EVALUATION OF HUMAN HEALTH RISK IN THE VICINITY OF NARELA BAWANA LANDFILL SITE

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by

SWATI RANI
(2K12/ENE/17)

Under the esteemed Guidance

Of

LOVLEEN GUPTA
(Assistant Professor, Environmental Engineering)

DEPARTMENT OF ENVIRONMENTAL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(FORMERLY DELHI COLLEGE OF ENGINEERING)
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DELHI TECHNOLOGICAL UNIVERSITY
(formerly DELHI COLLEGE OF ENGINEERING)
MAIN BAWANA ROAD, NEW DELHI-110042

DEPARTMENT OF ENVIRONMENTAL ENGINEERING

CERTIFICATE

This is to certify that the research work embodied in this dissertation entitled "**Evaluation of Human Health Risk in the Vicinity of Narela Bawana Landfill Site**" has been carried out in the Department of Environmental Engineering, Delhi Technological University, New Delhi. This work is original and has not been submitted in part or full for any other degree or diploma to any university or institute. The work is approved for submission.

MRS. LOVLEEN GUPTA
(Assistant Professor)
(Guide)

SWATI RANI
(Candidate)

Prof. S.K. Singh
Head, Environmental Engineering Department

Date:
Place: Delhi

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SWATI RANI
(2K12/ENE/017)
M.Tech (2nd year)
Environmental Engineering

Abstract

Rapid population growth and urbanization in developing countries have led to the generation of enormous quantities of Municipal Solid Wastes (MSW) and consequential environmental degradation. Safe and reliable disposal of MSW and residues is an important component of integrated waste management. One of the most common waste disposal methods is land filling; resulting in potential sources of groundwater contamination, which is practiced by almost three-fourths of the countries worldwide. An MSW landfill is not a benign repository of discarded material; it is a biochemically active unit where toxic substances are leached or created from combinations of non-toxic precursors and gradually released into the surrounding environment over a period of decades. It is known that such releases contain a wide variety of potential carcinogens which comes in groundwater and thus intake of such polluted water directly or in directly may leave potentially toxic chemicals or carcinogens that represent a threat to public health. Thus motivation of this study was on fact of assessment of human health risk posed by various contaminants in groundwater leached from an existing landfill in Delhi.

Keyword: Landfill, Leachate characteristics, Groundwater characteristics, Human Health Risk Assessment.

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ACRONYMS USED

Abbreviation used	Full Form
AAS	Atomic Absorption Spectrometer
BOD	Biochemical Oxygen Demand
BIS	Bureau of Indian Standard
CDI	Chronic Daily Intake
CoC	Contaminant of Concern
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
GW	Ground Water
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
IMD	Indian Meteorological Department
LoD	Limit of Detection
MT	Metric Tonnes
MSL	Mean Sea Level
MSW	Municipal Solid Waste
NCTD	National Capital Territory of Delhi
ND	Not Detected
RBC	Red Blood Cells
RDF	Refused Derived Fuel
TDS	Total Dissolved Solids
WHO	World Health Organization
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

CHAPTER 1. INTRODUCTION

1.1 Background

Rapid population growth and urbanization in developing countries have led to the generation of enormous quantities of Municipal Solid Wastes (MSW) and consequential environmental degradation. Safe and reliable disposal of MSW and residues is an important component of integrated waste management. Solid wastes are usually disposed both below and above the ground surface resulting in potential sources of groundwater contamination. One of the most common waste disposal methods is landfilling; which is practiced by about three-fourths of the countries and territories in the world. (Rushbrook, 2001). The quantity and quality of MSW depends upon various factors such as population, life style, food habit, standard of living, the extent of industrial and commercial activities in the area, cultural tradition of inhabitants and climate. (Ramanatham et al, 2006).

An MSW landfill is not a benign repository of discarded material; it is a biochemically active unit where toxic substances are leached or created from combinations of non-toxic precursors and gradually released into the surrounding environment over a period of decades. Biological, chemical and physical processes within the landfill promote the degradation of wastes and result in the production of leachate and gases. Leachate consists of water and water-soluble compounds in the refuse that accumulate as water moves through the landfill. This water may be from rainfall or from the waste itself. Leachate may migrate from the landfill and contaminate soil and ground water, thus presenting a risk to human and environmental health (Hughes et al., 2008). MSW landfills are said to be major source for releasing large amounts of hazardous and deleterious chemicals to nearby groundwater, surface water, soil and to the air, by formation of deleterious substances like leachate and landfill gas.

In modern landfills, the waste is contained by a scientific system which has characteristics of having lined barrier and landfill gas collection system. The primary purpose of the liner system is to isolate the landfill contents from the environment and, therefore, to protect the soil and groundwater from pollution originating in the landfill but the greatest threat to groundwater is produced by

leachate. Waste placed in landfills or open dumps are subjected to either groundwater underflow or infiltration from precipitation. The dumped solid wastes gradually release its initial interstitial water and some of its decomposition by products get into water moving through the waste deposit. Such liquid containing innumerable organic and inorganic compounds is called leachate. This leachate accumulates at the bottom of the landfill and percolates through the soil. Areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site. Such contamination of groundwater resource poses a substantial risk to local resource user and to the natural environment .The impact of landfill leachate on the surface and groundwater has given rise to a number of studies in recent years (Saarela et al 2003).

1.1.1 Landfill leachate quantity and quality

Leachate produced within a landfill varies in both quantity and quality over the passage of time. Leachate can be emitted to the surrounding soil, after which the leachate can either enter in both groundwater and surface water. At landfill sites with a leachate collection system, threat to soil, groundwater and surface water are minimized, but the efficiency of barrier is eventually compromised. Leachate is treated at the landfill site and/or at the local wastewater treatment plant, prior to being discharged to surface water. The quantity of leachate generated depends mainly:

1. Contaminant properties (vapor pressure, solubility in water, degradability);
2. Soil properties (organic matter content, texture/structure, microbial population);
3. Environmental factors (net infiltration, temperature, humidity, pH, soil moisture content, and vegetation); and
4. On the net precipitation in the region and the type of landfill cover, which both influence the amount of moisture that eventually infiltrates into the landfill, as well as the initial moisture content of the waste. Of the above factors, soil properties and environmental factors are specified with respect to particular landfill site.

Leachate quality depends primarily on the nature of the waste to be land filled, and varies over time. Leachate passes through different stages throughout its life span. Initially the MSW is decomposed aerobically and thereafter by facultative and anaerobic organisms which hydrolysis

and ferment the cellulose and other putrescible material producing simpler, soluble compounds like volatile fatty acids and alcohols which are having high BOD and ammonical nitrogen. Acetic acid is produced by further decomposition of these volatile fatty acid, and the leachate is described as acetogenic. At this time there is also presence of hydrogen sulphide having bad egg smell and typically contains very high concentrations of organic carbon, ammonia, chloride, potassium, sodium and hydrogen carbonate, whilst concentrations of heavy metals and specific organic compounds are relatively low. The second phase of a leachate is point at which the waste becomes anaerobic is the start of the methanogenic duration of occurrence of this stage depends on many factors including ambient temperature, rate of waste input, water content, waste composition, etc. The methanogenic phase will then continue for a very long period of time. The methane generation rate rises to a peak, and then tails off. During this period the ammoniacal nitrogen concentration which rises in the acetogenic stage does not diminish, and been seen to rise if the leachate produced is not removed regularly. After a very long period, once the methanogenic phase ends, air will again penetrate into the waste mass and there will be a return to aerobic conditions. Predictions of leachate quality are associated with considerable uncertainty, reflecting a lack in understanding of the leaching process. Leachate composition data is only available for certain landfills for a period of about 30 years, however leachate generation may continue for several hundred years.

1.1.2 Leachate impact on groundwater contamination

The effectiveness of landfill liner systems in preventing leachate migration is eventually compromised after installation, and may be after some time but it will deteriorate over time thus it will eventually allow the leachate to pass through the liner into the groundwater system hydraulically connected to the bottom of the landfill. It is known that such releases contain a wide variety of potential carcinogens and potentially toxic chemicals that represent a threat to public health.

As per an estimate of the Central Pollution Control Board (CPCB), the landfills of the Delhi, cumulatively generate a significant amount of leachates annually, which is alarming in terms of groundwater (CPCB 2001). In many parts of India, especially in the arid and semiarid

regions, due to the vagaries of monsoons and scarcity of surface water, dependence on the groundwater resource has increased tremendously in recent years. Viewed from the international standard, availability of water "<1,700 m^3/person/year"qualifies as water-stressed and "1,000 m^3 /person/year" as water-scarce, India is water-stressed today and is likely to face severe water scarcity by 2050 (CPCB 2001). Delhi, as the rapidly growing capital city of Asia, is facing problems both in terms of the groundwater quality and quantity (Ramanthanm et al 2006)

The further contamination of this scare resource which is a necessity of life would lead to strain on the authorities because remediation of this resource is quite expensive and might not be logically feasible. As India is a developing nation, thus large percentage of farmer still depend on groundwater for irrigation and for their daily use. Therefore it is a necessity to pay urgent attention to all the activities contributing toward deteriorating quality and quantity of the groundwater resources, the MSW dumping is one of them.

1.1.3 Human health risk due to groundwater contamination

The presence of chemicals in groundwater and drinking water is an important factor in determining the risk posed by landfill sites. However, it does not tell us what effect, if any, the consumption of contaminated water has on human health. Up-to-date knowledge about epidemiologic evidence for potential human health effects of landfill sites is important for those deciding on regulation of sites, their sitting and remediation, and for those whose task it is to respond to concerns from the public in a satisfactory way (Martine Vrijheid et al 2006).

Literature material which is widely available on contaminated water and potential health effects is more extensive than that presented in this section, which focuses only on water contamination directly related to the disposal of waste. Migration of hazardous substances into groundwater is often an important environmental concern in relation to landfill sites, which may represent a public health problem, especially when a site is located near aquifers supplying public drinking water

When water supplies are contaminated with leachate containing heavy metals, the mechanism leading to health hazards is bioaccumulation. Bio accumulation is considered to be

accumulation at a rate which results in a concentration of contaminant greatly exceeding that to which the organism was exposed. Many living organisms, including man, are known to accumulate specific toxicants like chemical pesticides, industrial organics, and heavy metals from the environment. This capability is widespread and the amount accumulated may range from barely detectable concentrations to concentrations that greatly exceed the amount present in the environment, depending on the contaminant and organism involved

It is important to note here that the health effects from leachates are not limited to drinking water but may also occur through the food chain due to the ingestion of other organisms that habitat an environment contaminated by leachates. Classic examples of the effect of bio-concentrated toxicants are the painful and fatal Itai- Itai disease, caused by chronic cadmium poisoning, and Mina Mata disease, caused by chronic mercury poisoning. In both diseases, the contaminants were concentrated in fishes from industrial wastes discharged into coastal waters which was consumed by human.

1.2 Objective of study

Looking at the current scenario of MSW disposal practices being followed in India and extent of likely impact on groundwater contamination, this study is conducted with the focus on Human Health Risk Assessment (HHRA) for residential population in the vicinity of Narela-Bawana landfill site, a landfill site located in the Indian national capital, Delhi.

To carry out HHRA, we need to study the quality of leachate generated at the landfill site; and quality of groundwater in the vicinity of the landfill site. The outcome of the study will provide an insight of the existing situation and can also be used to aid in decision making for planning issues such as issues related to prospective types of land use in the region, water resources development, health aspects, etc. This would also help us evaluate possible risks of the migration of these chemicals from landfill sites into the environment and will give an insight into appropriate, effective and sustainable treatment approach.

Following are the specific objectives of the study:

1. To identify the commonly occurring contaminants of leachate from an MSW landfill;
2. To carry out the sampling and analysis of leachate from Narela-Bawana landfill site;
3. To design and implement the sampling and analysis program of groundwater in the vicinity of Narela-Bawana landfill site; and
4. To carry out HHRA for the Narela–Bawana landfill site.

CHAPTER 2. LITERATURE REVIEW

The present municipal waste production in the NCTD (National Capital Territory of Delhi) is approximately 7,000 tons/day (Ramantham et al 2006). Growth assumptions of around 10% for collection efficiency, will result in a major expansion of waste. Thus, the quantity of waste produced in 2021 would be between 17,000 and 25,000 tons/day (CPCB 2001). The composition of MSW in recent decade has been highly modified and now a days the percentage of organic matter is decreasing gradually and waste related to massive packing like cardboard, plastics, paper etc has increased to a higher rate. Thus the calorific value of waste has increased. A typical composition of waste reaching the landfill site in Delhi is presented in Table 2.1 below.

Table 2.1 Composition of MSW

Parameter	**Average %**	**Range**
Biodegradables	73.7	20.9-94.6
Recyclables	9.2	2.8-16.3
Inerts (glass, debris)	10.8	0.0-72.2
Others	6.3	0.3-16.2
Ash	15.3	3.4-61.9
Moisture	47%	8-82

Source: (Composition of Municipal Solid Waste-Need for Thermal Treatment in the present Indian context; 2006*)*

2.1 Typical leachate characteristics from MSW landfills at the global level

The typical leachate quality from MSW landfill as available in literature are summarized in Table 2.2. Below:

Table 2.2 Range of constituents observed from different landfills

Constituents		Range		Units
Type	**Parameters**	**Minimum**	**Maximum**	
Physical	pH	3.7	8.9	mg/l
	EC	480	72500	mho/cm
	TDS	725	55000	mg/l
Inorganic	Chloride	2	11375	mg/l
	Sulphate	0	1850	mg/l
	Hardness	300	225000	mg/l
	Alkalinity	0	20350	mg/l
	Total Kejeldahl Nitrogen	2	3320	mg/l
	Potassium	0	3200	mg/l
	Sodium	2	6010	mg/l
	Calcium	3	3000	mg/l
	Magnesium	4	1500	mg/l
	Lead	0	17.2	mg/l
	Copper	0	9	mg/l
	Zinc	0	12	mg/l
	Nickel	0	3.5	mg/l
Organic	COD	50	99000	mg/l
	TOC	0	45000	mg/l
	Acetone	170	11000	mg/l
	Benzene	2	410	mg/l
	BOD	0	195000	mg/l

[Source: Reported by Bagchi (1994), Tchobanoglous et. al. (1993) and Oweis and Khera (1990).]

2.2. Typical leachate characteristics from MSW landfills in Delhi

2.2.1 Leachate characteristics of Gazipur landfill

According to a study conducted by (Mor et al 2006) the pH value of the collected sample was found to be 6.9. The relatively high values of EC (24500 μScm^{-1}) and TDS (27956 mg /l) .The presence of high BOD (19000 mg /l) and COD (27200 mg /l) .Among the nitrogenous compound, ammonia nitrogen (2675 mg /l) was present in high concentration. High concentrations of NO3- (380 mg /l) and Si (326 mg /l) were also observed in the leachate samples. The high level of heavy metals like Fe (70.62 mg /l), Zn (2.21 mg /l), Pb (1.54 mg /l) were present in the leachate sample and heavy metals like Cr (0.29 mg /l), Cu (0.93 mg /l) and Ni (0.41 mg /l) were also present in trace concentration in the leachate samples.

2.2.2 Leachate characteristics of Bhalswa Landfill

Systematic study was conducted by Bharat Jhamnani and SK Singh et al 2009 to determine the impact of MSW disposal revealed that the groundwater is being significantly contaminated due to the leachate from landfill. The test was conducted for average concentrations of Chlorides, and heavy metals in leachate, and showed that landfill leachates contain high concentrations of Cl (~4,000 mg/l), NO_3(~30 mg/l), F(~50 mg/l) and PO_4^{3-} (~4 mg/l) higher than the values recommended by the CPCB, Delhi, India. High concentrations of other heavy metals like Nickel which was present in high concentration of greater than 3 mg/l, Copper and zinc which was greater than 10 mg/l, and iron concentration was 20 mg/l in the leachate sample, which is hazardous for health.

2.2.3. Leachate characteristics of Okhla landfill:

The review of characteristics of Okhla landfill was done by focusing on a study done by (V. Singh and A. K. Mittal et al 2009). Leachate samples were collected in the month of June and December of the year 2007. The characteristics of leachate varied significantly with space and time. From study it was observed that pH value varied between 7.6 – 8.2, and alkalinity in the

range of 12,000 – 32,000 mg/l, the inorganic constituent like Hardness and chloride had range of 9,000 – 25,000 mg/l and 16,000 – 23,000 mg/l respectively. Presence of high organic matter was indicated by COD having range 6,000 – 20,000 mg/l. the ammonia concentration was between NH_3 1,000 – 3,000 mg/l. the total dissolved solid were observed in the range of 2,000 – 19,000 mg/l .amongst heavy metal which tested in leachate sample, Lead had concentration of 0.9 – 1.5 mg/l., Copper and Manganese were in the trace amount of 0.2 - 0.4 mg/l, 0.2 - 1.5 mg/l, 0.2 - 0.5 mg/l .high concentration of Chromium, Iron and Nickel was seen which was 0.8 – 2.2 mg/l, 4.0 – 9.5 mg/l and 1.0 – 5.0 mg/l was observed.

2.3. Groundwater characteristics in the vicinity of landfill sites in Delhi

The earliest landfill was started in Delhi in 1975 near Ring road. In 1978 two other landfills were started at Timarpur and Kailash Nagar. Till date 17 landfill sites have been filled and closed. At present there are three large saturated yet functioning landfill sites at Ghazipur, Okhla and Bhalswa. These sites are spread over an area of about 1.5 x 10^6 m. None of their bases is lined, which may result in continuous groundwater contamination. The sites had not been designed systematically before being used for disposal /dumping of wastes. Furthermore no environmental impact assessment had been carried out prior to selection of these sites. (AL.Ramanathan, et al 2011)

2.3.1 GW characteristics in the vicinity of Gazipur landfill

According to (Mor et al 2006), the pH of all the GW was about neutral, the range being 7.02 to 7.85. The EC in the studied area range between 617 and 3620 μS/cm. The range of TDS at all sites falls in between 302 and 2208 mg /l. TDVS in the water samples ranged from 36 to 268 mg /l. The COD level in the samples varied from 2 to17 mg /l, indicating the presence of organic contaminants in the water. The concentration of Total alkalinity as $CaCO_3$ in GW ranges from 230 to 734 mg/l. Total hardness ranged from 296 to 1388 mg /l. Calcium concentration in groundwater ranged from 43 to 477 mg /l. The concentration of sodium in water samples varied from 22 to 313 mg /l. The concentration of Potassium in the water samples varied from 6 to 56 mg /l and was found to be well within the permissible limit at Gazipur.

The concentration of Chloride in the groundwater samples ranged between 28 mg/l to 737 mg/l. The concentration of NO^{3-} in water sample varied from nd to 56 mg /l. PO_4^{3-} in the water sample was well below the permissible limit and the concentration varied from ND to 0.06 mg/l Concentration of sulphate in water sample ranged from 12 to 1096 mg /l. A very low concentration of phenol was also observed in water samples and its concentration varied from non-detected to 0.1 mg/l, which further support that groundwater near landfill site is being significantly affected by leachate percolation.

With regards to presence of heavy metals, only Fe and Zn showed their presence in samples above the LOD of the present analytical method. Fe concentration in the water samples varied from 0.04 to 2.48 mg /l. The concentration of Zn varied from ND to 0.8 mg/l.

2.3.2 GW characteristics in the vicinity of Bhalswa landfill

As per Jhamnani and Singh et al. 2009 and Ramantham et al. 2011, the pH of all the GW was about neutral, and came in the range of 7.18 to 7.32. The EC in the studied area range between 1661.21 to 1721.16 μS cm^{-1}. The range of TDS was comparatively very high and was in the range of 1166.82 to 1183.79 mg /l. The COD level in the samples varied from ND to 2 mg/l, which shows absence of major organic contamination. The concentration of Total alkalinity as $CaCO_3$ in ranges from 230 to 734 mg /l. Calcium concentration ranged from 101.21 to107.39 mg/l. The concentration of sodium in water samples was very high which definitely indicate contamination from leachate and was in the range of 294.07 to 296.44 mg/l. The concentration of K^+ in the water samples varied from 6 to 56 mg/l. The concentration of Chloride in the groundwater samples ranged between 444.05 to 434.89 mg /l. The concentration of NO^{3-} and sulphate obtained in water sample varied from 19.92 to 22.73 mg/l and 236.83 to238.49 mg/l respectively. A very low concentration of phenol was also observed in water samples and its concentration varied from non-detected to 0.1 mg/l, which further support that groundwater near landfill site is being significantly affected by leachate percolation.

The concentration of heavy metal like iron and zinc were as follows: 0.64 to 7.04 mg/l, 0.02 to 3.37 mg/l respectively which is more than the permissible limit. And concentration of nickel and copper in samples analyzed were 0.13 to 0.43 mg/l and 0.08 to 0.1 mg/l.

2.3.3 GW characteristics in the vicinity of Okhla landfill

According to a report submitted by V.K.Singh & A.K Mittal et al 2009 the GW of Okhla landfill was slightly acidic in nature, as pH was found to be in the range of 5.5 - 6.54 was reported in 1 km radii around landfill. In general, conductivity ranges from 480 μS/cm to 1648 μS/cm indicate consistent rise in conductivity, it may be due to leaching of pollutant from landfill with time. Sulphate concentration ranges from 163.49 mg/1 to 521.56 mg/, 162.09 mg/1 to 531.71 mg/1. The natural source of chloride are sand dunes (1075-2562 μg/g), alluvium (31-282 μg/g), and quartzite (61-156 μg/g) .The chloride concentration were found to be higher in the area covered with sand dunes, especially western and northern part of the study area which are mainly covered with the sand dunes forms, due to weathering of ridge-material and was found to be in the range of 361.96 to 749.89 mg/l. The extensive GW study showed that ground waters in the vicinity of the landfill are characterized by high contents of organic and inorganic chemicals: more than having calcium 160.54-146.61 mg/l, magnesium 33.60 -38.24 mg/l , potassium 10.35 -12.35mg/l, sodium in the range of 26.01-22.70 mg/l respectively.

Similarly the concentration of heavy metals like iron was present more than permissible limit and was in the range 0.78-6.02 mg/l, zinc was obtained comparatively less 0.24-1.40 mg/l and concentration of nickel and lead in samples analyzed were 0.05 to 0.14 mg/l and 0.18 to 0.33 mg/l.

2.4 Human health effects due to MSW landfills

Various studies have been carried out worldwide to estimate the effect of MSW landfills on human health. Some of it has been illustrated below.

A review of literature by Vrijheid et al, 2000 showed an increase of reports of adverse health effects by people living near hazardous wastes landfill sites in the form of increase in self-reported health outcomes and symptoms such as headaches, sleepiness, respiratory symptoms, psychological conditions, and gastro-intestinal problems; excesses in bladder, lung, and stomach cancers reported; adverse pregnancy outcomes such as low birth weight and increased risk of birth defects; and increased presence of chromosomal changes, especially in children.

A study was instituted by CPCB on assessment of health status of conservancy staff of their community associated with handling of solid waste management. The study was taken up at

Kolkata through Chittaranjan Cancer Research Institute. The examination was carried on individuals of which, 376 were conservancy workers, 151 rag pickers and 205 controls. The study concluded that around 30% of people were traced with problem in respiratory system implicating infection in nose, throat & infection in lung, asthma & respiratory malfunctions. Around 40% of patient were recognize with impaired lung function which results in breathing problems mainly were rag pickers. Similarly, 22% of people were having chromosomal disorder and same percentage of individuals were diagnosed cardiovascular risk detected.13% were distinguish with anemia having symptoms of low hemoglobin, Red Blood Cells (RBCs) in blood.

Landfill sites may be a source of airborne chemical contamination via the site migration of gases and via particles and chemicals adhered to dust, especially during the period of active operation of the site. Very little is known about the likelihood of air exposure from landfill sites through landfill gases or dust. At some of the sites described below, low levels of volatile organic chemicals have been detected in indoor air of homes near landfill sites Elia VJ. (1982) et al and outdoor air, in areas surrounding sites and in on-site landfill gas Riberdy H. (1995). Other possible routes of exposure include contamination of soil, ground, and surface water, contamination via the food chain may sometimes be of concern for nearby residents in the case of consumption of homegrown vegetables. Drinking water is a possible route of exposure only if water for domestic use is locally extracted. If this is the case, other domestic water uses (bathing, washing) may also lead to exposure via inhalation of evaporated VOCs and/or direct contact Elia VJ. (1982) et al.

A number of other community health surveys have investigated a wide range of health problems, including respiratory symptoms; irritation of skin, nose, and eyes; gastrointestinal problems; fatigue; headaches; psychological disorders; and allergies. These studies have been conducted in response to concerns from the public, often triggered by smells and odors from the sites. In a number of studies, self-reported health problems were increased in exposed populations (people living close to the waste sites) compared to control populations (Smith DF, Vance WA, Neutra RR, (1991) et al).

Because knowledge of whether and to what extent substances from waste sites reach the human population is still largely lacking, and because resources are rarely available to carry out extensive exposure measurements or modeling, epidemiologic studies have based the assessment

of exposure to landfills mainly on surrogate measures such as residence in an area close to a waste site or distance of residence from a waste site. The use of such surrogate, indirect exposure measurements can lead to misclassification of exposure which, if not different for diseased and non-infecting persons, will decrease the sensitivity of the study to find a true effect. In addition to being hampered by insufficient exposure data, the study of landfill exposures is complicated by the fact that if residential populations are exposed to chemicals from landfill sites, it will generally be to low doses of mixtures of chemicals over long periods of time. Associations with such low-level environmental exposures in the general population are by their nature hard to establish. Low-dose exposures are generally expected to generate small increases in relative risk that will be difficult to distinguish.

CHAPTER 3. METHODOLOGY USED FOR CARRYING OUT HHRA FROM MSW LANDFILL SITE

According to the US National Academy of Sciences, HHRA can be defined as the process to estimate the nature and probability of adverse health effects in humans who may be exposed to chemicals in contaminated environmental media, now or in the future. It is a combination of toxicology, epidemiology, exposure assessment, biostatistics and assumptions.

We have followed the internationally recognized HHRA methodology developed by United States Environmental Protection Agency (USEPA) has been used, the salient features of which has been described in the following sections. In order to employ this methodology, one should know the concentration of Contaminants of Concern (CoC) in the vicinity of the landfill site. For that the leachate and GW samples have been collected and analyzed, the procedure of which has been explained in the next chapter. Leachate samples have been collected in order to decide on the CoCs to be analyzed in GW.

3.1 Salient features of USEPA HHRA methodology

According to USEPA, risk assessment is subdivided into four stages, essentially following the classical source pathway – receptor model. They are:

1. Step 1: Hazard Identification;
2. Step 2: Exposure Assessment;
3. Step 3: Dose response assessment;
4. Step 4: Risk characterization.

Step 1:Hazard Identification

Hazard Identification is the process of determining whether exposure to a concerned contaminant has the potential to cause harm to humans and if so identifies the contaminants of concern and its corresponding health effects like cancer, birth defects, diseases, and formation of tumors, reproductive defects, death or other effects. The step and analysis used for hazard identification analysis are:

a) Consideration on how the body absorbs, distributes, metabolizes, and eliminates specific chemicals which might cause deleterious effect on human.
b) The next step focuses on the effects that chemicals have on the human body. Models based on these studies can describe mechanisms by which a chemical may impact human health, thus providing insights into the possible effects of a chemical.

When assessing a chemical for potential carcinogenic behavior, it might affect human through one or more than one way which might be through physical, chemical and biological mode and thus gives information about carcinogenic or non - carcinogenic effect chemical might have on human. One of the component of hazard characterization is basically evaluating the weight of evidence regarding a chemical's potential to cause adverse on the human health effects. The weight of evidence narrative may include some standard descriptors that signify certain qualitative threshold levels of evidence or confidence have been met, such as Carcinogenic to humans or suggestive evidence of carcinogenic potential.

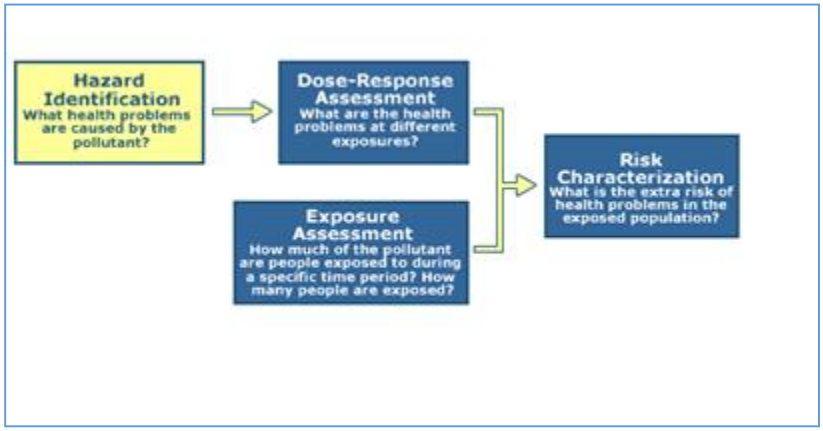


Figure 3.1 Flow diagram representing, risk assessment

Source: (http://www.epa.gov/risk/hazardous-identification.htm)

Sources of Data

Statistically controlled clinical studies on humans provide the best evidence linking a stressor, often a chemical, to a resulting effect. However, such studies are frequently not available since there are significant ethical concerns associated with human testing of environmental hazards. Epidemiological studies involve a statistical evaluation of human populations to examine whether there is an association between exposure to a stressor and a human health effect. When

data from human studies are unavailable, data from animal studies (rats, mice, rabbits, monkeys, dogs, etc) are relied on to draw inference about the potential hazard to humans. Animal studies can be designed, controlled, and conducted to address specific gaps in knowledge, but there are uncertainties associated with extrapolating results from animal subjects to humans.

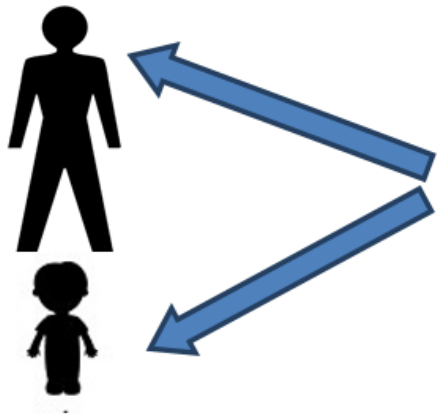
Step 2 Exposure Assessment

The basic term Exposure denotes: Contact of an organism with a chemical or physical agent. Exposure is quantified as the amount of the agent available at the exchange boundaries of the organism (e.g., skin, lungs) the visible exterior of the person (skin and openings into the body such as mouth and nostrils), which are available for absorption.

Exposure can be measured directly, but more commonly is estimated indirectly through consideration of measured concentrations in the environment, consideration of models of chemical transport and fate in the environment, and estimates of human intake over time.
An exposure assessment basically involves the technique of measuring or determining the various parameters like:

i. Exposure frequency,
ii. Exposure duration: which is basically the duration of human exposure to an agent in the environment or estimating future exposures for an agent that has not yet been released.
iii. Exposure potential pathways: which is basically a term or a path course a chemical or physical agent takes from a source to an exposed organism. An exposure pathway describes a unique mechanism by which an individual or population is exposed to chemicals or physical agents at or originating from a site. Each exposure pathway includes a source or release from a source, an exposure point, and an exposure route. If the exposure point differs from the source, a transport/exposure medium (e.g., air) or media (in cases of inter media transfer) also is included.
iv. Exposure rates or exposure concentration is the amount of concentration which is received by an individual by different Exposure pathways.
v. Exposure route is a termed which describes the way a chemical or physical agent comes in contact with an organism (e.g., by ingestion, inhalation, dermal contact)

vi. It also involves inclusion of various other factors like: permeability coefficient of a particular contaminant, skin surface area of an individual, size, nature, and types of human populations exposed to the agent,



Ingestion of groundwater contaminated by leachate
Ingestion of surface water contaminated by leachate
Ingestion of contaminated soil/particles
Consumption of contaminated fruits, vegetable/fish
Dermal exposure (Swimming, farming etc.)
Intake of meat & diary product
Intake rates of home produced food items
Activity factors

Figure 3.2 Potential pathways of various contaminants

Range of Exposure

For any specific agent, there is a range of exposure experienced by individuals. Some individuals may have a high degree of contact for an extended period e.g. factory workers exposed to an agent on the job, residential population near contaminant source Other individuals may have a lower degree of contact for a shorter period e.g. individuals using a recreational site downwind of the factory. EPA policy for exposure assessment requires consideration of a range of possible exposure levels. Two common scenarios for possible exposure are Central Tendency or average exposure conditions and High End or worst exposure conditions. Central Tendency exposure is an estimate of the various average exposure conditions experienced by the affected population, based on the amount of agent present in the environment and the frequency and duration of exposure. High End exposure is the highest dose estimated to be experienced by some individuals, commonly stated as approximately equal to the 90^{th} percentile exposure category for individuals.

The next step after estimating various exposure rate (magnitude, frequency, duration) is the assessing of the chronic daily value, which is represented by Chronic Daily Intake (CDI) for

non-carcinogen contaminant and Lifetime Average Daily Absorbed Dose (LADD) for carcinogenic contaminant.

a. **For non-carcinogenic contaminant**:

When, a non-carcinogen is ingested, the CDI is represented by the following formula:

$$\mathbf{CDI\ (mg/kg\text{-}day)} = \frac{\mathbf{IR} * \mathbf{EF} * \mathbf{ED} * \mathbf{C_{GW}}}{\mathbf{Bw} * \mathbf{AT}}$$

where:

CDI = Chronic daily intake (mg/kg*day)

C_{GW} = Chemical concentration in groundwater for non-carcinogenic inorganic (mg/l)

IR = Ingestion rate (l/day)

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

BW = Body weight (kg)

AT = Averaging time for non-cancer (years)

It should be noted that AT is equal to the exposure duration for above equation.

In case of absorption of non-carcinogenic toxicant, through dermal contact, CDI value is given by the following equation:

$$\mathbf{CDI} = \frac{\boldsymbol{C_{GW}} \times \boldsymbol{S_A} \times \boldsymbol{K_P} \times \mathbf{ET} \times \mathbf{ED} \times \mathbf{ET} \times \mathbf{CF}}{\boldsymbol{AT} \times \boldsymbol{B_W}}$$

where:

C_{GW} = Chemical concentration in groundwater for non-carcinogenic chemical (mg/l)

S_A = Surface area of body.

Kp = coefficient of permeability for particular chemical (cm/hr)

BW = Body weight (kg)

CF = Conversion factor (10^3 L/Cm^3)

ET = Exposure time (hr/day)

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

AT = Averaging time for non-cancer (years)

b. For carcinogenic contaminant:

Similarly LADD values for ingestion is represented by:

$$\textbf{LADD (mg/kg-day)} = \frac{\textbf{IR * EF} * \textbf{EF} * \textbf{ED} * \textbf{C}_{GW}}{\boldsymbol{B_W}\textbf{*AT}}$$

where:

LADD = Lifetime Average Daily Absorbed Dose (mg/kg/day)

C_{GW} = Chemical concentration in groundwater for carcinogenic compound (mg/l)

AT = Averaging time for cancer effects (years)

IR = Ingestion rate (l/day)

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

BW = Body weight (kg)

It should be noted that averaging time in this case would be equal to that life span of an individual

In case of absorption of carcinogenic toxicant, through dermal contact, LADD is given by:

$$\textbf{CDI} = \frac{\textbf{C}_{GW} \times \textbf{S}_A \times \textbf{K}_P \times \textbf{EF} \times \textbf{ED} \times \textbf{ET} \times \textbf{CF}}{\textbf{AT} \times \textbf{B}_W}$$

where:

LADD = lifetime average daily absorbed dose(mg/kg/day)

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

ET = Exposure time (hr/day)

S_A = Surface area of body.

Kp = coefficient of permeability for particular chemical (cm/hr)

B_W = Body weight (kg)

C_{GW} = Chemical concentration in groundwater for non-carcinogenic chemical (mg/l)

AT = Averaging time for non-cancer (years)

CF= Conversion factor (1 litre = $10^3 cm^3$)

Step-3 Dose-response assessment

Dose-response relationship is a qualitative relationship that indicates the agent's degree of toxicity to exposed species. Threshold involves derivation of occupational, clinical and epidemiological studies of risk of that agent. (Balsher Singh Sidhu et al, 2013). Dose is calculated from the intake, inhaled and the absorption efficiency. It usually is expressed as mass of a substance absorbed into the body per unit body weight per unit time (e.g. mg/kg-day).Thus dose-response assessment basically elaborates how the likelihood and severity of adverse health effects i.e. the responses are related to the amount and condition of exposure to a given agent. The term exposure-response relationship may be used to describe either a dose-response or a concentration-response, or other specific exposure conditions.

Typically, as the dose increases, the measured response also increases. At low doses there may be no response. At some level of dose the responses begin to occur in a small fraction of the study population. Both the dose at which response begin to appear and the rate at which it increases given increasing dose can be variable between different pollutants, individuals, exposure routes, etc. The shape of the dose-response relationship depends on the agent, the kind of response like tumor, incidence of disease, death etc, and the experimental subject which specifically are human and animal. It is impractical to study all possible relationships for all possible responses, scientist specifically focuses on testing for a limited number of adverse effects. Upon considering all available studies, measure of response that leads to an adverse effect, which occurs at the lowest dose is selected as the critical effect for risk assessment.

Dose-response assessment is a two-step process. The initial step is assessment of all data that are available or can be gathered through the scientific information available is evaluated for

a better biological understanding of how each type of toxicity or response occurs; the understanding of how the toxicity is caused, in order to document the dose-response relationship over the range of observed doses. However, this range of observation may not include sufficient data to identify a dose where the adverse effect is not observed in the human population.

The second step consists of extrapolation to estimate the risk for probability of adverse effect beyond the lower range of available observed data in order to make decisions about the critical region where the dose level begins to cause the adverse effect in the human population. The result of second step gives the inferences about a specific concerned containment the main aim of practicing this exercise is to have mathematical relationship between the amount of toxicant to which human being is exposed and the risk of hazardous outcomes from specific toxicant. A particular contaminant or toxicant can be both non-carcinogen and potential carcinogen which is inferred from the study carried out above by studying the amount of dosage given and response obtained by it.

a. Non- carcinogen effect

The dose response for non- carcinogen is based on the existence of a dose which is called as oral Reference dose (RfD) below which no appreciable results or effect are being obtained. According to EPA, RfD is an estimate, with uncertainty spanning perhaps an order of magnitude, of a daily oral exposure to the human population (including sensitive groups like child, adult, working class population) that is likely to cause no appreciable risk of deleterious effects during a lifetime. Reference doses are chemical-specific, *i.e.* unique value is obtained for every substance Thus in the next step the chronic daily intake value is divided by RfD value to obtain a ratio which is called Hazard Quotient.

b. Carcinogen effect

A contaminant is known to be potential carcinogenic by experimentation or study of toxicant which does not have a threshold value. In this type of assessment, there is theoretically no level of exposure for such a chemical that does not pose a small, but finite, probability of generating a carcinogenic response. For the extrapolation phase of this type of assessment a straight line is drawn from the point of departure for the observed data to the origin The slope of this straight

line, called the slope factor (SF) or cancer slope factor, it simply converts estimated daily intakes averaged over a lifetime of exposure directly to incremental risk of an individual developing cancer. Thus slope factor can be said to be an upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent by ingestion or inhalation.

Thus for cancer risk a terminology called LADD is used and determined, in which the averaging time is considered equal to lifetime span of an individual.

Step-4 Risk characterization

Risk characterization is the final stage of the risk assessment process, combining information from hazard identification, dose-response evaluation and exposure assessment into a form that is useful for decision makers - risk managers, legislators, journalists and the public. Therefore, it is critical that the results and uncertainties of the risk assessment process be communicated in a way that is straightforward, informative and scientifically credible. Risk characterization also serves as the bridge between risk assessment and risk management and is therefore a key step in the ultimate site decision making process. This step assimilates risk assessment information for the risk manager (regional upper management involved in site decision-making) to be considered alongside other factors important for decision-making such as economics, technical feasibility, and regulatory context. A risk characterization is considered to be complete only when the numerical expressions of risk are accompanied by explanatory text interpreting and qualifying the results.

As discussed above steps, separate discussions for carcinogenic and non- carcinogenic effects because of the methodology difference in the modes of chemical toxicity of both is described below as:

a) **Non-carcinogenic effects**

The measure used to describe the potential for non-carcinogenic toxicity to occur in an individual is not expressed as the probability of an individual suffering an adverse effect. EPA does not at the present time use a probabilistic approach to estimating the potential for non-carcinogenic health effects. Instead, the potential for non-carcinogenic effects is evaluated by comparing an

exposure level over a specified time period (e.g. exposure duration) with reference dose derived for a specific chemical. This ratio of toxicity is called a hazard quotient, which is give as:

$$\mathbf{HI} = \sum \mathbf{HQ} = \sum \frac{\boldsymbol{CDI}}{\boldsymbol{RFD}}$$

where:

HI =Hazard index

H.Q = Hazard quotient

CDI =Chronic daily intake

RFD = Reference dose value

In final step the hazard index (H.I) is obtained which is basically the summation of hazard quotient for several contaminants that might cause adverse (non-carcinogenic effect). If H.I ≤ 1, then cumulative exposure to the different contaminants is not expected to cause adverse health effects.

b. Carcinogenic effects

For carcinogens, risks are estimated as incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (i.e, incremental or excess individual lifetime cancer risk).which is given by:

$$\text{ILCR} = \sum (\text{SF} \times \text{LADD})$$

where:

ILCR.....=..... incremental lifetime cancer risk

LADD = ...Lifetime average daily absorbed dose(mg/kg*day)

S.F..... = ...Slope Factor

After obtaining cancer risk value the amount of population which will be affected by the adverse effect of carcinogenic chemical is calculated. The USEPA (1989) regards cancer risks ranging between 1 in 10 million (i.e., 10^{-7}) and 100 in 1 million (i.e., 10^{-4}) as within the range of acceptable risk.

3.2 Methodology adopted for analysis of leachate and GW samples

The various physico-chemical parameters were analyzed for all the leachate and GW samples. APHA (1994) methods were used for chemical analysis of all the samples. Specific methods employed are summarized in Table 3.2

Table 3.1 Methods used for analysis of various parameters of leachate and GW sample.

S.No.	Parameters	Methods
1	pH, EC, TDS, DO	Electrode
3	Sodium and Potassium	Flame photometer
4	Calcium ,Magnesium and Chlorine	Titration method
5	COD	Open reflux digestion and titration
7	Sulphate, Phosphate ,Iron	Spectrophotometer
8	Heavy metals (Chromium, Copper, Nickel, Zinc)	Atomic Absorption Spectrometer (AAS)

CHAPTER 4. HHRA OF HEAVY METALS FROM NARELA-BAWANA LANDFILL

4.1 Introduction:

In this chapter describes the evaluation of potential public health risks that might be attributable due to coming in contact with different receptors. The hazard identified receptors are oral ingestion of groundwater, contact through dermal route of groundwater, by the focused residential populations of the proposed landfill sites. Only ingestion and dermal route exposure pathways were evaluated assuming that hazard due to ingestion of soil or dust particles that adhere to food ,intake of fruits and vegetables etc is negligible. The health risk assessment was performed in accordance with USEPA health risk assessment guidance (USEPA 1989, 1997, 2003b).

Although the proposed landfill site hazardous effects will be mixed for residential, commercial and working class population, the health risk assessment focused on the more critical residential population. For risk assessment, the two main differences between the residential and commercial populations are the exposure time and the necessary inclusion of children in the residential population. Whereas the ingestion of groundwater depends upon individual capability of intake of water per day but in any case it will be more for residential population. Dermal pathway which also mainly focuses residential population and exposure time through bathing, showering is considered more for children as compared to adults. For the dermal exposure route, the soil adherence factor term is neglected. Thus, the health risk assessment are based on exposure characteristics that are individually appropriate for the hypothetical adult residential populations.

In the absence of specific exposure data from the receptor populations at the nearby landfill site, exposure assumptions were made regarding average body weight, inhalation rate, exposure frequency, etc., on the basis of USEPA default exposure factor characteristics to calculate human health risk for worst-case exposure scenarios for both child and adult

populations. For each exposure factor, the central Tendency or average values value was assumed pertaining to USEPA 50th percentile values, whereas the High End or worst exposure conditions was assumed equivalent to the 95th percentile value. If the 95th percentile data were not available for an exposure characteristic, the average value was used instead

4.2 Study area

The Narela-Bawana landfill site is located in Delhi, the capital city of India, which sprawls over 1483 km^2 (AL.Ramanathan, et al 2011) and ranks second in population among other Indian metropolitan cities. Delhi is is situated in North India at an altitude of 293 m (AL.Ramanathan, et al 2011) above mean sea level (MSL). Delhi, is estimated to generate about 7000 metric tons of MSW daily. The per capita generation of solid waste in Delhi ranging from 150 grams to 600 grams a day depending upon the economic status of the community involved and it mainly includes waste from household, industries and medical establishments.

4.2.1. Geology of area

The Gangetic Plain and the Aravalli Ridge converge at Delhi and they give a mixed geological character with alluvial plains as well as quartzite bedrocks. It is surrounded by the Thar Desert of Rajasthan to the west and the hot plains of Central India to the south. The distance from the nearest ocean exceeds one thousand kilometers. The groundwater availability in the territory is controlled by the hydro geological situation characterized by occurrence of alluvial formation and quartzite hard rocks. The hydro-geological set up of groundwater and the following distinct physiographic units: Alluvial plain on eastern and western sides of the ridge, Yamuna flood plain deposits, Isolated and nearly closed Chattarpur alluvial basin. The Delhi ridge, which is the northernmost extension of Aravalli Mountain, consists of quartzite rocks and extended from southern part of the territory to western Bank of the river Yamuna for about 35 Km. the alluvial formations overlying the quartzite bedrock have different nature on either side of the ridge. The Yamuna flood plain contains a distinct river sediment deposits. The closed Chattarpur alluvial basin occupies an area of about 48 sq. km, occupied by alluvium derived from the adjacent quartzite ridge. (National Institute of Hydrology, Jal Vigyan Bhawan (2001) et al)

4.2.2. Climate of area

The climate of Delhi is semi–arid and is mainly influenced by its inland position and prevalence of continental air during most of the years. According to the classification given by Indian Meteorological Department (IMD), Delhi has four distinct seasons: winter (December–March), pre–monsoon or summer (April–June), monsoon (July–September) and post– monsoon (October–November). Summer is long and extremely hot, with maximum temperatures of 45–48°C and the maximum frequency of dust storms. The average rainfall is 721 mm with more than 80% during the monsoon season and the annual evaporation is about 2,565 mm (IMD, 1990–2005, et al). Humidity is high only during the monsoon season, characterized by heavy rainfalls, while the air is dry during the rest of the year. The winter season is moderately cold, with minimum temperatures around 1 – 4 °C. The mean minimum and maximum temperatures are 18.7 ^{0}C and 30.5 ^{0}C, respectively, with daily maximum temperatures during the hottest months commonly exceeding 42.2 ^{0}C

4.2.3. Hydrology of the area

Delhi, as the rapidly growing capital city of Asia, is facing problems both in terms of the groundwater quality and quantity. The variation of quality of groundwater in space as well as depth adds another dimension to the complex groundwater situation in the territory. According to National Institute of Hydrology, Jal Vigyan Bhawan, 2001) The groundwater level depth in Delhi varies between 15 to 20 meter. The presence of saline water aquifers at shallow depths varying from 20 to 50 m(below ground level in many parts presents a typical groundwater scenario. The total ground water available in the territory is 291.54 million cm/year. Presently ground water is used for irrigation, drinking and industrial purposes. the surface is irrigated by ground water is about 47.5 hectares ,while the quantity of ground water withdrawn for other uses is difficult to assess. The river Yamuna is the main source of surface water in the capital territory, it enters Delhi near Wazirabad and extend till Okhla .Yamuna receives sewage and industrial wastes through twenty two drains which join river Yamuna between Wazirabad and Okhla. Delhi is the largest contributor of pollution to river Yamuna almost 80% of pollution load

through these drains.(AL.Ramanathan, et al 2011) et al 2011, National Institute of Hydrology, Jal Vigyan Bhawan, 2001)

4.2.4. Location and site description of Narela Bawana landfill

Narela-Bawana is a scientific / engineered landfill which came in operation from July 2011. Specific co-ordinates of the site are $28^0$48'21"N and $77^0$04'14"E (google map) and is located in Northern part of Delhi along Haryana border. The landfill site is located on Narela- Bawana road at a distance of about 5-6 kilometers from Bawana village towards Narela Village. It is located at an aerial distance of 14 km from Old Delhi railway station and 23 km from nearest airport of Safdarjang airport. The construction of the landfill is carried out in phases. according to EIA summary conducted by ramky enviro engineers limited stated that Currently, the second phase of construction is being undertaken, but once fully functional 4000 tonnes /day of waste would be dumped in Narela Bawana site. The site is being claimed to be efficiently installed with instrument which leads to waste reduction, effective management of waste produced after waste reduction, generation of electricity from waste. It has area approximately of 100 acre (40 hectares), out of which material recovery facility, including Refuse Derived Fuel (RDF) covers an area of 0.27 hectares. Compost Plant and Recyclables storage area are said to be placed in 2.7 Hectares and 0.27 hectares respectively. Power plant has an area of 13.1 hectares and landfill occupy majority of land which is around 16.1 hectares .According to Environmental Impact Assessment (EIA) summary presented by (Ramky Enviro Engineer's Limited, 2009) on that site around 1,300 metric tons of solid waste will be segregated and processed to obtain RDF for industrial use and electricity production at landfill site.

It is claimed that the landfill is lined with two layers of clay and a High Density Polythene (HDPE) layer in between. Once the RDF plant becomes operational, there is a plan n place to to collect the harmful gases and flare it before releasing in the atmosphere which will be produced when RDF would be burned.

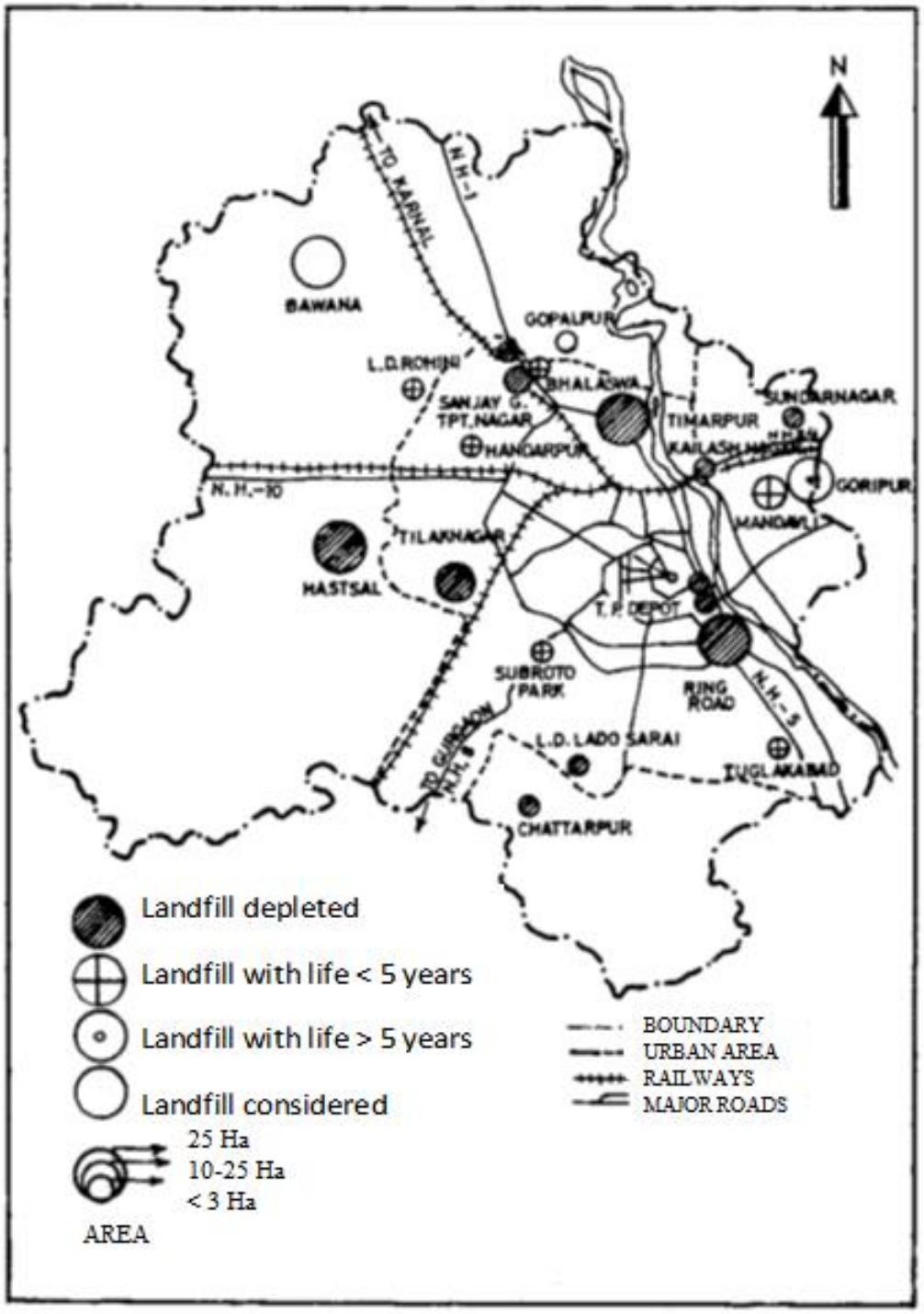


Figure 4.1 representing various operational and closed landfill in Delhi

Reference: A.L Ramanatham et al 2006

4.3 Leachate characteristics of Narela-Bawana landfill

4.3.1. Sample collection

Leachate sample were collected on 20 March 2014 from the slump pond in the center of the MSW landfill site. Triplicate samples were collected from there whose values are discussed in annexure

Figure 4.2: Images of leachate sample being collected

The leachate treatment plant was not operational at the time of sample collection, thus post treatment leachate sample could not be collected. The leachate sample were collected in BOD bottles which were sterilized before use by heating for some time at 180^0C together with their stoppers. After collection, all samples were properly labelled with details of the source, date of sampling, time of sampling and address. Leachate sample was collected in BOD bottles, picture of which is presented in Fig 4.4

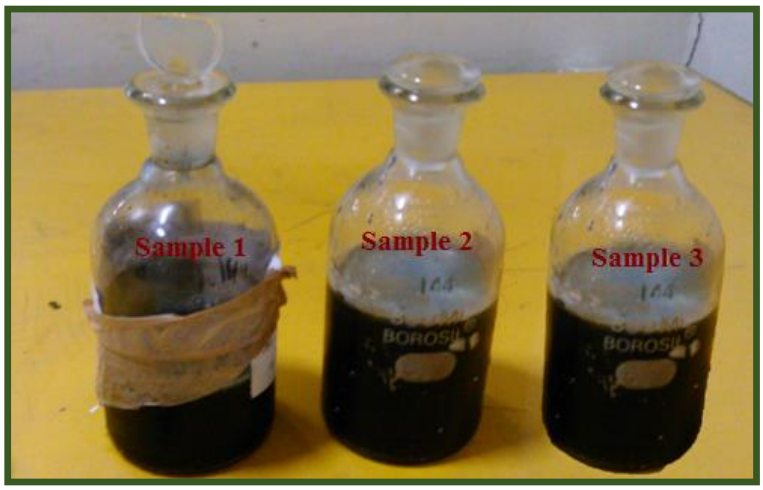


Figure 4.3: Leachate samples collected (in triplicate)

4.3.2. Sample storage and shipment

After collection, samples were immediately placed in a cooler box which was made of thermal box carrying coolant ice packages in it so that they can be transported to the laboratory at 4°C .at temperature close to 4°C. The distance between the Narela-Bawana landfill and the Delhi Technological University (DTU) Laboratory, where the sample was tested is 16.1 km which takes about 45 minutes in transportation. Every effort was made to keep the temperature of the samples around 4°C during the transportation time.

4.3.3. Sample Preservation

As soon as the samples reached the DTU laboratory, they were kept in in a refrigerator at 4°C for preservation. The samples were tested in laboratory within 24 hours from the time of collection. Sample Analysis. The various physiochemical parameters were tested on the leachate sample. The testing was carried out in triplicate. The table below presents the method employed for testing and the values thus obtained.

Table 4.1 Leachate characteristics are being represented

Parameters	Units	Values observed	Method employed
pH		8.40	Glass electrode
EC	µS/cm	965	Glass electrode
TDS	mg/l	26320	Gravimetric method
Cl	mg/l	4466.10	Titration method
SO_4^{2-}	mg/l	N.D	Spectrophotometer
PO_4^{3+}	mg/l	251.92	Spectrophotometer
COD	mg/l	47600	Open reflux digestion and titration
Ca	mg/l	133.6	Titration method
Na	mg/l	3532	Flame photometer
K	mg/l	3218	Flame photometer
Mg	mg/l	330.7	Titration method
Fe	mg/l	23.26	Spectrophotometer
Cr	mg/l	0.21	Atomic Absorption Spectrometer
Cu	mg/l	3.52	Atomic Absorption Spectrometer
Ni	mg/l	N.D	Atomic Absorption Spectrometer
Zn	mg/l	1.096	Atomic Absorption Spectrometer

4.4 Groundwater characteristics in the vicinity of Narela-Bawana landfill

4.4.1 Sample Collection

Six GW samples (GW-1, GW-2, GW-3, GW-4, GW-5 and GW-6) were collected from specific tube wells, bore wells and hand pumps. GW-1 was collected from a Hand Pump (HP) located in a house located at 28º48'20.4''N and 77º04'36.6''E , GW-2 was collected from 28º48'27.5''N and 77º03'19.6''E, and similarly GW-3 was located at 28º49'17.2'N and 77º03'28.4''E GW-4 was collected from 28º47'12.7'N and 77º05'36.3''E, coordinates of GW-5 and GW-6 were located at 28º49'49.6''N and 77º05'49.6''E and lastly at 28º46'45.1'N and 77º05'45.8''E respectively. All sampling points were located at 0.725 km, 1.5km, 2.32km, 3.0km, 3.4 km and lastly at 3.8 km from the landfill dumping point. Priority was kept to take sample nearest to landfill, as considered landfill is situated in industrial area, precaution of not collecting sample nearby the industrial area was kept in mind. Landfill at one side was also confined by Yamuna canal thus it was kept in mind to not collect sample beyond Yamuna canal. During samples collection, 500 ml PVC sampling bottles for groundwater were used, which were rinsed 2 - 3 times with the sample water which was to be collected. To prevent the loss of certain cations such as Cd, Cu, Cr, Ni and Zn and so forth by adsorption, or ion exchange with the walls of glass containers, some sampling bottles were acidified with concentrated Hcl or HNO_3 to pH below 2.0 and the other were un-acidified and used to analyze for anions.

Table 4.2 Specification of GW sample collection location

GW Sample No.	Source	Co-ordinates	Distance from the landfill
GW1	Hand pump	28º48'20.4''N,77º04'36.6''E	725 m
GW2	Hand pump	28º48'27.5''N,77º03'19.3''E	1.51 Km
GW3	Bore well	28º49'17.2''N,77º03'28.4''E	2.32 Km
GW4	Tube well	28º47'12.7''N,77º05'36.3''E	3.0 Km
GW5	Bore well	28º49'49.6''N,77º05'13.9''E	3.40 Km
GW6	Hand pump	28º46'45.1''N,77º05'45.8''E	3.8 Km

Figure 4.4: Water samples collected from different locations

Figure 4.5: Image showing location of MSW landfill and GW sampling

4.4.2. Sample Storage and Shipment

Storage and shipment of groundwater samples were performed in manners that maintain sample quality. Samples were cooled to 4^0C as soon as after samples were collected. These conditions were maintained until the samples were received at the laboratory. Transportation arrangement was maintain proper storage conditions and provide for effective sample pickup and delivery to the laboratory. Sampling plan was coordinated with the laboratory so that appropriate sample receipt, storage, analysis, and custody arrangements were provided.

4.4.3. Sample Preservation

In groundwater sampling, every attempt was made to minimize changes in the chemistry of the samples. To ensure it samples were deep freeze in a refrigerator at 4°C for preservation. The samples were tested in laboratory within 24 hours from the time of collection. The analyses covered physical and chemical parameters of groundwater sample.

4.4.4 GW analysis

The results obtained from analyzing GW samples are presented in the table below:

Table 4.3 Characteristics of GW observed at various locations

Parameters	Units	GW1	GW2	GW3	GW4	GW5	GW6	BIS Standards (Max. allowable Limit)	WHO Standards (Max allowable limit)
pH		8.93	6.37	7.47	5.15	5.77	6.04	6.5-8.5	9.2
EC	µS/cm	4583	4280	4440	4387	4620	3360	-	-
TDS	mg/l	2220	2160.67	2112.3	1542.96	1564.67	1685.33	2000	1500
Cl	mg/l	1585	1693.98	1108.74	1202.86	428.10	807.21	1000	600
SO_4	mg/l	73.91	96.89	186.4	112.4	84.7	73.42	400	400
PO_4	mg/l	0.572	0.44	0.256	0.10	0.34	0.62		
COD	mg/l	-	-	-	-	-	-	-	-
BOD	mg/l	-	-	-	-	-	-	-	-
Ca	mg/l	86.61	113.58	92.01	78.27	68.28	87.24	200	200
Na	mg/l	85.62	64.29	56.23	33.53	54.58	48.25	-	200
K	mg/l	28.67	18.66	15.93	14.91	13.86	9.47	-	200
Mg	mg/l	58.64	54.02	40.64	28.16	19.5	17.68	30	150
Fe	mg/l	0.542	0.660	0.342	0.101	0.090	0.070	0.3	0.3
Cr	mg/l	0.116	0.112	0.088	0.076	0.064	0.085	0.05	
Cu	mg/l	0.291	0.265	.250	0.219	0.092	N.D	1.5	
Ni	mg/l	N.D	N.D	N.D	N.D	N.D	N.D		
Zn	mg/l	0.861	N.D	0.363	N.D	N.D	N.D	5.0	5.0

4.5. HHRA of heavy metals from Narela-Bawana landfill:

Two types of exposure routes viz. through ingestion and through dermal contact has been considered. Also, two type of receptors that are adult and child are considered which are categorized on basis of age, weight body type. Thus, overall there are four cases which are considered:

1. Case 1: Exposure through GW ingestion for adults
2. Case 2: Exposure through GW ingestion for children
3. Case 3: Exposure through dermal contact for adults
4. Case 4: Exposure through dermal contact for children

Out of the heavy metals tested in GW samples, Iron (Fe), Copper (Cu) and Zinc (Zn) are non-carcinogenic in nature and Chromium (Cr) is carcinogenic. As explained in the methodology in the previous chapter, the calculations would be done separately for carcinogens and non-carcinogenic metals.

4.5.1. Exposure through ground water ingestion

For non-carcinogens: As explained in the previous chapter, non-carcinogenic effect is indicated by finding the value of HI, which is numerically represented as:

$$\mathbf{HI} = \sum \mathbf{HQ} = \sum \frac{\boldsymbol{CDI}}{\boldsymbol{RFD}}$$

Various exposure factor values which are obtained from (USEPA, 1992b) are in table 4.4

Table 4.4 Exposure factor considered for HHRA

Exposure factor	Adult population	
	Average value	95th percentile value
Ingestion rate, IR (m^3/h)	2.3	No data
Body weight, BW (kg)	72	98
Exposure duration, ED (years)	N.A	4
Exposure frequency,EF (days/year)	350	365
Averaging time, AT (years)	70	75

Table 4.5 Value of toxicity and non-toxicity dosage USEPA 2003(b)

PARAMETERS	RFD	SLOPE FACTOR
Fe	$2.50x10^{-4}$	---
Cr	$5.00x10^{-3}$	$5.00x10^{-01}$
Cu	$4.00x10^{-02}$	---
Ni	$2.00x10^{-02}$	---
Zn	$3.00x10^{-01}$	---

Putting these values in above equation and values observed for **ingestion** are:

Table 4.6 Calculation for different contaminants for GW1

Contaminant	C_{GW1}	For Adult		For Children	
		CDI	HQ	CDI	HQ
Iron	0.54	1.72×10^{-2}	2.46×10^{-2}	3.24×10^{-2}	4.63×10^{-2}
Chromium	0.116	3.71×10^{-3}	7.41×10^{-1}	6.96×10^{-3}	1.39×10^{0}
Copper	*0.291*	9.30×10^{-3}	2.31×10^{-1}	1.75×10^{-2}	8.73×10^{-1}
Zinc	*0.86*	2.75×10^{-2}	9.16×10^{-2}	5.16×10^{-2}	1.72×10^{-1}
∑HQ=H.I.			1.09		2.48

Sample calculation for iron:

i. $C.D.I = \frac{2.3*4*365*0.54}{72*4*365} = 1.72*10^{-2}$ mg/kg*day

ii. $H.Q = \frac{.00172}{0.7} = 2.46*10^{-2}$

Table 4.7 Calculation for different contaminants for GW2

Contaminant	C_{GW2}	For Adult		For Child	
		CDI	HQ	CDI	HQ
Iron	0.66	2.108×10^{-2}	3.011×10^{-2}	3.96×10^{-02}	5.66×10^{-02}
Chromium	0.11	3.513×10^{-3}	7.02×10^{-1}	6.60×10^{-03}	1.32×10^{0}
Copper	*0.265*	8.465×10^{-3}	2.116×10^{-1}	1.59×10^{-02}	7.95×10^{-01}
Zinc	N.D.	--	--	---	---
∑HQ=HI.			0.945		2.17

Sample calculation for iron:

i. $C.D.I = \frac{2.3*4*365*0.66}{72*4*365}$ = 0.02108304 mg/kg*day

ii. $H.Q = \frac{.021}{0.7}$ = 0.030118629

Table 4.8 Calculation for different contaminants for GW3

Contaminant	C_{GW3}	For Adult		For Child	
		CDI	HQ	CDI	HQ
Iron	0.34	1.0861×10^{-2}	1.551×10^{-2}	2.04×10^{-02}	2.91×10^{-02}
Chromium	0.038	1.213×10^{-3}	2.427×10^{-1}	2.28×10^{-03}	4.56×10^{-01}
Copper	0.25	7.986×10^{-3}	1.996×10^{-3}	1.50×10^{-02}	7.50×10^{-01}
Zinc	0.36	1.149×10^{-2}	3.833×10^{-2}	2.16×10^{-02}	7.20×10^{-02}
∑H.Q=H.I.			0.754		1.31

Sample calculation for iron:

i. $C.D.I = \frac{2.3*4*365*0.34}{72*4*365}$=0.01086096mg/kg*day

ii. $H.Q = \frac{.00108}{0.7}$= 0.015515657

Table 4.9 Calculation for different contaminants for GW4

Contaminant	C_{GW4}	For Adult		For Child	
		CDI	HQ	CDI	HQ
Iron	0.1	3.194×10^{-3}	4.563×10^{-3}	6.00×10^{-3}	8.57×10^{-3}
Chromium	0.09	2.875×10^{-3}	5.749×10^{-1}	5.40×10^{-3}	1.08×10^{0}
Copper	0.219	6.995×10^{-3}	1.748×10^{-1}	1.31×10^{-2}	6.57×10^{-1}
Zinc	N.D.	--	--	---	---
∑H.Q=H.I.			0.75		1.75

Sample calculation for iron:

i. $C.D.I = \frac{2.3*4*365*0.10}{72*4*365}$= 0.0031944 mg/kg*day

ii. $H.Q = \frac{.0031}{0.7}$= 0.004563429

Table 4.10 Calculation for different contaminants for GW5

Contaminant	C_{GW5}	For Adult		For Children	
		CDI	HQ	CDI	HQ
Iron	0.09	2.875×10^{-3}	4.107×10^{-3}	5.40×10^{-03}	7.71×10^{-3}
Chromium	0.16	5.111×10^{-3}	1.022	9.60×10^{-03}	1.92×10^{0}
Copper	0.092	2.9388×10^{-3}	7.347×10^{-2}	5.52×10^{-03}	2.76×10^{-1}
Zinc	*N.D*	--	--	---	---
∑H.Q=H.I.			1.099		2.20

Sample calculation for iron:

i. $C.D.I = \frac{2.3*4*365*0.09}{72*4*365}$ = 0.00287496mg/kg*day

ii. $H.Q = \frac{.0028}{0.7}$ = 0.004107086

Table 4.11 Calculation for different contaminants for GW6

Contaminant	C_{GW6}	For Adult		For Children	
		CDI	HQ	CDI	HQ
Iron	0.07	2.241×10^{-3}	3.19×10^{-3}	4.2010^{-3}	6.00×10^{-3}
Chromium	0.08	2.56×10^{-3}	5.11×10^{-01}	4.80×10^{-3}	9.60×10^{-1}
Copper	*N.D*	----	----	---	---
Zinc	*N.D*	-----	----	---	---
∑H.Q=H.I.			$5.14x10^{-1}$		$9.66x10^{-1}$

Sample calculations for iron:

i. $C.D.I = \frac{2.3*4*365*0.07}{72*4*365} = 2.24\times10^{-03}$ mg/kg*day

ii. $H.Q = \frac{.00224}{0.7} = 3.19E\text{-}03$

In case for carcinogenic:

Table 4.12 Calculation for carcinogenic

G_w location	Chromiuim	For Adult		For Child	
		LADD	ILCR	LADD	ILCR
GW1	0.116	$2.12 \text{ X } 10^{-4}$	$1.06 \text{ X } 10^{-4}$	$3.48 \text{ X } 10^{-6}$	$1.74 \text{ X } 10^{-6}$
GW2	0.11	$2.01 \text{ X } 10^{-4}$	$1 \text{ X } 10^{-4}$	$3.30 \text{ X } 10^{-6}$	$1.65 \text{ X } 10^{-6}$
GW3	0.038	$6.94 \text{ X } 10^{-5}$	$3.47 \text{ X } 10^{-5}$	$1.14 \text{ X } 10^{-6}$	$5.7 \text{ X } 10^{-6}$
GW4	0.09	$1.64 \text{ X } 10^{-4}$	$8.21 \text{ X } 10^{-5}$	$2.7 \text{ X } 10^{-6}$	$1.35 \text{ X } 10^{-6}$
GW5	0.16	$2.94 \text{ X } 10^{-7}$	$1.46 \text{ X } 10^{-4}$	$4.3 \text{ X } 10^{-6}$	$2.4 \text{ X } 10^{-6}$
GW6	0.08	$1.46 \text{ X } 10^{-4}$	$7.30 \text{ X } 10^{-5}$	$2.4 \text{ X } 10^{-6}$	$1.2 \text{ X } 10^{-6}$

4.5.2. Exposure through absorption through dermal effects:

Table 4.13 Calculation for different contaminants for GW1

Contaminant	C_{GW1}	For Adult		For Child	
		CDI	HQ	CDI	HQ
Iron	0.54	$8.70\text{X } 10^{-06}$	$1.24\text{X } 10^{-05}$	$1.43\text{X}10^{-04}$	$2.04\text{X}10^{-04}$
Chromium	0.116	$3.74\text{X } 10^{-06}$	$7.48\text{X } 10^{-04}$	$6.12\text{X}10^{-05}$	$1.22\text{X}10^{-02}$
Copper	*0.291*	$4.69\text{X } 10^{-06}$	$1.17\text{X } 10^{-04}$	$7.68\text{X}10^{-05}$	$3.84\text{X}10^{-03}$
Zinc	0.86	$8.31\text{X } 10^{-05}$	$2.77\text{X } 10^{-04}$	$1.36\text{X}10^{-03}$	$4.54\text{X}10^{-03}$
HI=∑HQ			$1.15\ \text{X}10^{-3}$		$2.08\text{X}10^{-2}$

Sample calculations:

i. $C.D.I = \frac{4*0.001*365*0.001*2000*0.58*0.54}{72*4*365}$

$= 8.70*10^{-5}$ mg/kg*day

ii. $H.Q = \frac{.0000870}{0.7} = 1.24*10^{-4}$

Table 4.14 Calculation for different contaminants for GW2

Contaminant	C_{GW2}	For Adult		For Child	
		CDI	**HQ**	**CDI**	**HQ**
Iron	0.66	$1.06X10^{-05}$	$1.52X10^{-05}$	$1.74X10^{-04}$	$2.49X10^{-04}$
Chromium	0.11	$3.54X\ 10^{-06}$	$7.09X10^{-04}$	$5.81X10^{-05}$	$1.16X10^{-02}$
Copper	*0.265*	$4.27X10^{-06}$	$1.07X10^{-04}$	$7.00X10^{-05}$	$3.50X10^{-03}$
Zinc	*N.D*	---	---	---	----
HI=∑HQ			$8.31\ X10^{-4}$		1.54E-02

Sample calculations:

i. $C.D.I = \frac{4*0.001*365*0.001*2000*0.58*0.66}{72*4*365}$

$= 1.06x10^{-05}$mg/kg*day

ii. $H.Q = \frac{.00000106}{0.7} = 1.52x\ 10^{-05}$

Table 4.15 Calculation for different contaminants for GW3

Contaminant	C_{GW3}	For Adult		For Child	
		CDI	HQ	CDI	HQ
Iron	0.34	$5.48X\ 10^{-06}$	$7.82X\ 10^{-06}$	$8.98X10^{-05}$	$1.28X10^{-04}$
Chromium	0.038	$1.22X\ 10^{-06}$	$2.45X\ 10^{-04}$	$2.01X10^{-05}$	$4.01X10^{-03}$
Copper	0.25	$4.03X\ 10^{-06}$	$1.01X\ 10^{-04}$	$6.60X10^{-05}$	$3.30X10^{-03}$
Zinc	0.36	$3.48X\ 10^{-05}$	$1.16X\ 10^{-04}$	$5.70X10^{-04}$	$1.90X10^{-03}$
HI=∑HQ			$4.69\ X10^{-4}$		$9.34\ X10^{-03}$

Sample calculations:

i. $C.D.I = \frac{4*0.001*365*0.001*2000*0.58*0.34}{72*4*365}$

$= 5.48x10^{-06}$mg/kg*day

ii. $H.Q = \frac{.00000548}{0.7} = 7.82x10^{-06}$

Table 4.16 Calculation for different contaminants for GW4

Contaminant	C_{GW4}	For Adult		For Child	
		CDI	HQ	CDI	HQ
Iron	0.1	$1.61X\ 10^{-06}$	$2.30X\ 10^{-06}$	$2.64X10^{-05}$	$3.77X10^{-05}$
Chromium	0.09	$2.90X\ 10^{-06}$	$5.80X\ 10^{-04}$	$4.75X10^{-05}$	$9.50X10^{-03}$
Copper	0.219	$3.53X\ 10^{-06}$	$8.82X\ 10^{-05}$	$5.78X10^{-05}$	$2.89X10^{-03}$
zinc	---	$6.00X\ 10^{-03}$	$1.61X\ 10^{-02}$	---	---
HI=∑HQ			$6.7\ X10^{-4}$		$1.24x10^{-2}$

Sample calculations:

i. $C.D.I = \frac{4*0.001*365*0.001*2000*0.58*0.10}{72*4*365}$

$= 1.61 \times 10^{-06}$ mg/kg*day

ii. $H.Q = \frac{.0000016}{0.7} = 2.30 \times 10^{-06}$

Table 4.17 Calculation for different contaminants for GW5

Contaminant	C_{GW5}	For Adult		For Child	
		CDI	HQ	CDI	HQ
Iron	0.09	$1.45X\ 10^{-06}$	$2.07X\ 10^{-06}$	$2.38X10^{-05}$	$3.39X10^{-05}$
Chromium	0.16	$5.16X\ 10^{-06}$	$1.03X\ 10^{-03}$	$8.45X10^{-05}$	$1.69X10^{-02}$
Copper	0.092	$1.48X\ 10^{-06}$	$3.71X\ 10^{-05}$	$2.43X10^{-05}$	$1.21X10^{-03}$
zinc	N.D	---	---	--	---
HI=∑HQ			$1.07\ X10^{-3}$		$1.81x10^{-2}$

Sample calculations:

i. $C.D.I = \frac{4*0.001*365*0.001*2000*0.58*0.09}{72*4*365}$

$= 1.45 \times 10^{-06}$ mg/kg*day

ii. $H.Q = \frac{.0000014}{0.7} = 2.07 \times 10^{-06}$

Table 4.18 Calculation for different contaminants for GW6

Contaminant	C_{GW6}	For Adult		For Child	
		CDI	HQ	CDI	HQ
Iron	0.07	$1.13X\ 10^{-06}$	$1.61X\ 10^{-06}$	$1.85X10^{-05}$	$2.64X10^{-05}$
Chromium	0.08	$2.58X\ 10^{-06}$	$5.16X\ 10^{-04}$	$4.22X10^{-05}$	$8.45X10^{-03}$
Copper	N.D	---	---	---	--
zinc	N.D	---	---	---	
HI=∑HQ			$5.17x10^{-4}$		$8.47x10^{-3}$

Sample calculations:

i. $$C.D.I = \frac{4*0.001*365*0.001*2000*0.58*0.07}{72*4*365}$$

$= 1.13\ x10^{-06}$ mg/kg*day

ii. $$H.Q = \frac{.0000011}{0.7} = 1.61X\ 10^{-06}$$

For carcinogens:

$$\mathbf{LADD} = \frac{\mathbf{IR * ED * EF * ET * CF * SA * Kp * C_{GW}}}{\mathbf{AT * BW}}$$

$$\mathbf{ILCR = \sum (S.F * LADD)}$$

Equations are being used and their corresponding values are:

Table 4.19 Calculations for carcinogenic

G_w location	Chromiuim	For Adult		For Child	
		LADD	ILCR	LADD	ILCR
GW1	0.116	2.13×10^{-7}	1.07×10^{-7}	3.97×10^{-4}	1.98×10^{-4}
GW2	0.11	2.02×10^{-7}	1.01×10^{-7}	3.76×10^{-4}	1.86×10^{-4}
GW3	0.038	6.9×10^{-8}	3.5×10^{-8}	1.30×10^{-4}	6.5×10^{-4}
GW4	0.09	1.6×10^{-7}	8.28×10^{-8}	3.80×10^{-4}	1.54×10^{-4}
GW5	0.16	2.94×10^{-7}	1.47×10^{-7}	5.47×10^{-4}	2.74×10^{-4}
GW6	0.08	1.47×10^{-7}	7.36×10^{-8}	2.74×10^{-4}	1.37×10^{-4}

CHAPTER 5. RESULT AND DISCUSSION

5.1 Leachate characteristics

Physico-chemical characteristics of the leachate depend primarily upon the waste composition and water content in total waste. The characteristics of the leachate samples collected from the Narela Bawana Municipal Solid Waste landfill site has been presented in Table 5.1.

Table 5.1 Characteristics of Leachate

Parameters	Units	Values
pH		8.40
EC	µS/cm	965
TDS	mg/l	26320
Cl	mg/l	4466.10
SO_4	mg/l	N.D
PO_4	mg/l	251.92
COD	mg/l	47600
BOD	mg/l	13094
Ca	mg/l	133.6
Na	mg/l	3532
K	mg/l	3218
Mg	mg/l	330.7
Fe	mg/l	23.26
Cr	mg/l	0.21
Cu	mg/l	3.52
Ni	mg/l	N.D
Zn	mg/l	1.096

From above results following inferences can be made:

The high value of pH is obtained for leachate sample, this indicates as the phase of decomposition of wastes characterized by the production of volatile fatty acids and carbon

dioxide (Kjeldsen et al., 2002). Value of EC which is observed as965µS/cm in given leachate sample reflects presence of anions or inorganic materials. The relatively high values of TDS of the order of 26320 mg/l was observed which indicates the presence of inorganic material in the samples. Value of BOD_5 in leachate was observed around 13094 mg/l which tends to indicate the maturity of the landfill and tells us that microbial activity in the decomposing leachate is yet to attain stability. As per Curi et al., 1994, the ratio of BOD_5/COD which comes out to be 0.275 indicates that this particular section of the landfill has attained maturity Value of Chloride observed was very high of 4466.10 mg/l. The presence of Phosphate (251.92 mg/l) in such a high concentration in leachate is dangerous anion as its presence in water promotes the growth of algae and correspondingly increases eutrophication.

The heavy metals content of the leachate samples obtained from the laboratory analysis include Zinc (Zn), Iron (Fe^2+), Copper (Cu), Chromium (Cr). Fe^{2+} has the highest concentration of all the heavy metals present in the leachate, followed by Cu, and then by Zn, and then in Cr, whereas the concentration levels of Ni went undetected. The high level of total iron (23.26 mg/l), in the leachate samples is evidence of dumping of iron and steel scraps wastes in the dumpsite, which is totally justified as there is a huge industrial area called as Bawana industrial area in the proximity of landfill. Concentration of Cur observed was 3.52 mg/l .Potential source of Cu is thought to have originated from the dumping of waste related to cement like bags in the dumpsite. On the other hand, the concentration of Zn which was around 1.096 mg/l was less than permissible limit. It depicts that dumping of batteries and fluorescent lamps in the landfill could be a possible source of it. The presence of Cr (0.21 mg/l) in the leachate samples may have originated from the emission of automobile exhaust of diesel tanker vehicles which use the vicinity of the dumpsite as a garage and other vehicle which ply the road that leads to oil refinery in the city. The different heavy metals detected is indication that the Narela- Bawana landfill site receives variety of wastes.

5.2 Physico-chemical characteristics of GW

The GW of the study area is used for domestic and agricultural purposes. The table 5.2 shows the concentration various parameters present in the groundwater samples from which the quality of groundwater can be understood, as it is compared with the acceptable limit of Bureau of Indian Standard.(B.I.S 1991) and W.H.O (WHO, 1997) standards

Table 5.2 Characteristics of GW in the vicinity of landfill

Parameters	Units	GW1	GW2	GW3	GW4	GW5	GW6	BIS Standards (Max. allowable Limit)	WHO Standards (Max allowable limit)
pH		8.93	6.37	7.47	5.15	5.77	6.04	6.5-8.5	9.2
EC	µS/cm	4583	4280	4440	4387	4620	3360	-	-
TDS	mg/l	2220	2160.67	2112.3	1542.96	1564.67	1685.33	2000	1500
Cl	mg/l	1585	1693.98	1108.74	1202.86	428.10	807.21	1000	600
SO_4	mg/l	73.91	96.89	186.4	112.4	84.7	73.42	400	400
PO_4	mg/l	0.572	0.44	0.256	0.10	0.34	0.62		
COD	mg/l	-	-	-	-	-	-	-	-
BOD	mg/l	-	-	-	-	-	-	-	-
Ca	mg/l	86.61	113.58	92.01	78.27	68.28	87.24	200	200
Na	mg/l	85.62	64.29	56.23	33.53	54.58	48.25	-	200
K	mg/l	28.67	18.66	15.93	14.91	13.86	9.47	-	200
Mg	mg/l	58.64	54.02	40.64	28.16	19.5	17.68	30	150
Fe	mg/l	0.542	0.660	0.342	0.101	0.090	0.070	0.3	0.3
Cr	mg/l	0.116	0.112	0.088	0.076	0.064	0.085	0.05	
Cu	mg/l	0.291	0.265	.250	0.219	0.092	N.D	1.5	
Ni	mg/l	N.D	N.D	N.D	N.D	N.D	N.D		
Zn	mg/l	0.861	N.D	0.363	N.D	N.D	N.D	5.0	5.0

Under normal circumstance there should be no variation in the concentration of the constituents of water. On the contrary variation in the ionic concentration of groundwater is expected in the direction of groundwater flow specifically nearby landfill site. The pH value for groundwater samples is slightly acidic to neutral in which the range is from 5.15 – 8.93. These values are exceeding the World Health Organization (WHO) limits and the B.I.S standards permissible limit for portable drinking water. The pH value of water has no obvious effects on

the consumers, but gives an indication that water is slightly acidic for GW-4 and GW-5 and was found basic for GW-1. The EC of water is reflection of the quantity of ionic constituents dissolved in it. The obtained EC ranges between 3360-4620 μS/cm for groundwater samples. The maximum value of 4620 μS/cm was measured for GW5; this value is higher than the recommended standard by WHO and B.I.S for potable water. Highest value was observed for GW1, which is a strong indication of contaminant through landfill site.

The concentration of TDS in water gives assistance in knowing the nature of quality or its salinity. The obtained concentrations of TDS in GW in the study area vary between 1542.96-2220mg/l. A high value of 2220 mg/l was measured for GW1, followed by GW2 with a value of 2160 mg/l and least value was observed of 1542.96 mg/l for GW4. According to WHO, 2004 high level of TDS may be responsible for reduction in the palatability of water, inflict gastro-intestinal inconveniences in human and may also cause laxative effect particularly upon transits. These TDS values tend to decrease with distance of groundwater wells from the refuse dumpsite, along groundwater flow paths in down gradient direction. In addition, the work of (Olaniya and Saxena et al (1977)) has established measurable high level of TDS concentration as an indication of contamination of groundwater near refused dumpsite.

The concentration of Ca^{2+} and Mg^{2+} ions in natural water influences its hardness, which is the ability of the water to form lather with soap. Total hardness actually reflects the total concentration of Ca^{2+} and Mg^{2+} in mg/l, equivalent $CaCO_3$. Source of calcium and magnesium can also be through weathering of underground rocks present. The value of Ca^{2+} ranged from 68.28 to 113.58 mg/l, the highest recorded value, is for GW2 and the least value for GW4. The concentration of Ca^{2+} is below permissible range of WHO, 2004 and BIS standards for potable groundwater, it has been known that consumption of water with very high concentration of Ca^{2+} may leads to concretion in kidney or bladder stone and also causes irritation in urinary passage (Mor et al., 2006). Magnesium concentration observed was between 17.68 to 58.64, highest at GW1, concentration at 1st, 2nd, 3rd location was more than BIS standard but were under WHO standards.

The concentrations of Cl^- were in the range of 1693.98 to 428.10 mg/l and significant proportion was found in GW2 and GW1 sampling location. High quantity of Chloride concentrations in water is indicator for pollution and as tracer for groundwater contamination (Loizidou and Kapetanois et al 1993). Domestic effluents, fertilizers, septic tank and natural sources such as rainfall and dissolution of fluid inclusion are some of the sources that may contribute to high Chloride concentration in groundwater and thus causing pollution, other than leaching from landfill. According to the WHO, 1997 high concentration of Cl- is detrimental to people with heart diseases and Kidney problem.

The value of Na^+ ions in the water samples varied from 85.62 to 33.53 mg/l. The highest value is associated with GW1 and lowest with GW4. Comparatively higher values were observed at GW5 that may have been due to geology of area or due to anthropogenic source .The consumption of water with high concentration of Na^+ ions is inimical to people with cardiac, renal and circulatory diseases (Mor et al, 2006). Testing of sample has demonstrated the presence of potassium in groundwater sample. The value of K+ in the groundwater samples varied from 28.67 to 9.4 mg/l, highest at GW1 and lowest being at GW6.

Phosphate was found to be present in minimal quantity of 0.62 to 0.1 mg/l, with GW6 having the maximum value of 0.62mg/l. source of it might the agricultural activities which being carried out in the area on small scale GW4 with a minimum value of 0.1. A minute value of phosphate as low as 0.01mg/l in groundwater may result in the water being slimy and also promotes the growth of algal (Adekunle et al, 2007).

The range of the concentration of sulphate in GW samples varied from 186.40mg/l to 73.42 mg/l and was significantly higher in GW3 than the other. High quantity of sulphate in water is dangerous as it causes dehydration and diarrhea in children than adults (Longe et al, 2010). The concentration of COD in water expresses the quantity of oxygen that is required by total matter both organic and inorganic matter, thus is a strong indicator of pollution in water. COD concentration was ND for GW in any location.

Among the heavy metals analyzed, Fe^{2+} has the maximum concentration of 0.66 mg/l. The obtained value for GW1 is evidently higher than the 0.3mg/l standard requirement for portable drinking water but GW4, GW5 and GW6 fall within the standard stipulated by the B.I.S and WHO standards. The colour of GW at all places were colorless this however conforms to (Rowe et al., 1995) findings, that a change in colour is often expected in groundwater which contains Fe^{2+}. Total chromium present, varied from 0.116 to 0.085 mg/l .and concentration in GW was above permissible limit at all locations, highest was observed at GW1. Heavy doses of chromium salts even though are rapidly eliminated from human body, could corrode the intestinal tract (WHO, 2004). There was minute concentrations of the following heavy metals were detected in the groundwater samples and are below the required standard for portable drinking water of B.I.S and WHO. This includes Cu with a concentration of 0.259mg/l and went undetected for GW6, at all location was well under limits. Consumption of high levels of copper can cause nausea, vomiting, diarrhea, gastric complaints and headaches. Long term exposure over many months and years can cause liver damage and death's was detected at only 1st and 3rdlocation of sample locations and was 0.861 and 0.363 mg/l respectively. These were in the minute concentrations and assumption has been made that they have come from the underground soil stratum. Nickel was ND at any GW locations nearby landfill, which is acceptable as there was no concentration achieved in leachate also.

The GW sample analysis result indicated the trend of reducing contaminant concentration at increasing radial distances away from the landfill site for all contaminants studied but variation of concentration is totally justified as the concerned area is confined by various industries of plastic, metals etc.

5.3 HHRA RESULTS:

From calculation done in the previous chapters, graphs were plotted for CDI values for different cases shown below:

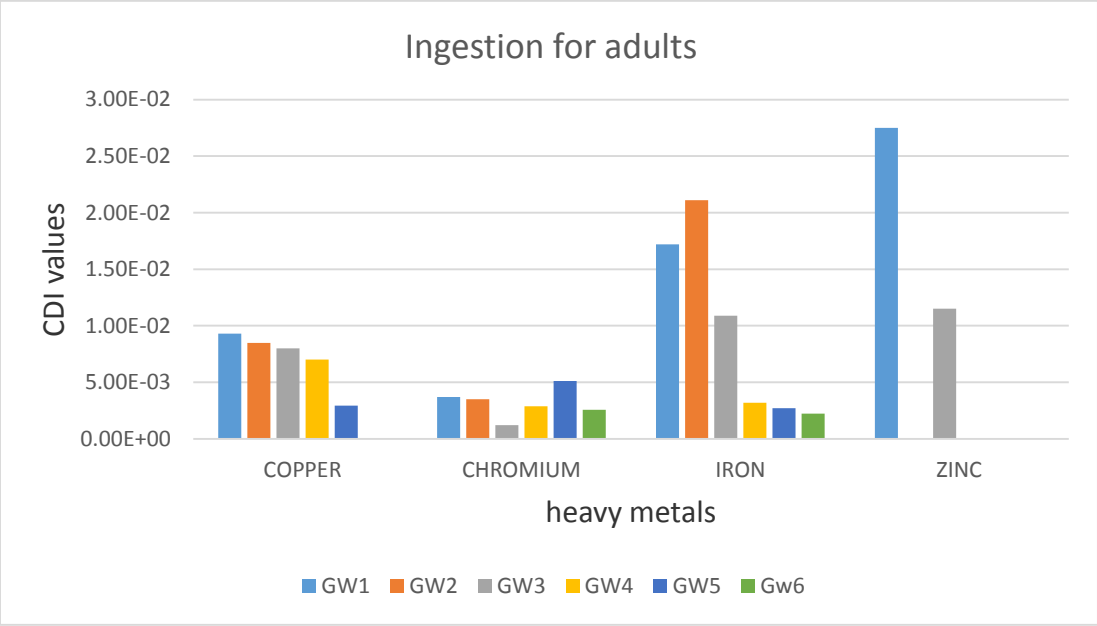


Figure 5.1 CDI values for adult in case of ingestion

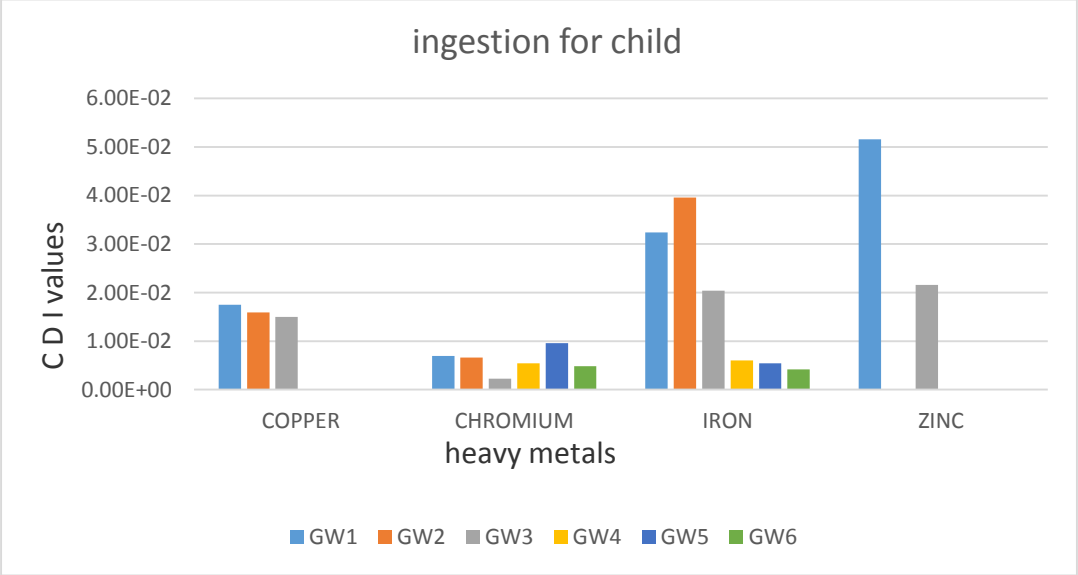


Figure 5.2 CDI values for child in case of ingestion

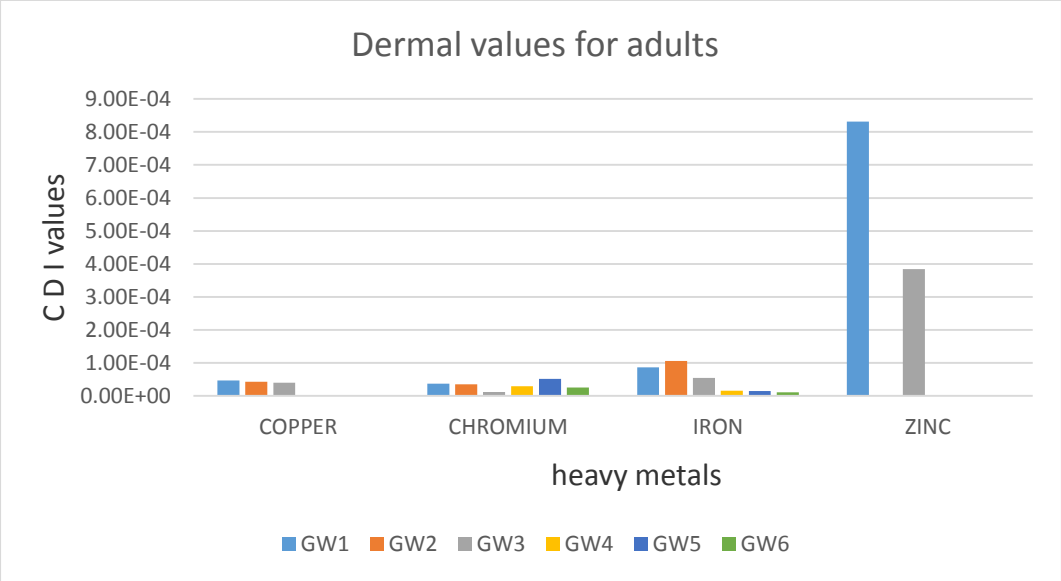


Figure 5.3 CDI values for adults in case of absorption by dermal route

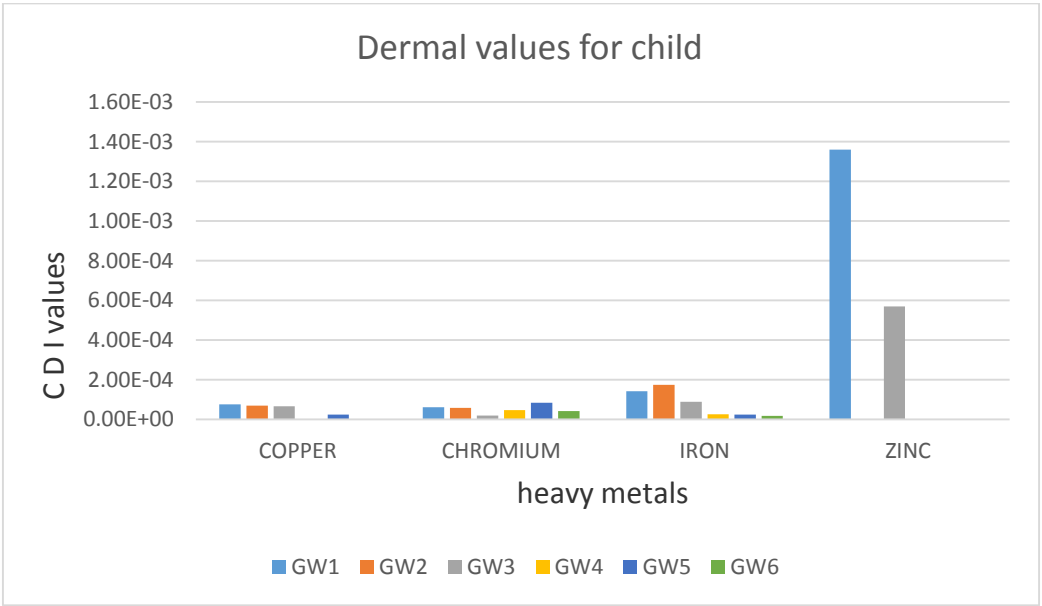


Figure 5.4 CDI values for child in case of absorption by dermal route

Based on the graphs following observations are made:

1. Risk related to ingestion of groundwater is more than risk related to absorption through dermal route.
2. CDI risk related to ingestion of groundwater by adult is highest in comparison to all other risk.
3. Chronic daily risk related to zinc is more than all other all other heavy metals, for GW-1 and GW-3 and for all locations risk related to iron then for copper and least for chromium was observed at all locations.
4. For absorption of toxicant through dermal route, have high risk for adult than risk related to child.

The risk estimates for high end scenario are summarized in Table 6.3. Figure and figure shows calculated HI values for each groundwater location, for both pathways i.e by ingestion of ground water assuming worst-case exposure conditions for both the hypothetical adult and child receptors

Table 5.3 Hazard index and cancer risk values

	Ingestion		**Dermal**	
	Adult	**Child**	**Adult**	**Child**
Hazard Index	$8.17x10^{-1}$	1.81	$7.85x10^{-4}$	$1.15x10^{-2}$
Cancer Risk(ILCR)	$9.03x10^{-5}$	$1.69x10^{-4}$	$9.11x10^{-8}$	$1.49x10^{-6}$

H.I value of groundwater ingestion for both the hypothetical adult and child receptors is 0.817 and 1.81 respectively. It should be noted that this value should be less than one, which is observed for adult but not for child thus it represents that risk for child by consumption of contaminated water and thus is expected to cause adverse health effects.

Figure 5.5 Total hazard index for each sampling location for ingestion.

Similarly H.I value of absorption of contaminates through dermal for both adult and child receptors is $7.85x10^{-4}$ (0.000785) and $1.15x10^{-2}$ (0.0115) respectively. Both values of risk are less than one, thus represents that even in worst-case exposure conditions, the predicted concentrations of various toxicant are lower than concentrations that would be statistically expected to cause various adverse health effects

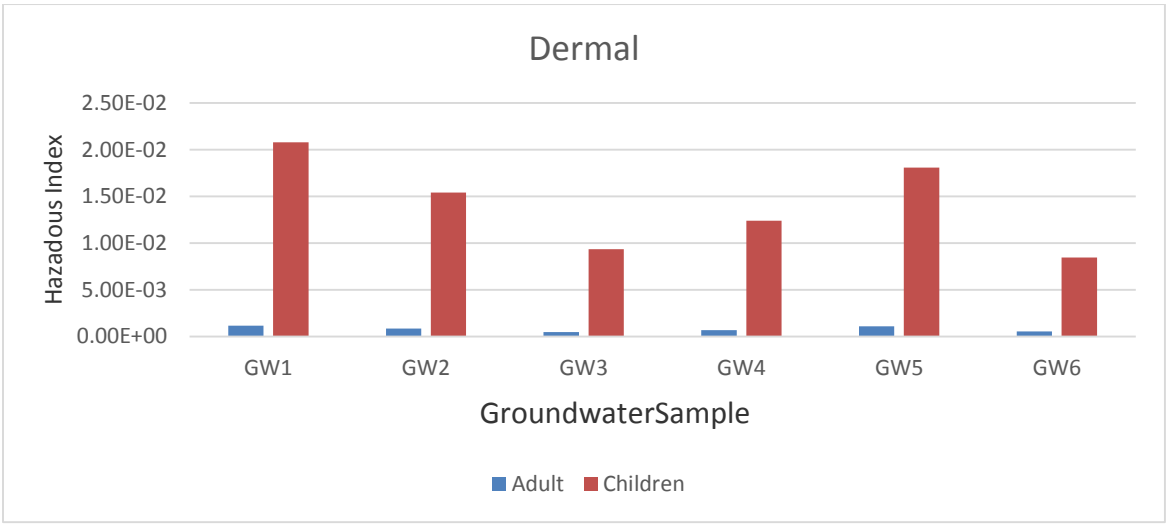


Figure 5.6 Total hazard index for each sampling location for dermal absorption.

It should be noted that for estimation of HI value only hazard quotient value of iron, copper, zinc were used as non- carcinogenic toxicity data (RFD) values of other contaminants like chlorine, calcium, magnesium, Sulphate etc is not being evaluated by USEPA instead SMCL (secondary maximum contaminant level) are being estimated which represents the adversity with contaminant affects taste, odour or appearance of water and leads to decrease of its usage by substantial amount of population.

Theoretical cancer risks by ingestion of contaminant through groundwater for assumed exposure conditions for both hypothetical adult and child receptors is given as $9.03x10^{-5}$ and $1.69\ x10^{-4}$ respectively. This indicates that, the additional risk of cancer attributable to cumulative exposure to the predicted contaminants in water are approximately 10 in 100,000 and 2in 100,00 for the adult and child receptors, respectively. The USEPA (1989) regards cancer risks ranging between 1 in 10 million (i.e., 10^{-7}) and 100 in 1 million (i.e., 10^{-4}) as within the range of acceptable risk, thus observed value for adult can said to be in acceptable range but for child receptor population results demonstrate that there is the potential for carcinogenic risk from groundwater consumption at this site. ILCR values for the case of dermal absorption was estimated to be $9.11\ x10^{-8}$ and$1.49\ x10^{-6}$ thus representing approximately 1 in 1 million adult would be affected and 2 in 1 million for children .which is under permissible limits, thus it is safe to use groundwater for showering, bathing purpose.

Variability and uncertainty in exposure and risk assessments

Essentially Variability and uncertainty in the health risk assessments of human arise from natural variability in exposure characteristics among the receptor populations, as well as lack of full knowledge regarding important factors that affect the risk estimates. Uncertainty represents a lack of knowledge, uncertainty regarding some of the data and assumptions used in the analysis implies that exposures will probably be underestimated or overestimated for individual members of the receptor population, whereas variability arises from true heterogeneity in receptor population will likely be subject to exposures both above and below the exposure levels selected as reference values for use in risk assessment for variable places or time. In other words, uncertainty can lead to inaccurate or biased estimates, whereas variability can affect the precision of the estimates and the degree to which they can be generalized. On the other hand, representing

a range of risk estimates rather than single-point values helps to communicate the potential consequences of variability and uncertainty as described herein. Other measures that were adopted to address variability were disaggregating and hence minimizing variability by performing the risk assessment separately for the child and adult populations with the use of appropriate exposure characteristics for each population category and use of a statistically reliable worst case scenario value for the exposure point concentration.

CHAPTER 6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Study was focused on testing leachate and groundwater samples and then calculating human risk through different receptors. Thus following conclusions were drawn from the present study:

1. The study primarily indicated that Narela-Bawana landfill cumulatively generates significant amount of leachate which contains higher concentration of heavy metals and other cations. The groundwater samples around all these landfills is also contaminated having heavy metals and other cations and anions more than recommended by BIS and WHO standard for drinking water. The spatial, distributions of all these heavy metals indicate possible leaching of contaminant from landfill.

2. The analyzed groundwater samples obtained from the vicinity of the landfill dump site did not evidently reflect water quality that is affected by the leachates collected from the refuse landfill site. Nevertheless the elevated values of EC, TDS, chloride, iron, copper and chromium obtained, strongly depict the influence of leachates on the groundwater quality and may pose serious threat to groundwater quality in the distant future.

3. The groundwater sample analysis result clearly indicated that the trend of reducing contaminant concentration at increasing radial distances away from the landfill site for all contaminates studied.

4. There is no single strategy that can be forwarded to address all public health concerns related to a landfill. The selection of study approach for a landfill, and its level of refinement, depends on a number of factors, including site-specific landfill conditions, the public health concerns raised by a local community, and the likelihood that a study method will be able to scientifically address the community's concern.

5. From this study we can conclude that there is an increase in toxicity and cancer risk in consuming ground water by child but adult were found to be safe reported near Narela-Bawana landfill area. Although biases and confounding factors cannot be excluded as explanations for this finding, the finding revealed that high risks are associated with groundwater pollution and public health.

6.2. Recommendations

1. Proper management of MSW landfill should be practiced so that a clean, odour free, nuisance free atmosphere can be provided for population living nearby landfill site.

2. People living around the landfill should be educated about possible consequences of using contaminated water.

3. Delhi government and Delhi Jal Board (DJB) should be more cautious in supplying ground water to public from their drinking water needs and should take all necessary precautions.

4. It is being said that concerned landfill is lined properly, chances of leakage of leachate are minimal but proper cleanup or corrective measures should be taken if hazardous waste leaks from a facility.

5. Recycling, reuse of heavy-metals associated in waste which is an effective means of controlling heavy metals in leachate should be practiced which would significantly lessen the potential public health and environmental risk associated with heavy metals in MSW leachate

6.3. Scope of future work

The work carried out in this can be extended as under:

1. Application of contaminated transport Ground water model can be done to determine the amount of contaminant migrating from landfill site and polluting ground water.

2. Testing of soil in the vicinity of landfill for various contaminants, so that human health risk associated with direct contact with soil can be assessed.

3. Application of various software based model like HELP and CHRONO for assessment of landfill performance

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ANNEXURE:A

Parameters	Leachate sample 1	Leachate sample 2	Leachate sample 3	Average value
TDS	27301	28790	22869	26320
Electrical conductivity	1107	872	916	965
pH	8.1	9.2	8.7	8.4
Chloride	4603	4687.5	4107.8	4466.1
Calcium	127.4	156.8	116.6	133.6
Magnesium	320	355.2	316.9	330.7
Phosphate	293.31	234.86	227.59	251.92
Sodium	2558	3982	4056	3532
Potassium	2428	3567	3659	3218
COD	48100	45800	48900	47600
BOD	13227	8970	17085	13094
Iron	23.58	24.56	21.64	23.26
Copper	3.52	1.840	2.967	3.52
Chromium	0.3097	0.1878	0.1250	0.2075
Zinc	1.523	0.998	0.7670	1.096

ANNEXURE B

In general a summary is given of potential health and other effect of contaminants:

Contaminant	**Potential health & Other effects**
Arsenic	Causes acute & Chronic toxicity, liver & kidney damage, decreases blood hemoglobin, Possible carcinogen.
Chloride	Deteriorates plumbing, water heaters and municipal water works equipment at high levels. Above secondary maximum contaminant level & taste becomes noticeable.
Chromium	It causes liver & Kidney damage, hemorrhaging, respiratory damage, dermatitis and ulcers on the skin at high concentrations.
Copper	Can cause stomach and intestinal distress, liver and kidney damage, anemia in high dose, toxic to plants, imparts adverse taste.
Cyanide	Poisoning is the result of damage to spleen, brain and liver.
Dissolved Solids	May have influence on the acceptability of water in general. Drinking Act-which would make water objectionable. High concentration of DS may shorten the life of water heaters.
Hardness	Decreases the lather formation of soap and increases scale formation in hot water heaters and low pressure boilers at high level.
Iron	Imparts a bitter astringent taste to water and a brownish color to laundered clothing and plumbing fixtures.
Lead	Affects red blood cell chemistry, delays mental, physical and normal development in babies and young children. Causes slight deficit in attention span, hearing and learning in children.
Manganese	Causes aesthetic and economic damage and imparts brownish stains to laundry. Affects taste of water and causes dark brown or black stains on plumbing fixtures. Toxic to plants at high levels.
Mercury	Causes acute and chronic toxicity. Targets the kidney and can cause nervous system disorder.
Nickel	Damages the heart and liver of laboratory animals exposed to large amounts over their lifetime.
Nitrate (Nitrogen)	Causes blue baby diseases or methemoglobinemia-which threatens oxygen carrying capacity of the blood.

Contaminant	Potential health & Other effects
Nitrite (combined nitrate/nitrite)	Causes blue baby diseases or methemoglobinemia-which threatens oxygen carrying capacity of the blood.
Sodium	Can be a health risk factor for those individuals on a low sodium diet.
Sulfate	Forms hard scales on boilers and heat exchangers, can change the taste of water and has a laxative effect in high doses.
Zinc	Use in the healing of wounds. Causes no health effects. Imparts an undesirable taste to water. Toxic to plants at high level.
Volatile Organic Compounds	Can cause cancer and liver damage, anemia, gastrointestinal disorder, skin irritation, blurred vision, exhaustion, weight loss, damage to the nervous system and respiratory tract irritation.
Pesticides	Cause poisoning, headaches, dizziness, gastrointestinal disorders, numbness, weakness, cancer. Destroys nervous system, thyroid, reproductive system, liver and kidneys.

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ANNEXURE C

PICTURES DURING LAB WORK