WATER AND SOIL QUALITY MONITORING AROUND DHAPA LANDFILL SITE FOR HUMAN HEALTH RISK ASSESSMENT

A THESIS IS SUBMITTED FOR THE PARTIAL FULFILLMENT OF THE CONTINUOUS ASSESSMENT OF THE COURSE OF MASTER OF CIVIL ENGINEERING OF JADAVPUR UNIVERSITY FOR THE SESSION 2015-2016

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DECLARATION

This thesis titled "**water and soil quality monitoring around dhapa landfill site for human health risk assessment**" is prepared and submitted for the partial fulfillment of the continuous assessment of Master of Engineering in Environmental Engineering course of Jadavpur University for the session 2015-2016.

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CERTIFICATE OF APPROVAL*

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Final Examination for evaluation of thesis

(Signature of Examiner)

*Only in case the thesis is approved

ACKNOWLEDGEMENT

At the outset I would like to express my deep gratitude and kindest regards to Dr. Somnath Mukerjee for his invaluable and generous guidance rendered to me for the preparation of this Thesis report. This Thesis would have never been completed without his guidance, supervision and inspiration at all stages of the work.

I am sincerely thankful and indebted to Prof.S.N.Chakrabarty, Dr. A. Dutta, Dr. A. Debsarkar, and Dr. T. Hazra, faculty members, Env. Engg Div., Jadavpur University for their constant encouragement and continuous valuable suggestions throughout my thesis work.

I would like to express my appreciation to Dr. Vandana Parth, UGC, Post doctoral fellow for her constant inspiration and kind support during the work.

I am also very grateful to the officials of Kolkata Municipal Corporation , SWM Deptt for their kind support rendered during the fields studies.

Last, but not the least, I express my sincere gratitude to the Research Scholars of Environmental Engineering Division, Department of Civil Engineering, Jadavpur University; my classmates and my family for the encouragements and supports they provided throughout the work. This thesis would not have been possible without them.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

SECTION – 1

INTRODUCTION

1.1 Solid Waste Disposal Problem

The incremental trend of human settlement in and around the metropolitan cities, urban centers and peri-urban interface, yields an uphill task of management of municipal solid waste (MSW) owing to both quantity and quality in addition to land acquisition conflict that being poised in recent times. As a result of various commodity used by inhabitants of the city in effect of consumer market, the nature of disposal problem is invocating in ascending trend. 366 numbers of Indian cities representing 70% of Indian urban population generate one-tenth of millions of solid waste per day indicating a per capita waste generation of 500 gm/day. In 2001 the above cities produced 31.6 million tons of waste and currently generate 46 million tons, which shows a formidable increase in a tune of 50% increase in one decade. More than 90% of the MSW generated in India is disposed in unscientific way that results in environmental pollution (Kumar et al. 2009). The land filling has been to the main method of the waste management. The same disposal-tripping site are on use years long together by overlaying waste material even their useful life span is over. Older, poorly designed or poorly managed landfills can create a number of adverse environmental impacts such as wind-blown litter, attraction of vermin, and generation of liquid known as leachate even at the closer stage. Leachate extracts a series of contaminants and attributes to a complex interplay between the hydrological and biogeochemical reactions. The emission of leachate imparts various environmental problems for which the issue is a serious threat to society as it has potential for causing ground water pollution along with partial contribution for adverse effect on soil fertility (Aziz et al., 2004). Leachate contains large amount of organic matter of which humic substances are the major group along pesticidal residues etc. More than 90 organic and metal organic compounds and 50 inorganic elements have been traced by number of investigations conducted at different times in different parts of the world (Cecilia et al. 2008). The age of landfill, also influence the characteristics of leachate pollutant concentrations. A few no. of studies have been conducted by some earlier researchers to explore the characteristics of leachate from various landfill sites of Indian metropolis and other important cities. The data of such investigations show a significant pollution load is being imparted by such leachate.

Older, poorly designed or poorly managed landfills can create a number of adverse environmental impacts such as wind-blown litter, attraction of vermin, and generation of liquid known as leachate is defined as any contaminated liquid effluent percolating through deposited waste and emitted within a landfill or dump site through external sources, of which its route of exposure and toxicity often remains unknown (Park et al. 2002). More precisely, it is a soluble organic and mineral compound formed when water infiltrates into the refuse layers, extracts a series of contaminants and instigates a complex interplay between the hydrological and biogeochemical reactions. Various environmental problems associated with landfill system of MSW disposal, leachate is gaining a serious threat to society as it has potential for causing ground water pollution along with partial contribution for negative effect on soil fertility (Aziz et al.2004).Under normal conditions, leachate migrates down through the pores within the waste mass, and in modern containment landfills, it drains away in the engineered drainage layer, collected at the lowest point in a sump or storage reservoir. Leachate contains large amount of organic matter of which humic substances are the major group along with ammonia nitrogen, toxic metals, chlorinated organics, phenolic compounds even pesticidal residues etc. More than 90 organic and metal organic compounds and 50 inorganic elements are traced through various studies conducted in different parts of the world (Cecilia et al. 2008).

1.2 The Dhapa Dumping Area

Kolkata is the capital of the state of West Bengal located in the eastern part of India. It is one of the most highly populated cities in the country and with a population of 4.48 million (daytime population count rises to 8 million), the city generates about 3,500 to 3,700 tonnes of municipal solid waste (MSW) daily i.e. 1.3Million Tons annually. This waste is almost entirely disposed at the Dhapa Dumping Area with a very small portion going to another small municipal dump site in the city.

The Dhapa Dumping Area is owned and operated by the Kolkata Municipal Corporation (KMC) and lies within Ward Nos. 57 and 58 of the KMC administrative boundaries, on the eastern part of Kolkata. Almost the entire area is part of a large protected wetland area called the East Kolkata wetlands (listed as a Ramsar site in 2002). The entire raw sewage from the city flows through drainage channels into the wetlands and is eventually discharged into the river Vidyadhari. Dhapa has been historically used for waste dumping for many decades. With the gradual development of the city towards the east, the garbage dumping has moved away further eastwards and the old dumping areas nearer to the main city are now used for farming (locally referred to as garbage farming). The current "dumping area" is spread over about 35 hectares. It consists of two unlined dumpsites, spaced ~ 500m apart – one closed dump of area ~ 12.14 ha and one active dump of area ~ 23 ha. The closed dump site (referred to as the 'closed dumpsite' or 'the site' or "project site") commenced operations in 1987 and was closed in 2009. The active dumpsite (referred to as the "operational dumpsite" or 'active dumpsite') also commenced operations in 1987 and is expected to be operated for another two to three years.

In addition to the two dumpsites, the Dhapa Dumping Area includes an administrative office of the KMC, reception facilities for MSW, weighbridge, garage, a crematorium for unclaimed dead bodies, a privately operated compost plant and a private bone processing area. Immediately to the north of the closed dumpsite is Makaltala Village. Another four villages namely Unchupota, Dhapa-Durgapur, Anantabadal and Khanaberia are located in the near vicinity of the dumping area. Although all these settlements are very much within the Kolkata Municipal Area, they are still referred to as “villages”.

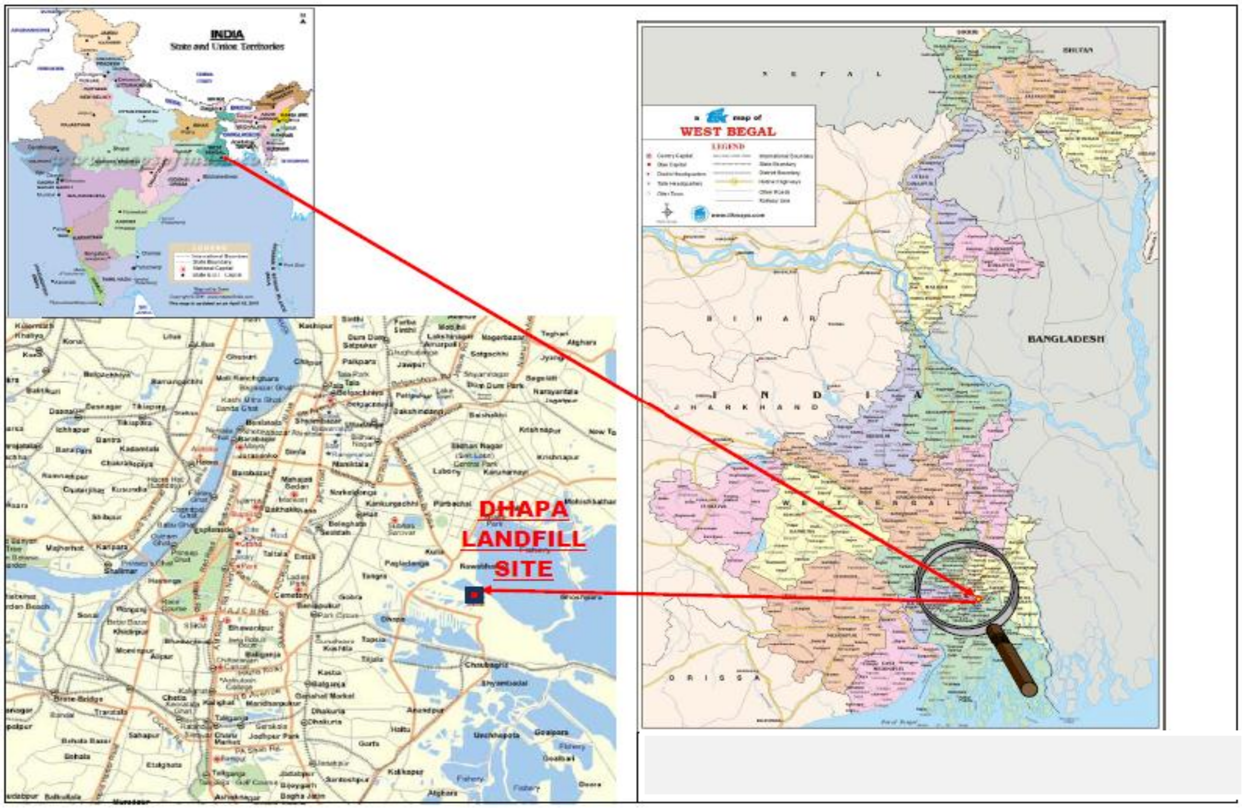


Figure 1.1: Location Map showing the site within the Kolkata Area

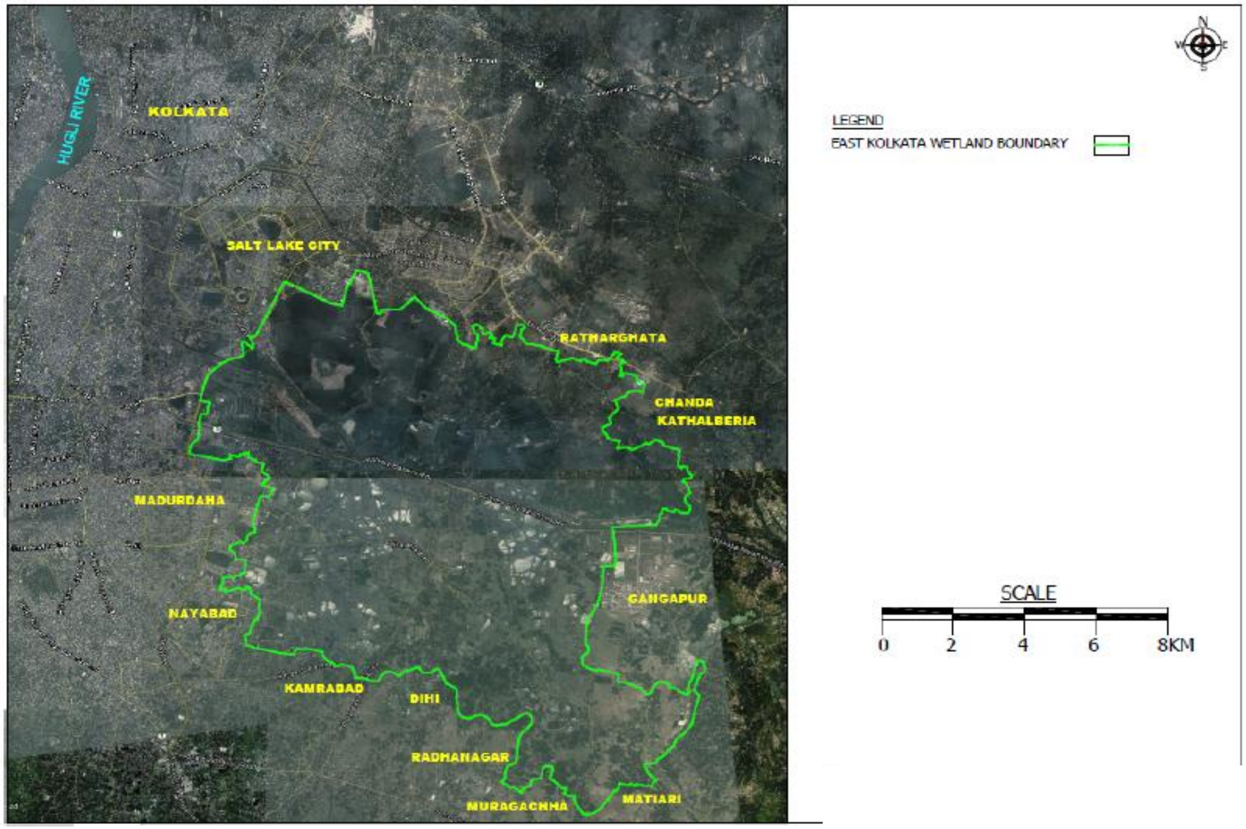


Figure 1.2: Location showing east Kolkata wetlands in the Kolkata area

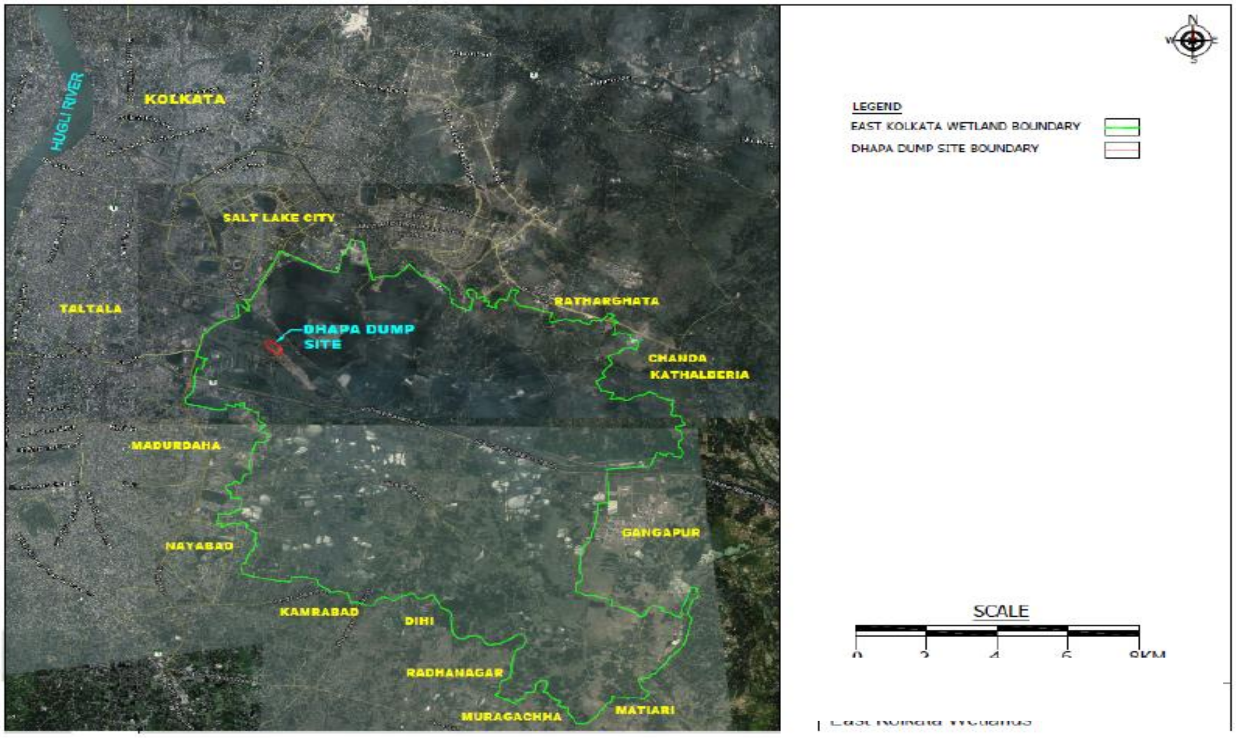
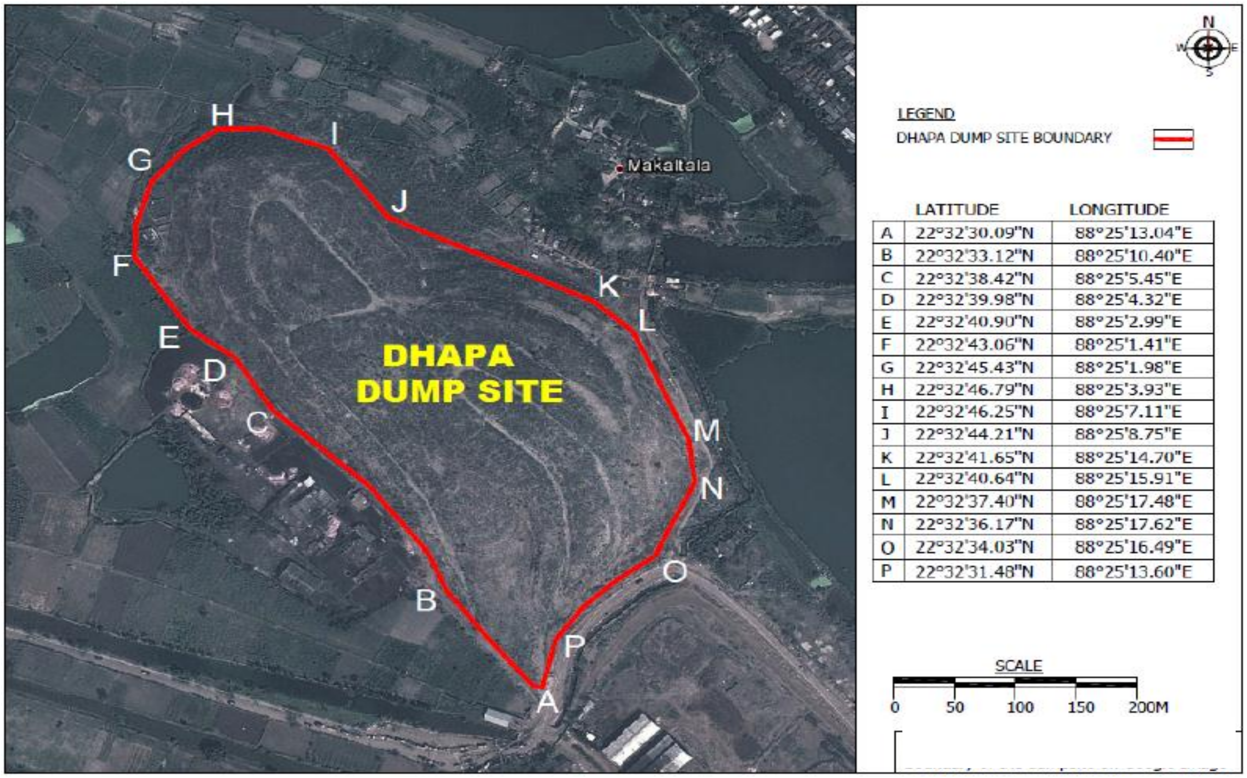


Figure 1.3: Location of the site within the east Kolkata wetlands



	LATITUDE	LONGITUDE
A	22°32'30.09"N	88°25'13.04"E
B	22°32'33.12"N	88°25'10.40"E
C	22°32'38.42"N	88°25'5.45"E
D	22°32'39.98"N	88°25'4.32"E
E	22°32'40.90"N	88°25'2.99"E
F	22°32'43.06"N	88°25'1.41"E
G	22°32'45.43"N	88°25'1.98"E
H	22°32'46.79"N	88°25'3.93"E
I	22°32'46.25"N	88°25'7.11"E
J	22°32'44.21"N	88°25'8.75"E
K	22°32'41.65"N	88°25'14.70"E
L	22°32'40.64"N	88°25'15.91"E
M	22°32'37.40"N	88°25'17.48"E
N	22°32'36.17"N	88°25'17.62"E
O	22°32'34.03"N	88°25'16.49"E
P	22°32'31.48"N	88°25'13.60"E

Figure 1.4: Coordinates along the boundary of the dumpsite

Figure 1.5: Area covered by the dumpsite

1.3 Health Effects Of Leachates On Humans

When water flows through improperly disposed waste and percolates to the ground, contaminating the groundwater sometimes with toxic substances drawn from the waste it passes through. Water could be rain, or contained in the waste itself. The leachate then pollutes the water with these substances, making nearby water sources unusable for consumption. Health effect could be from an acute/short exposure, or long term chronic exposure to leachates from landfills.

Table 1.1 : Various contaminant Heath Effects

Chemical/ metal Health effects from acute exposure	
Lead	Abdominal pain, diarrhoea, vomiting, confusion, drowsiness, seizures
Mercury	Bloody diarrhoea, dehydration, renal failure
Cadmium compounds	Metallic taste, cough, chest pain, nausea, diarrhoea, skin irritation.
Nickel	Skin irritation, dermatitis, diarrhea, gum disease
Toluene	Tremors, convulsions, coma
Phenols/ cresols	Burning pain in mouth and throat, nausea, vomiting, diarrhea, sweating, coma, shock.
Chemical/ metal Health effects from long term exposure	
Lead	Anorexia, abdominal pain, constipation, chronic nephropathy, hypertension.
Mercury	Tremors , memory loss, seizures, coma, irritability, acute kidney failure, decrease in platelets, anaemia that follows gastrointestinal bleed.
Cadmium compounds	Anaemia, kidney damage, possible prostrate and lung problems
Phenols/ cresols	Renal failure
Benzene	Blood – related disorders

Source: university of Edinbrgh’s electronic medical curriculum

Some of the most important unresolved problems within landfill sites include the following:

- Information regarding characterization of heavy metals and migration behavior in refuse within open municipal dumpsites and landfills are lacking in the country as well as in Dhapa site. Interestingly, there are large tracts of high metal and organics inclusive of priority pollutants and other hydrocarbon content in the proximity of such dumpsites whose origin and correlations are virtually unknown.
- A systematic and holistic approach toward identifying source (geogenic/anthropogenic) of heavy metal is still lagging behind in the vicinity of these dumpsites. Resolution of this problem is utmost important, as identifying the origin of metals and other pollutants will facilitate constructing an in-situ remediation/reclamation strategy.
- Quantification and evaluation of quality of leachate pollution is an important and promising task which enables the development of risk analysis and mitigation measures to conserve eco-system of the area and maintain sustainable development.
- A systematic evaluation of human health risk (carcinogenic, non carcinogenic) originating as a consequent of landfill leachate contaminating soil and water are not been considered crucial for areas surrounding landfill.

In this context, the study has been undertaken to investigate the water quality parameters in some selected tube wells, surface water detention pond and flowing channels along with top soil quality from the surrounding areas for assessments of ingress of pollution for leachate migration from the dumping site. The evaluation of health risk associated with this water quality and soil quality parameters for the neighboring habitats also has been examined. The primary focus was given to heavy metal contamination.

SECTION -2

LITERATURE REVIEW

2.1 Site

Kolkata is the capital of the state of West Bengal located in the eastern part of India. It is one of the most highly populated cities in the country and with a population of 4.48 million (daytime population count rises to 8 million), the city generates about 3,500 to 3,700 tonnes of municipal solid waste (MSW) daily i.e. 1.3Million Tons annually. This waste is almost entirely disposed at the Dhapa Dumping Area with a very small portion going to another small municipal dump site in the city.

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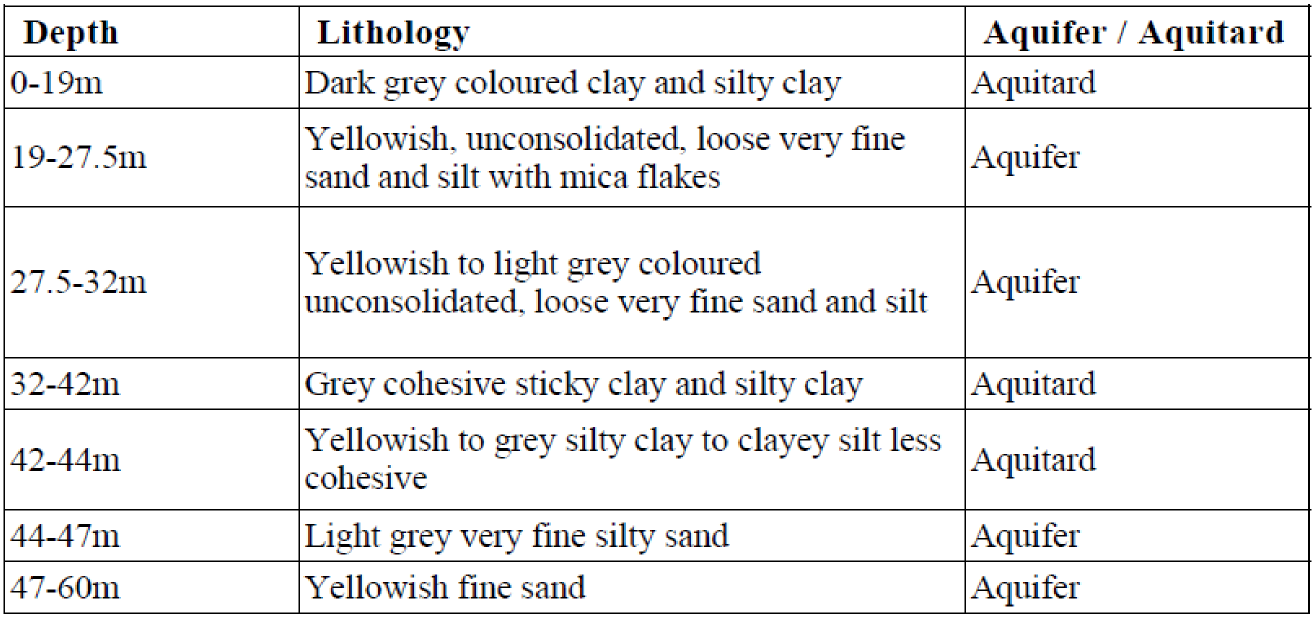
2.1.1 Climate

Kolkata has a tropical climate. Summers are hot and humid with minimum temperatures near 30°C and maximum temperatures often exceeding 40 C during May and June. The annual mean maximum temperature recorded over a period of 30 years is observed to be 31.8°C and the annual mean minimum temperature is observed to be 22.1°C.The south-west monsoons lash the city between June to September and supplies the city with most of its annual rainfall of approximately 1728.5mm.The predominant wind direction during most of the year is from South to North.

2.1.2 Geology and Hydrogeology

Based on lithologs generated through borehole drilling at the site, the geological formations found in the area are shown in Table 2.1

Table 2.1: Geological Formations observed at the site



Depth	Lithology	Aquifer / Aquitard
0-19m	Dark grey coloured clay and silty clay	Aquitard
19-27.5m	Yellowish, unconsolidated, loose very fine sand and silt with mica flakes	Aquifer
27.5-32m	Yellowish to light grey coloured unconsolidated, loose very fine sand and silt	Aquifer
32-42m	Grey cohesive sticky clay and silty clay	Aquitard
42-44m	Yellowish to grey silty clay to clayey silt less cohesive	Aquitard
44-47m	Light grey very fine silty sand	Aquifer
47-60m	Yellowish fine sand	Aquifer

The ground water flow direction is from South West to North East towards the wetlands.

2.1.3 Land Use Classification

A land use study was carried out over a 2 km radius around the closed dump site. The area statistics for Land use / Land cover in study area are presented in Table 2.2

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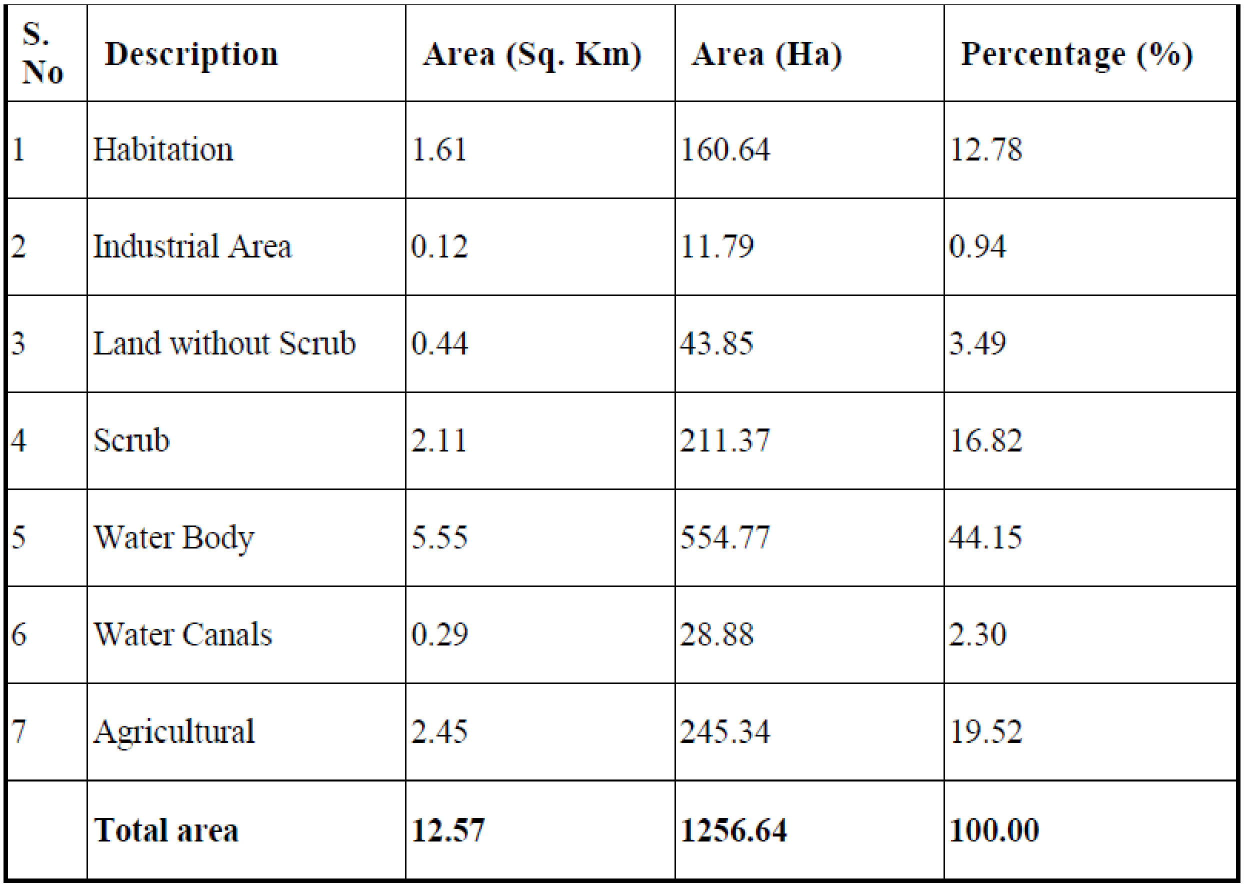
Table 2.2: Area statistics for Land Use / Land cover in the study area



S. No	Description	Area (Sq. Km)	Area (Ha)	Percentage (%)
1	Habitation	1.61	160.64	12.78
2	Industrial Area	0.12	11.79	0.94
3	Land without Scrub	0.44	43.85	3.49
4	Scrub	2.11	211.37	16.82
5	Water Body	5.55	554.77	44.15
6	Water Canals	0.29	28.88	2.30
7	Agricultural	2.45	245.34	19.52
	Total area	**12.57**	**1256.64**	**100.00**

2.1.4 Dhapa Area

The Dhapa area is located along the eastern fringe of Kolkata city within a protected wetland, namely the East Kolkata Wetlands, a Ramsar site.. Major area has been found to be covered by water bodies (44.15%) followed by 19.52% covered by agricultural land, scrubs taking up 16.78% and habitations cover taking up 12.78% land. Smaller percentage is taken up by industries, land without scrub and river area, amounting to 17.77%

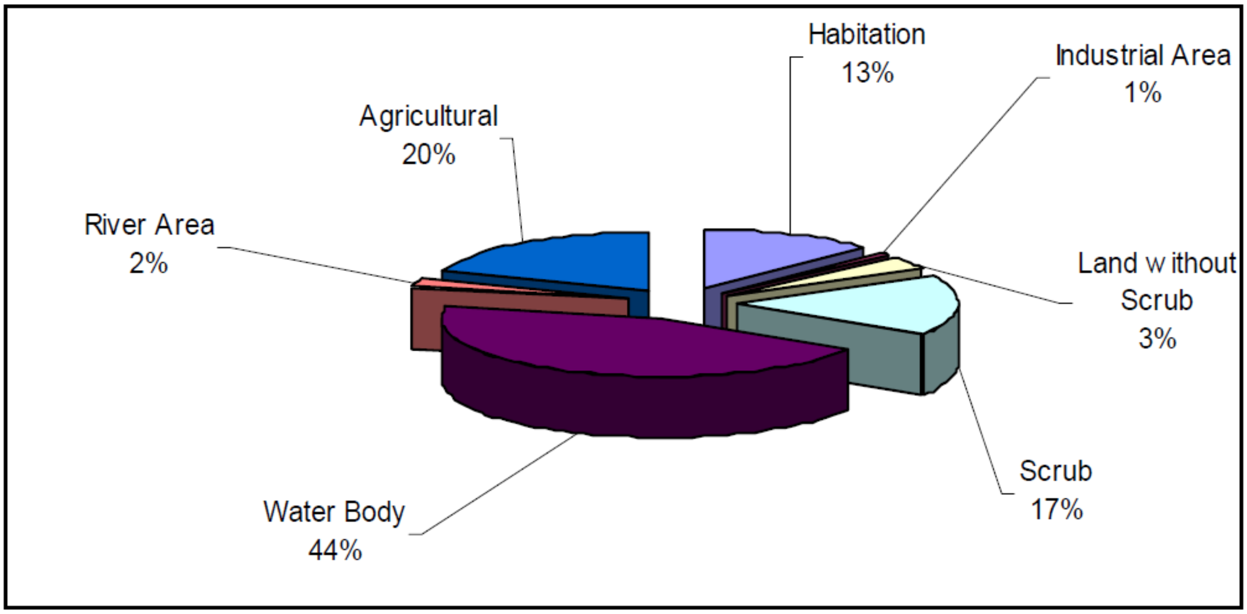


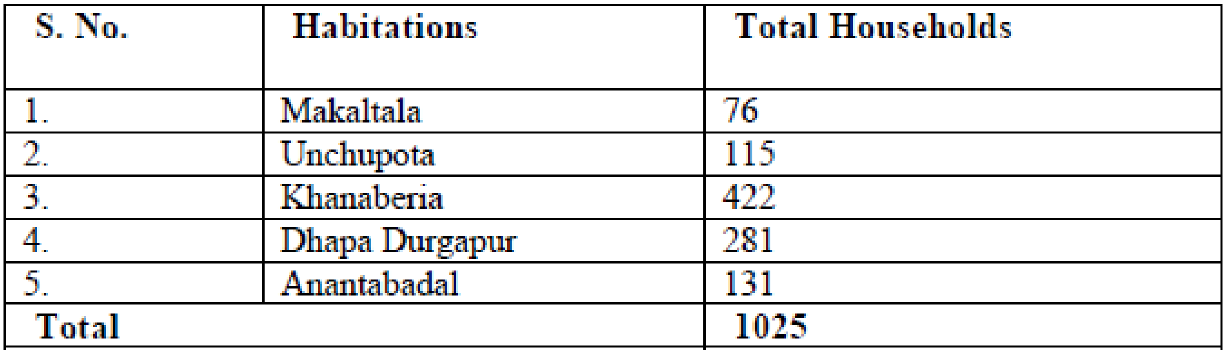
Figure 2.1: Land use pattern in dhapa

Within the 2 km radius five habitations (still referred to as villages) have been identified and marked in the said land use map. The villages and their distances from the closed dumpsite are as follows

Table 2.3: Local villages around dhapa

S. No.	**Habitations**	**Comments on selection**
1.	Makaltala	Adjacent to the closed dumpsite
2.	Unchupota	Within ½ km of closed dumpsite
3.	Khanaberia	Within 1 km of closed dumpsite
4.	Dhapa Durgapur	Within 1 ½ km of closed dumpsite
5.	Anantabadal	Within 2 km of closed dumpsite

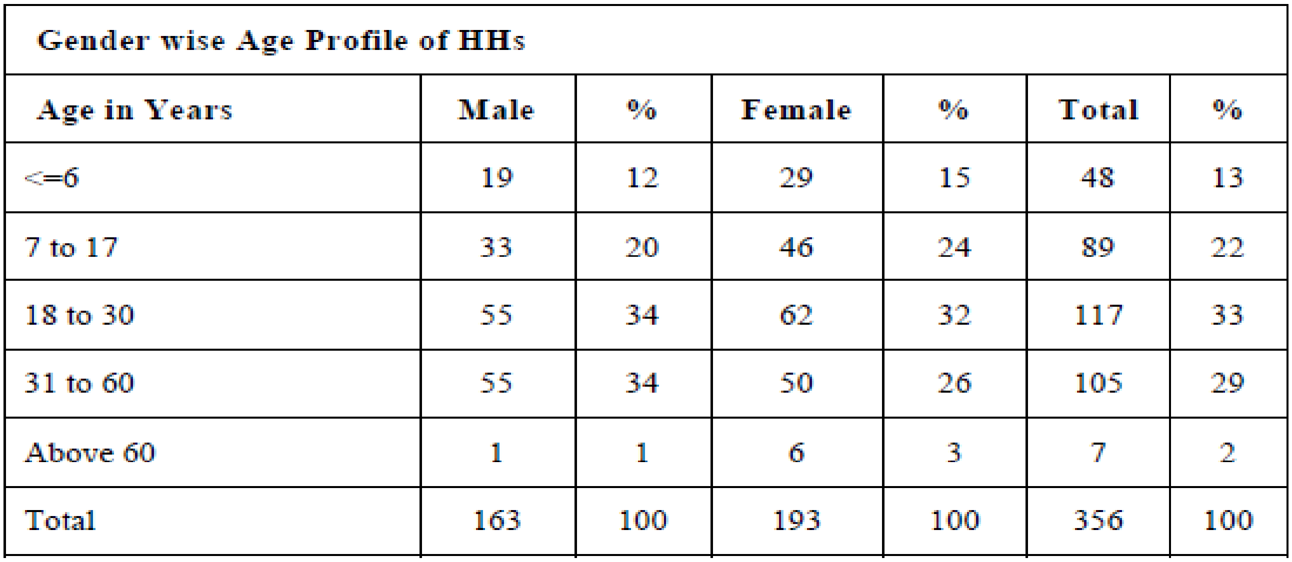
Table 2.4: Households in the villages within 2 kms of closed dumpsite



S. No.	Habitations	Total Households
1.	Makaltala	76
2.	Unchupota	115
3.	Khanaberia	422
4.	Dhapa Durgapur	281
5.	Anantabadal	131
Total		**1025**

gender wise age profile of Makaltala. Only 2% of the population are above 60 years of age and 13% are children. 62% are in the active age group of 18-60 years with 54% male and 56% female.

Table 2.5: Gender wise age



Gender wise Age Profile of HHs						
Age in Years	**Male**	**%**	**Female**	**%**	**Total**	**%**
<=6	19	12	29	15	48	13
7 to 17	33	20	46	24	89	22
18 to 30	55	34	62	32	117	33
31 to 60	55	34	50	26	105	29
Above 60	1	1	6	3	7	2
Total	163	100	193	100	356	100

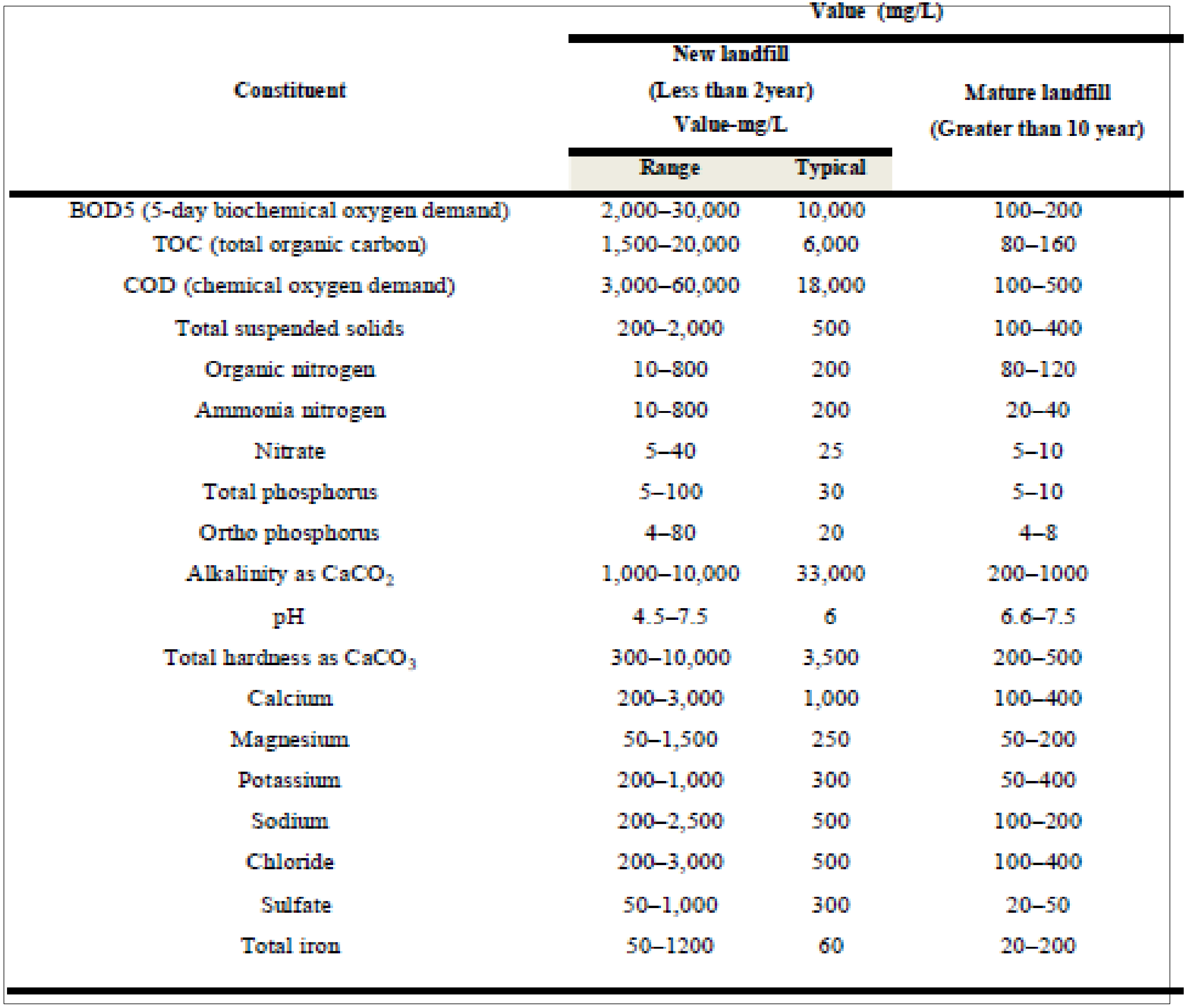
2.2 Leachate quality:

The factors that influence leachate quality significantly include waste composition, elapsed time, temperature, moisture and available oxygen. In general, leachate quality of the same waste type may be different in landfills located in different climatic regions. Landfill operational practices also influence leachate quality. Table indicates the typical data on characteristics of leachate reported by Bagchi (1994), Tchobanoglous et al., (1993) and Oweis and Khera (1990). It has been stated in their

respective papers, that assessment of leachate quality at an early stage should be undertaken for following aspects: (a) to identify whether the waste is hazardous, (b) to choose a landfill design, (c) to design or gain access to a leachate treatment plant, and (d) to develop a list of chemicals for the groundwater monitoring program.

To assess the leachate quality of a waste, the normal practice is to perform Toxicity Characteristics Leaching Procedure (TCLP) tests, along with series of laboratory leachate tests as well, to determine the quality of actual landfill leachate (Słomczyńska B and Słomczyńska T., 2004). However, when field data are not available for a particular waste type, it becomes difficult to assess. Laboratory leachate tests on MSW do not yield very accurate results because of heterogeneity of the waste as well as difficulty in simulating the time-dependent field conditions. Though the leachate samples from old landfill sites near the design site may give some indication regarding leachate quality; this too will depend on the age of the landfill. (CPHEEO Manual., 1999)

Table 2.6: Typical data on the composition of leachate from new and mature landfill (Tchobanoglous et al,2002)

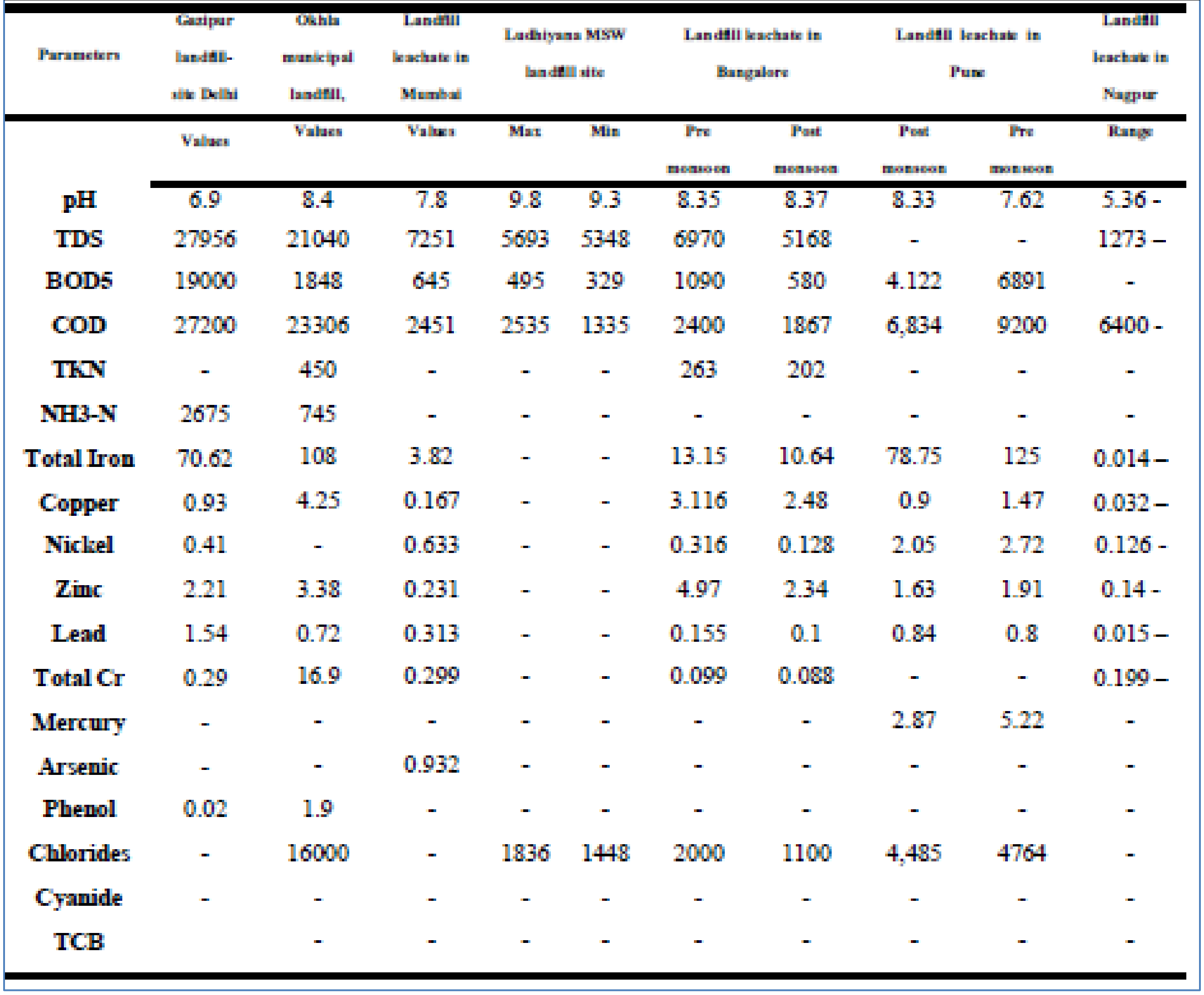


Constituent	Value (mg/L)		
	New landfill (Less than 2year) Value-mg/L		Mature landfill (Greater than 10 year)
	Range	Typical	
BOD5 (5-day biochemical oxygen demand)	2,000–30,000	10,000	100–200
TOC (total organic carbon)	1,500–20,000	6,000	80–160
COD (chemical oxygen demand)	3,000–60,000	18,000	100–500
Total suspended solids	200–2,000	500	100–400
Organic nitrogen	10–800	200	80–120
Ammonia nitrogen	10–800	200	20–40
Nitrate	5–40	25	5–10
Total phosphorus	5–100	30	5–10
Ortho phosphorus	4–80	20	4–8
Alkalinity as $CaCO_2$	1,000–10,000	33,000	200–1000
pH	4.5–7.5	6	6.6–7.5
Total hardness as $CaCO_3$	300–10,000	3,500	200–500
Calcium	200–3,000	1,000	100–400
Magnesium	50–1,500	250	50–200
Potassium	200–1,000	300	50–400
Sodium	200–2,500	500	100–200
Chloride	200–3,000	500	100–400
Sulfate	50–1,000	300	20–50
Total iron	50–1200	60	20–200

Chattopadhyay et al., (2009) presented a paper on municipal solid waste management in Kolkata, India. In this paper they have discussed about physical and chemical characterization of city refuse its collection, storage and transportation. The quality of natural leachate, sampled from the existing MSW disposal site at Dhapa, shows that concentrations of solids, BOD, COD, and chloride are much higher than those allowed for discharge into inland surface water. The concentration of toxic elements such as As, Hg, Pb, Cd, Cr, Cu, Zn, Ni, and fluoride are reported to be lower than those allowed for discharge in inland surface water. The quality of wastewater in the canal at the Dhapa

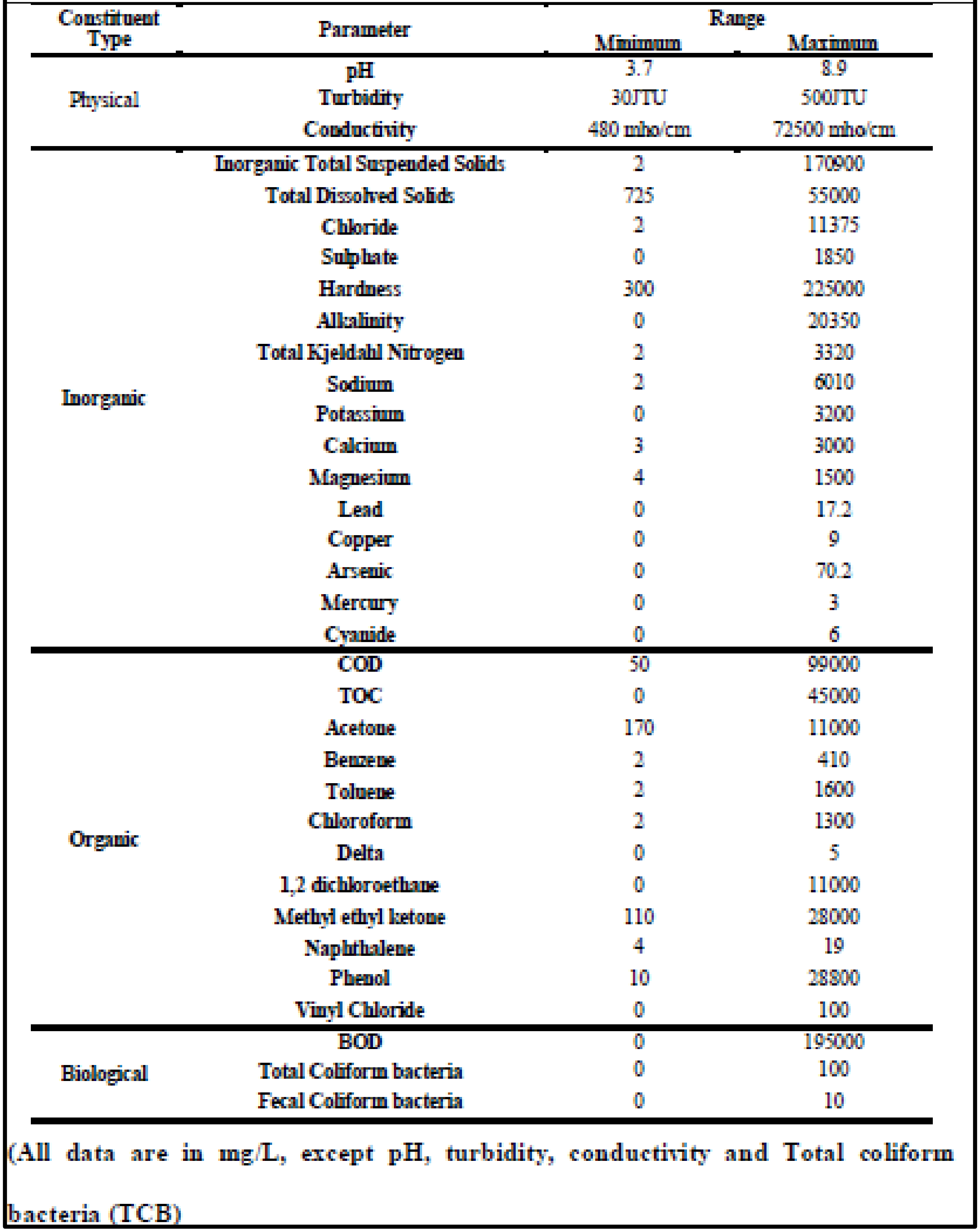
area shows that concentrations of TS, BOD, COD, and Cr are high. Similarly, large water bodies in the Dhapa area also have high BOD and COD. The major parameters of leachate quality are shown in Table 5 of the paper are nearly matching the characterization of the leachate of Dhapa site of the present study.

Table 2.7: Characteristics of MSW landfill leachate of some of the landfill sites in Indian context. (Renou et al, 2008 ; Parameswari et al, 2012; Dikshit et al.,2012)



Parameters	Gazipur landfill-site Delhi	Okhla municipal landfill,	Landfill leachate in Mumbai	Ladhiyana MSW landfill site		Landfill leachate in Bangalore		Landfill leachate in Pune		Landfill leachate in Nagpur
	Values	Values	Values	Max	Min	Pre monsoon	Post monsoon	Post monsoon	Pre monsoon	Range
pH	6.9	8.4	7.8	9.8	9.3	8.35	8.37	8.33	7.62	5.36 -
TDS	27956	21040	7251	5693	5348	6970	5168	-	-	1273 –
BOD5	19000	1848	645	495	329	1090	580	4.122	6891	-
COD	27200	23306	2451	2535	1335	2400	1867	6,834	9200	6400 -
TKN	-	450	-	-	-	263	202	-	-	-
NH3-N	2675	745	-	-	-	-	-	-	-	-
Total Iron	70.62	108	3.82	-	-	13.15	10.64	78.75	125	0.014 –
Copper	0.93	4.25	0.167	-	-	3.116	2.48	0.9	1.47	0.032 –
Nickel	0.41	-	0.633	-	-	0.316	0.128	2.05	2.72	0.126 -
Zinc	2.21	3.38	0.231	-	-	4.97	2.34	1.63	1.91	0.14 -
Lead	1.54	0.72	0.313	-	-	0.155	0.1	0.84	0.8	0.015 –
Total Cr	0.29	16.9	0.299	-	-	0.099	0.088	-	-	0.199 –
Mercury	-	-	-	-	-	-	-	2.87	5.22	-
Arsenic	-	-	0.932	-	-	-	-	-	-	-
Phenol	0.02	1.9	-	-	-	-	-	-	-	-
Chlorides	-	16000	-	1836	1448	2000	1100	4,485	4764	-
Cyanide	-	-	-	-	-	-	-	-	-	-
TCB		-	-	-	-	-	-	-	-	-

Table 2.8: Typical constituents of leachate from MSW landfills



Constituent Type	Parameter	Range Minimum	Range Maximum
Physical	pH	3.7	8.9
	Turbidity	30JTU	500JTU
	Conductivity	480 mho/cm	72500 mho/cm
Inorganic	Inorganic Total Suspended Solids	2	170900
	Total Dissolved Solids	725	55000
	Chloride	2	11375
	Sulphate	0	1850
	Hardness	300	225000
	Alkalinity	0	20350
	Total Kjeldahl Nitrogen	2	3320
	Sodium	2	6010
	Potassium	0	3200
	Calcium	3	3000
	Magnesium	4	1500
	Lead	0	17.2
	Copper	0	9
	Arsenic	0	70.2
	Mercury	0	3
	Cyanide	0	6
Organic	COD	50	99000
	TOC	0	45000
	Acetone	170	11000
	Benzene	2	410
	Toluene	2	1600
	Chloroform	2	1300
	Delta	0	5
	1,2 dichloroethane	0	11000
	Methyl ethyl ketone	110	28000
	Naphthalene	4	19
	Phenol	10	28800
	Vinyl Chloride	0	100
Biological	BOD	0	195000
	Total Coliform bacteria	0	100
	Fecal Coliform bacteria	0	10

(All data are in mg/L, except pH, turbidity, conductivity and Total coliform bacteria (TCB)

The chemical composition of leachate varies greatly depending on the age of landfill and the history of events preceding the time of sampling. For example, if a leachate sample is collected during the acid phase of decomposition, the pH value will be low and the concentrations of BOD5, TOC, COD, nutrients, and heavy metals will be high. On the other hand, if a leachate sample is collected during the methane fermentation phase the pH will be in the range from 6.5 to 7.5, and the BOD5, TOC, COD, and nutrient concentration values will be significantly lower. Similarly the concentrations of heavy metals will be lower because most metals are less soluble at neutral Ph values. The pH of the leachate will depend not only on the concentration of the acids that are present, but also on the partial pressure of the CO2 in the landfill gas that is in contact with the leachate. The biodegradability of the leachate also varies with time. Checking the BOD5/COD can monitor changes in the biodegradability of the leachate. Initially, the BOD5/COD ratios will be around 0.5. Ratios in the range from 0.4 to 0.6 are taken as an indication that the organic matter in the leachate is readily biodegradable. In mature landfills, the BOD5/COD ratio is often in the range of 0.05 to 0.2 (Tchobanoglous et al., 1993). Because of the variations found in the characteristics of leachate, the design of leachate treatment systems is complicated. For example, the type of treatment plant designed to treat a leachate with the characteristics reported for a new landfill would be quite different from one designed to treat the leachate from a mature landfill. The problem of analysis is complicated further by the fact that the leachate which is being generated at any point of time is a mixture of leachate derived from solid waste of different ages (Tchobanoglous et al., 2002).

Reinhart et al., (1998) reported and recorded some data based on the analysis of Florida MSW Landfill Leachate Quality in 1998. The main purpose of their research and analysis was to characterize Florida USA landfill leachate. According to above studies, BOD and COD concentrations have been observed to be low (less than 1500 mg/L) throughout the life of the landfill. Leachate from the shredded waste fill has significantly higher concentrations of organic pollutants than leachate from the unshredded waste landfills as found in the high COD and BOD levels from the South Dade Shredded Landfill. A wide variety of toxic and organic compounds such as Phenolic, AOXs, PCB, etc. was found in Florida landfill leachate. However, the concentration of these constituents is generally about micrograms per liter.

Hogland et al., **(2002)** did some investigation on the leachate quality of City Dump/Landfills in Katmandu valley, Nepal, emphasizing more on heavy metals and persistent organic content in leachate. The observations based on their analysis have been summarized, which states that, the closed landfills under anaerobic conditions produce leachate during the methane-generating phase. The leachate was characterized by the low organic value of COD or BOD and heavy metals concentration. The parameters like pH, BOD, COD, Fe, Mn, Ca, Cl were varied with time. Except for pH, all other parameters were found to decrease with time. The values of the nitrates, total dissolved solids (TDS), total suspended solids, ammonia, iron and magnesium were found to have significantly changed. The conductivity and chemical concentrations of zinc, ammonia and nitrate was found to increase in most water samples analyzed.

Słomczyńska et al., (2004) observed that the initial pH value is in the range of 3.7-6.5, which gradually shoots up to neutral and is marginally in the alkaline range (7.0-7.5) depending upon the age of the landfill. Leachate contains various fatty and volatile organic acids which are indicated as acidogenic products at the initial phase and are predominant due to absence of oxygen. The authors were of the view that other unidentified compounds perhaps could be humic acids, lignins and other cellulose-like materials. However, it was found that all the leachate samples contain high concentrations of nitrogen, mainly in the form of ammonium (NH4-N), whereas the contents of phosphates were found to be quite low. It was also mentioned that the physico-chemical characteristics of leachate seemed to be highly variable over the course of a landfill's life, though in young landfills, the concentrations of pollutants in the leachate were found to be high but with maturity the value of BOD5/ COD ratio seems to decrease. This phenomenon results from the fact that young landfills contain many organic compounds that are readily biodegradable, giving rise to refractory compounds that accumulates with the exploitation of landfill and are resistant to biochemical degradation.

Baun et al., (2004) have conducted a large number of chemical analysis and toxicity tests from ten Danish MSW landfills and reported on Xenobiotic organic compounds in leachate based on their observation. A monitoring program comprising of chemical analysis and biological toxicity test of the leachate samples collected from those 10 landfills (six engineered and four uncontrolled) revealed the presence of 55 different Xenobiotic organic compounds (XOCs) and 10 degradation products of XOCs. The compounds included phenols (chloro-, methyl-, dimethyl, and nonyl-), BTEX, C3- benzenes, bicycle compounds, napthalenes, chlorinated aliphatic, pesticides, and phthalates. Concentrations of single XOCs ranged from 0.1 to 2220 mg/L. Most of those fifty five numbers of XOC's and the ten known degradation products are identified here in the present study. The XOC's belonged to the aromatic compounds (18 compounds, including one degradation product), chlorinated aliphatic (3 compounds), phenols (14 compounds, including one possible degradation product: 3, 5 DCP), nonylphenolethoxycarboxylate (1 compound), phthalates (8 compounds, including five degradation products: monoesters of o-phthalic acid), and pesticide (21 compounds, including three degradation products of glyphosate, atrazine, and simazine)

Robinson et al., (2007) published a paper describing a detailed review of leachate quality at some of the largest landfill sites situated at different parts of the world viz. Hong Kong (old sites and new generation landfills are considered separately), South Africa, Malaysia, Indonesia and Thailand, the United Kingdom, the Island of Mauritius, Korea, and New Zealand. This article provided an extensive database on leachate quality. The recorded database exhibits a reasonable composition having similar leachate characteristics for different landfill sites in different countries. In particular, methanogenic leachate was found to be very consistent and extremely similar in composition, whether from sites in temperate northern hemisphere countries, or from tropical countries in either hemisphere, and irrespective of economic status of the country. Acetogenic leachate are also similar in nature from all very large landfills, but the period of transition from acetogenic to methanogenic conditions is almost always completed within 6-18 months in warmer climates (where wastes being land filled generally also have a higher initial moisture content), whereas this may typically take up to 3 years at landfills in other temperate countries. However, the study indicates age of landfill influences the quality of leachate.

Singh and Mittal (2009) investigated analyzing the toxicity, focusing on public health aspects of municipal landfill leachate for Okhla landfill near Delhi India. Their experimental results reveled that; leachates contain all major inorganic and organic pollutants and are inclusive of organo-halogenated compound and toxic metals. However, the concentration levels of different hydrocarbons are not reported in the work.

Bhalla et al., (2012), conducted experimentation to examine the characteristics of leachate generated from municipal solid waste land filling sites of Ludhiana City, Punjab (India). Leachate samples were collected and analyzed for various physicochemical parameters to estimate its pollution potential. The study was carried out primarily to establish a reference for implementing suitable techniques for the leachate treatment. They categorically selected three land fill sites of Ludhiana city which were non-engineered low lying open dumps, lacking of both suitable lining system or any leachate collection and treatment system. It was observed that leachate of all the sites were containing high concentrations of organic and inorganic constituents beyond the permissible limits and with time found its paths into the surrounding environment. Inspite of all this, it was also seen that, heavy metals concentration was in trace amount as the waste is domestic in nature. Their analysis indicated that the age of the landfill plays a significant role on leachate composition. The biodegradable fraction of organic pollutants in the leachate for old landfill site was found to decrease, perhaps due to the anaerobic decomposition occurring in the landfill. The concentration of leachate contaminants at Jamalpur and Noorpur belt land filling site were found to be comparatively greater than that of Jainpur land filling site which is older than both. Based on the characterization of landfill leachate, Jamalpur and Noorpur belt land filling site demonstrated low bio-degradability i.e. BOD5/COD=0.19 and BOD5/COD=0.20 compared with Jainpurland filling site i.e. BOD5/COD=0.24.

2.3 Risk Assessment

Bardos et al., (2003a, 2003b); SCEG, (2003); Nathanail and Nathanail, (2003) these articles draw on some aspects of hazard assessment and risk analysis from the perspective of contaminated land.

Bernard et al., (1996, 1997) two papers (Part 1 and 2) are on hazard analysis of landfill leachate. They discuss leachates from 25 landfill sites in France as case studies, with a number of methods of determining leachate toxicity. They then compare the physico-chemical characteristics of leachates.

Butt et al., (2011); Butt and Oduyemi, (2003) these publications are specifically for landfill leachate and focuses on the exposure assessment and hazards' concentration assessment sections of a total risk assessment system respectively. An integrated and quantitative model of exposure analysis is presented and some links are also drawn with the relevant parts of a baseline study.

DEFRA and Environment Agency, (2002) the publication relates to exposure assessment for humans from contaminated lands. Details on various aspects of exposure assessment are given. Examples include exposure parameters (such as exposure duration, frequency), soil release and transfer mechanisms, exposure equations, human activities and ages, exposure routes, and various land-uses.

DETR et al., Environment Agency (2000) The literature provides generic material for the development of functional risk assessment guidance to assist in issues like contaminated land, waste management, and major accident hazards (DEFRA, 2002). It examines a range of risk assessment topics such as dealing with uncertainty, types of quantification, and evaluation of the significance of a risk. This guidance is a useful starting point. It serves as the ‘first port of call’ for many Environment Agency officers, before they tackle the detailed project work. It can also be used by anyone else interested in risk-based decision-making in Government (DEFRA, 2002).

DoE Department of the Environment, (1995) the document can contribute to a landfill risk assessment in terms of exposure analysis. This publication portrays exposure assessment in a more complete manner than any other literature studied to date. The focus is not on environmental receptors but on only human health. Similarly, not all potential exposure pathways have been included, but only the six which cover most risk to human health from landfills.

Environment Agency, (1997) This document addresses risk assessment from the perspective of human health only as a receptor, and only for those landfills which have as a pollutant source contaminates from house hold waste.

Environment Agency, (2003a) and SEPA, (2003) This Environment Agency document provides guidelines for risk assessment of landfill leachate. Hazards are considered from the perceptive of groundwater as a receptor/target.

Environment Agency, (2007) this guidance, which is one of the most relevant guidance documents for landfills, addresses the landfill sector in a very broad sense. It includes a number of very relevant aspects that can help risk assessment and baseline study exercises for a given landfill e.g. site investigation, groundwater protection and hydrogeology, closure and after closure, landfill engineering, etc.

Environment Agency, (2011d) Unlike the Environment Agency's website of 2012 which is for various sectors, this website of the Agency is specifically for the landfill sector. Hence this website contains technical guidance to help readers to understand the standards that the Agency wants the landfill sector to achieve when designing and managing a landfill site. It covers diverse landfill related subjects such as waste acceptance; monitoring of landfill leachate, groundwater and surface water; landfill gas; landfill engineering; landfill permitting and surrender.

Environment Agency, (2012) this website of the Environment Agency lists down a diverse range of guidance documents relevant to all sectors regulated under EPR (Environmental Protection Regulations) which also includes the landfill sector. From the risk assessment perspective, the most relevant guidance is Environmental Risks Assessment, abbreviated as H1 in the list. The purpose of the H1 is to assist risk assessors in explaining and justifying choice of risk control measures (Environment Agency, 2011a). This document has a number of annexes and sub-annexes around various relevant aspects such as landfill itself (Environment Agency, 2011b), groundwater protection (Environment Agency, 2011c), hydrogeological risk assessments for landfills (Environment Agency, 2010).

EPA, (1992, 1999) these publications purely consider exposure assessment. However they cover the subject from many different perspectives including types of hazards, pathways, receptors and exposure; also, types of dose, (e.g. potential dose, intake dose, applied dose, etc.), exposure dose relationships, uncertainty assessment, individual and population exposure, exposure analysis in epidemiological studies, and the position of the exposure assessment itself with respect to risk characterisation.

EPA, (2009d) This book provides scientific and technical recommendations to address challenges that risk assessment procedures faces e.g. lengthy delays in making complex decisions; lack of data leading to significant uncertainty in risk assessment; etc. The book embeds various risk assessment concepts within a broader framework for risk-based decision-making.

EPA, (2011) Exposure Factors Handbook Some of the steps for performing an exposure assessment are illustrated in (1) identifying the source of the environmental contamination and the media that transports the contaminant; (2) determining the contaminant concentration; (3) determining the exposure scenarios, and pathways and routes of exposure; (4) determining the exposure factors related to human behaviors that define time, frequency, and duration of exposure; and (5) identifying the exposed population. Exposure factors are factors related to human behavior and characteristics that help determine an individual's exposure to an agent. This *Exposure Factors Handbook* provided some useful information and recommendations on various factors used in assessing exposure to both adults and children. The purpose of the *Exposure Factors Handbook* is to (1) summarize data on human behaviors and characteristics that affect exposure to environmental contaminants, and (2) recommend values to use for these factors.

EPA, (2012) This website of the EPA (Environmental Protection Agency) lists down a diverse range of guidance documents relevant to various types and aspects of risk assessment such as: exposure factors (EPA, 2011); toxic release inventory (TRI) (EPA, 2010); evaluation of toxicity of chemicals (EPA, 2009a); development, evaluation and application of environmental models (EPA, 2009b); dosimetry-based cumulative risk assessment (EPA, 2009c); cumulative health risk assessment of multiple chemicals, exposures and effects (EPA, 2008); and assessment of risks from metals (EPA, 2007).

Golder Associates, (2002) published a document regarding risk assessment only for small and closed landfills. The literature mentions hazards and risks involved in the context of contamination of groundwater; contamination of surface water; gas accumulation; and direct exposure to contaminated soil, sharp objects, or hazardous gases. These four scenarios are addressed very briefly in this document.

Kumar et al., (2005a) described the concept of LPI in brief and the various possible aggregations functions and used further to estimate the LPI values for an actual landfill site to decide on the most appropriate aggregation function. Based on the results, this concluded that the weighted linear sum aggregation function is the best possible aggregation function for calculating LPI. Sensitivity analysis of the six shortlisted aggregation functions was performed to substantiate their proposition.

Martinho et al., (2008) this publication provides guidelines for characterisation of municipal solid waste in Portugal. This can be helpful as a part of baseline study in the Site Management unit where ‘waste types’ is one of the parameters.

Peña-Fernández et al., (2014) Depicted the human health risk model in urban environment; after conducting few case studies in Spain,and described that trace elements in urban soils, and those that exist have been derived mainly from areas potentially exposed to industrial contamination or in the vicinity of point pollution. They evaluated the health risk associated with exposure to trace metal (Al, As, Be, Cd, Cr, Cu, Hg, Mn, Ni, Pb, Sn, Ti, Tl, V and Zn) in soil in and around the city of Alcalá de Henares (35 km NE of Madrid).

Rudland et al., (2001) this work describes a basic framework for risk analyses of contaminated land.

SEPA, (2002) this publication regards landfill risk assessment in the context of landfill leachate liners and drainage systems. Some baseline study modules such as geology and hydrogeology are briefly addressed. The SEPA document, on the other hand, in addition to these elements, also briefly touches upon aspects such as maximum, minimum and most likely values of various parameters such as leachate quality. However, as the title of the SEPA document states, the main focus of this guidance note is not risk assessment of landfill leachates but the monitoring aspects of landfill leachates, ground waters and surface waters alike.

SECTION 3

OBJECTIVE AND SCOPE OF WORK

3.1 Objective

The objective of the present study was to evaluate existing condition of hydro and pedospheric environmental quality (water and soil) around the Dhapa landfill site and consequent risk assessment of human health in adjoining areas through collection of samples from the site , laboratory testing and application risk assessment model.

3.2 Scope Of The Study

Following are the scopes considered in the present investigation.

- Identification and selection of some sampling points in suitable location around the dump mound site in Dhapa landfill. In this context, few numbers of tube wells and surface water ponds and canals are to be considered.
- Collection of water samples from ground and surface sources and estimation of their quality parameters.
- Collection of soil samples from around dumpsite up to a depth of 1 m for their quality parameters.
- Major water quality parameters with respect to leachate contamination from the site to be envisaged and accordingly test program to be formulated.
- Identification of predominant and important target pollutant parameters (major emphasis on heavy metal quality).
- Health risk assessment by existing available methods.

SECTION – 4
MATERIALS AND METHODS

4.1 Sampling

To examine the extent of pollution in groundwater, surface water and soil, samples were collected at different preselected sites which were identified on the basis of accessibility, locations, potential history of pollution and human health and the distance from the peripheral boundary of dumping area. A sum total of nine (9) sampling sites were selected for the collection of ground water from the existing tube wells (here denoted as GW). A sum total of six (6) sampling sites were selected for the collection of surface water from the existing ponds and canals (here denoted as SW). A sum total of four (4) sampling sites were selected for the collection of soil samples from around the dumping yard in the existing agricultural fields (here denoted as Soil). The co-ordinates and locations of the ground water sampling points are presented in Table 4.3. The co-ordinates and locations of the surface water sampling points are presented in Table 4.2. The co-ordinates and locations of the soil sampling points are presented in Table 4.1.To assess the contamination in ground water and surface water, groundwater and surface water sampling sites were selected in villages around the landfill site of Dhapa. Generally, the depths of the tube wells are within 200-250ft. In the Dhapa area, ground water flows from North- East(Up steam) to South-West(Down stream) direction(Bhattacharya, 2011).. All the groundwater samples were collected from tube wells and surface water samples in the month of August 2015 and December 2015 from the nearby bheris and jhils (large waterbodies) that are primarily use as fishing and urban agriculture source of water.

TABLE 4.1: Soil Sampling Locations Coordinates

SOIL SAMPLING LOCATION								
Sl no	North				South			
	degree	min	sec	decimal	degree	min	sec	decimal
Soil 1	22	32	0.5	22.53347	88	25	13.4	88.42039
Soil 2	22	32	0.5	22.53347	88	25	18.2	88.42172
Soil 3	22	32	0.5	22.53347	88	25	30	88.42380
Soil 4	22	32	27.6	22.54100	88	25	56.8	88.43244

TABLE 4.2: Surface Water Sampling Locations Coordinates

SURFACE WATER SAMPLING LOCATION								
Sl no	North				South			
	degree	min	sec	decimal	degree	min	sec	decimal
SW 1	22	32	48.9	22.54692	88	25	13.4	88.42039
SW 2	22	32	45.6	22.54600	88	25	18.2	88.42172
SW 3	22	32	28.5	22.54125	88	25	24.5	88.42347
SW 4	22	32	0.6	22.53350	88	25	56.8	88.43244
SW 5	22	32	0.5	22.53347	88	25	34.4	88.42622
SW 6	22	32	27.6	22.54100	88	26	10.8	88.43633

TABLE 4.3: Ground Water Sampling Locations Coordinates

GROUND WATER SAMPLING LOCATION								
Sl no	North				South			
	degree	min	sec	decimal	degree	min	sec	decimal
GW 1	22	32	43.8	22.54550	88	25	14.5	88.42069
GW 2	22	32	44.7	22.54575	88	25	14.1	88.42058
GW 3	22	32	47.4	22.54650	88	25	16.9	88.42136
GW 4	22	32	43.3	22.54536	88	25	13.8	88.42050
GW 5	22	32	43.3	22.54536	88	25	12.8	88.42022
GW 6	22	32	3.5	22.53431	88	26	4.4	88.43456
GW 7	22	32	3.5	22.53431	88	26	4.4	88.43456
GW 8	22	32	0.88	22.53358	88	26	4.93	88.43470
GW 9	22	32	1.4	22.53372	88	25	47.9	88.42997

The sampling locations are shown in figure 4.1, figure 4.2, figure 4.3, figure 4.4, figure 4.5.

FIGURE 4.1: Sampling Sites Around Dhapa

FIGURE 4.2: Sampling Sites Around Dhapa

FIGURE 4.3: Sampling Sites Around Dhapa

FIGURE 4.4: Sampling Sites Around Dhapa

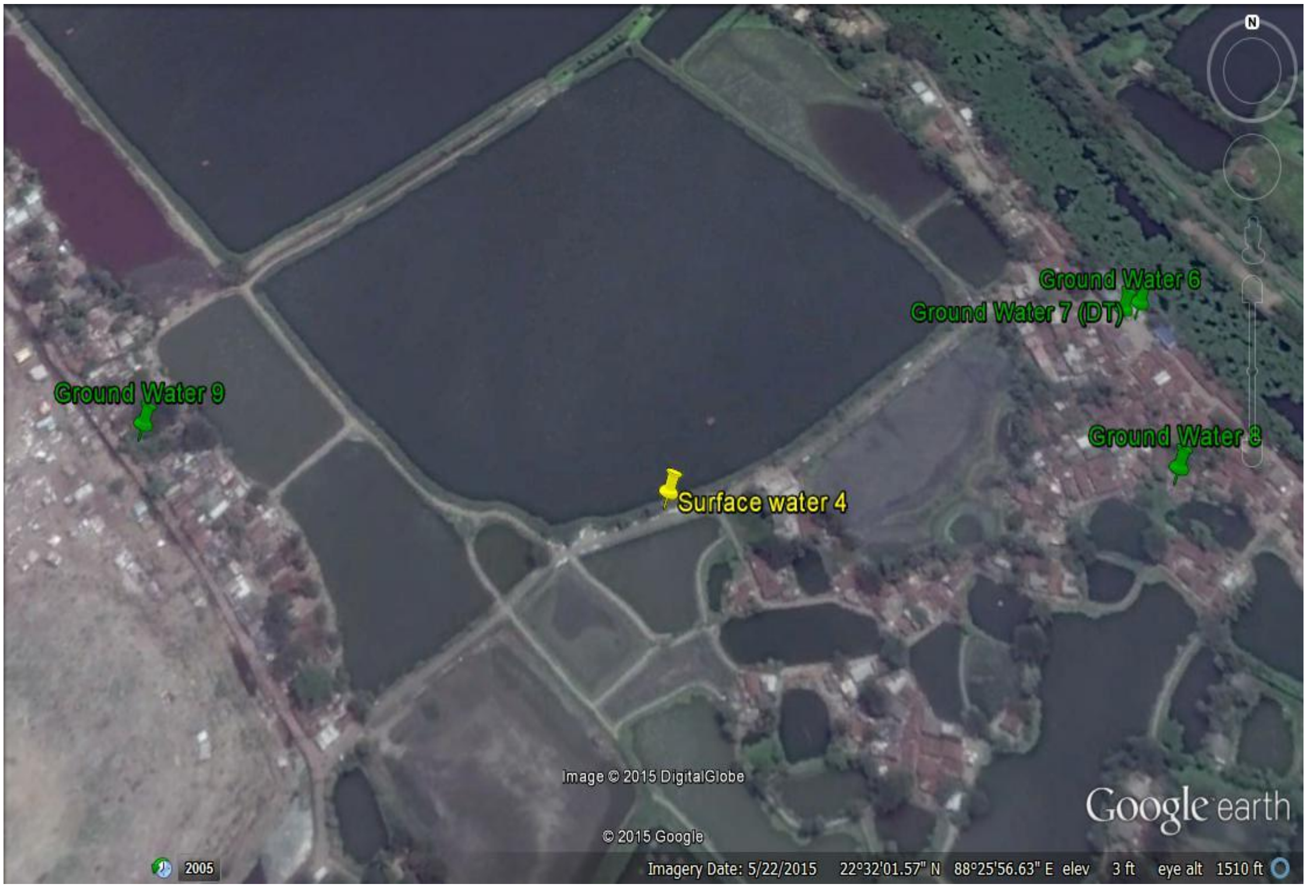


FIGURE 4.5: Sampling Sites Around Dhapa

4.2 Methods of Analysis

During sampling, pH and Temperature of the samples are measured. After the sampling, the samples were immediately transferred to the lab and were stored. The analysis was started without delay, based on the priority to analyze parameters as prescribed by APHA (1995) methods. All the samples were analyzed for selected relevant physico-chemical parameters, heavy metals according to internationally accepted procedures and standard methods (APHA, 1995) Various physico-chemical parameters examined in groundwater, surface water and soil samples, includes, pH, electrical conductivity (EC), total dissolved solids (TDS). pH was measured by Handy pH meter or EUTECH instruments pH tutor and Temperature was measured by Thermometer. EC was recorded using a Deluxe conductivity meter. TDS was done by S.A. Industries Drying Oven and Citizen Balance. The concentrations of heavy metals like cadmium (Cd), copper (Cu), chromium (Cr), iron (Fe), mercury (Hg), nickel (Ni), lead (Pb), manganese (Mn), zinc (Zn) and arsenic (As) were determined using Inductively Coupled Plasma Mass Spectrometry (ICPMS)- for water samples and X - ray florescence spectrometry (XRF)- for soil samples

4.2.1 Analytical Methods

Leachate/ water / soil samples will be collected from the identified collection points around Dhapa disposal sites and the following analytical procedures be adopted for their and quantitative analysis.

Table 4.4: Analytical Methods

Parameter	Method Adopted	Apparatus / Instrument Used
pH	Electrometric Method	Electronic pH meter
Electical Conductivity (EC)	Laboratory Method	Deluxe conductivity meter
Total Dissolved Solid (TDS)	Gavimetric Method	-
Heavy metal	Graphite Furnace Atomic adsorption spectrometric Method / Inductively Coupled Plasma Mass Spectrometry (ICPMS)- for water / X - ray florescence spectrometry (XRF)- for soil	Atomic Absorption Spectrophotometer (A Analyst 400, Perkin Elmer) ICPMS , XRF

4.2.2 ICP-MS

Inductively coupled plasma mass spectrometry (ICP-MS) is a type of mass spectrometry which is capable of detecting metals and several non-metals at concentrations as low as one part in 10^{15} (part per quadrillion, ppq) on non-interfered low-background isotopes. This is achieved by ionizing the sample with inductively coupled plasma and then using a mass spectrometer to separate and quantify those ions.

The ICP-MS allows determination of elements with atomic mass ranges 7 to 250 (Li to U), and sometimes higher. Some masses are prohibited such as 40 due to the abundance of argon in the sample. Other blocked regions may include mass 80 (due to the argon dimer), and mass 56 (due to ArO), the latter of which greatly hinders Fe analysis unless the instrumentation is fitted with a reaction chamber. Such interferences can be reduced by using a high resolution ICP-MS (HR-ICP-

MS) which uses two or more slits constrict the beam and distinguish between nearby peaks..

Unlike atomic absorption spectroscopy, which can only measure a single element at a time, ICP-MS has the capability to scan for all elements simultaneously. This allows rapid sample processing. A simultaneous ICP-MS that can record the entire analytical spectrum from lithium to uranium in every analysis won the Silver Award at the 2010 Pittcon Editors' Awards. An ICP-MS may use multiple scan modes, each one striking a different balance between speed and precision. Using the magnet alone to scan is slow, due to hysteresis, but is precise. Electrostatic plates can be used in addition to the magnet to increase the speed, and this, combined with multiple collectors, can allow a scan of every element from Lithium 6 to Uranium Oxide 256 in less than a quarter of a second. For low detection limits, interfering species and high precision, the counting time can increase substantially. The rapid scanning, large dynamic range and large mass range is ideally suited to measuring multiple unknown concentrations and isotope ratios in samples that have had minimal preparation (an advantage over TIMS), for example seawater, urine, and digested whole rock samples. It also lends well to laser ablated rock samples, where the scanning rate is so quick that a real time plot of any number of isotopes is possible. This also allows easy spatial mapping of mineral grains.

The first step in analysis is the introduction of the sample. This has been achieved in ICP-MS through a variety of means.

The most common method is the use of analytical nebulizers. Nebulizer converts liquids into an aerosol, and that aerosol can then be swept into the plasma to create the ions. Nebulizers work best with simple liquid samples (i.e. solutions).

However, there have been instances of their use with more complex materials like a slurry. Many varieties of nebulizers have been coupled to ICP-MS, including pneumatic, cross-flow, Babington, ultrasonic, and desolvating types. The aerosol generated is often treated to limit it to only smallest droplets, commonly by means of a Peltier cooled double pass or cyclonic spray chamber. Use of autosamplers makes this easier and faster, especially for routine work and large numbers of samples. A Desolvating Nebuliser (DSN) may also be used; this uses a long heated capillary, coated with a fluoropolymer membrane, to remove most of the solvent and reduce the load on the plasma. Matrix removal introduction systems are sometimes used for samples, such as seawater, where the species of interest are at trace levels, and are surrounded by much more abundant contaminants.

An inductively coupled plasma (ICP) for spectrometry is sustained in a torch that consists of three concentric tubes, usually made of quartz. The two major designs are the Fassel and Greenfield torches. The end of this torch is placed inside an induction coil supplied with a radio-frequency electric current. A flow of argon gas (usually 14 to 18 liters per minute) is introduced between the two outermost tubes of the torch and an electrical spark is applied for a short time to introduce free electrons into the gas stream. These electrons interact with the radio-frequency magnetic field of the induction coil and are accelerated first in one direction, then the other, as the field changes at high frequency (usually 27.12 MHz). The accelerated electrons collide with argon atoms, and sometimes a collision causes an argon atom to part with one of its electrons. The released electron is in turn accelerated by the rapidly changing magnetic field. The process continues until the rate of release of new electrons in collisions is balanced by the rate of recombination of electrons with argon ions (atoms that have lost an electron). This produces a ‘fireball’ that consists mostly of argon atoms with a rather small fraction of free electrons and argon ions.

Making the plasma from argon, instead of other gases, has several advantages. First, argon is abundant (in the atmosphere, as a result of the radioactive decay of potassium) and therefore cheaper than other noble gases. Argon also has a higher first ionization potential than all other elements except He, F, and Ne. Because of this high ionization energy, the reaction (Ar+ + e− → Ar) is less energetically favorable than the reaction (M+ + e− → M). This ensures that the sample remains ionized (as M+) so that the mass spectrometer can detect it.

Argon can be purchased for use with the ICP-MS in either a refrigerated liquid or a gas form. However it is important to note that whichever form of argon purchased, it should have a guaranteed purity of 99.9% Argon at a minimum. It is important to determine which type of argon will be best suited for the specific situation. Liquid argon is typically cheaper and can be stored in a greater quantity as opposed to the gas form, which is more expensive and takes up more tank space. If the instrument is in an environment where it gets infrequent use, then buying argon in the gas state will be most appropriate as it will be more than enough to suit smaller run times and gas in the cylinder will remain stable for longer periods of time, whereas liquid argon will suffer loss to the environment due to venting of the tank when stored over extended time frames. However if the ICP-MS is to be used routinely and is on and running for eight or more hours each day for several days a week, then going with liquid argon will be the most suitable. If there are to be multiple ICP-MS instruments running for long periods of time, then it will most likely be beneficial for the laboratory to install a bulk or micro bulk argon tank which will be maintained by a gas supply company, thus eliminating the need to change out tanks frequently as well as minimizing loss of argon that is left over in each used tank as well as down time for tank changeover.

For most clinical methods using ICP-MS, there is a relatively simple and quick sample prep process. The main component to the sample is an internal standard, which also serves as the diluent. This internal standard consists primarily of deionized water, with nitric or hydrochloric acid, and Indium and/or Gallium. Depending on the sample type, usually 5 ml of the internal standard is added to a test tube along with 10–500 microliters of sample. This mixture is then vortexed for several seconds or until mixed well and then loaded onto the autosampler tray. For other applications that may involve very viscous samples or samples that have particulate matter, a process known as sample digestion may have to be carried out, before it can be pipetted and analyzed. This adds an extra first step to the above process, and therefore makes the sample prep more lengthy.

4.2.3 X-Ray Fluorescence (XRF)

An X-ray fluorescence (XRF) spectrometer is an x-ray instrument used for routine, relatively non-destructive chemical analyses of rocks, minerals, sediments and fluids. It works on wavelength-dispersive spectroscopic principles that are similar to an electron microprobe (EPMA). However, an XRF cannot generally make analyses at the small spot sizes typical of EPMA work (2-5 microns), so it is typically used for bulk analyses of larger fractions of geological materials. The relative ease and low cost of sample preparation, and the stability and ease of use of x-ray spectrometers make this one of the most widely used methods for analysis of major and trace elements in rocks, minerals, and sediment.

The analysis of major and trace elements in geological materials by x-ray fluorescence is made possible by the behavior of atoms when they interact with radiation. When materials are excited with high-energy, short wavelength radiation (e.g., X-rays), they can become ionized. If the energy of the radiation is sufficient to dislodge a tightly-held inner electron, the atom becomes unstable and an outer electron replaces the missing inner electron. When this happens, energy is released due to the decreased binding energy of the inner electron orbital compared with an outer one. The emitted radiation is of lower energy than the primary incident X-rays and is termed fluorescent radiation. Because the energy of the emitted photon is characteristic of a transition between specific electron orbitals in a particular element, the resulting fluorescent X-rays can be used to detect the abundances of elements that are present in the sample.

The analysis of major and trace elements in geological materials by XRF is made possible by the behavior of atoms when they interact with X-radiation. An XRF spectrometer works because if a sample is illuminated by an intense X-ray beam, known as the incident beam, some of the energy is scattered, but some is also absorbed within the sample in a manner that depends on its chemistry. The incident X-ray beam is typically produced from a Rh target, although W, Mo, Cr and others can also be used, depending on the application.

When this primary X-ray beam illuminates the sample, it is said to be excited. The excited sample in turn emits X-rays along a spectrum of wavelengths characteristic of the types of atoms present in the sample. How does this happen? The atoms in the sample absorb X-ray energy by ionizing, ejecting electrons from the lower (usually K and L) energy levels. The ejected electrons are replaced by electrons from an outer, higher energy orbital. When this happens, energy is released due to the decreased binding energy of the inner electron orbital compared with an outer one. This energy release is in the form of emission of characteristic X-rays indicating the type of atom present. If a sample has many elements present, as is typical for most minerals and rocks, the use of a Wavelength Dispersive Spectrometer much like that in an EPMA allows the separation of a complex emitted X-ray spectrum into characteristic wavelengths for each element present. Various types of detectors (gas flow proportional and scintillation) are used to measure the intensity of the emitted beam. The flow counter is commonly utilized for measuring long wavelength (>0.15 nm) X-rays that are typical of K spectra from elements lighter than Zn. The scintillation detector is commonly used to analyze shorter wavelengths in the X-ray spectrum (K spectra of element from Nb to I; L spectra of Th and U). X-rays of intermediate wavelength (K spectra produced from Zn to Zr and L spectra from Ba and the rare earth elements) are generally measured by using both detectors in tandem. The intensity of the energy measured by these detectors is proportional to the abundance of the element in the sample. The exact value of this proportionality for each element is derived by comparison to mineral or rock standards whose composition is known from prior analyses by other techniques.

X-Ray fluorescence is used in a wide range of applications, including

- research in igneous, sedimentary, and metamorphic petrology
- soil surveys
- mining (e.g., measuring the grade of ore)
- cement production
- ceramic and glass manufacturing
- metallurgy (e.g., quality control)
- environmental studies (e.g., analyses of particulate matter on air filters)
- petroleum industry (e.g., sulfur content of crude oils and petroleum products)

- field analysis in geological and environmental studies (using portable, hand-held XRF spectrometers)

X-Ray fluorescence is particularly well-suited for investigations that involve

- bulk chemical analyses of major elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P) in rock and sediment
- bulk chemical analyses of trace elements (in abundances >1 ppm; Ba, Ce, Co, Cr, Cu, Ga, La, Nb, Ni, Rb, Sc, Sr, Rh, U, V, Y, Zr, Zn) in rock and sediment - detection limits for trace elements are typically on the order of a few parts per million

X-ray fluorescence is limited to analysis of

- relatively large samples, typically > 1 gram
- materials that can be prepared in powder form and effectively homogenized
- materials for which compositionally similar, well-characterized standards are available
- materials containing high abundances of elements for which absorption and fluorescence effects are reasonably well understood

In most cases for rocks, ores, sediments and minerals, the sample is ground to a fine powder. At this point it may be analyzed directly, especially in the case of trace element analyses. However, the very wide range in abundances of different elements, especially iron, and the wide range of sizes of grains in a powdered sample, makes the proportionality comparison to the standards particularly troublesome. For this reason, it is common practice to mix the powdered sample with a chemical flux and use a furnace or gas burner to melt the powdered sample. Melting creates a homogenous glass that can be analyzed and the abundances of the (now somewhat diluted) elements calculated.

4.3 Principles And Methods Of Risk Assessment

4.3.1 Principles, Definitions, and Perspectives of Solid Waste Risk Assessments

Risk assessment is the attempt to measure the potential for harm on human health. It is a process that aids in site assessments, determining end points in remediation, and evaluating the danger of engaging in potentially hazardous acts such as drinking contaminated groundwater. The use of risk assessment has become commonplace since the promulgation of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or Superfund, and has been important in assessing hazards such as the occurrence of earthquakes, hurricanes, and floods. Hazardous waste risk assessments are systematic and quantitative; there is a well-established algorithm for conducting the process. However, a significant amount of uncertainty and data gaps are inherent in making risk assessments of contaminated soil and contaminated groundwater; therefore, the quantitative methodologies are constrained by uncertainty limits. Furthermore, input data for many of the calculations (e.g., the volume of groundwater ingested per individual per day) may be difficult to obtain, or totally unavailable. Because of this, risk assessment teams must have sufficient risk assessment experience to accurately evaluate the inevitable data gaps.

4.3.2 Definitions of Hazard and Risk

Risk is the probability of damage or loss and can be considered to be a product of the probability and the severity of specific consequences. Risk, as it relates to hazardous wastes and groundwater contamination, may be defined as the chance that humans or other organisms will sustain adverse effects from exposure to these environmental hazards. Risk is inherent in the life of all organisms—humans, animals, and plants. Tornadoes, landslides, hurricanes, earthquakes, and other natural disasters carry a risk of injury or death to any living thing in their path. Similarly, human-caused risks such as automobile accidents, plane crashes, and nuclear disasters occur with varying levels of severity. Specific definitions apply to different aspects of risk assessment in hazardous waste management. Background risk is the risk to which a population is normally exposed, excluding risks from hazardous chemicals or groundwater contamination. Incremental risk is the additional risk caused by hazardous chemicals or the contaminated groundwater. Total risk is the background risk plus the incremental risk. The target incremental risk at Superfund sites for carcinogen exposure to the “most exposed individual,” proposed by the Environmental Protection Agency (EPA), is 1×10^{-6}. The target for total lifetime risk for exposure to carcinogenic contaminants at Superfund sites is then 0.25 plus 1×10^{-6}. Analysis of the total risk often involves critical evaluation of the quantitative risk assessment itself, including analysis of the uncertainties of the assessment and the acceptable risk of the hazardous waste.

Hazard is different from risk; it is a descriptive term that characterizes the intrinsic ability of an event or a substance to cause harm. Hazard is one source of risk and is a function of the persistence, mobility, and toxicity of the contaminants.

4.4 The Risk Assessment Process

4.4.1 Sources, Pathways, and Receptors: The Fundamental Algorithm for Risk Assessments

Hazardous waste problems are frequently generated by mixtures of complex wastes that have been disposed of on land and that have migrated through the subsurface. One approach to assessing the risks of contaminated sites has been to divide the problem into three elements: sources, pathways, and receptors (Watts, 1998) as noted in Table . The first step in assessing the risk at a hazardous waste site is to identify the waste components at the source, including their concentrations and physical properties such as density, water solubility, and flash point. After the source has been characterized, the pathways of the hazardous chemicals are analyzed by quantifying the rates at which the waste compounds volatilize, degrade, and migrate from the source. Pathway analysis is built on source information—the identity and nature of the source chemicals must be known in order to quantify their potential to migrate, degrade, or be treated. Pathway analyses may show that the contaminant will be transformed within weeks and cease to be a problem, or they may show that the contaminant persists in the environment and will reach a receptor (such as a drinking water well) long before it is degraded. Finally, if the pathway analysis shows that the contaminant will come into contact with receptors (humans, endangered species, etc.), the hazard must be assessed with the aid of toxicological data.

Table 4.5: Elements of sources, pathways, and receptors algorithm used in hazardous waste risk assessments (IRIS, 2010)

Sources	**Pathways**	**Receptors**
Time since environmental release Contaminants potentially present Sampling Contaminant concentrations Contaminant locations Contaminant properties Water solubility Octanol–water partition coefficient Vapor pressure Henry's law constant	Rate of release from the source Air Groundwater Atmospheric transport Wind speed Dispersion Groundwater transport Advection–dispersion Sorption Distance to receptors	Characteristics of receptor population Acute toxicity Chronic toxicity Non carcinogenic Carcinogenic

The Four-step Risk Assessment Process

The National Academy of Sciences and the EPA have formulated four steps in the assessment of risk from hazardous wastes (US EPA, 1989a; NAS, 1983):

(i) hazard identification (source analysis; investigating the chemicals present at the site and their characteristics),

(ii) exposure assessment (pathway analysis; estimating the potential transport of the chemicals to receptors and levels of intake),

(iii) toxicity assessment including the determination of numerical indices of toxicity (receptor analysis), and

(iv) risk characterization involving the determination of a number that expresses risk quantitatively, such as one in one hundred (0.01) or one in one million (1×10^{-6}).

4.4.2 Hazard Identification

The first step in risk assessment is to determine the nature of the hazard. For pollution-related problems, the hazard in question is usually pertaining to a specific chemical, a physical agent (such as irradiation), or a microorganism identified with a specific illness or disease. Thus the hazard identification component of a pollution risk assessment consists of a review of all relevant biological and chemical information bearing on whether or not an agent poses a specific threat.

For example, in the *Guidelines for Carcinogen Risk Assessment* (USEPA, 1986), the following information is evaluated for a potential carcinogen:

- Physical/chemical properties, routes, and patterns of exposure
- Structure/activity relationships of the substance

- Absorption, distribution, metabolism, and excretion characteristics of the substance in the body
- The influence of other toxicological effects
- Data from short-term tests in living organisms
- Data from long-term animal studies
- Data from human studies

Once these data are reviewed, the animal and human data are both separated into groups characterized by degree of evidence:

- Sufficient evidence of carcinogenicity
- Limited evidence of carcinogenicity
- Inadequate evidence
- No data available
- No evidence of carcinogenicity

The available information on animal and human studies is then combined into a weight-of-evidence classification scheme to assess the likelihood of carcinogenicity. This scheme-as such developed by the EPA—gives more weight to human than to animal evidence (when it is available) and includes several groupings (Table. Clinical studies of disease can be used to identify very large risks (between 1/10 and 1/100), most epidemiological studies can detect risks down to 1/1,000, and very large epidemiological studies can examine risks in the 1/10,000 range. However, risks lower than 1/10,000 cannot be studied with much certainty using epidemiological approaches. Since regulatory policy objectives generally strive to limit risks below 1/100,000 for life-threatening diseases like cancer, these lower risks are often estimated by extrapolating from the effects of high doses given to animals

4.4.3 Exposure Assessment

Exposure assessment is the process of measuring or estimating the intensity, frequency, and duration of human exposure to an environmental agent. Exposure to contaminants can occur via inhalation, ingestion of water or food, or absorption through the skin upon dermal contact. Contaminant sources, release mechanisms, transport, and transformation characteristics are all important aspects of exposure assessment, as are the nature, location, and activity patterns of the exposed population.

An exposure pathway is the course that a hazardous agent takes from a source to a receptor (*e.g.*, human or animal) via environmental carriers or media—generally, air (volatile compounds, particulates) or water (soluble compounds). The exposure route, or intake pathway, is the mechanism by which the transfer occurs—usually by inhalation, ingestion, and/or dermal contact. Direct contact can result in a local effect at the point of entry and/or in a systemic effect.

Table 4.6: EPA categories for carcinogenic groups

CLASS	DESCRIPTION
A	Human carcinogen
B	Probable carcinogen
B1	Linked human data
B2	No evidence in humans
C	Possible carcinogen
D	No classification
E	No evidence

Source: From U.S. EPA, 1986

The quantification of exposure, intake, or potential dose can involve equations with three sets of variables:

- Concentrations of chemicals or microbes in the media
- Exposure rates (magnitude, frequency, duration)
- Quantified biological characteristics of receptors (*e.g.*, body weight, absorption capacity for chemicals; level of immunity to microbial pathogens).

Exposure concentrations are derived from measured and/or modelled data. Ideally, exposure concentrations should be measured at the points of contact between the environmental media and current or potential receptors. It is usually possible to identify potential receptors and exposure points from field observations and other information. However, it is seldom possible to anticipate all potential exposure points and measure all environmental concentrations under all conditions. In practice, a combination of monitoring and modelling data, together with a great deal of professional judgment, is required to estimate exposure concentrations.

In order to assess exposure rates via different exposure pathways, we have to consider and weigh many factors. For example, in estimating exposure to a substance via drinking water, we first have to determine the average daily consumption of that water. But this isn't as easy as it sounds. Studies have shown that daily fluid intake varies greatly from individual to individual. Moreover, tap water intake depends on how much fluid is consumed as tap water, and how much is ingested in the form of soft drinks and other non-tap-water sources. Tap water intake also changes significantly with age, body weight, diet, and climate. Because these factors are so variable, the EPA has suggested a number of very conservative "default" exposure values that can be used when assessing contaminants in tap water, vegetables, soil, and the like (Table 4.7)

Table 4.7: EPA standard default exposure factors

LAND USE	EXPOSURE PATHWAY	DAILY INTAKE	EXPOSURE FREQUENCY (DAYS/YEAR)	EXPOSURE DURATION (YEAR)
Residential	Ingestion of potable water	2 L day^{-1}	350	30
	Ingestion of soil and dust	200 mg (child)	350	6
		100 mg (adult)		24
	Inhalation of contaminants	20 m^3 (total)	350	30
		15 m^3 (indoor)		
Industrial and commercial	Ingestion of potable water	1 L	250	25
	Ingestion of soil and dust	50 mg	250	25
	Inhalation of contaminants	20 m^3 (workday)	250	25
Agricultural	Consumption of homegrown produce	42 g (fruit)	350	30
		80 g (vegetable)		
Recreational	Consumption of locally caught fish	54 g	350	30

Source Modified from Kolluru (1993). From *Pollution Science* ©1996, Academic Press, San Diego, CA.

One important route of exposure is the food supply. Toxic substances are often bioaccumulated, or concentrated, in plant and animal tissues, thereby exposing humans who ingest those tissues as food. Moreover, many toxic substances tend to be biomagnified in the food chain, so that animal tissues contain relatively high concentrations of toxins. Take fish, for example. It is relatively straightforward to estimate concentrations of contaminants in water. Thus, we can use a bioconcentration factor (BCF) to estimate the tendency for a substance in water to accumulate in fish tissue. The concentration of a chemical in fish can be estimated by multiplying its concentration in water by the BCF. The greater the value of the

BCF, the more the chemical accumulates in the fish and the higher the risk of exposure to humans.

The units of BCF—litres per kilogram (L kg^{-1}) —are chosen to allow the concentration of a chemical to be expressed as milligrams per litre (mg L^{-1}) of water and the concentration in fish to be in milligrams per kilogram (mg kg^{-1}) of fish body weight. In Table 6.4, we see the BCFs of several common organic and inorganic chemicals. Note the high values of BCF for the chlorinated hydrocarbon pesticides like dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCBs).

Table 4.8: Bio concentration factors (BCFs) for various organic and inorganic compounds

CHEMICAL	**BCF (L kg^{-1})**
Aldrin	28
Benzene	44
Cadmium	81
Chlordane	14000
Chloroform	3.75
Copper	200
DDT	54000
Formaldehyde	0
Nickel	47
PCBs	100000
Trichloroethylene	10.6
Vinyl chloride	1.17

Source: From U.S. EPA, 1990.

4.4.4 Dose–Response Toxicity Assessment

Chemicals and other contaminants are not equal in their capacity to cause adverse effects. To determine the capacity of chemical agents to cause harmful effect, quantitative toxicity data are needed. Some toxicity data are derived from occupational, clinical, and epidemiological studies. Most toxicity data, however, come from animal experiments in which researchers expose laboratory animals, mostly mice and rats, to increasingly higher concentrations or doses and observe their corresponding effects. The result of these experiments is the *dose–response relationship*—a quantitative relationship that indicates the agent's degree of toxicity to exposed species. Dose is normalized as milligrams of substance or pathogen ingested, inhaled, or absorbed (in the case of chemicals) through the skin per kilogram of body weight per day (mg kg_1 day_1). Responses or effects can vary widely—from no observable effect, to temporary and reversible effects (*e.g.*, enzyme depression caused by some pesticides or diarrhoea caused by viruses), to permanent organ injury (*e.g.*, liver and kidney damage caused by chlorinated solvents, heavy metals, or viruses), to chronic functional impairment (*e.g.*, bronchitis or emphysema arising from smoke damage), to death.

The goal of a dose–response assessment is to obtain a mathematical relationship between the amount (concentration) of a toxicant or microorganism to which a human is exposed and the risk of an adverse outcome from that dose. The data resulting from experimental studies is presented as a dose–response curve, as shown in Figure 6.1. The abscissa describes the dose, while the ordinate measures the risk that some adverse health effect will occur. In the case of a pathogen, for instance, the ordinate may represent the risk of infection, and not necessarily illness.

Dose–response curves derived from animal studies must be interpreted with care. The data for these curves are necessarily obtained by examining the effects of large doses on test animals. Because of the costs involved, researchers are limited in the numbers of test animals they can use—it is both impractical and cost-prohibitive to use thousands (even millions) of animals to observe just a few individuals that show adverse effects at low doses (e.g., risks of 1:1,000 or 1:10,000). Researchers must therefore extrapolate low-dose responses from their high-dose data. Dose–response curves are subject to controversy because their results change depending on the method chosen to extrapolate from the high doses actually administered to laboratory test subjects to the low doses humans are likely to receive in the course of everyday living.

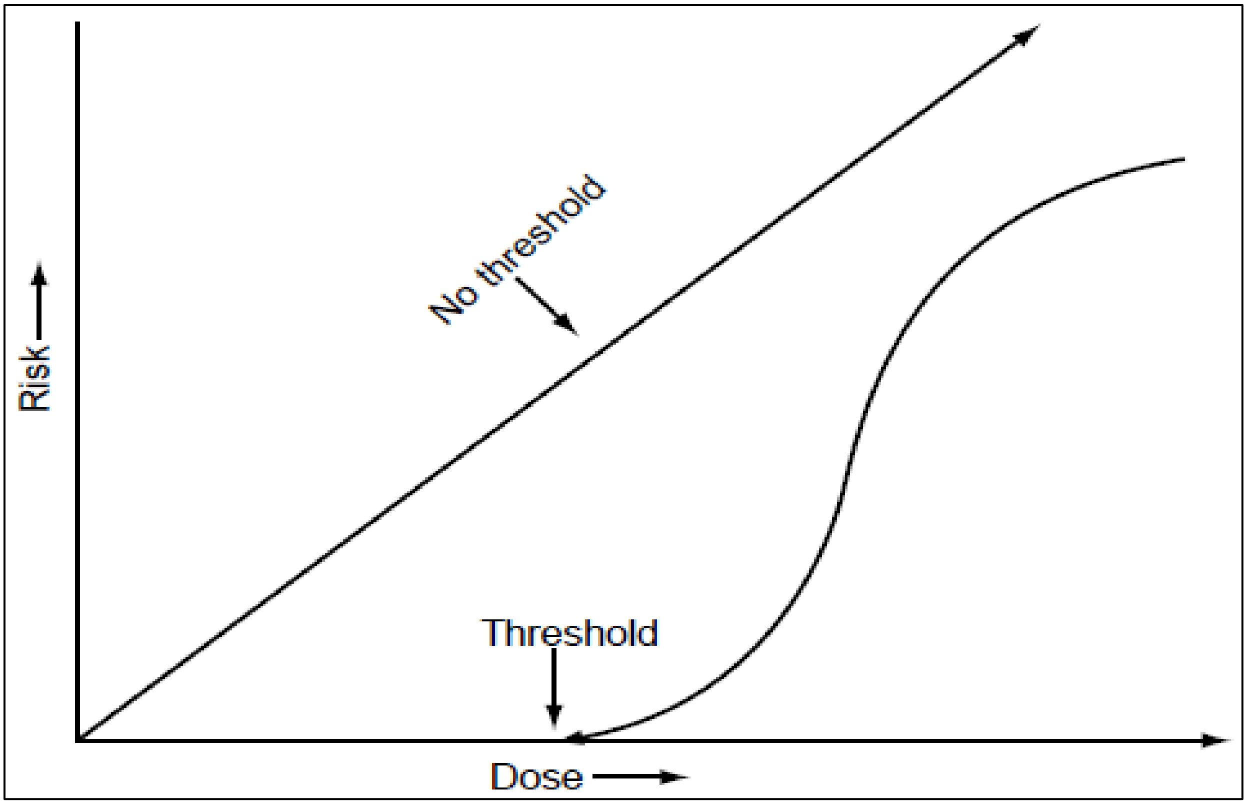


Figure 4.6: Relationship Between A Threshold And Non-Threshold Response

This assessment of risk revolves around the choice of several mathematical models that have been proposed for extrapolation to low doses. Unfortunately, no model can be proved or disproved from the data, so there is no way to know which model is the most accurate. The choice of models is therefore strictly a policy decision, which is usually based on understandably conservative assumptions. Thus, for noncarcinogenic chemical responses, the assumption is that some *threshold* exists below which there is no toxic response; that is, no adverse effects will occur below some very low dose (say, one in a million) (Figure 6.1). Carcinogens, however, are considered *nonthreshold*—that is, the conservative assumption is that exposure to any amount of carcinogen creates some likelihood of cancer. This means that the only "safe" amount of carcinogen is zero, so the dose–response plot is required to go through the origin (0), as shown in Figure .

There are many mathematical models to choose from, including the one-hit model, the multistage model, the multihit model, and the probit model. The characteristics of these models for nonthreshold effects are listed in Table 4.8

Table 4.9: Primary models used for assessment of non-threshold effects

MODEL	**Observation**
One-hit	Assumes (1) a single stage for cancer and (2) malignant change induced by one molecular interaction *Very conservative*
Linear	Assumes multiple stages for cancer
multistage	*Fits curve to the experimental data*
Multihit	Assumes several interactions needed before cell becomes transformed *Least conservative model*
Probit	Assumes probit (lognormal) distribution for tolerances of exposed population *Appropriate for acute toxicity; questionable for cancer*

The **one-hit model** is the simplest model of carcinogenesis in which it is assumed:
1. That a single chemical “hit,” or exposure, is capable of inducing malignant change (*i.e.*, a single hit causes irreversible damage of DNA, leading to tumour development). Once the biological target is hit, the process leading to tumour formation continues independently of dose.
2. That this change occurs in a single stage.

The **multistage model** assumes that tumours are the result of a sequence of biological events, or stages. In simplistic terms, the biological rationale for the multistage model is that there are a series of biological stages that a chemical must pass through (*e.g.*, metabolism, covalent bonding, DNA repair, and so on) without being deactivated, before the expression of a tumour is possible. The rate at which the cell passes through one or more of these stages is a function of the dose rate. The multistage model also has the desirable feature of producing a linear relationship between risk and dose.

The **multihit model** assumes that a number of dose related hits are needed before a cell becomes malignant. The most important difference between the multistage and multihit model is that in the multihit model, all hits must result from the dose, whereas in the multistage model, passage through some of the stages can occur spontaneously. The practical implication of this is that the multihit models are generally much flatter at low doses and consequently predict a lower risk than the multistage model.

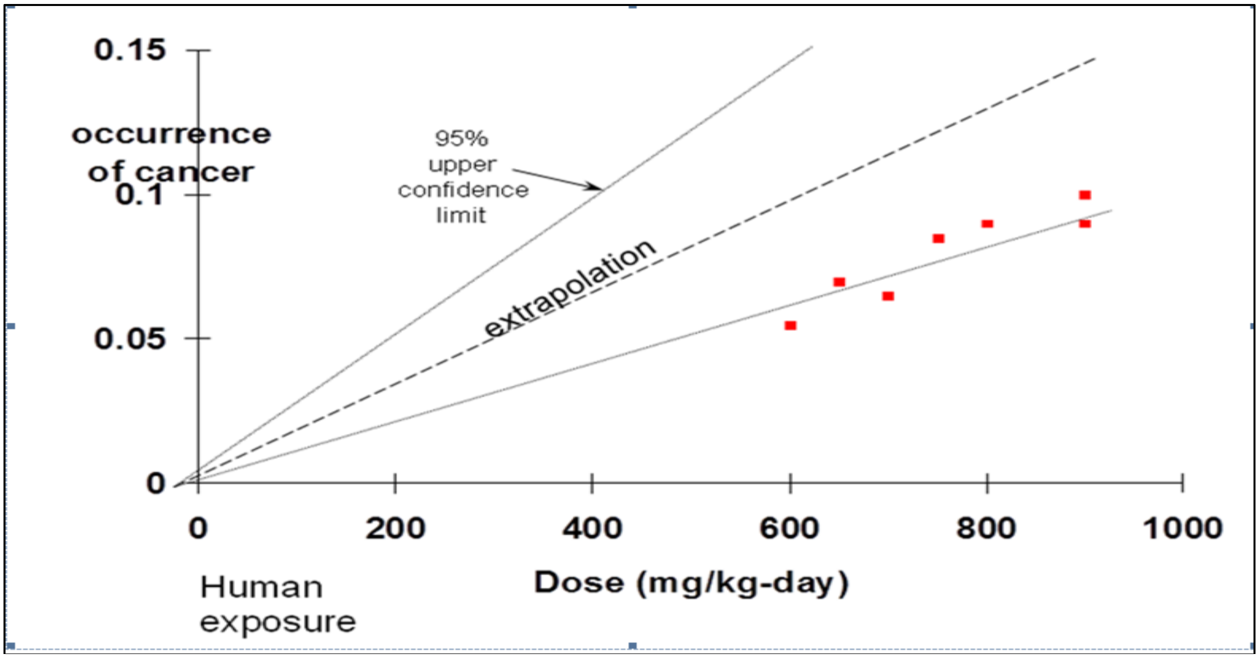
The **probit model** is not derived from mechanistic assumptions about the cancer process. It may be thought of as representing distributions of tolerances to carcinogens in a large population. The model assumes that the probability of the response (cancer) is a linear function of the log of the dose (log normal). While these models may be appropriate for acute toxicity they are considered questionable for carcinogens. These models would predict the lowest level of risk of all the models.

The effect of models on estimating risk for a given chemical is shown in Table 6.6 and Figure 6.2. As we can see, the choice of models results in order-of-magnitude differences in estimating the risk at low levels of exposure

Table 4.10: Lifetime risks of cancer derived from different extrapolation models

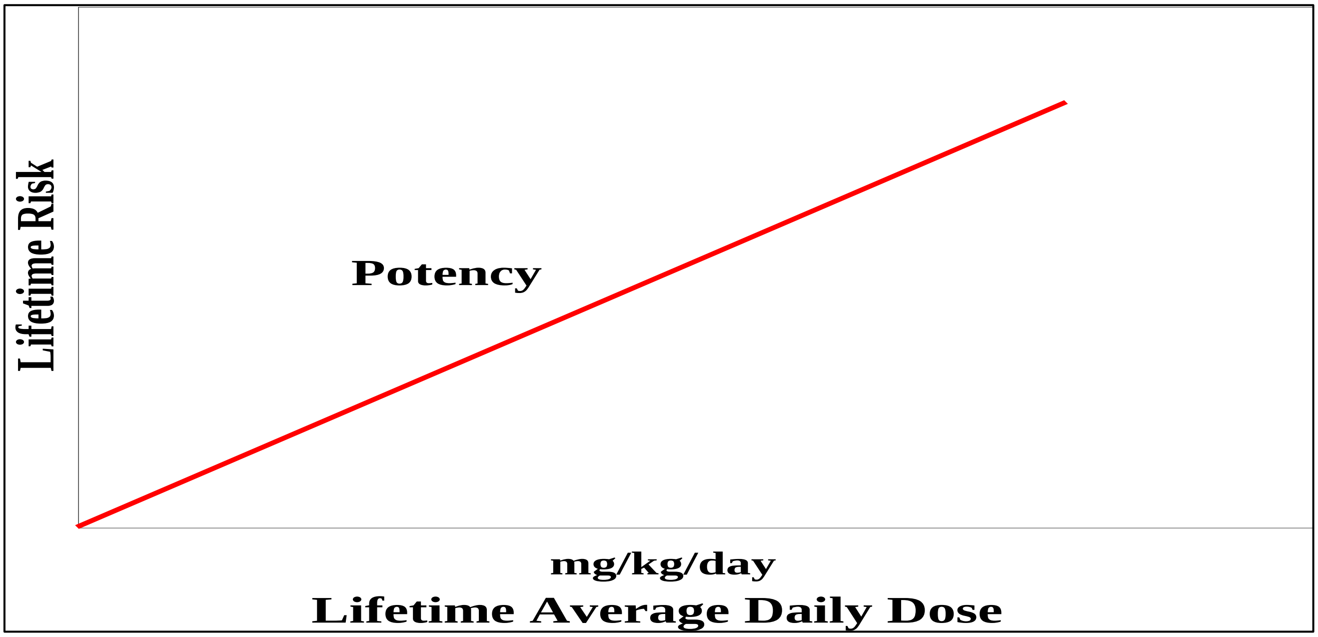
MODEL APPLIED	LIFETIME RISK (1.0 mg kg^{-1} day^{-1}) OF TOXIC CHEMICAL	
One-hit	6.0×10 -5	(1 in 17,000)
Multistage	6.0×10 - 6	(1 in 167,000)
Multihit	4.4×10 -7	(1 in 2.3 million)
Probit	1.9×10 -10	(1 in 5.3 billion)

All risks for a full lifetime of daily exposure. The lifetime is used as the unit of risk measurement, because the experimental data reflect the risk experienced by animals over their full lifetimes. The values shown are upper confidence limits on risk. Source: U.S. EPA, 1990. From Pollution Science © 1996, Academic Press, San Diego, CA.



Adapted from U.S. EPA 1990. From *Pollution Science* © 1996, Academic Press, San Diego, CA

Figure 4.7: Extrapolation Of Dose–Response Curves..



Potency factor is the slope of the dose–response curve at low doses. At low doses, the slope of the dose– response curve produced by the multistage model is called the potency factor. It is the risk produced by a lifetime average dose of 1 mg kg_1 day_1. Adapted from U.S. EPA, 1990. From Pollution Science © 1996, Academic Press, San Diego, CA.

Figure 4.8: Lifetime Risk Vs Daily Dose Curves

The **linear multistage model,** a modified version of the multistage model, is the EPA's model of choice, because this agency chooses to err on the side of safety and overemphasize risk. This model assumes that there are multiple stages for cancer (*i.e.*, a series of mutations or biotransformations) involving many carcinogens, co-carcinogens, and promoters that can best be modeled by a series of mathematical functions. At low doses, the slope of the dose-response curve produced by the linear multistage model is called the **potency factor (PF)** or **slope factor (SF)** (Figure 6.3), which is the reciprocal of the concentration of chemical measured in milligrams per kilogram of animal body weight per day, that is, 1/(mg kg-1 day-1), or the risk produced by a lifetime **average dose (AD)** of 1 mg kg-1 day-1.

Thus the dose–response equation for a carcinogen is

$$\text{Lifetime Risk} = \text{AD} \times \text{PF}$$

The probability of *getting* cancer (not the probability of *dying* of cancer) and the associated dose, consist of an average taken over an assumed 70-year human lifetime. This dose is called the lifetime average daily dose or **chronic daily intake**.

The dose–response effects for noncarcinogens allow for the existence of thresholds, that is, a certain quantity of a substance or dose below which there is **no observable toxic effect (NOAEL**) by virtue of the body's natural repair and detoxifying capacity. If a NOAEL is not available, a LOAEL (lowest observed adverse effect level) may be used, which is the lowest observed dose or concentration of a substance at which there is a detectable adverse health effect.

When a LOAEL is used instead of a NOAEL, an additional uncertainty factor is normally applied. Examples of toxic substances that have thresholds are heavy metals and polychlorinated biphenyls (PCBs). These thresholds are represented by the **reference dose**, or **RfD**, of a substance, which is the intake or dose of the substance per unit body weight per day (mg kg_1 day_1) that is likely to pose no appreciable risk to human populations, including such sensitive groups as children . A dose–response plot for carcinogens therefore goes through this reference point.

Table 4.11: Chemical RfDs for chronic noncarcinogenic effects of selected chemicals

CHEMICAL	RfD (mg kg-1 day-1)
Acetone	0.1
Cadmium	0.0005
Chloroform	0.01
Methylene chloride	0.06
Phenol	0.04
Polychlorinated biphenyl	0.0001
Toluene	0.3
Xylene	2.0

Source: (U.S. EPA, 1990).

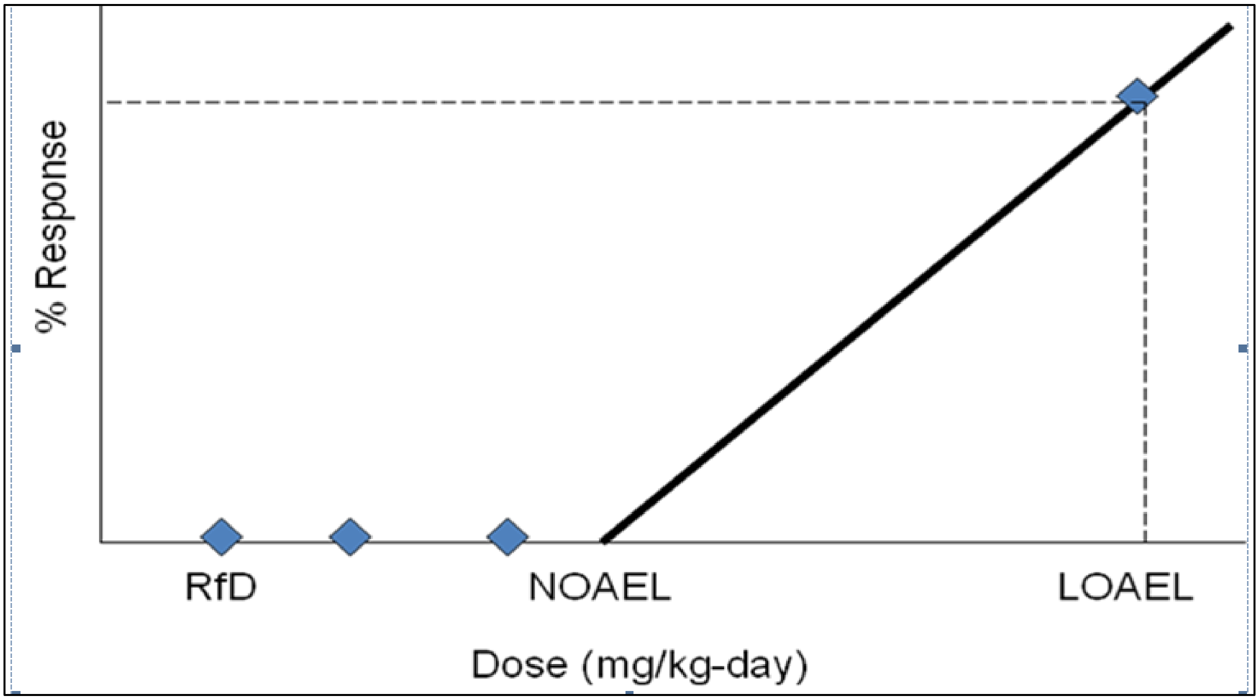


Figure 4.9: Relationships Between Rfd, NOAEL, And LOAEL For Noncarcinogens

In general, substances with relatively high slope factors and low reference doses tend to be associated with higher toxicities. The RfD is obtained by dividing the NOAEL by an appropriate uncertainty factor, sometimes called a **safety factor** or **uncertainty factor**. A 10-fold uncertainty factor is used to account for differences in sensitivity between the most sensitive individuals in an exposed human population. These include pregnant women, young children, and the elderly, who are more sensitive than "average" people. Another factor of 10 is added when the NOAEL is based on animal data that are extrapolated to humans.

In addition, another factor of 10 is sometimes applied when questionable or limited human and animal data are available. The general formula for deriving an RfD is

$$RfD = \frac{\text{NOAEL}}{\text{VF1} \times \text{VF2} \ldots \times \text{VFn}}$$

where VFi are the uncertainty factors. As the data become more uncertain, higher safety factors are applied. For example, if data are available from a high-quality epidemiological study, a simple uncertainty factor of 10 may be used by simply dividing the original value for RfD by 10 to arrive at a new value of RfD, which reflects the concern for safety. The RfDs of several noncarcinogenic chemicals are shown in Table 4.11.The RfD can be used in quantitative risk assessments by using the following relationship:

$$Risk = PF\ (CDI - RfD)$$

where CDI is the chronic daily intake, and the *potency factor (PF)* is the slope of the dose-response curve. Table 6.8 contains potency factors for some potential carcinogens:

$$\text{CDI (mg/kg/day)} = \frac{\text{average daily dose (mg/day)}}{\text{body weight (kg)}}$$

This type of risk calculation is rarely performed. In most cases, the RfD is used as a simple indicator of potential risk in practice. That is, the chronic daily intake is simply compared with the RfD, then, if the CDI is below the RfD, it is assumed that the risk is negligible for almost all members of an exposed population.

Table 4.12: Toxicity data for selected potential carcinogens

CHEMICAL	**POTENCY FACTOR ORAL ROUTE (mgkgday-1)**
Arsenic	1.75
Benzene	2.9×10^{-2}
Carbon tetrachloride	0.13
Chloroform	6.1×10^{-3}
DDT	0.34
Dieldrin	30
Heptachlor	3.4
Methylene chloride	7.5×10^{-3}
Polychlorinated biphenyls (PCBs)	7.7
2,3,7,8-TCDD (dioxin)	1.56×10^{5}
Tetrachloroethylene	5.1×10^{-2}
Trichloroethylene (TCE)	1.1×10^{-2}
Vinyl chloride	2.3

Source: From U.S. EPA, www.epa.gov/iris.

4.4.5 Risk Characterization

The final phase of risk assessment process is risk characterization. In this phase, exposure and dose–response assessments are integrated to yield probabilities of effects occurring in humans under specific exposure conditions. Quantitative risks are calculated for appropriate media and pathways. For example, the risks of lead in water are estimated over a lifetime assuming: (1) that the exposure of 2 liters of water per day is ingested over a 70-year lifetime; and (2) that different concentrations of lead occur in the drinking water. This information can then be used by risk managers to develop standards or guidelines for specific toxic chemicals or infectious microorganisms in different media, such as the drinking water or food supply.

4.4.6 Cancer risks

If the dose–response curve is assumed to be linear at low doses for a carcinogen, then:

$$\text{Incremental lifetime risk of cancer} = (\text{CDI})\ (\text{PF})$$

The linearized multistage model assumptions (see Table 6.5) estimates the risk of getting cancer, which is not necessarily the same as the risk of dying of cancer, so it should be even more conservative as an upper-bound estimate of cancer deaths. Potency factors can be found in the EPA database on toxic substances called the Integrated Risk Information System (IRIS). Table 6.8 contains the potency factor for some of these chemicals. The mean exposure concentration of contaminants is used with exposed population variables and the assessment determined variables to estimate contaminant intake.

The general equation for chemical intake is

$$\mathrm{CDI} = \frac{\mathrm{C} \times \mathrm{CR} \times \mathrm{EFD}}{\mathrm{BW}} \times 1/\mathrm{AT}$$

where:

CDI _ chronic daily intake; the amount of chemical at the exchange boundary (mg/kg-day)

C - average exposure concentration over the period (*e.g.*, mg/L for water or mg/m3 for air)

CR - contact rate, the amount of contaminated medium contacted per unit time (L/day or m3/day)

EFD - exposure frequency and duration, a variable that describes how long and how often exposure occurs. The EFD is usually divided into two terms:

EF - exposure frequency (days/year) and

ED - exposure duration (years)

BW - average body mass over the exposure period (kg)

AT - averaging time; the period over which the exposure is averaged (days)

Determination of accurate intake data is sometimes difficult; for example, exposure frequency and duration vary among individuals and must often be estimated; site-specific information may be available; and professional judgment may be necessary. Equations for estimating daily contamination intake rates from drinking water, the air, and contaminated food, and for dermal exposure while swimming, have been reported by the EPA. Two of the most common routes of exposure are through drinking contaminated water and breathing contaminated air.

The intake for ingestion of waterborne chemicals is

$$CDI = \frac{\mathrm{CW} \times \mathrm{IR} \times \mathrm{EF} \times \mathrm{ED}}{\mathrm{BW} \times \mathrm{ET}}$$

where

CDI - chronic daily intake by ingestion (mg/kg-day)
CW - chemical concentration in water (mg/L)
IR - ingestion rate (L/day)
EF - exposure frequency (days/year)
ED - exposure duration (years)
BW - body weight (kg)
AT - averaging time (period over which the exposure is averaged-days)

Some of the values used in Equation 14.5 are
CW: site-specific measured or modeled value
IR: 2 L/day (adult, 90th percentile); 1.4 L/day (adult, average)
EF: pathway-specific value (dependent on the frequency of exposure-related activities)
ED: 70 years (lifetime; by convention); 30 years [national upper-bound time (90th percentile) at one residence]; 9 years [national median time (50th percentile) at one residence]
BW: 70 kg (adult, average); Age-specific values
AT: pathway-specific period of exposure for noncarcinogenic effects (*i.e.*, ED-365 days/year), and 70-year lifetime for carcinogenic effects (*i.e.*, 70 years-365 days/year), averaging time.

4.4.7 Non-cancer risks

Noncarcinogenic risks are expressed in terms of a hazard quotient (HQ) for a single substance, or hazard index (HI) for multiple substances and/or exposure pathways.

$$\text{Hazard quotient (HQ)} = \frac{\text{Average daily dose during exposure period mgkg}-1\text{ day}-1}{\text{RfD mgkg}-1\text{ day}-1}$$

Unlike a carcinogen, the toxicity is important only during the time of exposure, which may be one day, a few days, or years. The HQ has been defined so that if it is less than 1.0, there should be no significant risk or systemic toxicity. Ratios above 1.0 could represent a potential risk, but there is no way to establish that risk with any certainty. When exposure involves more than one chemical, the sum of the individual hazard quotients for each chemical is used as a measure of the potential for harm. This sum is called the hazard index (HI)

HI =Sum of hazard quotients

SECTION – 5

RESULTS AND DISCUSSION

5.1 Results And Discussion

Potential human health risks associated with select uses of the water and soil were evaluated using USEPA protocols. Chemicals of potential concern (COPCs) at the Site were selected on the basis of measured concentrations in surface water, groundwater and in soil, inherent toxicity, and frequency of detection. Conservative estimates of the average concentrations of COPCs detected in samples collected were calculated for the entire site and the nature and magnitude of actual or potential exposures to site COPCs were characterized for specific exposure scenarios. These potential exposure scenarios include:

- Residents exposed to surface water, groundwater and soil via direct ingestion, dermal contact, and inhalation exposure routes.
- Villager and excavation workers exposed to surface water and soil via direct ingestion, dermal contact, and inhalation exposure routes.

5.2 Analysis result of ground water

TABLE 5.1 : ICP MS Analysis Of Ground Water Samples (μg/l) - Sampling date: 02/09/2015

S ID	As	Cd	Cr	Co	Cu	Fe	Pb	Ni	Zn
GW 1	13.43	2.23	37.044	1.858	8.26	102.31	5.313	18.5	1459.61
GW 2	10.22	2.03	44.271	2.183	5.69	176.7	4.563	25.876	25.41
GW 3	26.03	2.05	57.6	5.05	7.96	893.69	10.32	30.56	428.09
GW 4	12.33	2.02	64.477	7.50	6.48	410.635	10.38	10.9	49.339
GW 5	17.18	2.14	65.167	6.50	9.85	297.913	11.30	8.112	1394.07
GW 6	32.72	2.05	53.728	3.133	6.18	481.985	5.75	5.678	29.94
GW 7	23.42	4.59	76.19	2.688	8.220	79.053	5.105	8.180	108.57
GW 8	122.54	2.12	112.87	3.335	7.9	1193.998	76.603	57.79	298.71
GW 9	23.33	2.03	54.335	2.269	11.63	123.15	5.14	3.09	23.75

TABLE 5.2 : ICP MS Analysis Of Ground Water Samples (μg/l) - Sampling date: 14/12/2015

S ID	As	Cd	Cr	Co	Cu	Fe	Pb	Ni	Zn
GW 1	28.332	3.53	49.714	3.428	11.25	126.08	32.41	27.75	1469.812
GW 2	42.128	2.23	56.941	3.753	8.68	200.47	21.66	35.146	35.667
GW 3	37.97	2.35	70.27	6.62	10.95	917.46	37.417	39.83	438.309
GW 4	54.764	3.32	80.149	9.07	9.47	434.405	27.467	20.17	59.596
GW 5	59.088	2.44	79.837	9.07	12.84	321.683	48.40	17.382	1304.327
GW 6	44.627	3.35	95.398	4.703	9.17	505.755	22.85	14.948	40.196
GW 7	35.328	5.89	88.86	3.258	11.210	102.823	42.202	17.450	118.354
GW 8	134.465	3.42	135.54	4.905	10.89	1217.768	93.7	67.06	308.967
GW 9	35.238	4.33	67.005	3.839	14.62	146.92	22.237	12.36	34.007

TABLE 5.3: Statistical Analysis Of Ground Water Sample

S ID	As	Cd	Cr	Co	Cu	Fe	Pb	Ni	Zn
AVERAGE	41.84	2.90	71.63	4.62	9.51	429.60	26.82	23.38	423.71
MAX	128.50	5.24	124.21	8.29	13.13	1205.88	85.15	62.43	1464.71
MIN	20.88	2.13	43.38	2.64	7.19	90.94	13.11	7.73	28.88
STD DEV	31.09	0.89	21.89	2.04	1.75	366.17	21.27	16.39	542.50

Table 5.4: Physicochemical Analysis Of Ground Water Sample

S ID	pH	EC (ms/cm)	TDS (ppm)	pH	EC(ms/cm)	TDS(ppm)
	Sampling date: 02/09/2015			Sampling date: 14/12/2015		
GW 1	7.31	1923	430.00	7.63	2260	1220
GW 2	7.14	1906	437.33	7.67	1508	1330
GW 3	7.36	1932	441.33	7.5	1385	1250
GW 4	7.1	1998	457.00	7.37	1661	1270
GW 5	7.22	1903	445.67	7.7	1359	1330
GW 6	7.21	545	487.67	7.44	1849	1480
GW 7	7.17	416	500.67	7.31	1714	1700
GW 8	4.88	1462	4126.67	5.98	1070	1060
GW 9	7.12	367	440.67	7.31	1530	1350

5.3 Analysis result of surface water

Table 5.5 : ICP MS Analysis Of Surface Water Samples (µg/l) - Sampling date: 02/09/2015

S ID	As	Cd	Cr	Co	Cu	Fe	Pb	Ni	Zn
SW 1	22.17	2.04	46.626	2.729	6.25	286.95	5.266	8.18	898.54
SW 2	45.61	2.13	40.365	3.845	7.91	297.469	5.665	4.79	46.83
SW 3	13.41	2.05	40.344	2.095	15.03	154.655	5.703	9.531	59.71
SW 4	24.14	2.06	64.344	0.27	7.98	275.489	6.599	3.32	1075.52
SW 5	19.75	2.03	84.243	1.21	20.64	292.65	5.23	5.93	682.17
SW 6	24.03	2.18	27.203	0.426	7.49	262.541	8.78	12.2	1049.47

Table 5.6 : ICP MS Analysis Of Surface Water Samples (µg/l) - Sampling date: 14/12/2015

S ID	As	Cd	Cr	Co	Cu	Fe	Pb	Ni	Zn
SW 1	34.078	3.34	69.296	4.299	9.24	410.72	22.363	19.45	908.79
SW 2	57.517	2.43	53.035	5.415	12.9	321.239	28.762	14.06	57.087
SW 3	45.323	2.35	76.014	3.665	18.02	178.425	42.128	18.801	699.968
SW 4	66.048	3.36	97.014	1.84	10.97	299.259	23.696	32.59	1210.097
SW 5	51.67	4.43	96.913	2.78	23.63	316.42	27.33	25.291	692.425
SW 6	35.631	3.48	39.873	1.996	10.48	286.311	25.88	21.47	1012.877

Table 5.7: Statistical Analysis Of Surface Water Sample

S ID	As	Cd	Cr	Co	Cu	Fe	Pb	Ni	Zn
AVERAGE	36.61	2.66	61.27	2.55	12.55	281.84	17.28	14.63	699.46
MAX	51.56	3.23	90.58	4.63	22.14	348.84	23.92	17.96	1142.81
MIN	28.12	2.20	33.54	1.06	7.75	166.54	13.81	9.43	51.96
STD DEV	8.82	0.34	19.31	1.27	5.12	56.48	3.20	2.73	380.76

Table 5.8: : Physicochemical Analysis Of Surface Water Sample

S ID	pH	EC (ms/cm)	TDS (ppm)	pH	EC(ms/cm)	TDS(ppm)
	Sampling date: 02/09/2015			Sampling date: 14/12/2015		
SW 1	6.63	662	261.33	7.38	685	580
SW 2	6.95	510	216.33	7.53	677	540
SW 3	6.82	637	257.33	7.5	414	550
SW 4	6.85	862	309.00	7.25	1580	1220
SW 5	7.39	4500	1943.33	7.28	860	680
SW 6	7.87	1282	398.33	7.58	3560	1560

5.4 Analysis result of soil samples

Table 5.9: XRF Analysis Of Soil (mg/kg) - Sampling date: 02/09/2015

S ID	As	Ba	Co	Cr	Cu	Ni	Pb	V	Zn
SOIL 1	49.65	933.05	37.56	252.34	477.71	62.35	989.51	110.14	1099.03
SOIL 2	51.05	612.55	42.13	559.76	571.83	58.35	458.69	237.76	1030.99
SOIL 3	32.35	703.25	26.89	398.38	396.99	78.98	761.74	131.24	2122.32
SOIL 4	86.65	728.55	29.05	344.81	463.39	38.75	438.09	78.74	906.78

Table 5.10: XRF Analysis Of Soil (Mg/Kg) - Sampling Date: 14/12/2015

S ID	As	Ba	Co	Cr	Cu	Ni	Pb	V	Zn
SOIL 1	56.85	938.25	46.06	261.46	472.41	73.42	1012.62	103.07	1112.91
SOIL 2	58.65	617.15	31.11	568.71	468.93	69.48	481.8	430.69	943.97
SOIL 3	78.05	808.29	45.52	207.78	381.33	90.05	784.85	124.17	2135.3
SOIL 4	93.59	633.53	38.93	553.89	558.29	49.82	461.2	81.67	819.76

Table 5.11: Statistical Analysis Of Soil Sample

S ID	As	Ba	Co	Cr	Cu	Ni	Pb	V	Zn
AVERAGE	63.36	746.83	37.16	393.39	473.86	65.15	673.56	162.19	1271.38
MAX	90.12	935.65	41.81	564.24	520.38	84.52	1001.07	334.23	2128.81
MIN	53.25	614.85	33.99	256.90	389.16	44.29	449.65	80.21	863.27
STD DEV	15.47	119.87	2.87	121.56	51.74	14.31	228.41	100.74	502.42

Table 5.12: : Physicochemical Analysis Of Soil Sample

S ID	pH	EC (ms/cm)	pH	EC(ms/cm)
	Sampling date: 02/09/2015		Sampling date: 14/12/2015	
SOIL 1	7.88	792	7.4	417
SOIL 2	7.98	106	6.37	367
SOIL 3	7.11	117	7.37	270
SOIL 4	7.91	132	7.86	245

5.5 Heavy Metal Toxicity Assessment And Risk Characterization For Water And Soil

5.5.1 Risk Assessment For Ground Water

5.5.1.1 Non-Cancer Effects for ground water

The non-carcinogenic human health effect from site COPCs exceeds the site-specific acceptable levels for both child and adult residents. Hazard Quotient (HQ ingestion and dermal) for non-carcinogenic risks in child and adult was calculated from the ratio of average daily dose to reference dose (ADD/RfD). The child HQ_{ing}, HQ_{dermal} was estimated as 8.182 and 0.059 respectively, while adult HQ_{ing}, HQ_{dermal} was determined as 4.913 and 0.045 respectively. The measured Cumulative Hazard Index for child (Σ HI = 8.241) and adult (Σ HI = 4.958) reveals that toxic risk is beyond tolerable limit (HQ > 1.00) (Table 5.15).

5.5.1.2 Cancer Effects for ground water

Individual cancer risks were evaluated for arsenic and lead in the surface water and groundwater. According to Oregon Administrative Rule (OAR) 340-122-115(2)(a), the DEQ acceptable risk level for excess lifetime cancer risk (ECR) associated with potential exposures to individual compounds is 10E-06 (one in one million). The ECRs for lead (2.93E-06) in the resident (Table 5.17) is above the 1.0E-06 or one in one million threshold. The estimated risk level for As exposure (8.10E-04) is exceeding the safe standard for cancer (CR=1.0E-6) (Figure 5.17). Therefore, the present case investigation unveil that residents confront higher risks, with carcinogenic effects (Table 5.17) that average 8 in 10,000.

Table 5.13: Chemical RfD, RfC and Slope Factor of COI for ground water

Chemical	Chronic RfD (mg/kg-day)	Chronic RfC (mg/m^3)	Ingestion SF (mg/kg-day)$^{-1}$
Arsenic, Inorganic	3.00E-04	1.50E-05	1.50E+00
Cadmium (Water)	5.00E-04	1.00E-05	-
Chromium, Total	-	-	-
Cobalt	3.00E-04	6.00E-06	-
Copper	4.00E-02	-	-
Iron	7.00E-01	-	-
Lead and Compounds	-	-	8.50E-03
Nickel Soluble Salts	2.00E-02	9.00E-05	-
Zinc and Compounds	3.00E-01	-	-

Table 5.14: Non carcinogenic Chronic Daily Intake of COI for ground water of Dhapa

Chemical	Child Ingestion Non carcinogenic CDI	Child Inhalation Non carcinogenic CDI	Child Dermal Non carcinogenic CDI
Arsenic, Inorganic	2.09E-03	2.01E-02	9.19E-06
Cadmium (Water)	1.44E-04	1.39E-03	6.36E-07
Chromium, Total	3.57E-03	3.43E-02	1.57E-05
Cobalt	2.30E-04	2.22E-03	4.06E-07
Copper	4.74E-04	4.56E-03	2.09E-06
Iron	2.14E-02	2.06E-01	9.44E-05
Lead and Compounds	1.34E-03	1.29E-02	5.89E-07
Nickel Soluble Salts	1.17E-03	1.12E-02	1.03E-06
Zinc and Compounds	2.11E-02	2.03E-01	5.59E-05
Chemical	**Adult Ingestion Non carcinogenic CDI**	**Adult Inhalation Non carcinogenic CDI**	**Adult Dermal Non carcinogenic CDI**
Arsenic, Inorganic	1.25E-03	2.01E-02	7.00E-06
Cadmium (Water)	8.67E-05	1.39E-03	4.84E-07
Chromium, Total	2.15E-03	3.43E-02	1.20E-05
Cobalt	1.38E-04	2.22E-03	3.09E-07
Copper	2.85E-04	4.56E-03	1.59E-06
Iron	1.29E-02	2.06E-01	7.18E-05
Lead and Compounds	8.04E-04	1.29E-02	4.49E-07
Nickel Soluble Salts	7.00E-04	1.12E-02	7.82E-07
Zinc and Compounds	1.27E-02	2.03E-01	4.25E-05

Table 5.15: Non carcinogenic health risk of Dhapa Landfill site for ground water

GW	Child Ingestion HQ	Child Inhalation HQ	Child Dermal HQ	Child Total HI
Arsenic, Inorganic	6.954		0.031	**6.985**
Cadmium (Water)	0.289		0.025	**0.314**
Chromium, Total				**0.000**
Cobalt	0.768		0.001	**0.770**
Copper	0.012		0.000	**0.012**
Iron	0.031		0.000	**0.031**
Lead and Compounds				**0.000**
Nickel Soluble Salts	0.058		0.001	**0.060**
Zinc and Compounds	0.070		0.000	**0.071**
Total HI	**8.182**	**0.000**	**0.059**	**8.241**
GW	**Child Ingestion HQ**	**Child Inhalation HQ**	**Child Dermal HQ**	**Child Total HI**
Arsenic, Inorganic	4.176		0.023	**4.199**
Cadmium (Water)	0.174		0.019	**0.193**
Chromium, Total				**0.000**
Cobalt	0.461		0.001	**0.462**
Copper	0.007		0.000	**0.007**
Iron	0.018		0.000	**0.019**
Lead and Compounds				**0.000**
Nickel Soluble Salts	0.035		0.001	**0.036**
Zinc and Compounds	0.042		0.000	**0.042**
Total HI	**4.913**	**0.000**	**0.045**	**4.958**

Table 5.16: Carcinogenic Chronic Daily Intake for ground water

CHEMICAL	Ingestion Carcinogenic CDI	Inhalation Carcinogenic CDI	Dermal Carcinogenic CDI
Arsenic, Inorganic	5.37E-04	7.45E+00	2.87E-06
Cadmium (Water)	3.72E-05	5.16E-01	1.99E-07
Chromium, Total	9.19E-04	1.28E+01	4.91E-06
Cobalt	5.93E-05	8.24E-01	1.27E-07
Copper	1.22E-04	1.69E+00	6.52E-07
Iron	5.51E-03	7.65E+01	2.94E-05
Lead and Compounds	3.44E-04	4.78E+00	1.84E-07
Nickel Soluble Salts	3.00E-04	4.16E+00	3.20E-07
Zinc and Compounds	5.44E-03	7.54E+01	1.74E-05

Table 5.17: Carcinogenic Health Risk of Dhapa Landfill Site for Ground Water

Ground water	Ingestion Risk	Inhalation Risk	Dermal Risk	Total Risk
Arsenic, Inorganic	8.06E-04		4.30E-06	**8.10E-04**
Cadmium (Water)				**0**
Chromium, Total				**0**
Cobalt				**0**
Copper				**0**
Iron				**0**
Lead and Compounds	2.93E-06		1.56E-09	**2.93E-06**
Nickel Soluble Salts				**0**
Zinc and Compounds				**0**
Total Risk	**8.08E-04**	**0**	**4.30E-06**	**8.13E-04**

5.5.2 Risk Assessment For Surface Water

5.5.2.1 Non-Cancer Effects for surface water

The non-carcinogenic human health effect from site COPCs exceeds the site-specific acceptable levels for both child and adult residents. Hazard Quotient (HQ ingestion and dermal) for non-carcinogenic risks in child and adult was calculated from the ratio of average daily dose to reference dose (ADD/RfD). The child HQ_{ing}, HQ_{dermal} was estimated as 6.962 and 0.052 respectively, while adult HQ_{ing}, HQ_{dermal} was determined as 4.184 and 0.040 respectively. The measured Cumulative Hazard Index for child (Σ HI = 7.015) and adult (Σ HI = 4.224) reveals that toxic risk is beyond tolerable limit (HQ > 1.00) (Table 5.20).

5.5.2.2 Cancer Effects for surface water

Individual cancer risks were evaluated for arsenic and lead in the surface water and groundwater. According to Oregon Administrative Rule (OAR) 340-122-115(2) (a), the DEQ acceptable risk level for excess lifetime cancer risk (ECR) associated with potential exposures to individual compounds is 10E-06 (one in one million). The ECRs for lead (1.89E-06) in the resident (Table 5.22) are above the 1.0E-06 or one in one million threshold. The estimated risk level for As exposure (7.09E-04) is exceeding the safe standard for cancer (CR=1.0E-6) (Figure 5.22). Therefore, the present case investigation unveil that residents confront higher risks, with carcinogenic effects (Table 5.22) that average 7 in 10,000.

Table 5.18: Chemical RfD, RfC and Slope Factor of COI for surface water

Chemical	Chronic RfD (mg/kg-day)	Chronic RfC (mg/m^3)	Ingestion SF $(mg/kg\text{-}day)^{-1}$
Arsenic, Inorganic	3.00E-04	1.50E-05	1.50E+00
Cadmium (Water)	5.00E-04	1.00E-05	-
Chromium, Total	-	-	-
Cobalt	3.00E-04	6.00E-06	-
Copper	4.00E-02	-	-
Iron	7.00E-01	-	-
Lead and Compounds	-	-	8.50E-03
Nickel Soluble Salts	2.00E-02	9.00E-05	-
Zinc and Compounds	3.00E-01	-	-

Table 5.19: Non Carcinogenic Chronic Daily Intake Of COI For Surface Water

SW	Child Ingestion Non carcinogenic CDI	Child Inhalation Non carcinogenic CDI	Child Dermal Non carcinogenic CDI
Arsenic, Inorganic	1.83E-03	1.76E-02	8.04E-06
Cadmium (Water)	1.33E-04	1.27E-03	5.84E-07
Chromium, Total	3.06E-03	2.94E-02	1.35E-05
Cobalt	1.27E-04	1.22E-03	2.24E-07
Copper	6.26E-04	6.01E-03	2.76E-06
Iron	1.41E-02	1.35E-01	6.19E-05
Lead and Compounds	8.61E-04	8.29E-03	3.80E-07
Nickel Soluble Salts	7.30E-04	7.01E-03	6.43E-07
Zinc and Compounds	3.49E-02	3.35E-01	9.23E-05
Chemical	**Adult Ingestion Non carcinogenic CDI**	**Adult Inhalation Non carcinogenic CDI**	**Adult Dermal Non carcinogenic CDI**
Arsenic, Inorganic	1.10E-03	1.76E-02	6.12E-06
Cadmium (Water)	7.96E-05	1.27E-03	4.44E-07
Chromium, Total	1.84E-03	2.94E-02	1.02E-05
Cobalt	7.64E-05	1.22E-03	1.71E-07
Copper	3.76E-04	6.01E-03	2.10E-06
Iron	8.45E-03	1.35E-01	4.71E-05
Lead and Compounds	5.18E-04	8.29E-03	2.89E-07
Nickel Soluble Salts	4.39E-04	7.01E-03	4.90E-07
Zinc and Compounds	2.10E-02	3.35E-01	7.02E-05

Table 5.20: Non Carcinogenic Health Risk Of Dhapa Landfill Site For Surface Water

SW	Child Ingestion HQ	Child Inhalation HQ	Child Dermal HQ	Child Total HI
Arsenic, Inorganic	6.086		0.027	**6.113**
Cadmium (Water)	0.265		0.023	**0.288**
Chromium, Total				**0.000**
Cobalt	0.424		0.001	**0.424**
Copper	0.016		0.000	**0.016**
Iron	0.020		0.000	**0.020**
Lead and Compounds				**0.000**
Nickel Soluble Salts	0.036		0.001	**0.037**
Zinc and Compounds	0.116		0.000	**0.116**
Total HI	**6.962**	**0.000**	**0.052**	**7.015**
SW	**Adult Ingestion HQ**	**Adult Inhalation HQ**	**Adult Dermal HQ**	**Adult Total HI**
Arsenic, Inorganic	3.658		0.020	**3.678**
Cadmium (Water)	0.159		0.018	**0.177**
Chromium, Total				**0.000**
Cobalt	0.254		0.001	**0.255**
Copper	0.009		0.000	**0.009**
Iron	0.012		0.000	**0.012**
Lead and Compounds				**0.000**
Nickel Soluble Salts	0.022		0.001	**0.023**
Zinc and Compounds	0.070		0.000	**0.070**
Total HI	**4.184**	**0.000**	**0.040**	**4.224**

Table 5.21: Carcinogenic Chronic Daily Intake For Surface Water

CHEMICAL	Ingestion Carcinogenic CDI	Inhalation Carcinogenic CDI	Dermal Carcinogenic CDI
Arsenic, Inorganic	4.70E-04	6.52E+00	2.51E-06
Cadmium (Water)	3.41E-05	4.73E-01	1.82E-07
Chromium, Total	7.86E-04	1.09E+01	4.20E-06
Cobalt	3.27E-05	4.54E-01	6.98E-08
Copper	1.61E-04	2.24E+00	8.60E-07
Iron	3.62E-03	5.02E+01	1.93E-05
Lead and Compounds	2.22E-04	3.08E+00	1.18E-07
Nickel Soluble Salts	1.88E-04	2.61E+00	2.01E-07
Zinc and Compounds	8.98E-03	1.25E+02	2.88E-05

Table 5.22: Carcinogenic Health Risk Of Dhapa Landfill Site For Surface Water

Surface water	Ingestion Risk	Inhalation Risk	Dermal Risk	Total Risk
Arsenic, Inorganic	7.05E-04		3.76E-06	**7.09E-04**
Cadmium (Water)				
Chromium, Total				
Cobalt				
Copper				
Iron				
Lead and Compounds	1.89E-06		1.01E-09	**1.89E-06**
Nickel Soluble Salts				
Zinc and Compounds				
Total Risk	**7.07E-04**	**0.00E+00**	**3.76E-06**	**7.11E-04**

5.5.3 Heavy metal toxicity assessment and risk characterization for soil

5.5.3.1 Non-Cancer Effects for soil

The descriptive statistics of chronic daily intake (CDI) and non-carcinogenic hazard quotient (HQ) for both child and adult in the study area are presented in tables below. Generally, the CDI of the investigated heavy metals for child daily ingestion appeared to be higher than that of the adult, suggest that children have higher doses of these heavy metals in soil ingested orally than adults. Characterization of the risk of heavy metals (As, Ba, Cr, Co, Cu, Pb, Ni, V, Zn) demonstrate that toxic hazards of oral exposure for child HQ=3.912 (Table 5.25) exceeds the tolerable limit of HQ>1.00 . The hazards for adult in this study pointed that toxic hazard (HQ=0.366) are within the acceptable limits (Table 5.25). Generally speaking, the hazardous index (HQ) for the ingestion of soil by children is greater in comparison to the corresponding results obtained for adults. Considering the total chronic hazard quotient index of oral exposure to soil contamination in study area by the population, the Total HI (0.398 and 4.113 for adult and child respectively) depicted hazard for child.

5.5.3.2 Cancer Effects for soil

The estimated cancer risk level for heavy metal exposure, except Pb (8.24E-06) and As (9.36E-05) is within the target risk (CR=1.0E-6). The present case investigation unveil that residents confront higher risks, with carcinogenic effects of lead that average 1 in 10, 000 (Table 5.27).

Table 5.23: Chemical Rfd, And Slope Factor Of COI For Soil

SOIL	Chronic RfD (mg/kg-day)	Ingestion SF $(mg/kg\text{-}day)^{-1}$
Arsenic, Inorganic	0.0003	1.5
Barium	0.2	-
Chromium, Total	-	-
Cobalt	0.0003	-
Copper	0.04	-
Lead and Compounds	-	0.0085
Nickel Soluble Salts	0.02	-
Vanadium	0.00504	-
Zinc and Compounds	0.3	-

Table 5.24: Non Carcinogenic Chronic Daily Intake Of COI In Soil

SOIL	Child Ingestion Non carcinogenic CDI	Child Dermal Non carcinogenic CDI	Adult Ingestion Non carcinogenic CDI	Adult Dermal Non carcinogenic CDI
Arsenic, Inorganic	4.09E-04	4.85E-05	3.83E-05	8.09E-06
Barium	1.20E-02		1.12E-03	
Chromium, Total	3.29E-03		3.08E-04	
Cobalt	5.35E-04		5.01E-05	
Copper	6.08E-03		5.70E-04	
Lead and Compounds	1.28E-02		1.20E-03	
Nickel Soluble Salts	8.68E-04		8.14E-05	
Vanadium	1.37E-03		1.28E-04	
Zinc and Compounds	1.42E-02		1.33E-03	

Table 5.25: Non Carcinogenic Health Risk Of Dhapa Landfill Site For Soil

SOIL	Child Ingestion HQ	Child Dermal HQ	Child Total HI
Arsenic, Inorganic	1.621	0.192	**1.816**
Barium	0.048		**0.049**
Chromium, Total			**0.000**
Cobalt	1.585		**1.589**
Copper	0.152		**0.152**
Lead and Compounds			**0.000**
Nickel Soluble Salts	0.042		**0.042**
Vanadium	0.411		**0.411**
Zinc and Compounds	0.054		**0.054**
Total HI	**3.912**	**0.192**	**4.113**
SOIL	**Adult Ingestion HQ**	**Adult Dermal HQ**	**Adult Total HI**
Arsenic, Inorganic	0.152	0.032	**0.184**
Barium	0.004		**0.004**
Chromium, Total			**0.000**
Cobalt	0.148		**0.148**
Copper	0.014		**0.014**
Lead and Compounds			**0.000**
Nickel Soluble Salts	0.004		**0.004**
Vanadium	0.039		**0.039**
Zinc and Compounds	0.005		**0.005**
Total HI	**0.366**	**0.032**	**0.398**

Table 5.26: Carcinogenic Chronic Daily Intake Of COI In Soil

SOIL	Ingestion Carcinogenic CDI	Dermal Carcinogenic CDI
Arsenic, Inorganic	4.60E-05	6.47E-06
Barium	1.35E-03	
Chromium, Total	3.70E-04	
Cobalt	6.02E-05	
Copper	6.83E-04	
Lead and Compounds	1.44E-03	
Nickel Soluble Salts	9.79E-05	
Vanadium	1.53E-04	
Zinc and Compounds	1.59E-03	

Table 5.27: Carcinogenic Health Risk Of Dhapa Landfill Site For Soil

SOIL	Ingestion Risk	Dermal Risk	Total Risk
Arsenic, Inorganic	8.20E-05	1.15E-05	**9.35E-05**
Barium			**0.00E+00**
Chromium, Total			**0.00E+00**
Cobalt			**0.00E+00**
Copper			**0.00E+00**
Lead and Compounds	8.24E-06		**8.24E-06**
Nickel Soluble Salts			**0.00E+00**
Vanadium			**0.00E+00**
Zinc and Compounds			**0.00E+00**
Total Risk	**9.02E-05**	**1.15E-05**	**1.02E-04**

SECTION – 6

CONCLUSION

6.1 Conclusion

A preliminary study has been carried out for the oldest municipal landfill site of Kolkata Metropolitan city and described in this report. In evaluating the human health impact of leachate contamination of water and soil, the pathway considered has been direct ingestion and dermal contact of contaminated water and soil. The current study has demonstrated that groundwater with a high inorganic (heavy metal) loading, possibly leachate derived, give rise to the carcinogenic effects and non carcinogenic hazard.

Toxic heavy metals remain in the waste as a result of redox controlled precipitation reactions. This fixing of heavy metals dramatically reduces the risk of direct toxic effects due to ingestion of leachate-contaminated groundwater. However, once the leachate leaves the site, the scenario changes. The leachate formed due to MSW is generally a strongly reducing liquid formed under methanogenic conditions and on coming into contact with aquifer materials has the ability to reduce sorbed heavy metals in the aquifer matrix. The most important reactions are the reduction of iron and manganese to more soluble species and hence results in an increase in the concentration of these components under favorable conditions close to a landfill.

6.2.1 Non-Cancer Effects for ground water

The non-carcinogenic human health effect from Site COPCs exceeds the site-specific acceptable levels for both child and adult residents. The child HQ_{ing}, HQ_{dermal} was estimated as 8.182 and .059 respectively, while adult HQ_{ing}, HQ_{dermal} was determined as 4.913 and .045 respectively. The measured Cumulative Hazard Index for child (Σ HI = 8.241) and adult (Σ HI = 4.958) reveals that toxic risk is beyond tolerable limit (HQ > 1.00).

6.2.2 Cancer Effects for ground water

Individual cancer risks were evaluated for arsenic and lead in the surface water and groundwater. The excess lifetime cancer risk for lead (2.93E-06) in the resident are above the target level 1.0E-06 or one in one million threshold. Conversely the estimated risk level for As exposure (8.10E-04) is exceeding the safe standard for cancer. Therefore, the present case investigation unveil that residents confront higher risks, with carcinogenic effects that average 8 in 10,000.

6.3.1 Non-Cancer Effects for surface water

The non-carcinogenic human health effect from Site COPCs exceeds the site-specific acceptable levels for both child and adult residents. The child HQ_{ing}, HQ_{dermal} was estimated as 6.962 and 0.052respectively, while adult HQing, HQdermal was determined as 4.184 and 0.040 respectively. The measured Cumulative Hazard Index for child (Σ HI = 7.015) and adult (Σ HI = 4.224) reveals that toxic risk is beyond tolerable limit ($HQ > 1.00$).

6.3.2 Cancer Effects for surface water

Individual cancer risks were evaluated for arsenic and lead in the surface water and groundwater. The excess lifetime cancer risk for lead (1.89E-06) in the resident are above the target level 1.0E-06 or one in one million threshold. Conversely the estimated risk level for As exposure (7.09E-04) is exceeding the safe standard for cancer. Therefore, the present case investigation unveil that residents confront higher risks, with carcinogenic effects that average 7 in 10,000.

6.3.1 Non-Cancer Effects for soil

Characterization of the risk of heavy metals (As, Ba, Cr, Co, Cu, Pb, Ni, V, Zn) demonstrate that toxic hazards of oral exposure for child HQ = 3.912 exceeds the tolerable limit of HQ>1.00 . However, the hazards for adult in this study pointed that toxic hazard (HQ = 0.366) are within the tolerable boundary. Considering the total chronic hazard quotient index of oral exposure to soil contamination in study area by the population, the Total HI (0.398 and 4.113 for adult and child respectively) depicted hazard for child.

6.3.2 Cancer Effects for soil

The estimated cancer risk level for heavy metal exposure, except Pb (8.24E-06) and Arsenic (9.36E-05) is within the target risk (CR=1.0E-6). The present case investigation unveil that residents confront higher risks, with carcinogenic effects of lead that average 1 in 10, 000.

The risk assessment calculations are sensitive to choice of exposure factors and one of the most difficult values to obtain for case study sites was an estimate of daily water consumption. This lack of knowledge present throughout the assessment process, and the requirement to estimate parameters from limited knowledge means that the final outcome can be over-conservative and might flag up the need for inappropriate and expensive risk management measures.

An attempt has been made to produce a balanced risk assessment while at the same time adopting the precautionary approach in implementing risk management. Several options are explored to manage the risk to human health from landfill leachate and include: removal of the source term, leachate plume management, and the waste reduction. These options can be applied either singly or combined to optimise benefit.

SECTION 7

FUTURE SCOPE OF STUDY

7 Future Scope Of Study

- Due to some unavoidable financial constraints and interfering accessibility to site all seasonal data could not be monitored. Seasonal data for a calendar year (at least 12) shall be generated in the future for rational evaluation of human health risk model for both carcinogenic risk and non carcinogenic hazard.
- A questioner survey would be conducted in the neighboring areas to collate and correlate data with assessment of health status of human being. In this context epidemiological study may be carried out.
- Some ecological study with respect to flora and fauna in the water and soil environment to be performed.
- Leachate contamination through soil and groundwater shall be carried out along with transport modeling.
- Statistical analysis and interpretation of data for calendar period of 12 months using various software tools (SPSS ect.) and critical analysis of fluctuation of data.

Analysis and monitoring of recalcitrant toxic inorganic and organic pollutant present in the leachate and presence in different environment

SECTION 8

REFERENCE

8.1 References

A report on, "Environmental impact assessment of integrated municipal solid waste processing complex Gazipur, Delhi" submitted by: East Delhi Waste processing company Pvt. Ltd. January 2008.

Aziz H.A. Adlan M.N., Zahari M.S.M., Alias S., (2004)," Removal of ammonical nitrogen (N-NH3) from municipal solid waste leachate by using activated carbon and limestone", Waste Manage. Res. 22, 371–375.

Bardos P, Nathanail P, Nathanail J. (2003a) How do you treat contaminated sites? Wastes management. CIWM (Chartered Institute of Wastes Management); 20–3 [September].

Bardos P, Nathanail P, Nathanail J. (2003b) Risk assessment—have you got a real problem? Wastes management. CIWM (Chartered Institute of Wastes Management); 44–6 [November].

Bergström J and Björner B. (1992) Dioxiner och bränder vid avfallsuplag. Malmo Miljökonsulterna i Stusvik AB. Stiftelsen reforsk, 69, pp94.

Baun A, Ledin A, Reitzel L.A., Bjerg P.L., Christensen T.H.,(2004)," Xenobiotic organic compounds in leachates from ten Danish MSW landfills—chemical analysis and toxicity tests" Water Research 38, 3845–3858..

Bernard Clement, Guido Persoone, Colin Janssen R, Anne Le Dû-Delepierre. (1996) Estimation of the hazard of landfills through toxicity testing of leachates — 1. Determination of leachate toxicity with a battery of acute tests. Chemosphere, (33), No. 11. 2303–20.

Bernard Clement, Guido Persoone, Colin Janssen R, Anne Le Dû-Delepierre. (1997) Estimation of the hazard of landfills through toxicity testing of leachates — 2. Comparison of physico-chemical characteristics of landfill leachates with their toxicity determined with a battery of tests. Chemosphere (35) No.11, 2783–96.

Butt TE, Ingles AJD, BalochMI. (2011) A conceptual model outline for integrated exposure assessment. Environ Prog Sustain Energy J; 30(4):696–708.

Butt TE, Oduyemi KOK. (2003) A holistic approach to concentration assessment of hazards in the risk assessment of landfill leachate. Environment International, (28), Issue 7. 597–608.

Cecilia B.O., Christian J., (2008),"Chemical characterization of landfill leachates – 400 parameters and compounds", Science Direct, Waste Management 28, 1876–1891.

Chattopadhyay S., Dutta A., Ray S., (2009),"Municipal solid waste management in Kolkata, India – A review" Waste Management 29, 1449–1458.

Christensen, T. H., Kjeldsen, P., Albrechtsen, H.-J., Heron, G., Nielson, P. H., Bjerg, P. L. and Holm, P. E. (1994) Attenuation of Landfill Leachate Pollutants in

Aquifers. Critical Reviews in Environmental Science and Technology 24(2), 119-202.

Cockerham L.G. and Shane B.S. (1994) Basic Environmental Toxicology. CRC Press, Boca Raton, Florida.

Cointreau, S. (1982) Environmental Management of Urban Solid Wastes in Developing Countries. The World Bank. Technical Paper 5.

DEFRA (Department for Environment, Food and Rural Affairs), Environment Agency. (2002) The Contaminated Land Exposure Assessment Model (CLEA): technical basis and algorithms, R & D Publication CLR 10. Document prepared by the National Groundwater and Contaminated Land Centre of the Environment Agency.

DETR (Department of the Environment, Transport and the Regions), Environment Agency, the Institute for the Environment and Health. (2000) Guidelines for environmental risk assessment and management. London: The Stationary Office.

Ding, A., Zhang, Z., Fu, J., Cheng, L., (2001) Biological control of leachate from municipal landfills. Chemosphere 44 (1), 1–8.

DoE (Department of the Environment) (1995) The technical aspects of controlled waste management — health effects from hazardous waste landfill sites, report no. CWM/057/92. DoE.

Environment Agency (1997) An assessment of the risks to human health from landfilling household wastes, report no. CWM143/97. Environment Agency.

Environment Agency (2003a) Hydrogeological risk assessments for landfill and the derivation of groundwater control and trigger levels. Environment Agency.

Environment Agency (2007) Guidance for the landfill sector — technical requirements of the landfill directive and Integrated Pollution Prevention and Control (IPPC S5.02). Bristol: Environment Agency; [April].

Environment Agency (2010) H1 — Technical Annex to Annex J: Hydrogeological risk assessments for landfills and the derivation of groundwater control levels and compliance limits. Bristol: Environment Agency; [October].

Environment Agency (2011a) Horizontal guidance note H1 — Overview document, Version 2.1. [December]Bristol: Environment Agency.

Environment Agency (2011b) H1 Annex I — landfill. Bristol: Environment Agency; [December].

Environment Agency (2011c) H1 Annex J — groundwater. Bristol: Environment Agency; [December].

Environment Agency (2011d) Landfill guidance. Environment Agency; [12 December, http://www.environment-agency.gov.uk/business/sectors/108918.aspx].

Environment Agency Horizontal guidance. Environment Agency (2012) [Last updated: 03 February, http://www.environment-agency.gov.uk/business/topics/permitting/36414. aspx].

EPA ((Environmental Protection Agency — US) (2009d) Committee on Improving Risk Analysis Approaches Used by the U.S.EPA, Board on Environmental Studies and Toxicology, Division of Earth and Life Sciences, The National Research Council). Science and decisions: advancing risk assessment. Washington D. C., USA: NAP (National Academic Press).

EPA ((Environmental Protection Agency — US, National Center for Environmental Assessment, Office of Research and Development). (2009c) Consideration for developing a dosimetry-based cumulative risk assessment approach formixtures of environmental contaminants (final report), EPA/600/R-07/064. Cincinnati, OH, US: EPA.

EPA ((Environmental Protection Agency — US, National Center for Environmental Assessment, Office of Research and Development), (2011) Highlights of the exposure factors handbook, EPA/600/R-10/030. Washington D.C., US: EPA; [October].

EPA ((Environmental Protection Agency — US, National Centre for Environmental Assessment, Office of Research and Development). (2008) Concepts, methods, and data sources for cumulative health risk assessment of multiple chemicals, exposures and effects: a resource document (final report) EPA/600/R-06/013f. Cincinnati, OH, US: EPA.

EPA ((Environmental Protection Agency — US, Office of the Science Advisor, Risk Assessment Forum). (2007) Framework for metals risk assessment, EPA/120/R-07/001. Washington D. C., US: EPA; [March].

EPA (Environmental Protection Agency — US). (2010) Toxic release inventory — national analysis overview. Washington D.C., US: EPA.

EPA (Environmental Protection Agency — US). (2012) Risk assessment guidance & tools. EPA; [Last updated: 10 January, http://www.epa.gov/riskassessment/guicance.htm].

EPA (Environmental Protection Agency — US, Office of the Science Advisor, Council for Regulatory Environmental Modeling). (2009b) Guidance on the development, evaluation, and application of environmental models. EPA/100/K-09/003. [March]Washington D. C., US: EPA.

EPA (Environmental Protection Agency — US, Office of the Science Advisor, Science Policy Council). (2009a) The U.S. environmental protection agency's strategic plan for evaluating the toxicity of chemicals, EPA/100/K-09/001. Washington D. C., US: EPA; [March].

EPA (Environmental Protection Agency) US (1992) Guidelines for exposure assessment. Federal Register, No. 104, vol. 57. EPA.

EPA (Environmental Protection Agency) US (1999) Guidelines for exposure assessment. EPA; [Last modified March, http://www.epa.gov/nceawww1/exposure.htm, FR 57, EPA/600Z–92/001].

Flyhammar, P., (1997) Estimation of heavy metal information in Municipal Solid Waste. Sci. Total Environ. 198 (2), 123 – 133.

Golder Associates (2002) Risk assessment for small and closed landfills — small and closure criteria, application 4176. Golder Associates (NZ) Ltd.; [December].

Grzetic, I.; Ghariani R.H.A. (2008) Potential health risk assessment for soil heavy metal contamination in the central zone of Belgrade (Serbia). J. Serb. Chem. Soc., 73 (8-9): 923-934.

Hancock, J.S., Phillips, I.R., Seignor, M., (1995) Fate of contaminants deriving from Municipal Solid Wastes in saturated landfills. Proceedings Sardinia 95. Fifth International Landfill Symposium 3, pp. 611–620.

Jee P.K., Bandyopadhyay D.K. (2014) Reappraisal of the toxicity effects of the municipal garbage of Kolkata municipal corporation, Dhapa-Khanaberia area, Kolkata. GSI Report No. RP/CHQ/STSS/2013/018.

Kjeldsen, P., Grundtvig, A., (1995) Leaching of organic compounds from industrial waste disposed of at an old municipal landfill. Proceedings Sardinia 95. Fifth International Landfill Symposium 3, pp. 201–212.

Kang K.H., Shin H.S., Park H., (2002),"Characterization of humic substances present in landfill leachates with different landfill ages and its implications", Water Res. 36,4023–4032.

Kolluru R.V. (1993) Environmental Strategies Handbook. McGraw-Hill, New York.

Kumar D. Alappat B. J. (2003b) A technique to quantify landfill leachate pollution. In Proceedings of the 9th international landfill symposium. Cagliari, Sardinia, Paper No. 400.

Kumar D. Alappat B.J. (2005a) Evaluating leachate contamination potential of landfill sites using leachate pollution index", Clean Techn Environ Policy (7) 190–197.

Kumar D. and Alappat B.J. (2003a) Analysis of Leachate Contamination Potential of a Municipal Landfill using Leachate Pollution Index," Workshop on Sustainable Landfill Management,3–5, Chennai, India, pp. 147-153.

Kumar D., Alappat B.J. (2005b) Analysis of leachate pollution index and formulation of sub-leachate pollution indices. Waste Manage Res. (22) 230–239.

Loizidou, M., Kapetanios, E.G., (1993) Effect of leachate from landfills on underground water quality. Sci. Total Environ. 128 (1), 69–81.

Martinho Maria da Graca Madeira, Silveira Ana Isabel, Branco Elsa Maria Fernandes Duarte. (2008) Report: new guidelines for characterization of municipal solid waste: the Portuguese case. Waste Manag Res. (26) 484–90.

Motling S, Mukherjee S.N., Datta A. (2012-2013) Leachate characteristics of municipal solid waste landfill in Kolkata. Journal of institution of public health engineers, India, Vol.3.

Motling S., Datta A., Mukherjee S.N., Kumar S. (2013) Comparative evaluation of leachate pollution index of MSW landfill site of Kolkata with other metropolitan cities in India. Journal of Environ. Science and Engg. Vol. 55, No (3) 333-342.

Nathanail P, Nathanail J. (2003) Risk-based site characterisation. Wastes Management CIWM (Chartered Institute of Wastes Management); 49–50. [October].

National Academy of Sciences (NAS) (1983) Risk Assessment in the Federal Government: Managing the Process. National Academy Press, Washington, DC.

Oregon DEQ (2011) Risk Based Chemicals for Individual Chemicals, Environmental Cleanup and Tanks Program, Revision September 15, 2011.

Park J.Y., Batchelor B., (2006), "A multi-component numerical leach model coupled with a general chemical speciation code", Water Res. 36, 156–166.

Parameswari K., Mudgal B.V., Nelliyat P.,(2012),"Evaluation of groundwater contamination and its impact: an interdisciplinary approach". Environ Dev Sustain 14:725–744.

Peña-Fernández A., González-Muñoz M.J., Lobo-Bedmar M.C. (2014) Establishing the importance of human health risk assessment for metals and metalloids in urban environments. Environment International (72) 176–185

RAIS – online information system. US Department of Environment. www.risk.lsd.irnl.gov.

Robinson H.,(2007)," The Composition Of Leachates From Very Large Landfills: An International Review." CWRM, June 2007: Volume 8(1) pp. 19-32.

Rudland DJ, Lancefield RM, Mayell PN. (2001) Contaminated land risk assessment — a guide to good practice, CIRIA C552. CIRIA (Construction Industry Research and Information Association).

Renou S., Givaudan J.G., Poulain S., Dirassouyan F., Moulin P.(2008),” Landfill leachate treatment: Review and opportunity.” Journal of Hazardous Materials 150 (2008) 468–493.

Ruokojärvi, P., Ruuskanen, J., Ettala, M., Rahkonen, P. and Tarhanen, J. (1995) Formation of polyaromatic hydrocarbons and polychlorinated organic compounds in municipal waste landfill fires. Chemosphere 31(8), 3899-3908.

Słomczyńska B, Słomczyński T., (2004),” Physico-Chemical and Toxicological Characteristics of Leachates from MSW Landfills.” Polish Journal of Environmental Studies Vol. 13, No. 6 , 627-637.

SCEG (School of Civil Engineering and Geosciences). (2003) Risk Assessment of Contaminated Land — Professional Development. University of Newcastle upon Tyne; [http://www.hydroinformatics/profdev].

SEPA (Scottish Environment Protection Agency) (2002) Framework for risk assessment for landfill sites — the geological barrier, mineral layer and the leachate sealing and drainage system. SEPA;[August].

SEPA (Scottish Environment Protection Agency). (2003) Guidance on monitoring of landfill leachate, groundwater and surface water, v 2. SEPA; [July].

Shiowatana, J.; McLaren, R.G.; Chanmekha, N.; Samphao, A. (2001) Fractionation of arsenic in soil by a continuous flow sequential extraction method. Journal of Environmental Quality, 30(6): 1940–1949.

Strachan L.J., Trois C., Robinson H.D. and Olufsen J.S.,(2000),” Appropriate biological treatment of landfill leachates with full nitrification and denitrification”. Presented at WISA 2000 Biennial Conference, Sun City, South Africa,

Thuy, H.T.T., Tobschall, H.J., An, P.V. (2000) Trace element distributions in aquatic sediments of Danang-Hoian area, Vietnam. Environ Geol (39) 733–740.

U.S. Environmental Protection Agency (EPA) (2011) Exposure Factors Handbook: 2011 Edition. National Center for Environmental Assessment, Washington, DC; EPA/600/R-09/052F.

United States Environmental Protection Agency (U.S. EPA) (1990) Risk Assessment, Management and Communication of Drinking Water Contamination. EPA/625/4–89/024, Washington, D.C.

US EPA (1989) Risk Assessment Guidance for Superfund: Vol. 1- Human Health Manual (Part A), EPA/540/1-89/002.

US EPA (1989a) Risk Assessment Guidance for Superfund: Environmental Evaluation Manual (EPA/540/1-69/001A, OSWER Directive 9285.7-01). US Environmental Protection Agency, US Government Printing Office, Washington, DC.

US EPA (2010) Integrated Risk Information System. (IRIS). United States Environmental Protection. Available online: http://www.epa.gov/iris/index.html (accessed on 4 October 2011).

US EPA (2011) Regional Screening Levels (RSL) Summary Table, June 2011.

Watts R. J. (1998) Hazardous Wastes: Sources, Pathways, Receptors. Wiley, New York.