A report on

“Impact of solid waste disposal on groundwater quality at landfill site, Ghazipur, Delhi, India”

submitted in the partial fulfilment of the requirement for the award of degree of

MASTER OF TECHNOLOGY

(Environmental Engineering)

by

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(2K14/ENE/18)

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*This is to certify that Mr. SWAPNANIL KAPOOR, M. Tech, student in the Department of Environmental Engineering has submitted a project report on "**IMPACT OF SOLID WASTE DISPOSAL ON GROUNDWATER QUALITY AT LANDFILL SITE, GHAZIPUR, DELHI, INDIA**" in partial fulfillment of the requirement for award of degree of Master of Technology in Environmental Engineering, Delhi Technological University (formerly Delhi College of Engineering), Delhi, during the academic year 2015-16, is an authentic record. It is a record of the student's research work prepared under my supervision and guidance and has reached the requisite standards.*

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Abstract

The study in this report presents the results of the evaluation that has been performed on the analysis of various groundwater parameters, samples being taken from select observation points in close proximity of the Ghazipur landfill site in Delhi, India, over a period of one year mainly in the three seasons - rainy (August-September, 2015), winter (December-January, 2015) and summer (April-May, 2016). A total of thirty samples were taken, ten samples from different sites in each season during the year 2015-16. One sample included leachate sample which was taken during the summer season due to high concentration of contaminants obtained. The various physico-chemical parameters that have been looked into are pH, EC, TDS, DO, Cl^- levels and heavy metals such as Zn, Cd, Pb, Ni, Fe and Cr, which were compared with the standard values prescribed by APHA, WHO and BIS. The result shows contamination of groundwater in some of the surrounding areas of the landfill. DO and pH level were in the normal ranges in almost all sample sites whereas in some TDS, EC and Cl^- were above the desirable limit. Cd, Ni and Fe concentration levels were also found higher in some observations. Hence, the groundwater is unfit for drinking and utility purpose.

Keywords: ***Physico-chemical parameters, Ghazipur landfill, Groundwater, Heavy metals, Leachate.***

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List of Symbols, Abbreviations and Nomenclature

MSW	Municipal Solid Waste
USA	United States of America
NCT	National Capital Territory
TDS	Total Dissolved Solids
GPS	Global Positioning System
Fe	Iron
Ni	Nickel
Mn	Manganese
Cu	Copper
Zn	Zinc
Pb	Lead
Cd	Cadmium
Cr	Chromium
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
pH	Acidity
TSS	Total Suspended Solids
MPN	Most Probable Number
TA	Total Alkalinity
TH	Total Hardness
Cl^-	Chloride
EC	Electrical Condutance
BIS	Bureau of Indian Standards
APHA	American Public Health Association
WHO	World Health Organisation
ICMR	Indian Council of Medical Research
Cal. Hard	Calcium Hardness
Alk	Alkalinity
CO_2	Carbon di oxide
Na	Sodium
K	Potassium

SO_4^{2-}	Sulphate
NO_3^-	Nitrate
mm	millimetres
m	meters
Km	Kilometers
Mo-HP	Motor-operated Hand Pump
ml	millilitres
mg/l	milligram per litre
µS/cm	micro Siemens per centimetre
^0C	degree centigrade
AAS	Atomic Absorption Spectrometer
Ga	Ghazipur Site
RCRA	Resource Conservation and Recovery Act
DJB	Delhi Jal Board
DDT	Dichloro Diphenyl Trichloroethane
CGWB	Central Ground Water Board
CPCB	Central Pollution Control Board

Contents

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

This chapter is about the introduction to groundwater contamination through solid wastes, their quantification, objectives of the study and organisation of report. It tells us about the solid wastes, their various types and the impact that they produce to a healthy lifestyle. Also, a mention of groundwater quantification has been discussed. The various trends of population in Delhi, usage of groundwater resources and its contamination is looked briefly upon. Further the objectives of the study are also mentioned.

1.1 Solid waste

Solid wastes are the total wastes arising from human and animal activities that are normally solid and hence are useless or unwanted. It encompasses the heterogeneous mass of throw away from houses of commercial centres as well as the nearby homogeneous accommodation of a single industrial activity. Refuse represents the dry wastes of the society. The term 'refuse' is often used interchangeably with term solid wastes. The density of Indian refuse is generally higher than that of developed countries and hence the Indian refuse can be carried efficiently and effectively by mechanical transport (carrying more weight for the same volume). The major categories of solid waste generation are:

1. Municipal wastes
2. Industrial wastes
3. Hazardous wastes

Municipal wastes are the solid wastes generated from different zones of the city differ in characteristics. These solid wastes comprise refuse, ordinary refuse (includes garbage and rubbish) and trash. Refuse, refers to non hazardous solid waste from the community requiring collection and transporting to processing/disposal site. Garbage comprises of items that are highly decomposable (putrescible) food, waste vegetables and meat scarps. Rubbish contains mostly dry, non decomposable (non putrescible) material – glass, rubber, tin cans, also, or combustible material – paper, textiles, wooden articles, etc. Hence, community refuse can be referred to as municipal solid waste (MSW).

Industrial wastes are generated from the industrial activities or manufacturing processes. All the three types of wastes – solid, liquid and gaseous are generated. Industrial wastes can be categorised as hazardous and non hazardous. It is well known that hazardous have a potential for very deleterious impact on environment and life in general. Some of the common industries which generate solid waste along with other wastes on a large scale are:

(i) Paper and pulp

(ii) Metallurgical industries

(iii) Pesticides/Insecticides

(iv) Fertilizers

(v) Plastics

(vi) Refineries.

Hazardous wastes can be defined as anything which because of its concentration, quantity or characteristics may contribute to increased mortality, illness or hazard to human health and environment if not properly stored and transported or disposed off. The hazardous waste is one which posses any one of the characteristics, such as, ignitability, corrosivity, reactivity or toxicity [1]. Hazardous wastes differ in form as well as behaviour from ordinary solid wastes. They generally are produced in liquid form; however, they can also occur as solids, sludge, or gases. They are infectious and radioactive. Some of the common industries which generate hazardous wastes are:

(i) Ferrous, non ferrous industries

(ii) Foundries

(iii) Fertilizer industries

(iv) Cement industries

(v) Petroleum industries

(vi) Chemical industries.

The classification of refuse can be done in two ways: (i) Based on source (ii) Based on type of wastes. Refuse can be classified depending on its *source* as house refuse, street refuse and trade refuse. Refuse based on *type of wastes* are garbage, ashes and rubbish. Garbage includes all sorts of putrescible organic wastes obtained from kitchen, hospitals, restaurants, like waste food articles, vegetable peelings, fruit peelings, etc. These wastes are organic in nature, and hence, likely to decompose quickly, producing foul odours and health hazards. They may also result in breeding of flies, mosquitoes, insects, etc. Hence, garbage must be disposed of, properly and quickly when it is scientifically processed and composted then we may obtain some valuable products like grease, fertiliser, etc. from garbage. Ashes are the incombustible waste products from hearths and furnaces, and houses or industries. Rubbish includes all non putrescible wastes except ashes. All combustible wastes, such as rags, paper pieces, broken pieces of glass and furniture, card-boards, broken crockery comes under.

1.1.1 Methods of solid waste collection and disposal

Regular *collection* and transport of solid wastes are the most important operations in any efficient solid waste management which costs about 80 per cent of total cost of solid waste management. In India, refuse is generally collected in individual houses in small containers from there it is collected by sweepers in small hand driven lorries/carts and then dumped into community storage bins made by municipalities placed at intervals of 50-200 meters depending on the layout of street and density of population. The wastes from community storage bins are collected by transport vehicles daily for final disposal to landfill sites or treatment. Combined collection of garbage or rubbish is more economical. However, methods adopted in our country are not satisfactory and needs further improvements and changes. Landfilling is the most commonly used method of *disposal* for municipal wastes. Disposal on or inside the earth is the only feasible method for the long term handling of solid wastes that are collected and are of no further use, residual matter remaining after solid wastes have been processed and residual matter after recovery of conversion products and/or energy has been accomplished. The disposal of refuse is being done in this site since 1984, as the site then was a low lying dump away from the city of Delhi. But over the period of years as the city expanded so did the population which settled near the vicinity of the landfill. The method of disposal at this site is not at all eco-friendly and is contaminating the whole environment since its inception. This is highly unacceptable as it gives un-slightly nuisances, obnoxious smells and is a breeding place for flies and mosquitoes. Moreover, the Ghazipur landfill site is a non-engineered site i.e., no lining of the site is being done which increases the risk of leachate percolation [2].

1.2 Groundwater quantification and solid waste

Groundwater is one of the best resources of drinking water because it consists of minerals in it which has been found suitable for human consumption. The infiltration of harmful compounds to the ground water arises due to the excess burden of the population pressure, unplanned urbanization, unrestricted exploration policies and dumping of the polluted water in an inappropriate place. Some authors have studied regarding ground water quality analysis. According to them the primary causes of the deterioration of ground water quality are high rate of exploration then its recharging, inappropriate dumping of solid as well as liquid wastes, lack of strict enforcement of law and loose governance [3-7]. Municipal Corporation of Ghazipur makes easy the drinking water in a limited area. The people using hand pumps, jet pumps, wells etc. from last few decades has been deteriorating as these alternative options seemed to be turned yellowish. So, the people of these areas use Chlorine tablets for disinfecting of drinking water. To asses quality of drinking water in Ghazipur city near the landfill site is the main objective of this work. Various types of non-hazardous wastes from different sources such as household, business, restraints, medical facilities and schools are being dumped into the MSW landfill. Contaminated soils from gasoline spills are also accepted by the MSW landfill, conditionally exempted hazardous, and other toxic wastes. For the disposal of non-hazardous waste for the process of industrial facilities, such as sludge from paper mills and wood waste from wood processing facilities, it may utilize its own captive landfill. India irrigates about 39 million hectares of land through ground water irrigation. It is the largest user of ground water followed by China and USA. Over the last few decades rapid development in the water resource sector has been taking place in the country which has resulted various undesirable environmental impacts. Due to various reasons, the sustainability of ground water is hampered. There are various concerns and questions regarding groundwater resources mainly [8-9]:

1. Depletion of groundwater levels.
2. Reduction of resources.
3. Potential loss of groundwater dependent eco-systems.
4. Land subsidence and changes in groundwater quality.

In the Indian Political Federalism, Delhi and NCT Delhi holds a specific status. This territory consists of a pseudo-state status, which is under the mixed control of the local government similar to other state government. Over a total area of 1483 km^2, National Capital Territory is spread about, of which 65% of the area is urban [10]. Due to the Indian constitution, this political situation has a direct impact on the city's access to water resources. The management of the water resources is being controlled directly by the state National Capital Territory of Delhi consists of a population of around 16.8 million people. Therefore it directly controls a very few resources. In short, it is a necessity to protect our ground water resource from being contaminated by leaching of pollution. In recent years the dependence of ground water resource has been increasing tremendously in many parts of India especially in the arid and semi-arid regions due to the vagaries of monsoons and scarcity of surface water. As studied from the International Standard availability of water "less than 1,700 m^3/person/year" qualifies as water stressed and "1,000 m^3/person/year" as water scarce. By 2050, India is likely to face severe water scarcity as a study says that India is today a water-stressed [11]. Thus a detailed study of ground water quality in Delhi NCT and its surrounding areas is needed today.

One of the major threats of the ground water resources is the landfill [12]. Precipitation causes infiltration and ground water underflow of the waste which are placed in open dump or landfill. Interstitial water is gradually released by the solid wastes. Some of the decomposition by- products of the dumped solid wastes gets into the water and through the waste deposit. The liquids containing such innumerable organic and inorganic compound are called leachate. These leachate are accumulated at the bottom of the landfill and filtered through the soil. The areas near landfill have a greater possibility of ground water contamination. The reason behind this contamination is due to the potential pollution source of leachate originating from the nearby site. A substantial risk is posed to the local resource user and to the environment due to the contamination of the ground water resource. At an unlined landfill site at Ghazipur, Delhi, the impact of leachate percolation on ground water quality was estimated. In order to understand possible link of ground water contamination various physico-chemical parameters were analysed in ground water samples. Some remedy measures were discussed to reduce the contamination of ground water in future.

1.3 Objectives of the study

The study has been completed on the analysis of various groundwater parameters, samples being taken from select observation points near Ghazipur landfill site in Delhi, over a period of one year mainly in the three seasons - summer (April-May, 2016), rainy (August-September, 2015) and winter (December-January, 2015). The aims and objectives of the study are as follows:

- To select the observation points near the landfill site from where the groundwater samples are collected.
- To analyse the sample collected from selected points by standard methods.
- To study the present concentration levels of pH, DO, TDS, EC, Cl^-, Fe, Ni, Cr, Pb, Cd and Zn in groundwater near the close proximity of Ghazipur landfill site throughout the year in three different seasons, namely rainy, winter and summer.
- To find out the effect of change in groundwater quality with respect to distance from landfill.
- To find out the effect of change in groundwater quality with respect to seasons.

Chapter 2

Literature Review

CHAPTER 2

LITERATURE REVIEW

This chapter deals with the literature review. The various studies conducted as per solid wastes effect on groundwater analysis are being presented and various quantifications of the facts is being mentioned. Further, a very introspective studies carried out earlier on the Ghazipur site is being reported. Observations from various research papers are being presented thoroughly with their respective concentration level of different contaminants.

2.1 Impact on groundwater resources due to solid wastes

From the year 2004 to 2007, systematic sampling and analysis of ground water have been carried out in all three major landfills in Delhi. The three landfills (Bhalsawa, Okhla and Ghazipur) cover an area of 28 square kilometres each. Among all the three landfills, mostly the groundwater samples are colourless, odourless and alkaline in nature. An example of groundwater samples Bhalsawa is light yellowish with salty taste. Around Bhalsawa landfill there are few groundwater samples which have high value of TDS of 1020mg/1 and EC upto 2041 mg/l**.** Because of the high concentration of heavy metals in ground water through leaching contaminants from landfill, the Bhalsawa landfill are slightly acidic in nature (pH<6.0) whereas most of the samples around all the three landfill are basic in nature (pH>6.0). During monsoon due to dilution of groundwater in various proportions, seasonal variations generally occur. Almost all the groundwater samples have high concentration of chloride, fluoride, nitrate and sulphate. But there are some exceptions in groundwater samples collected from Narendra Dev College, Govindpuri and Nehru Place because these areas are far away from Okhla landfill sites. Around all the three landfills there has been found high concentration of heavy metals and other cautions. Due to variation in geology, soil and depth of water table around all the three landfill, the Bhalsawa landfill has more contamination than Okhla and Ghazipur. Bhalsawa landfill contains Fe (>20mg/1), Ni (3mg/1), Mn (<20mg/1), Cu (<10mg/1), Zn (10mg/1) and Pb (<2mg/1) which is higher than the values recommended by Central Pollution Control Board and world organizations [11] [13-17].

A comparative study of landfills of Ghazipur and Okhla are far better than the Bhalsawa landfill. These variations are due to the differences between quality and amount of dumping material. Thus the result indicates that these working landfills are used a lot. Thus it can be assumed by the spatial variations of heavy metal that the landfill is the major point source of contaminant in that area. Physico-chemical analysis of ground water sampling of Ghazipur city had been carried out [18-19]. In this study, different parameters like pH, TDS, COD, DO, etc have been analyzed. That water is nearly suitable for drinking purpose has been demonstrated. Physio-chemical analysis of surface and ground water of Bargarh district, Orissa, India had been carried out [20]. The two types of ground water viz., dug well and borewell water of 10 wards of the town and 3 types of pond namely - small community pond, large community pond and temple pond of the town is being monitored by present work. Various parameters have been found such as- temperature, pH, TDS, TSS, alkalinity, COD, DO, Chloride, nitrate, sodium, potassium, fluoride, phosphate and total coliform. That the water is below the pollution control level for ground water can be concluded by a brief study of the result. But in small community pond the surface water quality is above the permissible limit.

Physio-chemical and microbiological analysis of underground water in V.V Nagar and nearby places of Anand District, Gujarat, India had been carried out [21]. In this study various parameters like- pH, TDS, hardness, conductivity, dissolved oxygen and chemical oxygen demand, MPN have been analyzed. As per physio-chemical analysis it had been concluded that the water samples were acceptable and as bacteriological standard before using it in domestic purposes, the water needs to be treated. An assessment of physio-chemical status of ground water samples in Akot city had been carried out [22]. Various parameters like temperature, pH, TDS, turbidity, DO, TA, TH, Na, K, Cl^-, NO_3^-, SO_4^{2-}, phosphate, fluoride, calcium and magnesium of open well and bore well has been determined. At few sites the ground water was contaminated and at other sites the water quality standard is good and fit for drinking. From some places Ghazipur landfill and its adjacent areas, the ground water samples were collected in order to study the possible impact of leachate percolation on ground water quality. From ground water samples, the concentration of various physio-chemical parameters are determined. That the ground water is significantly affected by leachate percolation is the indication of the moderately high concentration of Cl^-, EC and TDS in ground water. The groundwater contamination through leachate percolation can be checked by some remedial measures; however the present study demands for some effective management of waste in Delhi.

The objective of this work is to assess the quality of drinking water in Ghazipur city. Three detailed literature reviews has been proposed as per selected site Ghazipur. Groundwater samples were collected from Ghazipur landfill site and its adjacent area to study the possible impact of leachate percolation on groundwater quality. Although some remedial measures are suggested to reduce further groundwater contamination via leachate percolation, the present study demands for the proper management of waste in Delhi.

2.2 Quantification

The impact of solid waste disposal on ground water quality near Ghazipur dumping site, Delhi and concluded that due to the Ghazipur municipal dumping, Delhi was found prone to the ground water contamination through leaching action. The present study was conducted around Ghazipur municipal dumping site at Delhi. The selected experimental area of Ghazipur landfill site started in the year 1984 and still in use. The ground water samples were collected from different 16 sampling sites randomly distributed near Ghazipur dumping site, Delhi, India. The water samples were collected from various sampling sites in plastic containers and sampling bottles. All samples were brought to the laboratory and then analyzed for various physico-chemical parameters viz. conductivity, TDS, alkalinity, total hardness, calcium, magnesium, chloride, sulphate, nitrate, phosphate, fluoride, sodium and potassium by following standard methods [23]. The pH of different areas around dumping sites was ranged 6.42 - 7.76, which were within the desirable limit of BIS. The Electrical Conductivity around the study site of Ghazipur was found to be in range between of 1220 µS/cm – 2945 µS/cm. TDS of Ghazipur area ranged from 840 mg/l to 2061 mg/l. The very high EC and TDS observed in the groundwater suggest a downward transfer of leachate into groundwater as reported earlier [24-25].

Physico-chemical analysis of ground water of selected area of Ghazipur city has been done. In their study they have analyzed different parameters like pH, TDS, DO, COD and other parameters. A comparison with various standards shows that the water is nearly suitable for drinking purpose. The experiment was conducted at department of Environmental Science, P. G. College, Ghazipur. This is suburban area and district headquarter, located in the eastern Gangetic plain of the Indian sub continent at 25º19`and 25º54`N latitude, 83º4`and 83º58`E longitude and 67.50 m above the sea level. pH was measured with the help of pH meter (Model number - 101 E) of Electronic India , standardized with pH buffer 4,7 and 9.2. TDS was estimated by evaporation method at 180ºC, Alkalinity, Hardness D.O., Chloride, CO_2 and all parameters were analyzed. The elemental analysis was carried out by digital flame photometer. The data were subjected to one way ANOVA analysis of variance using SPSS version 10 software Ducan’s multiple range test performed to test the significance difference among the treatments. The value of pH ranges among 6.8 to 8.3. It is in the prescribed limit. A little bit increase in pH level may depress the effectiveness of the disinfectants like chlorination thereby requiring the additional chlorines. The value of total dissolved solid ranges from 145-245 mg/l all the values of total dissolved solid is in the prescribed limit. Dissolved Oxygen ranges from 3.4-5 mg/l, D.O. indicating the nearly pure symptoms. Chloride content is 78-106 mg/l, chloride content is also in the limit. The following were the results obtained:

TABLE 2.1. PHYSICO-CHEMICAL PARAMETERS OF SAMPLES OF RESPECTIVE SITES [14].

Parameters	**S1**	**S2**	**S3**	**S4**	**S5**	**ICMR**
pH	7.4±.00	7.2±.00	6.8±.12	8±.11	8.3±.00	7.0-8.5
T.D.S.	200±6.5	175±2.5	145±2.8	225±2.8	245±7.6	500
T.H.	256±.1	235±.11	240±4.04	266±1.15	304±3.05	300
Cal. Hard.	108±.11	99±.7	106±2.3	140±.35	158±3.05	-
D.O.	3.4±.005	4.1±.006	3.6±.00	4±.00	5±.00	4-6
Cl	78±.30	100±1.5	83±1.1	91±.57	106±.17	200
Alk.	120±.10	140±7.5	110±5.77	140±.17	149±1.7	200
CO_2	7.42±.009	7.84±.003	7.92±.002	7.02±.002	7.67±.00	-
Na	23±.17	28±.005	25±.00	42±6.7	46±2.3	-
K	4±.00	4±.00	6±.00	8±.00	10±.00	75

Different letters in each group shows significant difference at P<0.05 levels. **S1**-Rauza, **S2**-Aam Ghat, **S3**-Vishweshwar Ganj, **S4**-Shastri nagar, **S5**-Gora bazaar

Leachate Characterization and assessment of groundwater pollution near municipal solid waste landfill site showed moderately high concentration of EC, TDS, Cl^-, SO_4^{2-}, NO_3^-, Na^+ and Fe etc. in groundwater near landfill deteriorates its quality for drinking and other domestic purposes. The present study was conducted around Ghazipur municipal dumping site at Delhi. The selected experimental area of Ghazipur landfill site started in the year 1984 and still in use. In an effort to study the extent of the groundwater contamination 12 sampling sites were selected within 1.5 km of landfill site from where the samples were taken. The samples collected were 5 after the extraction of water either from hand pump or from tube well in September 2003. The water was left to run from the source for about 4 minutes to equate the minimum number of well volume and to stabilize the electrical conductivity (EC). Since the landfill site was not equipped with a leachate collector, the leachate collected at the base of the landfill was sampled randomly from three different locations and were mixed prior to its analysis. The samples were store in cold room (4ºC). To analyze the parameters as prescribed.

EC and pH were recorded using a Systronics conductivity meter, Mode 306 and µ pH system 361 (Systronics). Cl^- was estimated by titrimetry. All the experiments were carried out in triplicate and the results were found reproducible within ± 3% error. The data were statistically analyzed by setting up and calculating a correlation matrix for the various parameters using Statistical Package for Social Sciences (SPSS) software package (Norusis and SPSS Inc) [26]. *Leachate* - The pH value of the collected sample was found to be 6.9, high values of EC of 24500 µS/cm. TDS was found to be 27956 mg/l, which indicates the presence of inorganic material in the samples. *Groundwater* - The pH of all the groundwater samples was about neutral, the range being 7.02 to 7.85. The EC in the studied area range between 617 and 3620 µS /cm and was found to be high, especially at sites 1, 3, 8, 9, 10, 12. These high conductivity values obtained for the underground water near the landfill is an indication of its effect on the water quality. The range of TDS at all sites falls in between 302 and 2208 mg/l. The TDS concentration was found to be remarkably high at sites 1, 8, 9, 10 and 12.

The groundwater pollution from refuse in the vicinity of the dumping site is detectable through increased TDS concentration of water. The high concentrations of TDS decrease the palatability and may cause gastro-intestinal irritation in human and may also have laxative effect particularly upon transits. The concentration of Cl^- the groundwater samples ranged between 28 to 737 mg/l. At sites 8 and 10, the chloride concentration was found to be comparatively high. High Cl^- content of groundwater is likely to originate from pollution sources such as domestic effluents, fertilizers, and septic tanks, and from natural sources such as rainfall, the dissolution of fluid inclusions. Increase in Cl^- level is injurious to people suffering from diseases of heart or kidney.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

This chapter is about the materials and methods used in sampling of groundwater and its testing in the laboratory. This chapter first tells the study area of the Ghazipur landfill site, the methodology adopted and the analysis of the chemical procedures being performed in laboratory. Also, data pertaining to the interval, number of samples, location through GPS (global positioning system), distance from landfill and the extent of contamination is being briefly shown.

3.1 Study Area: Ghazipur landfill site

In the year 1984, Ghazipur landfill was started and still in use. It is extended over an area of approximately 300000 m^2 and is situated near National Highway 24. On an average of 2200 metric tonnes per day waste are dumped and the waste fill height varies from 25 m to 45 m. It is situated nearby of Hindon Canal. Domestic waste from ex- kitchen waste, paper, plastic, glass, cardboard, clothes etc. are dumped at this site. Sometimes the construction and demolition wastes such as - sand, bricks and concrete block etc are also dumped at this site. Sometimes the wastes from the nearby poultry market, slaughter house, dairy farm and non-infectious hospital wastes are also dumped. The site is a non-engineered low-lying open dump and looks like a huge heap of waste. The trucks dumped wastes from different parts of the city in an irregular fashion. The wastes dumped aren't segregated except the rag pickers who segregate these wastes. Generally these rag pickers collect the glass material, plastic, metal and sell them in a recycling unit [27]. Two functional water bore wells are used for washing of refused removal vehicles and is maintained for heavy earth moving equipments at this landfill.

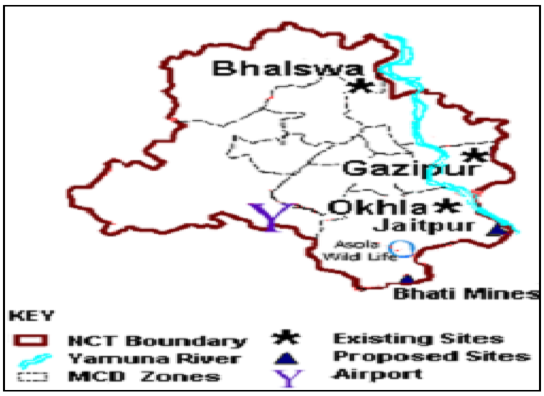

Figure 3.1 Location of Ghazipur and other landfill sites in Delhi. [Source: Google maps]

3.1.1 Site specification

The capital of India, Delhi extends over 1483 km^2 at 26º35'N and longitude 77º12'E, located at an altitude of 218 meters above the main sea level. Delhi is a mixed geological character with alluvial plains and quartzite bedrocks of the Gangetic plain and the Aravalli ridge. The climate of Delhi is semi-arid types and has extreme dry condition associated with hot summers and cold winters. The temperature lies between 18.7 ^{0}C (mean minimum) to 40.3 ^{0}C (mean maximum). During monsoon it experiences primarily heavy rainfall with an average of 714.6 mm. The population of Delhi which is approximately 14 million is estimated to produce about 7000 metric tonnes of garbage daily. The per capita solid wastes generated at Delhi are ranged from 150 to 600 gram daily, which depends upon the economic status of the community. The wastes mainly generated in Delhi is from household, industries and medical establishments. In 1975 near Ring road, the earliest landfill of Delhi was started. And the other two landfills namely Timarpur and Kailash Nagar was started in 1978.17 landfill sites are closed till date. There are three operational landfill sites at Ghazipur, Okhla and Bhalswa at present. These sites are extended over an area of about 1.5 x 10^6 m^2.The bases of the sites aren't lined resulting continuous ground water contamination [28]. The sites aren't designed in a systematic manner, before using it for disposal and dumping of waste. Before selecting these sites, no such environmental impact assessment is carried out.

3.1.2 Soil characteristics

Alluvial soils are mostly found in the study area. The weathering process of the soil in the study area is influenced by the precipitation and flood plain. Due to soil's mineralogical composition, topography, drainage pattern and geo-hydrological conditions, there has been found a wide variation in the type of the soil. The texture of soil in around Ghazipur landfill sandy loam, silt loam and clay loam, its colour is light grey in colour and its soil type is highly alkaline and calcareous in nature [29].

3.2 Methodology

This section deals with the different stages of the study. In the first stage the area of the map was studied which was taken from google maps [30]. By careful study of the map, it was possible to have an idea of several possible alternate routes so that further details of these may be studied later at the site. The probable alignment can be laid on the map from the following details available on the map –

(i) Alignment avoiding valleys, ponds or lakes.

(ii) When the sample was to be collected to know the shortest routes for each site, i.e. linking of the respective sites by the shortest route possible.

(iii) Approximate location of the landfill site.

Figure 3.2 Location of sample collection points [Source: Google maps]

The second stage was *site inspection*. In this stage sample collection sources available were noted and samples were collected from all the 10 sampling sites. Focus was on to be as precise as possible with respect to the GPS coordinates analysed during the map study. Samples were collected from the respective GPS coordinates and stored in 500 ml and 1000 ml bottles. These sampling sites for were selected within 1.0 kilometres radius of landfill site and from where the samples were taken for three seasons. The samples were collected after the extraction of water from motor-operated hand pump (Mo-HP). The water was left to run from the source for about 2 min to stabilize the electrical conductivity (EC). Details of GPS coordinates of each sampling points are mentioned.

Figure 3.3: Ghazipur main road

Figure 3.4: Groundwater sample location Ga-5

The third step was *preservation of samples*. The samples are stored to the lab in freezer at (24^0C) immediately before and after the necessary laboratory tests or when sampling was performed. Metal ion extraction from the leachate sample was done with nitric acid and the sample was kept in a *microwave digestion apparatus*.

Figure 3.5: Different groundwater samples from Ghazipur

Figure 3.6: Metal ion extraction from leachate by addition of nitric acid

Figure 3.7: Microwave digestion apparatus

The fourth stage in this study was analysis of the sample. The various parameters such as pH, DO, TDS, EC, Cl^-, and heavy metals (Fe, Zn, Cd, Cr, Pb, Ni) were analysed using standard methods.

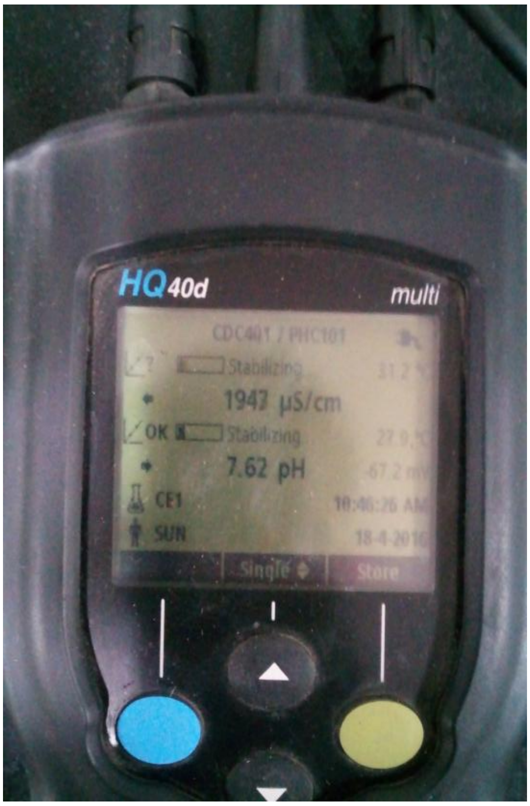

Figure 3.8: Multimeter reading 1

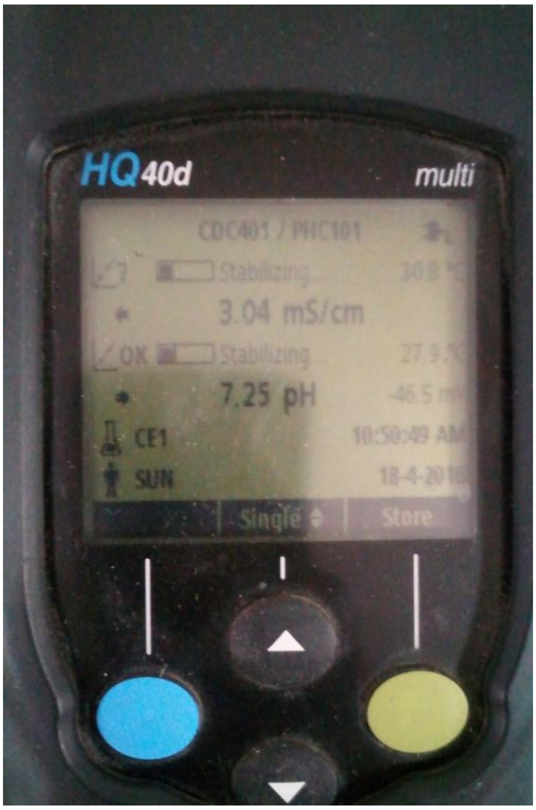

Figure 3.9: Multimeter reading 2

Figure 3.10: novAA 350 AAS

Figure 3.11: Standard solutions for heavy metal analysis

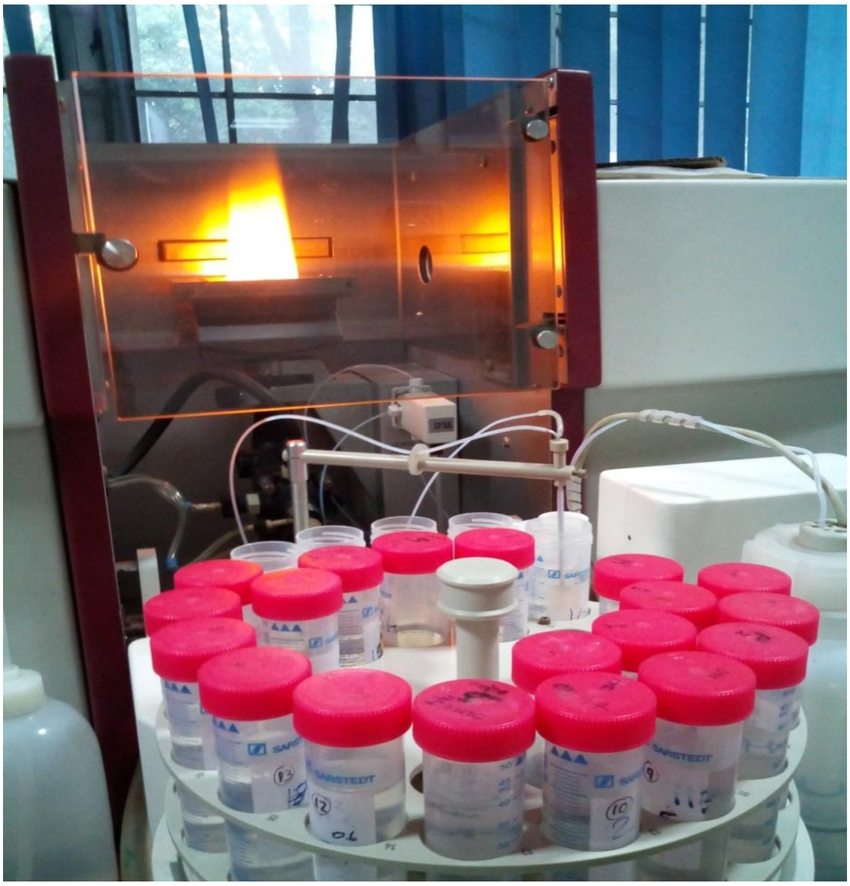

Figure 3.12: AAS at work

TABLE 3.1 ANALYTICAL INSTRUMENTS USED

Parameters	**Types**
pH	pH meter
Electrical Conductance (EC)	HACH Multi-parameter
Dissolved Oxygen (DO)	HACH DO meter
Total Dissolved Solids (TDS)	HACH Multi-parameter
Chloride (Cl^-)	Titrimetry
Heavy metals	Atomic Absorption Spectrometer(AAS)
Metal Ion Extraction	Microwave Digestion Apparatus

TABLE 3.2 DETAILS OF THE SAMPLING POINTS.

Site	**Location**	**Latitude (N)**	**Longitude (E)**	**Source**	**Depth* (m)**	**Distance* (km)**
Ga-1	Block D(1), GDF	28°37’30”	77°19’30”	Mo-HP*	150	0.20
Ga-2	Block D(2), GDF	28°37’33”	77°19’33”	Mo-HP	150	0.15
Ga-3	Overhead tank, Fish market	28°37’39”	77°19’40”	Mo-HP	150	0.25
Ga-4	Block E(1), GDF	28°37’14.9”	77°19’24.3”	Mo-HP	150	0.40
Ga-5	Block E(2), GDF	28°37’09”	77°19’16”	Mo-HP	150	0.60
Ga-6	Block C, GDF	28°37’32.8”	77°19’15.3”	Mo-HP	150	0.50
Ga-7	Block A, GDF	28°37’21.2”	77°19’15.2”	Mo-HP	150	0.50
Ga-8	Mullah colony	28°37’12”	77°19’45”	Mo-HP	150	0.50
Ga-9	Rajbir colony	28°37’18.7”	77°19’53.7”	Mo-HP	150	0.50
Ga-10	Kondli extention, Gharoli	28°37’02.8”	77°19’41.1”	Mo-HP	150	0.60

*Mo-HP = Motor Operated Hand Pump, *Depth = Depth of the First Aquifer, *Distance = Distance of sample site from the Mountain of Garbage.

Chapter 4

Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

This chapter deals with the results and discussion. The sample observations for various parameters, viz. pH, electrical conductance, total dissolved solids, dissolved oxygen chloride and heavy metals such as Zn, Cd, Pb, Fe, Cr and Ni, together with a heavy metal analysis of a leachate sample, were being discussed upon. The respective values for some of the the physico-chemical parameters for all the three seasons- rainy, summer and winter are being rigged upon thoroughly by comparing the values with various literature reviews. The tables, figures and discussion of the various seasons is comprehensibly dealt with in this chapter. At last, the trends of contamination over the period of one year by considering the results obtained in the three seasons are being analysed and shown.

4.1 Rainy season (Aug-Sep 2015)

The observation table for the various physic-chemical parameters for the different sites for the rainy season are as follows:

TABLE 4.1 PHYSICO-CHEMICAL CHARACTERISTICS OF GROUNDWATER NEAR GHAZIPUR LANDFILL (RAINY SEASON, AUG-SEP 2015).

Site	**pH**	**DO (mg/l)**	**EC (mS/cm)**	**TDS (mg/l)**	**Cl^- (mg/l)**
Ga-1	6.93	3.93	3012	1928	248
Ga-2	6.83	3.81	2635	1686	232
Ga-3	6.88	3.61	3985	2550	264
Ga-4	7.02	4.49	1998	1279	142
Ga-5	7.20	5.10	1010	646	89
Ga-6	7.23	5.18	1045	669	94
Ga-7	7.15	5.22	1186	759	98
Ga-8	7.47	5.38	795	509	60
Ga-9	7.39	5.31	689	441	51
Ga-10	7.29	5.57	602	385	37

The *pH* of all the groundwater samples was about neutral, the range being 6.83 to 7.47. The determination of pH value is very important, as it gives an idea about certain treatments which depend on pH value. The groundwater sample is alkaline but as time passes it becomes acidic, because of the bacterial action in anaerobic or nitrification process causing excessive production of CO_2. Hence, biological activities and nature of waste discharge influence the pH value of water.

The *dissolved oxygen* is the amount of oxygen that is present in the water. It is measured in milligrams per litre (mg/L), or the number of milligrams of oxygen dissolved in a liter of water. The DO level in the groundwater samples varied from 3.61 to 5.57 mg/l, indicating the presence of organic and inorganic contaminants in the water and can be used as indicators to assess the groundwater pollution caused by landfill.

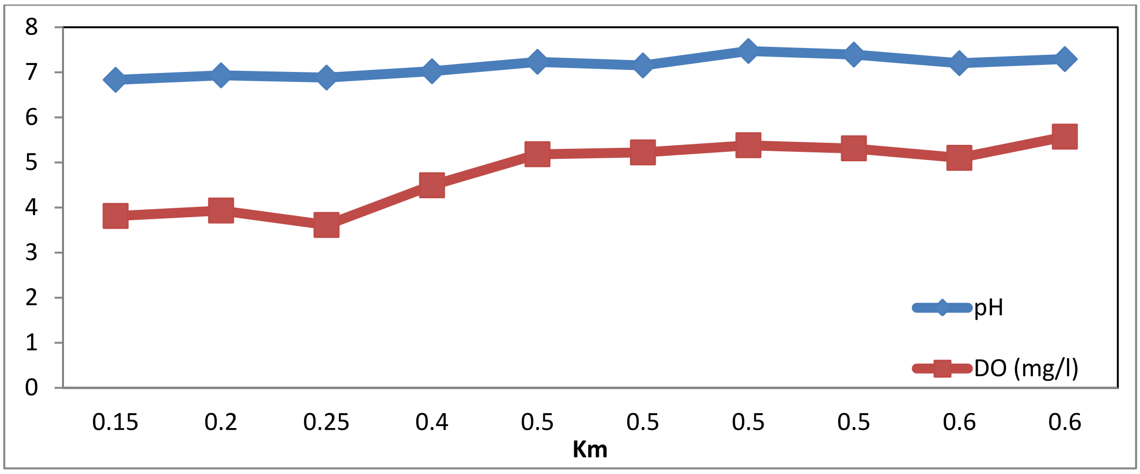

Figure 4.1 Variation of *pH* and *DO* with distance from landfill (rainy season)

The *electrical conductance* is a valuable indicator of the amount of material dissolved in water. The EC in the studied area range between 602 and 3985 µS/cm and was found to be high, especially at sites 1, 2, 3, 4, 5, 6, and7. These high conductivity values obtained for the underground water near the landfill is an indication of its effect on the water quality. The EC is an important factor which points out the presence of ion in the water. From the table 4.2, it has been noted that the conductivity values vary significantly in the different seasons in all the study sites. However, the values obtained from laboratory analysis is found to be on the higher side and are not suitable for drinking purposes when compared with drinking water specification.

The *total dissolved solids* indicate the general nature of water quality or salinity. The range of TDS at all sites falls in between 385 and 2550 mg/l. The TDS concentration was found to be remarkably high at some sites. This high value of TDS may be due to the leaching of various pollutants into the groundwater. The high concentrations of TDS decrease the palatability and may cause gastro-intestinal irritation in human and may also have laxative effect particularly upon transits. TDS had a strong correlation with Cl^-, which indicates the high mobility of these ions. Thus the single parameter of TDS can give a reasonable good indication of a number of parameters. Due to the varying TDS values the groundwater samples are identified as non-saline and slightly saline.

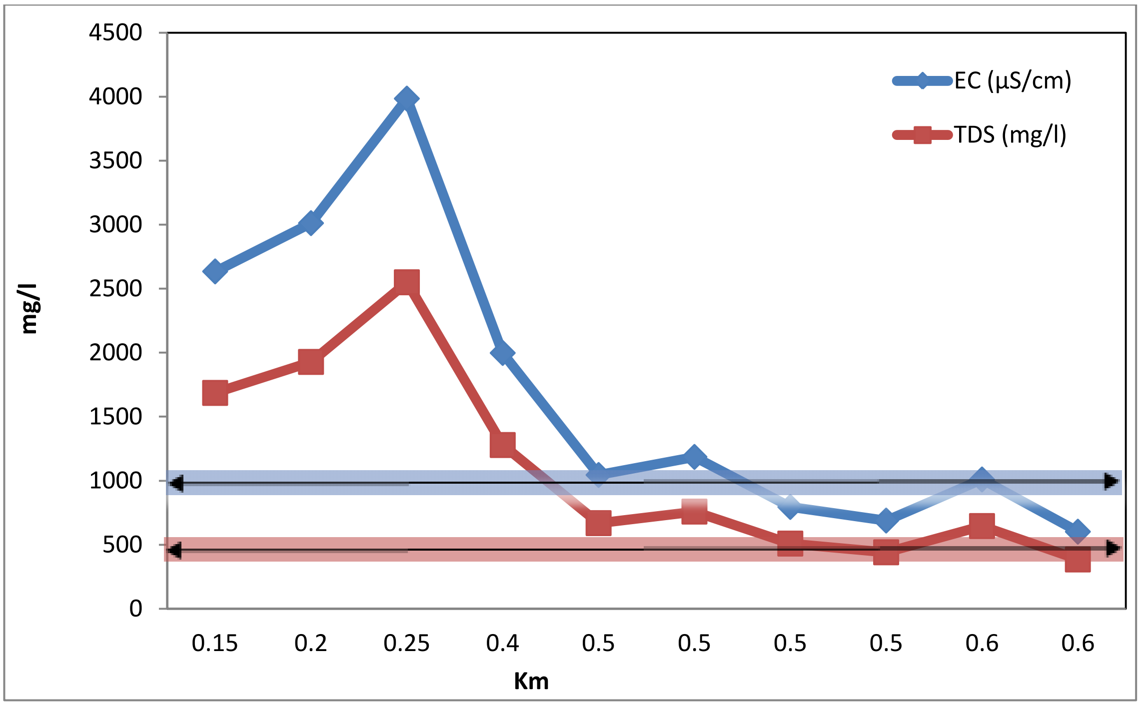

Figure 4.2 Variation of *EC* and *TDS* with distance from landfill (rainy season)

TABLE 4.2 CLASSIFICATION OF GROUNDWATER SAMPLES ON THE BASIS OF *TDS* CONCENTRATION (RAINY SEASON).

TYPES OF GROUNDWATER	**TDS (mg/l)**	**SAMPLES**
NON SALINE	<1000	6
SLIGHTLY SALINE	1000 – 3000	4

An excess of *chloride* content in water is usually taken as an index of pollution and considered as a tracer for groundwater contamination [31]. The concentration of Cl^- the groundwater samples ranged between 37 mg/l to 264 mg/l. At sites 1, 2 and 3 the chloride concentration was found to be comparatively high. High Cl- content of groundwater is likely to originate from pollution sources such as domestic effluents, fertilizers and septic tanks, and from natural sources such as rainfall, the dissolution of fluid inclusions. Increase in Cl- level is injurious to people suffering from diseases of heart or kidney.

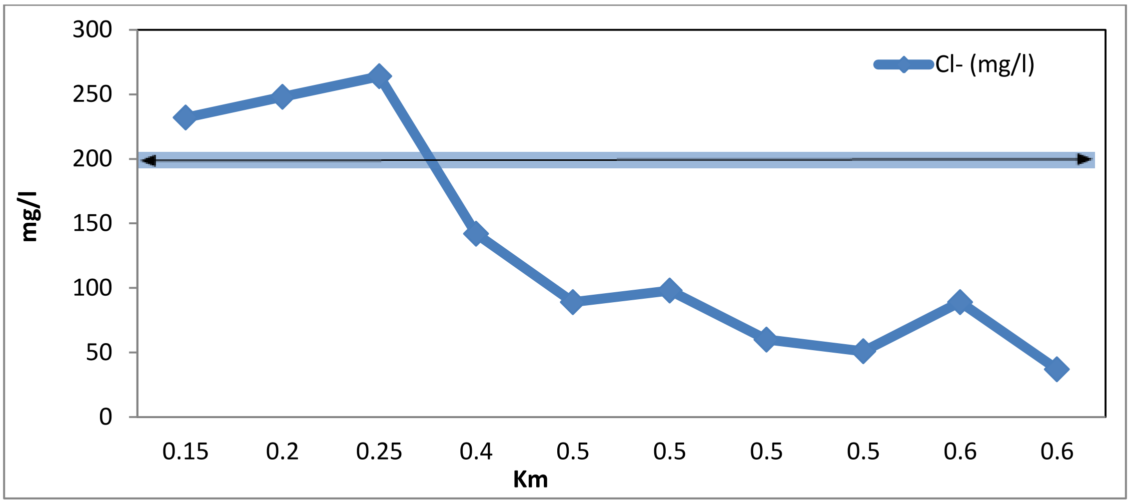

Figure 4.3 Variation of *Cl-* with distance from landfill (rainy season)

4.2 Winter season (Dec 2015 – JAN 2016)

The observation table for the various physic-chemical parameters for the different sites for the winter season are as follows:

TABLE 4.3 PHYSICO-CHEMICAL CHARACTERISTICS OF GROUNDWATER NEAR GHAZIPUR LANDFILL (WINTER SEASON, DEC 2015 - JAN 2016).

Site	pH	DO (mg/l)	EC (µS/cm)	TDS (mg/l)	Cl^- (mg/l)
Ga-1	7.11	279	3312	2120	3.73
Ga-2	7.07	263	2938	1880	3.64
Ga-3	7.12	291	4114	2633	3.43
Ga-4	7.20	177	2112	1352	4.31
Ga-5	7.43	110	1222	782	4.93
Ga-6	7.41	119	1280	819	4.97
Ga-7	7.33	122	1316	842	5.02
Ga-8	7.60	82	957	612	5.19
Ga-9	7.55	71	881	564	5.15
Ga-10	7.51	50	811	519	5.27

The *pH* of all the groundwater samples was about neutral, the range being 7.07 to 7.60. The determination of pH value is very important, as it gives an idea about certain treatments which depend on pH value. The groundwater sample is alkaline but as time passes it becomes acidic, because of the bacterial action in anaerobic or nitrification process causing excessive production of CO_2. Hence, biological activities and nature of waste discharge influence the pH value of water.

The *dissolved oxygen* is the amount of oxygen that is present in the water. It is measured in milligrams per litre (mg/L), or the number of milligrams of oxygen dissolved in a litre of water. The DO level in the groundwater samples varied from 3.3 to 6.79 mg/l, indicating the presence of organic and inorganic contaminants in the water and can be used as indicators to assess the groundwater pollution caused by landfill.

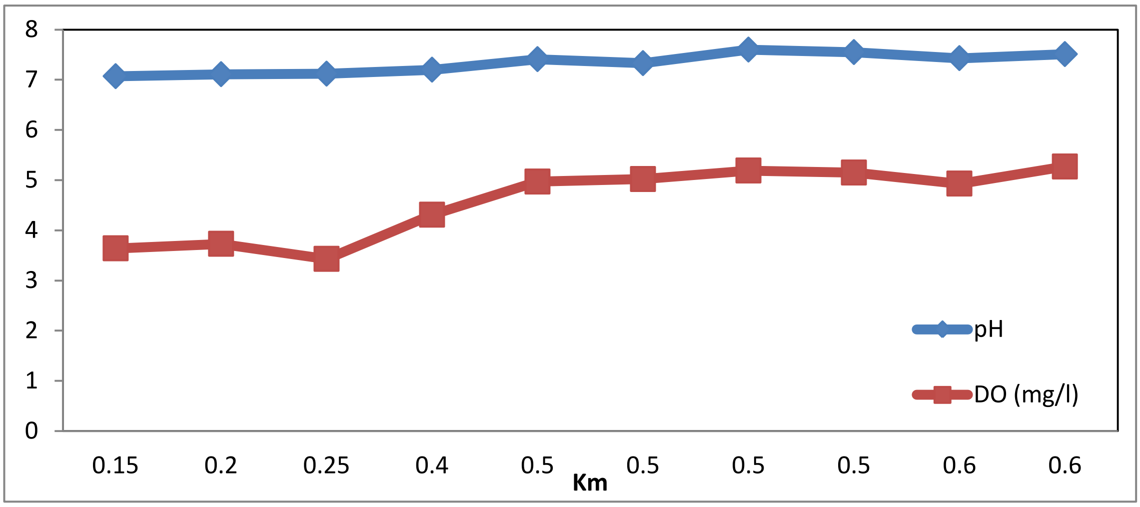

Figure 4.4 Variation of *pH* and *DO* with distance from landfill (winter season)

The *electrical conductance* is a valuable indicator of the amount of material dissolved in water. The EC in the studied area range between 1220 and 2820 µS/cm and was found to be high, especially at sites 1, 2, 5, 6, 7, 8, 9 and10. These high conductivity values obtained for the underground water near the landfill is an indication of its effect on the water quality. The EC is an important factor which points out the presence of ion in the water. From the table 4.5, it has been noted that the conductivity values vary significantly in the different seasons in all the study sites. However, the values obtained from laboratory analysis is found to be on the higher side and are not suitable for drinking purposes when compared with drinking water specification.

The *total dissolved solids* indicate the general nature of water quality or salinity. The range of TDS at all sites falls in between 550 and 1410 mg/l. The TDS concentration was found to be remarkably high at all sites. This high value of TDS may be due to the leaching of various pollutants into the groundwater. The high concentrations of TDS decrease the palatability and may cause gastro-intestinal irritation in human and may also have laxative effect particularly upon transits. TDS had a strong correlation with Cl^-, indicates the high mobility of these ions. Thus the single parameter of TDS can give a reasonable good indication of a number of parameters. Due to the varying TDS values the groundwater samples are identified as non-saline and slightly saline.

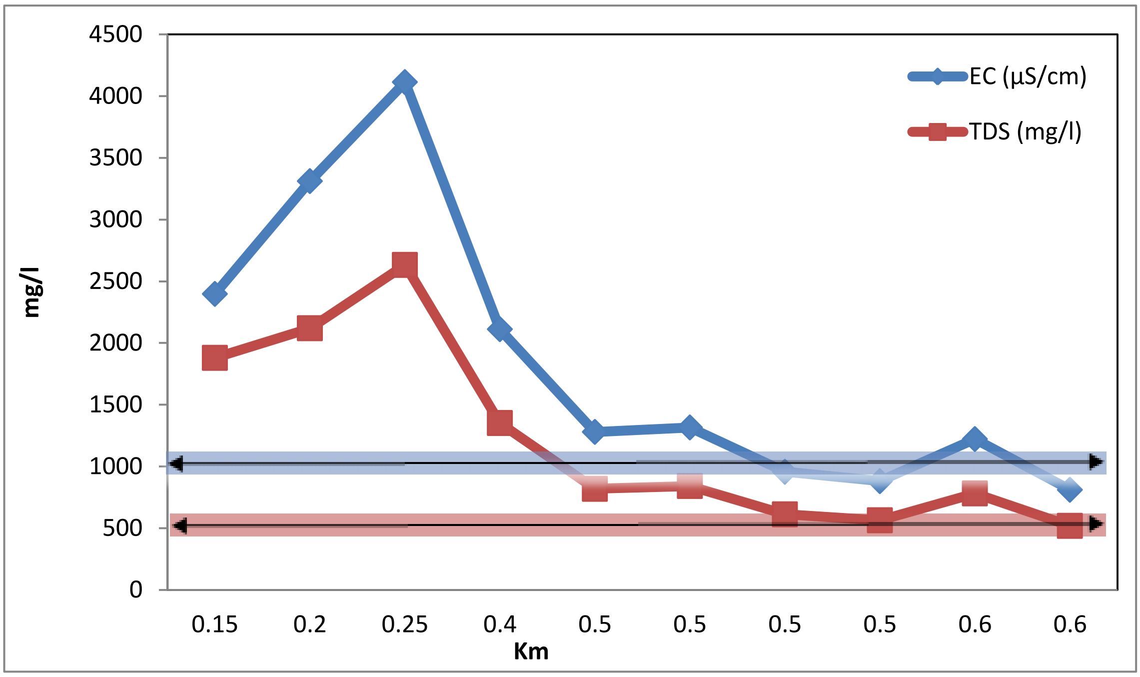

Figure 4.5 Variation of *EC* and *TDS* with distance from landfill (winter season)

TABLE 4.4 CLASSIFICATION OF GROUNDWATER SAMPLES ON THE BASIS OF *TDS* CONCENTRATION (WINTER SEASON).

Types of Groundwater	TDS (mg/ l)	Samples
Non saline	<1000	6
Slightly saline	1000 – 3000	4

An excess of *chloride* in water is usually taken as an index of pollution and considered as a tracer for groundwater contamination. The concentration of Cl^- the groundwater samples ranged between 65 mg/l to 499 mg/l. At sites 1, 2, 6, 7 and 8 the chloride concentration was found to be comparatively high. High Cl^- content of groundwater is likely to originate from pollution sources such as domestic effluents, fertilizers and septic tanks, and from natural sources such as rainfall, the dissolution of fluid inclusions. Increase in Cl^- level is injurious to people suffering from diseases of heart or kidney.

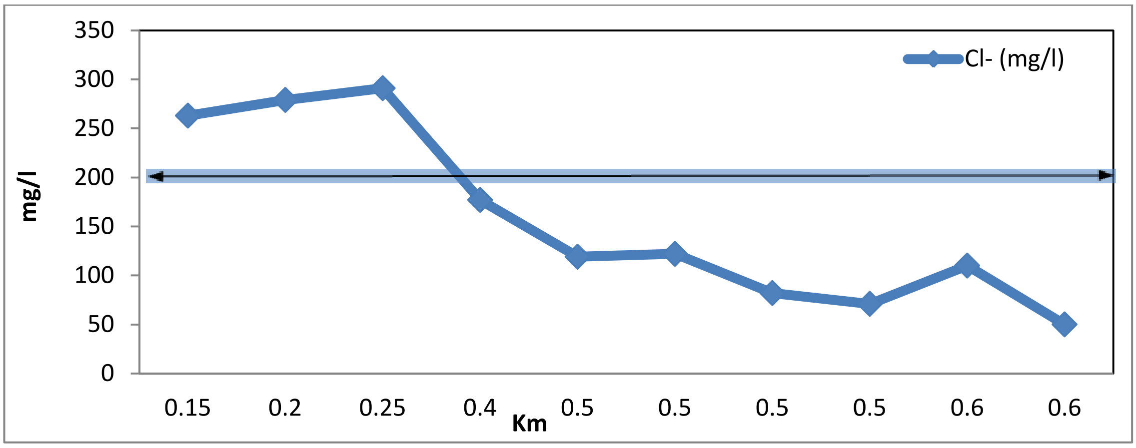

Figure 4.6 Variation of *Cl-* with distance from landfill (winter season).

4.3 Summer season (APR–MAY 2016)

The observation table for the various physic-chemical parameters for the different sites for the winter season are as follows:

TABLE 4.5 PHYSICO-CHEMICAL CHARACTERISTICS OF GROUNDWATER NEAR GHAZIPUR LANDFILL (SUMMER SEASON, APR-MAY 2016).

Site	**pH**	**EC (µS/cm)**	**TDS (mg/l)**	**Cl^- (mg/l)**	**DO (mg/l)**
Ga-1	7.35	3520	2253	289	3.61
Ga-2	7.25	3050	1952	271	3.52
Ga-3	7.37	4320	2765	301	3.33
Ga-4	7.42	2310	1478	185	4.21
Ga-5	7.62	1440	922	117	4.83
Ga-6	7.60	1490	954	127	4.91
Ga-7	7.58	1536	983	130	4.97
Ga-8	7.81	975	624	87	5.12
Ga-9	7.78	905	579	77	5.01
Ga-10	7.75	830	531	57	5.19

The *pH* of all the groundwater samples was about neutral, the range being 7.25 to 7.81. The determination of pH value is very important, as it gives an idea about certain treatments which depend on pH value. The groundwater sample is alkaline but as time passes it becomes acidic, because of the bacterial action in anaerobic or nitrification process causing excessive production of CO_2. Hence, biological activities and nature of waste discharge influence the pH value of water.

The *dissolved oxygen* is the amount of oxygen that is present in the water. It is measured in milligrams per litre (mg/L), or the number of milligrams of oxygen dissolved in a liter of water. The DO level in the groundwater samples varied from 3.3 to 6.79 mg/l, indicating the presence of organic and inorganic contaminants in the water and can be used as indicators to assess the groundwater pollution caused by landfill.

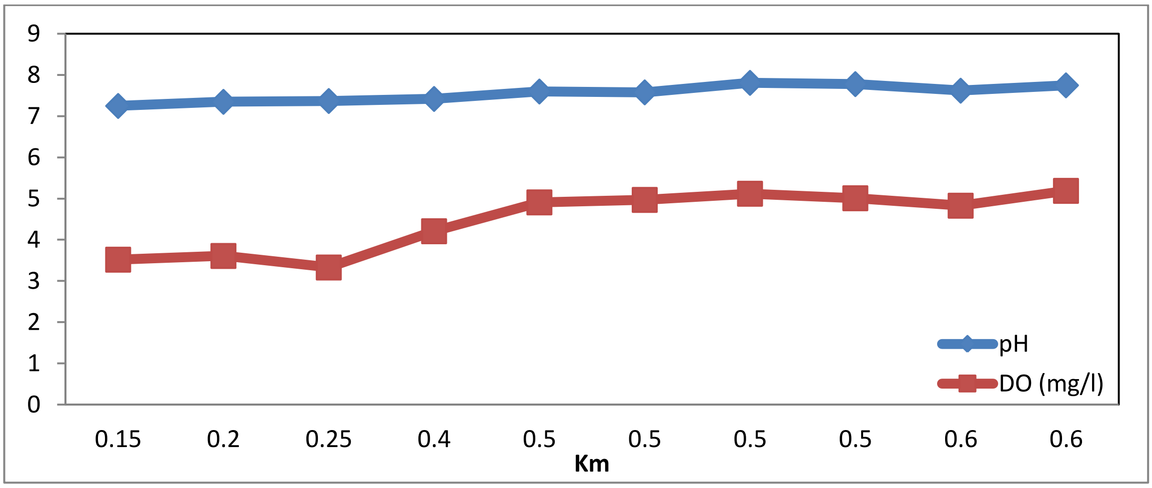

Figure 4.7 Variation of *pH* and *DO* with distance from landfill (summer season)

The *electrical conductance* is a valuable indicator of the amount of material dissolved in water. The EC in the studied area range between 1220 and 2820 µS/cm and was found to be high, especially at sites 1, 2, 5, 6, 7, 8, 9 and10. These high conductivity values obtained for the underground water near the landfill is an indication of its effect on the water quality. The EC is an important factor which points out the presence of ion in the water. From the table 4.8, it has been noted that the conductivity values vary significantly in the different seasons in all the study sites. However, the values obtained from laboratory analysis is found to be on the higher side and are not suitable for drinking purposes when compared with drinking water specification. High conductivity values are observed in summer than in winter and rainy seasons which is in agreement [32-33].

The *total dissolved solids* indicate the general nature of water quality or salinity. The range of TDS at all sites falls in between 550 and 1410 mg/l. The TDS concentration was found to be remarkably high at all sites. This high value of TDS may be due to the leaching of various pollutants into the groundwater. The high concentrations of TDS decrease the palatability and may cause gastro-intestinal irritation in human and may also have laxative effect particularly upon transits. TDS had a strong correlation with Cl-, indicates the high mobility of these ions. Thus the single parameter of TDS can give a reasonable good indication of a number of parameters. Due to the varying TDS values the groundwater samples are identified as non-saline and slightly saline.

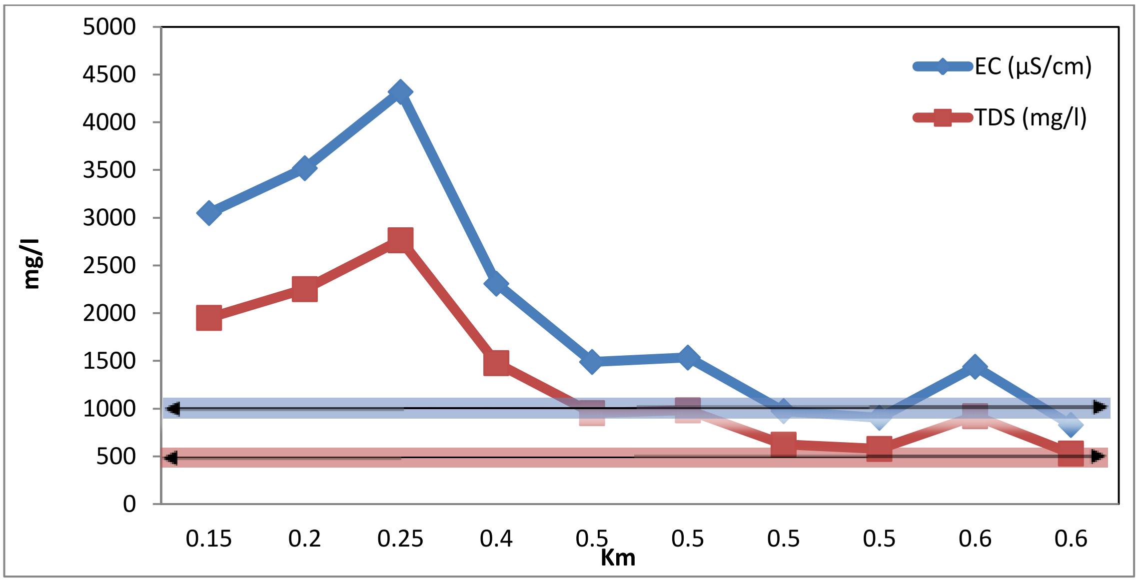

Figure 4.8 Variation of *EC* and *TDS* with distance from landfill (summer season)

TABLE 4.6 CLASSIFICATION OF GROUNDWATER SAMPLES ON THE BASIS OF *TDS* CONCENTRATION (SUMMER SEASON).

TYPES OF GROUNDWATER	TDS (mg/ l)	SAMPLES
NON SALINE	<1000	6
SLIGHTLY SALINE	1000 – 3000	4

An excess of *chloride* in water is usually taken as an index of pollution and considered as tracer for groundwater contamination. The concentration of Cl^- the groundwater samples ranged between 65 mg/l to 499 mg/l. At sites 1, 2, 6, 7 and 8 the chloride concentration was found to be comparatively high. High Cl- content of groundwater is likely to originate from pollution sources such as domestic effluents, fertilizers and septic tanks, and from natural sources such as rainfall, the dissolution of fluid inclusions. Increase in Cl- level is injurious to people suffering from diseases of heart or kidney.

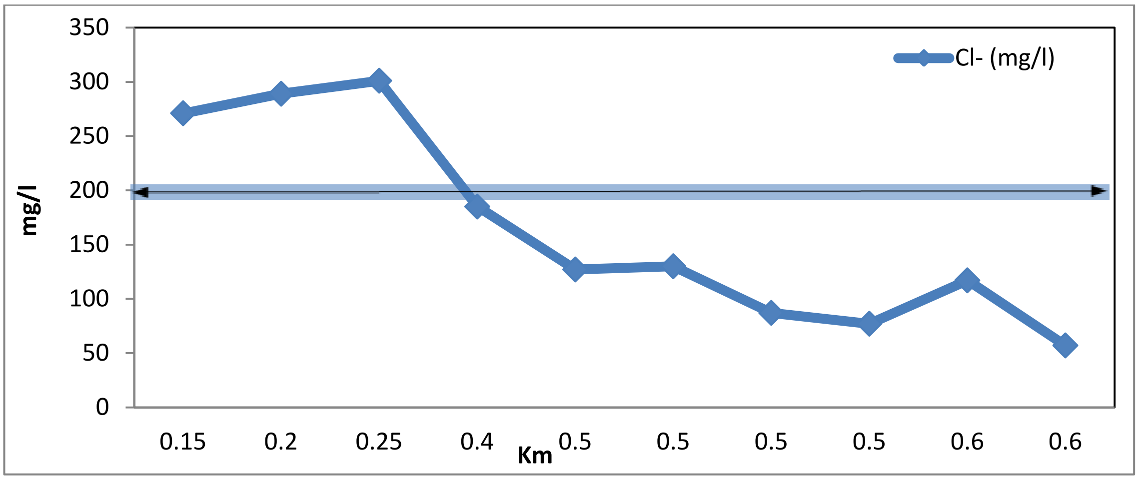

Figure 4.9 Variation of *Cl-* with distance from landfill (summer season)

4.4 Heavy metal analysis

The overall trend of the contamination of groundwater indicates that the values for the summer season (Apr-May, 2016), is the most affected. Therefore we check the groundwater concentrations of *six heavy metals* viz., *Zn, Cd, Pb, Ni, Fe and Cr* to further strengthen and enhance our research and determine the safety of the usable water at the site. The heavy metal testing is done for three samples. They are: *Ga-3, Ga-10* and *leachate*. The reason for taking the above mentioned three samples is that the sample Ga-3 is the most contaminated sample and the least contaminated sample is Ga-10, further the leachate characterisation is done in the month of *summer season*. The observation table for the heavy metal analysis are as obtained below:

TABLE 4.7 HEAVY METAL ANALYSIS FOR THREE SAMPLES IN THE SUMMER SEASON (All units are in mg/l)

Site	**Zn**	**Cd**	**Pb**	**Ni**	**Fe**	**Cr**
Ga-3	0.0223	0.0301	0.00125	0.2686	0.03043	0.00463
Ga-10	0.0218	0.0088	0.00077	0.2620	0.01283	0.00471
Leachate	1.658	0.2	0.0124	3.388	0.4821	0.0830

Zn is an essential nutrient for life. The concentration of Zn is found to be in the acceptable limit in all the three samples well within 15 mg/l [34]. Zn if present in very high quantity may pose a toxic effect and irritating effect such as nausea and vomiting. They also cause a disease called Zinc pox. They affect the eyes, skin and mucous membranes. It also leads to diarrhoea.

Cd is a cumulative, highly toxic in humans and livestock which affect all life. It causes reproductive and fertility problems, nausea, stomach cramps, vomiting, diarrhoea, liver damage, cancer and kidney damage. The concentration of Cd is found to be greater than acceptable limits in Ga-3 and the leachate samples while Ga-10 is found to be within permissible limits [34].

Pb is toxic to many organs and tissues including the heart, bones, kidney, intestines and reproductive and nervous systems. It causes brain damage, anaemia, mental retardation in children and vomiting. The sources of Pb contamination are industrial effluents, household wastes and sewage. The concentration of Pb is within acceptable limits in all the three samples [34].

The concentration of *Ni* is alarmingly high in all the three samples. It also causes reproductive and fertility problems. The higher concentration of Ni is injurious to human beings in particular. It causes allergic reactions beyond the permissible limits [34].

Fe pose colour problem, if concentrations are greater than 0.03 mg/l. Some bacteria use iron compounds for an energy source and resulting slime growth may produce bitter taste and odour. It pollutes the groundwater from various sources such as-industrial wastes, domestic discharges, natural geological sources and from by products. An excess amount of Fe causes hypertension, drowsiness, and blood pressure. The concentrations of Fe are acceptable in all samples but the groundwater should not be used for drinking purpose [34].

Cr is also an essential nutrient, but if present in high amounts is toxic to human and plants. They are potentially carcinogenic in simple Cr and chromates form. Form. The concentration of Cr is found to be within acceptable limits in the both the groundwater samples but on the higher side in case of leachate [34].

4.5 Overall trend

The BIS and WHO permissible limits for different physico-chemical parameters are given below:

TABLE 4.8 BIS AND WHO PERMISSIBLE AND DESIRABLE LIMITS

Parameters	**BIS (desirable)**	**BIS (permissible)**	**WHO (permissible)**
pH	6.5-8.5	No relaxation	7-8.5
Conductivity (µS/cm)	-	-	1000
TDS (mg/l)	500	2000	500-1500
Cl^- (mg/l)	250	1000	200
DO (mg/l)	4	8	6-10
Zn (mg/l)	5	15	15
Cd (mg/l)	Nil	0.01	0.003
Pb (mg/l)	Nil	0.05	0.1
Ni (mg/l)	-	0.02	0.02
Fe (mg/l)	0.1	1	1
Cr (mg/l)	-	0.05	0.01

The underground water of the studied area is used for domestic and other purposes such as livestock feeding and washing. Table 4.8 shows the desirable and maximum permissible limit recommended by BIS and WHO. The seasonal observations of the various groundwater sample sites are mentioned in tables 4.1 (rainy season), 4.3 (winter season) and 4.5 (summer season). Abiotic factors such as temperature, rainfall, humidity, pressure, etc mark an important role in the terrestrial environment and in the geology. A sound level of knowledge will help us in better understanding of the complex processes of interaction between the biological and climatic processes in the water bodies. Some of the interesting observations are summarised below:

The determination of *pH* value is very important, as it gives an idea about certain treatments which depend on pH value. Observed values of pH are high in winter and low during the rainy season [35]. Our results are in agreement with this result. Seasonal fluctuations reported had not mentioned about the seasonal variation of pH values [36-39]. The groundwater sample is alkaline but the reason for high level of pH in summer than in winter than in the rainy season may be due to the fact that as time passes it becomes acidic, because of the bacterial action in anaerobic or nitrification process causing excessive production of CO_2 [40]. Hence, biological activities and nature of waste discharge influence the pH value of water.

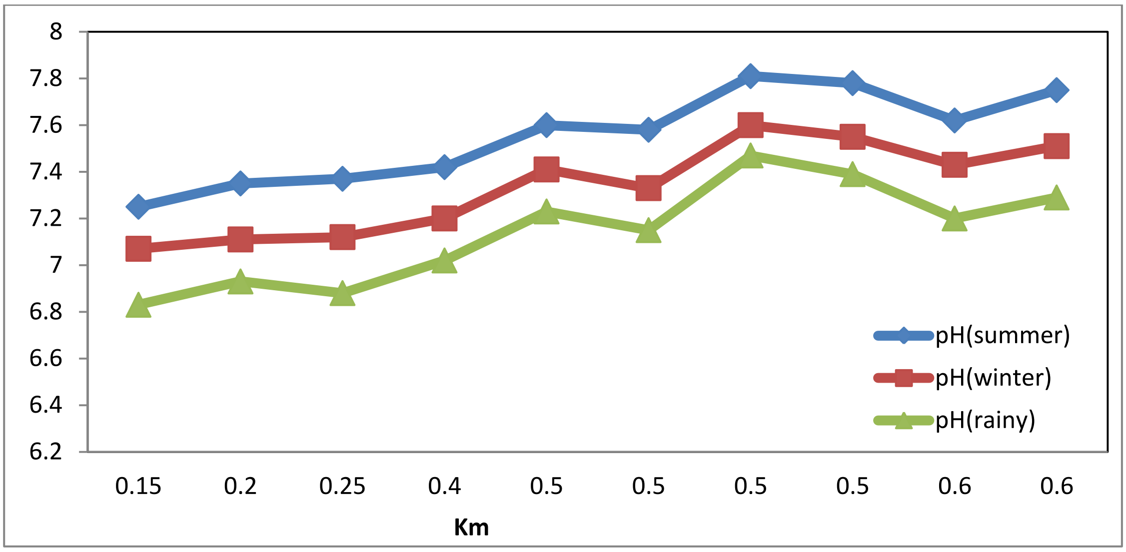

Figure 4.10 Variation of pH with distance from landfill for all the three seasons.

The *Dissolved oxygen* content is found to be lesser during the summer season which may be due to the loss of oxygen molecules to the atmosphere on account of evaporation due to high temperature and its utilisation through fast decomposition of organic matter [41]. The highest values of DO were found in the rainy season which may be on account of dilution of water or may be due to aeration of water on account of rapid flow. DO values which were lower than normal prescribed levels were found in some samples which may be due to the overloading of various concentrations from industrial, domestic, organic, etc. wastes accumulating over the period of months. The solubility of DO increases with decrease of water temperature during the winter season [42].

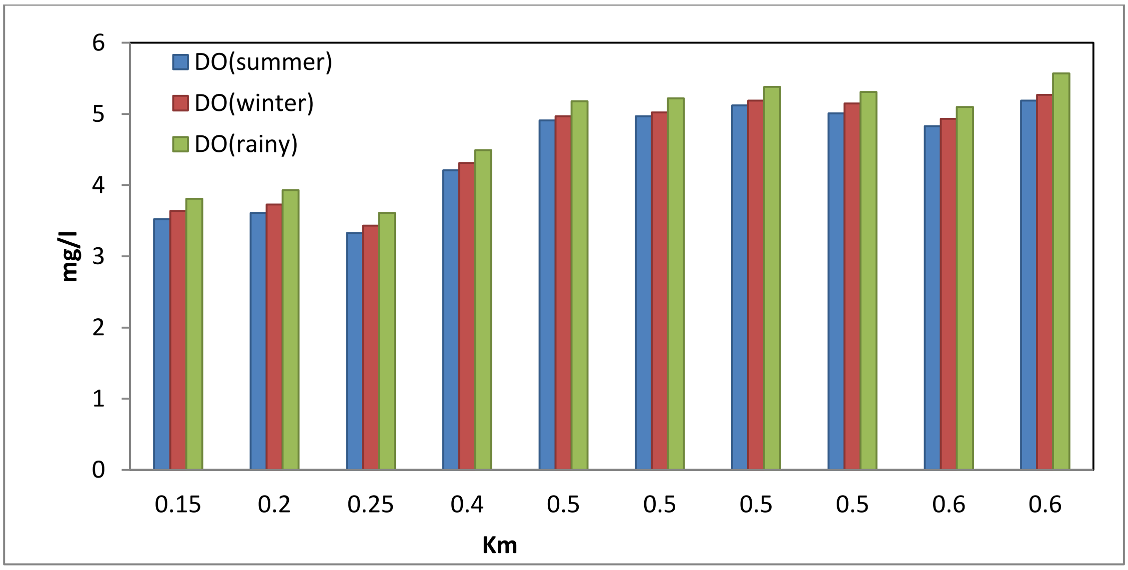

Figure 4.11 Graph of variation of DO with distance from landfill for all the three seasons.

The *total dissolved solids* is the material remaining in the water after filtration which is considered to be dissolved [43]. Approximate analysis of TDS is made by determining the electrical conductivity. In this study the TDS values are higher than the permissible values in almost all the samples which give us a very clear indication that the groundwater cannot be used for drinking purposes in the locality as it is heavily contaminated. The present study shows that the concentration level of TDS is maximum during the summer season, lesser during the winter season and least in the rainy season. The least values in the rainy season may be due to the fact of dilution of water [44]. During the summer season almost all of the vegetation had started to decay, so an increase in the concentration of dissolved solids was pretty natural as the produced decaying matter returned to the water. TDS had the highest values during the summer season due to the fact of the evaporation of groundwater and river water and also may be because of the raw disposal of wastes from the dairy industry, fish market and animal slaughter house nearby.

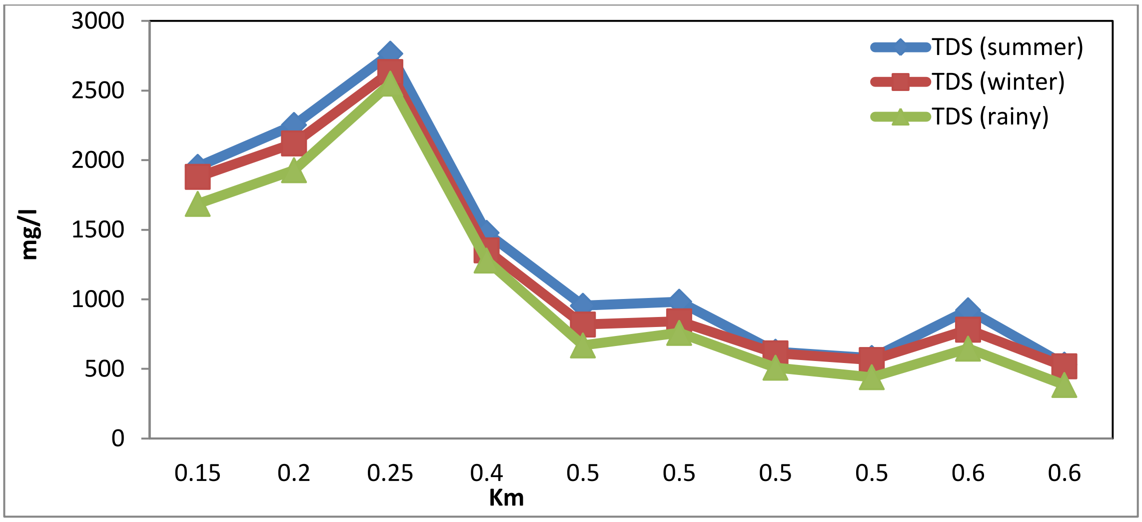

Figure 4.12 Variation of TDS with distance from landfill for all the three seasons.

The *Electrical conductance* is a valuable indicator of the amount of material dissolved in water. These high conductivity values obtained for the underground water near the landfill is an indication of its effect on the water quality [45]. The EC is an important factor which points out the presence of ion in the water. From the tables 4.1, 4.3 and 4.5, it has been noted that the conductivity values vary significantly in the different seasons in all the study sites. However, the values obtained from laboratory analysis is found to be on the higher side and are not suitable for drinking purposes when compared with drinking water specification [46]. High conductivity values are observed in summer than in winter and rainy seasons.

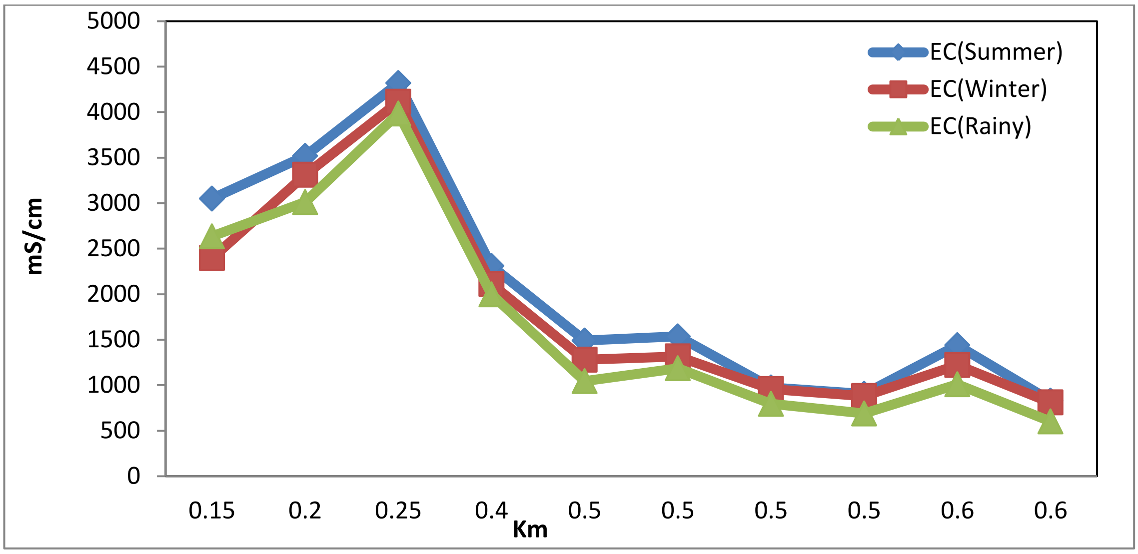

Figure 4.13 Variation of EC with distance from landfill for all the three seasons.

The concentration of *chloride* content as observed from the tables 4.1, 4.3, 4.5, is found to be higher for the observation sites near the landfill areas and of lower chloride content away from the vicinity of landfill. The areas present close to the proximity or the propinquity of the dairy farm, fish market, slaughter house on one side of the landfill shows higher concentrations of chloride content whereas the areas with housing or residential areas show lesser chloride levels. The high concentrations of chloride levels in the above cases indicates discharges derived from the kitchen wastes, human faeces, urinary discharges, solid wastes from landfill, dairy wastes, slaughter house wastes and fish market wastes like flesh salting, etc. However, the chlorides in water are also derived from natural mineral deposit, agriculture or irrigation deposits and pollution due to industrial waters [47].

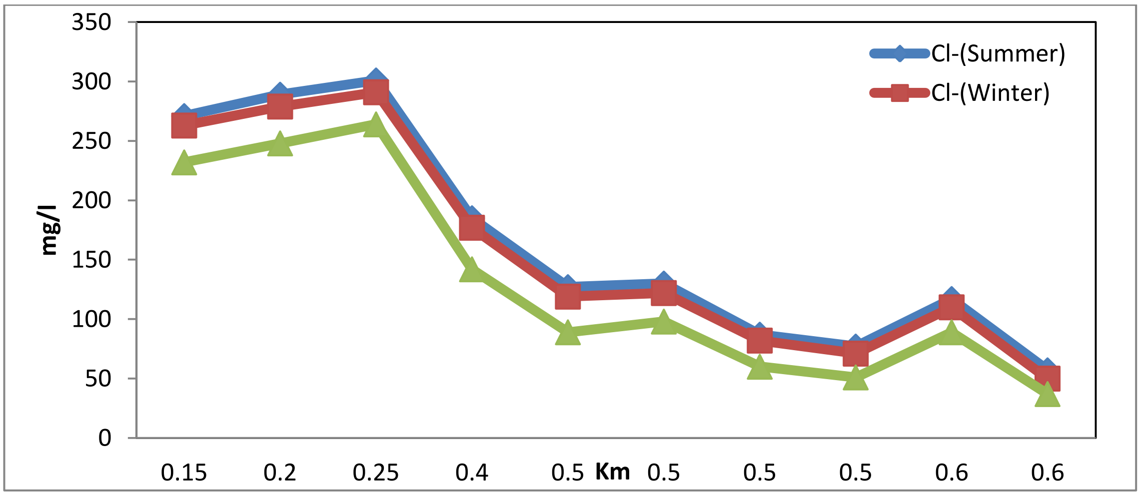

Figure 4.14 Variation of Cl- with distance from landfill for all the three seasons.

Chapter 5

Conclusion

CHAPTER 5

CONCLUSION

The sample concentration of the Ghazipur landfill is found above the permissible limits. Thus this area's ground water is unfit for drinking purpose. The people of this area must drink treated water and the water should be taken care under subsequent review and checking. The water should be discharged only after proper treatment by the dairy industry. The landfill dumping is suspected to influence the study area which is selected. The study area extends approximately within one kilometre of radius from the centre of the landfill site indicated as Mountain of Garbage and has almost the same underground lithology and aquifer system. The sampling sites were selected in such a way so as to indicate possible influences from the three different seasons. The landfill is unplanned, unlined and is situated in the flood plain of the Yamuna river. It is presumed that the alluvial lithology of landfills makes it more susceptible to contaminate the leaching of pollutants. The samples have high conductivity, chloride and TDS which indicates anthropogenic input. It is seen that as we move away from landfill, the pollutant concentrations seemed to be decreased in the direction of the groundwater flow within the radius of extent. Thus landfill plays a role as a source of contamination.

The groundwater near landfill consists high concentrations of EC, TDS, Cl^- which deteriorates the quality for drinking and domestic purpose. The Cl^- may be assumed to act as a tracer in relation to leachate percolation. Near the Ghazipur landfill site, it can be concluded that leachate has significant impact on groundwater quality as there is no natural or possible reason for high concentration of these pollutants. As the distance of the sample point increases from the pollution source, there becomes more chance of improved ground water quality. Even though the concentrations of a few contaminants do not exceed the drinking water standards but still the ground water quality represents a significant threat to the public health. Some remedial measures are also recommended to stop further groundwater contamination. The results obtained during the study were compared with their respective standards and it is concluded that most parameters of the groundwater samples were above their respective permissible standards and unsuitable for drinking purposes especially in samples site Ga-1, Ga-2 and Ga-3 in all the seasons, while samples sites Ga-8, Ga-9 and particularly Ga-10 were found to be safer and suitable for drinking purposes but with prior necessary treatments [43-44]. The study pertains to the fact that groundwater is one key source of drinking water to the residents of the area. So, care must be taken by them and the local authorities to ensure providing safe drinking water to the people near the propinquity of the Ghazipur landfill site. A regular chemical analysis must be done to check the quality of water in this area in addition to research of new alternatives to additional water for the resident people. Explicitly speaking, if an effective maintenance of water quality through appropriate control measures, continuous monitoring of the water quality parameters and their use as a supplement to river water will reduce the crisis of the whole of Delhi area and the country in general itself. The overall trends of the concentration of groundwater indicate that the values for the summer season are the most affected. After checking the groundwater concentrations of *six heavy metals* viz., *Zn, Cd, Pb, Ni, Fe and Cr,* we can conclude that the groundwater is not at all suitable for drinking purposes and that the sample Ga-3 is the most contaminated sample and the least contaminated sample is Ga-10. The concentration of Zn is found to be in the acceptable limit in all the three samples. The concentration of Cd is found to be greater than acceptable limits in Ga-3 and the leachate samples while Ga-10 is found to be within permissible limits. The concentration of Pb is within acceptable limits in all the three samples. *Ni* concentration is found to be alarmingly high**.** Fe poses colour and odour problem. The concentrations of Fe are acceptable in all samples but the groundwater should not be used for drinking purpose. The concentration of Cr is found to be within acceptable limits in both the groundwater samples but on the higher side in case of leachate. Hence it is necessary to admit that the Ghazipur dairy industry, the cattle owners, suppliers in the fish market and animal slaughter house nearby the landfill, should keep a check on the water quality served to their cattle for drinking and other usable purposes such as for cleaning animal flesh, else the animals may get affected due to the prolonged consumption of unsafe water. Further this may lead to biomagnifications in human beings when the food product obtained from these animals is consumed as it is contaminated with toxic chemicals.

Chapter 6

Remedial Measures

CHAPTER 6

REMEDIAL MEASURES

This chapter is addressed with some remedial measures. The various remedial measures for the groundwater pollution care during solid waste collection and disposal is being discussed.

6.1 Remedial measures for groundwater pollution

In my study of the groundwater quality near the vicinity of selected landfill (Ghazipur) of Delhi, I would like to suggest some positive approach which can be used as possible remedies in the form of reducing damage upto a particular limit and possible precaution be taken for future planning of landfill.

- The working landfills may be closed as soon as possible so that further source of contaminant can be reduced.
- Proper management should be undertaken to sort out or remove hazardous solid wastes before dumping so that leachates from Ghazipur landfill can be reduced and will not contaminate ground water.
- *Leachate management* by effectively controlling the leachate generation, its treatment and subsequent recycling throughout the waste.
- *Engineered landfill sites* are generally provided with an impermeable liner and a drainage system at the base of the landfill, which will not allow the leachate to percolate into the subsoil.
- *Techno economic feasibility studies* should be carried out for choosing the options of a landfill site. The various techniques of retrofitting for the existing old sites like Ghazipur would be tedious and expensive. The first option to be considered is that the Water supply should be drawn from safe distant sources. At and around this site.
- Guidelines must be stricter and a Resource Conservation and Recovery Act should be brought in to provide new restrictions and standards for land disposal facilities. This act will enforce:
    1. Banning liquids from landfills.
    2. Banning any direct drinking use from the groundwater well located within 1 to 4 miles from the site.

3. Requiring more stringent structural and design conditions for the landfills and surface impoundments, including two or more liners, leachate collection system above and between the liners, and continuous groundwater monitoring.
4. Requiring cleanup or corrective action if hazardous waste leaks from a facility.
5. Requiring information from disposal facilities on pathways of potential human exposure to hazardous substances.
6. Requiring location standards that are protective of human health and the environment; for example, only in suitable hydrogeological settings disposable facilities should allowed to be constructed.
7. People living around the landfill should be educated about possible consequences of using contaminated water.
8. 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.
9. Proper lined sanitary landfill sites along with segregation of wastes and incinerators using plasma techniques need to be developed which are effective in keeping the ground and surface water free from leachates enriched with pollutants.

6.2 Care during solid waste collection and disposal

The following points need to be taken care of while *collecting* solid waste:

- Spreading or scattering of refuse while dumping in the community storage bins by the house sweepers and street scavengers should be avoided.
- Transport vehicles should be cleaned periodically, thus avoiding decomposition and evolution of health hazard causing obnoxious gases.
- Community storage bins as well as transport vehicles should cover/lid thus reducing incidence of rodents, insect infestation and unpleasant sites at the site.
- Transport vehicles should be strong, durable and water tight and made of stainless steel with smooth interior having round corners and edges for facility of cleaning.

- Transport vehicles should visit the houses, twice a day, once in the morning and once in the evening to collect household refuse and street sweepings.
- Transport vehicles should have low loading line (about 1.5 meters), so that minimum of time and effort is required in filling them.
- Mechanical devices should be installed in these vehicles for lifting the body to the sides or back or for pushing the refuse out in order to empty it quickly and easily.
- An optimum collection route, particularly for large and densely populated area should be selected in order to optimise the collection system.

The following points need to be taken care while *disposing* solid wastes:

- Appropriate method of disposal of solid wastes should be chosen among the methods discussed in the section ahead in order to satisfy the present as well as the future requirements.
- It should not create environmental pollution and should result in recovery of material as well as energy. Most common methods of dumping used all over the world are open dumping, sanitary landfilling, composting, shredding (or pulverising), incineration and pyrolysis.
- The refuse carried for dumping should be disposed in a low lying dump, away from the city, in an engineered landfill prepared previously, designed and operated according to the acceptable standards.
- The refuse should be dumped and compacted in layers of 0.3 to 0.6 meters after the day's work when depth of filling becomes 1.5 meters, it should be covered by earth of about 15 to 30 centimetres thickness.
- Filling should be done by a grid pattern.
- Before dumping the second layer, compaction by movement of bulldozers, trucks, etc.
- A minimum clearance of 6 meters from the surrounding area should be left during filling operation of low lying areas.
- Insecticides like DDT, creosote, etc. should be sprayed to prevent mosquito breeding.

- Final cover of about 0.6 meters of earth is laid and compacted at the top of the filled up land in order to finish the complete operation and prevent rodents from burrowing into the refuse.
- The filled up refuse gets stabilised due to the decomposition of organic matter with time; subsequently getting converted into stable compounds

SCOPE FOR FURTHER WORK

Considering the limitation of the study we have identified following topics to be investigated further:

1. To *monitor periodically* i.e. the seasonal variations, the physicochemical parameters.
2. To develop a suitable *model* so as to predict an expected future concentration level of contaminants in the groundwater around landfill.

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