STUDY OF MUNICIPAL SOLID WASTE IN THE AREA OF KOLKATA MUNUCIPAL CORPORATION

A thesis submitted towards partial fulfillment of the requirements for the degree of

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Jadavpur University

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **"STUDY OF MUNICIPAL SOLID WASTE IN THE AREA OF KOLKATA MUNUCIPAL CORPORATION"** is bonafide work carried out by **SUBHRA PRATIM DAS** under our supervision and guidance for partial fulfilment of the requirement for Post Graduate Degree of Master of Engineering in Water Resources & Hydraulic Engineering during the academic session 2018-2019.

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This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactorily to warranty its acceptance as a pre-requisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approve the thesis only for purpose for which it has been submitted.

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I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as a part of my Master of Water Resources & Hydraulic Engineering degree during academic session 2018-2019.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

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Abstract

Kolkata serves as the state capital. Municipal solid waste includes waste generating from residential areas, commercial and institutional establishments comprising of organic and inorganic substances but excludes biomedical waste, industrial hazardous waste and also demolition waste. Solid waste management has become a major environmental issue in West Bengal. Municipal solid waste management (MSWM) System includes the handling of wastes in a hygienic and scientific manner by involving suitable practices because if the wastes are not handled properly, they may cause deleterious effects to public health and environment. It involves development of an insight into the impact of waste generation, collection, transportation and disposal methods adopted by a society on the environment and application of suitable techniques, technologies and management programs covering all types of solid wastes from all sources to achieve the twin objectives of waste reduction and effective management of waste still produced after waste reduction. The per capita of MSW generated daily, is about 300 to 600 gm/day in KMC.

The objective of this study is to assess the status of municipal solid waste collection, transportation, treatment and disposal as per MSW rules in the KMC. The SWM status was studied and assessed based on the information provided by the urban local bodies (ULBs) and also on the information collected through field survey.

In order to obtain information on MSWM practices applied by the Urban Local Bodies (ULBs) questionnaires were sent to ULBs to collect information relating to Municipal solid waste management. A number of Municipal towns were visited to assess the SWM systems and their status. The SWM status were studied and assessed on the basis of the information's furnished by the municipal towns. Quantitative and qualitative (physical analysis/ chemicals) of solid waste were carried out in the municipal towns (Kolkata). Characteristics of the waste were studied at the field as per standard methods and quantification were assessed for garbage, ash, paper, plastic, ceramic, glass etc.

This study also focused on the recycling process of solid waste generated in the municipal towns (Kolkata) by production of biogas. The experiment was carried out in a single stage anaerobic digestion system operated under mesophilic temperature.

We should go for creating an Organic Processing Facility to create biogas which will be more cost effective, eco-friendly, cut down on landfill waste, generate a high-quality renewable fuel, and reduce carbon dioxide & methane emissions. The anaerobic digestion of MSW produces biogas, a valuable energy resource. Anaerobic digestion is a microbial process for production of biogas, which consists of primarily methane (CH_4) & carbon dioxide (CO_2).

THIS THESIS WORK IS DEDICATED TO MY PARENTS

CONTENTS

CHAPTER

CHAPTER -1

INTRODUCTION

Introduction :-

The managements of Solid Waste is changing fast around the world and Solid Waste Management (SWM) department of Kolkata Management (KMC) is also modernizing themselves to keep up with those changes in all three primary segments of SWM viz. primary collection, primary and secondary transportation and treatment and disposal. KMC area comprises about 206.08 sq. Km. having population of 44,86,679 as per Census 2011 . Waste generation rate is 500- 550 gpsd (average). Quantity of Municipal Solid Waste generation in the city is about 4500 MT /Day. The collection , transportation and disposal of the Municipal Solid Waste (MSW) is primarily executed and managed by KMC with total workforce of around 15000 employees, most of which about 10,000 are engaged in the street sweeping and door to door collection. Before 2010, conservancy services were restricted up to 12.00 Noon but to improve the collection efficiency and to make the city presentable about 7000 number of employees under West Bengal Urban Employment Scheme are working in the afternoon and some areas in the evening also.

A pilot project with the mission of vat free city has been introduce in ward no - 85 by using Battery operated vehicle with hydraulic tipping system. In line with KMC has procured another 220 numbers of Battery operated Hydraulic Dumper in addition to conventional Hand Cart and Try -Cycle for door to door collection which helps to increase coverage of SWM services in household and bulk generator s and strengthen the present SWM system of KMC at level of primary collection . SWM department has also procured considerable number 240 liter trash bins which have been set up on the road side for the use of pedestrians, shop owners and commercial purposes, SWM department is also continuing the source segregation of waste at source in 07 Wards in view of recycling or reuse of segregated materials and to reduce the overburden on landfill.

The portable compactor and compactor station, a modern scientific eco-friendly system being introduced for garbage handling and disposal is a revolutionary steps for Kolkata . It also functions as mini transfer station . It also restricts communicability of disease and avoids foul smell, littering, informal collection etc. About 85 numbers of such compactor stations and 180 compactor containers have installed in the stations replace 300 numbers of open vats throughout the city of Kolkata.

For effective utilization of transpiration of MSW, SWM department of KMC has procured 54 numbers of Hook Loaders, 80 numbers of Movable compactors in different areas of KMC which helps odorless transpiration from compactor station to disposal site, avoids spillage and seepage of water during transpiration, and reduces fuel consumption. The SWM department has also achieved to replace about 90% very old KMC owned and hired vehicle (more than 15 years) by the combination of Stationary and Movable compactors.

In Case of waste disposal system KMC has removed 7459050 MT waste generated in the city during the last 5 years . Introduction of online central server with CCTV network system helps to provides security in the system, to facilitate huge data storage and helps to provide

spatial and visual validation for provision of services at waste disposal site. SWM department the modern vehicles. Existing landfill site Dhapa is almost exhausted and portion of 12.14 hectare land has been taken up for bio- remediation project which is near in completion. KMC has also identified two lands one at Patharghata , Rajarhat and another at Raspinja, South 24 Parganas. KEIIp of KMC has been entrusted to prepare the master plan and integrated Solid Waste Management facilities for the city ok Kolkata. annual budged estimate for the year 2018 - 2019 of SWM department is Rs. 58,071.00 Lakhs.

Objective of Solid Waste Management

Objective of Solid Waste Management The objective of solid waste management is to reduce the quantity of solid waste disposed off on land by recovery of materials and energy from solid waste as depicted. This in turn results in lesser requirement of raw material and energy as inputs for technological processes. A simplified flow chart showing how waste reduction can be achieved for household waste. Such techniques and management programs have to be applied to each and every solid waste generating activity in a society to achieve overall minimisation of solid waste.

PRINCIPLES OF MUNICIPAL SOLID WASTE MANAGEMENT

Municipal Solid Waste Management involves the application of principle of Integrated Solid Waste Management (ISWM) to municipal waste. ISWM is the application of suitable techniques, technologies and management programs covering all types of solid wastes from all sources to achieve the twin objectives of (a) waste reduction and (b) effective management of waste still produced after waste reduction. Waste Reduction It is now well recognized that sustainable development can only be achieved if society in general, and industry in particular, produces 'more with less' i.e. more goods and services with less use of the world's resources (raw materials and energy) and less pollution and waste. Production as well as product changes have been introduced in many countries, using internal recycling of materials or on-site energy recovery, as part of solid waste minimisation schemes.

Effective Management of Solid Waste

Effective solid management systems are needed to ensure better human health and safety. They must be safe for workers and safeguard public health by preventing the spread of disease. In addition to these prerequisites, an effective system of solid waste management must be both environmentally and economically sustainable. · Environmentally sustainable: It must reduce, as much as possible, the environmental impacts of waste management. · Economically sustainable: It must operate at a cost acceptable to community. Clearly it is difficult to minimize the two variables, cost and environmental impact, simultaneously. There will always be a trade off. The balance that needs to be struck is to reduce the overall environmental impacts of the waste management system as far as possible, within an acceptable level of cost. An economically and environmentally sustainable solid waste management system is effective if it follows an integrated approach i.e. it deals with all types of solid waste materials and all sources of solid waste. A multi-material, multi-source management approach is usually effective in environmental and economic terms than a material specific and source specific approach. Specific wastes should be dealt within such a system but in separate streams. An effective waste management system includes one or more of the following options: (a) Waste collection and transportation. (b) Resource recovery through sorting and recycling i.e. recovery of materials (such as paper, glass, metals) etc. through separation. (c) Resource recovery through waste processing i.e. recovery of materials (such as compost) or recovery of energy through biological, thermal or other processes. (d) Waste transformation (without recovery of resources) i.e. reduction of volume, toxicity or other physical/chemical properties of waste to make it suitable for final disposal. (e) Disposal on land i.e. environmentally safe and sustainable disposal in landfills.

Functional Elements of Municipal Solid Waste Management

The activities associated with the management of municipal solid wastes from the point of generation to final disposal can be grouped into the six functional elements: (a) waste generation; (b) waste handling and sorting, storage, and processing at the source; (c) collection; (d) sorting, processing and transformation; (e) transfer and transport; and (f) disposal**.**

CLASSIFICATION OF SOLID WASTES

Type of waste a comprehensive classification is described below:

(i) **Domestic/Residential Waste:** This category of waste comprises the solid wastes that originate from single and multi-family household units. These wastes are generated as a consequence of household activities such as cooking, cleaning, repairs, hobbies, redecoration, empty containers, packaging, clothing, old books, writing/new paper, and old furnishings. Households also discard bulky wastes such as furniture and large appliances which cannot be repaired and used.

(ii) **Municipal Waste:** Municipal waste include wastes resulting from municipal activities and services such as street waste, dead animals, market waste and abandoned vehicles. However, the term is commonly applied in a wider sense to incorporate domestic wastes, institutional wastes and commercial wastes.

(iii) **Commercial Waste:** Included in this category are solid wastes that originate in offices, wholesale and retail stores, restaurants, hotels, markets, warehouses and other commercial establishments. Some of these wastes are further classified as garbage and others as rubbish.

(iv) **Institutional Waste:** Institutional wastes are those arising from institutions such as schools, universities, hospitals and research institutes. It includes wastes which are classified as garbage and rubbish as well as wastes which are considered to be hazardous to public health and to the environment.

(v) **Garbage:** Garbage is the term applied to animal and vegetable wastes resulting from the handling, storage, sale, preparation, cooking and serving of food. Such wastes contain putrescible organic matter, which produces strong odours and therefore attracts rats, flies and other vermin. It requires immediate attention in its storage, handling and disposal.

(vi) **Rubbish:** Rubbish is a general term applied to solid wastes originating in households, commercial establishments and institutions, excluding garbage and ashes.

(vii) **Ashes:** Ashes are the residues from the burning of wood, coal, charcoal, coke and other combustible materials, for cooking and heating in houses, institutions and small industrial establishments. When produced in large quantities at power generating plants and factories these wastes are classified as industrial wastes. Ashes consist of a fine powdery residue, cinders and clinker often mixed with small pieces of metal and glass.

(viii) **Bulky Wastes:** In this category are bulky household wastes which cannot be accommodated in the normal storage containers of households. For this reason

they require special collection. In developed countries bulky wastes are large household appliances such as cookers, refrigerators and washing machines as well as furniture, crates, vehicle parts, tyres, wood, trees and branches. Metallic bulky wastes are sold as scrap metal but some portion is disposed of at sanitary landfills.

(ix) **Street Sweeping:** This term applies to wastes that are collected from streets, walkways, alleys, parks and vacant lots. In the more affluent countries manual street sweeping has virtually disappeared but it still commonly takes place in developing countries, where littering of public places is a far more widespread and acute problem. Mechanised street sweeping is the dominant practice in the developed countries. Street wastes include paper, cardboard, plastic, dirt, dust, leaves and other vegetable matter.

(x) **Dead Animals:** This is a term applied to dead animals that die naturally or accidentally killed. This category does not include carcass and animal parts from slaughterhouses which are regarded as industrial wastes. Dead animals are divided into two groups, large and small. Among the large animals are horses, cows, goats, sheep, hogs and the like. Small animals include dogs, cats, rabbits and rats. The reason for this differentiation is that large animals require special equipment for lifting and handling during their removal. If not collected promptly, dead animals are a threat to public health because they attract flies and other vermin as they putrefy. Their presence in public places is particularly offensive and emits foul smell from the aesthetic point of view.

(xi) **Construction and Demolition Wastes:** Construction and demolition wastes are the waste materials generated by the construction, refurbishment, repair and demolition of houses, commercial buildings and other structures. It mainly consists of earth, stones, concrete, bricks, lumber, roofing materials, plumbing materials, heating systems and electrical wires and parts of the general municipal waste stream, but when generated in large amounts at building and demolition sites, it is generally removed by contractors for filling low lying areas and by urban local bodies for disposal at landfills.

(xii) **Industrial Wastes:** In the category are the discarded solid material of manufacturing processes and industrial operations. They cover a vast range of substances which are unique to each industry. For this reason they are considered separately from municipal wastes. It should be noted, however, that solid wastes from small industrial plants and ash from power plants are frequently disposed of at municipal landfills. For details please refer to Chapter 6 on “Industrial Wastes”.

(xiii) **Hazardous Wastes:** Hazardous wastes may be defined as wastes of industrial, institutional or consumer origin which, because of their physical, chemical or biological characteristics are potentially dangerous to human and the environment. In some cases although the active agents may be liquid or gaseous, they are classified as solid wastes because they are confined in solid containers. Typical examples are: solvents, paints and pesticides whose spent containers are frequently mixed with municipal wastes and become part of the urban waste stream. Certain hazardous wastes cause explosions in incinerators and fires at landfill sites. Others, such as pathological wastes from hospitals and radioactive wastes, require special handling at all time. Good management practice should

ensure that hazardous wastes are stored, collected, transported and disposed off separately, preferably after suitable treatment to render them innocuous. For details please refer to Chapter 7 on "Bio-Medical Wastes".

(xiv) **Sewage Wastes:** The solid by-products of sewage treatment are classified as sewage wastes. They are mostly organic and derive from the treatment of organic sludge from both the raw and treated sewage. The inorganic fraction of raw sewage such as grit is separated at the preliminary stage of treatment, but because it entrains putrescible organic matter which may contain pathogens, must be buried/disposed off without delay. The bulk of treated, dewatered sludge is useful as a soil conditioner but invariably its use for this purpose is uneconomical. The solid sludge therefore enters the stream of municipal wastes unless special arrangements are made for its disposal.

Classification of Solid Wastes

TYPES OF SOLID WASTE	DESCRIPTION	SOURCES
Food waste (garbage)	Wastes from the preparation, cooking, and serving of food. Market refuse, waste from the handling, storage, and sale of produce and meats and vegetable.	
Rubbish	Combustible (primary organic) paper, cardboard, cartons wood, boxes, plastics, rags, cloth, bedding, leather, rubber, grass, leaves, yard trimmings Noncombustible (primary inorganic) metals, tin cans, metal foils dirt, stones, bricks, ceramics, crockery, glass bottles, other mineral refuse	Households, institutions and commercial such as hotels, stores, restaurants, markets, etc.
Ashes and Residues	Residue from fires used for cooking and for heating buildings, cinders, clinkers, thermal power plants.	
Bulky waste	Large auto parts, tyres, stoves refrigerators, others large appliances, furniture,	

	large crates, trees, branches, palm fronts, stumps, flotage	
Street waste	Street sweepings, Dirt, leaves, catch basin dirt, animal droppings, contents of litter receptacles dead animals	Streets, sidewalks, alleys, vacant lots, etc.
Dead animals	Small animals: cats, dogs, poultry etc. Large animals: horses, cows etc.	
Construction & demolition waste	Lumber, roofing, and sheathing scraps, crop residues, rubble, broken concrete, plaster, co	Construction and demolition sites, remodeling, repairing sites
Industrial waste & sludges	Solid wastes resulting from industry processes and manufacturing operations, such as food processing wastes, boiler house cinders, wood, plastic and metal scraps and shaving, etc. Effluent treatment plant sludge of industries and sewage treatment plant sludges, coarse screening, grit & septic tank	Factories, power plants, treatment plants, etc.
Hazardous wastes	Hazardous wastes: pathological waste, explosives, radioactive material, toxic waste etc.	Households, hospitals, institution, stores, industry, etc. Parks, gardens,
Horticulture Wastes	Tree-trimmings, leaves, waste from parks and gardens, etc.	Parks, gardens, roadside trees, etc.

Physical & Chemical Analysis of City Refuse :-

The analysis of refuse (Table -1) is carried out normally to know it's physical as well as chemical characteristics (Table 2) which enable us to decide the desired frequently of collection, precautions to be taken during its transpiration and method of processing and disposal.

Table 1 : Average physical composition of municipal solid waste

Total Compostable	Recyclables				Other including Inerts						Total
	Paper	Plastic	Glass	Metal	Inert	Rubber And Leather	Rags	Wooden Matter	Coconut	Bones	
50.56	6.07	4.88	0.34	0.19	29.60	0.68	1.87	1.15	4.50	0.16	100.00
50.56	11.48				37.96						100.00

(All values are expressed in percentage on wet weight basis)

Table 2: Average Chemical composition of municipal solid waste

Sl.No	Parameters	Year 2005
01	Mousture	46
02	pH	0.3-8.07
03	Loss of Ignition	38.53
04	Carbon	22.35
05	Nitrogen as N	076
06	Phosphorus as 205	077
07	Potassium as K2O	052
08	C/N Ratio	31.81
09	LCV Kcal /Kg	1201

(All values are in percent by dry weight basis except pH & LCV)

All values of physical parameters are in percent by net weight and values are of chemical parameters are in percent by dry weight basis except pH & LCV ; * Bio - resistant and synthetic material.

Characteristics of solid waste

In order to identify the exact characteristics of municipal wastes, it is necessary that we analyses them using physical and chemical parameters. This lesson will emphasize about the various characteristics of solid wastes and their importance**.**

Physical characteristics

Information and data on the physical characteristics of solid wastes are important for the selection and operation of equipment and for the analysis and design of disposal facilities. The following physical characteristics are to be studied in detail.

Density

Density of waste, i.e., its mass per unit volume (kg/m^3), is a critical factor in the design of a solid waste management system, e.g., the design of sanitary landfills, storage, types of collection and transport vehicles, etc. To explain, an efficient operation of a landfill demands compaction of wastes to optimum density. Any normal compaction equipment can achieve reduction in volume of wastes by 75%, which increases an initial density of 100 kg/m^3 to 400 kg/m^3. In other words, a waste collection vehicle can haul four times the weight of waste in its compacted state than when it is uncompacted . Significant changes in density occur spontaneously as the waste moves from source to disposal, due to scavenging, handling, wetting and drying by the weather, vibration in the collection vehicle and decomposition

Moisture content

Moisture content is defined as the ratio of the weight of water (wet weight - dry weight) to the total wet weight of the waste. Moisture increases the weight of solid wastes, and thereby, the cost of collection and transport. In addition, moisture content is a critical determinant in the economic feasibility of waste treatment by incineration, because wet waste consumes energy for evaporation of water and in raising the temperature of water vapour. In the main, wastes should be insulated from rainfall or other extraneous water.

A typical range of moisture content is 20 to 40%, representing the extremes of wastes in an arid climate and in the wet season of a region of high precipitation. However, values greater than 40% are not uncommon. Climatic conditions apart, moisture content is generally higher in low income countries because of the higher proportion of food and yard waste.

Size of Waste constituents

The size distribution of waste constituents in the waste stream is important because of its significance in the design of mechanical separators and shredder and waste treatment process. This varies widely and while designing a system, proper analysis of the waste characteristics should be carried out.

Calorific Value

Calorific value is the amount of heat generated from combustion of a unit weight of a substance, expressed as kcal/kg. The calorific value is determined experimentally using Bomb calorimeter in which the heat generated at a constant temperature of 25^{0}C from the combustion of a dry sample is measured.

The physical properties that are essential to analyse of wastes disposed at landfills are:

Field capacity

The field capacity of municipal solid waste is the total amount of moisture which can be retained in a waste sample subject to gravitational pull. It is a critical measure because water in excess of field capacity will form leachate, and leachate can be a major problem in landfills. Field capacity varies with the degree of applied pressure and the state of decomposition of the wastes.

Permeability of compacted wastes

The hydraulic conductivity of compacted wastes is an important physical property because it governs the movement of liquids and gases in a landfill. Permeability depends on the other properties of the solid material include pore size distribution, surface area and porosity. Porosity represents the amount of voids per unit total volume of material. The porosity of municipal solid waste varies typically from 0.40 to 0.67 depending on the compaction and composition of the waste.

Compressibility

It is the degree of physical changes of the suspended solids or filter cake when subjected to pressure**.**

Chemical characteristics

Knowledge of the classification of chemical compounds and their characteristics is essential for the proper understanding of the behaviour of waste, as it moves through the waste management system. The products of decomposition and heating values are two examples of chemical characteristics. If solid wastes are to be used as fuel, or are used for any other purpose, we must know their chemical characteristics, including the following

Chemical characteristics:

Chemical characteristics include pH, Nitrogen, Phosphorus and Potassium (N-P-K), total Carbon, C/N ratio, calorific value.

Bio-Chemical: Bio-Chemical characteristics include carbohydrates, proteins, natural fibre, and biodegradable factor.

Toxic: Toxicity characteristics include heavy metals, pesticides, insecticides, Toxicity test for Leachates (TCLP), etc**.**

Lipids

This class of compounds includes fats, oils and grease. Lipids have high calorific values, about 38000 kcal/kg, which makes waste with a high lipid content suitable for energy recovery processes. Since lipids in the solid state become liquid at temperatures slightly above ambient, they add to the liquid content during waste decomposition. They are biodegradable but because they have a low solubility in waste, the rate of biodegradation is relatively slow.

Carbohydrates

Carbohydrates are found primarily in food and yard waste. They include sugars and polymers of sugars such as starch and cellulose and have the general formula $(CH_2O)_x$. Carbohydrates are readily biodegraded to products such as carbon dioxide, water and methane. Decomposing carbohydrates are particularly attractive for flies and rats and for this reason should not be left exposed for periods longer than is necessary.

Proteins

Proteins are compounds containing carbon, hydrogen, oxygen and nitrogen and consist of an organic acid with a substituted amine group (NH_2). They are found mainly in food and garden wastes and comprise 5-10% of the dry solids in solid waste. Proteins decompose to form amino acids but partial decomposition can result in the production of amines, which have intensely unpleasant odours.

Natural fibres

This class includes the natural compounds, cellulose and lignin, both of which are resistant to biodegradation. They are found in paper and paper products and in food and yard waste. Cellulose is a larger polymer of glucose while lignin is composed of a group of monomers of which benzene is the primary member. Paper, cotton and wood products are 100%, 95% and 40% cellulose respectively. Since they are highly combustible, solid waste having a high proportion of paper and wood products, are suitable for incineration. The calorific values of ovendried paper products are in the range 12000 – 18000 kcal/kg and of wood about 20000 kcal/kg, which compare with 44200 kcal/kg for fuel oil.

Synthetic organic material (Plastics)

They are highly resistant to biodegradation and, therefore, are objectionable and of special concern in solid waste management. Hence the increasing attention being paid to the recycling of plastics to reduce the proportion of this waste component at disposal sites. Plastics have a high heating value, about 32,000 kJ/kg, which make them very suitable for incineration. But, one should note that polyvinyl chloride (PVC), when burnt, produces dioxin and acid gas. The latter increases corrosion in the combustion system and is responsible for acid rain.

Non-combustibles:

This class includes glass, ceramics, metals, dust and ashes, and accounts for 12 – 25% of dry solids.

Heating value

An evaluation of the potential of waste material for use as fuel for incineration requires a determination of its heating value, expressed as kilojoules per kilogram (kJ/kg). The heating value is determined experimentally using the *Bomb calorimeter test*, in which the heat generated, at a constant temperature of 25°C from the combustion of a dry sample is measured. Since the test temperature is below the boiling point of water (100°C), the combustion water remains in the liquid state. However, during combustion, the temperature of the combustion gases reaches above 100°C, and the resultant water is in the vapour form. While evaluating incineration as a means of disposal or energy recovery, one has to consider the heating values of respective constituents.

Ultimate analysis

This refers to an analysis of waste to determine the proportion of carbon, hydrogen, oxygen, nitrogen and sulphur, and it is done to perform mass balance calculation for a chemical or thermal process. Besides, it is necessary to determine ash fraction because of its potentially harmful environmental

effects, brought about by the presence of toxic metals such as cadmium, chromium, mercury, nickel, lead, tin and zinc. One should note that other metals (e.g., iron, magnesium, etc.) may also be present but they are non-toxic.

The following table shows an ultimate analysis of a typical municipal solid waste

Element	**Range (% dry weight)**
Carbon	25-30
Hydrogen	2.5-6.0
Oxygen	15-30
Nitrogen	0.25-1.2
Sulphur	0.02-0.12
Ash	12-30

Proximate analysis

This is important in evaluating the combustion properties of wastes or a waste or refuse derived fuel. The fractions of interest are:

- moisture content, which adds weight to the waste without increasing its heating value, and the evaporation of water reduces the heat released from the fuel;
- ash, which adds weight without generating any heat during combustion;
- volatile matter, i.e., that portion of the waste that is converted to gases before and during combustion;
- fixed carbon, which represents the carbon remaining on the surface grates as charcoal. A waste or fuel with a high proportion of fixed carbon requires a longer retention time on the furnace grates to achieve complete combustion than a waste or fuel with a low proportion of fixed carbon.

The following table shows an proximate analysis of a typical municipal solid waste

Components	**Value (%)**	
	Range	Typical
Moisture	15-40	20
Volatile matter	40-60	53
Fixed carbon	5-12	7
Glass, metal, ash	15-30	20

CHAPTER -2

LITERATURE REVIEW

BIOGAS IN INDIA:

The pioneer of anaerobic digestion in India is S.V. Desai, for his first experiments on biogasproduction in 1939. This led to the development of the first Indian biogas plant in 1951, theGramalaxi plant of the Khadi and Village Industries Commission (KVIC), better known as the KVIC digester. KVIC was the first to introduce biogas plants amongst the famers in rural India. In 1962 their design became standardised and are still built. Two other models which became popular, are the Janata biogas plant introduced in 1978 and its successor, the Deenbandhu digester, developed by Action for Food Production (AFPRO) in 1984 [Singh, K. J., *et.al*., (2004), 'Comparative study of economics of different models of family size biogas plants for state of Punjab, India, Energy Conversion and Management]. National Biogas and Manure Management Programme (NBMMP) is being implemented in the country since 1981-82 for promotion of biogas plants based on cattle dung and other organic wastes. The NBMMP caters to setting up of family type biogas plants for meeting
the cooking energy needs in rural areas of the country along with making enriched organic fertiliser availability to farmers. The existing institutional network for implementation of the programme includes state nodal departments/ state nodal agencies, and Khadi and Village Industries Commission (KVIC). These agencies, in-turn, involve their state/district level
network institutions, trained turn-key workers and rural entrepreneurs. The Panchayats are also involved for selection of the beneficiaries and monitoring of the programme. In order to provide training support and technical back-up, 13 Biogas Development and Training Centers (BDTCs) have been set up in the country in various universities, Indian Institute
of Technology (IITs) and other technical institutes. The family type biogas plants under NBMMP forms the part of Twenty Point Programme - 2006 (TPP 2006) under item No. 59 and is monitored accordi
With the increased support and initiation by Ministry of New and Renewable Energy (MNRE) to use the locally available organic wastes for anaerobic digestion, the cumulative total installation of 45.45 lakh family type biogas plants were installed till March, 2013, which is about 36.85 per cent of the estimated potential. Cumulative achievements and target and achievements during 2012-13 under the Programme are given in Table 1. It is observed that some of the backward states have taken better initiative to implement the biogas programme efficiently as compared to other developed states. The states Maharashtra and Kerala stood well ahead of others in implementing the biogas programme.
production of about 146 lakh kg of urea equivalent
or 27.58 lakh tonnes of organic manure per year.
It is estimated that the construction activity would have generated about 42.3 lakh person days of employment for skilled and unskilled workers in rural areas during the year 2010-11. In addition, the rural families would benefit in terms of reducing drudgery of women involved in collecting fuel wood from long distances andminimising health hazards during cooking in smoky kitchens.

Biogas For Sustainable Development

The benefits of biogas generation at domestic level are discussed at three different scales; the direct beneficiaries (the household members), the local benefits and the benefits at national and global scale. According to the UN energy security is a prerequisite to achieve the Millennium Development Goals (MDGs) and biogas is one of the means to obtain energy
security and thus an important step for sustainable development and poverty alleviation. The use of organic matter for biogas generation leads to changes in the society by directly benefiting different sections in different forms. The direct benefits are on-site farm energy generation, women empowerment, indoor air improvement, sanitation improvement and
pathogen removal, chemical fertiliser displacement and nutrient recovery apart from some financial benefits. One of the most noticeable benefits of biogas in rural areas is the provision of a clean and convenient cooking fuel. By utilising biogas

for cooking purposes, other fuels are displaced, this could be either traditional biomasses (dung, wood, charcoal) or fossil fuels (Sagar, A.D., *et.al*., (2007),'Bioenergy and sustainable development', Annual Review of Environment and Resources). In the case of traditional biomasses, biogas displaces woody fuels and has a time or revenue saving component. Biogas can also displace fossil fuels. In case fossil fuels are substituted by biogas, it saves primarily the valuable foreign exchange and in case of solid fossil fuels, it will result in the improvement of the indoor air quality. In addition, switching fossil fuel to biogas reduces greenhouse gas (GHG) emissions. Biogas can also be used for lighting which is a considerable improvement over the hazardous open fire lighting from kerosene lanterns or candles. The superior illumination of biogas lanterns could result in longer study hours for children, more activities in the evening which both have a positive return and improves the quality of life. A biogas system also acts as a tool which handles the sanitation and produces manure—this will lead in good public health and also result in destruction of pathogens which is not the case otherwise. Since manure is collected and
most of the volatile solids are converted to biogas, foul odours are reduced.

BIOGAS IN BANGLADESH:

Perspectives of Biogas Conversion into Bio-CNG for Automobile Fuel in Bangladesh

The need for liquid and gaseous fuel for transportation application is growing very fast. This high consumption trend causes swift
exhaustion of fossil fuel reserve as well as severe environment pollution. Biogas can be converted into various renewable automobilefuels such as bio-CNG, syngas, gasoline, and liquefied biogas.However, bio-CNG, a compressed biogas with highmethane content,can be a promising candidate as vehicle fuel in replacement of conventional fuel to resolve this problem. This paper presents anoverview of available liquid and gaseous fuel commonly used as transportation fuel in Bangladesh. The paper also illustrates thepotential of bio-CNG conversion from biogas in Bangladesh. It is estimated that, in the fiscal year 2012-2013, the country hadabout 7.6775 billionm3 biogas potential equivalent to 5.088 billionm3 of bio-CNG. Bio-CNG is competitive to the conventionalautomobile fuels in terms of its properties, economy, and emission.

1. Introduction

Transportation system is the basement of the industrial and socioeconomic development of any country and predominantly depends on fossil fuel [1]. In the United States, about 28% of the total energy consumption is used for
transportation system of which almost 86% comes from gasoline and diesel fuels [2]. Due to the rapid depletion and
high cost of liquid fuel, natural gas is used in compressed formnamed compressed natural gas (CNG). Currently, it has become very popular alternative to liquid fuel for vehicles in the world due to its low price [3]. It is estimated that during 2013, approximately 18.09 million natural gas vehicles (NGV) have been run by CNG in the world. Nowadays some countries like theUnited States, Germany, Australia, Austria, India, and so forth already have been using bio-CNG as the vehicles fuel in place of CNG . In the United States, 8 renewable natural gas projects, namely, bio-CNG 50, bio-CNG 100, and bio-CNG 200, have been installed during 2011 to 2013 [5, 6].These plants produce
approximately 200 gallons of diesel equivalents (DGEs)/day, 399.77DGEs/day, and 790DGEs/day, respectively, which can be enough fuel for 25–30 vehicles, 5–8 trash trucks, or 40–50 passenger vehicles and 25 heavy duty vehicles or 40–50 light duty vehicles per day. In India, first indigenous bio-CNG plant with capacity of 85 cubic meters has been made at Rajasthan with the help from IIT, Delhi. The plant uses cow dung as feed material and the production cost1of1kg of bio- CNG is about USD 0.23–0.24 which is much cheaper than the petro-based CNG [7]. During the year 2013, in Austria about 7GWh energy equivalent vehicle fuel (biomethane) was produced from biogas and three filling stations were established at biogas upgrading plants. On the other hand, Germany produced almost 0.1% of total consumption of vehicle fuel from biogas in year 2012 equivalent to approximately 0.35 TWh of energy. At the end of 2012, about 120 biomethane feed plants were in operation with an installed capacity of 72,000Nm3/h in Germany that could be fueled for 0.1 million gas vehicles in 119 out of the 900 CNG filling stations .Link¨oping, a city of Sweden is the promising

2 model of bio-CNG integration into public transportation.The plant produces about 4.7 millionm3 of upgraded biogasper year that is used in 64 buses and a number of heavyand light duty vehicles through 12 public refueling stations.
Besides, this is the pioneer in using biomethane in train. This plant reduces approximately 9,000 tons of CO2-emissions from urban transport as well as sulphur and nitrogen oxides
per year [9]. Bangladesh is an energy starved country where naturalgas and petroleum products are the main sources of energy. However, the country has only 0.3 trillion cubic meters ofproved natural gas reserve at the end of 2014 which will be exhausted within next 10–12 years if the existing

consumption rate continues. In addition, the petroleum reserve in Bangladesh is only about 8% of the total demand; it has to import about 1.2million tons of crude oil and 2.6million tons of refined petroleum products each year [10]. The country consumed almost 23.6 billion cubic meters of natural gas and 5.7million tons of oil in the year 2014 [11].The transportation sector consumes approximately 46.46% of total petroleum consumption and 6% of total natural gas consumption. Up to October 2015, the country has about 560 CNG refueling stations and 180 CNG conversion workshops which have converted approximately 245,372 vehicles into CNG vehicles. Currently, the country has total of 285,755 CNG run vehicles
including imported vehicles. However, taking into account the future security of liquid and gaseous vehicle fuel, it
is necessary to find out alternative renewable source for transport fuel immediately. Bio-CNG produced from the
purification and then compression of biogas can be the most suitable alternative for traditional vehicle fuel in Bangladesh. Bangladesh has enormous amount feed material for biogas production which can be the most effective option for bio- CNG. However,most of the biogas plants in the country aresmall-scale domestic digester producing biogas mainly for cooking and lighting.The main issues for commercial biogasimplementation in Bangladesh are technological knowledge gap, uncertainty of feed materials, and financial insufficiency. Although theGovernment of Bangladesh is financing domestic biogas digester through some organization, it has no specific policy regarding the commercialization of bio-CNG production from biogas. The study assesses the scope and potentiality of bio-CNG production from biogas and its technology for automobile in Bangladesh.

2 Present Status of TransportationFuels in Bangladesh

2.1. Petroleum Products. Petroleum products are the most usable liquid fuels which are derived from crude oil processingin oil refineries.Themajority of crude oil is converted into petroleum products, which include several classes of fuels [12].Petroleum fuel mainly contains kerosene, diesel, and petrol and is considered as the major sources of commercial energy in Bangladesh. The transportation sector is the primaryconsumer of petroleum fuels which accounts for about 46.46% of total consumption 5,321,423 tons as illustrated in Figure 1. In the fiscal year 2014-2015, transportation sector consumes approximately 2,472,486 tons of petroleum oilwhich is almost two times the consumption of power sector [13]. On the other hand, among the petroleum products, high speed diesel accounts for almost 63.82%of total consumption of which nearly 52.25% is consumed by vehicle. In fiscal year 2014-2015, Eastern refinery limited has produced about 386,449 tons of high speed diesel and 245,341 tons of superior kerosene oil. In addition to this, in the year 2014-2015, the country has imported about 5,398,789.20 tons of petroleum oil including crude oil and lube base oil of total cost of BDT 27,023.27 crores.

2.2. Compressed Natural Gas (CNG). Compressed natural gas is produced by compressing the natural gas under a pressure between 21–25 kPa. CNGis a better eco-friendly fuel compared to gasoline/diesel; hence, its use as an alternative option in replacement of gasolineor diesel to runautomobiles has attracted much more attention over the world. The use of CNG in vehicles mitigates the emission of nitrous oxide, hydrocarbons, carbonmonoxide, and carbon dioxide by 40%, 90%, 80%, and 25%, respectively, compared to petrol or diesel fuel [14].The need for CNG as vehicle fuel is growing very fast because of its low price and higher octane number (130) compared to petrol (93) indicating the high thermal efficiency and lowemissions. In Bangladesh,CNGas a vehicle fuel was introduced around 1985. The CNG run vehicles are consuming about 100.43 million cubic meters of gas per month. The demand of

natural gas for CNG in next 5 years will be nearly 110–127 million cubic meters [15]. On the other hand, the share of natural gas in power generation is increasing hastily. Therefore, due to lack of natural gas
production, poor gas transmission, and network distribution in Bangladesh, almost 39 districts have not previewed CNG opportunities yet. Hence, to reduce the rapid depletion of natural gas, it is necessary to give emphasis for production of CNG from alternative sources.

2.3. Liquefied Petroleum Gas (LPG). Liquefied petroleum gas
(LPG) is a blend of propane (C3H8) and butane (C4H8)which is produced during the processing of natural gas and is sold in cylinder. It becomes liquid at atmospheric temperature when compressed to

a pressure between 80 and 110 psi and returns into gases when the pressure is reduced adequately. The colorless and odorless LPG is easy to transport and store in liquid state and used as fuel in domestic cooking and commercial uses in the regions of insufficient pipeline. In addition to these, LPG is suitable for medium and small vehicles. Therefore, in Bangladesh, the annual demand for LPG is increasing hastily. However, the supply of LPG was only about 121 thousand tons against a demand of 500 thousand tons in year 2012 [16]. The sources of LPG in Bangladesh are presented in Table 1. Hence, the country has to import LPG to reduce the gap between demand and supply.The government has already taken initiatives to install import-based LPG storage and bottling plant in Mongla, Bagerhat, and in Chittagong [17]. In fiscal year 2014-2015, Eastern refinery limited has produced about 11,070 tons of LPG against the total consumption of 17,424 tons.

2.4. Liquefied Natural Gas (LNG). Liquefied natural gas (LNG) is produced from natural gas by condensing it artificially
belowa temperature of −162◦Cand is stored inveryhigh pressure storage tank. LNG is mainly applicable as vehicle
fuel for heavy duty transports.The storage and transportation system of LNG includes floating storage and regasification unit, subsea and overland gas pipelines to transport the gas from floating terminal to the consumers. To make LNG operation economically viable, Bangladesh has to dedicate at least 0.17 Trillion cubic meters gas with an investment cost of USD 6 billion. However, considering the present gas reserve in the country, it is necessary to give emphasis on alternative option immediately. Therefore, Bangladesh has already signed an agreement with Qatar for importing about 14.16 MMCM gas in the form of LNG to meet the country's increasing demand for LNG. However, the matter of concern is that whether the country can afford the costly LNG. Bangladesh has very limited transportation facilities as LNG storage and transportation require high draught. Hence, the country has set a plan to install LNG vessel at approximately 5-6 km offshore of Moheshkhali coast because of availability of required draught. The initial plan is to supply about 4 million tons of LNG annually. Global LNG production is expected to be 450million tons in 2020 [18]. *2.5. Biodiesel.* Biodiesel is nonpetroleum oil generally produced from vegetable oil, animal fats, waste cooking oil, and so forth and used as renewable source in replacement of diesel because of its nontoxicity and environmental sustainability compared to diesel [19–21]. Transesterification is the chemical process to produce biodiesel by using basecatalyst, acid catalyst, enzyme catalyst, and heterogeneously catalyst. Bangladesh has promising potential of edible (mustered, cottonseed, ground nut, sesame, rapeseed, sunflower, coconut, and soybean oil) oil and nonedible (jatropha curcas, karanja, castor, neem, and algae) oil crops for biodiesel feed stocks [22]. However, nonedible vegetable oil is the most suitable for biodiesel production in Bangladesh due to the food scarcity and lack of available land for oil crops production. On the contrary, the country has many unused marginal, road, and rail side land areas which can be used for commercial biodiesel plants. Therefore, it is possible to produce about 0.52 million tons of karanja biodiesel per year utilizing this unused land which reduce country's total diesel import approximately by 21.67% [23]. On the other hand, almost 1.19 million tons of Jatropha curcas, 0.15 million tons of castor, and 1.04 million tons of pithraj can be produced annually by considering the 50% use of the available land in
Bangladesh [24]. However, there is no biodiesel generation plant in Bangladesh yet.

3 Biogas to Automobile Fuels

3.1. Bio-CNG. Bio-CNG, a methane rich compressed fuel, is also known as compressed biomethane. Bio-CNG is produced from pure biogas containing more than 97% methane at a pressure of 20–25MPa. It is very similar to the regular CNG in terms of its fuel properties, economy, engine performance, and emissions. Like regular CNG, bio-CNG has high octane number which results in the high thermal efficiency. The performance of a constant speed internal combustion engine using CNG and bio-CNG was compared and it was noted that their engine performances were almost similar in terms of brake

power output, specific gas consumption, and thermal efficiency [25]. A typical bio-CNG station comprises a biogas purification unit, a multistage compressor, and a high pressure storage system [26]. Because of the shorter driving range of bio-CNG compared to diesel fuel, the consumers have to install additional fuel cylinders to extend their driving range [27]. Bio-CNG can be injected into the CNG grid and blended with CNG. However, if the current CNG grid is inadequate, bio-CNG can be transported by trucks or in cylinder from the locations of production to the filling stations. From the literature, bio-CNG delivers greater environmental benefits than other traditional vehicle fuels as well as biodiesel and bioethanol [28–30]. Considering both technical and financial performance production of bio-CNG for vehicle fuel is at least feasible as it is produced fromrenewable wastes [31]. Therefore, the huge potentiality of different wastes in Bangladesh can make bio-CNG production a viable option. *3.2. Liquefied Biogas (LBG).* Biomethane from biogas can be liquefied to a fuel called liquefied biomethane (LBM) or LBG which has the similar characteristics to LNG. The conversion of LBM frombiomethane requires a combination of high pressures and low temperatures and is a rather energy intensive process. LBM has the energy content of about 70% that of gasoline and can be used as a vehicle fuel in replacement of conventional vehicle fuel. Commonly

Table 2: Bioenergy potential in Bangladesh, 2012-2013 [40].

Biomass resources	Biomass generation (million tons)	Energy content (KJ)	Dry biomass recovery (million tons)
Agricultural residues	94.10	36.48	582.33
Animal manure	72.81	26.20	363.30
Poultry excreta	10.70 2.	68	36.12
Human excreta	5.38	5.38	56.99
MSW	13.38	5.15	95.61
Forest residues	17.44	14.32	210.64
Total	213.81	90.21	1344.99

used LBGproductionmethods include cryogenic technology, liquefaction, and pressure letdown.During the liquefaction of biogas even a small amount of impurity can cause substantial difficulties and presence of oxygen can also cause danger of explosions. Therefore, biogas has to contain less than 25 ppm, 4ppm, and 1 ppm of CO2, H2S, and H2O, respectively, to produce liquefied biomethane [32]. Ignoring the energy input for liquefaction, it has been estimated that 1,000 cubic feet of gas yield about 10 gallons of LBM. On the other hand, assuming 10% losses, a plant producing about 70,000 cubic feet of biogas per day can generate approximately 500 gallons of LBG per day [33]. There is not much practical experience with this option because of its high capital and operating cost of liquefaction equipment though it has a much higher energy density in comparison to bio-CNG. Bangladesh needs to import the technology from Germany/ Sweden for production of LBG from biogas available in the country. *3.3. Syngas.* Syngas is a mixture of fuel gases which mainly contains hydrogen, carbon monoxide, and a small amount of carbon dioxide. Carbon containing fuels are the major sources of syngas generally produced by gasification process. Syngas can be produced from pure biogas through any of the three reforming process, for example, dry reforming, steam reforming, and partial oxidative reforming or any combination of these processes [34]. Steam reforming can produce high purity hydrogen as clean vehicle fuel commercially [35]. Dry reforming and steam reforming are endothermic process, while partial oxidative reforming is an exothermic process. In addition to this,

syngas can be converted into methanol and dimethyl ether and further upgraded into transport fuel like diesel, jet fuel, gasoline, and so forth through Fischer–Tropsch synthesismethod [26].The calorific value of the syngas varies depending on the use of agent for gasification process. However, the use of oxygen or steam can increase the calorific value of syngas. *3.4. Biomethanol/Biogasoline.* Gasoline is produced by upgrading methanol through methanol-to-gasoline (MTG) process. In recent years, the attention has been increased for biomethanol production from biogas through partial oxidation of methane, photocatalytic conversion, biological conversion, and biogas reforming to syngas and hence to methanol via FTS method [36]. Partial oxidation of methane is most attractive and commonly used technology for biomethanol. It has been estimated that biomethanol can mitigate greenhouse gas emissions by 25–40% compared to methanol produced from fossil fuels. In the year 2012, global biomethanol production was about 0.2 million tons and expected to be more than 1 million tons in the next few years [8]. Biomethanol is converted into aromatic hydrocarbon known as biogasoline by two steps of exothermic MTG process [37]. Biogasoline has almost twice the energy content of that of biomethanol and has higher vapor pressure compared to biomethanol. Biogasoline or blending of biogasoline and biomethanol can be directly used as transport fuel in vehicle.

4. Prospective Analysis of Bio-CNG in Bangladesh

4.1. Potential of Biogas in Bangladesh. Biogas is a nonfossil, colorless, combustible gas containing about 40–70% methane. Biogas is produced by anaerobic digestion with anaerobic bacteria or fermentation of biodegradable materials such as manure, municipal waste and sewage, green waste, plant material, and crops [38, 39]. The biogas has combustion properties like natural gas as it burns at about 800∘C with an ignition temperature of 650–750∘C compared to 1000∘C for natural gas [4, 17]. To cope with the present world, Bangladesh is going very fast by using biogas technology to produce biogas. Bangladesh has huge potential of biodegradable biomass resources including agricultural residues, animal manure, municipal solid waste, and human excreta to produce biogas. In the year 2012-2013, the country had almost 23.241 million cattle, 25.212 million goat, 246.60 million chicken, and 46.635 million duck [40]. These large numbers of livestock can produce huge amount of biomass residues. Additionally, field residues and process residues fromagriculture are another promising candidate for biomass generation. It has been estimated that one ton of cattle excreta, sheep and goat excreta, poultry excreta, human excreta, crop residue, and organic fraction of MSW can generate almost 33m3, 58m3, 78m3, 50m3, 60m3, and 66m3 of biogas, respectively [41–44]. Taking into account the above biogas generation rate, it has been calculated that the country had about 213.81million tons of biomass generation potential (Table 2) in the fiscal year 2012-2013 which could produce nearly 7.6775 billionm3 biogas. If only cow dung is brought under biogas production plant, then it could be possible to produce about 2.54 billionm3 of biogas in 2012-2013 which is equivalent to 1.455

Table 3: Plant based daily biogas production data in Bangladesh [47].

Plant size (daily gas production), m3	Operation hours per day	Cow dung, Kg	Poultry stool, Kg Construction cost, (BDT
1.6	3-4	43	23 26000
2.0	4-5	54	28 32000
2.4	5-6	65	34 36000
3.2	7-8	87	35 43000
4.8	10–12	139	68 52000
0.0			

billion liters of diesel. On the other hand, poultry feces had the potential to produce approximately 0.749 billionm3 of
biogas in 2012-2013 as presented in Figure 2. However, if 50% of the total biomass is considered for biogas generation, then it is possible to generate almost 3.83875 billionm3 of biogas which is equivalent to 2.20 billion diesel fuel. In Bangladesh, most of the biogas plants constructed are fixed dome type biogas plant based on cow dung and poultry litter of capacity between 1.6 and 4.8m3 as depicted in Table 3. Up to October 2014, almost 79,612 domestic biogas plants have been constructed by technical and financial assistance of various government and nongovernment organizations [45]. However, the country has a potential of 4 million small-scale biogas digesters. In Bangladesh, first commercial biogas plant was constructed by Paragon Poultry Ltd. inMymensingh and Gazipur in 2010 which are producing 38.23 cubic feet and 76.46 cubic feet of biogas, respectively [46]. In addition to these, IDCOL has financed 8 biogas based power plants using poultry litters for gas production. Recently, Bangladesh has about 215,000 poultry farms and 15,000 cattle farms which may be an excellent source for biogas.

4.2. Biogas to Bio-CNG Conversion Technology/Process. Biogas produced from anaerobic digestion of biodegradable
biomass contains significant amount of impurities like water, N2, O2, H2S, NH3, and CO2 and so forth. Therefore, biogas has to be purified prior to the conversion into bio CNG.Generally, pressurized water scrubbing, pressure swing
adsorption, chemical absorption, membrane permeation, temperature swing adsorption, cryogenic approach, physical
absorption, and biological filtration methods are used to purify the biogas before conversion [48]. However, pressurized water scrubbing is the most commonly used method as it offers several advantages and higher percentages of CH4 purity compared to the other purifyingmethods [49]. Table 4 presents the process description of some common biogas cleaning methods. In context of Bangladesh, water scrubbing and membrane separation technology are the most feasible technology for biogas upgradation based on the technical availability and maintenance costs. Cleaned biogas containing more than 97% CH4 and less than 2% O2 is considered for production of bio-CNG. Generally, two approaches named physical (compression and liquefaction) and chemical approach (catalytic reforming and Fischer–Tropsch synthesis) are applied for this conversion. Pure biogas then undergoes a high compression pressure between 20 and 25MPa (Figure 3) and converts into bio- CNG which occupies less than 1% of its normal volume. It is required to store bio-CNG as it affects vehicle filling time, filling completeness, and energy consumption [53]. Typically, two storage systems such as buffer storage and cascade storage are used infilling station.The buffer storage system the pressure of CNG in the range of 20–25MPa and provides CNG with a maximum pressure of 20MPa to a vehicle's onboard cylinders. In this case, all filling station reservoirs are connected and maintained at the same pressure [27]. On the contrary, the cascade storage system contains three reservoirs of low, medium, and high pressure and provides CNG in three steps to vehicle's on-board cylinders. In this case, the vehicle's cylinders are connected to the low pressure reservoir firstly and then to the medium pressure reservoir when the pressure is increased into the cylinder and finally to the high pressure reservoir for completing the filling process. In comparison with the cascade reservoir, the buffer reservoir offers fast filling and charges 80% more gas [54].

4.3. Bio-CNG Vehicle Technology. Bio-CNG technology consists of the refueling station and vehicle technology. Bio-
CNG refueling station is much more complicated than the conventional diesel/petrol refueling station as all the components of bio-CNG vehicles and the refueling station are required to be maintained at a high pressure. On the
other hand, slow filling refueling station is simpler than the fast filling refueling station which normally provides

fuel overnight. Both the petrol (spark ignition) engine and diesel (compression ignition) engine driven vehicle can be converted to bio-CNG driven vehicle by the modification of some features through retrofitting. It offers the advantage of switching the option of using bio-CNG or conventional fuel. Figure 4 illustrates the process pathways of bio-CNG production and vehicle fueling in refueling station. In this case, a new fuel tank with a regulator, fuel lines, and new secondary injector are required to convert conventional fuel vehicle to bio-CNG vehicle. The regulator reduces tank pressure from 3,600 psi to 125 psi and the secondary injectoinjects the bio-CNG into the cylinder through fuel lines for combustion to produce energy.

4.4. Possibility of Bio-CNG in Bangladesh. Recently, in Bangladesh the consumption of CNG as transportation fuel and the number of CNG based vehicles are growing very fast because of its low cost and environmental sustainability. Figure 5 shows the cumulative growth of CNG vehicles including the number of converted CNG vehicles and the number of exported CNG vehicles.However, this high rate of consumption causes the threat for future reserve and forces us to harness the renewable and environmental friendly options for automobile fuel. It is obvious that some countries such as Germany, Austria, and the United States have proved that bio-CNG can take the place of fossil fuels as transportation fuel.However, in Bangladesh there are not so many industrial plants for biogas purification and bio-CNGproduction. Only, Effat BioCNG Limited has developed a technology based on water scrubbing for purifying the biogas by removing carbon dioxide and hydrogen sulphide and for producing bio-CNG with less than 2% methane loss. In the fiscal year 2012-2013, total biogas (7.6775 billionm3) available in the country could produce about 3.4549 billion kg (1m3 biogas = 0.45 kg bio-CNG) bio-CNG which is equivalent to 5.088 billionm3 (ρbio-CNG = 0.679 kg/m3) of bio- CNG. Figure 6 shows the amount of bio-CNGproduced from different biomass wastes. It is estimated that 1 liter of octane is equivalent to 0.81m3 of bio-CNG, 1 liter of petrol is equivalent to 0.80m3 of bio-CNG, and 1 liter of diesel is equivalent to 0.97m3 of bio-CNG. Accordingly, total bio-CNG potential in Bangladesh is equivalent to 5.25 billion liters of diesel, 6.36 billion liters of petrol, and 6.28 billion liters of octane. Therefore, Bangladesh shows the huge potentiality of bio- CNG production for alternative vehicle fuel. Sufficient feed material is the prerequisite for the continuous production of bio-CNG. It is difficult to collect feed materials from villages because of its high transportation cost. On the other hand, the sixmunicipalities in Bangladesh produce about 7690 tons [60] of waste per day which can be available to generate fuel for vehicle running in the municipality. It has been estimated that the organicmunicipal solid waste available only in Dhaka can produce almost 41,830m3 per day of biogas equivalent to 27,721.4m3 of bio-CNG. Furthermore, the rate of migration of people to municipality is increasing very fast which can increase the quantity of organic waste as well. In addition, the inclusion of human manure for biogas production can be also a secure feed material in long run of bio-CNG plant in the municipality.

5. Competitive Analysis of Bio-CNG as Transportation Fuel

The feasibility of biogas conversion into bio-CNG as transportation fuel primarily depends on some key factors such as economic, technical, environmental, and safety. Fuel properties of bio-CNG are nearly the same as regular CNG and also competitive compared to the other automobile fuels such as diesel and petrol. The percentage of methane (>97%) in bio- CNG is higher than that of natural gas (93%) produced from different gas fields in Bangladesh. Besides this, the calorific value of bio-CNG is about 52 MJ/kg which is higher than the calorific value of petrol (48 MJ/kg) and diesel (44.8 MJ/kg) as revealed in Table 5. The amount of energy cost in kJ/BDT is almost 3.5 times that of petrol and 2.25 times of diesel. Furthermore, in Bangladesh the cost of petrol and diesel fuel is significantly high as about BDT 96 per liter and BDT 68 per liter for petrol and diesel, respectively. On the other hand, the price of CNG and bio-CNG is approximately BDT 30 per m3 and BDT 14.22 per m3, respectively [13, 15, 61, 62]. Considering the equivalent ratio of bio-CNG to other transportation fuels, the use of 1 liter of bio-CNG as automobile fuel in replacement of 1 liter of petrol and 1 liter of diesel can save about BDT 84.62 and BDT 54.20, respectively. Additionally, bio-CNG contains negligible amount of impurities including less than 4% CO_2 and 8 ppm H_2S with no other impurities which are much lower than diesel and petrol fuel and responsible for up to 90% emission reduction compared to the conventional transportation fuel. Germany, Netherland, and Sweden are the most biomethane producing countries in the world. Sweden can be a role model for Bangladesh as the country is using 97% of bio-CNG for vehicle fuel, while Germany is using 1.4% of total bio-CNG successfully. Therefore, it is clearly depicted that bio-CNG is a rising candidate for automobile fuel. Although bio-CNG has several advantages over the conventional vehicle fuel, it has number of disadvantages. Because of decentralized feed material availability, the production cost of bio-CNG can be very high nowadays .Additionally, the lack of awareness about the suitability of bio-CNG over the other fuels hinders the support from the government as well as the other investors.

6. Issues and Challenges of Bio-CNG Technology in Bangladesh

It is well evident that the use of bio-CNG as automobile fuel provides significant benefits in economic, emissions, and engine performance perspective.However, the successful implementation of this technology in developing country like Bangladesh is a great challenge. Requirement of sufficient amount of feed materials, upgradation of equipment and the cost, lack of technically sound man power, and refueling infrastructure are considered the significant barriers to the deployment of bio-CNG as vehicle fuel. Typically, a bio-CNG plant requires a biogas unit, purification unit, compression unit, and storage unit with other accessories maintained at high pressure. Lack of technology standardization is themain stumbling block for production of cost efficient renewable bio-CNG. Although Bangladesh has huge potential of biogas generation resources, there is insufficiency of industrial scale biogas plants with high level of automation to produce bio- CNG because of its high investment cost and lack of standard technology. In addition to this, almost 75% of totalmunicipal waste in Bangladesh are unused and go for landfilling because of lack of proper technical knowledge and sufficient human resources to produce useful energy like bio-CNG. Besides this, in Bangladesh there are no specific guidelines and rules for renewable energy use. Additionally, there is no inclusion of legal, regulatory, and policy framework for bio-CNG conversion from waste in country's national energy policy.

CHAPTER-3

MATERIALS AND METHODOLOGY

Ward-wise Map Of Kolkata City:

Segregation at Source :-

- Source segregation in 7 wards : Wardno33, 47 , 64,103,110,115, and 130 .
- This system is in operation since March 2010
- House hold and population covered (Table 3).
- After collecting the segregated Municipal Solid Waste (MSW), bio-degradable wastes are transported to disposal site for composting and recyclable MSW are sent to recycling unit.
- Apart from that source segregation in another 20 wards will shortly be introduced for more effective management of solid waste.

Table 3

Ward no.	Number of household	Total Population as per Census 2011
33	11095	45919
47	3271	14684
64	6342	31280
103	7105	25428
110	7628	27470
115	8461	31919
130	6150	23227

Some photos in source segregation activities are shown below :

Primary Collection :-

A) Primary Collection

- Door to Door collection : 100 % in144 wards.
- Manpower engaged : 10,000
- Equipment used for primary collection ;
- Equipment used for primary collection ;
  - Hand Cart
  - Tricycle
  - Battery Operated Hydraulic Dumper
  - Auto tipper (2 cum capacity)
- Equipment used for street sweeping : Mainly in major roads, lanes. By - lanes manpower is used for sweeping and in high speed roads mechanical sweepers are used .
- To improve the air quality in traffic congested areas some street watering and washing vehicles are also used.

A) Storage - mini Transfer Station :

- Before 2010, MSW were stored in open storage points , container points, pay - loader operated vat point.
- Afterwards open storage points are gradually replaced by Modern Scientific Waste Compactor stations (Mini Transfer Stations) and Movable Compactors to comply the rule of SWM Rule 2000 & 2016.
- At present 85 numbers of Modern Scientific Waste Compactor station are in use and another 50 nos. of Mini Transfer Stations are in pipeline.
- 11,500 nos. 240 liter trash bins are placed on streets, footpaths etc. for the use of pedestrians, shop owners to avoid littering.

Primary collection of waste is the second essential step of Solid Waste Management activity. Primary collection system is necessary to ensure that waste stored at source is collected regularly and it is not disposed of on the streets, drains, water bodies, etc. However, step has to synchronize well with the first step i.e. Storage of Waste at source.

ARRANGEMENTS TO BE MADE FOR PRIMARY COLLECTION:

For the primary collection of waste stored at various sources of waste generation by any of the following methods or combination of more than one method: · Doorstep collection of waste through containerized handcarts/tricycles or other similar means with active community participation

·doorstep collection of waste through motorised vehicles having nonconventional/sounding horns deployed for doorstep waste collection with active community participation. ·

Collection through community bins from private societies multi-storied buildings, commercial complexes, ·

Doorstep or lane-wise collection of waste from authorised/unauthorised slums or collection from the community bins to be provided in the slums by local bodies

TOOLS & EQUIPMENT:

Hand Carts

The use of traditional hand carts should be discontinued and instead, hand carts having 4 to 6 detachable containers of capacity ranging from 30-40 litres i.e. 0.03 to 0.04 cu.m each should be used as shown in Fig.10.3. The containers should be of sturdy material preferably strong polyethylene/plastic with a handle on the top and rim at the bottom for easy handling of the container. The handcarts should have preferably three wheels and sealed ball bearing. There should be locking arrangement with a chain and a lock. The design and specifications of the handcart and the containers

Tricycles

Tri-cycles instead of handcarts in the areas which are spread out, and distances are long. The tricycles could have eight containers of 0.04 cu.m. (40 litres) capacity each These containers should also be detachable from the tricycle and should have a locking arrangement.

Community Bin Carrier

A community bin carrier having a capacity to carry 40 containers (bins) in a two tier arrangement may be used to pick up community bins from residential areas and slums in the cities and towns where direct transfer of waste into the hand carts or tricycles is not found suitable. These vehicles with two member crew should pick up filled community bins and replace empty ones and take the vehicle, when 40 filled containers are picked up, to the nearest temporary waste storage depot (large container for transfer of waste)

METHODS OF PRIMARY COLLECTION OF WASTE

1 Door Step Collection through Containerized Handcarts

A bell may be affixed to the handcart given to the sweeper or a whistle may be provided to the sweeper in lieu of a bell. Each sweeper may be given a fixed area or beat for sweeping plus a fixed number or stretch of houses for collection of waste. The local bodies may, based on local conditions, fix the work norms as they deem appropriate. It is suggested that in congested or thickly populated areas, 250 to 350 running metres (RMT) of road length and the adjoining houses may be given to each sweeper, whereas in less congested areas 400 to 600 running metres of the road length with adjoining houses may be allotted to a sweeper depending upon the density of population in the given area and local conditions. In low- 193 density areas even 650 to 750 running metres of road length and houses can be given. Normally 150 to 250 houses coupled with the above road length may be taken as a yardstick for allotment of work to an individual sweeper.

2 Role of Sweeper

The sweeper should ring the bell or blow the whistle indicating his arrival at the place of his work and start sweeping the street. The people may be directed through adequate publicity campaign that on hearing the bell or whistle they should deposit their domestic biodegradable waste into the handcart of the sweeper or hand over the waste to him/her. At places where it is not convenient for the householder to deposit the waste in the handcart/tricycle, on account of their non-availability at home when sweeper arrives in their areas, they may leave the domestic waste in domestic bins or bags just outside their houses on the street in the morning so as to enable the sweepers to pick up the waste and put it into the handcart. No sweeper may be expected or directed to do house-to-house collection by asking for waste at the doorsteps, as this will affect his energy and productivity.

Collection through Motorised Vehicles

An alternative to doorstep collection through containerised handcarts may deploy motorised vehicles having unconventional/sounding horn for doorstep collection of waste. Driver of the vehicle should intermittently blow the horn announcing his arrival in different residential localities and on hearing this, the householders should deposit their domestic waste directly into such vehicle without loss of time.

Transportation :-

- On an average 380 nos. of vehicles are used for transportation of MSW throughout the city of Kolkata .
- 54 nos. of Hook Loaders are used for lifting of compactor containers (10.5 cum) from different compactors stations.
- 80 nos. of Movable compactors are in use for transpiration of MSW throughout the city of Kolkata and it also helps for odourless spillage free transportations .
- On an average 250nos. of hired vehicles (covered) are engaged for transportation of waste including silt / rubbish/ tree branches etc.
- There are 10 numbers Garages under SWM department used for maintenance used of conservancy vehicles like Dumper Placers, Tipper Trucks, Movable Compactors, Hook Loaders for transporting Portable Compactors, Street Washing Vehicles, Mechanical Sweepers, Pay loader, Bull Dozers, Bio-Shredding Machines, Tractor trailers , cess pool emptier . These are deployed regularly for different activates including sprinkling of water to reduce air pollution around the city to keep it clean and safe.

Treatment & Disposal :-

A) Treatment

I. Compost Plant

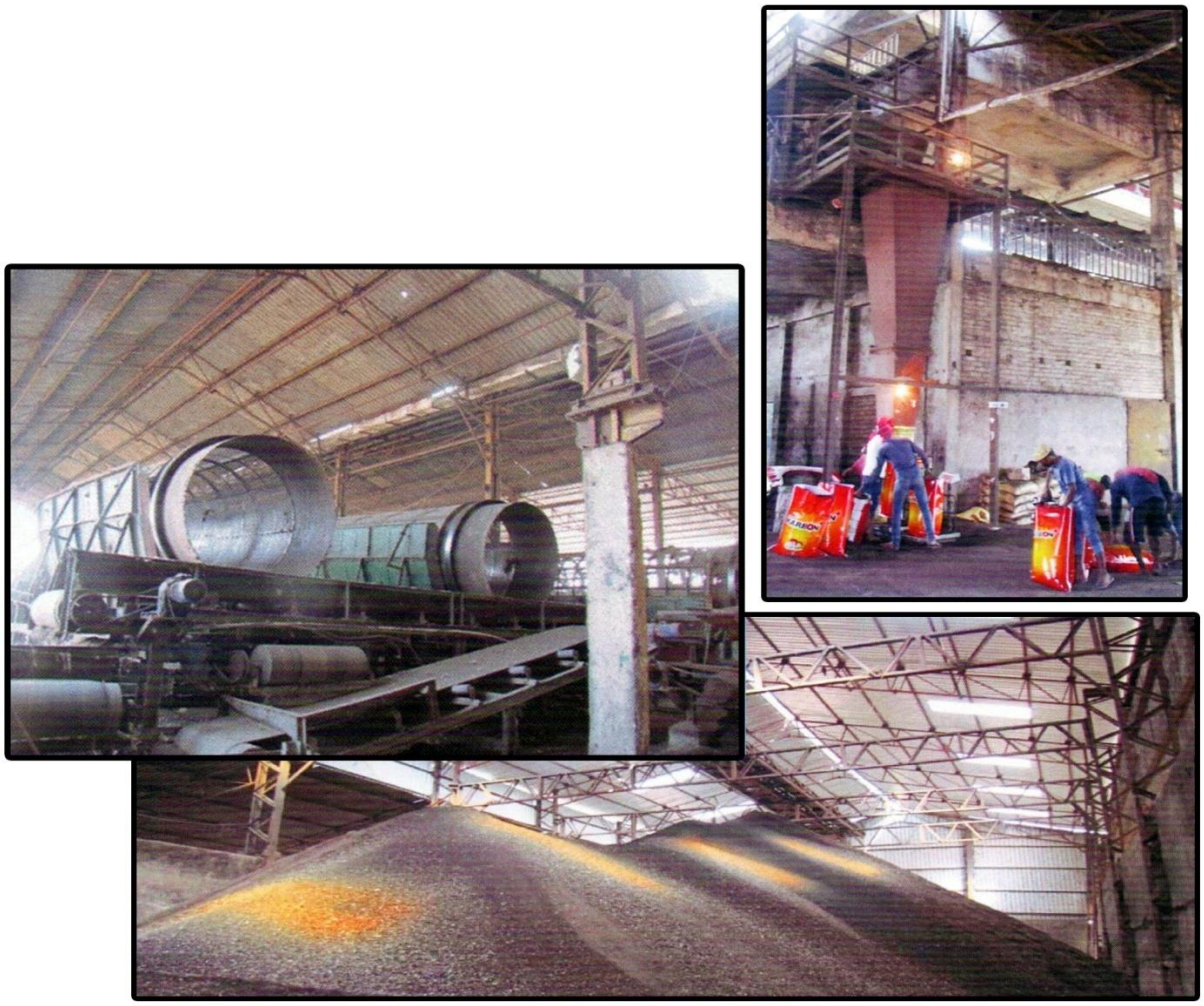
- Capacity of Compost plant : 500 MT per day
- Area used : 23 acre
- Location : Dhopa Disposal Site 9 wars -57, Br-VII)
- Mode of Operation :PPP model
- Operating agency : M/s Eastern Organic Fertilizer Pvt. Ltd.
- Method used for processing of compost : Window method.

II. Organic Composter

As pilot project, installation of 3 nos. Organic Composter of 1 ton capacity in pipeline.

III. Bio -CNG

A pilot project has been taken up for the conversion of organic market waste into Bio-CNG-CO2 and compost by processing 5M.T. market waste daily at Dhapa.



B) Disposal System

Location of disposal site :

Dhapa

- Dhapa is situated in the Eastern side of Kolkata, (ward-57 under Br-VII)
- Active area : 35 hectare (almost saturated)
- Dhapa disposal site is faced with proper gate to monitor incoming vehicles or other modes of transportation.
- Approach and other important roads for free of vehicles and other machineries exist at the landfill site.
- Landfill site has waste inspection facilities to monitor waste brought in for landfill, office facilities for record keeping and shelter for keeping equipment and machineries.
- Weigh Bridge: 5 nos. weigh Bridges are in operation to measure quantity of waste brought at landfill site.
- Utilities such as drinking water and lighting arrangements exist for easy landfill operations when carried out in night hours.
- Periodical health inspections of workers are done by the Health department of KMC
- The Dhapa Check Post is under 24 hrs surveillance with CCTV system.
- There is a Central Post is under system, which stores all the data regarding the gross and empty weight of all the different vehicles entering the Dhgapa disposal site for unloading the MSW.

- Washing Bay : 2 nos. of Washing Bay have been installed at Dhapa Chck Post area . The different vehicles entering the Dhapa disposal site for unloading the MSW gets diary by the mud mainly during the monsoons which are being washed in the Washing Bays.
- Street watering : To avoid air pollution street watering is done at the road around the disposal site.
- Infrastructure development : For rendering smooth disposal of MSW the roads are developed and maintained regularly by the inert and C & D waste coming to the disposal site.
- Bull dozers : 3nos. of bull dozers are used for dressing and leveling of MSW coming to the disposal site.

Remediation Project at Dhapa :-

Remediation project at Dhapa : Post closure care of existing landfill site (12.14 hectare) is nearing completion which includes .

- Maintaining the integrity and effectiveness of final cover, making repairs and preventing run- on and run- off from eroding or otherwise damaging the final cover.
- Monitoring leachate collection system in according with the requirement
- Monitoring of ground water in accordance with requirements and maintaining ground water quality .

Implementing agency : West Bengal Pollution Control Board under financial assistance of World Bank.

Ongoing Project : :-

- Strengthening Primary and Secondary Solid Waste Management System in Kolkata City.

  Description : Construction of Compactor Station, Purchase of Movable Compactor, Purchase of 4.5 cum, Capacity Container, Purchase of 1100 litre capacity Bin, Purchase of Portable Compactor, Purchase of Hook Loaders, Purchase of Auto Ti-ppers etc.
- Modernization of Solid Waste Management in in Ward 77 under KMC

  Description : Construction of Compactor Station, Battery operated Hydraulic, Procurement of 10 liter capacity bins, Procurement of 240 liter capacity bins, Street Washing, Bio shredding machine etc.
- Conversion of Organic Market Waste in Bio- CNG, Bio- CO_2, and Compost

  Description : Development of Civil Infrastructures like construction of boundary wall, shed, concrete platform, concrete road, pathways, drains-culverts, etc for Installation of Bio - CNG Plant with machinery equipment and electrical arrangement.

Future Plan :-

KEIIP of KMC has been entrusted to prepare the master plan and integrated Solid Waste management facilities for the city of Kolkata under financial assistance of ADB .

COMPOSTING

The organic content of Municipal Solid Waste (MSW) tends to decompose leading to various smell and odour problems. It also leads to pollution of the environment. To ensure a safe disposal of the MSW it is desirable to reduce its pollution potential and several processing methods are proposed for this purpose. Composting process is quite commonly used and results in production of a stable product - compost which depending upon its quality can be used as a low grade manure and soil conditioner. The process results in conservation of natural resources and is an important processing method, especially in agricultural and horticultural areas. In the case of individual households, small establishments and colonies, vermi-composting which involves the stabilisation of organic solid waste through earthworm consumption for conversion of the organic material to worm casting is being increasingly preferred.

PRINCIPLES OF COMPOSTING – MANUAL AND MECHANISED METHODSS

Decomposition and stabilisation of organic waste matter is a natural phenomenon. Composting is an organised method of producing compost manure by adopting this natural phenomenon. Compost is particularly useful as an organic manure which contains plant nutrients (Nitrogen, Phosphorous and Potassium) as well as micro nutrients which can be utilized for the growth of plants (Gotaas 1956). When used in conjunction with chemical fertilisers optimum results are obtained. Composting can be carried out in two ways i.e., aerobically and anaerobically. During aerobic composting aerobic micro-organisms oxidise organic compounds to Carbon di oxide, Nitrite and Nitrate. Carbon from organic compounds is used as a source of energy while nitrogen is recycled. Due to exothermic reaction, temperature of the mass rises. During anaerobic process, the 244 anaerobic micro organisms, while metabolising the nutrients, break down the organic compounds through a process of reduction. A very small amount of energy is released during the process and the temperature of composting mass does not rise much. The gases evolved are mainly Methane and Carbon di oxide. An anaerobic process is a reduction process and the final product is subjected to some minor oxidation when applied to land.

FACTORS AFFECTING THE COMPOSTING PROCESS

Organisms

Aerobic composting is a dynamic system wherein bacteria, actinomycetes, fungi and other biological forms are actively involved. The relative preponderance of one species over another depends upon the constantly changing food supply, temperature and substrate conditions. Facultative and obligate forms of bacteria, actinomycetes and fungi are most active in this process. In the initial stages mesophilic forms predominate and thermophilic bacteria and fungi soon take over except in the final stage of composting. Except when the temperature drops, actinomycetes and fungi are confined to 5 to 15 cm outer surface layer. If the turning is not carried out frequently the actinomycetes and fungi in these layers register increased growth imparting it typical greyish white colour. Thermophilic actinomycetes and fungi are known to grow well in the range of 45 to 60o C. Different organisms are known to play predominant role in breaking down different constituents of municipal solid waste. Thermophilic bacteria are mainly responsible for the breakdown of proteins and other readily biodegradable organic matter. Fungi and actinomycetes play an important role in the decomposition of cellulose and lignin. The actinomycetes common in compost are Streptomyces sp. and Micromonospora sp. the latter being more prevalent. The common fungi in compost are

Thermonomyces sp., Penicillium dupontii and Asperigallus fumigatus. Majority of these organisms responsible for composting are already present in municipal solid waste. Not much information is available regarding the organisms active in anaerobic composting, though many of the organisms responsible for anaerobic decomposition of sewage sludge will be active here also, and differences are expected due to the concentration of nutrients present and the temperature condition

Use of Cultures

During the development of composting process various innovators came forward with inoculum, enzymes etc., claimed to hasten the composting process. Investigations carried out by various workers have shown that they are not necessary. The required forms of bacteria, actinomycetes and fungi are indigenous to MSW. Under proper environmental conditions the indigenous bacteria adapted to MSW rapidly multiply, as compared to the added cultures which are more attuned to controlled laboratory conditions and carry out decomposition. The process is dynamic and as any specific organism can survive over a specific range of environmental conditions, as one group starts diminishing, another group of organisms starts flourishing. Thus, in such a mixed system appropriate life forms develop and multiply to keep pace with the available nutrients and environmental conditions. Hence, addition of similar and extraneous organisms in the form of inoculum is unnecessary. However, such inoculum will be required during composting of industrial and agricultural solid waste which do not have the large mix of indigenous bacterial population.

Moisture

The moisture tends to occupy the free air space between the particles. Hence, when the moisture content is very high, anaerobic conditions set in. However, the composting mass should have a certain minimum moisture content in it for the organisms to survive. The optimum moisture content is known to be between 50 to 60 % . Higher moisture content may be required while composting straw and strong fibrous material which soften the fibre and fills the large pore spaces. Higher moisture content can also be used in mechanically aerated digesters. In anaerobic composting the moisture content used will depend upon the method of handling and whether it is carried out in the open or in closed container.

Temperature

The aerobic decomposition of a gram mole of glucose releases 484 to 674 kilo calories (kcal) energy under controlled conditions, while only 26 kcal are released when it is decomposed anaerobically. Municipal solid waste is known to have good insulation properties and hence the released heat results in increase in temperature of the decomposing mass. As some of the heat loss occurs from the exposed surface, the actual rise in temperature will be slightly less. When the decomposing mass is disturbed, as during turning of windrows, the resultant heat loss results in drop in temperatures. Under properly controlled conditions temperatures are known to rise beyond 70oC in aerobic composting. Under properly controlled conditions temperatures are known to rise beyond 70oC in 248 aerobic composting. During anaerobic composting as the released heat is quite small and as part of it is lost from the surface only a marginal rise in temperature occurs. This increased temperature results in increased rate of biological activity and hence results in faster stabilisation of the material. However, if the temperature rise is very high, due to inactivation of the organisms & enzymes the rate of activity may decrease. The studies carried out have shown that the activity of cellulose enzyme reduces above 70oC and the optimum temperature range for nitrification is 30o to 50oC beyond which nitrogen loss is known to occur. The temperature range of 50o to 60oC is thus optimum for nitrification and

cellulose degradation. The high temperature also helps in destruction of some common pathogens and parasites (Table 14.1). According to Scott, during aerobic composting when the material is turned twice in 12 days Entamoeba histolytica is killed and the eggs of Ascaris lumbricoides are killed in 36 days when turned thrice. The studies carried out at NEERI have shown that the destruction of these organisms is not ensured under anaerobic conditions. Knoll has proved that the high temperature and long retention during aerobic composting along with the antibiotic effect results in destruction of parasites and pathogens. Thus, if the process is so controlled that the temperature is kept between 50o to 60 o C for 5 to 7 days, destruction of pathogens and parasites can be ensured.

Carbon/Nitrogen (C/N) Ratio

The organisms involved in stabilisation of organic matter utilise about 30 parts of carbon for each part of nitrogen and hence an initial C/N ratio of 30 is most favourable for composting. Research workers have reported the optimum value to range between 26-31 depending upon other environmental conditions. The C/N ratio considers the available carbon as well as the available nitrogen while the available carbon and nitrogen in the MSW may vary from sample to sample. Whenever the C/N ratio is less than the optimum, carbon source such as straw, sawdust, paper are added while if the ratio is too high, the sewage sludge, slaughter house waste, blood etc. are added as a source of nitrogen.

Standards for Compost

Parameter	Maximum acceptable concentration parts per million (ppm)
Arsenic	20
Cadmium	20
Chromium	300
Copper	500
Lead	500
Mercury	10 1
Nickel	00
Zinc	2500

ENERGY RECOVERY FROM MUNICIPAL SOLID WASTE

Municipal Solid Waste (MSW) contains organic as well as inorganic matter. The latent energy present in its organic fraction can be recovered for gainful utilisation through adoption of suitable Waste Processing and Treatment technologies. The recovery of energy from wastes also offers a few additional benefits as follows: (i) The total quantity of waste gets reduced by nearly 60% to over 90%, depending upon the waste composition and the adopted technology; (ii) Demand for land, which is already scarce in cities, for landfilling is reduced; (iii) The cost of transportation of waste to far-away landfill sites also gets reduced proportionately; and (iv) Net reduction in environmental pollution. It is, therefore, only logical that, while every effort should be made in the first place to minimise generation of waste materials and to recycle and reuse them to the extent feasible, the option of Energy Recovery from Wastes be also duly examined. Wherever feasible, this option should be incorporated in the over-all scheme of Waste Management.

BASIC TECHNIQUES OF ENERGY RECOVERY

Energy can be recovered from the organic fraction of waste (biodegradable as well as non-biodegradable) basically through two methods as follows:

(i) Thermo-chemical conversion : This process entails thermal de-composition of organic matter to produce either heat energy or fuel oil or gas; and

(ii) Bio-chemical conversion: This process is based on enzymatic decomposition of organic matter by microbial action to produce methane gas or alcohol. The Thermo-chemical conversion processes are useful for wastes containing high percentage of organic non-biodegradable matter and low moisture content. 263 The main technological options under this category include Incineration and Pyrolysis/ Gasification. The bio-chemical conversion processes, on the other hand, are preferred for wastes having high percentage of organic bio-degradable (putrescible) matter and high level of moisture/ water content, which aids microbial activity. The main technological options under this category is Anaerobic Digestion, also referred to as Biomethanation.

Parameters affecting Energy Recovery:

The main parameters which determine the potential of Recovery of Energy from Wastes (including MSW), are: ·

Quantity of waste, and ·

Physical and chemical characteristics (quality) of the waste.

The actual production of energy will depend upon specific treatment process employed, the selection of which is also critically dependent upon (apart from certain other factors described below) the above two parameters. Accurate information on the same, including % variations thereof with time (daily/ seasonal) is, therefore, of utmost importance.

The important physical parameters requiring consideration include: ·

size of constituents

· density · moisture content

Smaller size of the constituents aids in faster decomposition of the waste. Wastes of the high density reflect a high proportion of biodegradable organic matter and moisture. Low density wastes, on the other hand, indicate a high proportion of paper, plastics and other combustibles. High moisture content causes biodegradable waste fractions to decompose more rapidly than in dry conditions. It also makes the waste rather unsuitable for thermo-chemical conversion (incineration, pyrolysis/ gasification) for energy recovery as heat must first be supplied to remove moisture.

The important chemical parameters to be considered for determining the energy recovery potential and the suitability of waste treatment through bio- 264 chemical or thermo-chemical conversion technologies include: - ·

Volatile Solids ·

Fixed Carbon content ·

Inerts, ·

Calorific Value ·

C/N ratio (Carbon/Nitrogen ratio) ·

Toxicity

The desirable range of important waste parameters for technical viability of energy recovery through different treatment routes is given in the Table 15.1. The parameter values indicated therein only denote the desirable requirements for adoption of particular waste treatment method and do not necessarily pertain to wastes generated / collected and delivered at the waste treatment facility. In most cases the waste may need to be suitably segregated/ processed/ mixed with suitable additives at site before actual treatment to make it more compatible with the specific treatment method. This has to be assessed and ensured before hand. For example, in case of Anaerobic digestion, if the C/N ratio is less, high carbon content wastes (straw, paper etc.) may be added; if it is high, high nitrogen content wastes (sewage sludge, slaughter house waste etc.) may be added, to bring the C/N ratio within the desirable range.

Desirable range of important waste parameters for technical viability of energy recovery:

Waste Treatment Method Desirable	Basic principle	Important Waste Parameters	Range*
Thermo-chemical conversion – Incineration	Decomposition of organic matter by action of heat.	Moisture content Organic/ Volatile matter	< 45 % > 40 %

- Pyrolysis – Gasification		Fixed Carbon Total Inerts Calorific Value (Net Calorific Value)	< 15 % < 35 % >1200 k-cal/kg
Bio-chemical conversion - Anaerobic Digestion/ Bio-methanation	Decomposition of organic matter by microbial action.	Moisture content Organic / Volatile matter C/N ratio	>50 % > 40 % 25-30

Assessment of Energy Recovery Potential

A rough assessment of the potential of recovery of energy from MSW through different treatment methods can be made from a knowledge of its calorific value and organic fraction, as under: In thermo-chemical conversion all of the organic matter, biodegradable as well as non-biodegradable, contributes to the energy output

Total waste quantity : W tonnes
Net Calorific Value : NCV k-cal/kg.
Energy recovery potential (kWh) = NCV x W x 1000/860 = 1.16 x NCV x W
Power generation potential (kW) = 1.16 x NCV x W/ 24 = 0.048 x NCV x W
Conversion Efficiency = 25%
Net power generation potential (kW) = 0.012 x NCV x W If NCV = 1200 k-cal/kg., then
Net power generation potential (kW) = 14.4 x W

In bio-chemical conversion, only the biodegradable fraction of the organic matter can contribute to the energy output :

Total waste quantity: W (tonnes)
Total Organic / Volatile Solids: VS = 50 %, say
Organic bio-degradable fraction : approx. 66% of VS = 0.33 x W
Typical digestion efficiency = 60 %
Typical bio-gas yield: B (m3)= 0.80 m3 / kg. of VS destroyed = 0.80 x 0.60 x 0.33 x W x1000 = 158.4 x W Calorific Value of bio-gas = 5000 kcal/m3 (typical)
Energy recovery potential (kWh) = B x 5000 / 860 = 921 x W
Power generation potential (kW) = 921 x W/ 24 = 38.4 x W
Typical Conversion Efficiency = 30%
Net power generation potential (kW) = 11.5 x W

In general, 100 tonnes of raw MSW with 50-60% organic matter can generate about 1- 1.5 Mega Watt power, depending upon the waste characteristics.

TECHNOLOGICAL OPTIONS

There are various technological options which can be employed for recovery of energy from MSW While some of these have already been applied at a large scale, some others are under advanced stages of development. A brief on these technologies is given below

Anaerobic Digestion (AD)

In this process, also referred to as bio-methanation, the organic fraction of wastes is segregated and fed to a closed container (biogas digester) where, under anaerobic conditions, the organic wastes undergo bio-degradation producing methane-rich biogas and effluent/ sludge. The biogas production ranges from 50- 150m3 /tonne of wastes, depending upon the composition of waste. The biogas can be utilised either for cooking/ heating applications, or through dual fuel or gas engines or gas / steam turbines for generating motive power or electricity. The sludge from anaerobic digestion, after stabilisation, can be used as a soil conditioner, or even sold as manure depending upon its composition, which is determined mainly by the composition of the input waste. Fundamentally, the anaerobic digestion process can be divided into three stages with three distinct physiological groups of micro-organisms:

Stage I: It involves the fermentative bacteria, which include anaerobic and facultative micro-organisms. Complex organic materials, carbohydrates, proteins and lipids are hydrolyzed and fermented into fatty acids, alcohol, carbon dioxide, hydrogen, ammonia and sulfides.

Stage II: In this stage the acetogenic bacteria consume these primary products and produce hydrogen, carbon dioxide and acetic acid.

Stage III: It utilizes two distinct types of methanogenic bacteria. The first reduces carbon dioxide to methane, and the second decarboxylates acetic acid to methane and carbon dioxide.

Factors, which influence the Anaerobic Digestion process, are temperature, pH (Hydrogen Ion Concentration), nutrient concentration, loading rate, toxic compounds and mixing. For start-up a good innoculum such as digested sludge is required. A temperature of about 35-380C is generally considered optimal in mesophilic zone (20-450C) and higher gas production can be obtained under thermophillic temperature in the range of 45-600C. Provision of appropriate heating 268 arrangements and insulation may become necessary in some parts of the country. Anaerobic Digestion (AD) of MSW offers certain clear advantages over the option of Aerobic process, in terms of energy production/ consumption, compost quality and net environmental gains:

(i) AD process results in net production of energy.

(ii) The quality of the digested sludge (compost) is better as Nitrogen is not lost by oxidation.

(iii) Its totally enclosed system prevents escape of polluted air to atmosphere.

(iv) The net environmental gains are positive.

Main Steps in Anaerobic Treatment of MSW

Pre-treatment: to remove inerts and non-biodegradable materials, upgrade and homogenize the feedstock for digestion and to promote downstream treatment processes. Anaerobic Digestion: and to produce biogas for energy to de-odorise , stabilise and disinfect the feedstock.

Post-Treatment:

to complete the stabilisation of the digested material and to produce a refined product of suitable moisture content, particle size and physical structure for the proposed end-use as organic manure.

Effluent Treatment:

to treat the liquid effluent to specified standards before final disposa

Different Designs and Configurations of AD Systems

Different designs and configurations of AD systems have been developed by various companies to suit different total solid concentration in the feed and microbial activity i.e. single phase, bi-phasic, multi-phasic. The more popular ones are broadly categorised as low/ medium and high solids, two phase and leach bed systems.

(i) Low / Medium Solid Digestion Systems: A large number of systems presently available worldwide for digestion of 269 solid wastes are for low (< 10%) or medium (10-16%) solid concentrations. Some of these systems, when applied to MSW or Market Waste, require the use of water, sewage sludge or manure.

(ii) High Solid Continuous Digestion Systems: These systems have been developed since the late eighties principally for the organic fraction of municipal solid waste but have also been extended to other industrial, market and agricultural wastes. The digestion occurs at solid content of 16% to 40%. These systems are referred to as 'Dry Digestion' or Anaerobic Composting when the solid concentration is in the range of 25-40% and free water content is low. Systems in this category vary widely in design and include both completely mixed and plug-flow systems.

(iii) Two Stage Digestion Systems: In these systems the hydrolysis, acidogenesis and acetogenesis of the waste are carried out separately from the methanogenesis stage. Since each step is optimised separately, so that each of the reactions (i.e. acidogenesis, methanogenesis, etc.) is operated closer to its optimum, the rate of digestion is significantly increased. However, requirement of two reactors and more process controls may lead to higher capital costs and system complications.

(iv) Dry Batch Digestion/ Leach Bed Process: This design concept is closest to the processes occurring naturally in a landfill. The reactor containing the organic material is inoculated with previously digested waste from another reactor, sealed and allowed to digest naturally. The leachate from the bottom of the reactor is re-circulated and heated, if required, to promote the degradation process. In Leach Bed systems also referred to as SEBAC systems (Sequential Batch Anaerobic Composting) this leachate is treated in a wastewater digester prior to recirculation, and thus the solid phase digester essentially acts like a hydrolysis / acid forming stage of a two phase system. This approach has the distinct advantage of reduced materials handling but overall degradation of the organic matter can be lower than other systems. A great deal of experience with biomethanation systems already exists in India, but a large part of this is related to farm-scale biogas plants and industrial effluents. There is

little experience in the treatment of solid organic waste, except sewage sludge and animal manure. However, several schemes for bio-methanation 270 of MSW and Vegetable Market Yard Wastes, are currently planned for some cities of the country.

i. **1Biogas :** A significant amount of organic waste is generated every day in Kolkata from various fruit, vegetable and flower markets. Systematic disposal of this waste is essential while recovering energy and fertiliserfrom it. It has been identified that anaerobic digestion process is very effective to convert organic waste into energy. The biogas should be purified into bio-CNG and bio-CO_2 which has a much greater economic value than the raw biogas itself. This is because Bio-CNG has numerous applications e.g. refuelling of vehicles, power generation, replacing LPG cylinders. Bio-$CO_2$is used in various industrial and bio-logical applications.Biogas is primarily used for power generation using specially made biogas gensets. But these gensets havea short lifespan due to the highly toxic H_2S and moisture laden raw biogas accelerate the rate of corrosion in engines parts. Furthermore raw biogas has about 40% CO_2 resulting into 35% less power output than a CNG genset using bio-CNG having 95% CH4 content. Therefore bio-CNG powered standard gensets would result into greater power output and lower maintenance cost than raw biogas powered gensets. The raw biogas contained H_2S as one of the most corrosive impurities which should be removed by advanced technologies to prevent corrosion to lower the maintenance of gas compressors and bio-CNG upgrading plants

Biogas is a clean and renewable energy that may be substituted to natural gas to cook, to produce vapor, hot water or to generate electricity.At room pressure and temperature biogas is in gaseous form, not liquid like LPG (propane). Bottling biogas is a very expensive process. Organic waste is put into a sealed tank called a digester (or bioreactor) where it is heated and agitated. In the absence of oxygen anaerobic bacteria consume the organic matter to multiply and produce biogas.Any organic waste has the ability to produce biogas: human excreta, manure, animal slurry,fruit and vegetable waste, slaughterhouse waste, meat packing waste, dairy factory waste,
brewery and distillery waste, etc. Fiber rich wastes like wood, leaves, etc. make poor feedstock for digesters as they are difficult to digest. The amount of biogas you can extract from your organic waste depends on the waste itself and the design of the digester system. Some digesters can yield 20 m3 of biogas per tone of waste while others can yield as much as 800 m3 per tone. It all depends on wastequality, digester design and proper operation of the system. Biogas is normally produced in nature by the anaerobic degradation of organic waste in soil, marshes, ocean, etc. Biogas is also produced in landfills where organic food waste degrades in anaerobic conditions. Biogas can be produced in anaerobic digesters, equipment (tanks) providing full control of the process and ensuring full biogas recovery. Methane has a greenhouse gas (GHG) heating factor 21 times higher than CO2. Combustion of biogas converts methane into CO2and reduces the GHG impact by over 20 times. By extracting methane out of waste and using it to produce heat and/or electricity we ensure that the waste will not degrade in an open environment, therefore we are reducing direct methane atmospheric emissions. Moreover, the energy provided by the biogas is likely to displace fossil fuel which is the main contributor to GHG emissions. Biogas energy is

considered carbon neutral, since carbon emitted by its combustion comes from carbon fixed by plants (natural carbon cycle). Each cubic meter (m3) of biogas contains the equivalent of 6 kWh of calorific energy. However, when we convert biogas to electricity, in a biogas powered electric generator, we get about 2 kWh of useable electricity, the rest turns into heat which can also be used for heating applications. 2 kWh is enough energy to power a 100 W light bulb for 20 hours or a 2000W hair dryer for 1 hour. Use our calculator to find out more. Despite popular belief, the amount of waste going into the digester is almost equal to the amount coming out, however the quality of the waste is altered for the better (less odor, better fertilizer, organic load reduced, less polluting). Waste coming out of the digester can be separated (solid/liquid): the solid part can be composted and the liquid part can be used as liquid fertilizer or can be treated further and disposed of. Biogas plants can take various shapes and forms. A simple agricultural plant could cost as low as $3,500 per electrical kW installed. Municipal food waste plant can cost up to $19,000/kWe installed! Every project is different. A typical payback on a biogas plant is 7 years. Biogas systems are significant capital investments that require careful planning to maximize the chances of success. If you feel exposed to energy price fluctuation and you have an environmental conscience about your waste then a biogas plant could be a sustainable solution for you. For a moderate to large scale digester (300 m3 +) it will typically take, from the first call to a running biogas plant, anywhere from 8 months to 2 years. If you are interested in building a small family size digester (10 m3 or less), you can count about 1 to 2 months until you have a functioning biogas plant.

A biogas plant is like an animal. You must feed it every day and feed it the right stuff in the right amount. Just like an animal if you don't take good care of it, it will become ill and will yield poor results. The formation of biogas is a natural phenomenon that naturally occurs in wetland, manure stack, human and animal intestines. For centuries, humans have harvested the power of bacteriological digestion, by recovering naturally formed biogas to use for lighting, cooking, heating or to power mechanical engines. In Asia, millions of family digesters were built to provide cooking fuel and lighting in rural areas. During the Second World War, German army trucks were fueled with biogas collected from farmers manure (gas engine). Over the last 50 years, remarkable progress has been made in the development of anaerobic digesters (bioreactors) to increase methane (CH4) yield and improve its process flow technologies. Nowadays, thousands of projects around the world, from small dairy farms to large municipal waste water treatment plants, are demonstrating that biogas recovery systems are environmentally and economically sound. In Europe, villages are entirely supplied in electricity and heat from their local centralized biogas pant.

2 CO_2Capture and use: the by-product CO_2 should be converted into algae to reduce the overall carbon footprint from the project to promote close loop carbon cycle.

3 Bio-CNG conversion: Water scrubbing based biogas upgrading process should be used where the raw biogas is not exposed to any pre-compressor to prevent corrosion of the compressor and to increase the plant run time. The footprint of the biogas upgrading plant must be small and the height of the plant preferably should be lower than 3m. The smaller footprint helps to reduce the land cost & installation cost.

Use of Bio-CNG**:** The bio-CNG refuelling station should be set up onsite to refuel CNG vehicles and for power generation where possible.

Advantages of biogas

Generation of renewable, green electricity

Low operating costs

Underground construction minimizes land use

Long life span

Reduces greenhouse gases

Increases family income by selling back electric energy to the electric power grid

On site use of heat

Disadvantages of biogas

Requires expert design, skilled construction and expert maintenance required

Biogas production below 15°C, is no longer economically feasible

High capital costs

Benefits of anaerobic digestion and biogas

- Production of renewable power through combined heat and power cogeneration
- Disposal of problematic wastes
- Diversion of waste from landfill
- Production of a low-carbon fertilizer
- Avoidance of landfill gas escape and reduction in carbon emissions

Biogas formation

Basic Techniques of Energy recovery

Energy can be recovered from organic fraction of waste (biodegradable and non-bio-degradable) basically by two methods.

i) Thermo-chemical conversion

This process entails thermal decomposition of organic waste to produce either heat energy or fuel or gas. There are several types of thermal processes.

Incineration has been widely used to burn mixed municipal waste (e.g. woods, cardboards, paper, plastics, metal, glass, old electronics, agricultural waste, tree-branches, household waste), but the emission of toxic gases, VOCs, dioxin are limiting new incineration plants. The heat derived from incineration could be used for electricity generation but the efficiency and the high maintenance of engines are known for their challenges.

Gasification of MSW (municipal solid waste) is commonly done where dry combustible waste is gasified into syngas (CO, H_2, CO_2, steam) in oxygen starvation mode (i.e. lack of oxygen than what is required for complete combustion) at around **600^0-900^0C** temperature depending of various types of gasifiers and feedstock. If the operating temperature is low i.e. around 600^0C or less more bio oil will be produced (**pyrolytic bio oil**, and more tar) than the gaseous substances. At higher temperature (around 900^0C) more syngas will be produced than bio-oil and tar.

If wet organic waste is fed into the gasifier the efficiency will naturally be reduced but this also adds other complexity due to corrosion of the fluidized bed reactors and poisoning/degradation of the catalyst. This is a high temperature process, so the syngas gasifier must be running continuously (24/7). If the gasifier is turning on and off i.e. undergoing intermittent operation, then it will have adverse effects on the working life of catalyst and fluidized bed reactor. Syngas gasifiers are more suited to large volume of dry MSW (in the range of >500 tonnes/day) which may not be feasible to process wet vegetable market waste collected in small volumes (5 tonnes/day) from single sites. The MSW must be processed to segregate metals and other toxic substances to prevent emission of dioxins, Nox, & other toxic gases into the atmosphere. The main problems in standard gasifiers are co-production of tar along with syngas which brings significant maintenance issues for the downstream equipment (engine, turbine, blower, fans, filters). Various attempts are being made to arrest tar by passing the hot syngas through the wet feedstock to condensate the tar at lower temperature with limited success. There are several rice husks based syngas gasifiers in West Bengal which shows gasification is a real contender despite its maintenance routines. RE Hydrogen' proposed solution to utilize the scattered organic waste from vegetable markets into high value bio-CNG fuel and bio-CO_2 does not compete against large scale gasifiers which is more suited to dry, mixed waste of high carbon content.

Plasma gasification is the advanced variant of the gasification technology where the dry waste is gasified at a much higher temperature using plasma (around 1200^0C-1400^0C) in oxygen starvation mode. At high temperature, the amount of tar is significantly less and most of the waste are gasified. But this ultra high temperature system comes at a much higher price, complexity and more robust material for high temperature operation. In principle Plasma gasification has many technical advantages over normal gasification process but the economics and practical aspects are yet to be fully proven in the Indian

context. Plasma gasifiers still have the same issues of continuous (24/7) operation to maintain its efficiency and to prevent thermal degradation of catalyst and reaction bed. The feedstock must also be processes first into small pieces to feed the standard gasified or plasma gasifier. Various new technologies are being tried within the plasma gasification sector e.g. using oxygen concentrator instead of supplying air to prevent or reduce Nox emissions from gasifiers or plasma gasifiers.

ii) Bio-Chemical conversion

This process is based on enzymatic decomposition of organic matter by microbial action to produce methane gas or alcohol. There are several types of bio-chemical conversion technologies available with their respective pros and cons.

a) **Anaerobic digestion (AD)**

AD plants use an engineered-natural process facilitated by bacteria. There are two main types of anaerobic digestion **mesophilic and thermophilic**. In **thermophilic process** the digestion takes place at an elevated temperature around 55^0C using a different set of bacteria. Higher temperature reduces the retention time to down to around 15 days to convert the waste into biogas (CH_4, CO_2 and other impurities). **Mesophilic type digester**as shown below has a retention time of about 30-35 days depending on the feedstock type and quality.

Mesophilic Digester during construction

Mesophilic digester with floating drum gas holder

Mesophilic digester, floating drum gas holders, and feeding tank

Thermophilic biogas digesters must be heated to maintain 55^0C temperature which increases its energy consumption to run such engineered biogas plants and it also require supervision as there are more equipment, and controls required. On the other hand, mesophilic bacteria type biogas digesters operate at around 25^0-40^0 C temperature which has the advantages of being self-controlled without any external heating; however, during winter month biogas production can drop when additional heating can help to maintain the same operational efficiency.

Mesophilic plants are generally simpler, bigger, robust, and cheaper to construct, cheaper to operate/ maintain than the thermophilic plants. Mesophilic biogas plants are
the dominant types in India and across the world due to their proven economics and operational data.

b) **Composting of organic waste**

Composting of organic is a natural process and highly cost effective in treating the waste. There are bylaws and regulations to make mandatory segregation and composting of wet waste by all new housing and commercial societies as per the development control regulations (DCR 1991). However, the time and space required for composting to decompose the waste into fertiliser often makes unfeasible/impractical. The smell/odour from the open composting site is another major barrier for its adoption as a practical solution in cities/towns. Open composting also poses great danger to run off leachate and water pollution. The Capital cost of open composting is low compared to other methods but the value of the by-product (composted fertiliser) is also proportionately small than e.g. Bio-CNG and Bio-CO_2.

Anaerobic Digestion (AD) of "bio-degradable MSW" gas a clear advantage over the option of aerobic process in terms of energy production/ consumption, compost quality, and net environment gains (Page 268, Manual on Solid Waste Management).

- **AD process results in net production of energy.**

- The quality of digested sludge (compost) is better as Nitrogen is not lost by oxidation.

- It's a totally enclosed system, which prevents escape of polluted air to atmosphere.

- The net environmental gains are significantly positive.

Shredder and inspection of waste

Waste macerator

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Land requirement

The area of land required for setting up any waste processing/ treatment facility generally depends upon the following factors.

- Total waste processing /treatment capacity which will govern the overall plant design / size of various sub-systems.

- Waste quality and characteristics, which will determine the need for pre-processing, if required to match the plant design.

- Waste treatment technology selected, which will determine the waste fraction destroyed / converted to energy.

- Quantity and quality of reject waste, liquid effluent, and air emissions, which will determine the need for disposal /post treatment requirements to meet EPC norms.

As such the actual land area requirement can be worked out only in the detail project report for each specific project. However, for initial planning the following figures may be considered as reference benchmark figures for a typical 300 TPD (Input Capacity) waste to energy facilities.

Incineration /Gasification/ pyrolysis plants **=0.8 hectares**

Anaerobic Digestion(AD)Plants **= 2 hectares**

Sanitary landfills (open composting) **= 36 hectares**

While Incineration is a more compact method than Anaerobic Digestion process but the emissions from incineration is significantly greater, and also the reject waste (ash) has significant issues for its disposal to the environment.

On the other hand, the AD process is significantly more compact than landfill disposal for open composting. In Europe, the organics waste (food-waste, vegetable waste is now banned from landfill disposal and they are promoting AD as the only technology for its disposal for its major advantages and environmental friendliness.

However, if Bio-CO_2 from an AD plant is used to produce algae to improve the BOD of the rejected waste (i.e. digested compost), this will significantly reduce the overall carbon footprint, the required space may increase to reflect the improved performance of a specific project.

If modular AD plants are used instead of one large digester, the space requirement will be greater, but the project would have lower risk in terms of bypassing the potential malfunction of one of the digesters just in case, either due to human errors around C/N ratio/ feeding of the digester or any other potential cross-contamination of the feedstock.

The subjected waste under this project for disposal and utilisation are vegetable waste, flower, fruit, meat, and fish market waste.

As per the guidelines (Page 197, Manual on Solid Waste Management) such wastes should be removed on daily basis. Large containers kept in the fruit and vegetable markets should be removed during night time or during off peak hours. The waste from the fish and meat waste should be collected by closed pick up vans/vehicles.

Raw biogas generally contains CH_4 (50-65%), CO_2 (35-50%, H_2S (50-2000ppm), Oxygen (0.1-1%), Nitrogen (<1%), Siloxanes (trace level) and Ammonia (NH_3 at trace level) and moisture (0.1-2%). According to the Indian Standards on Biogas and Biomethane the following specification is required (Please refer Annex-1 for complete BIS Standard).

Primarily raw biogas is treated to remove only the H_2S and moisture before it is used for electricity generation. Due to lower CH_4 content (i.e. 60-65%) in the fuel the power output from the Generator sets is only 60-65% of its rated capacity, thus not fully utilizing the assets. High CO_2 content also make the gas corrosive (carbonic acid formation) resulting into high maintenance breakdown leading to loss of productivity. The biogas is therefore often vented to the atmosphere during the long and frequent maintenance period or the digesters are not fed slow down the gas production both of which are effectively a loss of production.

Based on the above analysis KMC is proposing following elements:-

i. **Anaerobic Digestion (AD) to be used for disposal of organic waste from various markets under the Kolkata Municipal Corporation (fruit, vegetableand flower waste, some fishery and poultry waste).**

ii. **The output raw biogas must be purified as per the Indian Standard for refuelling of vehicles and power generation.**

iii. **The by-product bio-CO_2 should be utilised in an effective manner.**

iv. **The compost fertiliser should have certain qualities and it must be disposed off at Dhapa site on regular basis.**

Availability of land:

Since on site land is not available therefore, 1 acre land will be provided at Dhapa disposal site.

5.0 Upgrading of raw biogas into bio-CNG

Raw Biogas can be converted into Bio-CNG by various methods. The comparative analysis is given below for two main competing technologies i.e. water scrubbing and pressure swing absorption (PSA).

i. **Conventional water scrubbing based biogas upgrading**

The conventional water scrubbing based technology is well known which uses a conventional gas compressor **(i.e. Pre-Compressor or gas blower)** to increase the gas pressure first. The pressurised gas is then injected at the bottom of a tall tower, where water is sprayed from the top of the tower. The rising raw biogas is mixed with the cascading water under 6-8 bar pressure when the Carbon Dioxide (CO_2) and Hydrogen Sulphide (H_2S) and other water soluble gas impurities are absorbed into the water.

Conventional Water Scrubbing for biogas purification

Clean methane (CH_4) is then collected from the top of the tower at 4-6 bar. The water which contains mostly CO_2, H_2S and some methane (10%) are then pumped into a flash tank at about 2 bar pressure to release the CH_4 since its solubility is lesser than CO_2 and H_2S. After the release of CH_4 the water in the flash tank contains only CO_2 and H_2S which thereafter is sprayed inside a degasser tower. Air is injected into the degasser tower from the bottom to remove the CO_2, and to react with hydrogen sulphide (H_2S) forming elemental Sulphur. CO_2 and air mixture is then released from the top of the degasser tower at atmospheric pressure. The fresh water is then re-circulated into system for reuse with some additional topping up.

- **Problems of the Conventional water scrubbing technology**

  - Raw biogas containing the corrosive H_2S and moisture is compressed first using a screw compressor or a centrifugal compressor which requires frequent maintenance shutdown.

  - The capital cost of this conventional gas compressor is very high.

  - Energy consumption in this pre-compressor is high

ii. Pressure Swing Absorption (PSA) technologies

The main issues of PSA are as below.

- The mechanical gas blower or gas compressor is essential to pressurised the corrosive raw biogas which is susceptible to breakdown.

- The presence of moisture or surface water in raw biogas will clog the molecular sieve and reduce the capacity to filter the gas and eventually the molecular sieve must be replaced with fresh material which has operating cost. Therefore, upfront gas drier is required prior to PSA filters. The drier bed must be regenerated when they are moist, which leads to the loss of methane.

- The presence of H_2S, NH_3, and VOC, oil will degrade / poison the molecular sieve rapidly, therefore, H_2S scrubber, NH_3 scrubber, oil scrubbers are needed prior to the PSA filters containing molecular sieve, resin, activated alumina, activated carbon etc.

- It is a batch process so at least two cylinders are required. One cylinder is in CO_2 absorption mode to capture CO_2 in the molecular sieve, whereas the other cylinder is in depressurisation mode to release CO_2 at near ambient pressure. High methane loss is common in PSA based system as it is absorbed to some extent in the molecular sieve along with CO_2, resulting in methane loss. The methane loss could be minimized by operating at lower pressure range (i.e. lower pressure swing) but then the residual CO_2 level will be high in the processed bio-CNG. The increased complexities also add to the increased servicing cost and regular replacement of PSA medium (molecular sieve, zeolite).

Solid Waste Management under KMC

Flow Diagram of Primary collection system of market waste is shown in figure 1.

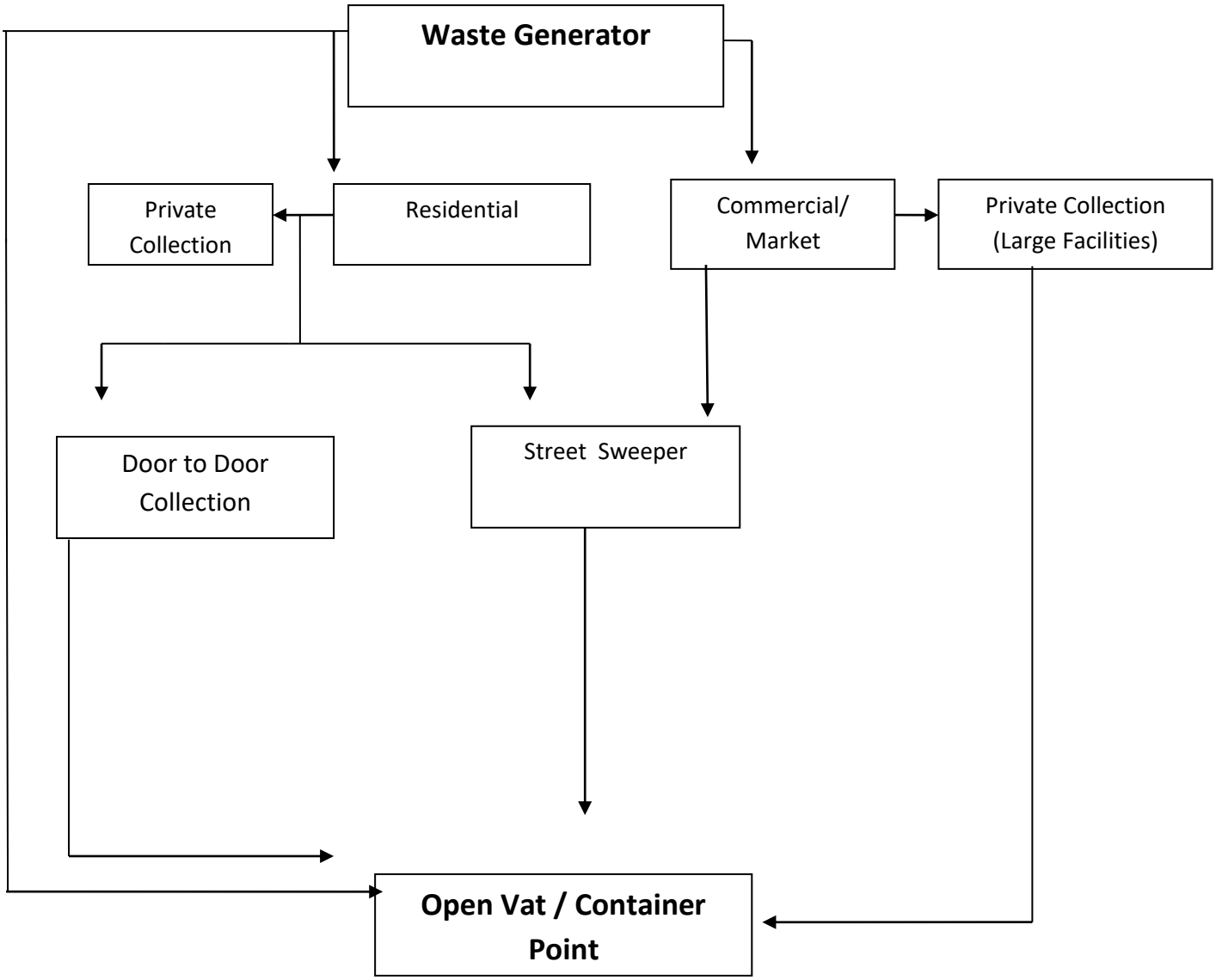


Figure 1. Flow diagram of Existing Market Waste management System

Borough wise Distribution of Fruit and Vegetable markets in Kolkata is shown in table 1.

Borough wise Distribution of Fruit and Vegetable Markets in Kolkata

Borough	Registered Private Market	Unregistered Roadside Market	KMC Owned Market	Wholesale Private Market	Total	% of Total Market	% of Total Population
I	3	11	-	1	15	6.0	7.6
II	9	6	1	1	17	6.8	5.6
III	5	10	3	-	18	7.1	8.0
IV	12	7	1	2	22	8.7	6.8
V	16	6	1	2	25	9.9	6.4
I	7	7	2	1	17	6.8	6.8
VII	9	10	1	-	20	7.9	11.0
VIII	4	8	3	-	15	5.9	7.2
IX	7	9	-	1	17	6.8	9.7
X	8	10	2	-	20	7.9	8.0
XI	2	7	1	-	10	4.0	3.8
XII	2	10	3	-	15	6.0	3.6
XIII	2	3	1	-	6	2.4	5.0
XIV	10	14	4	1	29	11.5	5.4
XV	-	6	-	-	6	2.4	5.2
Total	**96**	**124**	**23**	**9**	**252**	**100.00**	**100.00**

SPECIFICATIONS

240 Litre Trash Bins:

The bins shall conform to following specifications:-

1) The manufacturing process should be injection moulding with "**Virgin HDPE"** only.
2) The bin should be as per EN 840-1 Standards. (Valid EN 840 Certificate should be submitted along with the tender or with a valid Test report from CIPET not earlier than 03 months from the date of tendering)
3) Marking: - Each container/bin shall be duly embossed with
    a) KMC letters on the body of the bins specially on the front side
    b) Manufacturer's name or the trade mark on the back side.
    c) Year & month of manufacturing
    d) The nominal volume
    e) Minimum carrying weight in kg.

Make a note that screen printing or hot stamping will not be accepted.

4) The typical drawing is attached. The tenderer shall submit his detail drawing and brochure/literature. The detailed drawing and brochure/literature shall specially indicate KMC letters (with its size), the nominal volume and the minimum weight carrying capacity of bins in kg.
5) The bins shall have no obvious damages, no cracks, bubbles, large flashes or sharp edges in hand grip areas.
6) The bin should be compatible to be lifted easily by compactors having universal bin lifters
7) The HDPE material shall be chemical resistant and shall be UV stabilized. Therefore bin made from such material which shall meet the performance requirements.
8) The bins shall have suitable lid of HDPE at the top which shall be hinged on one side and open easily by gravity while unloading the refuse in compactors. The HDPE lid shall be made of virgin material by Injection moulding process.
9) The bins shall have extra ribs at bottom and shock absorber for better strength
10) The bins shall have nominal volume of 240 litres.
11) The bins shall have two solid rubber wheels of 200 mm dia, both these tyres shall be mounted on axle, which shall be corrosion resistant.
12) Bins should have minimum load carrying capacity 96 Kg.
13) The bin shall be provided with single piece anti-skid pulling handle.
14) The bins shall be provided with a lid at the top and shall have hand slot for easy opening.

ADDITIONAL SPECIFICATION OF 240 LITRE TRASH BIN

1. Trash bin should conform to EN/DIN standard
2. The bins specified as weighing around 12 Kg of blue/olive green in colours fitted with wheels at the bottom for push/pull moving made of "**Virgin HDPE-Injection moulded**" and a hole on the top lid/body of the bins as directed with sticking "USE ME, KMC, SWM" on the body of the bins and with minimum capacity 240 liters.
3. Net volume 240 liters & material should be resistant to heat and chemical should have high resistance to UV Radiation. Container should have a suitable lid at the top, should have two solid rubber wheels of 200 mm dia. Wheels should mounted on shaft and should be resistant to corrosion. The bin shall be provided with one piece-pulling handle with approximate dia 30 mm.
4. The bins shall be designed to be lifted by compactors (Comb-Lifting) having UNIVERSAL Bin Lifters of EN standard.
5. The bins should be delivered at 16 boroughs under KMC.

Anaerobic Digestion to Bio-CNG storage, Bio-CO2 and Algae

Items	Required Specification
Biogas Digester an associated component to process 5000 kg raw organic waste/day.	• Mesophilic (35-45^{0}C). • Hydraulic Retention Time= 30-45 days. • Total Solid Content = 8-10% • Sludge agitator/ mixer • Suitable arrangements to control H_2S level more effectively inside the digesters. • Digester to produce 200-300 Nm^3/day raw biogas depending on the feedstock quality and quantity. • Flexible or floating gas holder with pressure relief mechanism to feed the Bio-CNG upgrader.
Bio-CNG production and Bio-CO_2 capture	• Advanced water scrubbing based biogas upgrader. • Preferably gas compression, gas cleaning and gas drying in a single step for greater reliability, higher efficiency, and lower servicing and lower maintenance shutdown. • Raw gas flow rate: 200 – 300 Nm^3/day • Raw input biogas specification: CH_4 = 50% - 65% CO_2= 50% - 35% H_2S= less than 500ppm O_2 = 1% max • Inlet gas pressure= 1 – 20 mbar • Outlet gas pressure after upgrading = 6-7 bar • Outlet gas specification as per the BIS Standard. Contd..

<table>
<tr><td>Items</td><td>Required Specification</td></tr>
<tr><td>Bio-CNG production and Bio-CO_2 capture</td><td>
<table>
<tr><th>Sl. No.</th><th>Characteristic</th><th>Requirements</th><th>Method of Test, Ref to</th></tr>
<tr><td>i.)</td><td>CH_4, percent, Min</td><td>90</td><td>IS 15130 (Part-3)</td></tr>
<tr><td>ii.)</td><td>Moisture, mg/m^3,Max</td><td>16</td><td>IS 15641 (Part- 2)</td></tr>
<tr><td>iii.)</td><td>H_2S, mg/m^3,Max</td><td>30.3</td><td>ISO 6326-3</td></tr>
<tr><td>iv.)</td><td>$CO_2+N_2+O_2$, Percent</td><td>10</td><td>IS 15130 (Part -3)</td></tr>
<tr><td>v.)</td><td>CO_2, Percent, Max(v/v)</td><td>4</td><td>IS 15130 (Part-3)</td></tr>
<tr><td>vi.)</td><td>O_2, Percent, Max(v/v)</td><td>0.5</td><td>IS 15130 (Part-3)</td></tr>
</table>

Preferably made of light weight structures.
Preferably compact low height (<3m),
Capture CO_2 from raw biogas for other usage.

</td></tr>
<tr><td>CO_2 to algae conversion</td><td>Preferably convert CO_2 into algae inside a bio-reactor using digestate water to control the BOD of discharged water and to meet all environmental safety requirement.</td></tr>
<tr><td>CNG bottling and storage</td><td>Compressor for Vehicle Refuelling
Outlet pressure= 150-200bar
Cylinder cascade capacity, 500 kg CNG
Up to 200bar refuelling system including vehicle filling hose, break way coupling, and gas filling nozzles.</td></tr>
</table>

8.0 Responsibilities

i. Kolkata Municipal Corporation (KMC)

- KMC would deliver vegetable waste at 5 tonnes/day to the bio-CNG site free of charge.

- 2 m^3 /day fresh water required for 5000kg waste/day.
- KMC would provide free space for setting up this bio-CNG plant.
- 1 acre space required for up to 25 tonnes/day waste processing which will leave scope for future expansion from 5 tonnes/day pilot plant. The area will be used for waste segregation, liquid feedstock storage tank, digesters, gas holders, CO_2 to algae reactor, Bio-CNG upgrader, bio-CNG compressor and storage cylinders, Bio-CNG refuelling station where vehicle (Buses) can come in for refuelling.
-
- Supply of AC power 415 V, 50 Hz, 3Phase right at Bio-CNG plant. 15kW average demand. The total connected load and start up power demand (inrush current) could go up to 40kW including the office block and the security gatehouse.
- All Electrical and Instrument/power cabling to bring power to the site from outside.
- All access roads, boundary walls, drainage.
- Concrete pads for waste receiving, sorting, segregation, processing.
- Lined shallow pond for storage of digestate and to CO_2 to algae bio-reactor.
- Entrance gates, security room, office block including a kitchenet facilities for the operators making for tea, coffee, snacks, and for the visitors to the site, modern toilet facilities (Ladies and Gents separately, or Universal toilets).
- Site beautification, landscaping to promote as an eco-friendly green waste to energy recovery site in Kolkata.
- Supervision during erection and commissioning of plant.
- Full 24/7 access provided to the operator to the site.
- General security of the area to protect the equipment and the people.
- KMC will own the bio-CNG plant.
- The operational and servicing contract of the bio-CNG plant will be given to the project operator.
- Additional services can be provided on a chargeable basis.
- Anything not specifically mentioned in the contract.

ii. Project Operator

The operator will Comply with health and safety, environmental, and PESO regulation for all operations.

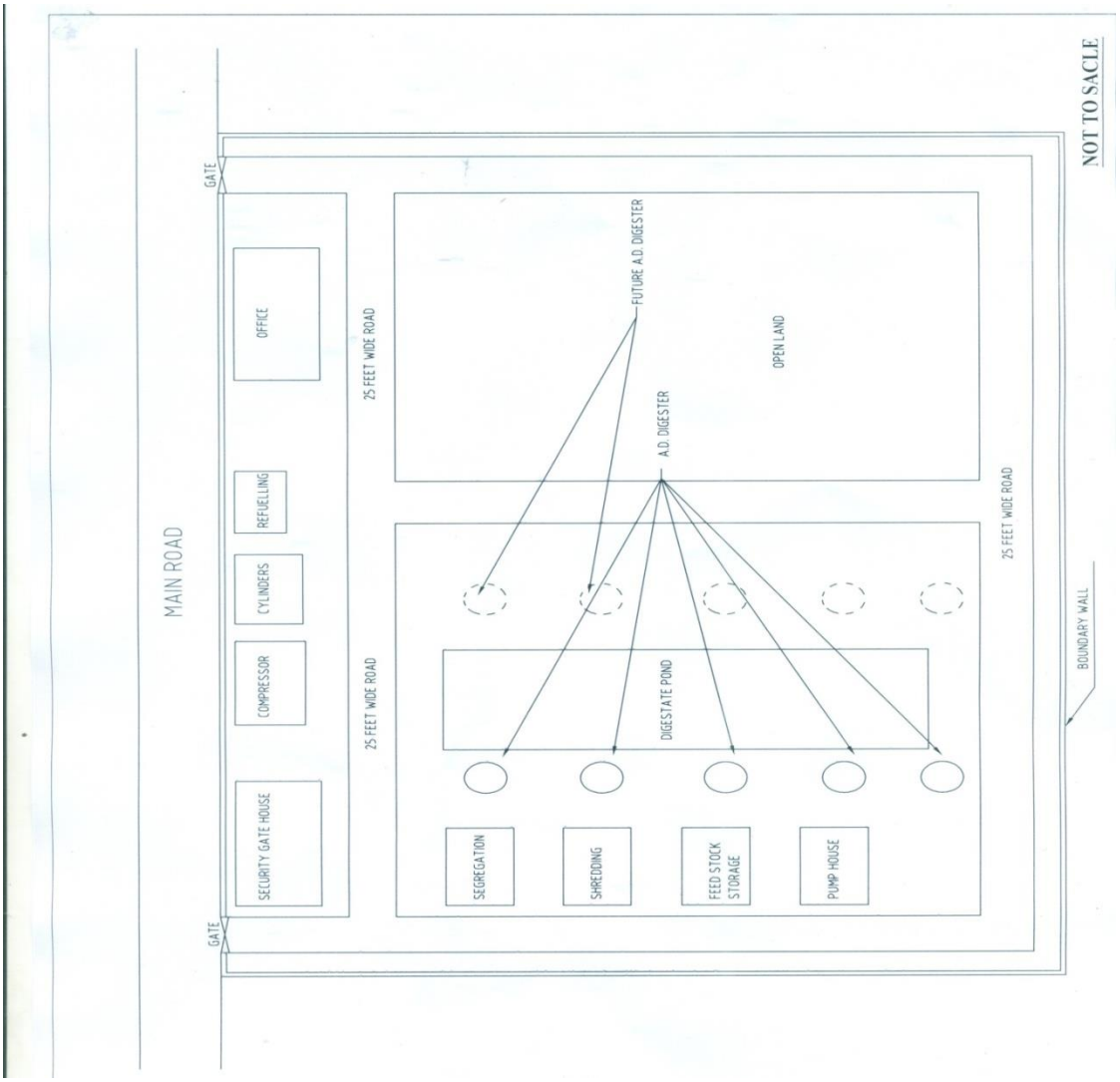
- Meet the specification as per the contract.
- Segregate the waste,

- Blend various types of waste in right proportion,
- Process the waste to produce feedstock and store in a tank.
- Feed the digester at specific interval
- Produce raw biogas of specific quality and volume
- Upgrade the raw biogas into bio-CNG fuel of specific quality.
- Compress bio-CNG and store in gas cylinders.
- Set up -bio-CNG refuelling station onsite.
- Develop all electronics control for remote monitoring, and control from mobile devices.

iii. Scope of supply by the project operator

- Waste Shredder
- Feed mixer tank
- Mixing Agitator
- Feeding pump
- Digester Tank with Stirring
- Flexible gas holders
- Associated liquid & Gas piping system
- Biogas purification system
- Bio-CNG compressor
- Bio-CNG storage cylinders
- Bio-CNG refuelling station with filling hose and nozzle
- Gas analyser
- All electronics, remote monitoring and control

- **Plant layout and site layout**



Cost Estimation of plants and Equipment

Capital Cost

i)	Capex of AD plant, Biogas upgrading to bio-CNG, Bio-reactor for CO_2 to algae conversion, System integration, monitoring, remote control	Rs	1,46,71,000
	Capex of gas cylinder	Rs/ cylinder	34,890
	Capex of gas cylinders for five days storage of CNG	Rs	1,535,160
	Cost of CNG compressor for bottling	Rs	15,88,500
	Total CAPEX	**Rs**	**17,794,660**

Operational cost

Rate of feedstock (food-waste)	Rs/kg	0
Cost of delivered feedstock (KMC)	Rs/year bio waste	0
Labour cost, 4 persons, Rs 15,000/month	Rs/year	720,000
Electricity cost to run the plant @Rs 5/kWh	Rs/year	337,260
Servicing and maintenance cost	Rs/year	229,507
Project management- Admin, security, insurance	Rs/year	298,000
Cost of waste processing (segregation, feeding-digester, removal of fertiliser)	Rs/year	425,000
Lease of land (1 acre for future expansion)	Rs/year	0
Total OPEX	**Rs/year**	**20,09,767**

If larger volume of waste e.g. 25 tonnes/day or greater is processed on the same site in a modular fashion the opex will be much lower per site. This is a pilot scale project with a scope for future expansion on the same site up to 25 tonnes/day waste or more if it is planned in advanced.

The labour cost, project management cost, cost of waste processing, servicing & maintenance cost would have been mostly common, which would significantly improve the economics of the project beyond the pilot scale.

Potential Revenue

Selling price of CNG	Rs/cylinder (11kg CNG)	656
Required volume of organic/ food waste	Kg/day (Total Solid)	5,280
Volume of raw biogas output	Nm^3/day	264
Volume of Clean Bio-CNG output	Nm^3/day	132
Volume of Clean Bio-CNG output	Kg/day	99
CNG cylinder production per day	cylinders /day	9
Revenue by selling bio-CNG	**Rs/day**	**5,773**
Bio-CO_2 production	Nm^3/day	106
Bio-CO_2 production	kg/day	207
Market price of CO_2	Rs/kg	0
Revenue from CO_2 (it will be turned into algae)	**Rs/day**	**0**
Bio-fertiliser production	Kg/day	422
Sale price of bio-fertiliser	Rs/kg	5
Revenue from bio-fertiliser	**Rs/day**	**2,112**
Total revenue per day	**Rs/day**	**7,885**
Annual revenue potential	Rs/day	2,877,931
Capacity factor	%	1
Effective Annual revenue	**Rs/year**	**2,590,138**

The above projected revenue is subjected to various market risks which are beyond the control of KMC or the Project operator because the bio-CNG market is non-existent in Kolkata and it is fairly new even in India. This is a pilot scale project to validate the pricing model and if the risks are mitigated this project could be highly profitable for the KMC in the long run.

The conversion of CO_2 into algae would allow more carbonaceous feedstock which is otherwise difficult to process by mesophilic anaerobic digesters, has a different value attached to it, for systematic disposal of the vast quantity of vegetable market waste from cities.

Construction, design, drawing, engineering, supply, installation, commissioning and 5 years comprehensive operation and maintenance of (200–300 Nm^3/day capacity) Bio-CNG plant by converting organic market waste into Bio-CNG, Bio-CO_2 & Compost at Dhapa Dumping Ground under SWM-I department of Kolkata Municipal Corporation

TECHNICAL SPECIFICATION

Conversion of organic market waste to Bio-CNG storage, Bio-CO_2 and compost / Algae through Anaerobic Digestion.

Items	**Required Specification**
Biogas Digester an associated component to process 5000 kg raw organic waste/day.	• Mesophilic (35-45^{0}C). • Hydraulic Retention Time= 30-45 days. • Total Solid Content = 8-10% • Sludge agitator/ mixer • Suitable arrangements to control H_2S level more effectively inside the digesters. • Digester to produce 200-300 Nm^3/day raw biogas depending on the feedstock quality and quantity. • Flexible or floating gas holder with pressure relief mechanism to feed the Bio-CNG upgrader.
Items	**Required Specification**
Bio-CNG production and Bio-CO2 capture	• Advanced water scrubbing based biogas upgrader. • Preferably gas compression, gas cleaning and gas drying in a single step for greater reliability, higher efficiency, and lower servicing and lower maintenance shutdown. • Raw gas flow rate: 200 – 300 Nm^3/day • Raw input biogas specification:

<table>
<tr><td></td><td>CH_4 = 50% - 65%
CO_2= 50% - 35%
H_2S= less than 500ppm
O_2 = 1% max

• Inlet gas pressure= 1 – 20 mbar
• Outlet gas pressure after upgrading = 6-7 bar
• Outlet gas specification as per the BIS Standard.</td></tr>
<tr><td>Bio-CNG production and Bio-CO_2 capture</td><td>
<table>
<tr><th>Sl. No.</th><th>Characteristic</th><th>Requirements</th><th>Method of Test, Ref to</th></tr>
<tr><td>i.)</td><td>CH_4, percent, Min</td><td>90</td><td>IS 15130 (Part-3)</td></tr>
<tr><td>ii.)</td><td>Moisture, mg/m^3,Max</td><td>16</td><td>IS 15641 (Part- 2)</td></tr>
<tr><td>iii.)</td><td>H_2S, mg/m^3,Max</td><td>30.3</td><td>ISO 6326-3</td></tr>
<tr><td>iv.)</td><td>CO_2+N_2+O_2, Percent</td><td>10</td><td>IS 15130 (Part -3)</td></tr>
<tr><td>v.)</td><td>CO_2, Percent, Max(v/v)</td><td>4</td><td>IS 15130 (Part-3)</td></tr>
<tr><td>vi.)</td><td>O_2, Percent, Max(v/v)</td><td>0.5</td><td>IS 15130 (Part-3)</td></tr>
</table>
• Preferably made of light weight structures.
• Preferably compact low height (<3m).
• Capture CO_2 from raw biogas for other usage.</td></tr>
<tr><td>CO_2 to algae conversion</td><td>• Preferably convert CO_2 into algae inside a bio-reactor using digestate water to control the BOD of discharged water and to meet all environmental safety requirement.</td></tr>
<tr><td>CNG bottling and storage</td><td>• Compressor for Vehicle Refuelling
• Outlet pressure= 200bar (minimum)
• Cylinder cascade capacity, 500 kg CNG
Up to 200bar refuelling system including vehicle filling hose, break way coupling, and gas filling nozzles.</td></tr>
</table>

- **<u>Responsibilities of stake holders:</u>**

- KMC would deliver vegetable waste at 5 tonnes/day to the bio-CNG site free of charge.
- 2 m^3 /day fresh water required for 5000kg waste/day.
- KMC would provide free space for setting up this bio-CNG plant.
- 1 acre space required for up to 25 tonnes/day waste processing which will leave scope for future expansion from 5 tonnes/day pilot plant. The area will be used for waste segregation, liquid feedstock storage tank, digesters, gas holders, CO_2 to algae reactor, Bio-CNG upgrader, bio-CNG compressor and storage cylinders, Bio-CNG refuelling station where vehicle (Buses) can come in for refuelling.
- Supply of AC power 415 V, 50 Hz, 3Phase right at Bio-CNG plant. 15kW average demand. The total connected load and start up power demand (inrush current) could go up to 40kW including the office block and the security gatehouse.
- All Electrical and Instrument/power cabling to bring power to the site from outside.
- All access roads, boundary walls, drainage.
- Concrete pads for waste receiving, sorting, segregation, processing.
- Lined shallow pond for storage of digestate and to CO_2 to algae bio-reactor.
- Entrance gates, security room, office block including a kitchenet facilities for the operators making for tea, coffee, snacks, and for the visitors to the site, modern toilet facilities (Ladies and Gents separately, or Universal toilets).
- Site beautification, landscaping to promote as an eco-friendly green waste to energy recovery site in Kolkata.
- Supervision during erection and commissioning of plant.
- Full 24x7 access provided to the operator to the site.
- General security of the area to protect the equipment and the people.
- KMC will own the bio-CNG plant.
- The operational and servicing contract of the bio-CNG plant will be given to the project operator.
- Additional services can be provided on a chargeable basis.
- Anything not specifically mentioned in the contract.

Project Operator

The operator will comply with health and safety, environmental, and PESO regulation for all operations.

- Meet the specification as per the contract.
- Segregate the waste,
- Blend various types of waste in right proportion,
- Process the waste to produce feedstock and store in a tank.
- Feed the digester at specific interval
- Produce raw biogas of specific quality and volume
- Upgrade the raw biogas into bio-CNG fuel of specific quality.
- Compress bio-CNG and store in gas cylinders.
- Set up -bio-CNG refuelling station onsite.
- Develop all electronics control for remote monitoring, and control from mobile devices.

Scope of supply by the project operator

- Waste Shredder
- Feed mixer tank
- Mixing Agitator
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- Digester Tank with Stirring
- Flexible gas holders
- Associated liquid & Gas piping system
- Biogas purification system
- Bio-CNG compressor
- Bio-CNG storage cylinders
- Bio-CNG refuelling station with filling hose and nozzle
- Gas analyser
- All electronics, remote monitoring and control

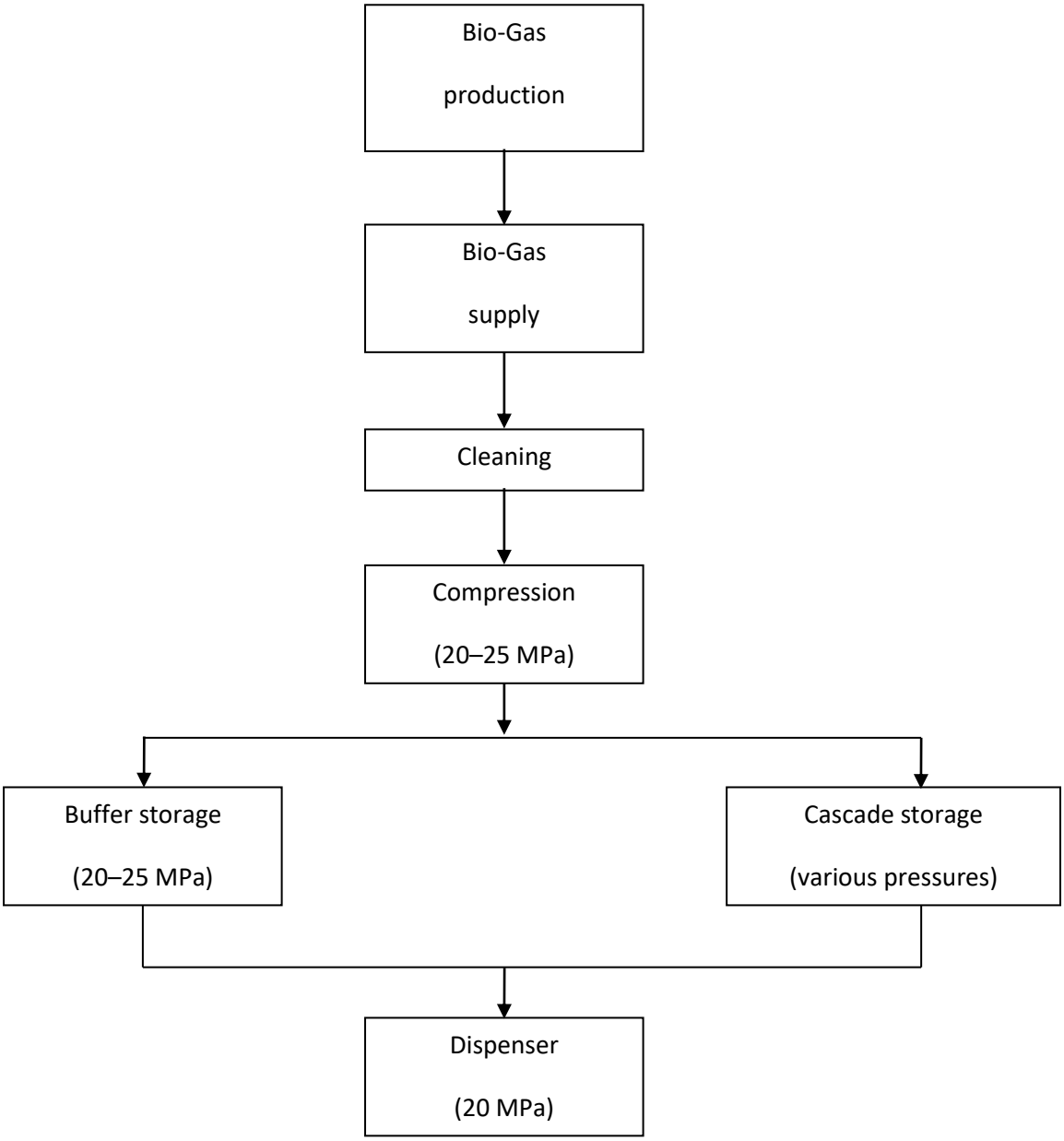
Salient features regarding Bio-CNG plant:

Description	Unit	Quantity
Required volume of organic/ food waste	**Kg/day (Total Solid)**	**5,280**
Volume of raw biogas output	**Nm^3/day**	**264**
Volume of Clean Bio-CNG output	**Nm^3/day**	**132**
Volume of Clean Bio-CNG output	**Kg/day**	**99**
CNG cylinder production per day	**cylinders /day**	**9**
Bio-CO_2 production	**Nm^3/day**	**106**
Bio-CO_2 production	**kg/day**	**207**
Bio-fertiliser production	**Kg/day**	**422**
Cylinder of CNG	**Kg**	**11**

The Bio-CNG plant must get the approval or clearance from

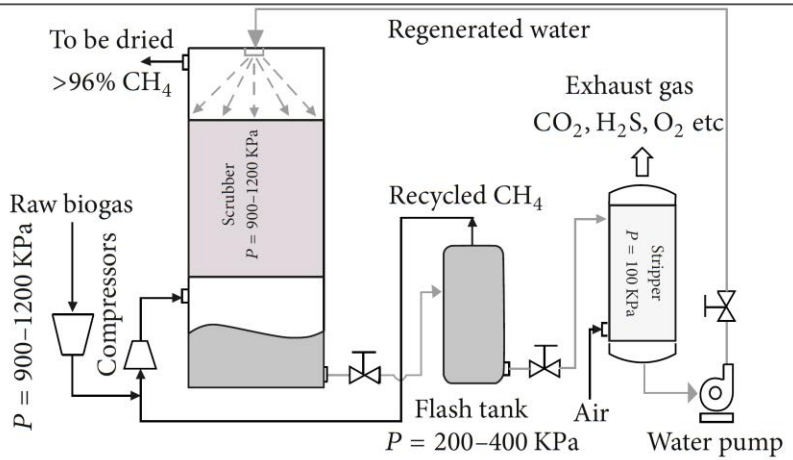
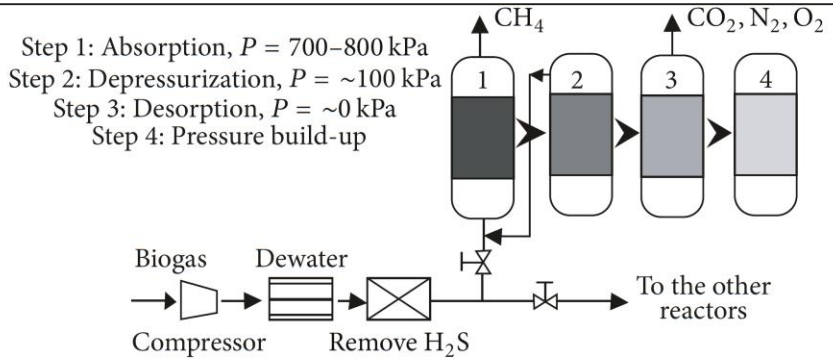
- Chief Controller of Explosioves
- Ministries of Road Transportation
- West Bengal Pollution Control Board.

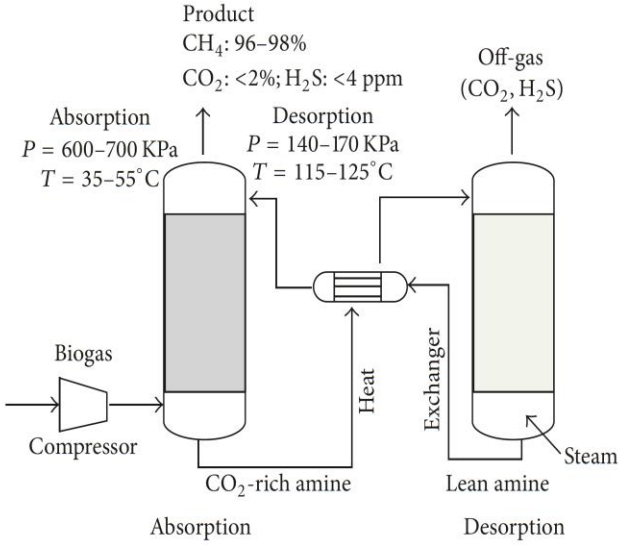
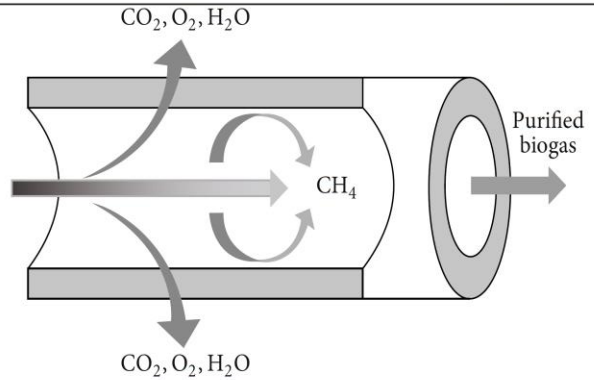
After production of Bio-Gas the following processes may be implemente



Raw Bio-Gas can be purified into Bio-CNG by the following methods.

- Pressurised water scrubbing
- Pressure Swing adsorption
- Chemical absorption
- Membrane permeation
- Temperature swing adsorption
- Cyrogenic approach
- Physical absorption
- Biological filtration

Diagram	Characteristics	Reference
	(i) Eliminates CO_2, NH_3, dust, and so forth and provides up to 96.1% CH_4 purity (ii) Large quantity is required	[
	(i) Eliminates CO_2, N_2, and O_2 and purifies biogas up to 95.8% of CH_4(ii) Low emission and power demand, however, relatively more expensive (iii) Additional steps are required for removing H_2S prior to the process	[49]

Biogas cleaning methods	Diagram	Characteristics
Chemical absorption		(i) High efficiency, complete removal of H_2S, and 94.6% CH_4 containing biogas (ii) Relatively high cost and additional chemical and energy input requirement
Membrane permeation		(i) Light in weight, simple in operation and maintenance (ii) Comparatively low CH_4 (90.3%) percentage in biogas (iii) High cost of membrane

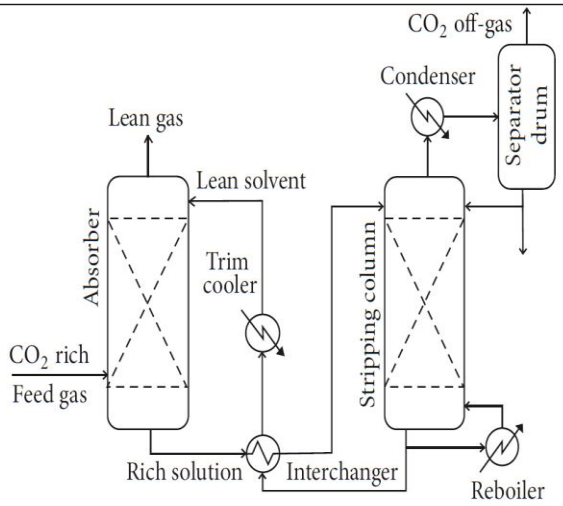
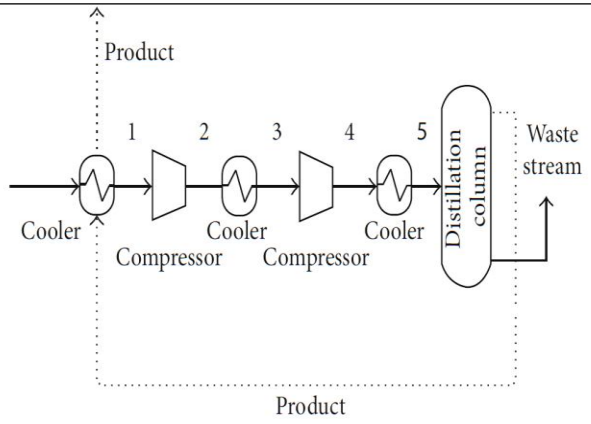
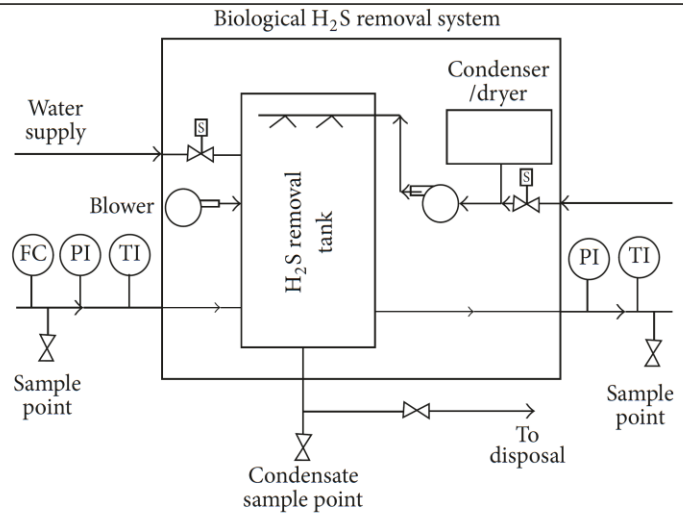
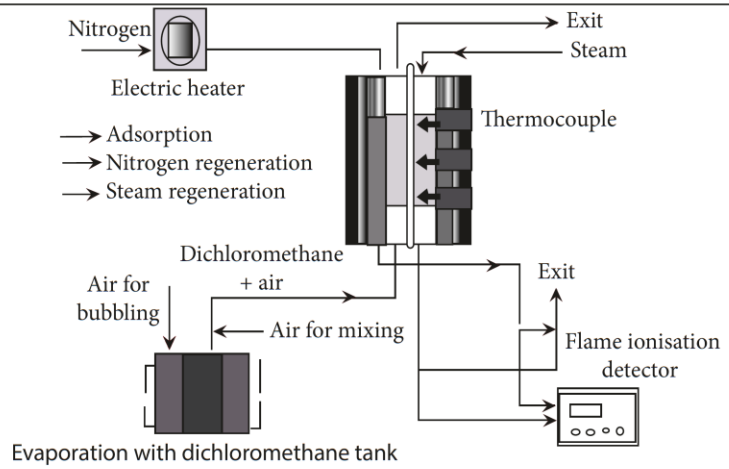
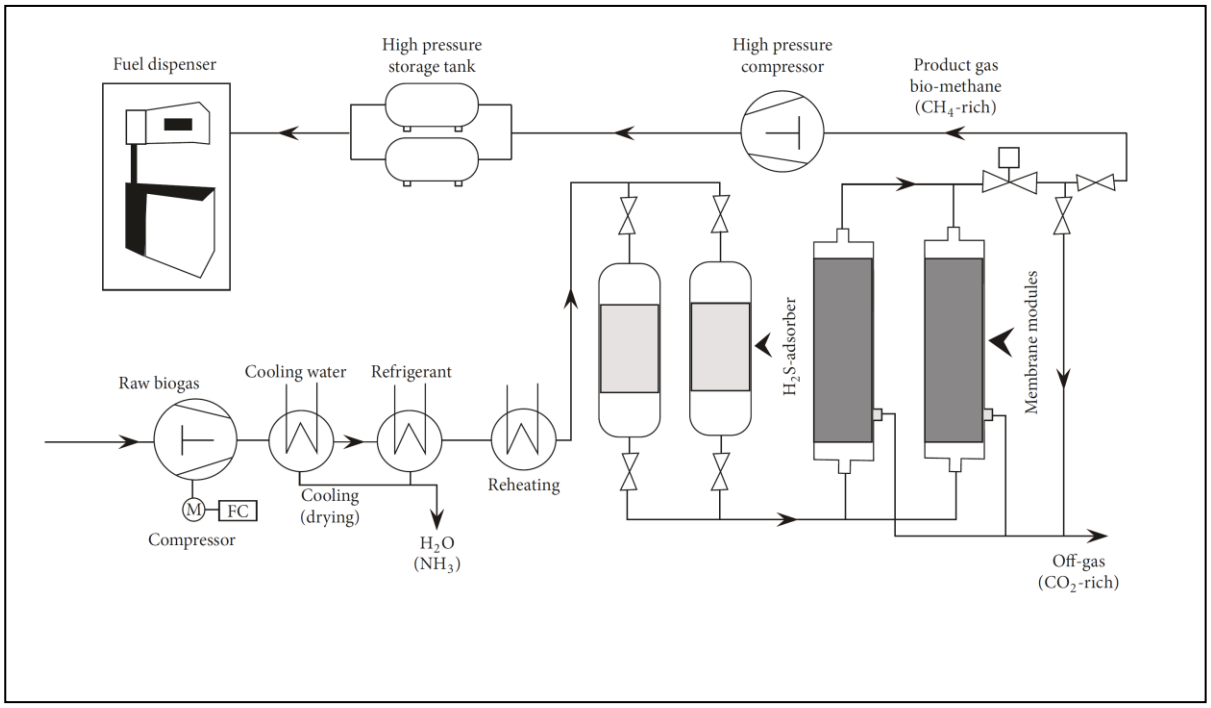
Biogas cleaning methods	Diagram	Characteristics
Physical absorption		(i) Requires less energy input, about 93% CH_4 purity in biogas (ii) Requires more absorbent to capture CO_2
Cryogenic method		(i) Removes CO_2, H_2S, and all other impurities from biogas and contains 88% CH_4 (ii) Additional equipment like turbines, compressors, and heat exchangers causes high investment cost

Diagram	Characteristics	Reference
	(i) Eliminates H_2S, and purifies biogas up to 94% of CH_4(ii) Low energy requirement (iii) Additional nutrients requirement and biogas may contain small amount of O_2 and N_2	[51]
	(i) Low operating cost with the lowest CH_4 (84%) percentage among the cleaning methods (ii) Requirement of high energy input	[52]



Schematic diagram of Bio-CNG purifying process and vehicle refueling process.

The conversion of CO_2 into algae would allow more carbonaceous feedstock which is otherwise difficult to process by mesophilic anaerobic digesters, has a different value attached to it, for systematic disposal of the vast quantity of vegetable market waste from cities The above projected revenue is subjected to various market risks which are beyond the control of KMC or the Project operator because the bio-CNG market is non-existent in Kolkata and it is fairly new even in India. This is a pilot scale project to validate the pricing model and if the risks are mitigated this project could be highly profitable for the KMC in the long run.

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CHAPTER - 4

RESULT AND DISCUSSION

Annual (April,18-March,19) Cost analysis of secondary transportation (Dumper placer vehicle number WB03B-7957) of M.S.W. of K.M.C.

April, 2018													
Date	No. of trip	Total weight collection(kg)	Running Job For maintanance	Costing for Maintanance of vehicle									
				Fual(lit)	cost of fual (@Rs58.91)	Engine Oil(lit.)	cost of engine oil (Rs)	Spear Parts	cost of Spear parts (Rs)	Tyer , Tube	Tyere Cost	Battary	Battary cost
1	5	1330+2130+760+2170+2440=8830		50	2945.5								
2	**7**	**3950+1370+830+2140+2210+2390+2190=17180**	**P/S nut boltn open out And crossw to be check**	**65**	**3829.15**	**tipper - 10 (@Rs141.75)**	**1417.5**	**nut bolt-1nos(@Rs27)**	**27**				
3	5	1000+3130+1620+3040+2050=10840	rear outerleft side weel tube puncher to be cheack	-		mobil-2 (@Rs70)	140			tube-1	1246		

4	5	1890+1870+1590+2000++2630=9980		96	5655.36	steering oil-1/2 (@Rs445)	222.5						
5	5	1060+1900+2380+1770+2890=10000		50	2945.5	Gear oil-3 (@Rs258)	774						
6	5	1350+870+2510+1270+2510=8510	left side stabilizer channel to bwe welding	50	2945.5	Break oil-1/2 (@Rs 380)	190						
7	5	1330+3630+1160+1510+2590=10260		51	3004.41	coolent-1(@Rs295)	295						
8	8	1680+1090+2920+980+2840+1600=11110		63	3711.33								
9	6	2550+580+1140+1110+1310+860=7550	1)Break Defective 2)Break dala not lifting 3) Steering jam 4)P/S defectiv	62	3652.42			1) cam bush- 2Pc (@Rs 83)	166				
10	4	1020+1770+1410+2190=6390		48	2827.68								
11	6	1160+2420+1430+720+1280+2940=9950		62	3652.42								
12	5	1330+1330+1020+1970+1790=7440		50	2945.5								

13	5	1540+1860+780+1810+1480=7470		-									
14	5	2410+730+1160+1170+1360=6830		106	6244.46								
15	5	1030+1520+900+750+1970=6170	both side boom U bolt broken to be check	50	2945.5			u clamp 2nos (@Rs389)	778				
16			leaf spring broken to be check		0			1) Rear hanger-1pc (@Rs 1442) 2)Rear bracket-1pc (@Rs2560) 3)Leaf no3-1pc (@Rs2673) 4) Leaf no2 -1pc (@Rs2959)	8596				
17					0								
18					0								
19					0								
20					0								
21					0								
22	5	980+2160+2210+3390+2020=10760		51	3004.41								
23	7	1570+1700+3640+860+530+2260+1970=12530		68	4005.88								
24	6	740+1510+2020+1520+1120+1930=8840	P.T.O. Not working Properly	61	3593.51			1)P.T.O UJ Cross-2nos(@Rs.748.00),2)P.T.O Cylinder-1no(@Rs. 791.00), 3)P.T.O Cylinder 'O' Ring-2nos(@ Rs.35.00)	2357				

25	5	770+1530+1630+4490+1920=10340		50	2945.5								
26					0								
27					0								
28	5	1620+1490+1220+4190+3140=11660		114	6715.74								
29	6	810+1070+2280+1500+3310+2440=11410		61	3593.51								
30	5	2390+1130+1080+3760+1070=7040	1)rear right side spring center bolt open out 2)rear right side spring pin loose to be check 3)left side door lock broken	50	2945.5			1) sicel pin-2pc(@Rs277) 2)Center bolt-1pc(@Rs144) 3)Spring pin quater bolt-3pc (@Rs100) 4) Spring clam-1 pc (@Rs 220)	1218				
Total value of cost month wise					74108.8		3039		13142		1246		0

May, 2018

Date	No. of trip	Total weight collection(kg)	Running Job For maintanance	Costing for Maintanance of vehicle									
				Fual(lit)	cost of fual (@Rs58.91)	Engine Oil(lit.)	cost of engine oil (Rs)	Spear Parts	cost of Spear parts (Rs)	Tyer , Tube, Flap set	Tyere Cost	Battary	Battary cost

1	6	1990+1660+1850+2600+3470+3140=14660		50	2945.5								
2	5	840+690+3870+1540+2200=9140	Disel oil liking from disel Return line	50	2945.5	tipper - 10 (@Rs141.75)	1417.5						
3	5	2290+490+1190+1590+1650=7210		49	2886.59	mobil-2 (@Rs70)	140			1			
4	5	840+1310+3820+1150+1480=8600		50	2945.5	steering oil-1/2 (@Rs445)	222.5						
5	5	520+1290+750+3920+2570=9050	Disel linking from disel pipe line	50	2945.5	Gear oil-3 (@Rs258)	774						
6	6	830+1880+1800+4990+1160+2150=12810		60	3534.6	Break oil-1/2 (@Rs 380)	190						
7	6	1960+1850+330+1180+3410+1960=10690		59	3475.69	coolent-1(@Rs295)	295						
8	5	800+1150+1000+4900+1800=9650		49	2886.59								
9	6	1970+570+1160+2020+3220+1650=10590	1)Badly Smoking commin g From Turboch arger, turboch arger bolt	62	3652.42			1)Turbocharger stud, nut and washer (@Rs45) 2) Steel washer (@Rs18) 3) Packing (@Rs68)	131				

			broken 2) Center bearing UJ cross to be check										
10	5	1290+1460+1780+3170+1510=9210		48	2827.68								
11	5	960+1230+760+1800+2130=6880		48	2827.68								
12	5	2120+710+1840+1900+1760=8330		-									
13	6	2020+1080+1980+4070+800+3120=10970	Engine Mounting Braket Broken	65	3829.15			1)Mounting Braket With Bolt-8nos (@Rs49.5) 2) Mounting Pad-2nos(@Rs304.70)	1005.4				
14	6	3320+820+1410+1308+4040+2030=12980		65	3829.15								
15	5	570+3590+900+2180+2480=9720		49	2886.59								
16	6	830+930+2680+3730+2070+2240=12480		-									
17	4	690+1880+2490+2190=7520		-									
18	6	2210+2290+2230+1340+960+1290=10320		104	6126.64								
19	6	730+1010+1540+1660+3730+1850=10520	barraery throughly check and survice	61	3593.51								
20	6	1830+1300+3920+1610+1640+2280=12580		60	3534.6								
21	6	1690+2860+680+3010+4010+2240=12990	Radietor hose	62	3652.42			Radietor hose pipe-1pc (@Rs223)	223				

			pipe leakege to be check										
22	7	1400+2410+2540+1460+1570+1760+1750=12846		72	4241.52								
23	5	2650+1820+3910+2430+1230=12040		33	1944.03								
24	5	10101580+2050+2420+1710=6180	vehile pickup less, Air cleaner to be check break air droping	51	3004.41								
25	5	1820+3780+870+2580+1100=10150	break air badly droping, of four wheel	51	3004.41								
26	7	700+7050+1930+2400+2320+4060+1960=14120		70	4123.7								
27			front left weel stud bolt broken, warte liking from water pump through cheak and repair		0			1) weel stud - 8nos(@Rs236) 2) hose pipe- 1pc(@Rs223)	2111				

28	7	840+2410+2090+1730+4220+3260+2830=17160	king pin defective, Both weel dram heted	70	4123.7									
29	6	1950+610+3190+3840+1680+1840=18901	Veh. Pickup less, Air cleaneer to be check, Break air Droppping	59	3475.69			disel filter- 2nos (@Rs163)	326					
30	6	2770+2680+2790+2700+840+1460=14240		62	3652.42									
31			king pin defective, Clutch defectiv, top gear defectiv, front weel dram hetted		0			1)king pin repairing kit 1set (@Rs4380) 2) frong break shoue and rivet -1 set(@Rs2680), 3) nut with Washer -6nos (@Rs16) 3) Cambust (@Rs83) 4) O ring -1pc (@Rs 20)	7259					
Total value of cost month wise					88895.2		3039		11055		0		0	

June, 2018

Date	No. of trip	Total weight collection(kg)	Running Job For maintanance	Costing for Maintanance of vehicle									
				Fual(lit)	cost of fual	Engine Oil(lit.)	cost of engine oil (Rs)	Spear Parts	cost of Spear parts (Rs)	Tyer, Tube, Flap set	Tyere Cost	Battary	Battary cost

1	6	2320+1610+1190+2780+1940+2630=12470	Air drroping to be Check, P/S nut bolt to be check, All oil to be check	-									
2	6	3300+2400+1490+1500+1600+2140=12430	Front break air to be check & nessesary Work to be done	1230	72459.3								
3	8	1780+1720+2730+1580+2150+1670+100+352=162500		83	4889.53	tipper - 10 (@Rs141.75)	1417.5						
4			Air Cleaneer to be check		0	mobil-2 (@Rs70)	140	1)Air Cleaner Cover-1no(@Rs2915) 2) Air Ceaner Head-1set(@Rs1386) 3) Air cleaner filter-1Set (@Rs2341.90)	6642.9				
5	6	1220+1460+2060+2120+2180+1950=10990	Cabin	127	7481.5	steering	222.5	1) Nut &	460				

			maintanance air drope to be check all oil to be check P/S nut bolt loose		7	oil-1/2 (@Rs445)		Washer-4nos (@Rs70) 2) Bolt- 4 Nos (@Rs45)					
6	6	1050+840+3750+1680+15008=820		52	3063.32	Gear oil-3 (@Rs258)	774						
7	5	1260+1230+1140+1520+2480=7630	Disel liking from Disel filter, tobe check	55	3240.05	Break oil-1/2 (@Rs 380)	190	1) Disel Filter(Paper)-1pc (@Rs215.60) 2) Diesel Filter (Felt)-1pc(@Rs215.60)	431.2				
8	7	2470+3960+3700+1880+1320+2320+1230=16880		71	4182.61	coolent-1(@Rs295)	295						
9	6	1190+1730+1790+2300+1470+1800=10280		59	3475.69								
10					0								
11	6	1490+1920+2090+1190+2740+3060=12490	rear right side outer weel puncher to be check	-						tube-1	1246		
12	7	1540+2390+1990+1220+2400+1800+2730=14070		129	7599.39								

13	7	1430+2920+1990+1990+2410+2830+2250=15820	Air droping to be check, boom Slow lifting, Break to be check	67	3946.97								
14	5	2050+1440+2770+2060+2360=10180	Break air liking from air valve to be check and nessesary work to be done	55	3240.05			Dowel break valve cap-1 (@Rs8250)	8250				
15	6	1500+1040+1430+2010+1880+1730=9590		61	3593.51								
16	7	2890+2900+2010+2630+1710+2210+1640=16990		164	9661.24								
17	6	660+1010+500+2220+630+2240=7260		54	3181.14								
18	7	1500+1550+1450+1510+1130+1100+1250=9490		63	3711.33								
19	7	1670+2410+1460+1050+1490+920+1930=10930	Right side Stabilizer rib broken, P.T.O boom Slow lifting	71	4182.61								
20	6	1420+1900+2130+920+730+2200=9300	Battery turminal	-									

			loose										
21	6	1240+1660+1830+2360+1240+2100+=10430		115	6774.65								
22	5	1840+1690+1640+2260+750=8180	Tipper oil to be check and add, from air dropm, P/S to be check, horn is not properly acted	51	3004.41			1)horn 24 volt-1 (@Rs1578), 2) Black tap-1(@Rs84)	1662				
23	7	2730+1800+2250+2300+2270+1570+2270=15190		65	3829.15								
24	6	1600+1810+2680+1640+1180+2820=12430		56	3298.96								
25	6	1530+2190+1550+1440+2130+2470=11310		55	3240.05								
26	2	1840+2780=4620	rear right side outer weel cut out to be check	-						tyer-1	11520		
27					0								
28					0								
29					0								
30					0								
Total value of cost month wise					158056		3039		17446		12766		0

July, 2018

Date	No. of trip	Total weight collection(kg)	Running Job For maintanance	Costing for Maintanance of vehicle									
				Fual(lit)	cost of fual (@Rs58.91)	Engine Oil(lit.)	cost of engine oil (Rs)	Spear Parts	cost of Spear parts (Rs)	Tyer, Tube, Flap set	Tyere Cost	Battary	Battary cost
1	6	1890+1430+1960+1790+2180+1470=10720	1) Rear right side pipe broken 2) Break oil Coming from steering box 3)P/S Nut & bolt loose and all oil check	56	3298.96			1) Front Engine Mounting pad with nut bolt (@Rs354.2) 2)Radiator Braket Clamp (@Rs59.40)	413				
2	7	1490+2060+1720+1340+2200+2040=10850		72	4241.52								
3	5	2530+1820+620+1970+3080=8320		-		tipper - 10 (@Rs141.75)	1417.5						
4	6	2240+1920+3410+1300+1630+1370=11870		113	6656.83	mobil-2 (@Rs70)	140						

5	6	2190+2660+1500+2650+790+2420=11810	Cabin Both side door lock broken and repair, left side looking Glass broken, Wipper to be check and fitted	66	3888.06	steering oil-1/2 (@Rs445)	222.5	looking glass(@Rs678)	678				
6	6	1530+1640+1480+1940+2080+1380=10050		67	3946.97	Gear oil-3 (@Rs258)	774						
7	6	1270+1510+1510+1740+1140+1940=9110		69	4064.79	Break oil-1/2 (@Rs 380)	190						
8	6	1420+1070+1490+2280+2120+1460=9840		62	3652.42	coolent-1(@Rs295)	295						
9	6	670+1720+1480+1570+1350+1240=8030	Bad sound from Propeller Shaft	-				U/J cross-1pc (@Rs748.00)	748				
10	5	2460+1830+3000+1670+2540=11500	battery (11plate 12 volt) not charging properly	52	3063.32							2pc	9548
11	6	1990+2840+1990+2840+2550+2200+2440+1790=13810		69	4064.79								

12	6	1800+2120+2240+1900+2080+2550=11710	front right side weel tube puncher and weel cutout also to be check	68	4005.88					tyer -1, tube -1	12766		
13					0								
14					0								
15			Steering oil to be check		0								
16					0								
17					0								
18					0								
19					0								
20					0								
21					0								
22					0								
23					0								
24					0								
25			Gear 2nd and 4th defective to be check, clutch is hard tobe check throughly		0			Muster Cylinder Complite-1 (@Rs2230)	2230				

26	5	2380+1780+2000+2870+1850=10880	Gera liver defective , Steering oil to be check to be check,All oil to be check	27	1590.57			1)U bolt-2 (@Rs1090), 2) Tapper Washer-4 (@Rs 24)	2134	Received-1set	12766		
27	8	1390+3040+1430+2620+1270+2330+2550+570=15200		87	5125.17								
28	8	1970+4350+1940+1830+2060+1560+2370+1590=17670		89	5242.99								
29	8	2070+2350+2940+1490+2250+2210+2340+800+2750=19200	Vehicle not arising at damping ground	-				1)Flyweel Face plate assembly-1pc (@Rs4279.00) 2) Flyweel Ring Gear-1pc (@Rs12009.80) 3)Pressur Plate assembly 14" -1pc (@Rs17670.40) 4)Face plate pilot bearing (@Rs16402) 5) Clutch	39584				

								Plate14" - 1pc (@Rs3986.00)					
30	8	1940+2010+1340+3940+2700+3630+2140++1990=19690		191	11251.8								
31	7	2130+1400+2200+2210+36980+3900+1470=16790	rear right side inner weel tube puncher and weel cut out also	74	4359.34					tyer -1, tube -1	12766		
Total value of cost month wise					68453.4		3039		45787		38298		9548

August, 2018

Date	No. of trip	Total weight collection(kg)	Running Job For maintanance	Costing for Maintanance of vehicle									
				Fual(lit)	cost of fual (@Rs58.91)	Engine Oil(lit.)	cost of engine oil (Rs)	Spear Parts	cost of Spear parts (Rs)	Tyer, Tube, Flap set	Tyere Cost	Battary	Battary cost
1	7	3220+1260+2740+2180+2690+1600+2340=16030	P.T.O. Lifting is very slow, check and repair it	56	3298.96			P.T.O flange (@Rs1475)	1475				
2					0								
3	8	1620+2470+2960+2150+2390+2170+1620+1620=17000		64	3770.24	tipper - 10 (@Rs141.	1417.5						

						75)							
4	6	2810+1160+1540+2170+1850+2690=12020		48	2827.68	mobil-2 (@Rs70)	140						
5	5	1050+1300+1200+2050+2380=7980		40	2356.4	steering oil-1/2 (@Rs445)	222.5						
6	7	620+1160+3570+2660+1910+1510+1430=13100		74	4359.34	Gear oil-3 (@Rs258)	774						
7	6	2130+1000+3210+1930+2240+1830=12440		63	3711.33	Break oil-1/2 (@Rs 380)	190						
8	6	1940+2670+2480+1000+1260+1700=11050	Seering oil to be check, steering badly jam	63	3711.33	coolent-1(@Rs295)	295	1) Dry rod end-1pc(@Rs2405.70) 2) tie rod end-1, (@Rs2895.00)	5300.7				
9	7	2760+2050+2240+2600+1350+2900+2970=16810	front right side wheel puncher	80	4712.8								

10	6	4310+1700+2790+1170+1690+2280=14010	Right side boom U bolt broken, disel oil pipe broken, Boom liner Open out, Battary Survicing, Gear Defective , Seering Oil added	65	3829.15								
11	1	1040		-									
12					0								
13					0								
14	4	3310+1070+1840+2900=9120		40	2356.4								
15	7	2190+1170+2330+3190+2800+3620+1180=16880	rear left side inner weel tube puncher and weel cut out also to be check	74	4359.34					tyer-1, tube 1	12766		
16	3	134+2040+520=2694		30	1767.3								

17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													
31													
Total value of cost month wise					41060.3		3039		6775.7		12766		0

September, 2018

Date	No. of trip	Total weight collection(kg)	Running Job For maintanance	Costing for Maintanance of vehicle									
				Fual(lit)	cost of fual (@Rs58.91)	Engine Oil(lit.)	cost of engine oil (Rs)	Spear Parts	cost of Spear parts (Rs)	Tyer, Tube, Flap set	Tyere Cost	Battary	Battary cost
1													
2													
3													
4													
5	5	1530+1690+2230+1860+400=7710	Self not working properly to be	-				1)Self armeture (@Rs7148) 2) Oil Seal	7313				

			check					(@Rs120) 3)stander bnth (@Rs45)					
6	5	2810+2450+1580+1430+1320=9590		-		mobil-2 (@Rs70)	140						
7	5	4700+2260+2510+1190+2820=13480		103	6067.73	steering oil-1/2 (@Rs445)	222.5						
8	6	3020+2070+2070+2270+1810+2370=13610		62	3652.42	Gear oil-3 (@Rs258)	774						
9	6	3320+950+1770+2190+1850+1430=11510	Manifold to be Defect	63	3711.33	Break oil-1/2 (@Rs 380)	190	1)Silencer Manifold pipe-1pc(@Rs1914) 2) Silencer manifold packing-1pc (@Rs42.00)	1956				
10	6	1920+2390+2970+1710+1590+1400=11980		-		coolent-1(@Rs295)	295						
11	5	3940+2500+1950+1940+1860=12160	1) Air filter broken to be check 2) Redietor Hosh pipe broken	52	3063.32			1) Air filter-1pc (@Rs1654.40) 2) Air hose(@Rs223) 3)hose clamp (@Rs38)	1915.4				
12	6	3380+2940+3080+2190+1750+2540=15880	mobil & diesel	-				1) Mobil filter-1pc	658.5				

			filter to be check					(@Rs299.90) 2) disel filter-2pc (@Rs179.30)					
13	7	2380+2430+1550+3080+2480+1100+3400=16420		131	7717.21								
14	6	1770+2300+2920+1940+1830+2440=13200		2	117.82								
15	7	2570+1360+3620+2330+3210+2580+2260=17930		-									
16	6	2430+3200+3610+3010+5250+3960=21460		132	7776.12								
17	6	2140+1640+2280+4540+4980+3590=19170		62	3652.42								
18					0								
19	5	4210+3240+1790+3310+3350=15900	rear right side inner weel tube puncher	51	3004.41					tube -1	1246		
20	5	1760+4900+3430+1370+2170=13630		52	3063.32								
21	5	2830+2050+1130+1800+1760=9570	1) king pin defectiv e to be check 2)clatch defectiv e to be check 3)foot break air droping 4)top Gear	52	3063.32			1) king pin repearing kit-1 set (@Rs4470) 2) Front break shoe with revet-1set(@Rs2687) 3) cam bush-4pc (@Rs83) 4) 'O' ring-4pc(@Rs20	7933				

			defective to be check 5) front left side wheel dram defective to be check					) 5) 'I' bolt-1no (@Rs231) 6)Split Spring-2 nos (@Rs6) 9) munting nut-3pc(@Rs28) 10) banzo Washer-3pc (@Rs3)					
22	5	1120+2610+2170+930+3460=10290	Break not working properly	51	3004.41			1) break valve -1pc (@Rs6924.50)	6924.5				
23	6	2110+1770+2830+3540+3050+2520=15820		62	3652.42								
24	5	3440+2890+2430+710+720=10190		51	3004.41								
25	6	2810+1700+2050+2000+2950+3190=14700		-									
26	5	3100+2170+3870+3390+1460=13990		52	3063.32								
27	6	3370+3000+2000+2260+1900+2700=15230		-									
28	5	19502740+2250+1980+1630=10550		120	7069.2								
29	5	1740+3200+2300+1040+3540=11820		48	2827.68								
30	6	3610+1440+2460+1980+2030+2240=13960		60	3534.6								
Total value of cost month wise					71045.5		1621.5		26700		1246		0

October, 2019

Date	No. of trip	Total weight collection(kg)	Running Job For maintanance	Costing for Maintanance of vehicle									
				Fual(lit)	cost of fual (@Rs58.91)	Engine Oil(lit.)	cost of engine oil (Rs)	Spear Parts	cost of Spear parts (Rs)	Tyer, Tube, Flap set	Tyere Cost	Battary	Battary cost

1	6	1850+3220+2050+3350+4040+2970=17480	boom cylinder kit check and repair & filter to be check	50	2945.5			1)Boom cylinder Reapering kit both side (@Rs 4250) 2)hand primer (@Rs325) 3) Engine boxkit(@Rs 270)	4845				
2	6	3540+2090+2740+3430+1590+1270=14660	1)right looking glass broken 2) searing tipper oil break oil	48	2827.68								
3	6	2010+2250+1900+2050+1910+1780=11900		50	2945.5	tipper - 10 (@Rs141.75)	1417.5						
4	4	2840+1540+2890+2520=9790	Vehicle starting problem & battary down	32	1885.12	mobil-2 (@Rs70)	140	1)Self sterting Armatur (@Rs7148) 2)Self strater drive pinion(@Rs 1138.00) 3)Self auto switch (@Rs2270) 4)Self starter	65314				

								front casebem bosh (@Rs49844) 5) Self staterclatc h full(@Rs29 45) Half (@Rs1419. 60) 6) ignition switch (@Rs549)				
5	1	1190		8	471.28	steering oil-1/2 (@Rs445)	222.5						
6	6	2950+2400+4240+3040=12630	1) silencer pipe box broken to be check & work	32	1885.1 2	Gear oil-3 (@Rs258)	774	1) Silencer blow pipe (@Rs 1495.31) 2)silencer pipe (@Rs74852) 3) silencer box -1pc (@Rs38871) 4)Silencer pipe clamp- 2pc (@Rs220) 5) silencer box clamp-	11649 2				

								2pc (@Rs315.70) 6)Flange gasket-4pc (@Rs50.60)					
7	7	1150+1750+1580+1520+810+2070+3100=11980		56	3298.96	Break oil-1/2 (@Rs 380)	190						
8	7	1550+1230+2900+2040+1240+2060+1370=12390		56	3298.96	coolent-1(@Rs295)	295						
9	7	1990+1490+1150+1120+1430+1770+1560=10460		56	3298.96								
10	7	1390+1490+3420+2950+1730+2710+1190=14880		58	3416.78								
11	4	1100+1360+2150+1770=6380		35	2061.85								
12	7	1500+1680+1190+1730+2180+1650+920=10850		56	3298.96								
13	7	2260+1030+1560+1370+1730+810+2560=11320		58	3416.78								
14	4	1090+1310+1180+1740=5320		32	1885.12								
15	5	570+3590+900+2180+2480=9720		49	2886.59								
16					0								
17	6	2590+2730+3600+2130+2000+1030=14080		48	2827.68								
18	4	1690+2280+930+640=5540		32	1885.12								
19	7	2480+2380+7030+500+1450+920+1440=10900		56	3298.96								
20	6	2080+2660+1990+1930+2290+840=11590	Centyer Braring cross	52	3063.32								

			Open Out, Center Bearing rubber casing Broken										
21	7	1200+2230+2280+2640+1950+1390+3530=15220		56	3298.96								
22	6	1290+1800+3020+3780+3840+930=14660		48	2827.68								
23	5	2500+1160+970+3380+2250=10260		40	2356.4								
24	7	1070+2010+2870+2560+2660+1560+1390=14120		56	3298.96								
25	7	2960+1830+1920+2260+3490+3330+3550=19340	Brake not acting properly	56	3298.96			break valve assy.-1set(@Rs6924.50)	6524.5				
26	7	1220+2160+2740+3420+3550+2220+2270=17560		56	3298.96								
27					0								
28					0								
29	5	1620+1490+1220+4190+3140=11660		114	6715.74								
30	6	810+1070+2280+1500+3310+2440=11410		61	3593.51								
31	5	2390+1130+1080+3760+1070=7040	1)rear right side spring center bolt open out 2)rear right side spring pin loose to be check 3)left side	50	2945.5			1) sicel pin-2pc(@Rs277) 2)Center bolt-1pc(@Rs144) 3)Spring pin quater bolt-3pc (@Rs100)	1218				

			door lock broken					4) Spring clam-1 pc (@Rs 220)					
Total value of cost month wise					82532.9		3039		194393		0		0
November, 2018													
Date	No. of trip	Total weight collection(kg)	Running Job For maintanance	Costing for Maintanance of vehicle									
				Fual(lit)	cost of fual (@Rs58.91)	Engine Oil(lit.)	cost of engine oil (Rs)	Spear Parts	cost of Spear parts (Rs)	Tyer, Tube, Flap set	Tyere Cost	Battary	Battary cost
1	5	2670+810+1910+890+1780=8060		42	2474.22								
2	5	2430+940+2500+4730+610=11210		44	2592.04								
3	3	2000+2960+2540=7500		-									
4	6	2840+2640+2440+2710+1840+3240=16210		58	3416.78	tipper - 5 (@Rs141.75)	708.75						
5	5	1185+2470+1450+1660+1450=8920		50	2945.5	mobil-2 (@Rs70)	140						
6	7	910+1390+1580+1870+1670+2060+1890=11370		70	4123.7	steering oil-1/2 (@Rs445)	222.5						
7	3	1980+1530+2200=5710	steering Problem to be check	32	1885.12	Gear oil-2(@Rs258)	516	1)Steering Box kit-1pc (@Rs2695.00) 2) Steering box seal kit-1pc	4316.4				

								(@Rs778.80) 3) Steering Box 'O' ring kit-1pc (@Rs842.60)					
8	4	1800+2400+2620+1800=8620		46	2709.86	Break oil-1/2 (@Rs 380)	190						
9	7	910+1390+1580+1870+1670+2060+1890=11370		-		coolent-1(@Rs295)	295						
10		-		-									
11	5	2870+3320+3860+4720+2440=17210		50	2945.5								
12	6	2660+2130+3120+2710+2460+1930=15010	Gear liver problem	60	3534.6			1)Gear lever assembly-1pc(@Rs1911.80) 2) Gear shifting Lever-1pc(@Rs2798.40) 3) gear lever ganta-1pc(@Rs1265.00) 4)Gear lever ball joint-1pc(@Rs2286.90)	8262.1				
13	6	1930+1300+1490+2390+3290+2090=12930		62	3652.4								

					2								
14	5	2050+2430+2580+2020+1480=10650		52	3063.32								
15	5	1710+2790+1860+1890+1890=10140		53	3122.23								
16	5	830+1710+1970+1270+2220=8000		50	2945.5								
17	6	1710+2100+2220+2930+2480+1570=13010	steering Problem to be check	60	3534.6			1) steering box kit (@Rs 2695) 2) Stearing box Seal kit-1pc (@Rs778) 3)Steering box 'O' ring -1pc (@Rs842)	4279				
18	6	1510+1330+3040+3660+3950+2000=15490		60	3534.6								
19	6	1840+4390+1200+1670+1520+2080=12750	steering oil to be added,	60	3534.6								
20	7	1560+1690+3000+3210+1520+1000+2070=14050		56	3298.96								
21	6	1800+1770+1610+2010+1760+1090=10040	P/S cross defect, strting problem	48	2827.68								
22	6	1290+1800+3020+3780+3840+930=14660		48	2827.68								
23	5	2500+1160+970+3380+2250=10260		40	2356.4								
24	7	1070+2010+2870+2560+2660+1560+1390=14120		56	3298.96								
25	7	2960+1830+1920+2260+3490+3330+3550=19340	Brake not acting properly	56	3298.96			break valve assy.-1set(@Rs6924.50)	6524.5				

26	7	1220+2160+2740+3420+3550+2220+2270=17560		56	3298.96								
27	4	2730+2500+2630+2300=10180		32	1885.12								
28	6	2030+1850+2790+2910+970+1460=12010		48	2827.68								
29	6	2100+1710+1630+2410+1220+1770=10840		48	2827.68								
30	5	2670+2450+2230+1700=9050		40	2356.4								
Total value of cost month wise					81119.1		2072.3		23382		0		0

December, 2018

Date	No. of trip	Total weight collection(kg)	Running Job For maintanance	Costing for Maintanance of vehicle									
				Fual (lit)	cost of fual (@Rs58.91)	Engine Oil(lit.)	cost of engine oil (Rs)	Spear Parts	cost of Spear parts (Rs)	Tyer, Tube, Flap set	Tyere Cost	Battary	Battary cost
1													
2													
3	7	1730+1430+1990+1290+1290+2640+2010+1640=12730		56	3298.96	tipper - 10 (@Rs141.75)	1417.5						
4	6	1800+2070+2230+4440+3930+1970=16440		50	2945.5	mobil-2 (@Rs70)	140						
5	7	2220+1040+1570+2690+3440+2320+1860=15140	engine over heating, water cooling problem to be check	56	3298.96	steering oil-1/2 (@Rs445)	222.5	1) Radietor Assy.(@Rs13331.00) 2) redietor coolent- 1 lit (@Rs825.00) 3) radietor	15765				

								fan-1 pc (@Rs1609.00)					
6	5	2310+2860+2020+1490+2500=11180		40	2356.4	Gear oil-3 (@Rs258)	774						
7	6	2080+3380+3960+2230+2520+2550=16720		52	3063.32	Break oil-1/2 (@Rs 380)	190						
8	6	2160+4700+2710+2470+2230+1980=16250		48	2827.68	coolent-1(@Rs295)	295						
9	6	1930+1200+2600+2360+4470+1600=14160		48	2827.68								
10	7	2480+2030+2800+2270+3330+2530+2020=17460		56	3298.96								
11	7	1590+2660+2420+1650+3300+2020+4330=17970		56	3298.96								
12	6	2310+2220+1720+1590+2150+2250=12240		48	2827.68								
13	6	3030+2840+5800+2710+2830+2010=19220		48	2827.68								
14	6	1480+2250+3140+1880+2480+1470=12700	P/S problem to be check	48	2827.68			1) rear p/s complete set(@Rs12540) 2) front P/s complite (@Rs12010)	24550				
15	6	4420+2900+3700+4020+2880+2110=19930		48	2827.68								
16	6	2950+5010+3220+1730+1070=13980		48	2827.68								
17	6	2590+2730+3600+2130+2000+1030=14080		48	2827.68								
18	4	1690+2280+930+640=5540		32	1885.12								
19	7	2480+2380+7030+500+1450+920+1440=10900		56	3298.96								
20	6	2080+2660+1990+1930+2290+840=11590	Centyer Braring cross Open Out, Center Bearing	52	3063.32								

			rubber casing Broken										
21	7	1200+2230+2280+2640+1950+1390+3530=15220		56	3298.96								
22	5	1440+1840+1860+3130+2860=11130		48	2827.68								
23	6	2970+1040+4860+2360+3560+2050=16840		50	2945.5								
24	7	1140+3160+3330+3710+3950+2610+1420=19320	front right side wheel puncher	60	3534.6								
25	6	3730+3190+2040+3940+4030+2330=18260	rear front break shoe is not working properly	48	2827.68			1) rear break shoe lining-1set (@Rs7227) 2)front Break Shoe lining-1set (@Rs5583)	12810				
26	6	1990+1830+400+2090=10020		52	3063.32								
27	7	2340+2380+3050+1880+1750+2560+3910=17870		-									
28	5	1340+2080+1050+1120+3310=8900		40	2356.4								
29	7	2060+1360+1520+2460+1780+2180+1960=13320		56	3298.96								
30	7	1280+2460+2270+2770+2760+3850+2360=17750		56	3298.96								
31	7	2000+840+2940+1650+1800+3070+2240=14540	rear outer left side weel tube pucher to be check	60	3534.6					tube-1	1246		
Total value of cost month wise					83416.6		3039		53125		1246		0

Jannuary, 2019

Date	No. of trip	Total weight collection(kg)	Running Job For maintanance	Costing for Maintanance of vehicle									
				Fual (lit)	cost of fual (@Rs58.91)	Engine Oil(lit.)	cost of engine oil (Rs)	Spear Parts	cost of Spear parts (Rs)	Tyer, Tube, Flap set	Tyere Cost	Battary	Battary cost
1	6	1850+3220+2050+3350+4040+2970=17480	boom cylinder kit check and repair & filter to be check	50	2945.5			1)Boom cylinder Reapering kit both side (@Rs 4250) 2)hand primer (@Rs325) 3) Engine boxkit(@Rs 270)	4845				
2	6	3540+2090+2740+3430+1590+1270=14660	1)right looking glass broken 2) searing tipper oil break oil	48	2827.68								
3	6	2010+2250+1900+2050+1910+1780=11900		50	2945.5	tipper - 10 (@Rs141.75)	1417.5						
4	4	2840+1540+2890+2520=9790	Vehicle starting problem & battary down	32	1885.12	mobil-2 (@Rs70)	140	1)Self sterting Armatur (@Rs7148) 2)Self strater drive	65314				

								pinion(@Rs 1138.00) 3)Self auto switch (@Rs2270) 4)Self starter front casebem bosh (@Rs49844) 5) Self staterclatc h full(@Rs29 45) Half (@Rs1419. 60) 6) ignition switch (@Rs549)					
5	1	1190		8	471.28	steering oil-1/2 (@Rs445)	222.5						
6	6	2950+2400+4240+3040=12630	1) silencer pipe box broken to be check & work	32	1885.12	Gear oil-3 (@Rs258)	774	1) Silencer blow pipe (@Rs 1495.31) 2)silencer pipe (@Rs74852) 3) silencer box -1pc (@Rs38871	11649 2				

								) 4)Silencer pipe clamp- 2pc (@Rs220) 5) silencer box clamp- 2pc (@Rs315.70) 6)Flange gasket-4pc (@Rs50.60)					
7	6	2110+2830+3980+3250+19240=19240	Cilencer pipe box is broken to be chake, battary survicing	48	2827.68	Break oil-1/2 (@Rs 380)	190						
8		21			0	coolent-1(@Rs295)	295						
9					0								
10	4	2040+2030+3440+2840=10350	1) clatch not acting properly 2)Rear left side tipper boom pipe broken tipperb oil,mobile to be check	32	1885.12			1) clatch disch(@Rs6187)	6187				
11	4	1680+3080+560+2850=8840		32	1885.12								
12	6	1160+2800+1940+2360+2710+2960=13930		48	2827.68								
13	6	1160+2800+1940+2360+2710=29630	Feed pump	48	2827.68								

			defective, to be checked and work										
14	7	4280+2590+2990+2400+2220+1240+2170=17390		58	3416.78								
15	8	1820+1760+2170+2080+2760+2210+2030=18900		66	3888.06								
16	7	2740+1970+690+4210+1680+1710+1860=14860		56	3298.96								
17	3	1020+1430+1830=4280	1.Engine Over heated 2.Engine ont working properly 3.Bad smooke comming from Engine 4.Engine high race 5.Bad sound comming from Engine 6.Bad sound comming from Prop./Shaft 7.Break not working	24	1413.84			1.Turbocharger rep. Kit (@Rs3840) 2. Turbocharger fan & shaft(@Rs595) 3.Air Compressure Rep.kit (@Rs1675) 4.Air Compressure cylinder liner(@Rs) 5.Air Compressure piston ring(@Rs1675) 6.Air Compressure cam rod bearing	56478				

			Properly					(@Rs245) 7. Air Compressure packing (@Rs130) 8.Clutch pressure plate (@Rs16402) 9.Oil pump complete (@Rs3000) 10.Main Bearing(@Rs1800) 11. Fan Belt,(@Rs525) 12.Diesle filter(@Rs1631) 13. Mobile filter (@Rs240) 14.Main bearing oil seal (@Rs987)					
18	5	2700+1610+2290+2310+2690=11600		49	2886.59								
19	7	1320+890+1190+2580+2180+2000+1690=11850		56	3298.96								
20					0								
21	7	2390+3020+850+2640+4210+4290+3080=20480	PTO Engaging do not	56	3298.96								

			Working repair It										
22	6	2200+1100+3220+3680+3370+3020+4450+3850=23730		48	2827.68								
23	7	3450+2030+3560+3370+3020+4450+3850=23730		56	3298.96								
24	4	4120+2210+2710+1960=11000		32	1885.12								
25	5	3820+4590+2670+2500+1420=15000		40	2356.4								
26	6	2170+2620+2310+3490+2920=13510		48	2827.68								
27	7	730+3020+1650+2730+3940+2930+3150+2160=19580		58	3416.78								
28	7	830+2330+2370+3280+2880+2810+1260=14930		60	3534.6								
29	5	735+3110+3150+2990+1480+2300=13030		40	2356.4								
30	7	745+740+1740+3040+2570+2940+3020=14050	Battary turminal broken to be check and repair	56	3298.96								
31	7	3000+2410+2550+4160+1460+1380+2630=17590		58	3416.78								
Total value of cost month wise					75935		3039		249316		0		0

February, 2019

Date	No. of trip	Total weight collection(kg)	Running Job For maintanance	Costing for Maintanance of vehicle									
				Fual (lit)	cost of fual (@Rs58.91)	Engine Oil(lit.)	cost of engine oil (Rs)	Spear Parts	cost of Spear parts (Rs)	Tyer, Tube, Flap set	Tyere Cost	Battary	Battary cost
1	6	2210+2020+1240+2320+1370+1650=10810	Shock absorving problem to be	48	2827.68			1) shock absobver 2 nos (@Rs3443	16938				

			check					) 2) Shock adjustur - 4 nos(@Rs2513)					
2	7	1620+1560+880+1360+1530+3020+1320=11290		60	3534.6								
3	4	535+1760+1760+2180+1690=7390		32	1885.12	tipper - 9 (@Rs141.75)	1275.8						
4	7	1920+1920+2440+1630+1480+2850+2810+840=13970			0	mobil-2 (@Rs70)	140						
5			P/S center beraring rubber casing defective		0	steering oil-1/2 (@Rs445)	222.5						
6	4	2960+2210+2690+2200=10060	Break not working properly	33	1944.03	Gear oil-3 (@Rs258)	774	1)Rear break shoe linening-1pc (@Rs5646) 2) Front break shoe lining-1pc (@Rs4362)	10008				
7	7	1150+1750+1580+1520+810+2070+3100=11980		56	3298.96	Break oil-1/2 (@Rs380)	190						
8	7	1550+1230+2900+2040+1240+2060+1370=12390		56	3298.96	coolent-1(@Rs295	295						

						)							
9	7	1990+1490+1150+1120+1430+1770+1560=10460		56	3298.96								
10	7	1390+1490+3420+2950+1730+2710+1190=14880		58	3416.78								
11	4	1100+1360+2150+1770=6380		35	2061.85								
12	6	3040+540+1760+1450+1410+630=8830		48	2827.68								
13	7	750+2690+1450+2160+1380+3340+2020=13790		56	3298.96								
14	7	1500+1050+9080+2900+1560+1870+1240=13100		56	3298.96								
15	7	2200+1920+1400+1270+2010+3600+2030=14430		56	3298.96								
16	7	200+1820+1520+1200+1230+760+2680=11210		56	3298.96								
17	7	1620+820+1100+1180+2330+2260+3320=12630		58	3416.78								
18	7	590+2550+1510+1630+1370+1950+1410=11010		56	3298.96								
19	7	1280+1980+2290+2970+620+2000+840=11980	boom tipper pipe broken	56	3298.96			hydrolik hose pipe -2pc (@Rs7182.66)	14365				
20	7	2120+1650+2590+2700+1630+1570+2160=14420		56	3298.96								
21	5	2580+1520+2220+1870+1910=10100		42	2474.22								
22	7	1620+1840+600+2230+720+1740+680=9430		60	3534.6								
23	6	970+1500+1070+1140+780+1950=7410	battery (11plate 12 volt) not charging properly	48	2827.68							2pc	9548
24	6	1300+2530+1160+1190+230+1020=7430		48	2827.68								
25	6	1920+2480+4040+4010+2070+2520=17040											

26													
27													
28													
Total value of cost month wise					66568.3		2897.3		41311		0		9548

March, 2019

Date	No. of trip	Total weight collection(kg)	Running Job For maintanance	Costing for Maintanance of vehicle									
				Fual (lit)	cost of fual (@Rs58.91)	Engine Oil(lit.)	cost of engine oil (Rs)	Spear Parts	cost of Spear parts (Rs)	Tyer, Tube, Flap set	Tyere Cost	Battary	Battary cost
1													
2													
3													
4	6	1060+1050+1910+940+1540+1920=8420		49	2886.59	tipper - 10 (@Rs141.75)	1417.5						
5	4	2080+970+2980+2030=8060		32	1885.12	mobil-2 (@Rs70)	140						
6	7	1650+830+1850+1790+1920+2210+1020=11270		58	3416.78	steering oil-1/2 (@Rs445)	222.5						
7	7	1470+1760+1760+1370+770+2130+1410=21670		58	3416.78	Gear oil-3 (@Rs258)	774						
8	7	1650+1100+1140+1210+1880+1830+1890=10700	rear left side outer weel tube puncher and also weel cutout to be check	58	3416.78	Break oil-1/2 (@Rs 380)	190			tube-1, tyer-1	1276 6		
9	7	1160+1390+1110+1460+1700+2170+1950=109		55	3240.05	coolent-	295						

		40				1(@Rs295)							
10	6	1010+1090+1100+790+1560+900=6450		50	2945.5								
11	7	1400+1490+1470+1830+1930+2720+1240=120 80		56	3298.96								
12	7	1500+1680+1190+1730+2180+1650+920=1085 0		56	3298.96								
13	7	2260+1030+1560+1370+1730+810+2560=1132 0		58	3416.78								
14	4	1090+1310+1180+1740=5320		32	1885.12								
15	4	900+1240+1990+1090=5220	gear is not working, left side glass to be check, stop switch defective, cilencer pipe broken to be check, Air droping to be check	34	2002.94			1)Ignition switch (@Rs537), 2)Solenoid Switch (@RS 2251), 2)pressure plate complite (@Rs1640 2), 3)clutch disc (@Rs3986), 4)P.T.O shaft complite (@Rs4250), 5)Clatch sleev cylinder (@Rs1470),	44292				

								6)Actuator Spring (@Rs8706), 7)Selector Assemly (@Rs5940), 8)Break Unloader Repairing kit (@Rs750)					
16					0								
17					0								
18					0								
19					0								
20					0								
21					0								
22					0								
23					0								
24					0								
25					0								
26					0								
27					0								
28					0								
29					0								
30					0								
31					0								
Total value of cost month wise					35110.4		3039		44292		12766		0

SL NO	Annual summary of Transportation cost of Dumper-Placer WB03B-7957 of Dist-III garage, SWM-II Of Kolkata Municipal Corporation		
1	**Cost of fuel**	Rs	926,300.84
2	**Cost of Engine oil**	Rs	33,942.00
3	**cost of Spear parts**	Rs	726,725.84
4	**Tyre coast**	Rs	80,334.00
5	**Battery coast**	Rs	19,096.00
6	**Driver cost (@Rs20580/month)**	Rs	354,960.00
7	**Khalashi cost (@Rs25280/month)**	Rs	303,360.00
8	**Mechanic cost (2nos Mechanic @Rs31596/month)**	Rs	758,304.00
9	**Labor cost (@Rs25280/month)**	Rs	303,360.00
Total cost		Rs	3,203,022.68

Conversion of Organic Fluctuation Waste to Energy (Prescribe by C.P.H.E.E.O manual) for the period of April,18 to March,19 of the vehicle no WB03B-7957					
April, 2018 for Vehicle no WBO3B-7957					
Date	Total weight collection (W)(kg)	Organic Matter in Kg (50% of W)	Produce Bio Gas genaration (Cubic meter) (W X 0.1584)	power genaration potention in KW (W X 0.0115)	Manure 70% moisture in kg (W X 0.3)
4/1/2018	1330+2130+760+2170+2440=8830	4415	1398.672	101.545	2649
4/2/2018	3950+1370+830+2140+2210+2390+2190=17180	8590	2721.312	197.57	5154
4/3/2018	1000+3130+1620+3040+2050=10840	5420	1717.056	124.66	3252
4/4/2018	1890+1870+1590+2000++2630=9980	4990	1580.832	114.77	2994
4/5/2018	1060+1900+2380+1770+2890=10000	5000	1584	115	3000
4/6/2018	1350+870+2510+1270+2510=8510	4255	1347.984	97.865	2553
4/7/2018	1330+3630+1160+1510+2590=10260	5130	1625.184	117.99	3078
4/8/2018	1680+1090+2920+980+2840+1600=11110	5555	1759.824	127.765	3333
4/9/2018	2550+580+1140+1110+1310+860=7550	3775	1195.92	86.825	2265
4/10/2018	1020+1770+1410+2190=6390	3195	1012.176	73.485	1917
4/11/2018	1160+2420+1430+720+1280+2940=9950	4975	1576.08	114.425	2985
4/12/2018	1330+1330+1020+1970+1790=7440	3720	1178.496	85.56	2232
4/13/2018	1540+1860+780+1810+1480=7470	3735	1183.248	85.905	2241
4/14/2018	2410+730+1160+1170+1360=6830	3415	1081.872	78.545	2049

4/15/2018	1030+1520+900+750+1970=6170	3085	977.328	70.955	1851
4/16/2018		0	0	0	0
4/17/2018		0	0	0	0
4/18/2018		0	0	0	0
4/19/2018		0	0	0	0
4/20/2018		0	0	0	0
4/21/2018		0	0	0	0
4/22/2018	980+2160+2210+3390+2020=10760	5380	1704.384	123.74	3228
4/23/2018	1570+1700+3640+860+530+2260+1970=12530	6265	1984.752	144.095	3759
4/24/2018	740+1510+2020+1520+1120+1930=8840	4420	1400.256	101.66	2652
4/25/2018	770+1530+1630+4490+1920=10340	5170	1637.856	118.91	3102
4/26/2018		0	0	0	0
4/27/2018		0	0	0	0
4/28/2018	1620+1490+1220+4190+3140=11660	5830	1846.944	134.09	3498
4/29/2018	810+1070+2280+1500+3310+2440=11410	5705	1807.344	131.215	3423
4/30/2018	2390+1130+1080+3760+1070=7040	3520	1115.136	80.96	2112
Total	211090	105545	33436.656	2427.535	63327

May, 2018 for Vehicle no WBO3B-7957

Date	Total weight collection (W)(kg)	Organic Matter in Kg (50% of W)	Produce Bio Gas genaration (Cubic meter) (W X 0.1584)	power genaration potention in KW (W X 0.0115)	Manure 70% moisture in kg (W X 0.3)
5/1/2018	1990+1660+1850+2600+3470+3140=14660	7330	2322.144	168.59	4398
5/2/2018	840+690+3870+1540+2200=9140	4570	1447.776	105.11	2742

5/3/2018	2290+490+1190+1590+1650=7210	3605	1142.064	82.915	2163
5/4/2018	840+1310+3820+1150+1480=8600	4300	1362.24	98.9	2580
5/5/2018	520+1290+750+3920+2570=9050	4525	1433.52	104.075	2715
5/6/2018	830+1880+1800+4990+1160+2150=12810	6405	2029.104	147.315	3843
5/7/2018	1960+1850+330+1180+3410+1960=10690	5345	1693.296	122.935	3207
5/8/2018	800+1150+1000+4900+1800=9650	4825	1528.56	110.975	2895
5/9/2018	1970+570+1160+2020+3220+1650=10590	5295	1677.456	121.785	3177
5/10/2018	1290+1460+1780+3170+1510=9210	4605	1458.864	105.915	2763
5/11/2018	960+1230+760+1800+2130=6880	3440	1089.792	79.12	2064
5/12/2018	2120+710+1840+1900+1760=8330	4165	1319.472	95.795	2499
5/13/2018	2020+1080+1980+4070+800+3120=10970	5485	1737.648	126.155	3291
5/14/2018	3320+820+1410+1308+4040+2030=12980	6490	2056.032	149.27	3894
5/15/2018	570+3590+900+2180+2480=9720	4860	1539.648	111.78	2916
5/16/2018	830+930+2680+3730+2070+2240=12480	6240	1976.832	143.52	3744
5/17/2018	690+1880+2490+2190=7520	3760	1191.168	86.48	2256
5/18/2018	2210+2290+2230+1340+960+1290=10320	5160	1634.688	118.68	3096
5/19/2018	730+1010+1540+1660+3730+1850=10520	5260	1666.368	120.98	3156
5/20/2018	1830+1300+3920+1610+1640+2280=12580	6290	1992.672	144.67	3774
5/21/2018	1690+2860+680+3010+4010+2240=12990	6495	2057.616	149.385	3897
5/22/2018	1400+2410+2540+1460+1570+1760+1750=12846	6423	2034.8064	147.729	3853.8

5/23/2018	2650+1820+3910+2430+1230=12040	6020	1907.136	138.46	3612
5/24/2018	10101580+2050+2420+1710=6180	3090	978.912	71.07	1854
5/25/2018	1820+3780+870+2580+1100=10150	5075	1607.76	116.725	3045
5/26/2018	700+7050+1930+2400+2320+4060+1960=14120	7060	2236.608	162.38	4236
5/27/2018		0	0	0	0
5/28/2018	840+2410+2090+1730+4220+3260+2830=17160	8580	2718.144	197.34	5148
5/29/2018	1950+610+3190+3840+1680+1840=18901	9455	2995.344	217.465	5673
5/30/2018	2770+2680+2790+2700+840+1460=14240	7120	2255.616	163.76	4272
5/31/2018		0	0	0	0
Total	322546	161273	51091.2864	3709.279	96763.8

June, 2018 for Vehicle no WBO3B-7969

Date	Total weight collection (W)(kg)	Organic Matter in Kg (50% of W)	Produce Bio Gas genaration (Cubic meter) (W X 0.1584)	power genaration potention in KW (W X 0.0115)	Manure 70% moisture in kg (W X 0.3)
6/1/2018	2320+1610+1190+2780+1940+2630=12470	6235	1975.248	143.405	3741
6/2/2018	3300+2400+1490+1500+1600+2140=12430	6215	1968.912	142.945	3729
6/3/2018	1780+1720+2730+1580+2150+1670+100+352=12082	6041	1913.7888	138.943	3624.6
6/4/2018		0	0	0	0
6/5/2018	1220+1460+2060+2120+2180+1950=10990	5495	1740.816	126.385	3297
6/6/2018	1050+840+3750+1680+15008=22328	11164	3536.7552	256.772	6698.4

6/7/2018	1260+1230+1140+1520+2480=7630	3815	1208.592	87.745	2289
6/8/2018	2470+3960+3700+1880+1320+2320+1230=16880	8440	2673.792	194.12	5064
6/9/2018	1190+1730+1790+2300+1470+1800=10280	5140	1628.352	118.22	3084
6/10/2018		0	0	0	0
6/11/2018	1490+1920+2090+1190+2740+3060=12490	6245	1978.416	143.635	3747
6/12/2018	1540+2390+1990+1220+2400+1800+2730=14070	7035	2228.688	161.805	4221
6/13/2018	1430+2920+1990+1990+2410+2830+2250=15820	7910	2505.888	181.93	4746
6/14/2018	2050+1440+2770+2060+2360=10180	5090	1612.512	117.07	3054
6/15/2018	1500+1040+1430+2010+1880+1730=9590	4795	1519.056	110.285	2877
6/16/2018	2890+2900+2010+2630+1710+2210+1640=16990	8495	2691.216	195.385	5097
6/17/2018	660+1010+500+2220+630+2240=7260	3630	1149.984	83.49	2178
6/18/2018	1500+1550+1450+1510+1130+1100+1250=9490	4745	1503.216	109.135	2847
6/19/2018	1670+2410+1460+1050+1490+920+1930=10930	5465	1731.312	125.695	3279
6/20/2018	1420+1900+2130+920+730+2200=9300	4650	1473.12	106.95	2790
6/21/2018	1240+1660+1830+2360+1240+2100+=10430	5215	1652.112	119.945	3129
6/22/2018	1840+1690+1640+2260+750=8180	4090	1295.712	94.07	2454
6/23/2018	2730+1800+2250+2300+2270+1570+2270=15190	7595	2406.096	174.685	4557

6/24/2018	1600+1810+2680+1640+1180+2820=12430	6215	1968.912	142.945	3729
6/25/2018	1530+2190+1550+1440+2130+2470=11310	5655	1791.504	130.065	3393
6/26/2018	1840+2780=4620	2310	731.808	53.13	1386
6/27/2018		0	0	0	0
6/28/2018		0	0	0	0
6/29/2018		0	0	0	0
6/30/2018		0	0	0	0
Total	283370	141685	44885.808	3258.755	85011
July, 2018 for Vehicle no WBO3B-7957					
Date	Total weight collection (W)(kg)	Organic Matter in Kg (50% of W)	Produce Bio Gas genaration (Cubic meter) (W X 0.1584)	power genaration potention in KW (W X 0.0115)	Manure 70% moisture in kg (W X 0.3)
7/1/2018	1890+1430+1960+1790+2180+1470=10720	5360	1698.048	123.28	3216
7/2/2018	1490+2060+1720+1340+2200+2040=10850	5425	1718.64	124.775	3255
7/3/2018	2530+1820+620+1970+3080=8320	4160	1317.888	95.68	2496
7/4/2018	2240+1920+3410+1300+1630+1370=11870	5935	1880.208	136.505	3561
7/5/2018	2190+2660+1500+2650+790+2420=11810	5905	1870.704	135.815	3543
7/6/2018	1530+1640+1480+1940+2080+1380=10050	5025	1591.92	115.575	3015
7/7/2018	1270+1510+1510+1740+1140+1940=9110	4555	1443.024	104.765	2733
7/8/2018	1420+1070+1490+2280+2120+1460=9840	4920	1558.656	113.16	2952
7/9/2018	670+1720+1480+1570+1350+1240=8030	4015	1271.952	92.345	2409

7/10/2018	2460+1830+3000+1670+2540=11500	5750	1821.6	132.25	3450
7/11/2018	1990+2840+1990+2840+2550+2200+2440+1790=13810	6905	2187.504	158.815	4143
7/12/2018	1800+2120+2240+1900+2080+2550=11710	5855	1854.864	134.665	3513
7/13/2018		0	0	0	0
7/14/2018		0	0	0	0
7/15/2018		0	0	0	0
7/16/2018		0	0	0	0
7/17/2018		0	0	0	0
7/18/2018		0	0	0	0
7/19/2018		0	0	0	0
7/20/2018		0	0	0	0
7/21/2018		0	0	0	0
7/22/2018		0	0	0	0
7/23/2018		0	0	0	0
7/24/2018		0	0	0	0
7/25/2018		0	0	0	0
7/26/2018	2380+1780+2000+2870+1850=10880	5440	1723.392	125.12	3264
7/27/2018	1390+3040+1430+2620+1270+2330+2550+570=15200	7600	2407.68	174.8	4560
7/28/2018	1970+4350+1940+1830+2060+1560+2370+1590=17670	8835	2798.928	203.205	5301
7/29/2018	2070+2350+2940+1490+2250+2210+2340+800+2750=19200	9600	3041.28	220.8	5760
7/30/2018	1940+2010+1340+3940+2700+3630+2140++1990=19690	9845	3118.896	226.435	5907
7/31/2018	2130+1400+2200+2210+36980+3900+1470=16790	8395	2659.536	193.085	5037
Total	227050	113525	35964.72	2611.075	68115

August, 2018 for Vehicle no WBO3B-7957

Date	Total weight collection (W)(kg)	Organic Matter in Kg (50% of W)	Produce Bio Gas genaration (Cubic meter) (W X 0.1584)	power genaration potention in KW (W X 0.0115)	Manure 70% moisture in kg (W X 0.3)
8/1/2018	3220+1260+2740+2180+2690+1600+2340=16030	8015	2539.152	184.345	4809
8/2/2018		0	0	0	0
8/3/2018	1620+2470+2960+2150+2390+2170+1620+1620=17000	8500	2692.8	195.5	5100
8/4/2018	2810+1160+1540+2170+1850+2690=12020	6010	1903.968	138.23	3606
8/5/2018	1050+1300+1200+2050+2380=7980	3990	1264.032	91.77	2394
8/6/2018	620+1160+3570+2660+1910+1510+1430=13100	6550	2075.04	150.65	3930
8/7/2018	2130+1000+3210+1930+2240+1830=12440	6220	1970.496	143.06	3732
8/8/2018	1940+2670+2480+1000+1260+1700=11050	5525	1750.32	127.075	3315
8/9/2018	2760+2050+2240+2600+1350+2900+2970=16810	8405	2662.704	193.315	5043
8/10/2018	4310+1700+2790+1170+1690+2280=14010	7005	2219.184	161.115	4203
8/11/2018	1040	520	164.736	11.96	312
8/12/2018		0	0	0	0
8/13/2018		0	0	0	0
8/14/2018	3310+1070+1840+2900=9120	4560	1444.608	104.88	2736
8/15/2018	2190+1170+2330+3190+2800+3620+1180=16880	8440	2673.792	194.12	5064
8/16/2018	134+2040+520=2694	1347	426.7296	30.981	808.2
8/17/2018		0	0	0	0
8/18/2018		0	0	0	0

8/19/2018		0	0	0	0
8/20/2018		0	0	0	0
8/21/2018		0	0	0	0
8/22/2018		0	0	0	0
8/23/2018		0	0	0	0
8/24/2018		0	0	0	0
8/25/2018		0	0	0	0
8/26/2018		0	0	0	0
8/27/2018		0	0	0	0
8/28/2018		0	0	0	0
8/29/2018		0	0	0	0
8/30/2018		0	0	0	0
8/31/2018		0	0	0	0
Total	150174	75087	23787.5616	1727.001	45052.2

September, 2018 for Vehicle no WBO3B-7962

Date	Total weight collection (W)(kg)	Organic Matter in Kg (50% of W)	Produce Bio Gas genaration (Cubic meter) (W X 0.1584)	power genaration potention in KW (W X 0.0115)	Manure 70% moisture in kg (W X 0.3)
9/1/2018		0	0	0	0
9/2/2018		0	0	0	0
9/3/2018		0	0	0	0
9/4/2018		0	0	0	0
9/5/2018	1530+1690+2230+1860+400=7710	3855	1221.264	88.665	2313
9/6/2018	2810+2450+1580+1430+1320=9590	4795	1519.056	110.285	2877
9/7/2018	4700+2260+2510+1190+2820=13480	6740	2135.232	155.02	4044
9/8/2018	3020+2070+2070+2270+1810+2370=13610	6805	2155.824	156.515	4083

9/9/2018	3320+950+1770+2190+1850+1430=11510	5755	1823.184	132.365	3453
9/10/2018	1920+2390+2970+1710+1590+1400=11980	5990	1897.632	137.77	3594
9/11/2018	3940+2500+1950+1940+1860=12160	6080	1926.144	139.84	3648
9/12/2018	3380+2940+3080+2190+1750+2540=15880	7940	2515.392	182.62	4764
9/13/2018	2380+2430+1550+3080+2480+1100+3400=16420	8210	2600.928	188.83	4926
9/14/2018	1770+2300+2920+1940+1830+2440=13200	6600	2090.88	151.8	3960
9/15/2018	2570+1360+3620+2330+3210+2580+2260=17930	8965	2840.112	206.195	5379
9/16/2018	2430+3200+3610+3010+5250+3960=21460	10730	3399.264	246.79	6438
9/17/2018	2140+1640+2280+4540+4980+3590=19170	9855	3122.064	226.665	5913
9/18/2018		0	0	0	0
9/19/2018	4210+3240+1790+3310+3350=15900	7950	2518.56	182.85	4770
9/20/2018	1760+4900+3430+1370+2170=13630	6815	2158.992	156.745	4089
9/21/2018	2830+2050+1130+1800+1760=9570	4785	1515.888	110.055	2871
9/22/2018	1120+2610+2170+930+3460=10290	5145	1629.936	118.335	3087
9/23/2018	2110+1770+2830+3540+3050+2520=15820	7910	2505.888	181.93	4746
9/24/2018	3440+2890+2430+710+720=10190	5095	1614.096	117.185	3057
9/25/2018	2810+1700+2050+2000+2950+3190=14700	7350	2328.48	169.05	4410

9/26/2018	3100+2170+3870+3390+1460=13990	6995	2216.016	160.885	4197
9/27/2018	3370+3000+2000+2260+1900+2700=15230	7615	2412.432	175.145	4569
9/28/2018	19502740+2250+1980+1630=10550	5275	1671.12	121.325	3165
9/29/2018	1740+3200+2300+1040+3540=11820	5910	1872.288	135.93	3546
9/30/2018	3610+1440+2460+1980+2030+2240=13960	6980	2211.264	160.54	4188
Total	340290	170145	53901.936	3913.335	102087

October, 2018 for Vehicle no WBO3B-7957

Date	Total weight collection (W)(kg)	Organic Matter in Kg (50% of W)	Produce Bio Gas genaration (Cubic meter) (W X 0.1584)	power genaration potention in KW (W X 0.0115)	Manure 70% moisture in kg (W X 0.3)
10/1/2019	1850+3220+2050+3350+4040+2970=17480	8740	2768.832	201.02	5244
10/2/2019	3540+2090+2740+3430+1590+1270=14660	7330	2322.144	168.59	4398
10/3/2019	2010+2250+1900+2050+1910+1780=11900	5950	1884.96	136.85	3570
10/4/2019	2840+1540+2890+2520=9790	4895	1550.736	112.585	2937
10/5/2019	1190	595	188.496	13.685	357
10/6/2019	2950+2400+4240+3040=12630	6315	2000.592	145.245	3789
10/7/2019	1150+1750+1580+1520+810+2070+3100=11980	5990	1897.632	137.77	3594
10/8/2019	1550+1230+2900+2040+1240+2060+1370=12390	6195	1962.576	142.485	3717
10/9/2019	1990+1490+1150+1120+1430+1770+1560=10460	5230	1656.864	120.29	3138

10/10/2019	1390+1490+3420+2950+1730+2710+1190=14880	7440	2356.992	171.12	4464
10/11/2019	1100+1360+2150+1770=6380	3190	1010.592	73.37	1914
10/12/2019	1500+1680+1190+1730+2180+1650+920=10850	5425	1718.64	124.775	3255
10/13/2019	2260+1030+1560+1370+1730+810+2560=11320	5660	1793.088	130.18	3396
10/14/2019	1090+1310+1180+1740=5320	2660	842.688	61.18	1596
10/15/2019	570+3590+900+2180+2480=9720	4860	1539.648	111.78	2916
10/16/2019		0	0	0	0
10/17/2019	2590+2730+3600+2130+2000+1030=14080	7040	2230.272	161.92	4224
10/18/2019	1690+2280+930+640=5540	2770	877.536	63.71	1662
10/19/2019	2480+2380+7030+500+1450+920+1440=10900	5450	1726.56	125.35	3270
10/20/2019	2080+2660+1990+1930+2290+840=11590	5795	1835.856	133.285	3477
10/21/2019	1200+2230+2280+2640+1950+1390+3530=15220	7610	2410.848	175.03	4566
10/22/2019	1290+1800+3020+3780+3840+930=14660	7330	2322.144	168.59	4398
10/23/2019	2500+1160+970+3380+2250=10260	5130	1625.184	117.99	3078
10/24/2019	1070+2010+2870+2560+2660+1560+1390=14120	7060	2236.608	162.38	4236
10/25/2019	2960+1830+1920+2260+3490+3330+3550=19340	9670	3063.456	222.41	5802
10/26/2019	1220+2160+2740+3420+3550+2220+2270=17560	8780	2781.504	201.94	5268
10/27/2019		0	0	0	0
10/28/2019		0	0	0	0
10/29/2019	1620+1490+1220+4190+3140=11660	5830	1846.944	134.09	3498

10/30/2019	810+1070+2280+1500+3310+2440=11410	5705	1807.344	131.215	3423
10/31/2019	2390+1130+1080+3760+1070=7040	3520	1115.136	80.96	2112
Total	324330	162165	51373.872	3729.795	97299

November, 2018 for Vehicle no WBO3B-7957

Date	Total weight collection (W)(kg)	Organic Matter in Kg (50% of W)	Produce Bio Gas genaration (Cubic meter) (W X 0.1584)	power genaration potention in KW (W X 0.0115)	Manure 70% moisture in kg (W X 0.3)
11/1/2018	2670+810+1910+890+1780=8060	4030	1276.704	92.69	2418
11/2/2018	2430+940+2500+4730+610=11210	5605	1775.664	128.915	3363
11/3/2018	2000+2960+2540=7500	3750	1188	86.25	2250
11/4/2018	2840+2640+2440+2710+1840+3240=16210	6305	1997.424	145.015	3783
11/5/2018	1185+2470+1450+1660+1450=8920	4460	1412.928	102.58	2676
11/6/2018	910+1390+1580+1870+1670+2060+1890=11370	5685	1801.008	130.755	3411
11/7/2018	1980+1530+2200=5710	2855	904.464	65.665	1713
11/8/2018	1800+2400+2620+1800=8620	4310	1365.408	99.13	2586
11/9/2018	910+1390+1580+1870+1670+2060+1890=11370	5685	1801.008	130.755	3411
11/10/2018	-	0	0	0	0
11/11/2018	2870+3320+3860+4720+2440=17210	8605	2726.064	197.915	5163
11/12/2018	2660+2130+3120+2710+2460+1930=15010	7505	2377.584	172.615	4503
11/13/2018	1930+1300+1490+2390+3290+2090=12930	6465	2048.112	148.695	3879
11/14/2018	2050+2430+2580+2020+1480=10650	5325	1686.96	122.475	3195

11/15/2018	1710+2790+1860+1890+1890=10140	5070	1606.176	116.61	3042
11/16/2018	830+1710+1970+1270+2220=8000	4000	1267.2	92	2400
11/17/2018	1710+2100+2220+2930+2480+1570=13010	6505	2060.784	149.615	3903
11/18/2018	1510+1330+3040+3660+3950+2000=15490	7745	2453.616	178.135	4647
11/19/2018	1840+4390+1200+1670+1520+2080=12750	6375	2019.6	146.625	3825
11/20/2018	1560+1690+3000+3210+1520+1000+2070=14050	7025	2225.52	161.575	4215
11/21/2018	1800+1770+1610+2010+1760+1090=10040	5020	1590.336	115.46	3012
11/22/2018	1290+1800+3020+3780+3840+930=14660	7330	2322.144	168.59	4398
11/23/2018	2500+1160+970+3380+2250=10260	5130	1625.184	117.99	3078
11/24/2018	1070+2010+2870+2560+2660+1560+1390=14120	7060	2236.608	162.38	4236
11/25/2018	2960+1830+1920+2260+3490+3330+3550=19340	9670	3063.456	222.41	5802
11/26/2018	1220+2160+2740+3420+3550+2220+2270=17560	8780	2781.504	201.94	5268
11/27/2018	2730+2500+2630+2300=10180	5090	1612.512	117.07	3054
11/28/2018	2030+1850+2790+2910+970+1460=12010	6005	1902.384	138.115	3603
11/29/2018	2100+1710+1630+2410+1220+1770=10840	5420	1717.056	124.66	3252
11/30/2018	2670+2450+2230+1700=9050	4525	1433.52	104.075	2715
Total	342670	171335	54278.928	3940.705	102801
December, 2018 for Vehicle no WBO3B-7957					
Date	Total weight collection (W)(kg)	Organic Matter	Produce Bio Gas	power	Manure 70% moisture in

		in Kg (50% of W)	genaration (Cubic meter) (W X 0.1584)	genaration potention in KW (W X 0.0115)	kg (W X 0.3)
12/1/2018		0	0	0	0
12/2/2018		0	0	0	0
12/3/2018	1730+1430+1990+1290+1290+2640+2010+1640=12730	6365	2016.432	146.395	3819
12/4/2018	1800+2070+2230+4440+3930+1970=16440	8220	2604.096	189.06	4932
12/5/2018	2220+1040+1570+2690+3440+2320+1860=15140	7570	2398.176	174.11	4542
12/6/2018	2310+2860+2020+1490+2500=11180	5590	1770.912	128.57	3354
12/7/2018	2080+3380+3960+2230+2520+2550=16720	8360	2648.448	192.28	5016
12/8/2018	2160+4700+2710+2470+2230+1980=16250	8125	2574	186.875	4875
12/9/2018	1930+1200+2600+2360+4470+1600=14160	7080	2242.944	162.84	4248
12/10/2018	2480+2030+2800+2270+3330+2530+2020=17460	8730	2765.664	200.79	5238
12/11/2018	1590+2660+2420+1650+3300+2020+4330=17970	8985	2846.448	206.655	5391
12/12/2018	2310+2220+1720+1590+2150+2250=12240	6120	1938.816	140.76	3672
12/13/2018	3030+2840+5800+2710+2830+2010=19220	9610	3044.448	221.03	5766
12/14/2018	1480+2250+3140+1880+2480+1470=12700	6350	2011.68	146.05	3810
12/15/2018	4420+2900+3700+4020+2880+2110=19930	9965	3156.912	229.195	5979
12/16/2018	2950+5010+3220+1730+1070=13980	6990	2214.432	160.77	4194

12/17/2018	2590+2730+3600+2130+2000+1030=14080	7040	2230.272	161.92	4224
12/18/2018	1690+2280+930+640=5540	2770	877.536	63.71	1662
12/19/2018	2480+2380+7030+500+1450+920+1440=10900	5450	1726.56	125.35	3270
12/20/2018	2080+2660+1990+1930+2290+840=11590	5795	1835.856	133.285	3477
12/21/2018	1200+2230+2280+2640+1950+1390+3530=15220	7610	2410.848	175.03	4566
12/22/2018	1440+1840+1860+3130+2860=11130	5565	1762.992	127.995	3339
12/23/2018	2970+1040+4860+2360+3560+2050=16840	8420	2667.456	193.66	5052
12/24/2018	1140+3160+3330+3710+3950+2610+1420=19320	9660	3060.288	222.18	5796
12/25/2018	3730+3190+2040+3940+4030+2330=18260	9130	2892.384	209.99	5478
12/26/2018	1990+1830+400+2090=10020	5010	1587.168	115.23	3006
12/27/2018	2340+2380+3050+1880+1750+2560+3910=17870	8935	2830.608	205.505	5361
12/28/2018	1340+2080+1050+1120+3310=8900	4450	1409.76	102.35	2670
12/29/2018	2060+1360+1520+2460+1780+2180+1960=13320	6660	2109.888	153.18	3996
12/30/2018	1280+2460+2270+2770+2760+3850+2360=17750	8875	2811.6	204.125	5325
12/31/2018	2000+840+2940+1650+1800+3070+2240=14540	7270	2303.136	167.21	4362
Total	421400	210700	66749.76	4846.1	126420
Jannuary, 2019 for Vehicle no WBO3B-7957					
Date	Total weight collection (W)(kg)	Organic Matter	Produce Bio Gas	power	Manure 70% moisture in

		in Kg (50% of W)	genaration (Cubic meter) (W X 0.1584)	genaration potention in KW (W X 0.0115)	kg (W X 0.3)
1/1/2019	1850+3220+2050+3350+4040+2970=17480	857	271.4976	19.711	514.2
2-Jan	3540+2090+2740+3430+1590+1270=14660	733	232.2144	16.859	439.8
1/3/2019	2010+2250+1900+2050+1910+1780=11900	5950	1884.96	136.85	3570
4-Jan	2840+1540+2890+2520=9790	4895	1550.736	112.585	2937
1/5/2019	1190	595	188.496	13.685	357
6-Jan	2950+2400+4240+3040=12630	6315	2000.592	145.245	3789
1/7/2019	2110+2830+3980+3250+19240=19240	9620	3047.616	221.26	5772
8-Jan	21	10.5	3.3264	0.2415	6.3
1/9/2019		0	0	0	0
10-Jan	2040+2030+3440+2840=10350	5175	1639.44	119.025	3105
1/11/2019	1680+3080+560+2850=8840	4420	1400.256	101.66	2652
12-Jan	1160+2800+1940+2360+2710+2960=13930	6965	2206.512	160.195	4179
1/13/2019	1160+2800+1940+2360+2710=29630	14815	4693.392	340.745	8889
14-Jan	4280+2590+2990+2400+2220+1240+2170=17390	8695	2754.576	199.985	5217
1/15/2019	1820+1760+2170+2080+2760+2210+2030=18900	9450	2993.76	217.35	5670
16-Jan	2740+1970+690+4210+1680+1710+1860=14860	7430	2353.824	170.89	4458
1/17/2019	1020+1430+1830=4280	2140	677.952	49.22	1284
18-Jan	2700+1610+2290+2310+2690=11600	5800	1837.44	133.4	3480
1/19/2019	1320+890+1190+2580+2180+2000+1690=11850	5925	1877.04	136.275	3555

20-Jan		0	0	0	0
1/21/2019	2390+3020+850+2640+4210+4290+3080=20480	10240	3244.032	235.52	6144
22-Jan	2200+1100+3220+3680+3370+3020+4450+3850=23730	11865	3758.832	272.895	7119
1/23/2019	3450+2030+3560+3370+3020+4450+3850=23730	11865	3758.832	272.895	7119
24-Jan	4120+2210+2710+1960=11000	5500	1742.4	126.5	3300
1/25/2019	3820+4590+2670+2500+1420=15000	7500	2376	172.5	4500
26-Jan	2170+2620+2310+3490+2920=13510	6755	2139.984	155.365	4053
1/27/2019	730+3020+1650+2730+3940+2930+3150+2160=19580	9790	3101.472	225.17	5874
28-Jan	830+2330+2370+3280+2880+2810+1260=14930	7465	2364.912	171.695	4479
1/29/2019	735+3110+3150+2990+1480+2300=13030	1515	479.952	34.845	909
30-Jan	745+740+1740+3040+2570+2940+3020=14050	7025	2225.52	161.575	4215
1/31/2019	3000+2410+2550+4160+1460+1380+2630=17590	8795	2786.256	202.285	5277
Total	376211	188105.5	59591.8224	4326.4265	112863.3
February, 2019 for Vehicle no WBO3B-7957					
Date	Total weight collection (W)(kg)	Organic Matter in Kg (50% of W)	Produce Bio Gas genaration (Cubic meter) (W X 0.1584)	power genaration potention in KW (W X 0.0115)	Manure 70% moisture in kg (W X 0.3)
2/1/2019	2210+2020+1240+2320+1370+1650=10810	5405	1712.304	124.315	3243
2/2/2019	1620+1560+880+1360+1530+3020+1320=11290	5645	1788.336	129.835	3387

2/3/2019	535+1760+1760+2180+1690=7390	3695	1170.576	84.985	2217
2/4/2019	1920+1920+2440+1630+1480+2850+2810+840=13970	6985	2212.848	160.655	4191
2/5/2019		0	0	0	0
2/6/2019	2960+2210+2690+2200=10060	5030	1593.504	115.69	3018
2/7/2019	1150+1750+1580+1520+810+2070+3100=11980	5990	1897.632	137.77	3594
2/8/2019	1550+1230+2900+2040+1240+2060+1370=12390	6195	1962.576	142.485	3717
2/9/2019	1990+1490+1150+1120+1430+1770+1560=10460	5230	1656.864	120.29	3138
2/10/2019	1390+1490+3420+2950+1730+2710+1190=14880	7440	2356.992	171.12	4464
2/11/2019	1100+1360+2150+1770=6380	3190	1010.592	73.37	1914
2/12/2019	3040+540+1760+1450+1410+630=8830	4415	1398.672	101.545	2649
2/13/2019	750+2690+1450+2160+1380+3340+2020=13790	6895	2184.336	158.585	4137
2/14/2019	1500+1050+9080+2900+1560+1870+1240=13100	6550	2075.04	150.65	3930
2/15/2019	2200+1920+1400+1270+2010+3600+2030=14430	7215	2285.712	165.945	4329
2/16/2019	200+1820+1520+1200+1230+760+2680=11210	5605	1775.664	128.915	3363
2/17/2019	1620+820+1100+1180+2330+2260+3320=12630	6315	2000.592	145.245	3789
2/18/2019	590+2550+1510+1630+1370+1950+1410=11010	5505	1743.984	126.615	3303
2/19/2019	1280+1980+2290+2970+620+2000+840=11980	5990	1897.632	137.77	3594
2/20/2019	2120+1650+2590+2700+1630+1570+2160=14420	7210	2284.128	165.83	4326

2/21/2019	2580+1520+2220+1870+1910=10100	5050	1599.84	116.15	3030
2/22/2019	1620+1840+600+2230+720+1740+680=9430	4715	1493.712	108.445	2829
2/23/2019	970+1500+1070+1140+780+1950=7410	3705	1173.744	85.215	2223
2/24/2019	1300+2530+1160+1190+230+1020=7430	3715	1176.912	85.445	2229
2/25/2019	1920+2480+4040+4010+2070+2520=17040	8520	2699.136	195.96	5112
2/26/2019		0	0	0	0
2/27/2019		0	0	0	0
2/28/2019		0	0	0	0
Total	272420	136210	43151.328	3132.83	81726

March, 2019 for Vehicle no WBO3B-7957

Date	Total weight collection (W)(kg)	Organic Matter in Kg (50% of W)	Produce Bio Gas genaration (Cubic meter) (W X 0.1584)	power genaration potention in KW (W X 0.0115)	Manure 70% moisture in kg (W X 0.3)
3/1/2019		0	0	0	0
3/2/2019		0	0	0	0
3/3/2019		0	0	0	0
3/4/2019	1060+1050+1910+940+1540+1920=8420	4210	1333.728	96.83	2526
3/5/2019	2080+970+2980+2030=8060	4030	1276.704	92.69	2418
3/6/2019	1650+830+1850+1790+1920+2210+1020=11270	5635	1785.168	129.605	3381
3/7/2019	1470+1760+1760+1370+770+2130+1410=21670	10835	3432.528	249.205	6501
3/8/2019	1650+1100+1140+1210+1880+1830+1890=10700	5350	1694.88	123.05	3210

3/9/2019	1160+1390+1110+1460+1700+2170+1950=10940	5470	1732.896	125.81	3282
3/10/2019	1010+1090+1100+790+1560+900=6450	3225	1021.68	74.175	1935
3/11/2019	1400+1490+1470+1830+1930+2720+1240=12080	6040	1913.472	138.92	3624
3/12/2019	1500+1680+1190+1730+2180+1650+920=10850	5425	1718.64	124.775	3255
3/13/2019	2260+1030+1560+1370+1730+810+2560=11320	5660	1793.088	130.18	3396
3/14/2019	1090+1310+1180+1740=5320	2660	842.688	61.18	1596
3/15/2019	900+1240+1990+1090=5220	2610	826.848	60.03	1566
3/16/2019		0	0	0	0
3/17/2019		0	0	0	0
3/18/2019		0	0	0	0
3/19/2019		0	0	0	0
3/20/2019		0	0	0	0
3/21/2019		0	0	0	0
3/22/2019		0	0	0	0
3/23/2019		0	0	0	0
3/24/2019		0	0	0	0
3/25/2019		0	0	0	0
3/26/2019		0	0	0	0
3/27/2019		0	0	0	0
3/28/2019		0	0	0	0
3/29/2019		0	0	0	0
3/30/2019		0	0	0	0
3/31/2019		0	0	0	0
Total	122300	61150	19372.32	1406.45	36690

ORGANIC WASTE AND WATER RATIO 1:1

SL. NO.	Annual Summary of Result of Energy Conversion of Organic waste	
1	Produce Biogas generation	537585.9984 m^3
2	Power generation potential	39029.2865 KW
3	Manure 70% moisture	916068.3 Kg

CHAPTER – 5

CONCLUSION

CONCLUSION:

The scope of future waste generation is here analyzed by forecasting method, illustrates the estimates of waste quantum for period from 2011 to 2041 which shows that if the growth of population and the growth of percentage increase in per capita waste generation rate will be increase proportionally.

To achieve a target of 100% collection, transportation, treatment and disposal, Municipal Corporation would first need to prepare a macro plan which would identify the quantity of waste generated in the whole municipality and the broad strategy to be adopted to manage the system. This should be followed by a micro or locality-based plan, which would provide details as to routes, timing, equipments, and manpower deployment. With rapid development of economy and change of living standard, waste composition is expected to change. For a decoupling to take place between economic growth and waste generation, the waste generation by firms and households in relation to their economic activities must decrease in the future. A number of studies have found that the higher the household income and standard of living, the higher the amount of MSW generated.

Success of Solid Waste Management System is directly related to Disposal efficiency. It is decided upon how much of the total dumped waste is finally disposed properly. To dispose waste in efficient way technology knowledge, trained Manpower, appropriate infrastructure & availability of land is required.

The present study also indicated that much larger land areas need to be used for landfill shortage of natural resources such as land because the municipal solid waste generation will be increased. The biodegradable waste can be processed by aerobic compositing, Vermi compositing, anaerobic digestion or any other appropriate biological processing for stabilization of waste. Regarding municipal solid waste to energy, it should be either thermally treated or biologically treated. The other options are Pyrolysis and Plasma technology which are not cost effective. It is necessary for the success of such technology in municipalities to evolve and integrated waste management system, coupled with necessary legislative and control measures.

The current regulations (MSWM rules, 2000) are very stringent. Norms have been developed to ensure a proper MSWM system. Unfortunately, clearly there is a large gap between policy and implementation. The producer responsibility is to avoid having products on the market that cannot be handled effectively and environmentally correctly when they become waste products.

Finally, the study concluded that the lack of resources such as financing, infrastructure, suitable planning, data and leadership, are the main barriers in MSWM. The increase of service demands combined with the lack of resources for municipalities are putting a huge strain on the existing MSWM system.

RECOMMENDATION:

The following recommendations are made:

- Quantitative are qualitative analysis of MSW should be carried out for municipal towns for assessment of generation, characteristics, proportion, chemical components, density and calorific value.
- Practice of segregation of MSW (organic, non-recyclable inorganic and recyclable inorganic) at the source of generation need to be introduced for introduction of rational management of waste.
- Practice of storing MSW in road side vats must be abolished.
- In each ward at least one Primary Transfer Station may be considered.
- The secondary transportation in MSW should be designed by the networking all the wards.
- Recycling of certain category of inorganic waste should be encouraged by the ULBs.
- Alternative option for treatment and disposal of waste e.g. bio-gas generation, refused derived fuel generation etc. may be explored for adoption, if feasible.

CHAPTER -6

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[66] 15130 (part 3): 2002/ISO 6974-3: 2000 Natural gas composition

[67] IS 15319 Biogas (Biomithane)

APPENDIX -I

I. **Anaerobic digestion:** It means a controlled process involving microbial decomposition of organic matter in the absence of oxygen.

II. **Authorization:**It means the consent given by the Board or Committee to the "operator of a facility".

III. **Biodegradable substance:** It means a substance that can be degraded by micro-organisms.

IV. **Biomethanation:** It means a process which entails enzymatic decomposition of the organic matter by microbial action to produce methane rich biogas.

V. **Collection:** It means lifting and removal of solid wastes from collection points or any other location.

VI. **Compositing:** It means a controlled process involving microbial decomposition of organic matter.

VII. **Demolition and construction waste:** It means wastes from building materials debris and rubble resulting from construction, remodeling, repair and demolition operation.

VIII. **Disposal:** It means final disposal of municipal solid wastes in terms of the specified measures to prevent contamination of ground-water, surface water and ambient air quality.

IX. **Form:** It means a form appended to these rules.

X. **Generators of wastes:** It means persons or establishments generating municipal solid wastes.

XI. **Landfilling:** It means disposal of residual solid wastes on land in a facility designed with protective measures against pollution of ground water, surface water and air fugitive dust, wind-blown lifter, bad-odour, fire hazard, bird menace, pests or rodents, greenhouse gas emissions, slope instability and erosion.

XII. **Leachate:** It means liquid that seeps through solid wastes or other medium and has extracts of dissolved or suspended material from it.

APPENDIX -II

I. **CPHEEO:** Central Public Health and Environmental Engineering Organization
II. **MSWM:** Municipal Solid Waste Management
III. **SWM:** Solid Waste Management
IV. **CPCB:** Central Pollution Control Board
V. **NERRI:** National Engineering and Environmental Research Institute
VI. **ULBs:** Urban Local Bodies
VII. **ECR:** Environment Conservation Rule
VIII. **ARTI:** Appropriate Rural Technology of India
IX. **CDM:** Clean Development Mechanism
X. **GHG:** Green House Gas
XI. **CSTR:** Continuously Stirred Tank Reactor
XII. **PPP:** Public-Private Partnership
XIII. **APHA:** American Public Health Association
XIV. **MO:** Micro Organism
XV. **AD:** Anaerobic Digestion
XVI. **C/N:** Carbon Nitrogen Ratio
XVII. **MT:** Metric Ton
XVIII. **KMC:** Kolkata Municipal Corporation