S\_4\_S + 9.226 * Q\_BH\_D\_HV\_S\_5\_E + 10.49922222 * Q\_BH\_D\_HV\_S\_5\_N + 18.83777778 * Q\_BH\_D\_HV\_S\_5\_S + 8.496444444 * Q\_BH\_D\_HV\_S\_6\_E + 12.98111111 * Q\_BH\_D\_HV\_S\_6\_N + 17.65166667 * Q\_BH\_D\_HV\_S\_6\_S + 2.359777778 * Q\_BH\_D\_HV\_S\_7\_E + 16.19333333 * Q\_BH\_D\_HV\_S\_7\_N + 17.60888889 * Q\_BH\_D\_HV\_S\_7\_S + 7.430888889 * Q\_BH\_D\_HV\_S\_8\_E + 18.45277778 * Q\_BH\_D\_HV\_S\_8\_N + 11.48622222 * Q\_BH\_D\_HV\_S\_8\_S + 12.92666667 * Q\_BH\_D\_HV\_S\_9\_E + 20.51233333 * Q\_BH\_D\_HV\_S\_9\_N + 12.86522222 * Q\_BH\_D\_HV\_S\_9\_S + 11.54377778 * Q\_BH\_D\_HV\_S\_10\_E + 23.98822222 * Q\_BH\_D\_HV\_S\_10\_N + 8.818444444 * Q\_BH\_D\_HV\_S\_10\_S + 14.64555556 * Q\_BH\_D\_HV\_S\_11\_E + 27.85066667 * Q\_BH\_D\_HV\_S\_11\_N + 6.86 * Q\_BH\_D\_HV\_S\_11\_S + 5.764888889 * Q\_BH\_D\_HV\_S\_12\_E + 23.87388889 * Q\_BH\_D\_HV\_S\_12\_N + 16.00666667 * Q\_BH\_D\_HV\_S\_12\_S + 16.47877778 * Q\_BH\_D\_HV\_S\_13\_E + 27.27666667 * Q\_BH\_D\_HV\_S\_13\_N + 5.063333333 * Q\_BH\_D\_HV\_S\_13\_S + 20.02777778 * Q\_BH\_D\_HV\_S\_14\_E + 28.43555556 * Q\_BH\_D\_HV\_S\_14\_N + 9.798444444 * Q\_BH\_D\_HV\_S\_14\_S + 22.85888889 * Q\_BH\_D\_HV\_S\_15\_E + 28.96677778 * Q\_BH\_D\_HV\_S\_15\_N + 23.31622222 * Q\_BH\_D\_HV\_S\_15\_S + 23.03015556 * Q\_BH\_D\_HV\_S\_16\_E + 32.75717778 * Q\_BH\_D\_HV\_S\_16\_N + 3.003933333 * Q\_BH\_D\_HV\_S\_16\_S - NOX\_EMSN\_HV\_S\_HV = 0;$
 $[\_652] 2.307666667 * Q\_BH\_D\_HV\_S\_1\_E + 0.4518888889 * Q\_BH\_D\_HV\_S\_1\_N + 3.886555556 * Q\_BH\_D\_HV\_S\_1\_S + 1.847222222 * Q\_BH\_D\_HV\_S\_2\_E + 0.9512222222 * Q\_BH\_D\_HV\_S\_2\_N + 3.349888889 * Q\_BH\_D\_HV\_S\_2\_S + 1.485555556 * Q\_BH\_D\_HV\_S\_3\_E + 1.502666667 * Q\_BH\_D\_HV\_S\_3\_N + 3.543555556 * Q\_BH\_D\_HV\_S\_3\_S + 1.620888889 * Q\_BH\_D\_HV\_S\_4\_E + 1.274 * Q\_BH\_D\_HV\_S\_4\_N + 3.062111111 * Q\_BH\_D\_HV\_S\_4\_S + 1.362666667 * Q\_BH\_D\_HV\_S\_5\_E + 1.550888889 * Q\_BH\_D\_HV\_S\_5\_N + 2.782888889 * Q\_BH\_D\_HV\_S\_5\_S + 1.255333333 * Q\_BH\_D\_HV\_S\_6\_E + 1.918777778 * Q\_BH\_D\_HV\_S\_6\_N + 2.607888889 * Q\_BH\_D\_HV\_S\_6\_S + 0.3484444444 * Q\_BH\_D\_HV\_S\_7\_E + 2.392444444 * Q\_BH\_D\_HV\_S\_7\_N + 2.601666667 * Q\_BH\_D\_HV\_S\_7\_S + 1.097444444 * Q\_BH\_D\_HV\_S\_8\_E + 2.726111111 * Q\_BH\_D\_HV\_S\_8\_N + 1.697111111 * Q\_BH\_D\_HV\_S\_8\_S + 1.910222222 * Q\_BH\_D\_HV\_S\_9\_E + 3.030222222 * Q\_BH\_D\_HV\_S\_9\_N + 1.900888889 * Q\_BH\_D\_HV\_S\_9\_S + 1.705666667 * Q\_BH\_D\_HV\_S\_10\_E + 3.543555556 * Q\_BH\_D\_HV\_S\_10\_N + 1.302777778 * Q\_BH\_D\_HV\_S\_10\_S + 2.163777778 * Q\_BH\_D\_HV\_S\_11\_E + 4.114444444 * Q\_BH\_D\_HV\_S\_11\_N + 1.013444444 * Q\_BH\_D\_HV\_S\_11\_S + 0.8516666667 * Q\_BH\_D\_HV\_S\_12\_E + 3.527222222 * Q\_BH\_D\_HV\_S\_12\_N + 2.364444444 * Q\_BH\_D\_HV\_S\_12\_S + 2.434444444 * Q\_BH\_D\_HV\_S\_13\_E + 4.029666667 * Q\_BH\_D\_HV\_S\_13\_N + 0.7482222222 * Q\_BH\_D\_HV\_S\_13\_S + 2.958666667 * Q\_BH\_D\_HV\_S\_14\_E + 4.200777778 * Q\_BH\_D\_HV\_S\_14\_N + 1.447444444 * Q\_BH\_D\_HV\_S\_14\_S + 3.377111111 * Q\_BH\_D\_HV\_S\_15\_E + 4.279333333 * Q\_BH\_D\_HV\_S\_15\_N + 3.444777778 * Q\_BH\_D\_HV\_S\_15\_S + 3.402466667 * Q\_BH\_D\_HV\_S\_16\_E + 4.839533333 * Q\_BH\_D\_HV\_S\_16\_N + 0.4438 * Q\_BH\_D\_HV\_S\_16\_S - HC\_EMSN\_HV\_S\_HV = 0;$
 $[\_653] 0.8252222222 * Q\_BH\_D\_HV\_S\_1\_E + 0.1617777778 * Q\_BH\_D\_HV\_S\_1\_N + 1.389111111 * Q\_BH\_D\_HV\_S\_1\_S + 0.6603333333 * Q\_BH\_D\_HV\_S\_2\_E + 0.3398888889 * Q\_BH\_D\_HV\_S\_2\_N + 1.197 * Q\_BH\_D\_HV\_S\_2\_S + 0.5312222222 * Q\_BH\_D\_HV\_S\_3\_E + 0.5374444444 * Q\_BH\_D\_HV\_S\_3\_N + 1.267 * Q\_BH\_D\_HV\_S\_3\_S + 0.5794444444 * Q\_BH\_D\_HV\_S\_4\_E + 0.4557777778 * Q\_BH\_D\_HV\_S\_4\_N + 1.095111111 * Q\_BH\_D\_HV\_S\_4\_S + 0.4868888889 * Q\_BH\_D\_HV\_S\_5\_E + 0.5545555556 * Q\_BH\_D\_HV\_S\_5\_N + 0.9947777778 * Q\_BH\_D\_HV\_S\_5\_S + 0.4487777778 * Q\_BH\_D\_HV\_S\_6\_E + 0.686 * Q\_BH\_D\_HV\_S\_6\_N + 0.9317777778 * Q\_BH\_D\_HV\_S\_6\_S + 0.1244444444 * Q\_BH\_D\_HV\_S\_7\_E + 0.8547777778 * Q\_BH\_D\_HV\_S\_7\_N + 0.9302222222 * Q\_BH\_D\_HV\_S\_7\_S + 0.3927777778 * Q\_BH\_D\_HV\_S\_8\_E + 0.9745555556 * Q\_BH\_D\_HV\_S\_8\_N + 0.6066666667 * Q\_BH\_D\_HV\_S\_8\_S + 0.6828888889 * Q\_BH\_D\_HV\_S\_9\_E + 1.083444444 * Q\_BH\_D\_HV\_S\_9\_N + 0.6797777778 * Q\_BH\_D\_HV\_S\_9\_S + 0.6097777778 * Q\_BH\_D\_HV\_S\_10\_E + 1.267 * Q\_BH\_D\_HV\_S\_10\_N + 0.4658888889 * Q\_BH\_D\_HV\_S\_10\_S + 0.7738888889 *$

Annexure 9

Q_BH_D_HV_S_11_E + 1.470777778 * Q_BH_D_HV_S_11_N + 0.3624444444 * Q_BH_D_HV_S_11_S + 0.3041111111 *
Q_BH_D_HV_S_12_E + 1.260777778 * Q_BH_D_HV_S_12_N + 0.8454444444 * Q_BH_D_HV_S_12_S + 0.8711111111 *
Q_BH_D_HV_S_13_E + 1.440444444 * Q_BH_D_HV_S_13_N + 0.2675555556 * Q_BH_D_HV_S_13_S + 1.057777778 *
Q_BH_D_HV_S_14_E + 1.501888889 * Q_BH_D_HV_S_14_N + 0.5172222222 * Q_BH_D_HV_S_14_S + 1.2071111111 *
Q_BH_D_HV_S_15_E + 1.529888889 * Q_BH_D_HV_S_15_N + 1.231222222 * Q_BH_D_HV_S_15_S + 1.216444444 *
Q_BH_D_HV_S_16_E + 1.730222222 * Q_BH_D_HV_S_16_N + 0.1586666667 * Q_BH_D_HV_S_16_S -
PM_EMSN_HV_S_HV = 0;
[_654] 0.101111111E-01 * Q_BH_D_HV_S_1_E + 0.202222222E-02 * Q_BH_D_HV_S_1_N + 0.171111111E-01 *
Q_BH_D_HV_S_1_S + 0.816666667E-02 * Q_BH_D_HV_S_2_E + 0.42E-02 * Q_BH_D_HV_S_2_N + 0.147777778E-01 *
Q_BH_D_HV_S_2_S + 0.653333333E-02 * Q_BH_D_HV_S_3_E + 0.661111111E-02 * Q_BH_D_HV_S_3_N + 0.156333333E-
01 * Q_BH_D_HV_S_3_S + 0.715555556E-02 * Q_BH_D_HV_S_4_E + 0.56E-02 * Q_BH_D_HV_S_4_N + 0.135333333E-01 *
Q_BH_D_HV_S_4_S + 0.598888889E-02 * Q_BH_D_HV_S_5_E + 0.684444444E-02 * Q_BH_D_HV_S_5_N + 0.122888889E-
01 * Q_BH_D_HV_S_5_S + 0.552222222E-02 * Q_BH_D_HV_S_6_E + 0.855555556E-02 * Q_BH_D_HV_S_6_N +
0.115111111E-01 * Q_BH_D_HV_S_6_S + 0.147777778E-02 * Q_BH_D_HV_S_7_E + 0.105777778E-01 *
Q_BH_D_HV_S_7_N + 0.114333333E-01 * Q_BH_D_HV_S_7_S + 0.482222222E-02 * Q_BH_D_HV_S_8_E + 0.120555556E-
01 * Q_BH_D_HV_S_8_N + 0.746666667E-02 * Q_BH_D_HV_S_8_S + 0.84E-02 * Q_BH_D_HV_S_9_E + 0.133777778E-01 *
Q_BH_D_HV_S_9_N + 0.84E-02 * Q_BH_D_HV_S_9_S + 0.754444444E-02 * Q_BH_D_HV_S_10_E + 0.156333333E-01 *
Q_BH_D_HV_S_10_N + 0.575555556E-02 * Q_BH_D_HV_S_10_S + 0.933333333E-02 * Q_BH_D_HV_S_11_E +
0.181222222E-01 * Q_BH_D_HV_S_11_N + 0.443333333E-02 * Q_BH_D_HV_S_11_S + 0.373333333E-02 *
Q_BH_D_HV_S_12_E + 0.155555556E-01 * Q_BH_D_HV_S_12_N + 0.104222222E-01 * Q_BH_D_HV_S_12_S +
0.108888889E-01 * Q_BH_D_HV_S_13_E + 0.178888889E-01 * Q_BH_D_HV_S_13_N + 0.330555556E-02 *
Q_BH_D_HV_S_13_S + 0.132222222E-01 * Q_BH_D_HV_S_14_E + 0.185111111E-01 * Q_BH_D_HV_S_14_N +
0.637777778E-02 * Q_BH_D_HV_S_14_S + 0.147777778E-01 * Q_BH_D_HV_S_15_E + 0.189E-01 * Q_BH_D_HV_S_15_N +
0.152444444E-01 * Q_BH_D_HV_S_15_S + 0.150266667E-01 * Q_BH_D_HV_S_16_E + 0.213733333E-01 *
Q_BH_D_HV_S_16_N + 0.196E-02 * Q_BH_D_HV_S_16_S - BENZ_EMSN_HV_S_HV = 0;
[_655] 0.157888889E-02 * Q_BH_D_HV_S_1_E + 0.308777778E-03 * Q_BH_D_HV_S_1_N + 0.264444444E-02 *
Q_BH_D_HV_S_1_S + 0.126E-02 * Q_BH_D_HV_S_2_E + 0.645555556E-03 * Q_BH_D_HV_S_2_N + 0.225555556E-02 *
Q_BH_D_HV_S_2_S + 0.101111111E-02 * Q_BH_D_HV_S_3_E + 0.101111111E-02 * Q_BH_D_HV_S_3_N + 0.241111111E-
02 * Q_BH_D_HV_S_3_S + 0.108888889E-02 * Q_BH_D_HV_S_4_E + 0.933333333E-03 * Q_BH_D_HV_S_4_N + 0.21E-02 *
Q_BH_D_HV_S_4_S + 0.933333333E-03 * Q_BH_D_HV_S_5_E + 0.105777778E-02 * Q_BH_D_HV_S_5_N + 0.186666667E-
02 * Q_BH_D_HV_S_5_S + 0.855555556E-03 * Q_BH_D_HV_S_6_E + 0.132222222E-02 * Q_BH_D_HV_S_6_N +
0.178888889E-02 * Q_BH_D_HV_S_6_S + 0.241111111E-03 * Q_BH_D_HV_S_7_E + 0.163333333E-02 *
Q_BH_D_HV_S_7_N + 0.177333333E-02 * Q_BH_D_HV_S_7_S + 0.746666667E-03 * Q_BH_D_HV_S_8_E + 0.186666667E-
02 * Q_BH_D_HV_S_8_N + 0.116666667E-02 * Q_BH_D_HV_S_8_S + 0.132222222E-02 * Q_BH_D_HV_S_9_E +
0.206888889E-02 * Q_BH_D_HV_S_9_N + 0.132222222E-02 * Q_BH_D_HV_S_9_S + 0.116666667E-02 *
Q_BH_D_HV_S_10_E + 0.241111111E-02 * Q_BH_D_HV_S_10_N + 0.855555556E-03 * Q_BH_D_HV_S_10_S +
0.147777778E-02 * Q_BH_D_HV_S_11_E + 0.28E-02 * Q_BH_D_HV_S_11_N + 0.692222222E-03 * Q_BH_D_HV_S_11_S +
0.583333333E-03 * Q_BH_D_HV_S_12_E + 0.241111111E-02 * Q_BH_D_HV_S_12_N + 0.161777778E-02 *
Q_BH_D_HV_S_12_S + 0.163333333E-02 * Q_BH_D_HV_S_13_E + 0.272222222E-02 * Q_BH_D_HV_S_13_N +
0.513333333E-03 * Q_BH_D_HV_S_13_S + 0.202222222E-02 * Q_BH_D_HV_S_14_E + 0.287777778E-02 *
Q_BH_D_HV_S_14_N + 0.101111111E-02 * Q_BH_D_HV_S_14_S + 0.225555556E-02 * Q_BH_D_HV_S_15_E +
0.292444444E-02 * Q_BH_D_HV_S_15_N + 0.235666667E-02 * Q_BH_D_HV_S_15_S + 0.232555556E-02 *
Q_BH_D_HV_S_16_E + 0.330777778E-02 * Q_BH_D_HV_S_16_N + 0.303333333E-03 * Q_BH_D_HV_S_16_S -
BUTDN_EMSN_HV_S_HV = 0;
[_656] TOTAL_CO_EMISSION_DV - CO_EMSN_DV1 - CO_EMSN_DV2 - CO_EMSN_DV3 - CO_EMSN_DV4 = 0;
[_657] TOTAL_CO2_EMISSION_DV - CO2_EMSN_DV1 - CO2_EMSN_DV2 - CO2_EMSN_DV3 - CO2_EMSN_DV4 = 0;
[_658] TOTAL_SO2_EMISSION_DV - SO2_EMSN_DV1 - SO2_EMSN_DV2 - SO2_EMSN_DV3 - SO2_EMSN_DV4 = 0;
[_659] TOTAL_HC_EMISSION_DV - HC_EMSN_DV1 - HC_EMSN_DV2 - HC_EMSN_DV3 - HC_EMSN_DV4 = 0;
[_660] TOTAL_NOX_EMISSION_DV - NOX_EMSN_DV1 - NOX_EMSN_DV2 - NOX_EMSN_DV3 - NOX_EMSN_DV4 =
0;
[_661] TOTAL_PM_EMISSION_DV - PM_EMSN_DV1 - PM_EMSN_DV2 - PM_EMSN_DV3 - PM_EMSN_DV4 = 0;
[_662] TOTAL_BENZ_EMISSION_DV - BENZ_EMSN_DV1 - BENZ_EMSN_DV2 - BENZ_EMSN_DV3 -
BENZ_EMSN_DV4 = 0;
[_663] TOTAL_BUTDN_EMISSION_DV - BUTDN_EMSN_DV1 - BUTDN_EMSN_DV2 - BUTDN_EMSN_DV3 -
BUTDN_EMSN_DV4 = 0;
[_664] - TOTAL_CO_EMISSION_HV + CO_EMSN_HV_G_HV + CO_EMSN_HV_S_HV = 0;
[_665] - TOTAL_CO2_EMISSION_HV + CO2_EMSN_HV_G_HV + CO2_EMSN_HV_S_HV = 0;
[_666] - TOTAL_SO2_EMISSION_HV + SO2_EMSN_HV_G_HV + SO2_EMSN_HV_S_HV = 0;
[_667] - TOTAL_NOX_EMISSION_HV + NOX_EMSN_HV_G_HV + NOX_EMSN_HV_S_HV = 0;
[_668] - TOTAL_HC_EMISSION_HV + HC_EMSN_HV_G_HV + HC_EMSN_HV_S_HV = 0;
[_669] - TOTAL_PM_EMISSION_HV + PM_EMSN_HV_G_HV + PM_EMSN_HV_S_HV = 0;
[_670] - TOTAL_BENZ_EMISSION_HV + BENZ_EMSN_HV_G_HV + BENZ_EMSN_HV_S_HV = 0;
[_671] - TOTAL_BUTDN_EMISSION_HV + BUTDN_EMSN_HV_G_HV + BUTDN_EMSN_HV_S_HV = 0;
[_672] 2.936 * XF_E - CO_EMSN_TRUCK_E = 0;
[_673] 4.843 * XF_N - CO_EMSN_TRUCK_N = 0;
[_674] 1.962 * XF_S - CO_EMSN_TRUCK_S = 0;
[_675] 541.52 * XF_E - CO2_EMSN_TRUCK_E = 0;
[_676] 893.23 * XF_N - CO2_EMSN_TRUCK_N = 0;
[_677] 361.87 * XF_S - CO2_EMSN_TRUCK_S = 0;
[_678] 0.12 * XF_E - SO2_EMSN_TRUCK_E = 0;
[_679] 0.1977 * XF_N - SO2_EMSN_TRUCK_N = 0;
[_680] 0.8E-01 * XF_S - SO2_EMSN_TRUCK_S = 0;
[_681] 2.571 * XF_E - NOX_EMSN_TRUCK_E = 0;
[_682] 4.24 * XF_N - NOX_EMSN_TRUCK_N = 0;
[_683] 1.72 * XF_S - NOX_EMSN_TRUCK_S = 0;
[_684] 0.4045 * XF_E - HC_EMSN_TRUCK_E = 0;
[_685] 0.67 * XF_N - HC_EMSN_TRUCK_N = 0;
[_686] 0.27 * XF_S - HC_EMSN_TRUCK_S = 0;

[_687] 0.26E-01 * XF_E - PM_EMSN_TRUCK_E = 0;
 [_688] 0.43E-01 * XF_N - PM_EMSN_TRUCK_N = 0;
 [_689] 0.17E-01 * XF_S - PM_EMSN_TRUCK_S = 0;
 [_690] 0.25E-02 * XF_E - BENZ_EMSN_TRUCK_E = 0;
 [_691] 0.41E-02 * XF_N - BENZ_EMSN_TRUCK_N = 0;
 [_692] 0.16E-02 * XF_S - BENZ_EMSN_TRUCK_S = 0;
 [_693] 0.2E-03 * XF_E - BUTDN_EMSN_TRUCK_E = 0;
 [_694] 0.32E-03 * XF_N - BUTDN_EMSN_TRUCK_N = 0;
 [_695] 0.13E-03 * XF_S - BUTDN_EMSN_TRUCK_S = 0;
 [_696] - TOTAL_CO_EMSN_LPT_TRUCK + 2.936 * XF_E + 4.843 * XF_N + 1.962 * XF_S = 0;
 [_697] - TOTAL_CO2_EMSN_LPT_TRUCK + 541.52 * XF_E + 893.23 * XF_N + 361.87 * XF_S = 0;
 [_698] - TOTAL_SO2_EMSN_LPT_TRUCK + 0.12 * XF_E + 0.1977 * XF_N + 0.8E-01 * XF_S = 0;
 [_699] - TOTAL_HC_EMSN_LPT_TRUCK + 0.4045 * XF_E + 0.67 * XF_N + 0.27 * XF_S = 0;
 [_700] - TOTAL_NOX_EMSN_LPT_TRUCK + 2.571 * XF_E + 4.24 * XF_N + 1.72 * XF_S = 0;
 [_701] - TOTAL_PM_EMSN_LPT_TRUCK + 0.26E-01 * XF_E + 0.43E-01 * XF_N + 0.17E-01 * XF_S = 0;
 [_702] - TOTAL_BENZ_EMSN_LPT_TRUCK + 0.25E-02 * XF_E + 0.41E-02 * XF_N + 0.16E-02 * XF_S = 0;
 [_703] - TOTAL_BUTDN_EMSN_LPT_TRUCK + 0.2E-03 * XF_E + 0.32E-03 * XF_N + 0.13E-03 * XF_S = 0;
 [_704] 888.3 * SIF_E - CO2_EMSN_INC_E = 0;
 [_705] 888.3 * SIF_N - CO2_EMSN_INC_N = 0;
 [_706] 888.3 * SIF_S - CO2_EMSN_INC_S = 0;
 [_707] 17.7 * SIF_E - NO2_EMSN_INC_E = 0;
 [_708] 17.7 * SIF_N - NO2_EMSN_INC_N = 0;
 [_709] 17.7 * SIF_S - NO2_EMSN_INC_S = 0;
 [_710] 2.1 * SIF_E - SO2_EMSN_INC_E = 0;
 [_711] 2.1 * SIF_N - SO2_EMSN_INC_N = 0;
 [_712] 2.1 * SIF_S - SO2_EMSN_INC_S = 0;
 [_713] - TOTAL_CO2_EMSN_INC + 888.3 * SIF_E + 888.3 * SIF_N + 888.3 * SIF_S = 0;
 [_714] - TOTAL_NO2_EMSN_INC + 17.7 * SIF_E + 17.7 * SIF_N + 17.7 * SIF_S = 0;
 [_715] - TOTAL_SO2_EMSN_INC + 2.1 * SIF_E + 2.1 * SIF_N + 2.1 * SIF_S = 0;
 [_716] 4.123 * SIF_E - NO2_EMSN_INC_STD_E = 0;
 [_717] 4.123 * SIF_N - NO2_EMSN_INC_STD_N = 0;
 [_718] 4.123 * SIF_S - NO2_EMSN_INC_STD_S = 0;
 [_719] 2.0617 * SIF_E - SO2_EMSN_INC_STD_E = 0;
 [_720] 2.0617 * SIF_N - SO2_EMSN_INC_STD_N = 0;
 [_721] 2.0617 * SIF_S - SO2_EMSN_INC_STD_S = 0;
 [_722] - TOTAL_NO2_EMSN_INC_STD + 4.123 * SIF_E + 4.123 * SIF_N + 4.123 * SIF_S = 0;
 [_723] - TOTAL_SO2_EMSN_INC_STD + 2.0617 * SIF_E + 2.0617 * SIF_N + 2.0617 * SIF_S = 0;
 [_724] 206.88 * SCF_E - CO2_EMSN_CP_E = 0;
 [_725] 206.88 * SCF_N - CO2_EMSN_CP_N = 0;
 [_726] 206.88 * SCF_S - CO2_EMSN_CP_S = 0;
 [_727] 9.098 * SCF_E - CH4_EMSN_CP_E = 0;
 [_728] 9.098 * SCF_N - CH4_EMSN_CP_N = 0;
 [_729] 9.098 * SCF_S - CH4_EMSN_CP_S = 0;
 [_730] 0.4 * SCF_E - NO2_EMSN_CP_E = 0;
 [_731] 0.4 * SCF_N - NO2_EMSN_CP_N = 0;
 [_732] 0.4 * SCF_S - NO2_EMSN_CP_S = 0;
 [_733] 0.665E-01 * SCF_E - SO2_EMSN_CP_E = 0;
 [_734] 0.665E-01 * SCF_N - SO2_EMSN_CP_N = 0;
 [_735] 0.665E-01 * SCF_S - SO2_EMSN_CP_S = 0;
 [_736] - TOTAL_CO2_EMSN_CP + 206.88 * SCF_E + 206.88 * SCF_N + 206.88 * SCF_S = 0;
 [_737] - TOTAL_CH4_EMSN_CP + 9.098 * SCF_E + 9.098 * SCF_N + 9.098 * SCF_S = 0;
 [_738] - TOTAL_NO2_EMSN_CP + 0.4 * SCF_E + 0.4 * SCF_N + 0.4 * SCF_S = 0;
 [_739] - TOTAL_SO2_EMSN_CP + 0.665E-01 * SCF_E + 0.665E-01 * SCF_N + 0.665E-01 * SCF_S = 0;
 [_740] 0.27E-02 * XF_E - NH3_N_EMSN_E = 0;
 [_741] 0.27E-02 * XF_N - NH3_N_EMSN_N = 0;
 [_742] 0.27E-02 * XF_S - NH3_N_EMSN_S = 0;
 [_743] 0.535E-02 * XF_E - TKN_EMSN_E = 0;
 [_744] 0.535E-02 * XF_N - TKN_EMSN_N = 0;
 [_745] 0.535E-02 * XF_S - TKN_EMSN_S = 0;
 [_746] 0.11E-04 * XF_E - AS_EMSN_E = 0;
 [_747] 0.11E-04 * XF_N - AS_EMSN_N = 0;
 [_748] 0.11E-04 * XF_S - AS_EMSN_S = 0;
 [_749] 0.5354E-06 * XF_E - HG_EMSN_E = 0;
 [_750] 0.5354E-06 * XF_N - HG_EMSN_N = 0;
 [_751] 0.5354E-06 * XF_S - HG_EMSN_S = 0;
 [_752] 0.535E-05 * XF_E - PB_EMSN_E = 0;
 [_753] 0.535E-05 * XF_N - PB_EMSN_N = 0;
 [_754] 0.535E-05 * XF_S - PB_EMSN_S = 0;
 [_755] 0.1071E-03 * XF_E - CR_EMSN_E = 0;
 [_756] 0.1071E-03 * XF_N - CR_EMSN_N = 0;
 [_757] 0.1071E-03 * XF_S - CR_EMSN_S = 0;
 [_758] 0.161E-03 * XF_E - CU_EMSN_E = 0;
 [_759] 0.161E-03 * XF_N - CU_EMSN_N = 0;
 [_760] 0.161E-03 * XF_S - CU_EMSN_S = 0;
 [_761] 0.268E-03 * XF_E - ZN_EMSN_E = 0;
 [_762] 0.268E-03 * XF_N - ZN_EMSN_N = 0;
 [_763] 0.268E-03 * XF_S - ZN_EMSN_S = 0;
 [_764] 0.161E-03 * XF_E - NI_EMSN_E = 0;

Annexure 9

[_765] 0.161E-03 * XF_N - NI_EMSN_N = 0;
 [_766] 0.161E-03 * XF_S - NI_EMSN_S = 0;
 [_767] 0.107E-04 * XF_E - CN_EMSN_E = 0;
 [_768] 0.107E-04 * XF_N - CN_EMSN_N = 0;
 [_769] 0.107E-04 * XF_S - CN_EMSN_S = 0;
 [_770] 0.535E-01 * XF_E - CL_EMSN_E = 0;
 [_771] 0.535E-01 * XF_N - CL_EMSN_N = 0;
 [_772] 0.535E-01 * XF_S - CL_EMSN_S = 0;
 [_773] 0.535E-04 * XF_E - PHENOL_EMSN_E = 0;
 [_774] 0.535E-04 * XF_N - PHENOL_EMSN_N = 0;
 [_775] 0.535E-04 * XF_S - PHENOL_EMSN_S = 0;
 [_776] - TOTAL_NH3_N_EMSN + 0.27E-02 * XF_E + 0.27E-02 * XF_N + 0.27E-02 * XF_S = 0;
 [_777] - TOTAL_TKN_EMSN + 0.535E-02 * XF_E + 0.535E-02 * XF_N + 0.535E-02 * XF_S = 0;
 [_778] - TOTAL_AS_EMSN + 0.11E-04 * XF_E + 0.11E-04 * XF_N + 0.11E-04 * XF_S = 0;
 [_779] - TOTAL_HG_EMSN + 0.5354E-06 * XF_E + 0.5354E-06 * XF_N + 0.5354E-06 * XF_S = 0;
 [_780] - TOTAL_PB_EMSN + 0.535E-05 * XF_E + 0.535E-05 * XF_N + 0.535E-05 * XF_S = 0;
 [_781] - TOTAL_CR_EMSN + 0.1071E-03 * XF_E + 0.1071E-03 * XF_N + 0.1071E-03 * XF_S = 0;
 [_782] - TOTAL_CU_EMSN + 0.161E-03 * XF_E + 0.161E-03 * XF_N + 0.161E-03 * XF_S = 0;
 [_783] - TOTAL_ZN_EMSN + 0.268E-03 * XF_E + 0.268E-03 * XF_N + 0.268E-03 * XF_S = 0;
 [_784] - TOTAL_NI_EMSN + 0.161E-03 * XF_E + 0.161E-03 * XF_N + 0.161E-03 * XF_S = 0;
 [_785] - TOTAL_CN_EMSN + 0.107E-04 * XF_E + 0.107E-04 * XF_N + 0.107E-04 * XF_S = 0;
 [_786] - TOTAL_CL_EMSN + 0.535E-01 * XF_E + 0.535E-01 * XF_N + 0.535E-01 * XF_S = 0;
 [_787] - TOTAL_PHENOL_EMSN + 0.535E-04 * XF_E + 0.535E-04 * XF_N + 0.535E-04 * XF_S = 0;
 [_788] TOTAL_CO2_EMISSION_DV + TOTAL_CO2_EMISSION_HV + TOTAL_CO2_EMSN_INC +
 TOTAL_CO2_EMSN_CP - TOTAL_CO2_EMSN + TOTAL_CO2_EMSN_LPT_TRUCK = 0;
 [_789] TOTAL_CO_EMISSION_DV + TOTAL_CO_EMISSION_HV - TOTAL_CO_EMSN +
 TOTAL_CO_EMSN_LPT_TRUCK = 0;
 [_790] TOTAL_SO2_EMISSION_DV + TOTAL_SO2_EMISSION_HV + TOTAL_SO2_EMSN_INC_STD +
 TOTAL_SO2_EMSN_CP - TOTAL_SO2_EMSN + TOTAL_SO2_EMSN_LPT_TRUCK = 0;
 [_791] TOTAL_NOX_EMISSION_DV + TOTAL_NOX_EMISSION_HV + TOTAL_NO2_EMSN_INC_STD +
 TOTAL_NO2_EMSN_CP - TOTAL_NOX_EMSN + TOTAL_NOX_EMSN_LPT_TRUCK = 0;
 [_792] TOTAL_HC_EMISSION_DV + TOTAL_HC_EMISSION_HV - TOTAL_HC_EMSN +
 TOTAL_HC_EMSN_LPT_TRUCK = 0;
 [_793] TOTAL_PM_EMISSION_DV + TOTAL_PM_EMISSION_HV - TOTAL_PM_EMSN +
 TOTAL_PM_EMSN_LPT_TRUCK = 0;
 [_794] TOTAL_BENZ_EMISSION_DV + TOTAL_BENZ_EMISSION_HV - TOTAL_BENZ_EMSN +
 TOTAL_BENZ_EMSN_LPT_TRUCK = 0;
 [_795] TOTAL_BUTDN_EMISSION_DV + TOTAL_BUTDN_EMISSION_HV - TOTAL_BUTDN_EMSN +
 TOTAL_BUTDN_EMSN_LPT_TRUCK = 0;
 [_796] TOTAL_CH4_EMSN_CP - TOTAL_CH4_EMSN = 0;
 [_797] 0.6100519931E-09 * TOTAL_CO2_EMSN - PEI_GWP_CO2 = 0;
 [_798] 0.1708145581E-07 * TOTAL_CH4_EMSN - PEI_GWP_CH4 = 0;
 [_799] PEI_GWP_CO2 + PEI_GWP_CH4 - PEI_GWP = 0;
 [_800] 0.2319218241E-05 * TOTAL_SO2_EMSN - PEI_AP_SO2 = 0;
 [_801] 0.1623452769E-05 * TOTAL_NOX_EMSN - PEI_AP_NOX = 0;
 [_802] PEI_AP_SO2 + PEI_AP_NOX - PEI_AP = 0;
 [_803] 0.6615929204E-05 * TOTAL_CH4_EMSN - PEI_POCP_CH4 = 0;
 [_804] PEI_POCP_CH4 - PEI_POCP = 0;
 [_805] 0.5716092831E-02 * TOTAL_BENZ_EMSN - PEI_HTPE_BENZ = 0;
 [_806] 0.318350816E-03 * TOTAL_CO_EMSN - PEI_HTPE_CO = 0;
 [_807] 0.2023879758E-05 * TOTAL_CO2_EMSN - PEI_HTPE_CO2 = 0;
 [_808] 0.2789672099E-04 * TOTAL_HC_EMSN - PEI_HTPE_HC = 0;
 [_809] 0.1938183949E-02 * TOTAL_NOX_EMSN - PEI_HTPE_NOX = 0;
 [_810] 0.1393012734E-02 * TOTAL_SO2_EMSN - PEI_HTPE_SO2 = 0;
 [_811] 0.9116575488E-02 * TOTAL_BUTDN_EMSN - PEI_HTPE_BUTDN = 0;
 [_812] 0.2734972646E-06 * TOTAL_PM_EMSN - PEI_HTPE_PM = 0;
 [_813] 0.2789672099E-04 * TOTAL_CH4_EMSN - PEI_HTPE_CH4 = 0;
 [_814] PEI_HTPE_BENZ + PEI_HTPE_CO + PEI_HTPE_CO2 + PEI_HTPE_HC + PEI_HTPE_NOX + PEI_HTPE_SO2 +
 PEI_HTPE_BUTDN + PEI_HTPE_PM + PEI_HTPE_CH4 - PEI_HTPE = 0;
 [_815] 0.1091028223 * TOTAL_PHENOL_EMSN - PEI_HTPI_PHENOL = 0;
 [_816] 3.830083289 * TOTAL_AS_EMSN - PEI_HTPI_AS = 0;
 [_817] 0.1894943756E-01 * TOTAL_CL_EMSN - PEI_HTPI_CL = 0;
 [_818] 8.975142701 * TOTAL_CN_EMSN - PEI_HTPI_CN = 0;
 [_819] 0.1435563452 * TOTAL_CR_EMSN - PEI_HTPI_CR = 0;
 [_820] 0.9187606092E-01 * TOTAL_CU_EMSN - PEI_HTPI_CU = 0;
 [_821] 57.42253807 * TOTAL_HG_EMSN - PEI_HTPI_HG = 0;
 [_822] 0.8154000406E-01 * TOTAL_NI_EMSN - PEI_HTPI_NI = 0;
 [_823] 47.85020098 * TOTAL_PB_EMSN - PEI_HTPI_PB = 0;
 [_824] 0.7924310254E-01 * TOTAL_ZN_EMSN - PEI_HTPI_ZN = 0;
 [_825] 0.1642284589 * TOTAL_NH3_N_EMSN - PEI_HTPI_NH3_N = 0;
 [_826] PEI_HTPI_PHENOL + PEI_HTPI_AS + PEI_HTPI_CL + PEI_HTPI_CN + PEI_HTPI_CR + PEI_HTPI_CU +
 PEI_HTPI_HG + PEI_HTPI_NI + PEI_HTPI_PB + PEI_HTPI_ZN + PEI_HTPI_NH3_N - PEI_HTPI = 0;
 [_827] 0.3374003231E-03 * TOTAL_SO2_EMSN - PEI_TTPG_SO2 = 0;
 [_828] 0.1384489546E-02 * TOTAL_BENZ_EMSN - PEI_TTPG_BENZ = 0;
 [_829] 0.6756838931E-05 * TOTAL_CH4_EMSN - PEI_TTPG_CH4 = 0;
 [_830] 0.7710745603E-04 * TOTAL_CO_EMSN - PEI_TTPG_CO = 0;
 [_831] 0.4902020401E-06 * TOTAL_CO2_EMSN - PEI_TTPG_CO2 = 0;
 [_832] 0.4694457375E-03 * TOTAL_NOX_EMSN - PEI_TTPG_NOX = 0;

[_833] 0.6624351893E-07 * TOTAL_PM_EMSN - PEI_TTPG_PM = 0;
 [_834] 0.2208117298E-02 * TOTAL_BUTDN_EMSN - PEI_TTPG_BUTDN = 0;
 [_835] 0.4416234595E-05 * TOTAL_HC_EMSN - PEI_TTPG_HC = 0;
 [_836] PEI_TTPG_SO2 + PEI_TTPG_BENZ + PEI_TTPG_CH4 + PEI_TTPG_CO + PEI_TTPG_CO2 + PEI_TTPG_NOX +
 PEI_TTPG_PM + PEI_TTPG_BUTDN + PEI_TTPG_HC - PEI_TTPG = 0;
 [_837] 1.391521384 * TOTAL_AS_EMSN - PEI_TTPL_AS = 0;
 [_838] 0.6884588559E-02 * TOTAL_CL_EMSN - PEI_TTPL_CL = 0;
 [_839] 3.26079149 * TOTAL_CN_EMSN - PEI_TTPL_CN = 0;
 [_840] 0.5215597393E-01 * TOTAL_CR_EMSN - PEI_TTPL_CR = 0;
 [_841] 0.3337982331E-01 * TOTAL_CU_EMSN - PEI_TTPL_CU = 0;
 [_842] 20.86238957 * TOTAL_HG_EMSN - PEI_TTPL_HG = 0;
 [_843] 0.5966643418E-01 * TOTAL_NH3_N_EMSN - PEI_TTPL_NH3_N = 0;
 [_844] 0.2962459319E-01 * TOTAL_NI_EMSN - PEI_TTPL_NI = 0;
 [_845] 17.37837051 * TOTAL_PB_EMSN - PEI_TTPL_PB = 0;
 [_846] 0.3963854019E-01 * TOTAL_PHENOL_EMSN - PEI_TTPL_PHENOL = 0;
 [_847] 0.2879009761E-01 * TOTAL_ZN_EMSN - PEI_TTPL_ZN = 0;
 [_848] PEI_TTPL_AS + PEI_TTPL_CL + PEI_TTPL_CN + PEI_TTPL_CR + PEI_TTPL_CU + PEI_TTPL_HG +
 PEI_TTPL_NH3_N + PEI_TTPL_NI + PEI_TTPL_PB + PEI_TTPL_PHENOL + PEI_TTPL_ZN - PEI_TTPL = 0;
 [_849] 0.7094864789E-01 * TOTAL_AS_EMSN - PEI_ATP_AS = 0;
 [_850] 0.9513376505E-01 * TOTAL_CL_EMSN - PEI_ATP_CL = 0;
 [_851] - PEI_ATP_CN = 0;
 [_852] 0.6928274996E-01 * TOTAL_CR_EMSN - PEI_ATP_CR = 0;
 [_853] 0.1268450201 * TOTAL_CU_EMSN - PEI_ATP_CU = 0;
 [_854] 0.1259993866 * TOTAL_HG_EMSN - PEI_ATP_HG = 0;
 [_855] 0.9031365428E-01 * TOTAL_NH3_N_EMSN - PEI_ATP_NH3_N = 0;
 [_856] 0.695237555E-01 * TOTAL_NI_EMSN - PEI_ATP_NI = 0;
 [_857] 0.1037169447 * TOTAL_PB_EMSN - PEI_ATP_PB = 0;
 [_858] 0.4820110762E-01 * TOTAL_PHENOL_EMSN - PEI_ATP_PHENOL = 0;
 [_859] 0.8716366962E-01 * TOTAL_ZN_EMSN - PEI_ATP_ZN = 0;
 [_860] PEI_ATP_AS + PEI_ATP_CL + PEI_ATP_CN + PEI_ATP_CR + PEI_ATP_CU + PEI_ATP_HG + PEI_ATP_NH3_N
 + PEI_ATP_NI + PEI_ATP_PB + PEI_ATP_PHENOL + PEI_ATP_ZN - PEI_ATP = 0;
 [_861] - Q_D_DV_E_DV1 + Q_BH_D_DV_G_1_E_DV1 + Q_BH_D_DV_G_2_E_DV1 + Q_BH_D_DV_G_3_E_DV1 +
 Q_BH_D_DV_G_4_E_DV1 + Q_BH_D_DV_G_5_E_DV1 +
 Q_BH_D_DV_G_6_E_DV1 + Q_BH_D_DV_G_7_E_DV1 + Q_BH_D_DV_G_8_E_DV1 + Q_BH_D_DV_G_9_E_DV1 +
 Q_BH_D_DV_G_10_E_DV1 + Q_BH_D_DV_G_11_E_DV1 + Q_BH_D_DV_G_12_E_DV1 + Q_BH_D_DV_G_13_E_DV1 +
 Q_BH_D_DV_G_14_E_DV1 + Q_BH_D_DV_G_15_E_DV1 +
 Q_BH_D_DV_G_16_E_DV1 = 0;
 [_862] - Q_D_DV_E_DV2 + Q_BH_D_DV_G_1_E_DV2 + Q_BH_D_DV_G_2_E_DV2 + Q_BH_D_DV_G_3_E_DV2 +
 Q_BH_D_DV_G_4_E_DV2 + Q_BH_D_DV_G_5_E_DV2 + Q_BH_D_DV_G_6_E_DV2 + Q_BH_D_DV_G_7_E_DV2 +
 Q_BH_D_DV_G_8_E_DV2 + Q_BH_D_DV_G_9_E_DV2 + Q_BH_D_DV_G_10_E_DV2 + Q_BH_D_DV_G_11_E_DV2 +
 Q_BH_D_DV_G_12_E_DV2 + Q_BH_D_DV_G_13_E_DV2 + Q_BH_D_DV_G_14_E_DV2 + Q_BH_D_DV_G_15_E_DV2 +
 Q_BH_D_DV_G_16_E_DV2 = 0;
 [_863] - Q_D_DV_E_DV3 + Q_BH_D_DV_G_1_E_DV3 + Q_BH_D_DV_G_2_E_DV3 + Q_BH_D_DV_G_3_E_DV3 +
 Q_BH_D_DV_G_4_E_DV3 + Q_BH_D_DV_G_5_E_DV3 + Q_BH_D_DV_G_6_E_DV3 + Q_BH_D_DV_G_7_E_DV3 +
 Q_BH_D_DV_G_8_E_DV3 + Q_BH_D_DV_G_9_E_DV3 + Q_BH_D_DV_G_10_E_DV3 + Q_BH_D_DV_G_11_E_DV3 +
 Q_BH_D_DV_G_12_E_DV3 + Q_BH_D_DV_G_13_E_DV3 + Q_BH_D_DV_G_14_E_DV3 + Q_BH_D_DV_G_15_E_DV3 +
 Q_BH_D_DV_G_16_E_DV3 = 0;
 [_864] - Q_D_DV_E_DV4 + Q_BH_D_DV_G_1_E_DV4 + Q_BH_D_DV_G_2_E_DV4 + Q_BH_D_DV_G_3_E_DV4 +
 Q_BH_D_DV_G_4_E_DV4 + Q_BH_D_DV_G_5_E_DV4 + Q_BH_D_DV_G_6_E_DV4 + Q_BH_D_DV_G_7_E_DV4 +
 Q_BH_D_DV_G_8_E_DV4 + Q_BH_D_DV_G_9_E_DV4 + Q_BH_D_DV_G_10_E_DV4 + Q_BH_D_DV_G_11_E_DV4 +
 Q_BH_D_DV_G_12_E_DV4 + Q_BH_D_DV_G_13_E_DV4 + Q_BH_D_DV_G_14_E_DV4 + Q_BH_D_DV_G_15_E_DV4 +
 Q_BH_D_DV_G_16_E_DV4 = 0;
 [_865] - Q_D_DV_N_DV1 + Q_BH_D_DV_G_1_N_DV1 + Q_BH_D_DV_G_2_N_DV1 + Q_BH_D_DV_G_3_N_DV1 +
 Q_BH_D_DV_G_4_N_DV1 + Q_BH_D_DV_G_5_N_DV1 + Q_BH_D_DV_G_6_N_DV1 + Q_BH_D_DV_G_7_N_DV1 +
 Q_BH_D_DV_G_8_N_DV1 + Q_BH_D_DV_G_9_N_DV1 + Q_BH_D_DV_G_10_N_DV1 + Q_BH_D_DV_G_11_N_DV1 +
 Q_BH_D_DV_G_12_N_DV1 + Q_BH_D_DV_G_13_N_DV1 + Q_BH_D_DV_G_14_N_DV1 + Q_BH_D_DV_G_15_N_DV1 +
 Q_BH_D_DV_G_16_N_DV1 = 0;
 [_866] - Q_D_DV_N_DV2 + Q_BH_D_DV_G_1_N_DV2 + Q_BH_D_DV_G_2_N_DV2 + Q_BH_D_DV_G_3_N_DV2 +
 Q_BH_D_DV_G_4_N_DV2 + Q_BH_D_DV_G_5_N_DV2 + Q_BH_D_DV_G_6_N_DV2 + Q_BH_D_DV_G_7_N_DV2 +
 Q_BH_D_DV_G_8_N_DV2 + Q_BH_D_DV_G_9_N_DV2 + Q_BH_D_DV_G_10_N_DV2 + Q_BH_D_DV_G_11_N_DV2 +
 Q_BH_D_DV_G_12_N_DV2 + Q_BH_D_DV_G_13_N_DV2 + Q_BH_D_DV_G_14_N_DV2 + Q_BH_D_DV_G_15_N_DV2 +
 Q_BH_D_DV_G_16_N_DV2 = 0;
 [_867] - Q_D_DV_N_DV3 + Q_BH_D_DV_G_1_N_DV3 + Q_BH_D_DV_G_2_N_DV3 + Q_BH_D_DV_G_3_N_DV3 +
 Q_BH_D_DV_G_4_N_DV3 + Q_BH_D_DV_G_5_N_DV3 + Q_BH_D_DV_G_6_N_DV3 + Q_BH_D_DV_G_7_N_DV3 +
 Q_BH_D_DV_G_8_N_DV3 + Q_BH_D_DV_G_9_N_DV3 + Q_BH_D_DV_G_10_N_DV3 + Q_BH_D_DV_G_11_N_DV3 +
 Q_BH_D_DV_G_12_N_DV3 + Q_BH_D_DV_G_13_N_DV3 + Q_BH_D_DV_G_14_N_DV3 + Q_BH_D_DV_G_15_N_DV3 +
 Q_BH_D_DV_G_16_N_DV3 = 0;
 [_868] - Q_D_DV_N_DV4 + Q_BH_D_DV_G_1_N_DV4 + Q_BH_D_DV_G_2_N_DV4 + Q_BH_D_DV_G_3_N_DV4 +
 Q_BH_D_DV_G_4_N_DV4 + Q_BH_D_DV_G_5_N_DV4 + Q_BH_D_DV_G_6_N_DV4 + Q_BH_D_DV_G_7_N_DV4 +
 Q_BH_D_DV_G_8_N_DV4 + Q_BH_D_DV_G_9_N_DV4 + Q_BH_D_DV_G_10_N_DV4 + Q_BH_D_DV_G_11_N_DV4 +
 Q_BH_D_DV_G_12_N_DV4 + Q_BH_D_DV_G_13_N_DV4 + Q_BH_D_DV_G_14_N_DV4 + Q_BH_D_DV_G_15_N_DV4 +
 Q_BH_D_DV_G_16_N_DV4 = 0;
 [_869] - Q_D_DV_S_DV1 + Q_BH_D_DV_G_1_S_DV1 + Q_BH_D_DV_G_2_S_DV1 + Q_BH_D_DV_G_3_S_DV1 +
 Q_BH_D_DV_G_4_S_DV1 + Q_BH_D_DV_G_5_S_DV1 + Q_BH_D_DV_G_6_S_DV1 + Q_BH_D_DV_G_7_S_DV1 +
 Q_BH_D_DV_G_8_S_DV1 + Q_BH_D_DV_G_9_S_DV1 + Q_BH_D_DV_G_10_S_DV1 + Q_BH_D_DV_G_11_S_DV1 +
 Q_BH_D_DV_G_12_S_DV1 + Q_BH_D_DV_G_13_S_DV1 + Q_BH_D_DV_G_14_S_DV1 + Q_BH_D_DV_G_15_S_DV1 +
 Q_BH_D_DV_G_16_S_DV1 = 0;
 [_870] - Q_D_DV_S_DV2 + Q_BH_D_DV_G_1_S_DV2 + Q_BH_D_DV_G_2_S_DV2 + Q_BH_D_DV_G_3_S_DV2 +

Q_BH_D_DV_G_4_S_DV2+ Q_BH_D_DV_G_5_S_DV2+Q_BH_D_DV_G_6_S_DV2+ Q_BH_D_DV_G_7_S_DV2+
Q_BH_D_DV_G_8_S_DV2+ Q_BH_D_DV_G_9_S_DV2+Q_BH_D_DV_G_10_S_DV2+ Q_BH_D_DV_G_11_S_DV2+
Q_BH_D_DV_G_12_S_DV2+ Q_BH_D_DV_G_13_S_DV2+Q_BH_D_DV_G_14_S_DV2+ Q_BH_D_DV_G_15_S_DV2+
Q_BH_D_DV_G_16_S_DV2=0;
[.871]- Q_D_DV_S_DV3+ Q_BH_D_DV_G_1_S_DV3+Q_BH_D_DV_G_2_S_DV3+ Q_BH_D_DV_G_3_S_DV3+
Q_BH_D_DV_G_4_S_DV3+ Q_BH_D_DV_G_5_S_DV3+Q_BH_D_DV_G_6_S_DV3+ Q_BH_D_DV_G_7_S_DV3+
Q_BH_D_DV_G_8_S_DV3+ Q_BH_D_DV_G_9_S_DV3+Q_BH_D_DV_G_10_S_DV3+ Q_BH_D_DV_G_11_S_DV3+
Q_BH_D_DV_G_12_S_DV3+ Q_BH_D_DV_G_13_S_DV3+Q_BH_D_DV_G_14_S_DV3+ Q_BH_D_DV_G_15_S_DV3+
Q_BH_D_DV_G_16_S_DV3=0;
[.872]- Q_D_DV_S_DV4+ Q_BH_D_DV_G_1_S_DV4+Q_BH_D_DV_G_2_S_DV4+ Q_BH_D_DV_G_3_S_DV4+
Q_BH_D_DV_G_4_S_DV4+ Q_BH_D_DV_G_5_S_DV4+Q_BH_D_DV_G_6_S_DV4+ Q_BH_D_DV_G_7_S_DV4+
Q_BH_D_DV_G_8_S_DV4+ Q_BH_D_DV_G_9_S_DV4+Q_BH_D_DV_G_10_S_DV4+ Q_BH_D_DV_G_11_S_DV4+
Q_BH_D_DV_G_12_S_DV4+ Q_BH_D_DV_G_13_S_DV4+Q_BH_D_DV_G_14_S_DV4+ Q_BH_D_DV_G_15_S_DV4+
Q_BH_D_DV_G_16_S_DV4=0;
[.873]- Q_D_HV_G_E+ Q_BH_D_HV_G_1_E+ Q_BH_D_HV_G_2_E+Q_BH_D_HV_G_3_E+ Q_BH_D_HV_G_4_E+
Q_BH_D_HV_G_5_E+Q_BH_D_HV_G_6_E+ Q_BH_D_HV_G_7_E+ Q_BH_D_HV_G_8_E+ Q_BH_D_HV_G_9_E+
Q_BH_D_HV_G_10_E+ Q_BH_D_HV_G_11_E+Q_BH_D_HV_G_12_E+ Q_BH_D_HV_G_13_E+ Q_BH_D_HV_G_14_E+
Q_BH_D_HV_G_15_E+ Q_BH_D_HV_G_16_E=0;
[.874]- Q_D_HV_G_N+ Q_BH_D_HV_G_1_N+ Q_BH_D_HV_G_2_N+Q_BH_D_HV_G_3_N+ Q_BH_D_HV_G_4_N+
Q_BH_D_HV_G_5_N+ Q_BH_D_HV_G_6_N+ Q_BH_D_HV_G_7_N+ Q_BH_D_HV_G_8_N+ Q_BH_D_HV_G_9_N+
Q_BH_D_HV_G_10_N+ Q_BH_D_HV_G_11_N+Q_BH_D_HV_G_12_N+ Q_BH_D_HV_G_13_N+ Q_BH_D_HV_G_14_N+
+
Q_BH_D_HV_G_15_N+ Q_BH_D_HV_G_16_N=0;
[.875]- Q_D_HV_G_S+ Q_BH_D_HV_G_1_S+ Q_BH_D_HV_G_2_S+Q_BH_D_HV_G_3_S+ Q_BH_D_HV_G_4_S+
Q_BH_D_HV_G_5_S+ Q_BH_D_HV_G_6_S+ Q_BH_D_HV_G_7_S+ Q_BH_D_HV_G_8_S+ Q_BH_D_HV_G_9_S+
Q_BH_D_HV_G_10_S+ Q_BH_D_HV_G_11_S+ Q_BH_D_HV_G_12_S+ Q_BH_D_HV_G_13_S+ Q_BH_D_HV_G_14_S+
Q_BH_D_HV_G_15_S+ Q_BH_D_HV_G_16_S=0;
[.876]- Q_D_G_E+ Q_D_HV_G_E+ Q_D_DV_E_DV1+Q_D_DV_E_DV2+ Q_D_DV_E_DV3+ Q_D_DV_E_DV4=0;
[.877]- Q_D_G_N+ Q_D_HV_G_N+ Q_D_DV_N_DV1+Q_D_DV_N_DV2+ Q_D_DV_N_DV3+ Q_D_DV_N_DV4=0;
[.878]- Q_D_G_S+ Q_D_HV_G_S+ Q_D_DV_S_DV1+Q_D_DV_S_DV2+ Q_D_DV_S_DV3+ Q_D_DV_S_DV4=0;
[.879]- TOTAL_GARBAGE+ Q_D_G_E+ Q_D_G_N+ Q_D_G_S=0;
[.880]- Q_D_HV_S_E+ Q_BH_D_HV_S_1_E+ Q_BH_D_HV_S_2_E+Q_BH_D_HV_S_3_E+ Q_BH_D_HV_S_4_E+
Q_BH_D_HV_S_5_E+ Q_BH_D_HV_S_6_E+ Q_BH_D_HV_S_7_E+ Q_BH_D_HV_S_8_E+ Q_BH_D_HV_S_9_E+
Q_BH_D_HV_S_10_E+ Q_BH_D_HV_S_11_E+Q_BH_D_HV_S_12_E+ Q_BH_D_HV_S_13_E+ Q_BH_D_HV_S_14_E+
Q_BH_D_HV_S_15_E+ Q_BH_D_HV_S_16_E=0;
[.881]- Q_D_HV_S_N+ Q_BH_D_HV_S_1_N+ Q_BH_D_HV_S_2_N+Q_BH_D_HV_S_3_N+ Q_BH_D_HV_S_4_N+
Q_BH_D_HV_S_5_N+ Q_BH_D_HV_S_6_N+ Q_BH_D_HV_S_7_N+ Q_BH_D_HV_S_8_N+ Q_BH_D_HV_S_9_N+
Q_BH_D_HV_S_10_N+ Q_BH_D_HV_S_11_N+Q_BH_D_HV_S_12_N+ Q_BH_D_HV_S_13_N+ Q_BH_D_HV_S_14_N+
Q_BH_D_HV_S_15_N+ Q_BH_D_HV_S_16_N=0;
[.882]- Q_D_HV_S_S+ Q_BH_D_HV_S_1_S+ Q_BH_D_HV_S_2_S+Q_BH_D_HV_S_3_S+ Q_BH_D_HV_S_4_S+
Q_BH_D_HV_S_5_S+ Q_BH_D_HV_S_6_S+ Q_BH_D_HV_S_7_S+ Q_BH_D_HV_S_8_S+ Q_BH_D_HV_S_9_S+
Q_BH_D_HV_S_10_S+ Q_BH_D_HV_S_11_S+Q_BH_D_HV_S_12_S+ Q_BH_D_HV_S_13_S+ Q_BH_D_HV_S_14_S+
Q_BH_D_HV_S_15_S+ Q_BH_D_HV_S_16_S=0;
[.883]- TOTAL_SILT+ Q_D_HV_S_E+ Q_D_HV_S_N+Q_D_HV_S_S=0;
[.884]- Q_BH_DV_1_DV1+ Q_BH_D_DV_G_1_E_DV1+ Q_BH_D_DV_G_1_N_DV1+ Q_BH_D_DV_G_1_S_DV1=0;
[.885]- Q_BH_DV_1_DV2+ Q_BH_D_DV_G_1_E_DV2+ Q_BH_D_DV_G_1_N_DV2+ Q_BH_D_DV_G_1_S_DV2=0;
[.886]- Q_BH_DV_1_DV3+ Q_BH_D_DV_G_1_E_DV3+ Q_BH_D_DV_G_1_N_DV3+ Q_BH_D_DV_G_1_S_DV3=0;
[.887]- Q_BH_DV_1_DV4+ Q_BH_D_DV_G_1_E_DV4+ Q_BH_D_DV_G_1_N_DV4+ Q_BH_D_DV_G_1_S_DV4=0;
[.888]- Q_BH_DV_2_DV1+ Q_BH_D_DV_G_2_E_DV1+ Q_BH_D_DV_G_2_N_DV1+ Q_BH_D_DV_G_2_S_DV1=0;
[.889]- Q_BH_DV_2_DV2+ Q_BH_D_DV_G_2_E_DV2+ Q_BH_D_DV_G_2_N_DV2+ Q_BH_D_DV_G_2_S_DV2=0;
[.890]- Q_BH_DV_2_DV3+ Q_BH_D_DV_G_2_E_DV3+ Q_BH_D_DV_G_2_N_DV3+ Q_BH_D_DV_G_2_S_DV3=0;
[.891]- Q_BH_DV_2_DV4+ Q_BH_D_DV_G_2_E_DV4+ Q_BH_D_DV_G_2_N_DV4+ Q_BH_D_DV_G_2_S_DV4=0;
[.892]- Q_BH_DV_3_DV1+ Q_BH_D_DV_G_3_E_DV1+ Q_BH_D_DV_G_3_N_DV1+ Q_BH_D_DV_G_3_S_DV1=0;
[.893]- Q_BH_DV_3_DV2+ Q_BH_D_DV_G_3_E_DV2+ Q_BH_D_DV_G_3_N_DV2+ Q_BH_D_DV_G_3_S_DV2=0;
[.894]- Q_BH_DV_3_DV3+ Q_BH_D_DV_G_3_E_DV3+ Q_BH_D_DV_G_3_N_DV3+ Q_BH_D_DV_G_3_S_DV3=0;
[.895]- Q_BH_DV_3_DV4+ Q_BH_D_DV_G_3_E_DV4+ Q_BH_D_DV_G_3_N_DV4+ Q_BH_D_DV_G_3_S_DV4=0;
[.896]- Q_BH_DV_4_DV1+ Q_BH_D_DV_G_4_E_DV1+ Q_BH_D_DV_G_4_N_DV1+ Q_BH_D_DV_G_4_S_DV1=0;
[.897]- Q_BH_DV_4_DV2+ Q_BH_D_DV_G_4_E_DV2+ Q_BH_D_DV_G_4_N_DV2+ Q_BH_D_DV_G_4_S_DV2=0;
[.898]- Q_BH_DV_4_DV3+ Q_BH_D_DV_G_4_E_DV3+ Q_BH_D_DV_G_4_N_DV3+ Q_BH_D_DV_G_4_S_DV3=0;
[.899]- Q_BH_DV_4_DV4+ Q_BH_D_DV_G_4_E_DV4+ Q_BH_D_DV_G_4_N_DV4+ Q_BH_D_DV_G_4_S_DV4=0;
[.900]- Q_BH_DV_5_DV1+ Q_BH_D_DV_G_5_E_DV1+ Q_BH_D_DV_G_5_N_DV1+ Q_BH_D_DV_G_5_S_DV1=0;
[.901]- Q_BH_DV_5_DV2+ Q_BH_D_DV_G_5_E_DV2+ Q_BH_D_DV_G_5_N_DV2+ Q_BH_D_DV_G_5_S_DV2=0;
[.902]- Q_BH_DV_5_DV3+ Q_BH_D_DV_G_5_E_DV3+ Q_BH_D_DV_G_5_N_DV3+ Q_BH_D_DV_G_5_S_DV3=0;
[.903]- Q_BH_DV_5_DV4+ Q_BH_D_DV_G_5_E_DV4+ Q_BH_D_DV_G_5_N_DV4+ Q_BH_D_DV_G_5_S_DV4=0;
[.904]- Q_BH_DV_6_DV1+ Q_BH_D_DV_G_6_E_DV1+ Q_BH_D_DV_G_6_N_DV1+ Q_BH_D_DV_G_6_S_DV1=0;
[.905]- Q_BH_DV_6_DV2+ Q_BH_D_DV_G_6_E_DV2+ Q_BH_D_DV_G_6_N_DV2+ Q_BH_D_DV_G_6_S_DV2=0;
[.906]- Q_BH_DV_6_DV3+ Q_BH_D_DV_G_6_E_DV3+ Q_BH_D_DV_G_6_N_DV3+ Q_BH_D_DV_G_6_S_DV3=0;
[.907]- Q_BH_DV_6_DV4+ Q_BH_D_DV_G_6_E_DV4+ Q_BH_D_DV_G_6_N_DV4+ Q_BH_D_DV_G_6_S_DV4=0;
[.908]- Q_BH_DV_7_DV1+ Q_BH_D_DV_G_7_E_DV1+ Q_BH_D_DV_G_7_N_DV1+ Q_BH_D_DV_G_7_S_DV1=0;
[.909]- Q_BH_DV_7_DV2+ Q_BH_D_DV_G_7_E_DV2+ Q_BH_D_DV_G_7_N_DV2+ Q_BH_D_DV_G_7_S_DV2=0;
[.910]- Q_BH_DV_7_DV3+ Q_BH_D_DV_G_7_E_DV3+ Q_BH_D_DV_G_7_N_DV3+ Q_BH_D_DV_G_7_S_DV3=0;
[.911]- Q_BH_DV_7_DV4+ Q_BH_D_DV_G_7_E_DV4+ Q_BH_D_DV_G_7_N_DV4+ Q_BH_D_DV_G_7_S_DV4=0;
[.912]- Q_BH_DV_8_DV1+ Q_BH_D_DV_G_8_E_DV1+ Q_BH_D_DV_G_8_N_DV1+ Q_BH_D_DV_G_8_S_DV1=0;
[.913]- Q_BH_DV_8_DV2+ Q_BH_D_DV_G_8_E_DV2+ Q_BH_D_DV_G_8_N_DV2

[918] - Q_BH_DV_9_DV3 + Q_BH_D_DV_G_9_E_DV3 + Q_BH_D_DV_G_9_N_DV3 + Q_BH_D_DV_G_9_S_DV3 = 0;
[919] - Q_BH_DV_9_DV4 + Q_BH_D_DV_G_9_E_DV4 + Q_BH_D_DV_G_9_N_DV4 + Q_BH_D_DV_G_9_S_DV4 = 0;
[920] - Q_BH_DV_10_DV1 + Q_BH_D_DV_G_10_E_DV1 + Q_BH_D_DV_G_10_N_DV1 + Q_BH_D_DV_G_10_S_DV1 = 0;
[921] - Q_BH_DV_10_DV2 + Q_BH_D_DV_G_10_E_DV2 + Q_BH_D_DV_G_10_N_DV2 + Q_BH_D_DV_G_10_S_DV2 = 0;
[922] - Q_BH_DV_10_DV3 + Q_BH_D_DV_G_10_E_DV3 + Q_BH_D_DV_G_10_N_DV3 + Q_BH_D_DV_G_10_S_DV3 = 0;
[923] - Q_BH_DV_10_DV4 + Q_BH_D_DV_G_10_E_DV4 + Q_BH_D_DV_G_10_N_DV4 + Q_BH_D_DV_G_10_S_DV4 = 0;
[924] - Q_BH_DV_11_DV1 + Q_BH_D_DV_G_11_E_DV1 + Q_BH_D_DV_G_11_N_DV1 + Q_BH_D_DV_G_11_S_DV1 = 0;
[925] - Q_BH_DV_11_DV2 + Q_BH_D_DV_G_11_E_DV2 + Q_BH_D_DV_G_11_N_DV2 + Q_BH_D_DV_G_11_S_DV2 = 0;
[926] - Q_BH_DV_11_DV3 + Q_BH_D_DV_G_11_E_DV3 + Q_BH_D_DV_G_11_N_DV3 + Q_BH_D_DV_G_11_S_DV3 = 0;
[927] - Q_BH_DV_11_DV4 + Q_BH_D_DV_G_11_E_DV4 + Q_BH_D_DV_G_11_N_DV4 + Q_BH_D_DV_G_11_S_DV4 = 0;
[928] - Q_BH_DV_12_DV1 + Q_BH_D_DV_G_12_E_DV1 + Q_BH_D_DV_G_12_N_DV1 + Q_BH_D_DV_G_12_S_DV1 = 0;
[929] - Q_BH_DV_12_DV2 + Q_BH_D_DV_G_12_E_DV2 + Q_BH_D_DV_G_12_N_DV2 + Q_BH_D_DV_G_12_S_DV2 = 0;
[930] - Q_BH_DV_12_DV3 + Q_BH_D_DV_G_12_E_DV3 + Q_BH_D_DV_G_12_N_DV3 + Q_BH_D_DV_G_12_S_DV3 = 0;
[931] - Q_BH_DV_12_DV4 + Q_BH_D_DV_G_12_E_DV4 + Q_BH_D_DV_G_12_N_DV4 + Q_BH_D_DV_G_12_S_DV4 = 0;
[932] - Q_BH_DV_13_DV1 + Q_BH_D_DV_G_13_E_DV1 + Q_BH_D_DV_G_13_N_DV1 + Q_BH_D_DV_G_13_S_DV1 = 0;
[933] - Q_BH_DV_13_DV2 + Q_BH_D_DV_G_13_E_DV2 + Q_BH_D_DV_G_13_N_DV2 + Q_BH_D_DV_G_13_S_DV2 = 0;
[934] - Q_BH_DV_13_DV3 + Q_BH_D_DV_G_13_E_DV3 + Q_BH_D_DV_G_13_N_DV3 + Q_BH_D_DV_G_13_S_DV3 = 0;
[935] - Q_BH_DV_13_DV4 + Q_BH_D_DV_G_13_E_DV4 + Q_BH_D_DV_G_13_N_DV4 + Q_BH_D_DV_G_13_S_DV4 = 0;
[936] - Q_BH_DV_14_DV1 + Q_BH_D_DV_G_14_E_DV1 + Q_BH_D_DV_G_14_N_DV1 + Q_BH_D_DV_G_14_S_DV1 = 0;
[937] - Q_BH_DV_14_DV2 + Q_BH_D_DV_G_14_E_DV2 + Q_BH_D_DV_G_14_N_DV2 + Q_BH_D_DV_G_14_S_DV2 = 0;
[938] - Q_BH_DV_14_DV3 + Q_BH_D_DV_G_14_E_DV3 + Q_BH_D_DV_G_14_N_DV3 + Q_BH_D_DV_G_14_S_DV3 = 0;
[939] - Q_BH_DV_14_DV4 + Q_BH_D_DV_G_14_E_DV4 + Q_BH_D_DV_G_14_N_DV4 + Q_BH_D_DV_G_14_S_DV4 = 0;
[940] - Q_BH_DV_15_DV1 + Q_BH_D_DV_G_15_E_DV1 + Q_BH_D_DV_G_15_N_DV1 + Q_BH_D_DV_G_15_S_DV1 = 0;
[941] - Q_BH_DV_15_DV2 + Q_BH_D_DV_G_15_E_DV2 + Q_BH_D_DV_G_15_N_DV2 + Q_BH_D_DV_G_15_S_DV2 = 0;
[942] - Q_BH_DV_15_DV3 + Q_BH_D_DV_G_15_E_DV3 + Q_BH_D_DV_G_15_N_DV3 + Q_BH_D_DV_G_15_S_DV3 = 0;
[943] - Q_BH_DV_15_DV4 + Q_BH_D_DV_G_15_E_DV4 + Q_BH_D_DV_G_15_N_DV4 + Q_BH_D_DV_G_15_S_DV4 = 0;
[944] - Q_BH_DV_16_DV1 + Q_BH_D_DV_G_16_E_DV1 + Q_BH_D_DV_G_16_N_DV1 + Q_BH_D_DV_G_16_S_DV1 = 0;
[945] - Q_BH_DV_16_DV2 + Q_BH_D_DV_G_16_E_DV2 + Q_BH_D_DV_G_16_N_DV2 + Q_BH_D_DV_G_16_S_DV2 = 0;
[946] - Q_BH_DV_16_DV3 + Q_BH_D_DV_G_16_E_DV3 + Q_BH_D_DV_G_16_N_DV3 + Q_BH_D_DV_G_16_S_DV3 = 0;
[947] - Q_BH_DV_16_DV4 + Q_BH_D_DV_G_16_E_DV4 + Q_BH_D_DV_G_16_N_DV4 + Q_BH_D_DV_G_16_S_DV4 = 0;
[948] - Q_BH_HV_G_1 - Q_BH_DV_1_DV1 - Q_BH_DV_1_DV2 - Q_BH_DV_1_DV3 - Q_BH_DV_1_DV4 = - 281.31831;
[949] - Q_BH_HV_G_2 - Q_BH_DV_2_DV1 - Q_BH_DV_2_DV2 - Q_BH_DV_2_DV3 - Q_BH_DV_2_DV4 = - 276.087;
[950] - Q_BH_HV_G_3 - Q_BH_DV_3_DV1 - Q_BH_DV_3_DV2 - Q_BH_DV_3_DV3 - Q_BH_DV_3_DV4 = - 282.9666;
[951] - Q_BH_HV_G_4 - Q_BH_DV_4_DV1 - Q_BH_DV_4_DV2 - Q_BH_DV_4_DV3 - Q_BH_DV_4_DV4 = - 246.304065;
[952] - Q_BH_HV_G_5 - Q_BH_DV_5_DV1 - Q_BH_DV_5_DV2 - Q_BH_DV_5_DV3 - Q_BH_DV_5_DV4 = - 297.155775;
[953] - Q_BH_HV_G_6 - Q_BH_DV_6_DV1 - Q_BH_DV_6_DV2 - Q_BH_DV_6_DV3 - Q_BH_DV_6_DV4 = - 369.26253;
[954] - Q_BH_HV_G_7 - Q_BH_DV_7_DV1 - Q_BH_DV_7_DV2 - Q_BH_DV_7_DV3 - Q_BH_DV_7_DV4 = - 380.77158;
[955] - Q_BH_HV_G_8 - Q_BH_DV_8_DV1 - Q_BH_DV_8_DV2 - Q_BH_DV_8_DV3 - Q_BH_DV_8_DV4 = - 252.86835;
[956] - Q_BH_HV_G_9 - Q_BH_DV_9_DV1 - Q_BH_DV_9_DV2 - Q_BH_DV_9_DV3 - Q_BH_DV_9_DV4 = - 419.36895;
[957] - Q_BH_HV_G_10 - Q_BH_DV_10_DV1 - Q_BH_DV_10_DV2 - Q_BH_DV_10_DV3 - Q_BH_DV_10_DV4 = - 531.176835;
[958] - Q_BH_HV_G_11 - Q_BH_DV_11_DV1 - Q_BH_DV_11_DV2 - Q_BH_DV_11_DV3 - Q_BH_DV_11_DV4 = - 150.49125;
[959] - Q_BH_HV_G_12 - Q_BH_DV_12_DV1 - Q_BH_DV_12_DV2 - Q_BH_DV_12_DV3 - Q_BH_DV_12_DV4 = - 131.701395;
[960] - Q_BH_HV_G_13 - Q_BH_DV_13_DV1 - Q_BH_DV_13_DV2 - Q_BH_DV_13_DV3 - Q_BH_DV_13_DV4 = - 222.834045;
[961] - Q_BH_HV_G_14 - Q_BH_DV_14_DV1 - Q_BH_DV_14_DV2 - Q_BH_DV_14_DV3 - Q_BH_DV_14_DV4 = - 101.90187;
[962] - Q_BH_HV_G_15 - Q_BH_DV_15_DV1 - Q_BH_DV_15_DV2 - Q_BH_DV_15_DV3 - Q_BH_DV_15_DV4 = - 34.9713;
[963] - Q_BH_HV_G_16 - Q_BH_DV_16_DV1 - Q_BH_DV_16_DV2 - Q_BH_DV_16_DV3 - Q_BH_DV_16_DV4 = - 121.8;
[964] - NO_TRIPS_BH_DV_1_DV1 + 0.1428571429 * Q_BH_DV_1_DV1 = 0;
[965] - NO_TRIPS_BH_DV_1_DV2 + 0.1111111111 * Q_BH_DV_1_DV2 = 0;
[966] - NO_TRIPS_BH_DV_1_DV3 + 0.1 * Q_BH_DV_1_DV3 = 0;
[967] - NO_TRIPS_BH_DV_1_DV4 + 0.1428571429 * Q_BH_DV_1_DV4 = 0;
[968] - NO_TRIPS_BH_DV_2_DV1 + 0.1428571429 * Q_BH_DV_2_DV1 = 0;
[969] - NO_TRIPS_BH_DV_2_DV2 + 0.1111111111 * Q_BH_DV_2_DV2 = 0;
[970] - NO_TRIPS_BH_DV_2_DV3 + 0.1 * Q_BH_DV_2_DV3 = 0;
[971] - NO_TRIPS_BH_DV_2_DV4 + 0.1428571429 * Q_BH_DV_2_DV4 = 0;
[972] - NO_TRIPS_BH_DV_3_DV1 + 0.1428571429 * Q_BH_DV_3_DV1 = 0;
[973] - NO_TRIPS_BH_DV_3_DV2 + 0.1111111111 * Q_BH_DV_3_DV2 = 0;
[974] - NO_TRIPS_BH_DV_3_DV3 + 0.1 * Q_BH_DV_3_DV3 = 0;
[975] - NO_TRIPS_BH_DV_3_DV4 + 0.1428571429 * Q_BH_DV_3_DV4 = 0;
[976] - NO_TRIPS_BH_DV_4_DV1 + 0.1428571429 * Q_BH_DV_4_DV1 = 0;
[977] - NO_TRIPS_BH_DV_4_DV2 + 0.1111111111 * Q_BH_DV_4_DV2 = 0;
[978] - NO_TRIPS_BH_DV_4_DV3 + 0.1 * Q_BH_DV_4_DV3 = 0;
[979] - NO_TRIPS_BH_DV_4_DV4 + 0.1428571429 * Q_BH_DV_4_DV4 = 0;
[980] - NO_TRIPS_BH_DV_5_DV1 + 0.1428571429 * Q_BH_DV_5_DV1 = 0;
[981] - NO_TRIPS_BH_DV_5_DV2 + 0.1111111111 * Q_BH_DV_5_DV2 = 0;
[982] - NO_TRIPS_BH_DV_5_DV3 + 0.1 * Q_BH_DV_5_DV3 = 0;
[983] - NO_TRIPS_BH_DV_5_DV4 + 0.1428571429 * Q_BH_DV_5_DV4 = 0;
[984] - NO_TRIPS_BH_DV_6_DV1 + 0.1428571429 * Q_BH_DV_6_DV1 = 0;
[985] - NO_TRIPS_BH_DV_6_DV2 + 0.1111111111 * Q_BH_DV_6_DV2 = 0;
[986] - NO_TRIPS_BH_DV_6_DV3 + 0.1 * Q_BH_DV_6_DV3 = 0;
[987] - NO_TRIPS_BH_DV_6_DV4 + 0.1428571429 * Q_BH_DV_6_DV4 = 0;
[988] - NO_TRIPS_BH_DV_7_DV1 + 0.1428571429 * Q_BH_DV_7_DV1 = 0;
[989] - NO_TRIPS_BH_DV_7_DV2 + 0.1111111111 * Q_BH_DV_7_DV2 = 0;
[990] - NO_TRIPS_BH_DV_7_DV3 + 0.1 * Q_BH_DV_7_DV3 = 0;
[991] - NO_TRIPS_BH_DV_7_DV4 + 0.1428571429 * Q_BH_DV_7_DV4 = 0;
[992] - NO_TRIPS_BH_DV_8_DV1 + 0.1428571429 * Q_BH_DV_8_DV1 = 0;
[993] - NO_TRIPS_BH_DV_8_DV2 + 0.1111111111 * Q_BH_DV_8_DV2 = 0;
[994] - NO_TRIPS_BH_DV_8_DV3 + 0.1 * Q_BH_DV_8_DV3 = 0;
[995] - NO_TRIPS_BH_DV_8_DV4 + 0.1428571429 * Q_BH_DV_8_DV4 = 0;

Annexure 9

[_996]- NO_TRIPS_BH_DV_9_DV1 + 0.1428571429 * Q_BH_DV_9_DV1 = 0;
 [_997]- NO_TRIPS_BH_DV_9_DV2 + 0.1111111111 * Q_BH_DV_9_DV2 = 0;
 [_998]- NO_TRIPS_BH_DV_9_DV3 + 0.1 * Q_BH_DV_9_DV3 = 0;
 [_999]- NO_TRIPS_BH_DV_9_DV4 + 0.1428571429 * Q_BH_DV_9_DV4 = 0;
 [_1000]- NO_TRIPS_BH_DV_10_DV1 + 0.1428571429 * Q_BH_DV_10_DV1 = 0;
 [_1001]- NO_TRIPS_BH_DV_10_DV2 + 0.1111111111 * Q_BH_DV_10_DV2 = 0;
 [_1002]- NO_TRIPS_BH_DV_10_DV3 + 0.1 * Q_BH_DV_10_DV3 = 0;
 [_1003]- NO_TRIPS_BH_DV_10_DV4 + 0.1428571429 * Q_BH_DV_10_DV4 = 0;
 [_1004]- NO_TRIPS_BH_DV_11_DV1 + 0.1428571429 * Q_BH_DV_11_DV1 = 0;
 [_1005]- NO_TRIPS_BH_DV_11_DV2 + 0.1111111111 * Q_BH_DV_11_DV2 = 0;
 [_1006]- NO_TRIPS_BH_DV_11_DV3 + 0.1 * Q_BH_DV_11_DV3 = 0;
 [_1007]- NO_TRIPS_BH_DV_11_DV4 + 0.1428571429 * Q_BH_DV_11_DV4 = 0;
 [_1008]- NO_TRIPS_BH_DV_12_DV1 + 0.1428571429 * Q_BH_DV_12_DV1 = 0;
 [_1009]- NO_TRIPS_BH_DV_12_DV2 + 0.1111111111 * Q_BH_DV_12_DV2 = 0;
 [_1010]- NO_TRIPS_BH_DV_12_DV3 + 0.1 * Q_BH_DV_12_DV3 = 0;
 [_1011]- NO_TRIPS_BH_DV_12_DV4 + 0.1428571429 * Q_BH_DV_12_DV4 = 0;
 [_1012]- NO_TRIPS_BH_DV_13_DV1 + 0.1428571429 * Q_BH_DV_13_DV1 = 0;
 [_1013]- NO_TRIPS_BH_DV_13_DV2 + 0.1111111111 * Q_BH_DV_13_DV2 = 0;
 [_1014]- NO_TRIPS_BH_DV_13_DV3 + 0.1 * Q_BH_DV_13_DV3 = 0;
 [_1015]- NO_TRIPS_BH_DV_13_DV4 + 0.1428571429 * Q_BH_DV_13_DV4 = 0;
 [_1016]- NO_TRIPS_BH_DV_14_DV1 + 0.1428571429 * Q_BH_DV_14_DV1 = 0;
 [_1017]- NO_TRIPS_BH_DV_14_DV2 + 0.1111111111 * Q_BH_DV_14_DV2 = 0;
 [_1018]- NO_TRIPS_BH_DV_14_DV3 + 0.1 * Q_BH_DV_14_DV3 = 0;
 [_1019]- NO_TRIPS_BH_DV_14_DV4 + 0.1428571429 * Q_BH_DV_14_DV4 = 0;
 [_1020]- NO_TRIPS_BH_DV_15_DV1 + 0.1428571429 * Q_BH_DV_15_DV1 = 0;
 [_1021]- NO_TRIPS_BH_DV_15_DV2 + 0.1111111111 * Q_BH_DV_15_DV2 = 0;
 [_1022]- NO_TRIPS_BH_DV_15_DV3 + 0.1 * Q_BH_DV_15_DV3 = 0;
 [_1023]- NO_TRIPS_BH_DV_15_DV4 + 0.1428571429 * Q_BH_DV_15_DV4 = 0;
 [_1024]- NO_TRIPS_BH_DV_16_DV1 + 0.1428571429 * Q_BH_DV_16_DV1 = 0;
 [_1025]- NO_TRIPS_BH_DV_16_DV2 + 0.1111111111 * Q_BH_DV_16_DV2 = 0;
 [_1026]- NO_TRIPS_BH_DV_16_DV3 + 0.1 * Q_BH_DV_16_DV3 = 0;
 [_1027]- NO_TRIPS_BH_DV_16_DV4 + 0.1428571429 * Q_BH_DV_16_DV4 = 0;
 [_1028]- TOT_QUANT_DV_DV1 + Q_BH_DV_1_DV1 + Q_BH_DV_2_DV1 + Q_BH_DV_3_DV1 + Q_BH_DV_4_DV1 + Q_BH_DV_5_DV1 + Q_BH_DV_6_DV1 + Q_BH_DV_7_DV1 + Q_BH_DV_8_DV1 + Q_BH_DV_9_DV1 + Q_BH_DV_10_DV1 + Q_BH_DV_11_DV1 + Q_BH_DV_12_DV1 + Q_BH_DV_13_DV1 + Q_BH_DV_14_DV1 + Q_BH_DV_15_DV1 + Q_BH_DV_16_DV1 = 0;
 [_1029]- TOT_QUANT_DV_DV2 + Q_BH_DV_1_DV2 + Q_BH_DV_2_DV2 + Q_BH_DV_3_DV2 + Q_BH_DV_4_DV2 + Q_BH_DV_5_DV2 + Q_BH_DV_6_DV2 + Q_BH_DV_7_DV2 + Q_BH_DV_8_DV2 + Q_BH_DV_9_DV2 + Q_BH_DV_10_DV2 + Q_BH_DV_11_DV2 + Q_BH_DV_12_DV2 + Q_BH_DV_13_DV2 + Q_BH_DV_14_DV2 + Q_BH_DV_15_DV2 + Q_BH_DV_16_DV2 = 0;
 [_1030]- TOT_QUANT_DV_DV3 + Q_BH_DV_1_DV3 + Q_BH_DV_2_DV3 + Q_BH_DV_3_DV3 + Q_BH_DV_4_DV3 + Q_BH_DV_5_DV3 + Q_BH_DV_6_DV3 + Q_BH_DV_7_DV3 + Q_BH_DV_8_DV3 + Q_BH_DV_9_DV3 + Q_BH_DV_10_DV3 + Q_BH_DV_11_DV3 + Q_BH_DV_12_DV3 + Q_BH_DV_13_DV3 + Q_BH_DV_14_DV3 + Q_BH_DV_15_DV3 + Q_BH_DV_16_DV3 = 0;
 [_1031]- TOT_QUANT_DV_DV4 + Q_BH_DV_1_DV4 + Q_BH_DV_2_DV4 + Q_BH_DV_3_DV4 + Q_BH_DV_4_DV4 + Q_BH_DV_5_DV4 + Q_BH_DV_6_DV4 + Q_BH_DV_7_DV4 + Q_BH_DV_8_DV4 + Q_BH_DV_9_DV4 + Q_BH_DV_10_DV4 + Q_BH_DV_11_DV4 + Q_BH_DV_12_DV4 + Q_BH_DV_13_DV4 + Q_BH_DV_14_DV4 + Q_BH_DV_15_DV4 + Q_BH_DV_16_DV4 = 0;
 [_1032]- Z_DV_TRIPS_DV1_1 + AT_DV_D_Z_DV1_E_1 + AT_DV_D_Z_DV1_N_1 + AT_DV_D_Z_DV1_S_1 = 0;
 [_1033]- Z_DV_TRIPS_DV1_2 + AT_DV_D_Z_DV1_E_2 + AT_DV_D_Z_DV1_N_2 + AT_DV_D_Z_DV1_S_2 = 0;
 [_1034]- Z_DV_TRIPS_DV2_1 + AT_DV_D_Z_DV2_E_1 + AT_DV_D_Z_DV2_N_1 + AT_DV_D_Z_DV2_S_1 = 0;
 [_1035]- Z_DV_TRIPS_DV2_2 + AT_DV_D_Z_DV2_E_2 + AT_DV_D_Z_DV2_N_2 + AT_DV_D_Z_DV2_S_2 = 0;
 [_1036]- Z_DV_TRIPS_DV3_1 + AT_DV_D_Z_DV3_E_1 + AT_DV_D_Z_DV3_N_1 + AT_DV_D_Z_DV3_S_1 = 0;
 [_1037]- Z_DV_TRIPS_DV3_2 + AT_DV_D_Z_DV3_E_2 + AT_DV_D_Z_DV3_N_2 + AT_DV_D_Z_DV3_S_2 = 0;
 [_1038]- Z_DV_TRIPS_DV4_1 + AT_DV_D_Z_DV4_E_1 + AT_DV_D_Z_DV4_N_1 + AT_DV_D_Z_DV4_S_1 = 0;
 [_1039]- Z_DV_TRIPS_DV4_2 + AT_DV_D_Z_DV4_E_2 + AT_DV_D_Z_DV4_N_2 + AT_DV_D_Z_DV4_S_2 = 0;
 [_1040]- CO_EF_BH_DV_1_DV1 + 13.26 * Q_BH_D_DV1_G_1_E + 2.598 * Q_BH_D_DV1_G_1_N + 22.33 * Q_BH_D_DV1_G_1_S = 0;
 [_1041]- CO_EF_BH_DV_2_DV1 + 10.613 * Q_BH_D_DV1_G_2_E + 5.464 * Q_BH_D_DV1_G_2_N + 19.25 * Q_BH_D_DV1_G_2_S = 0;
 [_1042]- CO_EF_BH_DV_3_DV1 + 8.536 * Q_BH_D_DV1_G_3_E + 8.633 * Q_BH_D_DV1_G_3_N + 20.36 * Q_BH_D_DV1_G_3_S = 0;
 [_1043]- CO_EF_BH_DV_4_DV1 + 9.313 * Q_BH_D_DV1_G_4_E + 7.322 * Q_BH_D_DV1_G_4_N + 17.595 * Q_BH_D_DV1_G_4_S = 0;
 [_1044]- CO_EF_BH_DV_5_DV1 + 7.832 * Q_BH_D_DV1_G_5_E + 8.913 * Q_BH_D_DV1_G_5_N + 15.99 * Q_BH_D_DV1_G_5_S = 0;
 [_1045]- CO_EF_BH_DV_6_DV1 + 7.213 * Q_BH_D_DV1_G_6_E + 11.026 * Q_BH_D_DV1_G_6_N + 14.98 * Q_BH_D_DV1_G_6_S = 0;
 [_1046]- CO_EF_BH_DV_7_DV1 + 2.003 * Q_BH_D_DV1_G_7_E + 13.745 * Q_BH_D_DV1_G_7_N + 14.95 * Q_BH_D_DV1_G_7_S = 0;
 [_1047]- CO_EF_BH_DV_8_DV1 + 6.31 * Q_BH_D_DV1_G_8_E + 15.664 * Q_BH_D_DV1_G_8_N + 9.75 * Q_BH_D_DV1_G_8_S = 0;
 [_1048]- CO_EF_BH_DV_9_DV1 + 10.98 * Q_BH_D_DV1_G_9_E + 17.41 * Q_BH_D_DV1_G_9_N + 10.92 * Q_BH_D_DV1_G_9_S = 0;
 [_1049]- CO_EF_BH_DV_10_DV1 + 9.799 * Q_BH_D_DV1_G_10_E + 20.36 * Q_BH_D_DV1_G_10_N + 7.486 * Q_BH_D_DV1_G_10_S = 0;
 [_1050]- CO_EF_BH_DV_11_DV1 + 12.434 * Q_BH_D_DV1_G_11_E + 23.64 * Q_BH_D_DV1_G_11_N + 5.82 * Q_BH_D_DV1_G_11_S = 0;

[_1051] - CO_EF_BH_DV_12_DV1 + 4.893 * Q_BH_D_DV1_G_12_E + 20.27 * Q_BH_D_DV1_G_12_N + 13.59 * Q_BH_D_DV1_G_12_S = 0;

[_1052] - CO_EF_BH_DV_13_DV1 + 13.988 * Q_BH_D_DV1_G_13_E + 23.16 * Q_BH_D_DV1_G_13_N + 4.298 * Q_BH_D_DV1_G_13_S = 0;

[_1053] - CO_EF_BH_DV_14_DV1 + 17 * Q_BH_D_DV1_G_14_E + 24.14 * Q_BH_D_DV1_G_14_N + 8.32 * Q_BH_D_DV1_G_14_S = 0;

[_1054] - CO_EF_BH_DV_15_DV1 + 19.404 * Q_BH_D_DV1_G_15_E + 24.59 * Q_BH_D_DV1_G_15_N + 19.79 * Q_BH_D_DV1_G_15_S = 0;

[_1055] - CO_EF_BH_DV_16_DV1 + 19.55 * Q_BH_D_DV1_G_16_E + 27.80714286 * Q_BH_D_DV1_G_16_N + 2.55 * Q_BH_D_DV1_G_16_S = 0;

[_1056] - SO2_EF_BH_DV_1_DV1 + 0.895 * Q_BH_D_DV1_G_1_E + 0.175 * Q_BH_D_DV1_G_1_N + 1.508 * Q_BH_D_DV1_G_1_S = 0;

[_1057] - SO2_EF_BH_DV_2_DV1 + 0.717 * Q_BH_D_DV1_G_2_E + 0.369 * Q_BH_D_DV1_G_2_N + 1.299 * Q_BH_D_DV1_G_2_S = 0;

[_1058] - SO2_EF_BH_DV_3_DV1 + 0.576 * Q_BH_D_DV1_G_3_E + 0.583 * Q_BH_D_DV1_G_3_N + 1.375 * Q_BH_D_DV1_G_3_S = 0;

[_1059] - SO2_EF_BH_DV_4_DV1 + 0.629 * Q_BH_D_DV1_G_4_E + 0.494 * Q_BH_D_DV1_G_4_N + 1.188 * Q_BH_D_DV1_G_4_S = 0;

[_1060] - SO2_EF_BH_DV_5_DV1 + 0.529 * Q_BH_D_DV1_G_5_E + 0.602 * Q_BH_D_DV1_G_5_N + 1.079 * Q_BH_D_DV1_G_5_S = 0;

[_1061] - SO2_EF_BH_DV_6_DV1 + 0.487 * Q_BH_D_DV1_G_6_E + 0.744 * Q_BH_D_DV1_G_6_N + 1.012 * Q_BH_D_DV1_G_6_S = 0;

[_1062] - SO2_EF_BH_DV_7_DV1 + 0.135 * Q_BH_D_DV1_G_7_E + 0.928 * Q_BH_D_DV1_G_7_N + 1.009 * Q_BH_D_DV1_G_7_S = 0;

[_1063] - SO2_EF_BH_DV_8_DV1 + 0.426 * Q_BH_D_DV1_G_8_E + 1.058 * Q_BH_D_DV1_G_8_N + 0.658 * Q_BH_D_DV1_G_8_S = 0;

[_1064] - SO2_EF_BH_DV_9_DV1 + 0.741 * Q_BH_D_DV1_G_9_E + 1.176 * Q_BH_D_DV1_G_9_N + 0.737 * Q_BH_D_DV1_G_9_S = 0;

[_1065] - SO2_EF_BH_DV_10_DV1 + 0.662 * Q_BH_D_DV1_G_10_E + 1.375 * Q_BH_D_DV1_G_10_N + 0.505 * Q_BH_D_DV1_G_10_S = 0;

[_1066] - SO2_EF_BH_DV_11_DV1 + 0.839 * Q_BH_D_DV1_G_11_E + 1.596 * Q_BH_D_DV1_G_11_N + 0.393 * Q_BH_D_DV1_G_11_S = 0;

[_1067] - SO2_EF_BH_DV_12_DV1 + 0.3305 * Q_BH_D_DV1_G_12_E + 1.368 * Q_BH_D_DV1_G_12_N + 0.917 * Q_BH_D_DV1_G_12_S = 0;

[_1068] - SO2_EF_BH_DV_13_DV1 + 0.945 * Q_BH_D_DV1_G_13_E + 1.564 * Q_BH_D_DV1_G_13_N + 0.29 * Q_BH_D_DV1_G_13_S = 0;

[_1069] - SO2_EF_BH_DV_14_DV1 + 1.148 * Q_BH_D_DV1_G_14_E + 1.63 * Q_BH_D_DV1_G_14_N + 0.562 * Q_BH_D_DV1_G_14_S = 0;

[_1070] - SO2_EF_BH_DV_15_DV1 + 1.31 * Q_BH_D_DV1_G_15_E + 1.66 * Q_BH_D_DV1_G_15_N + 1.34 * Q_BH_D_DV1_G_15_S = 0;

[_1071] - SO2_EF_BH_DV_16_DV1 + 1.3202 * Q_BH_D_DV1_G_16_E + 1.8778 * Q_BH_D_DV1_G_16_N + 0.1722 * Q_BH_D_DV1_G_16_S = 0;

[_1072] - CO2_EF_BH_DV_1_DV1 + 4059.81 * Q_BH_D_DV1_G_1_E + 795.605 * Q_BH_D_DV1_G_1_N + 6836.99 * Q_BH_D_DV1_G_1_S = 0;

[_1073] - CO2_EF_BH_DV_2_DV1 + 3249.33 * Q_BH_D_DV1_G_2_E + 1672.99 * Q_BH_D_DV1_G_2_N + 5892.67 * Q_BH_D_DV1_G_2_S = 0;

[_1074] - CO2_EF_BH_DV_3_DV1 + 2613.59 * Q_BH_D_DV1_G_3_E + 2643.34 * Q_BH_D_DV1_G_3_N + 6234.71 * Q_BH_D_DV1_G_3_S = 0;

[_1075] - CO2_EF_BH_DV_4_DV1 + 2851.53 * Q_BH_D_DV1_G_4_E + 2241.82 * Q_BH_D_DV1_G_4_N + 5387.06 * Q_BH_D_DV1_G_4_S = 0;

[_1076] - CO2_EF_BH_DV_5_DV1 + 2397.96 * Q_BH_D_DV1_G_5_E + 2728.847 * Q_BH_D_DV1_G_5_N + 4896.31 * Q_BH_D_DV1_G_5_S = 0;

[_1077] - CO2_EF_BH_DV_6_DV1 + 2208.36 * Q_BH_D_DV1_G_6_E + 3375.74 * Q_BH_D_DV1_G_6_N + 4587.74 * Q_BH_D_DV1_G_6_S = 0;

[_1078] - CO2_EF_BH_DV_7_DV1 + 613.43 * Q_BH_D_DV1_G_7_E + 4208.52 * Q_BH_D_DV1_G_7_N + 4576.58 * Q_BH_D_DV1_G_7_S = 0;

[_1079] - CO2_EF_BH_DV_8_DV1 + 1931.38 * Q_BH_D_DV1_G_8_E + 4795.93 * Q_BH_D_DV1_G_8_N + 2985.37 * Q_BH_D_DV1_G_8_S = 0;

[_1080] - CO2_EF_BH_DV_9_DV1 + 3360.86 * Q_BH_D_DV1_G_9_E + 5331.29 * Q_BH_D_DV1_G_9_N + 3343.77 * Q_BH_D_DV1_G_9_S = 0;

[_1081] - CO2_EF_BH_DV_10_DV1 + 3000.245 * Q_BH_D_DV1_G_10_E + 6234.71 * Q_BH_D_DV1_G_10_N + 2292 * Q_BH_D_DV1_G_10_S = 0;

[_1082] - CO2_EF_BH_DV_11_DV1 + 3807 * Q_BH_D_DV1_G_11_E + 7238.51 * Q_BH_D_DV1_G_11_N + 1783.05 * Q_BH_D_DV1_G_11_S = 0;

[_1083] - CO2_EF_BH_DV_12_DV1 + 1498.26 * Q_BH_D_DV1_G_12_E + 6204.96 * Q_BH_D_DV1_G_12_N + 4160.19 * Q_BH_D_DV1_G_12_S = 0;

[_1084] - CO2_EF_BH_DV_13_DV1 + 4282.88 * Q_BH_D_DV1_G_13_E + 7089.79 * Q_BH_D_DV1_G_13_N + 1316.09 * Q_BH_D_DV1_G_13_S = 0;

[_1085] - CO2_EF_BH_DV_14_DV1 + 5204.89 * Q_BH_D_DV1_G_14_E + 7390.94 * Q_BH_D_DV1_G_14_N + 2546.67 * Q_BH_D_DV1_G_14_S = 0;

[_1086] - CO2_EF_BH_DV_15_DV1 + 5941 * Q_BH_D_DV1_G_15_E + 7528.49 * Q_BH_D_DV1_G_15_N + 6059.98 * Q_BH_D_DV1_G_15_S = 0;

[_1087] - CO2_EF_BH_DV_16_DV1 + 5985.618571 * Q_BH_D_DV1_G_16_E + 8513.705918 * Q_BH_D_DV1_G_16_N + 780.7328571 * Q_BH_D_DV1_G_16_S = 0;

[_1088] - HC_EF_BH_DV_1_DV1 + 3.625 * Q_BH_D_DV1_G_1_E + 0.71 * Q_BH_D_DV1_G_1_N + 6.105 * Q_BH_D_DV1_G_1_S = 0;

[_1089] - HC_EF_BH_DV_2_DV1 + 2.901 * Q_BH_D_DV1_G_2_E + 1.494 * Q_BH_D_DV1_G_2_N + 5.262 * Q_BH_D_DV1_G_2_S = 0;

Annexure 9

[_1090] - HC_EF_BH_DV_3_DV1 + 2.33 * Q_BH_D_DV1_G_3_E + 2.36 * Q_BH_D_DV1_G_3_N + 5.567 * Q_BH_D_DV1_G_3_S = 0;

[_1091] - HC_EF_BH_DV_4_DV1 + 2.55 * Q_BH_D_DV1_G_4_E + 2 * Q_BH_D_DV1_G_4_N + 4.81 * Q_BH_D_DV1_G_4_S = 0;

[_1092] - HC_EF_BH_DV_5_DV1 + 2.14 * Q_BH_D_DV1_G_5_E + 2.436 * Q_BH_D_DV1_G_5_N + 4.372 * Q_BH_D_DV1_G_5_S = 0;

[_1093] - HC_EF_BH_DV_6_DV1 + 1.972 * Q_BH_D_DV1_G_6_E + 3.014 * Q_BH_D_DV1_G_6_N + 4.097 * Q_BH_D_DV1_G_6_S = 0;

[_1094] - HC_EF_BH_DV_7_DV1 + 0.548 * Q_BH_D_DV1_G_7_E + 3.758 * Q_BH_D_DV1_G_7_N + 4.086 * Q_BH_D_DV1_G_7_S = 0;

[_1095] - HC_EF_BH_DV_8_DV1 + 1.725 * Q_BH_D_DV1_G_8_E + 4.283 * Q_BH_D_DV1_G_8_N + 2.666 * Q_BH_D_DV1_G_8_S = 0;

[_1096] - HC_EF_BH_DV_9_DV1 + 3 * Q_BH_D_DV1_G_9_E + 4.76 * Q_BH_D_DV1_G_9_N + 2.986 * Q_BH_D_DV1_G_9_S = 0;

[_1097] - HC_EF_BH_DV_10_DV1 + 2.679 * Q_BH_D_DV1_G_10_E + 5.567 * Q_BH_D_DV1_G_10_N + 2.047 * Q_BH_D_DV1_G_10_S = 0;

[_1098] - HC_EF_BH_DV_11_DV1 + 3.399 * Q_BH_D_DV1_G_11_E + 6.464 * Q_BH_D_DV1_G_11_N + 1.592 * Q_BH_D_DV1_G_11_S = 0;

[_1099] - HC_EF_BH_DV_12_DV1 + 1.338 * Q_BH_D_DV1_G_12_E + 5.541 * Q_BH_D_DV1_G_12_N + 3.715 * Q_BH_D_DV1_G_12_S = 0;

[_1100] - HC_EF_BH_DV_13_DV1 + 3.825 * Q_BH_D_DV1_G_13_E + 6.33 * Q_BH_D_DV1_G_13_N + 1.175 * Q_BH_D_DV1_G_13_S = 0;

[_1101] - HC_EF_BH_DV_14_DV1 + 4.648 * Q_BH_D_DV1_G_14_E + 6.6 * Q_BH_D_DV1_G_14_N + 2.274 * Q_BH_D_DV1_G_14_S = 0;

[_1102] - HC_EF_BH_DV_15_DV1 + 5.305 * Q_BH_D_DV1_G_15_E + 6.723 * Q_BH_D_DV1_G_15_N + 5.412 * Q_BH_D_DV1_G_15_S = 0;

[_1103] - HC_EF_BH_DV_16_DV1 + 5.3452 * Q_BH_D_DV1_G_16_E + 7.6028 * Q_BH_D_DV1_G_16_N + 0.6972 * Q_BH_D_DV1_G_16_S = 0;

[_1104] - NOX_EF_BH_DV_1_DV1 + 23.58 * Q_BH_D_DV1_G_1_E + 4.62 * Q_BH_D_DV1_G_1_N + 39.706 * Q_BH_D_DV1_G_1_S = 0;

[_1105] - NOX_EF_BH_DV_2_DV1 + 18.87 * Q_BH_D_DV1_G_2_E + 9.716 * Q_BH_D_DV1_G_2_N + 34.22 * Q_BH_D_DV1_G_2_S = 0;

[_1106] - NOX_EF_BH_DV_3_DV1 + 15.18 * Q_BH_D_DV1_G_3_E + 15.35 * Q_BH_D_DV1_G_3_N + 36.21 * Q_BH_D_DV1_G_3_S = 0;

[_1107] - NOX_EF_BH_DV_4_DV1 + 16.56 * Q_BH_D_DV1_G_4_E + 13.02 * Q_BH_D_DV1_G_4_N + 31.286 * Q_BH_D_DV1_G_4_S = 0;

[_1108] - NOX_EF_BH_DV_5_DV1 + 13.93 * Q_BH_D_DV1_G_5_E + 15.85 * Q_BH_D_DV1_G_5_N + 28.436 * Q_BH_D_DV1_G_5_S = 0;

[_1109] - NOX_EF_BH_DV_6_DV1 + 12.825 * Q_BH_D_DV1_G_6_E + 19.605 * Q_BH_D_DV1_G_6_N + 26.64 * Q_BH_D_DV1_G_6_S = 0;

[_1110] - NOX_EF_BH_DV_7_DV1 + 3.562 * Q_BH_D_DV1_G_7_E + 24.44 * Q_BH_D_DV1_G_7_N + 26.58 * Q_BH_D_DV1_G_7_S = 0;

[_1111] - NOX_EF_BH_DV_8_DV1 + 11.22 * Q_BH_D_DV1_G_8_E + 27.85 * Q_BH_D_DV1_G_8_N + 17.34 * Q_BH_D_DV1_G_8_S = 0;

[_1112] - NOX_EF_BH_DV_9_DV1 + 19.52 * Q_BH_D_DV1_G_9_E + 30.96 * Q_BH_D_DV1_G_9_N + 19.42 * Q_BH_D_DV1_G_9_S = 0;

[_1113] - NOX_EF_BH_DV_10_DV1 + 17.424 * Q_BH_D_DV1_G_10_E + 36.21 * Q_BH_D_DV1_G_10_N + 13.31 * Q_BH_D_DV1_G_10_S = 0;

[_1114] - NOX_EF_BH_DV_11_DV1 + 22.11 * Q_BH_D_DV1_G_11_E + 42.04 * Q_BH_D_DV1_G_11_N + 10.35 * Q_BH_D_DV1_G_11_S = 0;

[_1115] - NOX_EF_BH_DV_12_DV1 + 8.701 * Q_BH_D_DV1_G_12_E + 36.04 * Q_BH_D_DV1_G_12_N + 24.16 * Q_BH_D_DV1_G_12_S = 0;

[_1116] - NOX_EF_BH_DV_13_DV1 + 24.87 * Q_BH_D_DV1_G_13_E + 41.17 * Q_BH_D_DV1_G_13_N + 7.64 * Q_BH_D_DV1_G_13_S = 0;

[_1117] - NOX_EF_BH_DV_14_DV1 + 30.23 * Q_BH_D_DV1_G_14_E + 42.924 * Q_BH_D_DV1_G_14_N + 14.79 * Q_BH_D_DV1_G_14_S = 0;

[_1118] - NOX_EF_BH_DV_15_DV1 + 34.503 * Q_BH_D_DV1_G_15_E + 43.72 * Q_BH_D_DV1_G_15_N + 35.19 * Q_BH_D_DV1_G_15_S = 0;

[_1119] - NOX_EF_BH_DV_16_DV1 + 34.7622 * Q_BH_D_DV1_G_16_E + 49.44437143 * Q_BH_D_DV1_G_16_N + 4.5342 * Q_BH_D_DV1_G_16_S = 0;

[_1120] - PM_EF_BH_DV_1_DV1 + 2.134 * Q_BH_D_DV1_G_1_E + 0.418 * Q_BH_D_DV1_G_1_N + 3.593 * Q_BH_D_DV1_G_1_S = 0;

[_1121] - PM_EF_BH_DV_2_DV1 + 1.71 * Q_BH_D_DV1_G_2_E + 0.879 * Q_BH_D_DV1_G_2_N + 3.097 * Q_BH_D_DV1_G_2_S = 0;

[_1122] - PM_EF_BH_DV_3_DV1 + 1.374 * Q_BH_D_DV1_G_3_E + 1.389 * Q_BH_D_DV1_G_3_N + 3.278 * Q_BH_D_DV1_G_3_S = 0;

[_1123] - PM_EF_BH_DV_4_DV1 + 1.498 * Q_BH_D_DV1_G_4_E + 1.178 * Q_BH_D_DV1_G_4_N + 2.832 * Q_BH_D_DV1_G_4_S = 0;

[_1124] - PM_EF_BH_DV_5_DV1 + 1.26 * Q_BH_D_DV1_G_5_E + 1.434 * Q_BH_D_DV1_G_5_N + 2.574 * Q_BH_D_DV1_G_5_S = 0;

[_1125] - PM_EF_BH_DV_6_DV1 + 1.161 * Q_BH_D_DV1_G_6_E + 1.774 * Q_BH_D_DV1_G_6_N + 2.411 * Q_BH_D_DV1_G_6_S = 0;

[_1126] - PM_EF_BH_DV_7_DV1 + 0.322 * Q_BH_D_DV1_G_7_E + 2.212 * Q_BH_D_DV1_G_7_N + 2.406 * Q_BH_D_DV1_G_7_S = 0;

[_1127] - PM_EF_BH_DV_8_DV1 + 1.015 * Q_BH_D_DV1_G_8_E + 2.521 * Q_BH_D_DV1_G_8_N + 1.569 * Q_BH_D_DV1_G_8_S = 0;

[_1128] - PM_EF_BH_DV_9_DV1 + 1.77 * Q_BH_D_DV1_G_9_E + 2.802 * Q_BH_D_DV1_G_9_N + 1.757 * Q_BH_D_DV1_G_9_S = 0;

[_1129] - PM_EF_BH_DV_10_DV1 + 1.58 * Q_BH_D_DV1_G_10_E + 3.278 * Q_BH_D_DV1_G_10_N + 1.205 * Q_BH_D_DV1_G_10_S = 0;

[_1130] - PM_EF_BH_DV_11_DV1 + 2.001 * Q_BH_D_DV1_G_11_E + 3.804 * Q_BH_D_DV1_G_11_N + 0.937 * Q_BH_D_DV1_G_11_S = 0;

[_1131] - PM_EF_BH_DV_12_DV1 + 0.787 * Q_BH_D_DV1_G_12_E + 3.262 * Q_BH_D_DV1_G_12_N + 2.187 * Q_BH_D_DV1_G_12_S = 0;

[_1132] - PM_EF_BH_DV_13_DV1 + 2.251 * Q_BH_D_DV1_G_13_E + 3.727 * Q_BH_D_DV1_G_13_N + 0.692 * Q_BH_D_DV1_G_13_S = 0;

[_1133] - PM_EF_BH_DV_14_DV1 + 2.736 * Q_BH_D_DV1_G_14_E + 3.885 * Q_BH_D_DV1_G_14_N + 1.338 * Q_BH_D_DV1_G_14_S = 0;

[_1134] - PM_EF_BH_DV_15_DV1 + 3.122 * Q_BH_D_DV1_G_15_E + 3.957 * Q_BH_D_DV1_G_15_N + 3.185 * Q_BH_D_DV1_G_15_S = 0;

[_1135] - PM_EF_BH_DV_16_DV1 + 3.1464 * Q_BH_D_DV1_G_16_E + 4.475314286 * Q_BH_D_DV1_G_16_N + 0.4104 * Q_BH_D_DV1_G_16_S = 0;

[_1136] - BENZ_EF_BH_DV_1_DV1 + 0.18E-01 * Q_BH_D_DV1_G_1_E + 0.35E-02 * Q_BH_D_DV1_G_1_N + 0.304E-01 * Q_BH_D_DV1_G_1_S = 0;

[_1137] - BENZ_EF_BH_DV_2_DV1 + 0.14E-01 * Q_BH_D_DV1_G_2_E + 0.75E-02 * Q_BH_D_DV1_G_2_N + 0.26E-01 * Q_BH_D_DV1_G_2_S = 0;

[_1138] - BENZ_EF_BH_DV_3_DV1 + 0.12E-01 * Q_BH_D_DV1_G_3_E + 0.12E-01 * Q_BH_D_DV1_G_3_N + 0.28E-01 * Q_BH_D_DV1_G_3_S = 0;

[_1139] - BENZ_EF_BH_DV_4_DV1 + 0.13E-01 * Q_BH_D_DV1_G_4_E + 0.99E-02 * Q_BH_D_DV1_G_4_N + 0.24E-01 * Q_BH_D_DV1_G_4_S = 0;

[_1140] - BENZ_EF_BH_DV_5_DV1 + 0.11E-01 * Q_BH_D_DV1_G_5_E + 0.122E-01 * Q_BH_D_DV1_G_5_N + 0.22E-01 * Q_BH_D_DV1_G_5_S = 0;

[_1141] - BENZ_EF_BH_DV_6_DV1 + 0.98E-02 * Q_BH_D_DV1_G_6_E + 0.15E-01 * Q_BH_D_DV1_G_6_N + 0.2E-01 * Q_BH_D_DV1_G_6_S = 0;

[_1142] - BENZ_EF_BH_DV_7_DV1 + 0.27E-02 * Q_BH_D_DV1_G_7_E + 0.187E-01 * Q_BH_D_DV1_G_7_N + 0.204E-01 * Q_BH_D_DV1_G_7_S = 0;

[_1143] - BENZ_EF_BH_DV_8_DV1 + 0.86E-02 * Q_BH_D_DV1_G_8_E + 0.21E-01 * Q_BH_D_DV1_G_8_N + 0.13E-01 * Q_BH_D_DV1_G_8_S = 0;

[_1144] - BENZ_EF_BH_DV_9_DV1 + 0.15E-01 * Q_BH_D_DV1_G_9_E + 0.24E-01 * Q_BH_D_DV1_G_9_N + 0.15E-01 * Q_BH_D_DV1_G_9_S = 0;

[_1145] - BENZ_EF_BH_DV_10_DV1 + 0.13E-01 * Q_BH_D_DV1_G_10_E + 0.28E-01 * Q_BH_D_DV1_G_10_N + 0.1E-01 * Q_BH_D_DV1_G_10_S = 0;

[_1146] - BENZ_EF_BH_DV_11_DV1 + 0.17E-01 * Q_BH_D_DV1_G_11_E + 0.32E-01 * Q_BH_D_DV1_G_11_N + 0.79E-02 * Q_BH_D_DV1_G_11_S = 0;

[_1147] - BENZ_EF_BH_DV_12_DV1 + 0.67E-02 * Q_BH_D_DV1_G_12_E + 0.28E-01 * Q_BH_D_DV1_G_12_N + 0.18E-01 * Q_BH_D_DV1_G_12_S = 0;

[_1148] - BENZ_EF_BH_DV_13_DV1 + 0.19E-01 * Q_BH_D_DV1_G_13_E + 0.32E-01 * Q_BH_D_DV1_G_13_N + 0.59E-02 * Q_BH_D_DV1_G_13_S = 0;

[_1149] - BENZ_EF_BH_DV_14_DV1 + 0.23E-01 * Q_BH_D_DV1_G_14_E + 0.33E-01 * Q_BH_D_DV1_G_14_N + 0.11E-01 * Q_BH_D_DV1_G_14_S = 0;

[_1150] - BENZ_EF_BH_DV_15_DV1 + 0.26E-01 * Q_BH_D_DV1_G_15_E + 0.34E-01 * Q_BH_D_DV1_G_15_N + 0.27E-01 * Q_BH_D_DV1_G_15_S = 0;

[_1151] - BENZ_EF_BH_DV_16_DV1 + 0.2668E-01 * Q_BH_D_DV1_G_16_E + 0.3794857143E-01 * Q_BH_D_DV1_G_16_N + 0.348E-02 * Q_BH_D_DV1_G_16_S = 0;

[_1152] - BUTDN_EF_BH_DV_1_DV1 + 0.34E-02 * Q_BH_D_DV1_G_1_E + 0.67E-03 * Q_BH_D_DV1_G_1_N + 0.58E-02 * Q_BH_D_DV1_G_1_S = 0;

[_1153] - BUTDN_EF_BH_DV_2_DV1 + 0.275E-02 * Q_BH_D_DV1_G_2_E + 0.14E-02 * Q_BH_D_DV1_G_2_N + 0.49E-02 * Q_BH_D_DV1_G_2_S = 0;

[_1154] - BUTDN_EF_BH_DV_3_DV1 + 0.22E-02 * Q_BH_D_DV1_G_3_E + 0.22E-02 * Q_BH_D_DV1_G_3_N + 0.53E-02 * Q_BH_D_DV1_G_3_S = 0;

[_1155] - BUTDN_EF_BH_DV_4_DV1 + 0.24E-02 * Q_BH_D_DV1_G_4_E + 0.189E-02 * Q_BH_D_DV1_G_4_N + 0.45E-02 * Q_BH_D_DV1_G_4_S = 0;

[_1156] - BUTDN_EF_BH_DV_5_DV1 + 0.202E-02 * Q_BH_D_DV1_G_5_E + 0.23E-02 * Q_BH_D_DV1_G_5_N + 0.41E-02 * Q_BH_D_DV1_G_5_S = 0;

[_1157] - BUTDN_EF_BH_DV_6_DV1 + 0.187E-02 * Q_BH_D_DV1_G_6_E + 0.28E-02 * Q_BH_D_DV1_G_6_N + 0.387E-02 * Q_BH_D_DV1_G_6_S = 0;

[_1158] - BUTDN_EF_BH_DV_7_DV1 + 0.52E-03 * Q_BH_D_DV1_G_7_E + 0.36E-02 * Q_BH_D_DV1_G_7_N + 0.386E-02 * Q_BH_D_DV1_G_7_S = 0;

[_1159] - BUTDN_EF_BH_DV_8_DV1 + 0.163E-02 * Q_BH_D_DV1_G_8_E + 0.4E-02 * Q_BH_D_DV1_G_8_N + 0.25E-02 * Q_BH_D_DV1_G_8_S = 0;

[_1160] - BUTDN_EF_BH_DV_9_DV1 + 0.284E-02 * Q_BH_D_DV1_G_9_E + 0.45E-02 * Q_BH_D_DV1_G_9_N + 0.28E-02 * Q_BH_D_DV1_G_9_S = 0;

[_1161] - BUTDN_EF_BH_DV_10_DV1 + 0.254E-02 * Q_BH_D_DV1_G_10_E + 0.53E-02 * Q_BH_D_DV1_G_10_N + 0.19E-02 * Q_BH_D_DV1_G_10_S = 0;

[_1162] - BUTDN_EF_BH_DV_11_DV1 + 0.322E-02 * Q_BH_D_DV1_G_11_E + 0.61E-02 * Q_BH_D_DV1_G_11_N + 0.15E-02 * Q_BH_D_DV1_G_11_S = 0;

[_1163] - BUTDN_EF_BH_DV_12_DV1 + 0.13E-02 * Q_BH_D_DV1_G_12_E + 0.52E-02 * Q_BH_D_DV1_G_12_N + 0.35E-02 * Q_BH_D_DV1_G_12_S = 0;

[_1164] - BUTDN_EF_BH_DV_13_DV1 + 0.36E-02 * Q_BH_D_DV1_G_13_E + 0.59E-02 * Q_BH_D_DV1_G_13_N + 0.11E-02 * Q_BH_D_DV1_G_13_S = 0;

[_1165] - BUTDN_EF_BH_DV_14_DV1 + 0.44E-02 * Q_BH_D_DV1_G_14_E + 0.62E-02 * Q_BH_D_DV1_G_14_N + 0.21E-02 * Q_BH_D_DV1_G_14_S = 0;

[_1166] - BUTDN_EF_BH_DV_15_DV1 + 0.502E-02 * Q_BH_D_DV1_G_15_E + 0.64E-02 * Q_BH_D_DV1_G_15_N + 0.51E-02 * Q_BH_D_DV1_G_15_S = 0;

[_1167] - BUTDN_EF_BH_DV_16_DV1 + 0.506E-02 * Q_BH_D_DV1_G_16_E + 0.7197142857E-02 * Q_BH_D_DV1_G_16_N + 0.66E-03 * Q_BH_D_DV1_G_16_S = 0;

Annexure 9

[_1168] - CO_EF_BH_DV_1_DV2 + 10.686 * Q_BH_D_DV2_G_1_E + 2.094 * Q_BH_D_DV2_G_1_N + 17.997 * Q_BH_D_DV2_G_1_S = 0;

[_1169] - CO_EF_BH_DV_2_DV2 + 8.55 * Q_BH_D_DV2_G_2_E + 4.4039 * Q_BH_D_DV2_G_2_N + 15.51 * Q_BH_D_DV2_G_2_S = 0;

[_1170] - CO_EF_BH_DV_3_DV2 + 6.879 * Q_BH_D_DV2_G_3_E + 6.958 * Q_BH_D_DV2_G_3_N + 16.41 * Q_BH_D_DV2_G_3_S = 0;

[_1171] - CO_EF_BH_DV_4_DV2 + 7.506 * Q_BH_D_DV2_G_4_E + 5.901 * Q_BH_D_DV2_G_4_N + 14.18 * Q_BH_D_DV2_G_4_S = 0;

[_1172] - CO_EF_BH_DV_5_DV2 + 6.312 * Q_BH_D_DV2_G_5_E + 7.183 * Q_BH_D_DV2_G_5_N + 12.89 * Q_BH_D_DV2_G_5_S = 0;

[_1173] - CO_EF_BH_DV_6_DV2 + 5.813 * Q_BH_D_DV2_G_6_E + 8.886 * Q_BH_D_DV2_G_6_N + 12.076 * Q_BH_D_DV2_G_6_S = 0;

[_1174] - CO_EF_BH_DV_7_DV2 + 1.615 * Q_BH_D_DV2_G_7_E + 11.08 * Q_BH_D_DV2_G_7_N + 12.047 * Q_BH_D_DV2_G_7_S = 0;

[_1175] - CO_EF_BH_DV_8_DV2 + 5.084 * Q_BH_D_DV2_G_8_E + 12.624 * Q_BH_D_DV2_G_8_N + 7.858 * Q_BH_D_DV2_G_8_S = 0;

[_1176] - CO_EF_BH_DV_9_DV2 + 8.85 * Q_BH_D_DV2_G_9_E + 14.03 * Q_BH_D_DV2_G_9_N + 8.802 * Q_BH_D_DV2_G_9_S = 0;

[_1177] - CO_EF_BH_DV_10_DV2 + 7.897 * Q_BH_D_DV2_G_10_E + 16.41 * Q_BH_D_DV2_G_10_N + 6.033 * Q_BH_D_DV2_G_10_S = 0;

[_1178] - CO_EF_BH_DV_11_DV2 + 10.02 * Q_BH_D_DV2_G_11_E + 19.05 * Q_BH_D_DV2_G_11_N + 4.693 * Q_BH_D_DV2_G_11_S = 0;

[_1179] - CO_EF_BH_DV_12_DV2 + 3.944 * Q_BH_D_DV2_G_12_E + 16.33 * Q_BH_D_DV2_G_12_N + 10.951 * Q_BH_D_DV2_G_12_S = 0;

[_1180] - CO_EF_BH_DV_13_DV2 + 11.274 * Q_BH_D_DV2_G_13_E + 18.66 * Q_BH_D_DV2_G_13_N + 3.464 * Q_BH_D_DV2_G_13_S = 0;

[_1181] - CO_EF_BH_DV_14_DV2 + 13.701 * Q_BH_D_DV2_G_14_E + 19.45 * Q_BH_D_DV2_G_14_N + 6.704 * Q_BH_D_DV2_G_14_S = 0;

[_1182] - CO_EF_BH_DV_15_DV2 + 15.64 * Q_BH_D_DV2_G_15_E + 19.82 * Q_BH_D_DV2_G_15_N + 15.952 * Q_BH_D_DV2_G_15_S = 0;

[_1183] - CO_EF_BH_DV_16_DV2 + 15.75617556 * Q_BH_D_DV2_G_16_E + 22.41095778 * Q_BH_D_DV2_G_16_N + 2.055153333 * Q_BH_D_DV2_G_16_S = 0;

[_1184] - SO2_EF_BH_DV_1_DV2 + 0.898 * Q_BH_D_DV2_G_1_E + 0.176 * Q_BH_D_DV2_G_1_N + 1.513 * Q_BH_D_DV2_G_1_S = 0;

[_1185] - SO2_EF_BH_DV_2_DV2 + 0.719 * Q_BH_D_DV2_G_2_E + 0.37 * Q_BH_D_DV2_G_2_N + 1.304 * Q_BH_D_DV2_G_2_S = 0;

[_1186] - SO2_EF_BH_DV_3_DV2 + 0.578 * Q_BH_D_DV2_G_3_E + 0.585 * Q_BH_D_DV2_G_3_N + 1.38 * Q_BH_D_DV2_G_3_S = 0;

[_1187] - SO2_EF_BH_DV_4_DV2 + 0.631 * Q_BH_D_DV2_G_4_E + 0.496 * Q_BH_D_DV2_G_4_N + 1.192 * Q_BH_D_DV2_G_4_S = 0;

[_1188] - SO2_EF_BH_DV_5_DV2 + 0.531 * Q_BH_D_DV2_G_5_E + 0.604 * Q_BH_D_DV2_G_5_N + 1.084 * Q_BH_D_DV2_G_5_S = 0;

[_1189] - SO2_EF_BH_DV_6_DV2 + 0.489 * Q_BH_D_DV2_G_6_E + 0.747 * Q_BH_D_DV2_G_6_N + 1.016 * Q_BH_D_DV2_G_6_S = 0;

[_1190] - SO2_EF_BH_DV_7_DV2 + 0.136 * Q_BH_D_DV2_G_7_E + 0.931 * Q_BH_D_DV2_G_7_N + 1.013 * Q_BH_D_DV2_G_7_S = 0;

[_1191] - SO2_EF_BH_DV_8_DV2 + 0.427 * Q_BH_D_DV2_G_8_E + 1.061 * Q_BH_D_DV2_G_8_N + 0.661 * Q_BH_D_DV2_G_8_S = 0;

[_1192] - SO2_EF_BH_DV_9_DV2 + 0.744 * Q_BH_D_DV2_G_9_E + 1.18 * Q_BH_D_DV2_G_9_N + 0.74 * Q_BH_D_DV2_G_9_S = 0;

[_1193] - SO2_EF_BH_DV_10_DV2 + 0.664 * Q_BH_D_DV2_G_10_E + 1.38 * Q_BH_D_DV2_G_10_N + 0.507 * Q_BH_D_DV2_G_10_S = 0;

[_1194] - SO2_EF_BH_DV_11_DV2 + 0.843 * Q_BH_D_DV2_G_11_E + 1.602 * Q_BH_D_DV2_G_11_N + 0.394 * Q_BH_D_DV2_G_11_S = 0;

[_1195] - SO2_EF_BH_DV_12_DV2 + 0.332 * Q_BH_D_DV2_G_12_E + 1.373 * Q_BH_D_DV2_G_12_N + 0.921 * Q_BH_D_DV2_G_12_S = 0;

[_1196] - SO2_EF_BH_DV_13_DV2 + 0.948 * Q_BH_D_DV2_G_13_E + 1.569 * Q_BH_D_DV2_G_13_N + 0.291 * Q_BH_D_DV2_G_13_S = 0;

[_1197] - SO2_EF_BH_DV_14_DV2 + 1.152 * Q_BH_D_DV2_G_14_E + 1.636 * Q_BH_D_DV2_G_14_N + 0.564 * Q_BH_D_DV2_G_14_S = 0;

[_1198] - SO2_EF_BH_DV_15_DV2 + 1.315 * Q_BH_D_DV2_G_15_E + 1.666 * Q_BH_D_DV2_G_15_N + 1.341 * Q_BH_D_DV2_G_15_S = 0;

[_1199] - SO2_EF_BH_DV_16_DV2 + 1.3249319 * Q_BH_D_DV2_G_16_E + 1.884530466 * Q_BH_D_DV2_G_16_N + 0.1728172043 * Q_BH_D_DV2_G_16_S = 0;

[_1200] - CO2_EF_BH_DV_1_DV2 + 4078.48 * Q_BH_D_DV2_G_1_E + 799.26 * Q_BH_D_DV2_G_1_N + 6868.43 * Q_BH_D_DV2_G_1_S = 0;

[_1201] - CO2_EF_BH_DV_2_DV2 + 3264.28 * Q_BH_D_DV2_G_2_E + 1680.69 * Q_BH_D_DV2_G_2_N + 5919.77 * Q_BH_D_DV2_G_2_S = 0;

[_1202] - CO2_EF_BH_DV_3_DV2 + 2625.62 * Q_BH_D_DV2_G_3_E + 2655.49 * Q_BH_D_DV2_G_3_N + 6263.38 * Q_BH_D_DV2_G_3_S = 0;

[_1203] - CO2_EF_BH_DV_4_DV2 + 2864.65 * Q_BH_D_DV2_G_4_E + 2252.13 * Q_BH_D_DV2_G_4_N + 5411.83 * Q_BH_D_DV2_G_4_S = 0;

[_1204] - CO2_EF_BH_DV_5_DV2 + 2408.99 * Q_BH_D_DV2_G_5_E + 2741.39 * Q_BH_D_DV2_G_5_N + 4918.82 * Q_BH_D_DV2_G_5_S = 0;

[_1205] - CO2_EF_BH_DV_6_DV2 + 2218.51 * Q_BH_D_DV2_G_6_E + 3391.26 * Q_BH_D_DV2_G_6_N + 4608.83 * Q_BH_D_DV2_G_6_S = 0;

[_1206] - CO2_EF_BH_DV_7_DV2 + 616.25 * Q_BH_D_DV2_G_7_E + 4227.87 * Q_BH_D_DV2_G_7_N + 4597.63 * Q_BH_D_DV2_G_7_S = 0;

[_1207] - CO2_EF_BH_DV_8_DV2 + 1940.27 * Q_BH_D_DV2_G_8_E + 4817.98 * Q_BH_D_DV2_G_8_N + 2999.1 * Q_BH_D_DV2_G_8_S = 0;

[_1208] - CO2_EF_BH_DV_9_DV2 + 3376.32 * Q_BH_D_DV2_G_9_E + 5355.81 * Q_BH_D_DV2_G_9_N + 3359.14 * Q_BH_D_DV2_G_9_S = 0;

[_1209] - CO2_EF_BH_DV_10_DV2 + 3014.04 * Q_BH_D_DV2_G_10_E + 6263.38 * Q_BH_D_DV2_G_10_N + 2302.55 * Q_BH_D_DV2_G_10_S = 0;

[_1210] - CO2_EF_BH_DV_11_DV2 + 3824.51 * Q_BH_D_DV2_G_11_E + 7271.8 * Q_BH_D_DV2_G_11_N + 1791.24 * Q_BH_D_DV2_G_11_S = 0;

[_1211] - CO2_EF_BH_DV_12_DV2 + 1505.15 * Q_BH_D_DV2_G_12_E + 6233.51 * Q_BH_D_DV2_G_12_N + 4179.32 * Q_BH_D_DV2_G_12_S = 0;

[_1212] - CO2_EF_BH_DV_13_DV2 + 4302.57 * Q_BH_D_DV2_G_13_E + 7122.4 * Q_BH_D_DV2_G_13_N + 1322.14 * Q_BH_D_DV2_G_13_S = 0;

[_1213] - CO2_EF_BH_DV_14_DV2 + 5228.82 * Q_BH_D_DV2_G_14_E + 7424.93 * Q_BH_D_DV2_G_14_N + 2558.39 * Q_BH_D_DV2_G_14_S = 0;

[_1214] - CO2_EF_BH_DV_15_DV2 + 5968.32 * Q_BH_D_DV2_G_15_E + 7563.11 * Q_BH_D_DV2_G_15_N + 6087.84 * Q_BH_D_DV2_G_15_S = 0;

[_1215] - CO2_EF_BH_DV_16_DV2 + 6013.144238 * Q_BH_D_DV2_G_16_E + 8552.857333 * Q_BH_D_DV2_G_16_N + 784.3231615 * Q_BH_D_DV2_G_16_S = 0;

[_1216] - HC_EF_BH_DV_1_DV2 + 2.95 * Q_BH_D_DV2_G_1_E + 0.578 * Q_BH_D_DV2_G_1_N + 4.969 * Q_BH_D_DV2_G_1_S = 0;

[_1217] - HC_EF_BH_DV_2_DV2 + 2.36 * Q_BH_D_DV2_G_2_E + 1.216 * Q_BH_D_DV2_G_2_N + 4.283 * Q_BH_D_DV2_G_2_S = 0;

[_1218] - HC_EF_BH_DV_3_DV2 + 1.899 * Q_BH_D_DV2_G_3_E + 1.921 * Q_BH_D_DV2_G_3_N + 4.532 * Q_BH_D_DV2_G_3_S = 0;

[_1219] - HC_EF_BH_DV_4_DV2 + 2.073 * Q_BH_D_DV2_G_4_E + 1.629 * Q_BH_D_DV2_G_4_N + 3.915 * Q_BH_D_DV2_G_4_S = 0;

[_1220] - HC_EF_BH_DV_5_DV2 + 1.743 * Q_BH_D_DV2_G_5_E + 1.983 * Q_BH_D_DV2_G_5_N + 3.559 * Q_BH_D_DV2_G_5_S = 0;

[_1221] - HC_EF_BH_DV_6_DV2 + 1.605 * Q_BH_D_DV2_G_6_E + 2.454 * Q_BH_D_DV2_G_6_N + 3.334 * Q_BH_D_DV2_G_6_S = 0;

[_1222] - HC_EF_BH_DV_7_DV2 + 0.446 * Q_BH_D_DV2_G_7_E + 3.059 * Q_BH_D_DV2_G_7_N + 3.326 * Q_BH_D_DV2_G_7_S = 0;

[_1223] - HC_EF_BH_DV_8_DV2 + 1.404 * Q_BH_D_DV2_G_8_E + 3.486 * Q_BH_D_DV2_G_8_N + 2.169 * Q_BH_D_DV2_G_8_S = 0;

[_1224] - HC_EF_BH_DV_9_DV2 + 2.443 * Q_BH_D_DV2_G_9_E + 3.875 * Q_BH_D_DV2_G_9_N + 2.43 * Q_BH_D_DV2_G_9_S = 0;

[_1225] - HC_EF_BH_DV_10_DV2 + 2.181 * Q_BH_D_DV2_G_10_E + 4.532 * Q_BH_D_DV2_G_10_N + 1.666 * Q_BH_D_DV2_G_10_S = 0;

[_1226] - HC_EF_BH_DV_11_DV2 + 2.767 * Q_BH_D_DV2_G_11_E + 5.261 * Q_BH_D_DV2_G_11_N + 1.296 * Q_BH_D_DV2_G_11_S = 0;

[_1227] - HC_EF_BH_DV_12_DV2 + 1.089 * Q_BH_D_DV2_G_12_E + 4.51 * Q_BH_D_DV2_G_12_N + 3.024 * Q_BH_D_DV2_G_12_S = 0;

[_1228] - HC_EF_BH_DV_13_DV2 + 3.112 * Q_BH_D_DV2_G_13_E + 5.153 * Q_BH_D_DV2_G_13_N + 0.956 * Q_BH_D_DV2_G_13_S = 0;

[_1229] - HC_EF_BH_DV_14_DV2 + 3.783 * Q_BH_D_DV2_G_14_E + 5.372 * Q_BH_D_DV2_G_14_N + 1.851 * Q_BH_D_DV2_G_14_S = 0;

[_1230] - HC_EF_BH_DV_15_DV2 + 4.318 * Q_BH_D_DV2_G_15_E + 5.472 * Q_BH_D_DV2_G_15_N + 4.405 * Q_BH_D_DV2_G_15_S = 0;

[_1231] - HC_EF_BH_DV_16_DV2 + 4.350577778 * Q_BH_D_DV2_G_16_E + 6.188088889 * Q_BH_D_DV2_G_16_N + 0.5674666667 * Q_BH_D_DV2_G_16_S = 0;

[_1232] - NOX_EF_BH_DV_1_DV2 + 19.04 * Q_BH_D_DV2_G_1_E + 3.731 * Q_BH_D_DV2_G_1_N + 32.059 * Q_BH_D_DV2_G_1_S = 0;

[_1233] - NOX_EF_BH_DV_2_DV2 + 15.24 * Q_BH_D_DV2_G_2_E + 7.845 * Q_BH_D_DV2_G_2_N + 27.632 * Q_BH_D_DV2_G_2_S = 0;

[_1234] - NOX_EF_BH_DV_3_DV2 + 12.26 * Q_BH_D_DV2_G_3_E + 12.395 * Q_BH_D_DV2_G_3_N + 29.236 * Q_BH_D_DV2_G_3_S = 0;

[_1235] - NOX_EF_BH_DV_4_DV2 + 13.37 * Q_BH_D_DV2_G_4_E + 10.51 * Q_BH_D_DV2_G_4_N + 25.261 * Q_BH_D_DV2_G_4_S = 0;

[_1236] - NOX_EF_BH_DV_5_DV2 + 11.24 * Q_BH_D_DV2_G_5_E + 12.796 * Q_BH_D_DV2_G_5_N + 22.959 * Q_BH_D_DV2_G_5_S = 0;

[_1237] - NOX_EF_BH_DV_6_DV2 + 10.35 * Q_BH_D_DV2_G_6_E + 15.829 * Q_BH_D_DV2_G_6_N + 21.512 * Q_BH_D_DV2_G_6_S = 0;

[_1238] - NOX_EF_BH_DV_7_DV2 + 2.88 * Q_BH_D_DV2_G_7_E + 19.734 * Q_BH_D_DV2_G_7_N + 21.46 * Q_BH_D_DV2_G_7_S = 0;

[_1239] - NOX_EF_BH_DV_8_DV2 + 9.06 * Q_BH_D_DV2_G_8_E + 22.489 * Q_BH_D_DV2_G_8_N + 13.99 * Q_BH_D_DV2_G_8_S = 0;

[_1240] - NOX_EF_BH_DV_9_DV2 + 15.76 * Q_BH_D_DV2_G_9_E + 24.99 * Q_BH_D_DV2_G_9_N + 15.68 * Q_BH_D_DV2_G_9_S = 0;

[_1241] - NOX_EF_BH_DV_10_DV2 + 14.069 * Q_BH_D_DV2_G_10_E + 29.236 * Q_BH_D_DV2_G_10_N + 10.75 * Q_BH_D_DV2_G_10_S = 0;

[_1242] - NOX_EF_BH_DV_11_DV2 + 17.852 * Q_BH_D_DV2_G_11_E + 33.94 * Q_BH_D_DV2_G_11_N + 8.361 * Q_BH_D_DV2_G_11_S = 0;

[_1243] - NOX_EF_BH_DV_12_DV2 + 7.026 * Q_BH_D_DV2_G_12_E + 29.096 * Q_BH_D_DV2_G_12_N + 19.51 * Q_BH_D_DV2_G_12_S = 0;

[_1244] - NOX_EF_BH_DV_13_DV2 + 20.08 * Q_BH_D_DV2_G_13_E + 33.24 * Q_BH_D_DV2_G_13_N + 6.171 * Q_BH_D_DV2_G_13_S = 0;

[_1245] - NOX_EF_BH_DV_14_DV2 + 24.41 * Q_BH_D_DV2_G_14_E + 34.657 * Q_BH_D_DV2_G_14_N + 11.94 * Q_BH_D_DV2_G_14_S = 0;

Annexure 9

[_1246] - NOX_EF_BH_DV_15_DV2 + 27.86 * Q_BH_D_DV2_G_15_E + 35.3 * Q_BH_D_DV2_G_15_N + 28.42 * Q_BH_D_DV2_G_15_S = 0;

[_1247] - NOX_EF_BH_DV_16_DV2 + 28.06766667 * Q_BH_D_DV2_G_16_E + 39.92233333 * Q_BH_D_DV2_G_16_N + 3.661 * Q_BH_D_DV2_G_16_S = 0;

[_1248] - PM_EF_BH_DV_1_DV2 + 1.876 * Q_BH_D_DV2_G_1_E + 0.368 * Q_BH_D_DV2_G_1_N + 3.159 * Q_BH_D_DV2_G_1_S = 0;

[_1249] - PM_EF_BH_DV_2_DV2 + 1.501 * Q_BH_D_DV2_G_2_E + 0.773 * Q_BH_D_DV2_G_2_N + 2.723 * Q_BH_D_DV2_G_2_S = 0;

[_1250] - PM_EF_BH_DV_3_DV2 + 1.207 * Q_BH_D_DV2_G_3_E + 1.221 * Q_BH_D_DV2_G_3_N + 2.881 * Q_BH_D_DV2_G_3_S = 0;

[_1251] - PM_EF_BH_DV_4_DV2 + 1.317 * Q_BH_D_DV2_G_4_E + 1.035 * Q_BH_D_DV2_G_4_N + 2.489 * Q_BH_D_DV2_G_4_S = 0;

[_1252] - PM_EF_BH_DV_5_DV2 + 1.108 * Q_BH_D_DV2_G_5_E + 1.261 * Q_BH_D_DV2_G_5_N + 2.262 * Q_BH_D_DV2_G_5_S = 0;

[_1253] - PM_EF_BH_DV_6_DV2 + 1.02 * Q_BH_D_DV2_G_6_E + 1.559 * Q_BH_D_DV2_G_6_N + 2.119 * Q_BH_D_DV2_G_6_S = 0;

[_1254] - PM_EF_BH_DV_7_DV2 + 0.283 * Q_BH_D_DV2_G_7_E + 1.944 * Q_BH_D_DV2_G_7_N + 2.114 * Q_BH_D_DV2_G_7_S = 0;

[_1255] - PM_EF_BH_DV_8_DV2 + 0.892 * Q_BH_D_DV2_G_8_E + 2.216 * Q_BH_D_DV2_G_8_N + 1.379 * Q_BH_D_DV2_G_8_S = 0;

[_1256] - PM_EF_BH_DV_9_DV2 + 1.553 * Q_BH_D_DV2_G_9_E + 2.463 * Q_BH_D_DV2_G_9_N + 1.545 * Q_BH_D_DV2_G_9_S = 0;

[_1257] - PM_EF_BH_DV_10_DV2 + 1.386 * Q_BH_D_DV2_G_10_E + 2.881 * Q_BH_D_DV2_G_10_N + 1.059 * Q_BH_D_DV2_G_10_S = 0;

[_1258] - PM_EF_BH_DV_11_DV2 + 1.759 * Q_BH_D_DV2_G_11_E + 3.344 * Q_BH_D_DV2_G_11_N + 0.824 * Q_BH_D_DV2_G_11_S = 0;

[_1259] - PM_EF_BH_DV_12_DV2 + 0.692 * Q_BH_D_DV2_G_12_E + 2.867 * Q_BH_D_DV2_G_12_N + 1.922 * Q_BH_D_DV2_G_12_S = 0;

[_1260] - PM_EF_BH_DV_13_DV2 + 1.978 * Q_BH_D_DV2_G_13_E + 3.276 * Q_BH_D_DV2_G_13_N + 0.608 * Q_BH_D_DV2_G_13_S = 0;

[_1261] - PM_EF_BH_DV_14_DV2 + 2.405 * Q_BH_D_DV2_G_14_E + 3.415 * Q_BH_D_DV2_G_14_N + 1.176 * Q_BH_D_DV2_G_14_S = 0;

[_1262] - PM_EF_BH_DV_15_DV2 + 2.745 * Q_BH_D_DV2_G_15_E + 3.478 * Q_BH_D_DV2_G_15_N + 2.799 * Q_BH_D_DV2_G_15_S = 0;

[_1263] - PM_EF_BH_DV_16_DV2 + 2.765622222 * Q_BH_D_DV2_G_16_E + 3.933711111 * Q_BH_D_DV2_G_16_N + 0.3607333333 * Q_BH_D_DV2_G_16_S = 0;

[_1264] - BENZ_EF_BH_DV_1_DV2 + 0.15E-01 * Q_BH_D_DV2_G_1_E + 0.29E-02 * Q_BH_D_DV2_G_1_N + 0.253E-01 * Q_BH_D_DV2_G_1_S = 0;

[_1265] - BENZ_EF_BH_DV_2_DV2 + 0.12E-01 * Q_BH_D_DV2_G_2_E + 0.62E-02 * Q_BH_D_DV2_G_2_N + 0.22E-01 * Q_BH_D_DV2_G_2_S = 0;

[_1266] - BENZ_EF_BH_DV_3_DV2 + 0.97E-02 * Q_BH_D_DV2_G_3_E + 0.98E-02 * Q_BH_D_DV2_G_3_N + 0.23E-01 * Q_BH_D_DV2_G_3_S = 0;

[_1267] - BENZ_EF_BH_DV_4_DV2 + 0.106E-01 * Q_BH_D_DV2_G_4_E + 0.83E-02 * Q_BH_D_DV2_G_4_N + 0.19E-01 * Q_BH_D_DV2_G_4_S = 0;

[_1268] - BENZ_EF_BH_DV_5_DV2 + 0.89E-02 * Q_BH_D_DV2_G_5_E + 0.101E-01 * Q_BH_D_DV2_G_5_N + 0.18E-01 * Q_BH_D_DV2_G_5_S = 0;

[_1269] - BENZ_EF_BH_DV_6_DV2 + 0.82E-02 * Q_BH_D_DV2_G_6_E + 0.125E-01 * Q_BH_D_DV2_G_6_N + 0.17E-01 * Q_BH_D_DV2_G_6_S = 0;

[_1270] - BENZ_EF_BH_DV_7_DV2 + 0.23E-02 * Q_BH_D_DV2_G_7_E + 0.156E-01 * Q_BH_D_DV2_G_7_N + 0.169E-01 * Q_BH_D_DV2_G_7_S = 0;

[_1271] - BENZ_EF_BH_DV_8_DV2 + 0.71E-02 * Q_BH_D_DV2_G_8_E + 0.178E-01 * Q_BH_D_DV2_G_8_N + 0.11E-01 * Q_BH_D_DV2_G_8_S = 0;

[_1272] - BENZ_EF_BH_DV_9_DV2 + 0.124E-01 * Q_BH_D_DV2_G_9_E + 0.197E-01 * Q_BH_D_DV2_G_9_N + 0.12E-01 * Q_BH_D_DV2_G_9_S = 0;

[_1273] - BENZ_EF_BH_DV_10_DV2 + 0.111E-01 * Q_BH_D_DV2_G_10_E + 0.23E-01 * Q_BH_D_DV2_G_10_N + 0.85E-02 * Q_BH_D_DV2_G_10_S = 0;

[_1274] - BENZ_EF_BH_DV_11_DV2 + 0.14E-01 * Q_BH_D_DV2_G_11_E + 0.27E-01 * Q_BH_D_DV2_G_11_N + 0.66E-02 * Q_BH_D_DV2_G_11_S = 0;

[_1275] - BENZ_EF_BH_DV_12_DV2 + 0.55E-02 * Q_BH_D_DV2_G_12_E + 0.22E-01 * Q_BH_D_DV2_G_12_N + 0.15E-01 * Q_BH_D_DV2_G_12_S = 0;

[_1276] - BENZ_EF_BH_DV_13_DV2 + 0.158E-01 * Q_BH_D_DV2_G_13_E + 0.26E-01 * Q_BH_D_DV2_G_13_N + 0.49E-02 * Q_BH_D_DV2_G_13_S = 0;

[_1277] - BENZ_EF_BH_DV_14_DV2 + 0.193E-01 * Q_BH_D_DV2_G_14_E + 0.27E-01 * Q_BH_D_DV2_G_14_N + 0.94E-02 * Q_BH_D_DV2_G_14_S = 0;

[_1278] - BENZ_EF_BH_DV_15_DV2 + 0.22E-01 * Q_BH_D_DV2_G_15_E + 0.28E-01 * Q_BH_D_DV2_G_15_N + 0.22E-01 * Q_BH_D_DV2_G_15_S = 0;

[_1279] - BENZ_EF_BH_DV_16_DV2 + 0.2218222222E-01 * Q_BH_D_DV2_G_16_E + 0.3155111111E-01 * Q_BH_D_DV2_G_16_N + 0.2893333333E-02 * Q_BH_D_DV2_G_16_S = 0;

[_1280] - BUTDN_EF_BH_DV_1_DV2 + 0.27E-02 * Q_BH_D_DV2_G_1_E + 0.52E-03 * Q_BH_D_DV2_G_1_N + 0.45E-02 * Q_BH_D_DV2_G_1_S = 0;

[_1281] - BUTDN_EF_BH_DV_2_DV2 + 0.21E-02 * Q_BH_D_DV2_G_2_E + 0.11E-02 * Q_BH_D_DV2_G_2_N + 0.39E-02 * Q_BH_D_DV2_G_2_S = 0;

[_1282] - BUTDN_EF_BH_DV_3_DV2 + 0.17E-02 * Q_BH_D_DV2_G_3_E + 0.17E-02 * Q_BH_D_DV2_G_3_N + 0.41E-02 * Q_BH_D_DV2_G_3_S = 0;

[_1283] - BUTDN_EF_BH_DV_4_DV2 + 0.19E-02 * Q_BH_D_DV2_G_4_E + 0.15E-02 * Q_BH_D_DV2_G_4_N + 0.35E-02 * Q_BH_D_DV2_G_4_S = 0;

[_1284] - BUTDN_EF_BH_DV_5_DV2 + 0.16E-02 * Q_BH_D_DV2_G_5_E + 0.18E-02 * Q_BH_D_DV2_G_5_N + 0.32E-02 * Q_BH_D_DV2_G_5_S = 0;

[_1285] - BUTDN_EF_BH_DV_6_DV2 + 0.14E-02 * Q_BH_D_DV2_G_6_E + 0.22E-02 * Q_BH_D_DV2_G_6_N + 0.31E-02 * Q_BH_D_DV2_G_6_S = 0;

[_1286] - BUTDN_EF_BH_DV_7_DV2 + 0.4E-03 * Q_BH_D_DV2_G_7_E + 0.27E-02 * Q_BH_D_DV2_G_7_N + 0.3E-02 * Q_BH_D_DV2_G_7_S = 0;

[_1287] - BUTDN_EF_BH_DV_8_DV2 + 0.13E-02 * Q_BH_D_DV2_G_8_E + 0.31E-02 * Q_BH_D_DV2_G_8_N + 0.196E-02 * Q_BH_D_DV2_G_8_S = 0;

[_1288] - BUTDN_EF_BH_DV_9_DV2 + 0.22E-02 * Q_BH_D_DV2_G_9_E + 0.35E-02 * Q_BH_D_DV2_G_9_N + 0.22E-02 * Q_BH_D_DV2_G_9_S = 0;

[_1289] - BUTDN_EF_BH_DV_10_DV2 + 0.197E-02 * Q_BH_D_DV2_G_10_E + 0.41E-02 * Q_BH_D_DV2_G_10_N + 0.15E-02 * Q_BH_D_DV2_G_10_S = 0;

[_1290] - BUTDN_EF_BH_DV_11_DV2 + 0.25E-02 * Q_BH_D_DV2_G_11_E + 0.476E-02 * Q_BH_D_DV2_G_11_N + 0.12E-02 * Q_BH_D_DV2_G_11_S = 0;

[_1291] - BUTDN_EF_BH_DV_12_DV2 + 0.98E-03 * Q_BH_D_DV2_G_12_E + 0.41E-02 * Q_BH_D_DV2_G_12_N + 0.27E-02 * Q_BH_D_DV2_G_12_S = 0;

[_1292] - BUTDN_EF_BH_DV_13_DV2 + 0.282E-02 * Q_BH_D_DV2_G_13_E + 0.46E-02 * Q_BH_D_DV2_G_13_N + 0.86E-03 * Q_BH_D_DV2_G_13_S = 0;

[_1293] - BUTDN_EF_BH_DV_14_DV2 + 0.34E-02 * Q_BH_D_DV2_G_14_E + 0.486E-02 * Q_BH_D_DV2_G_14_N + 0.17E-02 * Q_BH_D_DV2_G_14_S = 0;

[_1294] - BUTDN_EF_BH_DV_15_DV2 + 0.39E-02 * Q_BH_D_DV2_G_15_E + 0.495E-02 * Q_BH_D_DV2_G_15_N + 0.39E-02 * Q_BH_D_DV2_G_15_S = 0;

[_1295] - BUTDN_EF_BH_DV_16_DV2 + 0.3935555556E-02 * Q_BH_D_DV2_G_16_E + 0.5597777778E-02 * Q_BH_D_DV2_G_16_N + 0.5133333333E-03 * Q_BH_D_DV2_G_16_S = 0;

[_1296] - CO_EF_BH_DV_1_DV3 + 10.03 * Q_BH_D_DV3_G_1_E + 1.885 * Q_BH_D_DV3_G_1_N + 16.889 * Q_BH_D_DV3_G_1_S = 0;

[_1297] - CO_EF_BH_DV_2_DV3 + 8.027 * Q_BH_D_DV3_G_2_E + 3.963 * Q_BH_D_DV3_G_2_N + 14.556 * Q_BH_D_DV3_G_2_S = 0;

[_1298] - CO_EF_BH_DV_3_DV3 + 6.456 * Q_BH_D_DV3_G_3_E + 6.262 * Q_BH_D_DV3_G_3_N + 14.77 * Q_BH_D_DV3_G_3_S = 0;

[_1299] - CO_EF_BH_DV_4_DV3 + 7.044 * Q_BH_D_DV3_G_4_E + 5.311 * Q_BH_D_DV3_G_4_N + 13.31 * Q_BH_D_DV3_G_4_S = 0;

[_1300] - CO_EF_BH_DV_5_DV3 + 5.924 * Q_BH_D_DV3_G_5_E + 6.465 * Q_BH_D_DV3_G_5_N + 12.095 * Q_BH_D_DV3_G_5_S = 0;

[_1301] - CO_EF_BH_DV_6_DV3 + 5.455 * Q_BH_D_DV3_G_6_E + 7.997 * Q_BH_D_DV3_G_6_N + 11.333 * Q_BH_D_DV3_G_6_S = 0;

[_1302] - CO_EF_BH_DV_7_DV3 + 1.515 * Q_BH_D_DV3_G_7_E + 9.97 * Q_BH_D_DV3_G_7_N + 11.305 * Q_BH_D_DV3_G_7_S = 0;

[_1303] - CO_EF_BH_DV_8_DV3 + 4.771 * Q_BH_D_DV3_G_8_E + 11.362 * Q_BH_D_DV3_G_8_N + 7.374 * Q_BH_D_DV3_G_8_S = 0;

[_1304] - CO_EF_BH_DV_9_DV3 + 8.302 * Q_BH_D_DV3_G_9_E + 12.63 * Q_BH_D_DV3_G_9_N + 8.26 * Q_BH_D_DV3_G_9_S = 0;

[_1305] - CO_EF_BH_DV_10_DV3 + 7.411 * Q_BH_D_DV3_G_10_E + 14.77 * Q_BH_D_DV3_G_10_N + 5.662 * Q_BH_D_DV3_G_10_S = 0;

[_1306] - CO_EF_BH_DV_11_DV3 + 9.404 * Q_BH_D_DV3_G_11_E + 17.148 * Q_BH_D_DV3_G_11_N + 4.405 * Q_BH_D_DV3_G_11_S = 0;

[_1307] - CO_EF_BH_DV_12_DV3 + 3.701 * Q_BH_D_DV3_G_12_E + 14.7 * Q_BH_D_DV3_G_12_N + 10.276 * Q_BH_D_DV3_G_12_S = 0;

[_1308] - CO_EF_BH_DV_13_DV3 + 10.579 * Q_BH_D_DV3_G_13_E + 16.796 * Q_BH_D_DV3_G_13_N + 3.251 * Q_BH_D_DV3_G_13_S = 0;

[_1309] - CO_EF_BH_DV_14_DV3 + 12.858 * Q_BH_D_DV3_G_14_E + 17.509 * Q_BH_D_DV3_G_14_N + 6.291 * Q_BH_D_DV3_G_14_S = 0;

[_1310] - CO_EF_BH_DV_15_DV3 + 14.676 * Q_BH_D_DV3_G_15_E + 17.836 * Q_BH_D_DV3_G_15_N + 14.969 * Q_BH_D_DV3_G_15_S = 0;

[_1311] - CO_EF_BH_DV_16_DV3 + 14.78624 * Q_BH_D_DV3_G_16_E + 21.03136 * Q_BH_D_DV3_G_16_N + 1.92864 * Q_BH_D_DV3_G_16_S = 0;

[_1312] - SO2_EF_BH_DV_1_DV3 + 1.254 * Q_BH_D_DV3_G_1_E + 0.2456 * Q_BH_D_DV3_G_1_N + 2.111 * Q_BH_D_DV3_G_1_S = 0;

[_1313] - SO2_EF_BH_DV_2_DV3 + 1.003 * Q_BH_D_DV3_G_2_E + 0.517 * Q_BH_D_DV3_G_2_N + 1.819 * Q_BH_D_DV3_G_2_S = 0;

[_1314] - SO2_EF_BH_DV_3_DV3 + 0.807 * Q_BH_D_DV3_G_3_E + 0.816 * Q_BH_D_DV3_G_3_N + 1.925 * Q_BH_D_DV3_G_3_S = 0;

[_1315] - SO2_EF_BH_DV_4_DV3 + 0.88 * Q_BH_D_DV3_G_4_E + 0.692 * Q_BH_D_DV3_G_4_N + 1.663 * Q_BH_D_DV3_G_4_S = 0;

[_1316] - SO2_EF_BH_DV_5_DV3 + 0.74 * Q_BH_D_DV3_G_5_E + 0.843 * Q_BH_D_DV3_G_5_N + 1.512 * Q_BH_D_DV3_G_5_S = 0;

[_1317] - SO2_EF_BH_DV_6_DV3 + 0.682 * Q_BH_D_DV3_G_6_E + 1.042 * Q_BH_D_DV3_G_6_N + 1.417 * Q_BH_D_DV3_G_6_S = 0;

[_1318] - SO2_EF_BH_DV_7_DV3 + 0.189 * Q_BH_D_DV3_G_7_E + 1.299 * Q_BH_D_DV3_G_7_N + 1.413 * Q_BH_D_DV3_G_7_S = 0;

[_1319] - SO2_EF_BH_DV_8_DV3 + 0.596 * Q_BH_D_DV3_G_8_E + 1.481 * Q_BH_D_DV3_G_8_N + 0.922 * Q_BH_D_DV3_G_8_S = 0;

[_1320] - SO2_EF_BH_DV_9_DV3 + 1.038 * Q_BH_D_DV3_G_9_E + 1.646 * Q_BH_D_DV3_G_9_N + 1.032 * Q_BH_D_DV3_G_9_S = 0;

[_1321] - SO2_EF_BH_DV_10_DV3 + 0.926 * Q_BH_D_DV3_G_10_E + 1.925 * Q_BH_D_DV3_G_10_N + 0.708 * Q_BH_D_DV3_G_10_S = 0;

[_1322] - SO2_EF_BH_DV_11_DV3 + 1.175 * Q_BH_D_DV3_G_11_E + 2.235 * Q_BH_D_DV3_G_11_N + 0.5505 * Q_BH_D_DV3_G_11_S = 0;

Annexure 9

[_1323] - SO2_EF_BH_DV_12_DV3 + 0.463 * Q_BH_D_DV3_G_12_E + 1.916 * Q_BH_D_DV3_G_12_N + 1.285 * Q_BH_D_DV3_G_12_S = 0;

[_1324] - SO2_EF_BH_DV_13_DV3 + 1.322 * Q_BH_D_DV3_G_13_E + 2.189 * Q_BH_D_DV3_G_13_N + 0.406 * Q_BH_D_DV3_G_13_S = 0;

[_1325] - SO2_EF_BH_DV_14_DV3 + 1.607 * Q_BH_D_DV3_G_14_E + 2.282 * Q_BH_D_DV3_G_14_N + 0.786 * Q_BH_D_DV3_G_14_S = 0;

[_1326] - SO2_EF_BH_DV_15_DV3 + 1.834 * Q_BH_D_DV3_G_15_E + 2.325 * Q_BH_D_DV3_G_15_N + 1.871 * Q_BH_D_DV3_G_15_S = 0;

[_1327] - SO2_EF_BH_DV_16_DV3 + 1.830886578 * Q_BH_D_DV3_G_16_E + 2.604180287 * Q_BH_D_DV3_G_16_N + 0.2388112927 * Q_BH_D_DV3_G_16_S = 0;

[_1328] - CO2_EF_BH_DV_1_DV3 + 5697.14 * Q_BH_D_DV3_G_1_E + 1116.6 * Q_BH_D_DV3_G_1_N + 9594.372 * Q_BH_D_DV3_G_1_S = 0;

[_1329] - CO2_EF_BH_DV_2_DV3 + 4559.8 * Q_BH_D_DV3_G_2_E + 2347.99 * Q_BH_D_DV3_G_2_N + 8269.21 * Q_BH_D_DV3_G_2_S = 0;

[_1330] - CO2_EF_BH_DV_3_DV3 + 3667.67 * Q_BH_D_DV3_G_3_E + 3709.83 * Q_BH_D_DV3_G_3_N + 8750.18 * Q_BH_D_DV3_G_3_S = 0;

[_1331] - CO2_EF_BH_DV_4_DV3 + 4001.57 * Q_BH_D_DV3_G_4_E + 3146.31 * Q_BH_D_DV3_G_4_N + 7559.67 * Q_BH_D_DV3_G_4_S = 0;

[_1332] - CO2_EF_BH_DV_5_DV3 + 3365.07 * Q_BH_D_DV3_G_5_E + 3829.83 * Q_BH_D_DV3_G_5_N + 6871.01 * Q_BH_D_DV3_G_5_S = 0;

[_1333] - CO2_EF_BH_DV_6_DV3 + 3098.99 * Q_BH_D_DV3_G_6_E + 4737.73 * Q_BH_D_DV3_G_6_N + 6437.98 * Q_BH_D_DV3_G_6_S = 0;

[_1334] - CO2_EF_BH_DV_7_DV3 + 860.83 * Q_BH_D_DV3_G_7_E + 5906.5 * Q_BH_D_DV3_G_7_N + 6422.33 * Q_BH_D_DV3_G_7_S = 0;

[_1335] - CO2_EF_BH_DV_8_DV3 + 2710.32 * Q_BH_D_DV3_G_8_E + 6730.91 * Q_BH_D_DV3_G_8_N + 4189.39 * Q_BH_D_DV3_G_8_S = 0;

[_1336] - CO2_EF_BH_DV_9_DV3 + 4716.32 * Q_BH_D_DV3_G_9_E + 7482.27 * Q_BH_D_DV3_G_9_N + 4692.32 * Q_BH_D_DV3_G_9_S = 0;

[_1337] - CO2_EF_BH_DV_10_DV3 + 4210.25 * Q_BH_D_DV3_G_10_E + 8750.18 * Q_BH_D_DV3_G_10_N + 3216.38 * Q_BH_D_DV3_G_10_S = 0;

[_1338] - CO2_EF_BH_DV_11_DV3 + 5342.38 * Q_BH_D_DV3_G_11_E + 10158.98 * Q_BH_D_DV3_G_11_N + 2502.15 * Q_BH_D_DV3_G_11_S = 0;

[_1339] - CO2_EF_BH_DV_12_DV3 + 2102.52 * Q_BH_D_DV3_G_12_E + 8708.44 * Q_BH_D_DV3_G_12_N + 5838.01 * Q_BH_D_DV3_G_12_S = 0;

[_1340] - CO2_EF_BH_DV_13_DV3 + 6010.18 * Q_BH_D_DV3_G_13_E + 9950.267 * Q_BH_D_DV3_G_13_N + 1846.87 * Q_BH_D_DV3_G_13_S = 0;

[_1341] - CO2_EF_BH_DV_14_DV3 + 7304.03 * Q_BH_D_DV3_G_14_E + 10372.91 * Q_BH_D_DV3_G_14_N + 3573.76 * Q_BH_D_DV3_G_14_S = 0;

[_1342] - CO2_EF_BH_DV_15_DV3 + 8337.03 * Q_BH_D_DV3_G_15_E + 10565.96 * Q_BH_D_DV3_G_15_N + 8503.98 * Q_BH_D_DV3_G_15_S = 0;

[_1343] - CO2_EF_BH_DV_16_DV3 + 8320.376169 * Q_BH_D_DV3_G_16_E + 11834.57231 * Q_BH_D_DV3_G_16_N + 1085.266457 * Q_BH_D_DV3_G_16_S = 0;

[_1344] - HC_EF_BH_DV_1_DV3 + 2.801 * Q_BH_D_DV3_G_1_E + 0.549 * Q_BH_D_DV3_G_1_N + 4.717 * Q_BH_D_DV3_G_1_S = 0;

[_1345] - HC_EF_BH_DV_2_DV3 + 2.242 * Q_BH_D_DV3_G_2_E + 1.154 * Q_BH_D_DV3_G_2_N + 4.065 * Q_BH_D_DV3_G_2_S = 0;

[_1346] - HC_EF_BH_DV_3_DV3 + 1.803 * Q_BH_D_DV3_G_3_E + 1.824 * Q_BH_D_DV3_G_3_N + 4.301 * Q_BH_D_DV3_G_3_S = 0;

[_1347] - HC_EF_BH_DV_4_DV3 + 1.967 * Q_BH_D_DV3_G_4_E + 1.547 * Q_BH_D_DV3_G_4_N + 3.716 * Q_BH_D_DV3_G_4_S = 0;

[_1348] - HC_EF_BH_DV_5_DV3 + 1.654 * Q_BH_D_DV3_G_5_E + 1.883 * Q_BH_D_DV3_G_5_N + 3.378 * Q_BH_D_DV3_G_5_S = 0;

[_1349] - HC_EF_BH_DV_6_DV3 + 1.524 * Q_BH_D_DV3_G_6_E + 2.329 * Q_BH_D_DV3_G_6_N + 3.165 * Q_BH_D_DV3_G_6_S = 0;

[_1350] - HC_EF_BH_DV_7_DV3 + 0.423 * Q_BH_D_DV3_G_7_E + 2.903 * Q_BH_D_DV3_G_7_N + 3.157 * Q_BH_D_DV3_G_7_S = 0;

[_1351] - HC_EF_BH_DV_8_DV3 + 1.332 * Q_BH_D_DV3_G_8_E + 3.309 * Q_BH_D_DV3_G_8_N + 2.059 * Q_BH_D_DV3_G_8_S = 0;

[_1352] - HC_EF_BH_DV_9_DV3 + 2.318 * Q_BH_D_DV3_G_9_E + 3.678 * Q_BH_D_DV3_G_9_N + 2.307 * Q_BH_D_DV3_G_9_S = 0;

[_1353] - HC_EF_BH_DV_10_DV3 + 2.069 * Q_BH_D_DV3_G_10_E + 4.301 * Q_BH_D_DV3_G_10_N + 1.581 * Q_BH_D_DV3_G_10_S = 0;

[_1354] - HC_EF_BH_DV_11_DV3 + 2.626 * Q_BH_D_DV3_G_11_E + 4.994 * Q_BH_D_DV3_G_11_N + 1.23 * Q_BH_D_DV3_G_11_S = 0;

[_1355] - HC_EF_BH_DV_12_DV3 + 1.034 * Q_BH_D_DV3_G_12_E + 4.281 * Q_BH_D_DV3_G_12_N + 2.87 * Q_BH_D_DV3_G_12_S = 0;

[_1356] - HC_EF_BH_DV_13_DV3 + 2.955 * Q_BH_D_DV3_G_13_E + 4.891 * Q_BH_D_DV3_G_13_N + 0.908 * Q_BH_D_DV3_G_13_S = 0;

[_1357] - HC_EF_BH_DV_14_DV3 + 3.591 * Q_BH_D_DV3_G_14_E + 5.099 * Q_BH_D_DV3_G_14_N + 1.757 * Q_BH_D_DV3_G_14_S = 0;

[_1358] - HC_EF_BH_DV_15_DV3 + 4.098 * Q_BH_D_DV3_G_15_E + 5.194 * Q_BH_D_DV3_G_15_N + 4.181 * Q_BH_D_DV3_G_15_S = 0;

[_1359] - HC_EF_BH_DV_16_DV3 + 4.12965 * Q_BH_D_DV3_G_16_E + 5.87385 * Q_BH_D_DV3_G_16_N + 0.53865 * Q_BH_D_DV3_G_16_S = 0;

[_1360] - NOX_EF_BH_DV_1_DV3 + 17.902 * Q_BH_D_DV3_G_1_E + 3.508 * Q_BH_D_DV3_G_1_N + 30.148 * Q_BH_D_DV3_G_1_S = 0;

[_1361] - NOX_EF_BH_DV_2_DV3 + 14.328 * Q_BH_D_DV3_G_2_E + 7.377 * Q_BH_D_DV3_G_2_N + 25.98 * Q_BH_D_DV3_G_2_S = 0;

[_1362] - NOX_EF_BH_DV_3_DV3 + 11.524 * Q_BH_D_DV3_G_3_E + 11.656 * Q_BH_D_DV3_G_3_N + 27.49 * Q_BH_D_DV3_G_3_S = 0;

[_1363] - NOX_EF_BH_DV_4_DV3 + 12.574 * Q_BH_D_DV3_G_4_E + 9.885 * Q_BH_D_DV3_G_4_N + 23.755 * Q_BH_D_DV3_G_4_S = 0;

[_1364] - NOX_EF_BH_DV_5_DV3 + 10.574 * Q_BH_D_DV3_G_5_E + 12.033 * Q_BH_D_DV3_G_5_N + 21.59 * Q_BH_D_DV3_G_5_S = 0;

[_1365] - NOX_EF_BH_DV_6_DV3 + 9.738 * Q_BH_D_DV3_G_6_E + 14.886 * Q_BH_D_DV3_G_6_N + 20.23 * Q_BH_D_DV3_G_6_S = 0;

[_1366] - NOX_EF_BH_DV_7_DV3 + 2.705 * Q_BH_D_DV3_G_7_E + 18.56 * Q_BH_D_DV3_G_7_N + 20.18 * Q_BH_D_DV3_G_7_S = 0;

[_1367] - NOX_EF_BH_DV_8_DV3 + 8.517 * Q_BH_D_DV3_G_8_E + 21.15 * Q_BH_D_DV3_G_8_N + 13.164 * Q_BH_D_DV3_G_8_S = 0;

[_1368] - NOX_EF_BH_DV_9_DV3 + 14.82 * Q_BH_D_DV3_G_9_E + 23.509 * Q_BH_D_DV3_G_9_N + 14.745 * Q_BH_D_DV3_G_9_S = 0;

[_1369] - NOX_EF_BH_DV_10_DV3 + 13.23 * Q_BH_D_DV3_G_10_E + 27.49 * Q_BH_D_DV3_G_10_N + 10.107 * Q_BH_D_DV3_G_10_S = 0;

[_1370] - NOX_EF_BH_DV_11_DV3 + 16.787 * Q_BH_D_DV3_G_11_E + 31.92 * Q_BH_D_DV3_G_11_N + 7.862 * Q_BH_D_DV3_G_11_S = 0;

[_1371] - NOX_EF_BH_DV_12_DV3 + 6.607 * Q_BH_D_DV3_G_12_E + 27.36 * Q_BH_D_DV3_G_12_N + 18.345 * Q_BH_D_DV3_G_12_S = 0;

[_1372] - NOX_EF_BH_DV_13_DV3 + 18.885 * Q_BH_D_DV3_G_13_E + 31.26 * Q_BH_D_DV3_G_13_N + 5.803 * Q_BH_D_DV3_G_13_S = 0;

[_1373] - NOX_EF_BH_DV_14_DV3 + 22.952 * Q_BH_D_DV3_G_14_E + 32.59 * Q_BH_D_DV3_G_14_N + 11.229 * Q_BH_D_DV3_G_14_S = 0;

[_1374] - NOX_EF_BH_DV_15_DV3 + 26.197 * Q_BH_D_DV3_G_15_E + 33.197 * Q_BH_D_DV3_G_15_N + 26.72 * Q_BH_D_DV3_G_15_S = 0;

[_1375] - NOX_EF_BH_DV_16_DV3 + 26.39434 * Q_BH_D_DV3_G_16_E + 37.54226 * Q_BH_D_DV3_G_16_N + 3.44274 * Q_BH_D_DV3_G_16_S = 0;

[_1376] - PM_EF_BH_DV_1_DV3 + 1.924 * Q_BH_D_DV3_G_1_E + 0.379 * Q_BH_D_DV3_G_1_N + 3.24 * Q_BH_D_DV3_G_1_S = 0;

[_1377] - PM_EF_BH_DV_2_DV3 + 1.539 * Q_BH_D_DV3_G_2_E + 0.793 * Q_BH_D_DV3_G_2_N + 2.793 * Q_BH_D_DV3_G_2_S = 0;

[_1378] - PM_EF_BH_DV_3_DV3 + 1.239 * Q_BH_D_DV3_G_3_E + 1.253 * Q_BH_D_DV3_G_3_N + 2.955 * Q_BH_D_DV3_G_3_S = 0;

[_1379] - PM_EF_BH_DV_4_DV3 + 1.351 * Q_BH_D_DV3_G_4_E + 1.062 * Q_BH_D_DV3_G_4_N + 2.553 * Q_BH_D_DV3_G_4_S = 0;

[_1380] - PM_EF_BH_DV_5_DV3 + 1.136 * Q_BH_D_DV3_G_5_E + 1.293 * Q_BH_D_DV3_G_5_N + 2.32 * Q_BH_D_DV3_G_5_S = 0;

[_1381] - PM_EF_BH_DV_6_DV3 + 1.047 * Q_BH_D_DV3_G_6_E + 1.599 * Q_BH_D_DV3_G_6_N + 2.174 * Q_BH_D_DV3_G_6_S = 0;

[_1382] - PM_EF_BH_DV_7_DV3 + 0.291 * Q_BH_D_DV3_G_7_E + 1.994 * Q_BH_D_DV3_G_7_N + 2.169 * Q_BH_D_DV3_G_7_S = 0;

[_1383] - PM_EF_BH_DV_8_DV3 + 0.915 * Q_BH_D_DV3_G_8_E + 2.273 * Q_BH_D_DV3_G_8_N + 1.415 * Q_BH_D_DV3_G_8_S = 0;

[_1384] - PM_EF_BH_DV_9_DV3 + 1.593 * Q_BH_D_DV3_G_9_E + 2.527 * Q_BH_D_DV3_G_9_N + 1.585 * Q_BH_D_DV3_G_9_S = 0;

[_1385] - PM_EF_BH_DV_10_DV3 + 1.422 * Q_BH_D_DV3_G_10_E + 2.955 * Q_BH_D_DV3_G_10_N + 1.086 * Q_BH_D_DV3_G_10_S = 0;

[_1386] - PM_EF_BH_DV_11_DV3 + 1.804 * Q_BH_D_DV3_G_11_E + 3.431 * Q_BH_D_DV3_G_11_N + 0.845 * Q_BH_D_DV3_G_11_S = 0;

[_1387] - PM_EF_BH_DV_12_DV3 + 0.71 * Q_BH_D_DV3_G_12_E + 2.941 * Q_BH_D_DV3_G_12_N + 1.972 * Q_BH_D_DV3_G_12_S = 0;

[_1388] - PM_EF_BH_DV_13_DV3 + 2.029 * Q_BH_D_DV3_G_13_E + 3.36 * Q_BH_D_DV3_G_13_N + 0.624 * Q_BH_D_DV3_G_13_S = 0;

[_1389] - PM_EF_BH_DV_14_DV3 + 2.467 * Q_BH_D_DV3_G_14_E + 3.503 * Q_BH_D_DV3_G_14_N + 1.207 * Q_BH_D_DV3_G_14_S = 0;

[_1390] - PM_EF_BH_DV_15_DV3 + 2.816 * Q_BH_D_DV3_G_15_E + 3.568 * Q_BH_D_DV3_G_15_N + 2.872 * Q_BH_D_DV3_G_15_S = 0;

[_1391] - PM_EF_BH_DV_16_DV3 + 2.83682 * Q_BH_D_DV3_G_16_E + 4.03498 * Q_BH_D_DV3_G_16_N + 0.37002 * Q_BH_D_DV3_G_16_S = 0;

[_1392] - BENZ_EF_BH_DV_1_DV3 + 0.146E-01 * Q_BH_D_DV3_G_1_E + 0.29E-02 * Q_BH_D_DV3_G_1_N + 0.25E-01 * Q_BH_D_DV3_G_1_S = 0;

[_1393] - BENZ_EF_BH_DV_2_DV3 + 0.117E-01 * Q_BH_D_DV3_G_2_E + 0.6E-02 * Q_BH_D_DV3_G_2_N + 0.21E-01 * Q_BH_D_DV3_G_2_S = 0;

[_1394] - BENZ_EF_BH_DV_3_DV3 + 0.94E-02 * Q_BH_D_DV3_G_3_E + 0.95E-02 * Q_BH_D_DV3_G_3_N + 0.22E-01 * Q_BH_D_DV3_G_3_S = 0;

[_1395] - BENZ_EF_BH_DV_4_DV3 + 0.103E-01 * Q_BH_D_DV3_G_4_E + 0.81E-02 * Q_BH_D_DV3_G_4_N + 0.19E-01 * Q_BH_D_DV3_G_4_S = 0;

[_1396] - BENZ_EF_BH_DV_5_DV3 + 0.86E-02 * Q_BH_D_DV3_G_5_E + 0.98E-02 * Q_BH_D_DV3_G_5_N + 0.176E-01 * Q_BH_D_DV3_G_5_S = 0;

[_1397] - BENZ_EF_BH_DV_6_DV3 + 0.79E-02 * Q_BH_D_DV3_G_6_E + 0.12E-01 * Q_BH_D_DV3_G_6_N + 0.165E-01 * Q_BH_D_DV3_G_6_S = 0;

[_1398] - BENZ_EF_BH_DV_7_DV3 + 0.22E-02 * Q_BH_D_DV3_G_7_E + 0.15E-01 * Q_BH_D_DV3_G_7_N + 0.164E-01 * Q_BH_D_DV3_G_7_S = 0;

[_1399] - BENZ_EF_BH_DV_8_DV3 + 0.69E-02 * Q_BH_D_DV3_G_8_E + 0.17E-01 * Q_BH_D_DV3_G_8_N + 0.107E-01 * Q_BH_D_DV3_G_8_S = 0;

[_1400] - BENZ_EF_BH_DV_9_DV3 + 0.12E-01 * Q_BH_D_DV3_G_9_E + 0.19E-01 * Q_BH_D_DV3_G_9_N + 0.12E-01 * Q_BH_D_DV3_G_9_S = 0;

Annexure 9

[_1401] - BENZ_EF_BH_DV_10_DV3 + 0.108E-01 * Q_BH_D_DV3_G_10_E + 0.22E-01 * Q_BH_D_DV3_G_10_N + 0.83E-02 * Q_BH_D_DV3_G_10_S = 0;

[_1402] - BENZ_EF_BH_DV_11_DV3 + 0.14E-01 * Q_BH_D_DV3_G_11_E + 0.26E-01 * Q_BH_D_DV3_G_11_N + 0.643E-02 * Q_BH_D_DV3_G_11_S = 0;

[_1403] - BENZ_EF_BH_DV_12_DV3 + 0.54E-02 * Q_BH_D_DV3_G_12_E + 0.223E-01 * Q_BH_D_DV3_G_12_N + 0.149E-01 * Q_BH_D_DV3_G_12_S = 0;

[_1404] - BENZ_EF_BH_DV_13_DV3 + 0.15E-01 * Q_BH_D_DV3_G_13_E + 0.25E-01 * Q_BH_D_DV3_G_13_N + 0.47E-02 * Q_BH_D_DV3_G_13_S = 0;

[_1405] - BENZ_EF_BH_DV_14_DV3 + 0.187E-01 * Q_BH_D_DV3_G_14_E + 0.27E-01 * Q_BH_D_DV3_G_14_N + 0.92E-02 * Q_BH_D_DV3_G_14_S = 0;

[_1406] - BENZ_EF_BH_DV_15_DV3 + 0.214E-01 * Q_BH_D_DV3_G_15_E + 0.271E-01 * Q_BH_D_DV3_G_15_N + 0.22E-01 * Q_BH_D_DV3_G_15_S = 0;

[_1407] - BENZ_EF_BH_DV_16_DV3 + 0.21574E-01 * Q_BH_D_DV3_G_16_E + 0.30686E-01 * Q_BH_D_DV3_G_16_N + 0.2814E-02 * Q_BH_D_DV3_G_16_S = 0;

[_1408] - BUTDN_EF_BH_DV_1_DV3 + 0.26E-02 * Q_BH_D_DV3_G_1_E + 0.51E-03 * Q_BH_D_DV3_G_1_N + 0.44E-02 * Q_BH_D_DV3_G_1_S = 0;

[_1409] - BUTDN_EF_BH_DV_2_DV3 + 0.21E-02 * Q_BH_D_DV3_G_2_E + 0.11E-02 * Q_BH_D_DV3_G_2_N + 0.38E-02 * Q_BH_D_DV3_G_2_S = 0;

[_1410] - BUTDN_EF_BH_DV_3_DV3 + 0.17E-02 * Q_BH_D_DV3_G_3_E + 0.17E-02 * Q_BH_D_DV3_G_3_N + 0.4E-02 * Q_BH_D_DV3_G_3_S = 0;

[_1411] - BUTDN_EF_BH_DV_4_DV3 + 0.18E-02 * Q_BH_D_DV3_G_4_E + 0.14E-02 * Q_BH_D_DV3_G_4_N + 0.35E-02 * Q_BH_D_DV3_G_4_S = 0;

[_1412] - BUTDN_EF_BH_DV_5_DV3 + 0.15E-02 * Q_BH_D_DV3_G_5_E + 0.176E-02 * Q_BH_D_DV3_G_5_N + 0.32E-02 * Q_BH_D_DV3_G_5_S = 0;

[_1413] - BUTDN_EF_BH_DV_6_DV3 + 0.14E-02 * Q_BH_D_DV3_G_6_E + 0.22E-02 * Q_BH_D_DV3_G_6_N + 0.296E-02 * Q_BH_D_DV3_G_6_S = 0;

[_1414] - BUTDN_EF_BH_DV_7_DV3 + 0.39E-03 * Q_BH_D_DV3_G_7_E + 0.27E-02 * Q_BH_D_DV3_G_7_N + 0.29E-02 * Q_BH_D_DV3_G_7_S = 0;

[_1415] - BUTDN_EF_BH_DV_8_DV3 + 0.125E-02 * Q_BH_D_DV3_G_8_E + 0.31E-02 * Q_BH_D_DV3_G_8_N + 0.193E-02 * Q_BH_D_DV3_G_8_S = 0;

[_1416] - BUTDN_EF_BH_DV_9_DV3 + 0.217E-02 * Q_BH_D_DV3_G_9_E + 0.34E-02 * Q_BH_D_DV3_G_9_N + 0.216E-02 * Q_BH_D_DV3_G_9_S = 0;

[_1417] - BUTDN_EF_BH_DV_10_DV3 + 0.194E-02 * Q_BH_D_DV3_G_10_E + 0.4E-02 * Q_BH_D_DV3_G_10_N + 0.15E-02 * Q_BH_D_DV3_G_10_S = 0;

[_1418] - BUTDN_EF_BH_DV_11_DV3 + 0.24E-02 * Q_BH_D_DV3_G_11_E + 0.47E-02 * Q_BH_D_DV3_G_11_N + 0.115E-02 * Q_BH_D_DV3_G_11_S = 0;

[_1419] - BUTDN_EF_BH_DV_12_DV3 + 0.97E-03 * Q_BH_D_DV3_G_12_E + 0.4E-02 * Q_BH_D_DV3_G_12_N + 0.268E-02 * Q_BH_D_DV3_G_12_S = 0;

[_1420] - BUTDN_EF_BH_DV_13_DV3 + 0.276E-02 * Q_BH_D_DV3_G_13_E + 0.46E-02 * Q_BH_D_DV3_G_13_N + 0.85E-03 * Q_BH_D_DV3_G_13_S = 0;

[_1421] - BUTDN_EF_BH_DV_14_DV3 + 0.34E-02 * Q_BH_D_DV3_G_14_E + 0.48E-02 * Q_BH_D_DV3_G_14_N + 0.16E-02 * Q_BH_D_DV3_G_14_S = 0;

[_1422] - BUTDN_EF_BH_DV_15_DV3 + 0.38E-02 * Q_BH_D_DV3_G_15_E + 0.49E-02 * Q_BH_D_DV3_G_15_N + 0.39E-02 * Q_BH_D_DV3_G_15_S = 0;

[_1423] - BUTDN_EF_BH_DV_16_DV3 + 0.3864E-02 * Q_BH_D_DV3_G_16_E + 0.5496E-02 * Q_BH_D_DV3_G_16_N + 0.504E-03 * Q_BH_D_DV3_G_16_S = 0;

[_1424] - CO_EF_BH_DV_1_DV4 + 13.837 * Q_BH_D_DV4_G_1_E + 2.711 * Q_BH_D_DV4_G_1_N + 23.302 * Q_BH_D_DV4_G_1_S = 0;

[_1425] - CO_EF_BH_DV_2_DV4 + 11.075 * Q_BH_D_DV4_G_2_E + 5.702 * Q_BH_D_DV4_G_2_N + 20.084 * Q_BH_D_DV4_G_2_S = 0;

[_1426] - CO_EF_BH_DV_3_DV4 + 8.908 * Q_BH_D_DV4_G_3_E + 9.009 * Q_BH_D_DV4_G_3_N + 21.249 * Q_BH_D_DV4_G_3_S = 0;

[_1427] - CO_EF_BH_DV_4_DV4 + 9.719 * Q_BH_D_DV4_G_4_E + 7.641 * Q_BH_D_DV4_G_4_N + 18.36 * Q_BH_D_DV4_G_4_S = 0;

[_1428] - CO_EF_BH_DV_5_DV4 + 8.173 * Q_BH_D_DV4_G_5_E + 9.301 * Q_BH_D_DV4_G_5_N + 16.688 * Q_BH_D_DV4_G_5_S = 0;

[_1429] - CO_EF_BH_DV_6_DV4 + 7.527 * Q_BH_D_DV4_G_6_E + 11.506 * Q_BH_D_DV4_G_6_N + 15.64 * Q_BH_D_DV4_G_6_S = 0;

[_1430] - CO_EF_BH_DV_7_DV4 + 2.091 * Q_BH_D_DV4_G_7_E + 14.344 * Q_BH_D_DV4_G_7_N + 15.598 * Q_BH_D_DV4_G_7_S = 0;

[_1431] - CO_EF_BH_DV_8_DV4 + 6.583 * Q_BH_D_DV4_G_8_E + 16.346 * Q_BH_D_DV4_G_8_N + 10.175 * Q_BH_D_DV4_G_8_S = 0;

[_1432] - CO_EF_BH_DV_9_DV4 + 11.455 * Q_BH_D_DV4_G_9_E + 18.171 * Q_BH_D_DV4_G_9_N + 11.397 * Q_BH_D_DV4_G_9_S = 0;

[_1433] - CO_EF_BH_DV_10_DV4 + 10.226 * Q_BH_D_DV4_G_10_E + 21.249 * Q_BH_D_DV4_G_10_N + 7.812 * Q_BH_D_DV4_G_10_S = 0;

[_1434] - CO_EF_BH_DV_11_DV4 + 12.975 * Q_BH_D_DV4_G_11_E + 24.67 * Q_BH_D_DV4_G_11_N + 6.077 * Q_BH_D_DV4_G_11_S = 0;

[_1435] - CO_EF_BH_DV_12_DV4 + 5.106 * Q_BH_D_DV4_G_12_E + 21.149 * Q_BH_D_DV4_G_12_N + 14.179 * Q_BH_D_DV4_G_12_S = 0;

[_1436] - CO_EF_BH_DV_13_DV4 + 14.597 * Q_BH_D_DV4_G_13_E + 24.164 * Q_BH_D_DV4_G_13_N + 4.486 * Q_BH_D_DV4_G_13_S = 0;

[_1437] - CO_EF_BH_DV_14_DV4 + 17.74 * Q_BH_D_DV4_G_14_E + 25.191 * Q_BH_D_DV4_G_14_N + 8.679 * Q_BH_D_DV4_G_14_S = 0;

[_1438] - CO_EF_BH_DV_15_DV4 + 20.249 * Q_BH_D_DV4_G_15_E + 25.659 * Q_BH_D_DV4_G_15_N + 20.654 * Q_BH_D_DV4_G_15_S = 0;

[_1439] - CO_EF_BH_DV_16_DV4 + 20.401 * Q_BH_D_DV4_G_16_E + 29.01757143 * Q_BH_D_DV4_G_16_N + 2.661 * Q_BH_D_DV4_G_16_S = 0;

[_1440] - SO2_EF_BH_DV_1_DV4 + 1.227 * Q_BH_D_DV4_G_1_E + 0.24 * Q_BH_D_DV4_G_1_N + 2.066 * Q_BH_D_DV4_G_1_S = 0;

[_1441] - SO2_EF_BH_DV_2_DV4 + 0.982 * Q_BH_D_DV4_G_2_E + 0.505 * Q_BH_D_DV4_G_2_N + 1.7804 * Q_BH_D_DV4_G_2_S = 0;

[_1442] - SO2_EF_BH_DV_3_DV4 + 0.789 * Q_BH_D_DV4_G_3_E + 0.798 * Q_BH_D_DV4_G_3_N + 1.884 * Q_BH_D_DV4_G_3_S = 0;

[_1443] - SO2_EF_BH_DV_4_DV4 + 0.861 * Q_BH_D_DV4_G_4_E + 0.677 * Q_BH_D_DV4_G_4_N + 1.627 * Q_BH_D_DV4_G_4_S = 0;

[_1444] - SO2_EF_BH_DV_5_DV4 + 0.724 * Q_BH_D_DV4_G_5_E + 0.824 * Q_BH_D_DV4_G_5_N + 1.479 * Q_BH_D_DV4_G_5_S = 0;

[_1445] - SO2_EF_BH_DV_6_DV4 + 0.667 * Q_BH_D_DV4_G_6_E + 1.019 * Q_BH_D_DV4_G_6_N + 1.386 * Q_BH_D_DV4_G_6_S = 0;

[_1446] - SO2_EF_BH_DV_7_DV4 + 0.185 * Q_BH_D_DV4_G_7_E + 1.271 * Q_BH_D_DV4_G_7_N + 1.383 * Q_BH_D_DV4_G_7_S = 0;

[_1447] - SO2_EF_BH_DV_8_DV4 + 0.583 * Q_BH_D_DV4_G_8_E + 1.449 * Q_BH_D_DV4_G_8_N + 0.902 * Q_BH_D_DV4_G_8_S = 0;

[_1448] - SO2_EF_BH_DV_9_DV4 + 1.015 * Q_BH_D_DV4_G_9_E + 1.611 * Q_BH_D_DV4_G_9_N + 1.01 * Q_BH_D_DV4_G_9_S = 0;

[_1449] - SO2_EF_BH_DV_10_DV4 + 0.906 * Q_BH_D_DV4_G_10_E + 1.884 * Q_BH_D_DV4_G_10_N + 0.692 * Q_BH_D_DV4_G_10_S = 0;

[_1450] - SO2_EF_BH_DV_11_DV4 + 1.15 * Q_BH_D_DV4_G_11_E + 2.187 * Q_BH_D_DV4_G_11_N + 0.539 * Q_BH_D_DV4_G_11_S = 0;

[_1451] - SO2_EF_BH_DV_12_DV4 + 0.453 * Q_BH_D_DV4_G_12_E + 1.875 * Q_BH_D_DV4_G_12_N + 1.257 * Q_BH_D_DV4_G_12_S = 0;

[_1452] - SO2_EF_BH_DV_13_DV4 + 1.294 * Q_BH_D_DV4_G_13_E + 2.142 * Q_BH_D_DV4_G_13_N + 0.397 * Q_BH_D_DV4_G_13_S = 0;

[_1453] - SO2_EF_BH_DV_14_DV4 + 1.573 * Q_BH_D_DV4_G_14_E + 2.233 * Q_BH_D_DV4_G_14_N + 0.769 * Q_BH_D_DV4_G_14_S = 0;

[_1454] - SO2_EF_BH_DV_15_DV4 + 1.795 * Q_BH_D_DV4_G_15_E + 2.275 * Q_BH_D_DV4_G_15_N + 1.831 * Q_BH_D_DV4_G_15_S = 0;

[_1455] - SO2_EF_BH_DV_16_DV4 + 1.808493151 * Q_BH_D_DV4_G_16_E + 2.572328767 * Q_BH_D_DV4_G_16_N + 0.235890411 * Q_BH_D_DV4_G_16_S = 0;

[_1456] - CO2_EF_BH_DV_1_DV4 + 5568.18 * Q_BH_D_DV4_G_1_E + 1091.2 * Q_BH_D_DV4_G_1_N + 9377.19 * Q_BH_D_DV4_G_1_S = 0;

[_1457] - CO2_EF_BH_DV_2_DV4 + 4456.59 * Q_BH_D_DV4_G_2_E + 2294.58 * Q_BH_D_DV4_G_2_N + 8082.03 * Q_BH_D_DV4_G_2_S = 0;

[_1458] - CO2_EF_BH_DV_3_DV4 + 3584.65 * Q_BH_D_DV4_G_3_E + 3625.44 * Q_BH_D_DV4_G_3_N + 8551.14 * Q_BH_D_DV4_G_3_S = 0;

[_1459] - CO2_EF_BH_DV_4_DV4 + 3910.98 * Q_BH_D_DV4_G_4_E + 3074.78 * Q_BH_D_DV4_G_4_N + 7388.55 * Q_BH_D_DV4_G_4_S = 0;

[_1460] - CO2_EF_BH_DV_5_DV4 + 3288.9 * Q_BH_D_DV4_G_5_E + 3742.72 * Q_BH_D_DV4_G_5_N + 6715.47 * Q_BH_D_DV4_G_5_S = 0;

[_1461] - CO2_EF_BH_DV_6_DV4 + 3028.85 * Q_BH_D_DV4_G_6_E + 4629.95 * Q_BH_D_DV4_G_6_N + 6292.25 * Q_BH_D_DV4_G_6_S = 0;

[_1462] - CO2_EF_BH_DV_7_DV4 + 841.35 * Q_BH_D_DV4_G_7_E + 5772.15 * Q_BH_D_DV4_G_7_N + 6276.96 * Q_BH_D_DV4_G_7_S = 0;

[_1463] - CO2_EF_BH_DV_8_DV4 + 2648.97 * Q_BH_D_DV4_G_8_E + 6577.8 * Q_BH_D_DV4_G_8_N + 4094.55 * Q_BH_D_DV4_G_8_S = 0;

[_1464] - CO2_EF_BH_DV_9_DV4 + 4609.56 * Q_BH_D_DV4_G_9_E + 7312.07 * Q_BH_D_DV4_G_9_N + 4586.1 * Q_BH_D_DV4_G_9_S = 0;

[_1465] - CO2_EF_BH_DV_10_DV4 + 4114.95 * Q_BH_D_DV4_G_10_E + 8551.14 * Q_BH_D_DV4_G_10_N + 3143.58 * Q_BH_D_DV4_G_10_S = 0;

[_1466] - CO2_EF_BH_DV_11_DV4 + 5221.449 * Q_BH_D_DV4_G_11_E + 9927.89 * Q_BH_D_DV4_G_11_N + 2445.51 * Q_BH_D_DV4_G_11_S = 0;

[_1467] - CO2_EF_BH_DV_12_DV4 + 2054.93 * Q_BH_D_DV4_G_12_E + 8510.35 * Q_BH_D_DV4_G_12_N + 5705.86 * Q_BH_D_DV4_G_12_S = 0;

[_1468] - CO2_EF_BH_DV_13_DV4 + 5874.13 * Q_BH_D_DV4_G_13_E + 9723.93 * Q_BH_D_DV4_G_13_N + 1805.07 * Q_BH_D_DV4_G_13_S = 0;

[_1469] - CO2_EF_BH_DV_14_DV4 + 7138.69 * Q_BH_D_DV4_G_14_E + 10136.95 * Q_BH_D_DV4_G_14_N + 3492.86 * Q_BH_D_DV4_G_14_S = 0;

[_1470] - CO2_EF_BH_DV_15_DV4 + 8148.314 * Q_BH_D_DV4_G_15_E + 10325.62 * Q_BH_D_DV4_G_15_N + 8311.485 * Q_BH_D_DV4_G_15_S = 0;

[_1471] - CO2_EF_BH_DV_16_DV4 + 8209.50293 * Q_BH_D_DV4_G_16_E + 11676.87063 * Q_BH_D_DV4_G_16_N + 1070.80473 * Q_BH_D_DV4_G_16_S = 0;

[_1472] - HC_EF_BH_DV_1_DV4 + 3.828 * Q_BH_D_DV4_G_1_E + 0.75 * Q_BH_D_DV4_G_1_N + 6.447 * Q_BH_D_DV4_G_1_S = 0;

[_1473] - HC_EF_BH_DV_2_DV4 + 3.064 * Q_BH_D_DV4_G_2_E + 1.577 * Q_BH_D_DV4_G_2_N + 5.556 * Q_BH_D_DV4_G_2_S = 0;

[_1474] - HC_EF_BH_DV_3_DV4 + 2.464 * Q_BH_D_DV4_G_3_E + 2.492 * Q_BH_D_DV4_G_3_N + 5.879 * Q_BH_D_DV4_G_3_S = 0;

[_1475] - HC_EF_BH_DV_4_DV4 + 2.689 * Q_BH_D_DV4_G_4_E + 2.114 * Q_BH_D_DV4_G_4_N + 5.079 * Q_BH_D_DV4_G_4_S = 0;

[_1476] - HC_EF_BH_DV_5_DV4 + 2.261 * Q_BH_D_DV4_G_5_E + 2.573 * Q_BH_D_DV4_G_5_N + 4.617 * Q_BH_D_DV4_G_5_S = 0;

[_1477] - HC_EF_BH_DV_6_DV4 + 2.082 * Q_BH_D_DV4_G_6_E + 3.183 * Q_BH_D_DV4_G_6_N + 4.326 * Q_BH_D_DV4_G_6_S = 0;

[_1478] - HC_EF_BH_DV_7_DV4 + 0.578 * Q_BH_D_DV4_G_7_E + 3.968 * Q_BH_D_DV4_G_7_N + 4.315 * Q_BH_D_DV4_G_7_S = 0;

Annexure 9

[_1479] - HC_EF_BH_DV_8_DV4 + 1.821 * Q_BH_D_DV4_G_8_E + 4.522 * Q_BH_D_DV4_G_8_N + 2.815 * Q_BH_D_DV4_G_8_S = 0;

[_1480] - HC_EF_BH_DV_9_DV4 + 3.169 * Q_BH_D_DV4_G_9_E + 5.027 * Q_BH_D_DV4_G_9_N + 3.153 * Q_BH_D_DV4_G_9_S = 0;

[_1481] - HC_EF_BH_DV_10_DV4 + 2.829 * Q_BH_D_DV4_G_10_E + 5.879 * Q_BH_D_DV4_G_10_N + 2.161 * Q_BH_D_DV4_G_10_S = 0;

[_1482] - HC_EF_BH_DV_11_DV4 + 3.589 * Q_BH_D_DV4_G_11_E + 6.826 * Q_BH_D_DV4_G_11_N + 1.681 * Q_BH_D_DV4_G_11_S = 0;

[_1483] - HC_EF_BH_DV_12_DV4 + 1.413 * Q_BH_D_DV4_G_12_E + 5.851 * Q_BH_D_DV4_G_12_N + 3.923 * Q_BH_D_DV4_G_12_S = 0;

[_1484] - HC_EF_BH_DV_13_DV4 + 4.038 * Q_BH_D_DV4_G_13_E + 6.685 * Q_BH_D_DV4_G_13_N + 1.241 * Q_BH_D_DV4_G_13_S = 0;

[_1485] - HC_EF_BH_DV_14_DV4 + 4.908 * Q_BH_D_DV4_G_14_E + 6.969 * Q_BH_D_DV4_G_14_N + 2.401 * Q_BH_D_DV4_G_14_S = 0;

[_1486] - HC_EF_BH_DV_15_DV4 + 5.602 * Q_BH_D_DV4_G_15_E + 7.099 * Q_BH_D_DV4_G_15_N + 5.714 * Q_BH_D_DV4_G_15_S = 0;

[_1487] - HC_EF_BH_DV_16_DV4 + 5.6442 * Q_BH_D_DV4_G_16_E + 8.028085714 * Q_BH_D_DV4_G_16_N + 0.7362 * Q_BH_D_DV4_G_16_S = 0;

[_1488] - NOX_EF_BH_DV_1_DV4 + 24.656 * Q_BH_D_DV4_G_1_E + 4.832 * Q_BH_D_DV4_G_1_N + 41.52 * Q_BH_D_DV4_G_1_S = 0;

[_1489] - NOX_EF_BH_DV_2_DV4 + 19.734 * Q_BH_D_DV4_G_2_E + 10.16 * Q_BH_D_DV4_G_2_N + 35.787 * Q_BH_D_DV4_G_2_S = 0;

[_1490] - NOX_EF_BH_DV_3_DV4 + 15.873 * Q_BH_D_DV4_G_3_E + 16.053 * Q_BH_D_DV4_G_3_N + 37.865 * Q_BH_D_DV4_G_3_S = 0;

[_1491] - NOX_EF_BH_DV_4_DV4 + 17.318 * Q_BH_D_DV4_G_4_E + 13.615 * Q_BH_D_DV4_G_4_N + 32.717 * Q_BH_D_DV4_G_4_S = 0;

[_1492] - NOX_EF_BH_DV_5_DV4 + 14.563 * Q_BH_D_DV4_G_5_E + 16.573 * Q_BH_D_DV4_G_5_N + 29.736 * Q_BH_D_DV4_G_5_S = 0;

[_1493] - NOX_EF_BH_DV_6_DV4 + 13.412 * Q_BH_D_DV4_G_6_E + 20.502 * Q_BH_D_DV4_G_6_N + 27.862 * Q_BH_D_DV4_G_6_S = 0;

[_1494] - NOX_EF_BH_DV_7_DV4 + 3.725 * Q_BH_D_DV4_G_7_E + 25.56 * Q_BH_D_DV4_G_7_N + 27.794 * Q_BH_D_DV4_G_7_S = 0;

[_1495] - NOX_EF_BH_DV_8_DV4 + 11.729 * Q_BH_D_DV4_G_8_E + 29.127 * Q_BH_D_DV4_G_8_N + 18.131 * Q_BH_D_DV4_G_8_S = 0;

[_1496] - NOX_EF_BH_DV_9_DV4 + 20.41 * Q_BH_D_DV4_G_9_E + 32.378 * Q_BH_D_DV4_G_9_N + 20.307 * Q_BH_D_DV4_G_9_S = 0;

[_1497] - NOX_EF_BH_DV_10_DV4 + 18.22 * Q_BH_D_DV4_G_10_E + 37.865 * Q_BH_D_DV4_G_10_N + 13.92 * Q_BH_D_DV4_G_10_S = 0;

[_1498] - NOX_EF_BH_DV_11_DV4 + 23.121 * Q_BH_D_DV4_G_11_E + 43.961 * Q_BH_D_DV4_G_11_N + 10.829 * Q_BH_D_DV4_G_11_S = 0;

[_1499] - NOX_EF_BH_DV_12_DV4 + 9.099 * Q_BH_D_DV4_G_12_E + 37.684 * Q_BH_D_DV4_G_12_N + 25.266 * Q_BH_D_DV4_G_12_S = 0;

[_1500] - NOX_EF_BH_DV_13_DV4 + 26.011 * Q_BH_D_DV4_G_13_E + 43.058 * Q_BH_D_DV4_G_13_N + 7.993 * Q_BH_D_DV4_G_13_S = 0;

[_1501] - NOX_EF_BH_DV_14_DV4 + 31.61 * Q_BH_D_DV4_G_14_E + 44.887 * Q_BH_D_DV4_G_14_N + 15.466 * Q_BH_D_DV4_G_14_S = 0;

[_1502] - NOX_EF_BH_DV_15_DV4 + 36.081 * Q_BH_D_DV4_G_15_E + 45.72 * Q_BH_D_DV4_G_15_N + 36.803 * Q_BH_D_DV4_G_15_S = 0;

[_1503] - NOX_EF_BH_DV_16_DV4 + 36.35196 * Q_BH_D_DV4_G_16_E + 51.70558286 * Q_BH_D_DV4_G_16_N + 4.74156 * Q_BH_D_DV4_G_16_S = 0;

[_1504] - PM_EF_BH_DV_1_DV4 + 2.465 * Q_BH_D_DV4_G_1_E + 0.483 * Q_BH_D_DV4_G_1_N + 4.151 * Q_BH_D_DV4_G_1_S = 0;

[_1505] - PM_EF_BH_DV_2_DV4 + 1.973 * Q_BH_D_DV4_G_2_E + 1.016 * Q_BH_D_DV4_G_2_N + 3.577 * Q_BH_D_DV4_G_2_S = 0;

[_1506] - PM_EF_BH_DV_3_DV4 + 1.587 * Q_BH_D_DV4_G_3_E + 1.605 * Q_BH_D_DV4_G_3_N + 3.785 * Q_BH_D_DV4_G_3_S = 0;

[_1507] - PM_EF_BH_DV_4_DV4 + 1.731 * Q_BH_D_DV4_G_4_E + 1.361 * Q_BH_D_DV4_G_4_N + 3.271 * Q_BH_D_DV4_G_4_S = 0;

[_1508] - PM_EF_BH_DV_5_DV4 + 1.456 * Q_BH_D_DV4_G_5_E + 1.657 * Q_BH_D_DV4_G_5_N + 2.973 * Q_BH_D_DV4_G_5_S = 0;

[_1509] - PM_EF_BH_DV_6_DV4 + 1.341 * Q_BH_D_DV4_G_6_E + 2.049 * Q_BH_D_DV4_G_6_N + 2.785 * Q_BH_D_DV4_G_6_S = 0;

[_1510] - PM_EF_BH_DV_7_DV4 + 0.372 * Q_BH_D_DV4_G_7_E + 2.555 * Q_BH_D_DV4_G_7_N + 2.778 * Q_BH_D_DV4_G_7_S = 0;

[_1511] - PM_EF_BH_DV_8_DV4 + 1.172 * Q_BH_D_DV4_G_8_E + 2.912 * Q_BH_D_DV4_G_8_N + 1.812 * Q_BH_D_DV4_G_8_S = 0;

[_1512] - PM_EF_BH_DV_9_DV4 + 2.04 * Q_BH_D_DV4_G_9_E + 3.237 * Q_BH_D_DV4_G_9_N + 2.03 * Q_BH_D_DV4_G_9_S = 0;

[_1513] - PM_EF_BH_DV_10_DV4 + 1.821 * Q_BH_D_DV4_G_10_E + 3.785 * Q_BH_D_DV4_G_10_N + 1.391 * Q_BH_D_DV4_G_10_S = 0;

[_1514] - PM_EF_BH_DV_11_DV4 + 2.311 * Q_BH_D_DV4_G_11_E + 4.395 * Q_BH_D_DV4_G_11_N + 1.082 * Q_BH_D_DV4_G_11_S = 0;

[_1515] - PM_EF_BH_DV_12_DV4 + 0.9096 * Q_BH_D_DV4_G_12_E + 3.767 * Q_BH_D_DV4_G_12_N + 2.526 * Q_BH_D_DV4_G_12_S = 0;

[_1516] - PM_EF_BH_DV_13_DV4 + 2.6 * Q_BH_D_DV4_G_13_E + 4.304 * Q_BH_D_DV4_G_13_N + 0.799 * Q_BH_D_DV4_G_13_S = 0;

[_1517] - PM_EF_BH_DV_14_DV4 + 3.16 * Q_BH_D_DV4_G_14_E + 4.487 * Q_BH_D_DV4_G_14_N + 1.546 * Q_BH_D_DV4_G_14_S = 0;

[_1518] - PM_EF_BH_DV_15_DV4 + 3.607 * Q_BH_D_DV4_G_15_E + 4.571 * Q_BH_D_DV4_G_15_N + 3.679 * Q_BH_D_DV4_G_15_S = 0;

[_1519] - PM_EF_BH_DV_16_DV4 + 3.634 * Q_BH_D_DV4_G_16_E + 5.168857143 * Q_BH_D_DV4_G_16_N + 0.474 * Q_BH_D_DV4_G_16_S = 0;

[_1520] - BENZ_EF_BH_DV_1_DV4 + 0.196E-01 * Q_BH_D_DV4_G_1_E + 0.38E-02 * Q_BH_D_DV4_G_1_N + 0.33E-01 * Q_BH_D_DV4_G_1_S = 0;

[_1521] - BENZ_EF_BH_DV_2_DV4 + 0.157E-01 * Q_BH_D_DV4_G_2_E + 0.81E-02 * Q_BH_D_DV4_G_2_N + 0.28E-01 * Q_BH_D_DV4_G_2_S = 0;

[_1522] - BENZ_EF_BH_DV_3_DV4 + 0.126E-01 * Q_BH_D_DV4_G_3_E + 0.128E-01 * Q_BH_D_DV4_G_3_N + 0.302E-01 * Q_BH_D_DV4_G_3_S = 0;

[_1523] - BENZ_EF_BH_DV_4_DV4 + 0.138E-01 * Q_BH_D_DV4_G_4_E + 0.11E-01 * Q_BH_D_DV4_G_4_N + 0.26E-01 * Q_BH_D_DV4_G_4_S = 0;

[_1524] - BENZ_EF_BH_DV_5_DV4 + 0.116E-01 * Q_BH_D_DV4_G_5_E + 0.132E-01 * Q_BH_D_DV4_G_5_N + 0.24E-01 * Q_BH_D_DV4_G_5_S = 0;

[_1525] - BENZ_EF_BH_DV_6_DV4 + 0.106E-01 * Q_BH_D_DV4_G_6_E + 0.163E-01 * Q_BH_D_DV4_G_6_N + 0.22E-01 * Q_BH_D_DV4_G_6_S = 0;

[_1526] - BENZ_EF_BH_DV_7_DV4 + 0.297E-02 * Q_BH_D_DV4_G_7_E + 0.203E-01 * Q_BH_D_DV4_G_7_N + 0.221E-01 * Q_BH_D_DV4_G_7_S = 0;

[_1527] - BENZ_EF_BH_DV_8_DV4 + 0.93E-02 * Q_BH_D_DV4_G_8_E + 0.23E-01 * Q_BH_D_DV4_G_8_N + 0.14E-01 * Q_BH_D_DV4_G_8_S = 0;

[_1528] - BENZ_EF_BH_DV_9_DV4 + 0.163E-01 * Q_BH_D_DV4_G_9_E + 0.26E-01 * Q_BH_D_DV4_G_9_N + 0.162E-01 * Q_BH_D_DV4_G_9_S = 0;

[_1529] - BENZ_EF_BH_DV_10_DV4 + 0.145E-01 * Q_BH_D_DV4_G_10_E + 0.302E-01 * Q_BH_D_DV4_G_10_N + 0.11E-01 * Q_BH_D_DV4_G_10_S = 0;

[_1530] - BENZ_EF_BH_DV_11_DV4 + 0.184E-01 * Q_BH_D_DV4_G_11_E + 0.35E-01 * Q_BH_D_DV4_G_11_N + 0.86E-02 * Q_BH_D_DV4_G_11_S = 0;

[_1531] - BENZ_EF_BH_DV_12_DV4 + 0.72E-02 * Q_BH_D_DV4_G_12_E + 0.3E-01 * Q_BH_D_DV4_G_12_N + 0.201E-01 * Q_BH_D_DV4_G_12_S = 0;

[_1532] - BENZ_EF_BH_DV_13_DV4 + 0.207E-01 * Q_BH_D_DV4_G_13_E + 0.34E-01 * Q_BH_D_DV4_G_13_N + 0.64E-02 * Q_BH_D_DV4_G_13_S = 0;

[_1533] - BENZ_EF_BH_DV_14_DV4 + 0.252E-01 * Q_BH_D_DV4_G_14_E + 0.36E-01 * Q_BH_D_DV4_G_14_N + 0.123E-01 * Q_BH_D_DV4_G_14_S = 0;

[_1534] - BENZ_EF_BH_DV_15_DV4 + 0.287E-01 * Q_BH_D_DV4_G_15_E + 0.364E-01 * Q_BH_D_DV4_G_15_N + 0.293E-01 * Q_BH_D_DV4_G_15_S = 0;

[_1535] - BENZ_EF_BH_DV_16_DV4 + 0.2898E-01 * Q_BH_D_DV4_G_16_E + 0.4122E-01 * Q_BH_D_DV4_G_16_N + 0.378E-02 * Q_BH_D_DV4_G_16_S = 0;

[_1536] - BUTDN_EF_BH_DV_1_DV4 + 0.345E-02 * Q_BH_D_DV4_G_1_E + 0.67E-03 * Q_BH_D_DV4_G_1_N + 0.58E-02 * Q_BH_D_DV4_G_1_S = 0;

[_1537] - BUTDN_EF_BH_DV_2_DV4 + 0.275E-02 * Q_BH_D_DV4_G_2_E + 0.14E-02 * Q_BH_D_DV4_G_2_N + 0.49E-02 * Q_BH_D_DV4_G_2_S = 0;

[_1538] - BUTDN_EF_BH_DV_3_DV4 + 0.22E-02 * Q_BH_D_DV4_G_3_E + 0.22E-02 * Q_BH_D_DV4_G_3_N + 0.527E-02 * Q_BH_D_DV4_G_3_S = 0;

[_1539] - BUTDN_EF_BH_DV_4_DV4 + 0.24E-02 * Q_BH_D_DV4_G_4_E + 0.189E-02 * Q_BH_D_DV4_G_4_N + 0.45E-02 * Q_BH_D_DV4_G_4_S = 0;

[_1540] - BUTDN_EF_BH_DV_5_DV4 + 0.203E-02 * Q_BH_D_DV4_G_5_E + 0.231E-02 * Q_BH_D_DV4_G_5_N + 0.41E-02 * Q_BH_D_DV4_G_5_S = 0;

[_1541] - BUTDN_EF_BH_DV_6_DV4 + 0.186E-02 * Q_BH_D_DV4_G_6_E + 0.285E-02 * Q_BH_D_DV4_G_6_N + 0.39E-02 * Q_BH_D_DV4_G_6_S = 0;

[_1542] - BUTDN_EF_BH_DV_7_DV4 + 0.52E-03 * Q_BH_D_DV4_G_7_E + 0.356E-02 * Q_BH_D_DV4_G_7_N + 0.386E-02 * Q_BH_D_DV4_G_7_S = 0;

[_1543] - BUTDN_EF_BH_DV_8_DV4 + 0.163E-02 * Q_BH_D_DV4_G_8_E + 0.405E-02 * Q_BH_D_DV4_G_8_N + 0.25E-02 * Q_BH_D_DV4_G_8_S = 0;

[_1544] - BUTDN_EF_BH_DV_9_DV4 + 0.284E-02 * Q_BH_D_DV4_G_9_E + 0.451E-02 * Q_BH_D_DV4_G_9_N + 0.283E-02 * Q_BH_D_DV4_G_9_S = 0;

[_1545] - BUTDN_EF_BH_DV_10_DV4 + 0.254E-02 * Q_BH_D_DV4_G_10_E + 0.527E-02 * Q_BH_D_DV4_G_10_N + 0.194E-02 * Q_BH_D_DV4_G_10_S = 0;

[_1546] - BUTDN_EF_BH_DV_11_DV4 + 0.322E-02 * Q_BH_D_DV4_G_11_E + 0.612E-02 * Q_BH_D_DV4_G_11_N + 0.15E-02 * Q_BH_D_DV4_G_11_S = 0;

[_1547] - BUTDN_EF_BH_DV_12_DV4 + 0.127E-02 * Q_BH_D_DV4_G_12_E + 0.524E-02 * Q_BH_D_DV4_G_12_N + 0.352E-02 * Q_BH_D_DV4_G_12_S = 0;

[_1548] - BUTDN_EF_BH_DV_13_DV4 + 0.362E-02 * Q_BH_D_DV4_G_13_E + 0.599E-02 * Q_BH_D_DV4_G_13_N + 0.111E-02 * Q_BH_D_DV4_G_13_S = 0;

[_1549] - BUTDN_EF_BH_DV_14_DV4 + 0.44E-02 * Q_BH_D_DV4_G_14_E + 0.625E-02 * Q_BH_D_DV4_G_14_N + 0.215E-02 * Q_BH_D_DV4_G_14_S = 0;

[_1550] - BUTDN_EF_BH_DV_15_DV4 + 0.502E-02 * Q_BH_D_DV4_G_15_E + 0.636E-02 * Q_BH_D_DV4_G_15_N + 0.512E-02 * Q_BH_D_DV4_G_15_S = 0;

[_1551] - BUTDN_EF_BH_DV_16_DV4 + 0.506E-02 * Q_BH_D_DV4_G_16_E + 0.7197142857E-02 * Q_BH_D_DV4_G_16_N + 0.66E-03 * Q_BH_D_DV4_G_16_S = 0;

[_1552] - CO_EF_BH_HV_G_1 + 11.39 * Q_BH_D_HV_G_1_E + 2.232 * Q_BH_D_HV_G_1_N + 19.183 * Q_BH_D_HV_G_1_S = 0;

[_1553] - CO_EF_BH_HV_G_2 + 9.117 * Q_BH_D_HV_G_2_E + 4.694 * Q_BH_D_HV_G_2_N + 16.534 * Q_BH_D_HV_G_2_S = 0;

[_1554] -CO_EF_BH_HV_G_3 + 7.33*Q_BH_D_HV_G_3_E+7.416*Q_BH_D_HV_G_3_N+17.49*Q_BH_D_HV_G_3_S=0;

[_1555] -CO_EF_BH_HV_G_4 + 8*Q_BH_D_HV_G_4_E+6.29*Q_BH_D_HV_G_4_N+15.11*Q_BH_D_HV_G_4_S=0;

[_1556] -CO_EF_BH_HV_G_5 + 6.728*Q_BH_D_HV_G_5_E+7.657*Q_BH_D_HV_G_5_N+13.738*Q_BH_D_HV_G_5_S=0;

[_1557] -CO_EF_BH_HV_G_6+6.196*Q_BH_D_HV_G_6_E+9.472*Q_BH_D_HV_G_6_N+12.872*Q_BH_D_HV_G_6_S=0;

[_1558] -CO_EF_BH_HV_G_7+ 1.721*Q_BH_D_HV_G_7_E+11.808*Q_BH_D_HV_G_7_N+12.841*Q_BH_D_HV_G_7_S=0;

Annexure 9

[_1559] - CO_EF_BH_HV_G_8 + 5.419 * Q_BH_D_HV_G_8_E + 13.456 * Q_BH_D_HV_G_8_N + 8.376 * Q_BH_D_HV_G_8_S = 0;

[_1560] - CO_EF_BH_HV_G_9 + 9.43 * Q_BH_D_HV_G_9_E + 14.96 * Q_BH_D_HV_G_9_N + 9.382 * Q_BH_D_HV_G_9_S = 0;

[_1561] - CO_EF_BH_HV_G_10 + 8.418 * Q_BH_D_HV_G_10_E + 17.49 * Q_BH_D_HV_G_10_N + 6.431 * Q_BH_D_HV_G_10_S = 0;

[_1562] - CO_EF_BH_HV_G_11 + 10.682 * Q_BH_D_HV_G_11_E + 20.31 * Q_BH_D_HV_G_11_N + 5.003 * Q_BH_D_HV_G_11_S = 0;

[_1563] - CO_EF_BH_HV_G_12 + 4.204 * Q_BH_D_HV_G_12_E + 17.41 * Q_BH_D_HV_G_12_N + 11.673 * Q_BH_D_HV_G_12_S = 0;

[_1564] - CO_EF_BH_HV_G_13 + 12.02 * Q_BH_D_HV_G_13_E + 19.893 * Q_BH_D_HV_G_13_N + 3.693 * Q_BH_D_HV_G_13_S = 0;

[_1565] - CO_EF_BH_HV_G_14 + 14.604 * Q_BH_D_HV_G_14_E + 20.737 * Q_BH_D_HV_G_14_N + 7.145 * Q_BH_D_HV_G_14_S = 0;

[_1566] - CO_EF_BH_HV_G_15 + 16.67 * Q_BH_D_HV_G_15_E + 21.124 * Q_BH_D_HV_G_15_N + 17.003 * Q_BH_D_HV_G_15_S = 0;

[_1567] - CO_EF_BH_HV_G_16 + 16.7946 * Q_BH_D_HV_G_16_E + 23.88797143 * Q_BH_D_HV_G_16_N + 2.1906 * Q_BH_D_HV_G_16_S = 0;

[_1568] - CO2_EF_BH_HV_G_1 + 2158.45 * Q_BH_D_HV_G_1_E + 422.99 * Q_BH_D_HV_G_1_N + 3634.96 * Q_BH_D_HV_G_1_S = 0;

[_1569] - CO2_EF_BH_HV_G_2 + 1727.55 * Q_BH_D_HV_G_2_E + 889.47 * Q_BH_D_HV_G_2_N + 3132.91 * Q_BH_D_HV_G_2_S = 0;

[_1570] - CO2_EF_BH_HV_G_3 + 1389.55 * Q_BH_D_HV_G_3_E + 1405.36 * Q_BH_D_HV_G_3_N + 3314.76 * Q_BH_D_HV_G_3_S = 0;

[_1571] - CO2_EF_BH_HV_G_4 + 1516.05 * Q_BH_D_HV_G_4_E + 1191.89 * Q_BH_D_HV_G_4_N + 2864.09 * Q_BH_D_HV_G_4_S = 0;

[_1572] - CO2_EF_BH_HV_G_5 + 1274.91 * Q_BH_D_HV_G_5_E + 1450.82 * Q_BH_D_HV_G_5_N + 2603.18 * Q_BH_D_HV_G_5_S = 0;

[_1573] - CO2_EF_BH_HV_G_6 + 1174.09 * Q_BH_D_HV_G_6_E + 1794.75 * Q_BH_D_HV_G_6_N + 2439.12 * Q_BH_D_HV_G_6_S = 0;

[_1574] - CO2_EF_BH_HV_G_7 + 326.14 * Q_BH_D_HV_G_7_E + 2237.51 * Q_BH_D_HV_G_7_N + 2433.19 * Q_BH_D_HV_G_7_S = 0;

[_1575] - CO2_EF_BH_HV_G_8 + 1026.84 * Q_BH_D_HV_G_8_E + 2549.81 * Q_BH_D_HV_G_8_N + 1587.21 * Q_BH_D_HV_G_8_S = 0;

[_1576] - CO2_EF_BH_HV_G_9 + 1786.84 * Q_BH_D_HV_G_9_E + 2834.44 * Q_BH_D_HV_G_9_N + 1777.75 * Q_BH_D_HV_G_9_S = 0;

[_1577] - CO2_EF_BH_HV_G_10 + 1595.11 * Q_BH_D_HV_G_10_E + 3314.76 * Q_BH_D_HV_G_10_N + 1218.57 * Q_BH_D_HV_G_10_S = 0;

[_1578] - CO2_EF_BH_HV_G_11 + 2024.04 * Q_BH_D_HV_G_11_E + 3848.44 * Q_BH_D_HV_G_11_N + 947.98 * Q_BH_D_HV_G_11_S = 0;

[_1579] - CO2_EF_BH_HV_G_12 + 796.57 * Q_BH_D_HV_G_12_E + 3298.94 * Q_BH_D_HV_G_12_N + 2211.81 * Q_BH_D_HV_G_12_S = 0;

[_1580] - CO2_EF_BH_HV_G_13 + 2277.04 * Q_BH_D_HV_G_13_E + 3769.37 * Q_BH_D_HV_G_13_N + 699.71 * Q_BH_D_HV_G_13_S = 0;

[_1581] - CO2_EF_BH_HV_G_14 + 2767.24 * Q_BH_D_HV_G_14_E + 3929.48 * Q_BH_D_HV_G_14_N + 1353.97 * Q_BH_D_HV_G_14_S = 0;

[_1582] - CO2_EF_BH_HV_G_15 + 3158.6 * Q_BH_D_HV_G_15_E + 4002.61 * Q_BH_D_HV_G_15_N + 3221.85 * Q_BH_D_HV_G_15_S = 0;

[_1583] - CO2_EF_BH_HV_G_16 + 3182.323152 * Q_BH_D_HV_G_16_E + 4526.40995 * Q_BH_D_HV_G_16_N + 415.0856286 * Q_BH_D_HV_G_16_S = 0;

[_1584] - SO2_EF_BH_HV_G_1 + 0.4775 * Q_BH_D_HV_G_1_E + 0.93E-01 * Q_BH_D_HV_G_1_N + 0.804 * Q_BH_D_HV_G_1_S = 0;

[_1585] - SO2_EF_BH_HV_G_2 + 0.382 * Q_BH_D_HV_G_2_E + 0.197 * Q_BH_D_HV_G_2_N + 0.693 * Q_BH_D_HV_G_2_S = 0;

[_1586] - SO2_EF_BH_HV_G_3 + 0.307 * Q_BH_D_HV_G_3_E + 0.311 * Q_BH_D_HV_G_3_N + 0.733 * Q_BH_D_HV_G_3_S = 0;

[_1587] - SO2_EF_BH_HV_G_4 + 0.335 * Q_BH_D_HV_G_4_E + 0.264 * Q_BH_D_HV_G_4_N + 0.634 * Q_BH_D_HV_G_4_S = 0;

[_1588] - SO2_EF_BH_HV_G_5 + 0.282 * Q_BH_D_HV_G_5_E + 0.321 * Q_BH_D_HV_G_5_N + 0.576 * Q_BH_D_HV_G_5_S = 0;

[_1589] - SO2_EF_BH_HV_G_6 + 0.259 * Q_BH_D_HV_G_6_E + 0.397 * Q_BH_D_HV_G_6_N + 0.539 * Q_BH_D_HV_G_6_S = 0;

[_1590] - SO2_EF_BH_HV_G_7 + 0.72E-01 * Q_BH_D_HV_G_7_E + 0.495 * Q_BH_D_HV_G_7_N + 0.538 * Q_BH_D_HV_G_7_S = 0;

[_1591] - SO2_EF_BH_HV_G_8 + 0.227 * Q_BH_D_HV_G_8_E + 0.564 * Q_BH_D_HV_G_8_N + 0.351 * Q_BH_D_HV_G_8_S = 0;

[_1592] - SO2_EF_BH_HV_G_9 + 0.395 * Q_BH_D_HV_G_9_E + 0.627 * Q_BH_D_HV_G_9_N + 0.393 * Q_BH_D_HV_G_9_S = 0;

[_1593] - SO2_EF_BH_HV_G_10 + 0.353 * Q_BH_D_HV_G_10_E + 0.733 * Q_BH_D_HV_G_10_N + 0.269 * Q_BH_D_HV_G_10_S = 0;

[_1594] - SO2_EF_BH_HV_G_11 + 0.448 * Q_BH_D_HV_G_11_E + 0.851 * Q_BH_D_HV_G_11_N + 0.209 * Q_BH_D_HV_G_11_S = 0;

[_1595] - SO2_EF_BH_HV_G_12 + 0.176 * Q_BH_D_HV_G_12_E + 0.729 * Q_BH_D_HV_G_12_N + 0.489 * Q_BH_D_HV_G_12_S = 0;

[_1596] - SO2_EF_BH_HV_G_13 + 0.504 * Q_BH_D_HV_G_13_E + 0.834 * Q_BH_D_HV_G_13_N + 0.155 * Q_BH_D_HV_G_13_S = 0;

[_1597] - SO2_EF_BH_HV_G_14 + 0.612 * Q_BH_D_HV_G_14_E + 0.869 * Q_BH_D_HV_G_14_N + 0.299 * Q_BH_D_HV_G_14_S = 0;

[_1598] - SO2_EF_BH_HV_G_15 + 0.699 * Q_BH_D_HV_G_15_E + 0.886 * Q_BH_D_HV_G_15_N + 0.713 * Q_BH_D_HV_G_15_S = 0;

[_1599] - SO2_EF_BH_HV_G_16 + 0.7041066667 * Q_BH_D_HV_G_16_E + 1.001493333 * Q_BH_D_HV_G_16_N + 0.9184E-01 * Q_BH_D_HV_G_16_S = 0;

[_1600] - NOX_EF_BH_HV_G_1 + 20.08 * Q_BH_D_HV_G_1_E + 3.936 * Q_BH_D_HV_G_1_N + 33.82 * Q_BH_D_HV_G_1_S = 0;

[_1601] - NOX_EF_BH_HV_G_2 + 16.074 * Q_BH_D_HV_G_2_E + 8.276 * Q_BH_D_HV_G_2_N + 29.15 * Q_BH_D_HV_G_2_S = 0;

[_1602] - NOX_EF_BH_HV_G_3 + 12.929 * Q_BH_D_HV_G_3_E + 13.076 * Q_BH_D_HV_G_3_N + 30.842 * Q_BH_D_HV_G_3_S = 0;

[_1603] - NOX_EF_BH_HV_G_4 + 14.106 * Q_BH_D_HV_G_4_E + 11.09 * Q_BH_D_HV_G_4_N + 26.649 * Q_BH_D_HV_G_4_S = 0;

[_1604] - NOX_EF_BH_HV_G_5 + 11.862 * Q_BH_D_HV_G_5_E + 13.499 * Q_BH_D_HV_G_5_N + 24.22 * Q_BH_D_HV_G_5_S = 0;

[_1605] - NOX_EF_BH_HV_G_6 + 10.924 * Q_BH_D_HV_G_6_E + 16.69 * Q_BH_D_HV_G_6_N + 22.695 * Q_BH_D_HV_G_6_S = 0;

[_1606] - NOX_EF_BH_HV_G_7 + 3.034 * Q_BH_D_HV_G_7_E + 20.82 * Q_BH_D_HV_G_7_N + 22.64 * Q_BH_D_HV_G_7_S = 0;

[_1607] - NOX_EF_BH_HV_G_8 + 9.554 * Q_BH_D_HV_G_8_E + 23.725 * Q_BH_D_HV_G_8_N + 14.768 * Q_BH_D_HV_G_8_S = 0;

[_1608] - NOX_EF_BH_HV_G_9 + 16.62 * Q_BH_D_HV_G_9_E + 26.373 * Q_BH_D_HV_G_9_N + 16.541 * Q_BH_D_HV_G_9_S = 0;

[_1609] - NOX_EF_BH_HV_G_10 + 14.842 * Q_BH_D_HV_G_10_E + 30.842 * Q_BH_D_HV_G_10_N + 11.338 * Q_BH_D_HV_G_10_S = 0;

[_1610] - NOX_EF_BH_HV_G_11 + 18.83 * Q_BH_D_HV_G_11_E + 35.808 * Q_BH_D_HV_G_11_N + 8.82 * Q_BH_D_HV_G_11_S = 0;

[_1611] - NOX_EF_BH_HV_G_12 + 7.412 * Q_BH_D_HV_G_12_E + 30.695 * Q_BH_D_HV_G_12_N + 20.58 * Q_BH_D_HV_G_12_S = 0;

[_1612] - NOX_EF_BH_HV_G_13 + 21.187 * Q_BH_D_HV_G_13_E + 35.07 * Q_BH_D_HV_G_13_N + 6.51 * Q_BH_D_HV_G_13_S = 0;

[_1613] - NOX_EF_BH_HV_G_14 + 25.75 * Q_BH_D_HV_G_14_E + 36.56 * Q_BH_D_HV_G_14_N + 12.598 * Q_BH_D_HV_G_14_S = 0;

[_1614] - NOX_EF_BH_HV_G_15 + 29.39 * Q_BH_D_HV_G_15_E + 37.243 * Q_BH_D_HV_G_15_N + 29.978 * Q_BH_D_HV_G_15_S = 0;

[_1615] - NOX_EF_BH_HV_G_16 + 29.6102 * Q_BH_D_HV_G_16_E + 42.11637143 * Q_BH_D_HV_G_16_N + 3.8622 * Q_BH_D_HV_G_16_S = 0;

[_1616] - HC_EF_BH_HV_G_1 + 2.967 * Q_BH_D_HV_G_1_E + 0.581 * Q_BH_D_HV_G_1_N + 4.997 * Q_BH_D_HV_G_1_S = 0;

[_1617] - HC_EF_BH_HV_G_2 + 2.375 * Q_BH_D_HV_G_2_E + 1.223 * Q_BH_D_HV_G_2_N + 4.307 * Q_BH_D_HV_G_2_S = 0;

[_1618] - HC_EF_BH_HV_G_3 + 1.91 * Q_BH_D_HV_G_3_E + 1.932 * Q_BH_D_HV_G_3_N + 4.556 * Q_BH_D_HV_G_3_S = 0;

[_1619] - HC_EF_BH_HV_G_4 + 2.084 * Q_BH_D_HV_G_4_E + 1.638 * Q_BH_D_HV_G_4_N + 3.937 * Q_BH_D_HV_G_4_S = 0;

[_1620] - HC_EF_BH_HV_G_5 + 1.752 * Q_BH_D_HV_G_5_E + 1.994 * Q_BH_D_HV_G_5_N + 3.578 * Q_BH_D_HV_G_5_S = 0;

[_1621] - HC_EF_BH_HV_G_6 + 1.614 * Q_BH_D_HV_G_6_E + 2.467 * Q_BH_D_HV_G_6_N + 3.353 * Q_BH_D_HV_G_6_S = 0;

[_1622] - HC_EF_BH_HV_G_7 + 0.448 * Q_BH_D_HV_G_7_E + 3.076 * Q_BH_D_HV_G_7_N + 3.345 * Q_BH_D_HV_G_7_S = 0;

[_1623] - HC_EF_BH_HV_G_8 + 1.411 * Q_BH_D_HV_G_8_E + 3.505 * Q_BH_D_HV_G_8_N + 2.182 * Q_BH_D_HV_G_8_S = 0;

[_1624] - HC_EF_BH_HV_G_9 + 2.456 * Q_BH_D_HV_G_9_E + 3.896 * Q_BH_D_HV_G_9_N + 2.444 * Q_BH_D_HV_G_9_S = 0;

[_1625] - HC_EF_BH_HV_G_10 + 2.193 * Q_BH_D_HV_G_10_E + 4.556 * Q_BH_D_HV_G_10_N + 1.675 * Q_BH_D_HV_G_10_S = 0;

[_1626] - HC_EF_BH_HV_G_11 + 2.782 * Q_BH_D_HV_G_11_E + 5.29 * Q_BH_D_HV_G_11_N + 1.303 * Q_BH_D_HV_G_11_S = 0;

[_1627] - HC_EF_BH_HV_G_12 + 1.095 * Q_BH_D_HV_G_12_E + 4.535 * Q_BH_D_HV_G_12_N + 3.04 * Q_BH_D_HV_G_12_S = 0;

[_1628] - HC_EF_BH_HV_G_13 + 3.13 * Q_BH_D_HV_G_13_E + 5.181 * Q_BH_D_HV_G_13_N + 0.962 * Q_BH_D_HV_G_13_S = 0;

[_1629] - HC_EF_BH_HV_G_14 + 3.804 * Q_BH_D_HV_G_14_E + 5.401 * Q_BH_D_HV_G_14_N + 1.861 * Q_BH_D_HV_G_14_S = 0;

[_1630] - HC_EF_BH_HV_G_15 + 4.342 * Q_BH_D_HV_G_15_E + 5.502 * Q_BH_D_HV_G_15_N + 4.429 * Q_BH_D_HV_G_15_S = 0;

[_1631] - HC_EF_BH_HV_G_16 + 4.3746 * Q_BH_D_HV_G_16_E + 6.222257143 * Q_BH_D_HV_G_16_N + 0.5706 * Q_BH_D_HV_G_16_S = 0;

[_1632] - PM_EF_BH_HV_G_1 + 1.061 * Q_BH_D_HV_G_1_E + 0.208 * Q_BH_D_HV_G_1_N + 1.786 * Q_BH_D_HV_G_1_S = 0;

[_1633] - PM_EF_BH_HV_G_2 + 0.849 * Q_BH_D_HV_G_2_E + 0.437 * Q_BH_D_HV_G_2_N + 1.539 * Q_BH_D_HV_G_2_S = 0;

[_1634] - PM_EF_BH_HV_G_3 + 0.683 * Q_BH_D_HV_G_3_E + 0.691 * Q_BH_D_HV_G_3_N + 1.629 * Q_BH_D_HV_G_3_S = 0;

[_1635] - PM_EF_BH_HV_G_4 + 0.745 * Q_BH_D_HV_G_4_E + 0.586 * Q_BH_D_HV_G_4_N + 1.408 * Q_BH_D_HV_G_4_S = 0;

[_1636] - PM_EF_BH_HV_G_5 + 0.626 * Q_BH_D_HV_G_5_E + 0.713 * Q_BH_D_HV_G_5_N + 1.279 * Q_BH_D_HV_G_5_S = 0;

[_1637] - PM_EF_BH_HV_G_6 + 0.577 * Q_BH_D_HV_G_6_E + 0.882 * Q_BH_D_HV_G_6_N + 1.198 * Q_BH_D_HV_G_6_S = 0;

[_1638] - PM_EF_BH_HV_G_7 + 0.16 * Q_BH_D_HV_G_7_E + 1.099 * Q_BH_D_HV_G_7_N + 1.196 * Q_BH_D_HV_G_7_S = 0;

[_1639] - PM_EF_BH_HV_G_8 + 0.505 * Q_BH_D_HV_G_8_E + 1.253 * Q_BH_D_HV_G_8_N + 0.78 * Q_BH_D_HV_G_8_S = 0;

Annexure 9

[_1640] - PM_EF_BH_HV_G_9 + 0.878 * Q_BH_D_HV_G_9_E + 1.393 * Q_BH_D_HV_G_9_N + 0.874 * Q_BH_D_HV_G_9_S = 0;

[_1641] - PM_EF_BH_HV_G_10 + 0.784 * Q_BH_D_HV_G_10_E + 1.629 * Q_BH_D_HV_G_10_N + 0.599 * Q_BH_D_HV_G_10_S = 0;

[_1642] - PM_EF_BH_HV_G_11 + 0.995 * Q_BH_D_HV_G_11_E + 1.891 * Q_BH_D_HV_G_11_N + 0.466 * Q_BH_D_HV_G_11_S = 0;

[_1643] - PM_EF_BH_HV_G_12 + 0.391 * Q_BH_D_HV_G_12_E + 1.621 * Q_BH_D_HV_G_12_N + 1.087 * Q_BH_D_HV_G_12_S = 0;

[_1644] - PM_EF_BH_HV_G_13 + 1.12 * Q_BH_D_HV_G_13_E + 1.852 * Q_BH_D_HV_G_13_N + 0.344 * Q_BH_D_HV_G_13_S = 0;

[_1645] - PM_EF_BH_HV_G_14 + 1.36 * Q_BH_D_HV_G_14_E + 1.931 * Q_BH_D_HV_G_14_N + 0.665 * Q_BH_D_HV_G_14_S = 0;

[_1646] - PM_EF_BH_HV_G_15 + 1.552 * Q_BH_D_HV_G_15_E + 1.967 * Q_BH_D_HV_G_15_N + 1.583 * Q_BH_D_HV_G_15_S = 0;

[_1647] - PM_EF_BH_HV_G_16 + 1.564 * Q_BH_D_HV_G_16_E + 2.224571429 * Q_BH_D_HV_G_16_N + 0.204 * Q_BH_D_HV_G_16_S = 0;

[_1648] - BENZ_EF_BH_HV_G_1 + 0.13E-01 * Q_BH_D_HV_G_1_E + 0.26E-02 * Q_BH_D_HV_G_1_N + 0.22E-01 * Q_BH_D_HV_G_1_S = 0;

[_1649] - BENZ_EF_BH_HV_G_2 + 0.105E-01 * Q_BH_D_HV_G_2_E + 0.54E-02 * Q_BH_D_HV_G_2_N + 0.19E-01 * Q_BH_D_HV_G_2_S = 0;

[_1650] - BENZ_EF_BH_HV_G_3 + 0.84E-02 * Q_BH_D_HV_G_3_E + 0.85E-02 * Q_BH_D_HV_G_3_N + 0.201E-01 * Q_BH_D_HV_G_3_S = 0;

[_1651] - BENZ_EF_BH_HV_G_4 + 0.92E-02 * Q_BH_D_HV_G_4_E + 0.72E-02 * Q_BH_D_HV_G_4_N + 0.174E-01 * Q_BH_D_HV_G_4_S = 0;

[_1652] - BENZ_EF_BH_HV_G_5 + 0.77E-02 * Q_BH_D_HV_G_5_E + 0.88E-02 * Q_BH_D_HV_G_5_N + 0.158E-01 * Q_BH_D_HV_G_5_S = 0;

[_1653] - BENZ_EF_BH_HV_G_6 + 0.71E-02 * Q_BH_D_HV_G_6_E + 0.11E-01 * Q_BH_D_HV_G_6_N + 0.148E-01 * Q_BH_D_HV_G_6_S = 0;

[_1654] - BENZ_EF_BH_HV_G_7 + 0.19E-02 * Q_BH_D_HV_G_7_E + 0.136E-01 * Q_BH_D_HV_G_7_N + 0.147E-01 * Q_BH_D_HV_G_7_S = 0;

[_1655] - BENZ_EF_BH_HV_G_8 + 0.62E-02 * Q_BH_D_HV_G_8_E + 0.155E-01 * Q_BH_D_HV_G_8_N + 0.96E-02 * Q_BH_D_HV_G_8_S = 0;

[_1656] - BENZ_EF_BH_HV_G_9 + 0.108E-01 * Q_BH_D_HV_G_9_E + 0.172E-01 * Q_BH_D_HV_G_9_N + 0.108E-01 * Q_BH_D_HV_G_9_S = 0;

[_1657] - BENZ_EF_BH_HV_G_10 + 0.97E-02 * Q_BH_D_HV_G_10_E + 0.201E-01 * Q_BH_D_HV_G_10_N + 0.74E-02 * Q_BH_D_HV_G_10_S = 0;

[_1658] - BENZ_EF_BH_HV_G_11 + 0.12E-01 * Q_BH_D_HV_G_11_E + 0.233E-01 * Q_BH_D_HV_G_11_N + 0.57E-02 * Q_BH_D_HV_G_11_S = 0;

[_1659] - BENZ_EF_BH_HV_G_12 + 0.48E-02 * Q_BH_D_HV_G_12_E + 0.2E-01 * Q_BH_D_HV_G_12_N + 0.134E-01 * Q_BH_D_HV_G_12_S = 0;

[_1660] - BENZ_EF_BH_HV_G_13 + 0.14E-01 * Q_BH_D_HV_G_13_E + 0.23E-01 * Q_BH_D_HV_G_13_N + 0.425E-02 * Q_BH_D_HV_G_13_S = 0;

[_1661] - BENZ_EF_BH_HV_G_14 + 0.17E-01 * Q_BH_D_HV_G_14_E + 0.238E-01 * Q_BH_D_HV_G_14_N + 0.82E-02 * Q_BH_D_HV_G_14_S = 0;

[_1662] - BENZ_EF_BH_HV_G_15 + 0.19E-01 * Q_BH_D_HV_G_15_E + 0.243E-01 * Q_BH_D_HV_G_15_N + 0.196E-01 * Q_BH_D_HV_G_15_S = 0;

[_1663] - BENZ_EF_BH_HV_G_16 + 0.1932E-01 * Q_BH_D_HV_G_16_E + 0.2748E-01 * Q_BH_D_HV_G_16_N + 0.252E-02 * Q_BH_D_HV_G_16_S = 0;

[_1664] - BUTDN_EF_BH_HV_G_1 + 0.203E-02 * Q_BH_D_HV_G_1_E + 0.397E-03 * Q_BH_D_HV_G_1_N + 0.34E-02 * Q_BH_D_HV_G_1_S = 0;

[_1665] - BUTDN_EF_BH_HV_G_2 + 0.162E-02 * Q_BH_D_HV_G_2_E + 0.83E-03 * Q_BH_D_HV_G_2_N + 0.29E-02 * Q_BH_D_HV_G_2_S = 0;

[_1666] - BUTDN_EF_BH_HV_G_3 + 0.13E-02 * Q_BH_D_HV_G_3_E + 0.13E-02 * Q_BH_D_HV_G_3_N + 0.31E-02 * Q_BH_D_HV_G_3_S = 0;

[_1667] - BUTDN_EF_BH_HV_G_4 + 0.14E-02 * Q_BH_D_HV_G_4_E + 0.12E-02 * Q_BH_D_HV_G_4_N + 0.27E-02 * Q_BH_D_HV_G_4_S = 0;

[_1668] - BUTDN_EF_BH_HV_G_5 + 0.12E-02 * Q_BH_D_HV_G_5_E + 0.136E-02 * Q_BH_D_HV_G_5_N + 0.24E-02 * Q_BH_D_HV_G_5_S = 0;

[_1669] - BUTDN_EF_BH_HV_G_6 + 0.11E-02 * Q_BH_D_HV_G_6_E + 0.17E-02 * Q_BH_D_HV_G_6_N + 0.23E-02 * Q_BH_D_HV_G_6_S = 0;

[_1670] - BUTDN_EF_BH_HV_G_7 + 0.31E-03 * Q_BH_D_HV_G_7_E + 0.21E-02 * Q_BH_D_HV_G_7_N + 0.228E-02 * Q_BH_D_HV_G_7_S = 0;

[_1671] - BUTDN_EF_BH_HV_G_8 + 0.96E-03 * Q_BH_D_HV_G_8_E + 0.24E-02 * Q_BH_D_HV_G_8_N + 0.15E-02 * Q_BH_D_HV_G_8_S = 0;

[_1672] - BUTDN_EF_BH_HV_G_9 + 0.17E-02 * Q_BH_D_HV_G_9_E + 0.266E-02 * Q_BH_D_HV_G_9_N + 0.17E-02 * Q_BH_D_HV_G_9_S = 0;

[_1673] - BUTDN_EF_BH_HV_G_10 + 0.15E-02 * Q_BH_D_HV_G_10_E + 0.31E-02 * Q_BH_D_HV_G_10_N + 0.11E-02 * Q_BH_D_HV_G_10_S = 0;

[_1674] - BUTDN_EF_BH_HV_G_11 + 0.19E-02 * Q_BH_D_HV_G_11_E + 0.36E-02 * Q_BH_D_HV_G_11_N + 0.89E-03 * Q_BH_D_HV_G_11_S = 0;

[_1675] - BUTDN_EF_BH_HV_G_12 + 0.75E-03 * Q_BH_D_HV_G_12_E + 0.31E-02 * Q_BH_D_HV_G_12_N + 0.208E-02 * Q_BH_D_HV_G_12_S = 0;

[_1676] - BUTDN_EF_BH_HV_G_13 + 0.21E-02 * Q_BH_D_HV_G_13_E + 0.35E-02 * Q_BH_D_HV_G_13_N + 0.66E-03 * Q_BH_D_HV_G_13_S = 0;

[_1677] - BUTDN_EF_BH_HV_G_14 + 0.26E-02 * Q_BH_D_HV_G_14_E + 0.37E-02 * Q_BH_D_HV_G_14_N + 0.13E-02 * Q_BH_D_HV_G_14_S = 0;

[_1678] - BUTDN_EF_BH_HV_G_15 + 0.29E-02 * Q_BH_D_HV_G_15_E + 0.376E-02 * Q_BH_D_HV_G_15_N + 0.303E-02 * Q_BH_D_HV_G_15_S = 0;

[_1679] - BUTDN_EF_BH_HV_G_16 + 0.299E-02 * Q_BH_D_HV_G_16_E + 0.4252857143E-02 * Q_BH_D_HV_G_16_N + 0.39E-03 * Q_BH_D_HV_G_16_S = 0;

[_1680] - CO_EF_BH_HV_S_1 + 8.858888889 * Q_BH_D_HV_S_1_E + 1.736 * Q_BH_D_HV_S_1_N + 14.92011111 * Q_BH_D_HV_S_1_S = 0;

[_1681] - CO_EF_BH_HV_S_2 + 7.091 * Q_BH_D_HV_S_2_E + 3.650888889 * Q_BH_D_HV_S_2_N + 12.85977778 * Q_BH_D_HV_S_2_S = 0;

[_1682] - CO_EF_BH_HV_S_3 + 5.701111111 * Q_BH_D_HV_S_3_E + 5.768 * Q_BH_D_HV_S_3_N + 13.60333333 * Q_BH_D_HV_S_3_S = 0;

[_1683] - CO_EF_BH_HV_S_4 + 6.222222222 * Q_BH_D_HV_S_4_E + 4.892222222 * Q_BH_D_HV_S_4_N + 11.75222222 * Q_BH_D_HV_S_4_S = 0;

[_1684] - CO_EF_BH_HV_S_5 + 5.232888889 * Q_BH_D_HV_S_5_E + 5.955444444 * Q_BH_D_HV_S_5_N + 10.68511111 * Q_BH_D_HV_S_5_S = 0;

[_1685] - CO_EF_BH_HV_S_6 + 4.819111111 * Q_BH_D_HV_S_6_E + 7.367111111 * Q_BH_D_HV_S_6_N + 10.01155556 * Q_BH_D_HV_S_6_S = 0;

[_1686] - CO_EF_BH_HV_S_7 + 1.338555556 * Q_BH_D_HV_S_7_E + 9.184 * Q_BH_D_HV_S_7_N + 9.987444444 * Q_BH_D_HV_S_7_S = 0;

[_1687] - CO_EF_BH_HV_S_8 + 4.214777778 * Q_BH_D_HV_S_8_E + 10.46577778 * Q_BH_D_HV_S_8_N + 6.514666667 * Q_BH_D_HV_S_8_S = 0;

[_1688] - CO_EF_BH_HV_S_9 + 7.334444444 * Q_BH_D_HV_S_9_E + 11.63555556 * Q_BH_D_HV_S_9_N + 7.297111111 * Q_BH_D_HV_S_9_S = 0;

[_1689] - CO_EF_BH_HV_S_10 + 6.547333333 * Q_BH_D_HV_S_10_E + 13.60333333 * Q_BH_D_HV_S_10_N + 5.001888889 * Q_BH_D_HV_S_10_S = 0;

[_1690] - CO_EF_BH_HV_S_11 + 8.308222222 * Q_BH_D_HV_S_11_E + 15.79666667 * Q_BH_D_HV_S_11_N + 3.891222222 * Q_BH_D_HV_S_11_S = 0;

[_1691] - CO_EF_BH_HV_S_12 + 3.269777778 * Q_BH_D_HV_S_12_E + 13.54111111 * Q_BH_D_HV_S_12_N + 9.079 * Q_BH_D_HV_S_12_S = 0;

[_1692] - CO_EF_BH_HV_S_13 + 9.348888889 * Q_BH_D_HV_S_13_E + 15.47233333 * Q_BH_D_HV_S_13_N + 2.872333333 * Q_BH_D_HV_S_13_S = 0;

[_1693] - CO_EF_BH_HV_S_14 + 11.35866667 * Q_BH_D_HV_S_14_E + 16.12877778 * Q_BH_D_HV_S_14_N + 5.557222222 * Q_BH_D_HV_S_14_S = 0;

[_1694] - CO_EF_BH_HV_S_15 + 12.96555556 * Q_BH_D_HV_S_15_E + 16.42977778 * Q_BH_D_HV_S_15_N + 13.22455556 * Q_BH_D_HV_S_15_S = 0;

[_1695] - CO_EF_BH_HV_S_16 + 13.06246667 * Q_BH_D_HV_S_16_E + 18.57953333 * Q_BH_D_HV_S_16_N + 1.7038 * Q_BH_D_HV_S_16_S = 0;

[_1696] - CO2_EF_BH_HV_S_1 + 1678.794444 * Q_BH_D_HV_S_1_E + 328.9922222 * Q_BH_D_HV_S_1_N + 2827.191111 * Q_BH_D_HV_S_1_S = 0;

[_1697] - CO2_EF_BH_HV_S_2 + 1343.65 * Q_BH_D_HV_S_2_E + 691.81 * Q_BH_D_HV_S_2_N + 2436.707778 * Q_BH_D_HV_S_2_S = 0;

[_1698] - CO2_EF_BH_HV_S_3 + 1080.761111 * Q_BH_D_HV_S_3_E + 1093.057778 * Q_BH_D_HV_S_3_N + 2578.146667 * Q_BH_D_HV_S_3_S = 0;

[_1699] - CO2_EF_BH_HV_S_4 + 1179.15 * Q_BH_D_HV_S_4_E + 927.0255556 * Q_BH_D_HV_S_4_N + 2227.625556 * Q_BH_D_HV_S_4_S = 0;

[_1700] - CO2_EF_BH_HV_S_5 + 991.5966667 * Q_BH_D_HV_S_5_E + 1128.415556 * Q_BH_D_HV_S_5_N + 2024.695556 * Q_BH_D_HV_S_5_S = 0;

[_1701] - CO2_EF_BH_HV_S_6 + 913.1811111 * Q_BH_D_HV_S_6_E + 1395.916667 * Q_BH_D_HV_S_6_N + 1897.093333 * Q_BH_D_HV_S_6_S = 0;

[_1702] - CO2_EF_BH_HV_S_7 + 253.6644444 * Q_BH_D_HV_S_7_E + 1740.285556 * Q_BH_D_HV_S_7_N + 1892.481111 * Q_BH_D_HV_S_7_S = 0;

[_1703] - CO2_EF_BH_HV_S_8 + 798.6533333 * Q_BH_D_HV_S_8_E + 1983.185556 * Q_BH_D_HV_S_8_N + 1234.496667 * Q_BH_D_HV_S_8_S = 0;

[_1704] - CO2_EF_BH_HV_S_9 + 1389.764444 * Q_BH_D_HV_S_9_E + 2204.564444 * Q_BH_D_HV_S_9_N + 1382.694444 * Q_BH_D_HV_S_9_S = 0;

[_1705] - CO2_EF_BH_HV_S_10 + 1240.641111 * Q_BH_D_HV_S_10_E + 2578.146667 * Q_BH_D_HV_S_10_N + 947.7766667 * Q_BH_D_HV_S_10_S = 0;

[_1706] - CO2_EF_BH_HV_S_11 + 1574.253333 * Q_BH_D_HV_S_11_E + 2993.231111 * Q_BH_D_HV_S_11_N + 737.3177778 * Q_BH_D_HV_S_11_S = 0;

[_1707] - CO2_EF_BH_HV_S_12 + 619.5544444 * Q_BH_D_HV_S_12_E + 2565.842222 * Q_BH_D_HV_S_12_N + 1720.296667 * Q_BH_D_HV_S_12_S = 0;

[_1708] - CO2_EF_BH_HV_S_13 + 1771.031111 * Q_BH_D_HV_S_13_E + 2931.732222 * Q_BH_D_HV_S_13_N + 544.2188889 * Q_BH_D_HV_S_13_S = 0;

[_1709] - CO2_EF_BH_HV_S_14 + 2152.297778 * Q_BH_D_HV_S_14_E + 3056.262222 * Q_BH_D_HV_S_14_N + 1053.087778 * Q_BH_D_HV_S_14_S = 0;

[_1710] - CO2_EF_BH_HV_S_15 + 2456.688889 * Q_BH_D_HV_S_15_E + 3113.141111 * Q_BH_D_HV_S_15_N + 2505.883333 * Q_BH_D_HV_S_15_S = 0;

[_1711] - CO2_EF_BH_HV_S_16 + 2475.14023 * Q_BH_D_HV_S_16_E + 3520.541072 * Q_BH_D_HV_S_16_N + 322.8443778 * Q_BH_D_HV_S_16_S = 0;

[_1712] - SO2_EF_BH_HV_S_1 + 0.3713888889 * Q_BH_D_HV_S_1_E + 0.7233333333E-01 * Q_BH_D_HV_S_1_N + 0.6253333333 * Q_BH_D_HV_S_1_S = 0;

[_1713] - SO2_EF_BH_HV_S_2 + 0.2971111111 * Q_BH_D_HV_S_2_E + 0.1532222222 * Q_BH_D_HV_S_2_N + 0.539 * Q_BH_D_HV_S_2_S = 0;

[_1714] - SO2_EF_BH_HV_S_3 + 0.2387777778 * Q_BH_D_HV_S_3_E + 0.2418888889 * Q_BH_D_HV_S_3_N + 0.5701111111 * Q_BH_D_HV_S_3_S = 0;

[_1715] - SO2_EF_BH_HV_S_4 + 0.2605555556 * Q_BH_D_HV_S_4_E + 0.2053333333 * Q_BH_D_HV_S_4_N + 0.4931111111 * Q_BH_D_HV_S_4_S = 0;

[_1716] - SO2_EF_BH_HV_S_5 + 0.2193333333 * Q_BH_D_HV_S_5_E + 0.2496666667 * Q_BH_D_HV_S_5_N + 0.448 * Q_BH_D_HV_S_5_S = 0;

[_1717] - SO2_EF_BH_HV_S_6 + 0.2014444444 * Q_BH_D_HV_S_6_E + 0.3087777778 * Q_BH_D_HV_S_6_N + 0.4192222222 * Q_BH_D_HV_S_6_S = 0;

Annexure 9

[_1718] - SO2_EF_BH_HV_S_7 + 0.56E-01 * Q_BH_D_HV_S_7_E + 0.385 * Q_BH_D_HV_S_7_N + 0.4184444444 * Q_BH_D_HV_S_7_S = 0;

[_1719] - SO2_EF_BH_HV_S_8 + 0.1765555556 * Q_BH_D_HV_S_8_E + 0.4386666667 * Q_BH_D_HV_S_8_N + 0.273 * Q_BH_D_HV_S_8_S = 0;

[_1720] - SO2_EF_BH_HV_S_9 + 0.3072222222 * Q_BH_D_HV_S_9_E + 0.4876666667 * Q_BH_D_HV_S_9_N + 0.3056666667 * Q_BH_D_HV_S_9_S = 0;

[_1721] - SO2_EF_BH_HV_S_10 + 0.2745555556 * Q_BH_D_HV_S_10_E + 0.5701111111 * Q_BH_D_HV_S_10_N + 0.2092222222 * Q_BH_D_HV_S_10_S = 0;

[_1722] - SO2_EF_BH_HV_S_11 + 0.3484444444 * Q_BH_D_HV_S_11_E + 0.6618888889 * Q_BH_D_HV_S_11_N + 0.1625555556 * Q_BH_D_HV_S_11_S = 0;

[_1723] - SO2_EF_BH_HV_S_12 + 0.1368888889 * Q_BH_D_HV_S_12_E + 0.567 * Q_BH_D_HV_S_12_N + 0.3803333333 * Q_BH_D_HV_S_12_S = 0;

[_1724] - SO2_EF_BH_HV_S_13 + 0.392 * Q_BH_D_HV_S_13_E + 0.6486666667 * Q_BH_D_HV_S_13_N + 0.1205555556 * Q_BH_D_HV_S_13_S = 0;

[_1725] - SO2_EF_BH_HV_S_14 + 0.476 * Q_BH_D_HV_S_14_E + 0.6758888889 * Q_BH_D_HV_S_14_N + 0.2325555556 * Q_BH_D_HV_S_14_S = 0;

[_1726] - SO2_EF_BH_HV_S_15 + 0.5436666667 * Q_BH_D_HV_S_15_E + 0.6891111111 * Q_BH_D_HV_S_15_N + 0.5545555556 * Q_BH_D_HV_S_15_S = 0;

[_1727] - SO2_EF_BH_HV_S_16 + 0.5476385185 * Q_BH_D_HV_S_16_E + 0.7789392593 * Q_BH_D_HV_S_16_N + 0.7143111111E-01 * Q_BH_D_HV_S_16_S = 0;

[_1728] - NOX_EF_BH_HV_S_1 + 15.61777778 * Q_BH_D_HV_S_1_E + 3.061333333 * Q_BH_D_HV_S_1_N + 26.30444444 * Q_BH_D_HV_S_1_S = 0;

[_1729] - NOX_EF_BH_HV_S_2 + 12.502 * Q_BH_D_HV_S_2_E + 6.436888889 * Q_BH_D_HV_S_2_N + 22.67222222 * Q_BH_D_HV_S_2_S = 0;

[_1730] - NOX_EF_BH_HV_S_3 + 10.05588889 * Q_BH_D_HV_S_3_E + 10.17022222 * Q_BH_D_HV_S_3_N + 23.98822222 * Q_BH_D_HV_S_3_S = 0;

[_1731] - NOX_EF_BH_HV_S_4 + 10.97133333 * Q_BH_D_HV_S_4_E + 8.625555556 * Q_BH_D_HV_S_4_N + 20.727 * Q_BH_D_HV_S_4_S = 0;

[_1732] - NOX_EF_BH_HV_S_5 + 9.226 * Q_BH_D_HV_S_5_E + 10.49922222 * Q_BH_D_HV_S_5_N + 18.83777778 * Q_BH_D_HV_S_5_S = 0;

[_1733] - NOX_EF_BH_HV_S_6 + 8.496444444 * Q_BH_D_HV_S_6_E + 12.98111111 * Q_BH_D_HV_S_6_N + 17.65166667 * Q_BH_D_HV_S_6_S = 0;

[_1734] - NOX_EF_BH_HV_S_7 + 2.359777778 * Q_BH_D_HV_S_7_E + 16.19333333 * Q_BH_D_HV_S_7_N + 17.60888889 * Q_BH_D_HV_S_7_S = 0;

[_1735] - NOX_EF_BH_HV_S_8 + 7.430888889 * Q_BH_D_HV_S_8_E + 18.45277778 * Q_BH_D_HV_S_8_N + 11.48622222 * Q_BH_D_HV_S_8_S = 0;

[_1736] - NOX_EF_BH_HV_S_9 + 12.92666667 * Q_BH_D_HV_S_9_E + 20.51233333 * Q_BH_D_HV_S_9_N + 12.86522222 * Q_BH_D_HV_S_9_S = 0;

[_1737] - NOX_EF_BH_HV_S_10 + 11.54377778 * Q_BH_D_HV_S_10_E + 23.98822222 * Q_BH_D_HV_S_10_N + 8.818444444 * Q_BH_D_HV_S_10_S = 0;

[_1738] - NOX_EF_BH_HV_S_11 + 14.64555556 * Q_BH_D_HV_S_11_E + 27.85066667 * Q_BH_D_HV_S_11_N + 6.86 * Q_BH_D_HV_S_11_S = 0;

[_1739] - NOX_EF_BH_HV_S_12 + 5.764888889 * Q_BH_D_HV_S_12_E + 23.87388889 * Q_BH_D_HV_S_12_N + 16.00666667 * Q_BH_D_HV_S_12_S = 0;

[_1740] - NOX_EF_BH_HV_S_13 + 16.47877778 * Q_BH_D_HV_S_13_E + 27.27666667 * Q_BH_D_HV_S_13_N + 5.063333333 * Q_BH_D_HV_S_13_S = 0;

[_1741] - NOX_EF_BH_HV_S_14 + 20.02777778 * Q_BH_D_HV_S_14_E + 28.43555556 * Q_BH_D_HV_S_14_N + 9.798444444 * Q_BH_D_HV_S_14_S = 0;

[_1742] - NOX_EF_BH_HV_S_15 + 22.85888889 * Q_BH_D_HV_S_15_E + 28.96677778 * Q_BH_D_HV_S_15_N + 23.31622222 * Q_BH_D_HV_S_15_S = 0;

[_1743] - NOX_EF_BH_HV_S_16 + 23.03015556 * Q_BH_D_HV_S_16_E + 32.75717778 * Q_BH_D_HV_S_16_N + 3.003933333 * Q_BH_D_HV_S_16_S = 0;

[_1744] - HC_EF_BH_HV_S_1 + 2.307666667 * Q_BH_D_HV_S_1_E + 0.4518888889 * Q_BH_D_HV_S_1_N + 3.886555556 * Q_BH_D_HV_S_1_S = 0;

[_1745] - HC_EF_BH_HV_S_2 + 1.847222222 * Q_BH_D_HV_S_2_E + 0.9512222222 * Q_BH_D_HV_S_2_N + 3.349888889 * Q_BH_D_HV_S_2_S = 0;

[_1746] - HC_EF_BH_HV_S_3 + 1.485555556 * Q_BH_D_HV_S_3_E + 1.502666667 * Q_BH_D_HV_S_3_N + 3.543555556 * Q_BH_D_HV_S_3_S = 0;

[_1747] - HC_EF_BH_HV_S_4 + 1.620888889 * Q_BH_D_HV_S_4_E + 1.274 * Q_BH_D_HV_S_4_N + 3.062111111 * Q_BH_D_HV_S_4_S = 0;

[_1748] - HC_EF_BH_HV_S_5 + 1.362666667 * Q_BH_D_HV_S_5_E + 1.550888889 * Q_BH_D_HV_S_5_N + 2.782888889 * Q_BH_D_HV_S_5_S = 0;

[_1749] - HC_EF_BH_HV_S_6 + 1.255333333 * Q_BH_D_HV_S_6_E + 1.918777778 * Q_BH_D_HV_S_6_N + 2.607888889 * Q_BH_D_HV_S_6_S = 0;

[_1750] - HC_EF_BH_HV_S_7 + 0.3484444444 * Q_BH_D_HV_S_7_E + 2.392444444 * Q_BH_D_HV_S_7_N + 2.601666667 * Q_BH_D_HV_S_7_S = 0;

[_1751] - HC_EF_BH_HV_S_8 + 1.097444444 * Q_BH_D_HV_S_8_E + 2.726111111 * Q_BH_D_HV_S_8_N + 1.697111111 * Q_BH_D_HV_S_8_S = 0;

[_1752] - HC_EF_BH_HV_S_9 + 1.910222222 * Q_BH_D_HV_S_9_E + 3.030222222 * Q_BH_D_HV_S_9_N + 1.900888889 * Q_BH_D_HV_S_9_S = 0;

[_1753] - HC_EF_BH_HV_S_10 + 1.705666667 * Q_BH_D_HV_S_10_E + 3.543555556 * Q_BH_D_HV_S_10_N + 1.302777778 * Q_BH_D_HV_S_10_S = 0;

[_1754] - HC_EF_BH_HV_S_11 + 2.163777778 * Q_BH_D_HV_S_11_E + 4.114444444 * Q_BH_D_HV_S_11_N + 1.013444444 * Q_BH_D_HV_S_11_S = 0;

[_1755] - HC_EF_BH_HV_S_12 + 0.8516666667 * Q_BH_D_HV_S_12_E + 3.527222222 * Q_BH_D_HV_S_12_N + 2.364444444 * Q_BH_D_HV_S_12_S = 0;

[_1756] - HC_EF_BH_HV_S_13 + 2.434444444 * Q_BH_D_HV_S_13_E + 4.029666667 * Q_BH_D_HV_S_13_N + 0.7482222222 * Q_BH_D_HV_S_13_S = 0;

[_1757] - HC_EF_BH_HV_S_14 + 2.958666667 * Q_BH_D_HV_S_14_E + 4.200777778 * Q_BH_D_HV_S_14_N + 1.447444444 * Q_BH_D_HV_S_14_S = 0;

[_1758] - HC_EF_BH_HV_S_15 + 3.377111111 * Q_BH_D_HV_S_15_E + 4.279333333 * Q_BH_D_HV_S_15_N + 3.444777778 * Q_BH_D_HV_S_15_S = 0;

[_1759] - HC_EF_BH_HV_S_16 + 3.402466667 * Q_BH_D_HV_S_16_E + 4.839533333 * Q_BH_D_HV_S_16_N + 0.4438 * Q_BH_D_HV_S_16_S = 0;

[_1760] - PM_EF_BH_HV_S_1 + 0.825222222 * Q_BH_D_HV_S_1_E + 0.161777778 * Q_BH_D_HV_S_1_N + 1.389111111 * Q_BH_D_HV_S_1_S = 0;

[_1761] - PM_EF_BH_HV_S_2 + 0.660333333 * Q_BH_D_HV_S_2_E + 0.339888889 * Q_BH_D_HV_S_2_N + 1.197 * Q_BH_D_HV_S_2_S = 0;

[_1762] - PM_EF_BH_HV_S_3 + 0.531222222 * Q_BH_D_HV_S_3_E + 0.537444444 * Q_BH_D_HV_S_3_N + 1.267 * Q_BH_D_HV_S_3_S = 0;

[_1763] - PM_EF_BH_HV_S_4 + 0.579444444 * Q_BH_D_HV_S_4_E + 0.455777778 * Q_BH_D_HV_S_4_N + 1.095111111 * Q_BH_D_HV_S_4_S = 0;

[_1764] - PM_EF_BH_HV_S_5 + 0.486888889 * Q_BH_D_HV_S_5_E + 0.554555556 * Q_BH_D_HV_S_5_N + 0.994777778 * Q_BH_D_HV_S_5_S = 0;

[_1765] - PM_EF_BH_HV_S_6 + 0.448777778 * Q_BH_D_HV_S_6_E + 0.686 * Q_BH_D_HV_S_6_N + 0.931777778 * Q_BH_D_HV_S_6_S = 0;

[_1766] - PM_EF_BH_HV_S_7 + 0.124444444 * Q_BH_D_HV_S_7_E + 0.854777778 * Q_BH_D_HV_S_7_N + 0.930222222 * Q_BH_D_HV_S_7_S = 0;

[_1767] - PM_EF_BH_HV_S_8 + 0.392777778 * Q_BH_D_HV_S_8_E + 0.974555556 * Q_BH_D_HV_S_8_N + 0.606666667 * Q_BH_D_HV_S_8_S = 0;

[_1768] - PM_EF_BH_HV_S_9 + 0.682888889 * Q_BH_D_HV_S_9_E + 1.083444444 * Q_BH_D_HV_S_9_N + 0.679777778 * Q_BH_D_HV_S_9_S = 0;

[_1769] - PM_EF_BH_HV_S_10 + 0.609777778 * Q_BH_D_HV_S_10_E + 1.267 * Q_BH_D_HV_S_10_N + 0.465888889 * Q_BH_D_HV_S_10_S = 0;

[_1770] - PM_EF_BH_HV_S_11 + 0.773888889 * Q_BH_D_HV_S_11_E + 1.470777778 * Q_BH_D_HV_S_11_N + 0.362444444 * Q_BH_D_HV_S_11_S = 0;

[_1771] - PM_EF_BH_HV_S_12 + 0.304111111 * Q_BH_D_HV_S_12_E + 1.260777778 * Q_BH_D_HV_S_12_N + 0.845444444 * Q_BH_D_HV_S_12_S = 0;

[_1772] - PM_EF_BH_HV_S_13 + 0.871111111 * Q_BH_D_HV_S_13_E + 1.440444444 * Q_BH_D_HV_S_13_N + 0.267555556 * Q_BH_D_HV_S_13_S = 0;

[_1773] - PM_EF_BH_HV_S_14 + 1.057777778 * Q_BH_D_HV_S_14_E + 1.501888889 * Q_BH_D_HV_S_14_N + 0.517222222 * Q_BH_D_HV_S_14_S = 0;

[_1774] - PM_EF_BH_HV_S_15 + 1.207111111 * Q_BH_D_HV_S_15_E + 1.529888889 * Q_BH_D_HV_S_15_N + 1.231222222 * Q_BH_D_HV_S_15_S = 0;

[_1775] - PM_EF_BH_HV_S_16 + 1.216444444 * Q_BH_D_HV_S_16_E + 1.730222222 * Q_BH_D_HV_S_16_N + 0.158666667 * Q_BH_D_HV_S_16_S = 0;

[_1776] - BENZ_EF_BH_HV_S_1 + 0.101111111E-01 * Q_BH_D_HV_S_1_E + 0.202222222E-02 * Q_BH_D_HV_S_1_N + 0.171111111E-01 * Q_BH_D_HV_S_1_S = 0;

[_1777] - BENZ_EF_BH_HV_S_2 + 0.816666667E-02 * Q_BH_D_HV_S_2_E + 0.42E-02 * Q_BH_D_HV_S_2_N + 0.147777778E-01 * Q_BH_D_HV_S_2_S = 0;

[_1778] - BENZ_EF_BH_HV_S_3 + 0.653333333E-02 * Q_BH_D_HV_S_3_E + 0.661111111E-02 * Q_BH_D_HV_S_3_N + 0.156333333E-01 * Q_BH_D_HV_S_3_S = 0;

[_1779] - BENZ_EF_BH_HV_S_4 + 0.715555556E-02 * Q_BH_D_HV_S_4_E + 0.56E-02 * Q_BH_D_HV_S_4_N + 0.135333333E-01 * Q_BH_D_HV_S_4_S = 0;

[_1780] - BENZ_EF_BH_HV_S_5 + 0.598888889E-02 * Q_BH_D_HV_S_5_E + 0.684444444E-02 * Q_BH_D_HV_S_5_N + 0.122888889E-01 * Q_BH_D_HV_S_5_S = 0;

[_1781] - BENZ_EF_BH_HV_S_6 + 0.552222222E-02 * Q_BH_D_HV_S_6_E + 0.855555556E-02 * Q_BH_D_HV_S_6_N + 0.115111111E-01 * Q_BH_D_HV_S_6_S = 0;

[_1782] - BENZ_EF_BH_HV_S_7 + 0.147777778E-02 * Q_BH_D_HV_S_7_E + 0.105777778E-01 * Q_BH_D_HV_S_7_N + 0.114333333E-01 * Q_BH_D_HV_S_7_S = 0;

[_1783] - BENZ_EF_BH_HV_S_8 + 0.482222222E-02 * Q_BH_D_HV_S_8_E + 0.120555556E-01 * Q_BH_D_HV_S_8_N + 0.746666667E-02 * Q_BH_D_HV_S_8_S = 0;

[_1784] - BENZ_EF_BH_HV_S_9 + 0.84E-02 * Q_BH_D_HV_S_9_E + 0.133777778E-01 * Q_BH_D_HV_S_9_N + 0.84E-02 * Q_BH_D_HV_S_9_S = 0;

[_1785] - BENZ_EF_BH_HV_S_10 + 0.754444444E-02 * Q_BH_D_HV_S_10_E + 0.156333333E-01 * Q_BH_D_HV_S_10_N + 0.575555556E-02 * Q_BH_D_HV_S_10_S = 0;

[_1786] - BENZ_EF_BH_HV_S_11 + 0.933333333E-02 * Q_BH_D_HV_S_11_E + 0.181222222E-01 * Q_BH_D_HV_S_11_N + 0.443333333E-02 * Q_BH_D_HV_S_11_S = 0;

[_1787] - BENZ_EF_BH_HV_S_12 + 0.373333333E-02 * Q_BH_D_HV_S_12_E + 0.155555556E-01 * Q_BH_D_HV_S_12_N + 0.104222222E-01 * Q_BH_D_HV_S_12_S = 0;

[_1788] - BENZ_EF_BH_HV_S_13 + 0.108888889E-01 * Q_BH_D_HV_S_13_E + 0.178888889E-01 * Q_BH_D_HV_S_13_N + 0.330555556E-02 * Q_BH_D_HV_S_13_S = 0;

[_1789] - BENZ_EF_BH_HV_S_14 + 0.132222222E-01 * Q_BH_D_HV_S_14_E + 0.185111111E-01 * Q_BH_D_HV_S_14_N + 0.637777778E-02 * Q_BH_D_HV_S_14_S = 0;

[_1790] - BENZ_EF_BH_HV_S_15 + 0.147777778E-01 * Q_BH_D_HV_S_15_E + 0.189E-01 * Q_BH_D_HV_S_15_N + 0.152444444E-01 * Q_BH_D_HV_S_15_S = 0;

[_1791] - BENZ_EF_BH_HV_S_16 + 0.150266667E-01 * Q_BH_D_HV_S_16_E + 0.213733333E-01 * Q_BH_D_HV_S_16_N + 0.196E-02 * Q_BH_D_HV_S_16_S = 0;

[_1792] - BUTDN_EF_BH_HV_S_1 + 0.157888889E-02 * Q_BH_D_HV_S_1_E + 0.308777778E-03 * Q_BH_D_HV_S_1_N + 0.264444444E-02 * Q_BH_D_HV_S_1_S = 0;

[_1793] - BUTDN_EF_BH_HV_S_2 + 0.126E-02 * Q_BH_D_HV_S_2_E + 0.645555556E-03 * Q_BH_D_HV_S_2_N + 0.225555556E-02 * Q_BH_D_HV_S_2_S = 0;

[_1794] - BUTDN_EF_BH_HV_S_3 + 0.101111111E-02 * Q_BH_D_HV_S_3_E + 0.101111111E-02 * Q_BH_D_HV_S_3_N + 0.241111111E-02 * Q_BH_D_HV_S_3_S = 0;

[_1795] - BUTDN_EF_BH_HV_S_4 + 0.108888889E-02 * Q_BH_D_HV_S_4_E + 0.933333333E-03 * Q_BH_D_HV_S_4_N + 0.21E-02 * Q_BH_D_HV_S_4_S = 0;

Annexure 9

[_1796] - BUTDN_EF_BH_HV_S_5 + 0.9333333333E-03 * Q_BH_D_HV_S_5_E + 0.1057777778E-02 * Q_BH_D_HV_S_5_N + 0.1866666667E-02 * Q_BH_D_HV_S_5_S = 0;

[_1797] - BUTDN_EF_BH_HV_S_6 + 0.8555555556E-03 * Q_BH_D_HV_S_6_E + 0.1322222222E-02 * Q_BH_D_HV_S_6_N + 0.1788888889E-02 * Q_BH_D_HV_S_6_S = 0;

[_1798] - BUTDN_EF_BH_HV_S_7 + 0.2411111111E-03 * Q_BH_D_HV_S_7_E + 0.1633333333E-02 * Q_BH_D_HV_S_7_N + 0.1773333333E-02 * Q_BH_D_HV_S_7_S = 0;

[_1799] - BUTDN_EF_BH_HV_S_8 + 0.7466666667E-03 * Q_BH_D_HV_S_8_E + 0.1866666667E-02 * Q_BH_D_HV_S_8_N + 0.1166666667E-02 * Q_BH_D_HV_S_8_S = 0;

[_1800] - BUTDN_EF_BH_HV_S_9 + 0.1322222222E-02 * Q_BH_D_HV_S_9_E + 0.2068888889E-02 * Q_BH_D_HV_S_9_N + 0.1322222222E-02 * Q_BH_D_HV_S_9_S = 0;

[_1801] - BUTDN_EF_BH_HV_S_10 + 0.1166666667E-02 * Q_BH_D_HV_S_10_E + 0.2411111111E-02 * Q_BH_D_HV_S_10_N + 0.8555555556E-03 * Q_BH_D_HV_S_10_S = 0;

[_1802] - BUTDN_EF_BH_HV_S_11 + 0.1477777778E-02 * Q_BH_D_HV_S_11_E + 0.28E-02 * Q_BH_D_HV_S_11_N + 0.6922222222E-03 * Q_BH_D_HV_S_11_S = 0;

[_1803] - BUTDN_EF_BH_HV_S_12 + 0.5833333333E-03 * Q_BH_D_HV_S_12_E + 0.2411111111E-02 * Q_BH_D_HV_S_12_N + 0.1617777778E-02 * Q_BH_D_HV_S_12_S = 0;

[_1804] - BUTDN_EF_BH_HV_S_13 + 0.1633333333E-02 * Q_BH_D_HV_S_13_E + 0.2722222222E-02 * Q_BH_D_HV_S_13_N + 0.5133333333E-03 * Q_BH_D_HV_S_13_S = 0;

[_1805] - BUTDN_EF_BH_HV_S_14 + 0.2022222222E-02 * Q_BH_D_HV_S_14_E + 0.2877777778E-02 * Q_BH_D_HV_S_14_N + 0.1011111111E-02 * Q_BH_D_HV_S_14_S = 0;

[_1806] - BUTDN_EF_BH_HV_S_15 + 0.2255555556E-02 * Q_BH_D_HV_S_15_E + 0.2924444444E-02 * Q_BH_D_HV_S_15_N + 0.2356666667E-02 * Q_BH_D_HV_S_15_S = 0;

[_1807] - BUTDN_EF_BH_HV_S_16 + 0.2325555556E-02 * Q_BH_D_HV_S_16_E + 0.3307777778E-02 * Q_BH_D_HV_S_16_N + 0.3033333333E-03 * Q_BH_D_HV_S_16_S = 0;

[_1808] = 0;

[_1809] = 0;

[_1810] = 0;

[_1811] = 0;

[_1812] = 0;

[_1813] = 0;

[_1814] Q_BH_D_DV1_G_1_E + Q_BH_D_DV1_G_1_N + Q_BH_D_DV1_G_1_S + Q_BH_D_DV1_G_2_E + Q_BH_D_DV1_G_2_N + Q_BH_D_DV1_G_2_S + Q_BH_D_DV1_G_3_E + Q_BH_D_DV1_G_3_N + Q_BH_D_DV1_G_3_S + Q_BH_D_DV1_G_4_E + Q_BH_D_DV1_G_4_N + Q_BH_D_DV1_G_4_S + Q_BH_D_DV1_G_5_E + Q_BH_D_DV1_G_5_N + Q_BH_D_DV1_G_5_S + Q_BH_D_DV1_G_6_E + Q_BH_D_DV1_G_6_N + Q_BH_D_DV1_G_6_S + Q_BH_D_DV1_G_7_E + Q_BH_D_DV1_G_7_N + Q_BH_D_DV1_G_7_S + Q_BH_D_DV1_G_8_E + Q_BH_D_DV1_G_8_N + Q_BH_D_DV1_G_8_S + Q_BH_D_DV1_G_9_E + Q_BH_D_DV1_G_9_N + Q_BH_D_DV1_G_9_S + Q_BH_D_DV1_G_10_E + Q_BH_D_DV1_G_10_N + Q_BH_D_DV1_G_10_S + Q_BH_D_DV1_G_11_E + Q_BH_D_DV1_G_11_N + Q_BH_D_DV1_G_11_S + Q_BH_D_DV1_G_12_E + Q_BH_D_DV1_G_12_N + Q_BH_D_DV1_G_12_S + Q_BH_D_DV1_G_13_E + Q_BH_D_DV1_G_13_N + Q_BH_D_DV1_G_13_S + Q_BH_D_DV1_G_14_E + Q_BH_D_DV1_G_14_N + Q_BH_D_DV1_G_14_S + Q_BH_D_DV1_G_15_E + Q_BH_D_DV1_G_15_N + Q_BH_D_DV1_G_15_S + Q_BH_D_DV1_G_16_E + Q_BH_D_DV1_G_16_N + Q_BH_D_DV1_G_16_S >= 372;

[_1815] Q_BH_D_DV1_G_1_E + Q_BH_D_DV1_G_1_N + Q_BH_D_DV1_G_1_S + Q_BH_D_DV1_G_2_E + Q_BH_D_DV1_G_2_N + Q_BH_D_DV1_G_2_S + Q_BH_D_DV1_G_3_E + Q_BH_D_DV1_G_3_N + Q_BH_D_DV1_G_3_S + Q_BH_D_DV1_G_4_E + Q_BH_D_DV1_G_4_N + Q_BH_D_DV1_G_4_S + Q_BH_D_DV1_G_5_E + Q_BH_D_DV1_G_5_N + Q_BH_D_DV1_G_5_S + Q_BH_D_DV1_G_6_E + Q_BH_D_DV1_G_6_N + Q_BH_D_DV1_G_6_S + Q_BH_D_DV1_G_7_E + Q_BH_D_DV1_G_7_N + Q_BH_D_DV1_G_7_S + Q_BH_D_DV1_G_8_E + Q_BH_D_DV1_G_8_N + Q_BH_D_DV1_G_8_S + Q_BH_D_DV1_G_9_E + Q_BH_D_DV1_G_9_N + Q_BH_D_DV1_G_9_S + Q_BH_D_DV1_G_10_E + Q_BH_D_DV1_G_10_N + Q_BH_D_DV1_G_10_S + Q_BH_D_DV1_G_11_E + Q_BH_D_DV1_G_11_N + Q_BH_D_DV1_G_11_S + Q_BH_D_DV1_G_12_E + Q_BH_D_DV1_G_12_N + Q_BH_D_DV1_G_12_S + Q_BH_D_DV1_G_13_E + Q_BH_D_DV1_G_13_N + Q_BH_D_DV1_G_13_S + Q_BH_D_DV1_G_14_E + Q_BH_D_DV1_G_14_N + Q_BH_D_DV1_G_14_S + Q_BH_D_DV1_G_15_E + Q_BH_D_DV1_G_15_N + Q_BH_D_DV1_G_15_S + Q_BH_D_DV1_G_16_E + Q_BH_D_DV1_G_16_N + Q_BH_D_DV1_G_16_S <= 373;

[_1816] Q_BH_D_DV2_G_1_E + Q_BH_D_DV2_G_1_N + Q_BH_D_DV2_G_1_S + Q_BH_D_DV2_G_2_E + Q_BH_D_DV2_G_2_N + Q_BH_D_DV2_G_2_S + Q_BH_D_DV2_G_3_E + Q_BH_D_DV2_G_3_N + Q_BH_D_DV2_G_3_S + Q_BH_D_DV2_G_4_E + Q_BH_D_DV2_G_4_N + Q_BH_D_DV2_G_4_S + Q_BH_D_DV2_G_5_E + Q_BH_D_DV2_G_5_N + Q_BH_D_DV2_G_5_S + Q_BH_D_DV2_G_6_E + Q_BH_D_DV2_G_6_N + Q_BH_D_DV2_G_6_S + Q_BH_D_DV2_G_7_E + Q_BH_D_DV2_G_7_N + Q_BH_D_DV2_G_7_S + Q_BH_D_DV2_G_8_E + Q_BH_D_DV2_G_8_N + Q_BH_D_DV2_G_8_S + Q_BH_D_DV2_G_9_E + Q_BH_D_DV2_G_9_N + Q_BH_D_DV2_G_9_S + Q_BH_D_DV2_G_10_E + Q_BH_D_DV2_G_10_N + Q_BH_D_DV2_G_10_S + Q_BH_D_DV2_G_11_E + Q_BH_D_DV2_G_11_N + Q_BH_D_DV2_G_11_S + Q_BH_D_DV2_G_12_E + Q_BH_D_DV2_G_12_N + Q_BH_D_DV2_G_12_S + Q_BH_D_DV2_G_13_E + Q_BH_D_DV2_G_13_N + Q_BH_D_DV2_G_13_S + Q_BH_D_DV2_G_14_E + Q_BH_D_DV2_G_14_N + Q_BH_D_DV2_G_14_S + Q_BH_D_DV2_G_15_E + Q_BH_D_DV2_G_15_N + Q_BH_D_DV2_G_15_S + Q_BH_D_DV2_G_16_E + Q_BH_D_DV2_G_16_N + Q_BH_D_DV2_G_16_S >= 2499;

[_1817] Q_BH_D_DV2_G_1_E + Q_BH_D_DV2_G_1_N + Q_BH_D_DV2_G_1_S + Q_BH_D_DV2_G_2_E + Q_BH_D_DV2_G_2_N + Q_BH_D_DV2_G_2_S + Q_BH_D_DV2_G_3_E + Q_BH_D_DV2_G_3_N + Q_BH_D_DV2_G_3_S + Q_BH_D_DV2_G_4_E + Q_BH_D_DV2_G_4_N + Q_BH_D_DV2_G_4_S + Q_BH_D_DV2_G_5_E + Q_BH_D_DV2_G_5_N + Q_BH_D_DV2_G_5_S + Q_BH_D_DV2_G_6_E + Q_BH_D_DV2_G_6_N + Q_BH_D_DV2_G_6_S + Q_BH_D_DV2_G_7_E + Q_BH_D_DV2_G_7_N + Q_BH_D_DV2_G_7_S + Q_BH_D_DV2_G_8_E + Q_BH_D_DV2_G_8_N + Q_BH_D_DV2_G_8_S + Q_BH_D_DV2_G_9_E + Q_BH_D_DV2_G_9_N + Q_BH_D_DV2_G_9_S + Q_BH_D_DV2_G_10_E + Q_BH_D_DV2_G_10_N + Q_BH_D_DV2_G_10_S + Q_BH_D_DV2_G_11_E + Q_BH_D_DV2_G_11_N + Q_BH_D_DV2_G_11_S + Q_BH_D_DV2_G_12_E + Q_BH_D_DV2_G_12_N + Q_BH_D_DV2_G_12_S + Q_BH_D_DV2_G_13_E + Q_BH_D_DV2_G_13_N + Q_BH_D_DV2_G_13_S + Q_BH_D_DV2_G_14_E + Q_BH_D_DV2_G_14_N + Q_BH_D_DV2_G_14_S + Q_BH_D_DV2_G_15_E + Q_BH_D_DV2_G_15_N + Q_BH_D_DV2_G_15_S + Q_BH_D_DV2_G_16_E + Q_BH_D_DV2_G_16_N + Q_BH_D_DV2_G_16_S <= 2500;

[_1818] Q_BH_D_DV3_G_1_E + Q_BH_D_DV3_G_1_N + Q_BH_D_DV3_G_1_S + Q_BH_D_DV3_G_2_E + Q_BH_D_DV3_G_2_N + Q_BH_D_DV3_G_2_S + Q_BH_D_DV3_G_3_E + Q_BH_D_DV3_G_3_N + Q_BH_D_DV3_G_3_S

