IMPACT ASSESSMENT ON GROUNDWATER CONTAMINATION FROM BHALSWA LANDFILL

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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE

OF

MASTER OF TECHNOLOGY

IN

GEOTECHNICAL ENGINEERING

Submitted by:

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CANDIDATE'S DECLARATION

I, Farhan Ali Mansoori Roll No. 2K21/GTE/07 of M. Tech Geotechnical Engineering, hereby declare that the project Dissertation titled "Impact Assessment on Groundwater Contamination From Bhalswa Landfill" which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for any Degree, Diploma Associateship, Fellowship, or other similar title or recognition.

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Date

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CERTIFICATE

I hereby certify that the project Dissertation titled “Impact Assessment on Groundwater Contamination From Bhalswa Landfill” which is submitted by Farhan Ali Mansoori roll number 2K21/GTE/07 Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is record of the project work carried out by the students under my supervision. To the best of my knowledge, this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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Date: **SUPERVISOR**

ABSTRACT

Municipal solid waste (MSW) dumps are widespread, and their numerous hazardous materials pose a serious threat to the environment and the local population. Leachate, which seeps into the porous ground surface after waste is dumped in a landfill, can contaminate groundwater. Such leachate makes groundwater and the associated aquifer unsuitable for houses water supplies and other uses. In the present study, five leachate samples are collected around Bhalswa landfill, and ten groundwater samples are collected between Bhalswa landfill to Delhi technological university at random distances of 366.82 m, 443.14 m, 557.09 m, 557.09 m, 679.07 m, 2890 m, 3220 m, 3510 m, 3630 m, 4240 m and 4290 m for physicochemical analysis of leachates and groundwater. This physicochemical analysis includes parameters like pH, total dissolved solids (TDS), alkalinity, sulphate, nitrate, electrical conductivity, chloride, and phosphate and the results obtained for groundwater are compared with the BIS code of drinking water to know whether groundwater is suitable for drinking or another domestic purpose.

ACKNOWLEDGEMENT

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Farhan ali mansoori

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LIST OF SYMBOLS, ABBREVIATIONS, AND NOMENCLATURE

MSW	Municipal Solid Waste
UNEP	United Nation Environment Programme
NCT	National Capital Territory
TDS	Total Dissolved Solids
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
pH	Acidity
TSS	Total Suspended Solids
Cl^-	Chloride
EC	Electrical Conductivity
BIS	Bureau of Indian Standards
APHA	American Public Health Association
WHO	World Health Organization
ICMR	Indian Council of Medical Research
CO_2	Carbon dioxide
SO_4^{2-}	Sulphate
NO_3^-	Nitrate
mm	millimeters
m	meters
Km	Kilometers
ml	milliliters
mg/l	milligram per liter
µS/cm	micro-Siemens per centimeter
^0C	degree centigrade
CPCB	Central Pollution Control Board
USEPA	United States Environmental Protection Association

CHAPTER 1

INTRODUCTION

1.1 GENERAL

For human survival, water is a need. Groundwater, utilized for irrigation, drinking, and other uses, is one of the most significant water sources. In accordance with the hydrological cycle, groundwater is described as water that is present below the surface of the earth and ultimately rises to the surface. While groundwater helps to maintain ecosystems, the majority of it is utilized to meet basic human needs. Water quality is crucial for its usage, and when unwanted contaminants alter water's biological, physical, and chemical properties, it is considered water pollution. According to the USEPA, both natural causes and human activities contribute to groundwater pollution, but human activities have a longer-lasting impact on water bodies than other natural causes.

Water shortages are a global problem due to a lack of fresh water. The available water has become limited due to human activity and excessive resource utilization. Population increase and changing lifestyles are closely tied to waste management and waste-related environmental challenges. In addition to landfills, pesticides, chemicals, and excessive fertilizer, use are other common causes of groundwater pollution. On the other hand, groundwater is deemed suitable for use by the general public without treatment. Due to their subsurface storage and lack of germs, odour, turbidity, coloration, suspended particulates, etc., they are of outstanding quality. It is easy to use and naturally recharges. However, there has been a startling decline in both quantity and quality.

Every year, numerous landfills across the world are filled with millions of metric tonnes of municipal solid waste. However, scientific techniques are used to process only 5% of the 70 million metric tonnes of municipal solid waste produced annually in India, according to a 2011 report by the Planning Commission of India. Waste collection rates in India range from 30 to 70 percent, and there are over 5100 municipalities in the country. The commission's waste characterization study found that municipal solid waste is composed of 51% organic matter, 17% recyclable matter, 11% hazardous matter, and 21% inert matter.

The Indian government has established a set of regulations for managing waste generation, and all action plans put into place are compared to these regulations to determine whether they are compliant or not. The Municipal Solid Waste Rules have been poorly implemented in Indian cities and towns, as stated in a report of Central Pollution Control Board (CPCB). The CPCB conducted surveys in 1999-2000, 2009-2012, and 2020-2021 through the Environmental Protection Training & Research Institute (EPTRI) and State Pollution Control Boards/Pollution Control Committees to evaluate the amount of waste produced by various towns and cities in India. According to data collected between municipal waste production in Class-I and Class-II cities showed a significant increase from 52,125 tonnes to 127,485 tonnes, respectively. During the 2009-2012 period, West Bengal had the highest municipal waste production rate of 12,557 tonnes per day, followed by Tamil Nadu, Uttar Pradesh, and other states. Notably, Delhi's daily waste production also increased from 4,000 tonnes in 1999-2000 to 7,384 tonnes in 2009-2012 and 10990 tonnes in 2020-2021.

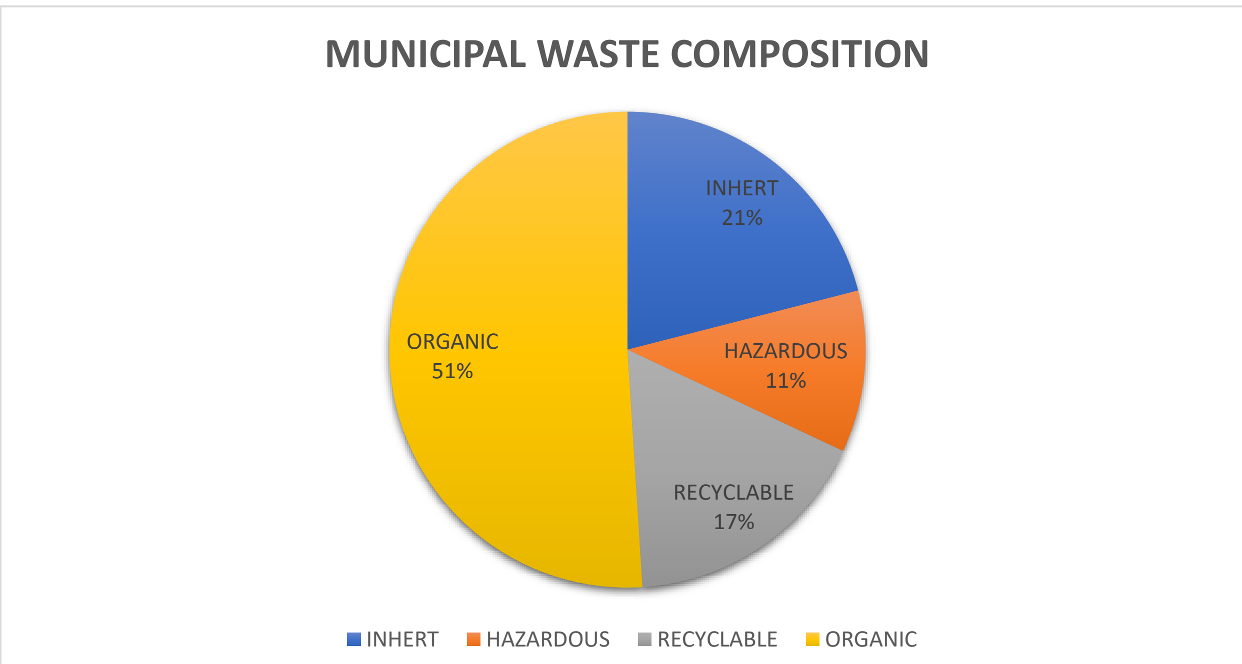

Figure 1.1 Waste Composition of MSW in India (SOURCE: Planning Commission 2011)

The Central Pollution Control Board (CPCB) periodically conducts studies to determine how much waste is produced in each of the nation's states and union territories. To enforce the Municipal Solid Wastes (Management & Handling) Rules, the collaboration between the Central Pollution Control Board, Union Territory Control Committees, and various State Pollution Control Boards was established.

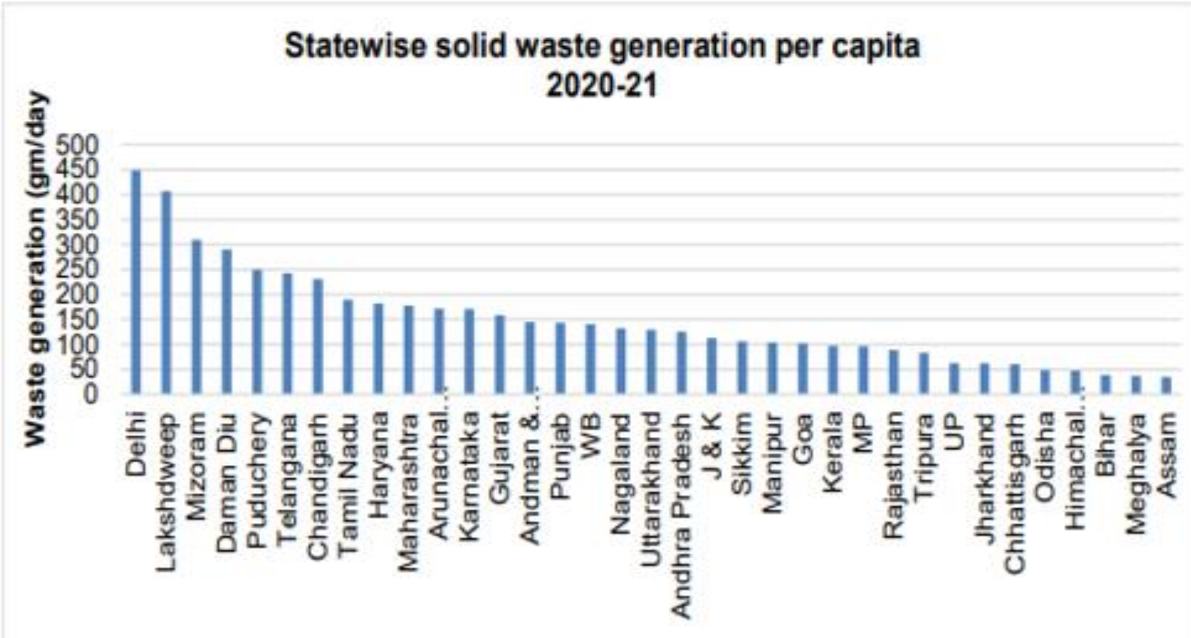

Figure 1.2 State-wise India's per capita solid waste generation (Source: CPCB 2020-2021)

Nevertheless, an annual report from these entities reveals that the majority of cities and towns are not following the rules or implementing the required action plan. Only 70% of the total waste produced in the country is collected, while the remaining 30% is left untreated and is lost in the municipal environment. Out of a total of 1,27,487 tonnes of garbage produced per day in 2021, the country's waste collection and processing rates reveal a sizable discrepancy, with 89,335 tonnes per day collected and 15,882 tonnes per day treated. In Delhi, the total solid waste generation is approximately 10990 tonnes, of which 5193 tonnes are treated, and 5533 tonnes per day of waste is landfilled. Several states in India, including Mizoram, Uttar Pradesh Punjab, Arunachal Pradesh, and Nagaland, do not have any waste treatment facilities. Other states, such as Manipur, Assam, Jharkhand, and Sikkim, do not have sufficient waste treatment facilities to manage the amount of waste they produce. In most states, there are municipalities that lack proper sanitary landfill waste disposal options, and as a result, waste is often just dumped in dumpsites.

Landfills are widely used for waste disposal around the world because they are the most cost-effective method. When waste is dumped in landfills, it undergoes chemical, physical, or biological processes that result in the production of harmful gases and leachate. In India, these waste dumping sites are known as dumpsites or sometimes landfills. However, they lack the essential components of a sanitary landfill, such as daily cover or liner, treatment units or leachate collection, proper site design, periodic waste compaction, and exhaust gas recovery systems. The environment and human health are both adversely affected by this negligent garbage disposal practice. The primary cause of waste decomposition in landfills is microbiological activity, which can lead to various issues such as the production of waste-derived gases, chemical oxidation of waste materials, and movement of landfill leachate through subsurface strata (Lo, 1996). One of the significant concerns associated with landfill leachate is the risk of contaminating groundwater. Furthermore, waste production has a detrimental impact on the environment, contributing to greenhouse gas emissions. According to UNEP 2010, landfills are a source of greenhouse gases. Methane emissions from landfills are often cited as the leading cause of climate change in the waste management industry.

1.2 NEED OF STUDY

India is one of the world's most populous countries, and as the population grows, the rate of waste production also increases. Proper waste management is a significant concern due to this rapid population growth. Landfills are a commonly used but also heavily polluted method of waste management. The improper design and maintenance of landfills have caused numerous environmental problems, such as the production of leachate and the emission of methane, which contributes to the increase in greenhouse gas emissions. Improper waste management practices directly harm people, animals, plants, and the environment while also depleting natural resources. One of the significant drawbacks of open garbage disposal is the pollution of soil and groundwater. Leachate is a liquid that enters a landfill from external sources such as rain.

The research of landfill leachate is vital because of the serious effects of groundwater contamination in communities around waste sites (Butt & Ghaffar, 2012). Leachate has a large chance of polluting groundwater supplies. Numerous studies have demonstrated that landfills are steadily lowering the quality of groundwater and diminishing natural water resources (George et al., 1999; Christopher O. et al., 2012; Butt & Ghaffar, 2012). Water shortage is a result of this groundwater deterioration. Even after waste disposal has stopped, emissions are still produced by the landfill's carbon stockpile due to its constant decay rate. This is because chemical and biological reactions advance slowly over the years and are released in this manner. The emission of carbon dioxide and methane contributes significantly to global warming and climate change, according to UNEP (2010). The Ministry of Environment and Forests (MoEF) stated in 2010a, that

India ranks fifth globally in terms of total emissions of greenhouse gases, behind the United States, China, the European Union, and Russia.

Since 1975, there have been numerous reports of groundwater contamination caused by landfill leachate. This necessitates an immediate understanding of landfill leachate migration and its harmful consequences on groundwater quality. As a result, a study of the landfill leachate and nearby groundwater is required because:

- If someone lives near a landfill, it is critical to know whether the available groundwater is safe to drink or not.
- If contaminated water is consumed on a regular basis, a variety of health risks, diseases, and illnesses may spread.
- The authorities responsible for the landfill can assess the extent of contamination and take prompt action by implementing rehabilitation and remediation programs, which may involve strategies to prevent the production or leaching of leachate through the soil.
- The local people must be relocated, which necessitates a substantial financial outlay if the pollution has spread so extensively and deeply that recovery is impossible.

1.3 OBJECTIVES OF THE STUDY

Bhalswa disposal site, located in New Delhi, India's capital city, is one of three active landfills in the area, along with Okhla and Ghazipur. This landfill, unlike a sanitary landfill, lacks scientific lining and thus serves only as a dumping ground. Unfortunately, because of saturation, the dump is a major hazard to the health and property of the nearby population. To assess and reduce the environmental impact, samples of landfill leachate and groundwater were collected and analyzed from multiple sources. Analyzing the characteristics of both can aid in reducing the environmental impact. The main objective of the present study is outlined below:

- To determine the physicochemical properties of leachate produced at the Bhalswa landfill site.
- To determine the contamination of groundwater by comparing its physicochemical properties with the BIS code of drinking water to know whether the groundwater is suitable for drinking or domestic purpose.

CHAPTER 2

REVIEW OF LITERATURE

- **Gawai et al. (2020),** In this paper Leachate analysis is done in order to determine the possible effects of sloppy landfilling procedures at solid waste disposal sites on groundwater quality. Leachate was created in the lab using a solid waste sample that was taken from the Sukali dumping site in the city of Amravati because there was no leachate collection and treatment facility nearby. The physicochemical analysis of the leachate indicated values higher than the acceptable limits, suggesting periodic leaching from the dumps and possible contamination of groundwater due to the leaching of heavy metals and mineral ingredients. Heavy metal analysis of the leachate revealed that iron (Fe), manganese (Mn), lead (Pb), copper (Cu), and cobalt (Co) were present above the permissible limits, except for zinc (Zn), indicating the possibility of heavy metal contamination from the dumps.

- **Sharma et al. (2019)**, This study aims to evaluate the contamination potential of leachate from four non-engineered dump sites situated in the Himachal Pradesh (India) areas of Solan, Baddi, Mandi, and Sundernagar. Investigations were done on how the leachate might affect the nearby groundwater. The focus of the analysis was to determine the leachate pollution index (LPI) by examining the leachate characteristics. Furthermore, the water quality index (WQI) was used to evaluate the groundwater quality at varying distances downstream from the dump site. The results showed that water quality improved with increasing distance from the dumpsite, as evidenced by the indexing method used.

- **Sanni et al. (2019)**, This study examines how landfill site leachate affects the groundwater quality index in certain Maiduguri regions. Various physicochemical parameters, such as turbidity, temperature, electrical conductivity (EC), pH, dissolved oxygen (DO), total dissolved solids (TDS), chemical oxygen demand (COD), iron (Fe), nitrate (NO_3), zinc (Zn), chromium (Cr), arsenic (As), copper (Cu), manganese (Mn), cadmium (Cd), and lead were measured in water samples collected during the wet and dry seasons. Using a Turbo pH/mV/temperature meter, pH, and temperature were measured on-site. A TDS meter was used to detect total dissolved solids, while turbidity and electrical conductivity were measured using an electrical conductivity meter, respectively. The Winkler technique was used to calculate the DO and BOD_5 while the Refluxing method was used to analyze the COD. Nitrate was determined calorimetrically using the Hach Colorimeter. The study utilized the multi-wave plasma atomic emission spectrophotometer to analyze heavy metals in water samples. Each sample was measured with 5 ml and placed in the system, where standard codes for each heavy metal were selected after calibration. Results showed that changes in groundwater temperature were associated with climatic conditions. The concentration of heavy metals such as Cr, Cd, Pb, Zn, Mn, and Cu decreased as the water table of an aquifer increased (from dry to wet season), while As and Fe increased. It was discovered that seasonal fluctuation has an early influence on soil as the concentrations grow with an increase in leachate in the rainy season, which in turn pollutes the groundwater. The calculated water quality index for the water samples varied from 10.61-72.4.

- **Kanownik et al. (2018)**, The aim of this study is to investigate the physicochemical components of groundwater that have changed in proximity to a small municipal solid waste dump in the European Union. Groundwater and leachate samples were collected four times a year during two periods, from 2013 to 2014, when the landfill was in the process of being closed. The findings indicate that increased levels of Cd, EC, and TOC were the primary factors leading to the negative impact of leachate on groundwater quality below the landfill. The elevated content of cadmium, as one of the microelements, was found to be responsible for the deterioration of the water quality.

- **Kavitha et al. (2018),** The objective of this study was to evaluate the physicochemical properties of water samples from different sampling points in Dindigul, Tamilnadu. These physicochemical properties including hardness, temperature, EC, chlorides, pH, alkalinity, DO, COD, BOD, sulphate, and phosphate. It was discovered that the concentration of contaminants was higher in regions with a larger load of residential sewage, which is responsible for 75% of water contamination. Various wastes, like detergent and soap, garden waste, kitchen waste, human rubbish, and excreta, are included in domestic sewage. These wastes contain minute quantities of hazardous metals and decomposable oxygen matter. The results showed that the water sample's average pH value was between 7.09 and 7.81, its total hardness was 464 mg/l, its electrical conductivity was 1950 S/cm, its chloride content was 262 mg/l, its total dissolved solids were 1326 mg/l, its sulphate content was 59 mg/l and its phosphate content was 0.10 mg/l. This study illustrated how waste from markets and households can pollute the water supply. Therefore, urgent water quality management is necessary to meet the water quality standards established by the World Health Organization.

- **Olagunju et al. (2017),** In this study potential effects of the waste dumpsite on the groundwater in and around the Ilokun surroundings were conducted. Seven water samples were taken on the trash disposal site. Two water samples from boreholes and five water samples from hand-dug wells were obtained. The concentration of cations such as Ni, As, Sr, Rb, Zn, P, Zr, and K which ranges from 500 to 2444ppm, 113 to 1094ppm, 166 to 1257ppm, 70 to 1131ppm, 251 to 714ppm, 24 to 161352ppm, 1500 to 12914ppm, and 542 to 1065ppm, respectively. The World Health Organization's requirements and the Nigerian norm for potable water quality were found to be exceeded by the concentration levels of a few metrics in the water samples. More specifically, the water's alkalinity levels, which varied from 120.0 to 232.0 mg/l as $CaCO_3$ were higher than the permitted upper limit for drinking water. Additionally, high concentrations of metals like iron and lead were found in several of the study area's wells, indicating that the groundwater in many of the studied hand-dug wells and boreholes is unfit for human consumption.

- **Deepanshu et al. (2015)**, The physio-chemical properties of groundwater in the vicinity of the Gazipur landfill site were examined and compared to data obtained prior to the implementation of the lining system. Water samples were collected from nearby locations and the concentrations of various physicochemical parameters, as well as microbiological parameters and traces of heavy metals, were analyzed. The results of the study suggest that the installation of lining and covering systems at specific parts of the landfill has effectively minimized further groundwater contamination.

- **Atul et al. (2015)**, The present research focuses on the Okhla municipal disposal site located in Delhi. toxicological and physiochemical analyses were conducted on the leachate samples to evaluate the extent of pollution and contamination present in the water. The results showed significant variations in the properties of leachate depending on the sampling time. The analysis revealed that fresh leachate has a high organic content and, low pH while old leachate has lower organic content and high pH due to degradation. However, both types of leachates are highly polluted and pose a severe threat to human health and the environment, surpassing the pollution potential of municipal sewage.

- **Agrawal et al. (2015)**, This study, conducted in the Indian city of Dhanbad, sought to determine the effects of unrestrained and unscientific municipal solid waste (MSW) disposal on groundwater quality. Water samples were taken at various distances from two locations in Hirapur as part of research that concentrated on the quality of groundwater near MSW disposal facilities. The results demonstrate that the drinking water quality standard established by IS:10500-2012 is not being met by the groundwater near dumping sites. The impact of unregulated MSW disposal on groundwater was evident from the high levels of electrical conductivity, total dissolved solids, chemical oxygen demand, sulphate, and chlorides found in the water samples. Additionally, the groundwater samples had high levels of various metals, including K, Na, Mg, Ca, Cd, Ni, Cu, Fe, Mn, and Zn. The leachate characterization analysis also revealed a considerable risk of groundwater contamination. The presence of fecal coliform contamination in groundwater suggests that those who drink it may be at risk of developing health issues.

- **Ramachandra et al. (2014),** This study investigates the properties of leachate produced by municipal solid waste dumpsite and its impact on the surrounding water bodies near the Mavallipura dumpsite area in Bangalore. Two water samples were taken from a downstream well and pond in the Mavallipura dumpsite. The leachate's physicochemical analysis found that it had significant amounts of organic and inorganic elements, exceeding the allowable limits. The pH of the leachate was 7.4, which was somewhat alkaline. Furthermore, iron had the greatest metal content in the leachate, at nearly 11.16 ppm. The leachate's BOD_5 and COD readings were 1500 mg/l and 10400 mg/l, respectively, reflecting severe levels of pollution.

- **Amadi et al. (2014**), A study was conducted in Lagos, Nigeria to assess and compare the impact of an abandoned and functional waste dump site on the quality of groundwater in the surrounding area at Olusosun and Oke-Afa . water samples were collected from nine hand-dug wells located at different distances from the dumpsites. The levels of microbial, heavy metal and physicochemical parameters were analyzed. Conductivity, pH, Total dissolved solids, total solids, Biochemical oxygen demand, Dissolved oxygen, Chloride, Acidity, Hardness, Alkalinity, Nitrate, Phosphate, copper, Sulphate, cadmium, lead, zinc, chromium and iron, Total coliform, Total heterotrophic fungi, and Total heterotrophic bacteria, were determined in the water samples. The findings demonstrated that, except for sulphate and phosphate, the mean concentration of physicochemical parameters was greater in wells close to the operational dumpsite at Olusosun. However, all the indicators examined fell within the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality allowed ranges (NSDWQ). Except for lead in both dumpsites, the metal concentrations in the water samples were within WHO and NSDWQ acceptable levels. Wells close to the Olusosun and Oke-Afa dumpsites have mean lead concentrations of 0.17 and 0.86 mg/l, respectively.

- **Patil et al. (2013)**, To investigate the impact of dumpsite on groundwater quality, this paper analyzed the chemical, bacteriological, and physical properties of water samples from three bore wells situated near Turmuri landfill site in Belgaum. The study was conducted between February and May, and the selected bore wells were located at distances of 500, 750, and 1000 meters from the dumpsite. The researchers employed standard laboratory techniques to measure various parameters such as total hardness, total dissolved solids (TDS), pH, and heavy metals like lead. During February to March, the pH values were found to be acidic in nature and ranged from 6.01 to 6.96. The bore wells located within 500 meters of the landfill site exhibited concentrations of TDS, nitrate, and hardness that ranged from 49 to 190 mg/L, 4 to 79.89 mg/L, and 0 to 80 mg/L, respectively. The findings of the investigation revealed that the boreholes situated within 500 meters from the landfill site contained nitrate and E. coli bacteria concentrations that surpassed the permissible limits for drinking water established by the Bureau of Indian Standards and World Health Organization (WHO), whereas the wells between 500 and 1000 meters were within BIS and WHO guidelines' permitted ranges.

- **Kumar et al. (2012)**, In this investigation, groundwater samples impacted by leachate was collected between December 2008 and May 2009 at several places, including the Union Carbide Area, Bhanpor district, Mohali village, Shivnagar, Nishatpora, and Peoples Group Colony. Several physicochemical parameters, including electrical conductivity, total dissolved solids, pH, dissolved oxygen, alkalinity, free carbon dioxide, total hardness, biological oxygen demand, and chloride, as well as bacterial parameters, including total coliform, and fecal coliform, were measured using standard techniques in each collected sample to assess the effect of leachate percolation on groundwater quality. The findings revealed that the World Health Organization's (WHO) recommended limits for drinking water were surpassed by the electrical conductivity (EC), Na+, and total dissolved solids (TDS) levels in 100%, 37.5%, and 62.5% of the groundwater samples. Furthermore, pH and Fe levels in 75% of the samples.

- **Yusoff et al. (2011)**, This study aims to evaluate the impact of dumpsite pollution on groundwater quality by conducting chemical, bacteriological, and physical analyses of water samples from three boreholes situated near a landfill in Akure, Nigeria. The boreholes were located at radial distances of 50m, 80m, and 100m, respectively, away from the landfill. The findings indicated inadequate sanitation and potential health risks to both humans and animals if surrounding well waters were used for domestic purposes. The high levels of bacteriological and chemical contamination in the water from the boreholes suggest the possibility of health problems, such as worm infestation and typhoid fever, if such water is consumed in its current state.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 STUDY AREA

Delhi, India's capital, is spread out over a 1484 km^2 region and is located at latitudes 28° 35'N and longitudes 77° 12'E at 218 meters altitude above mean sea level. The Eastern Ghats Plain and the Aravalli Ridge's integration, which results in alluvial plains and quartzite bedrock, shapes Delhi's geological landscape. The semi-arid climate of Delhi is characterized by hot summers, cold winters, and extremely dry conditions. The temperature varies from 18.7 ° C (mean minimum) to 40.3 ° C (mean maximum). Delhi faces significant rainfall, particularly during the monsoon season, at an average of 714.6 mm. In Delhi, the depth of the subsurface water is between 45 and 60 meters. Delhi, which has a population of nearly 16.754 million, produces 10990 metric tonnes of garbage every day. It primarily consists of waste from hospitals, houses, and businesses companies. In 1975, Delhi's first dumpsite was built close to the Ring Road. So far, 20 landfill have been built out of which 17 landfills have already been filled and shuttered. There are currently Ghazipur, Okhla, and Bhalswa are the three high-operating landfill sites. Because none of those bases are lined, continuous wastewater injection is possible. Before being used for disposal sites, these facilities were not thoroughly planned. Furthermore, prior to the selection of these sites, no environmental risk assessment was performed. In the present study, the Bhalswa dumpsite is selected.

Figure 3.1 Location of Bhalswa and other landfill sites in Delhi. (Source: Google Maps)

3.1.1 LOCATION

The Bhalswa landfill, which is in the northeast of the city, is the subject of the investigation. The landfill was built in 1993 and has a land area of about 31 hectares. There is no scientific lining material used to line it. Approximately 2200 tonnes of waste are delivered to the Bhalaswa landfill site every day, mostly from the North Delhi Municipal Corporation's Civil Lines, Karol Bagh, Rohini, and Najafgarh zones (NDMC). A number of communities, including Bhalaswa, Rajiv Nagar, Jahagirpuri, Mukundpur, Swami Shradhanand Park, Nathupura, and others, surround the dump site. Geographically, the landfill is located at 28°44'26"N latitude and 77°9'26"E longitude. The Delhi Tourism-maintained Bhalaswa lake is not far from the Bhalaswa dump. The majority of the garbage that enters the system is generated in residential and commercial sectors, and it is transported from municipal dhalaos to the dump. However, some waste from industrial areas is also dumped at the landfill, as Jhamnani and Singh (2009) point out. In 1999, a private developer named Natural Waste Management India Limited built a 300-ton-per-day compost treatment facility on the property. The landfill facility is still in use even though it has already reached its maximum capacity, posing serious threats to human life and property. There are no acceptable locations to build a new dumpsite due to the high population density. Therefore, in order to manage and dispose of the garbage at the present landfill site, the government is looking into a number of technologies to segregate inert material, set up e-waste treatment facilities to deal with electronic waste disposed together with municipal solid refuse to recover the landfill.

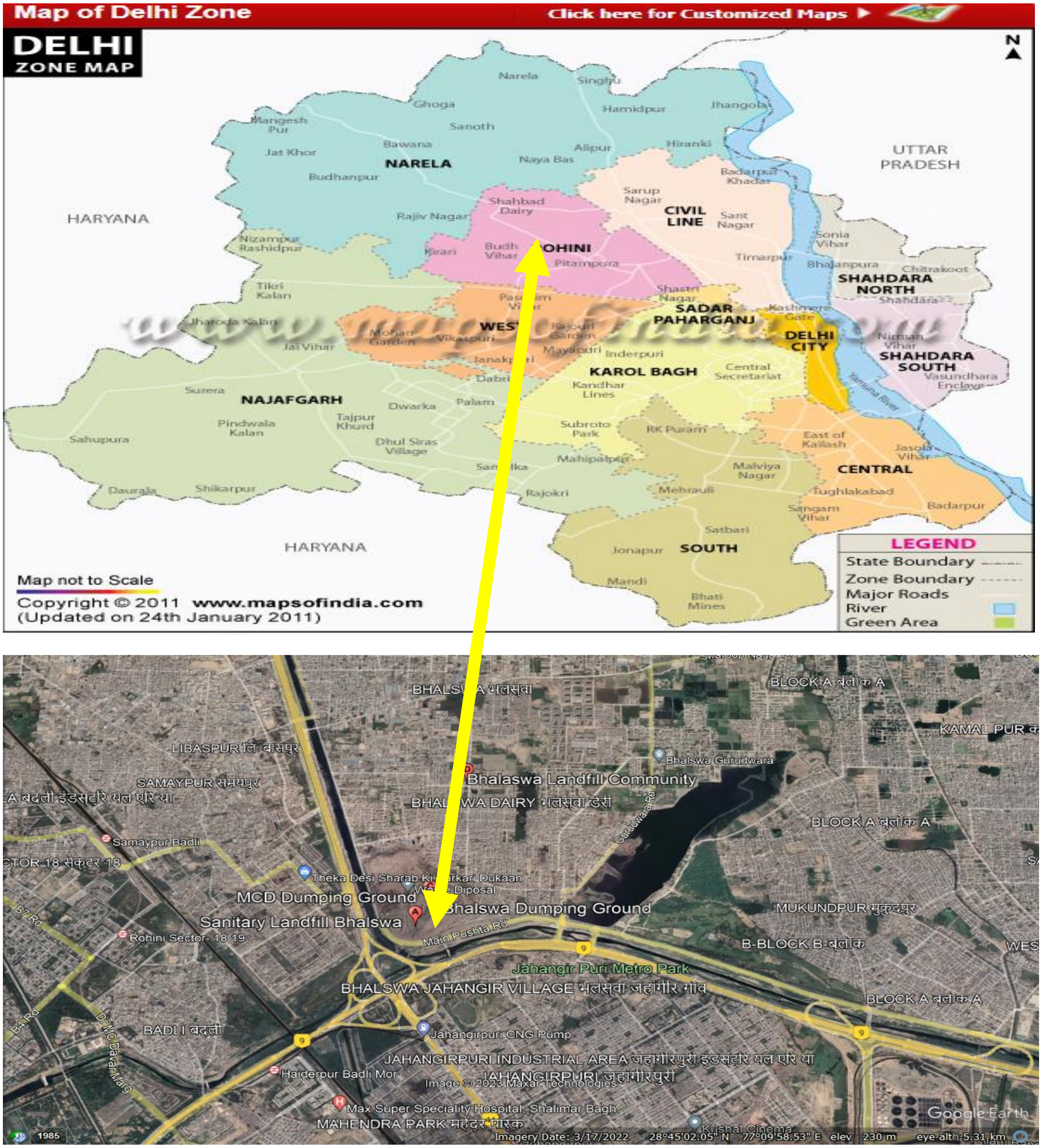

Figure 3.2 Study Area: Bhalaswa Landfill, New Delhi

3.1.2 GEOLOGY OF AREA

The qualities of the groundwater are directly impacted by the hydrogeological features of the region. Most of the rocks in the study region are hard quartzite and alluvial. The region is also traversed by the Delhi Ridge, which may be found at the most northern point of the Aravalli Mountains. The features of the alluvial deposits on either side of the ridge vary. The soil of Bhalswa is made up of a polycyclic sequence of brown silt, clay, and gravel, according to the Geological Survey of India. Different drainage and topographical patterns, as well as the existence of different mineralogical deposits, are to blame for the variance in soil types. One of the main resources used to sustain life in Delhi is groundwater. Drinking, cleaning, bathing, and other human activities are done using groundwater. Groundwater can be found up to a depth of 60 meters in about 90% of Delhi's geographic area and is regarded as safe for consumption. However, the groundwater table in the Bhalswa region is 7 to 10 meters below the surface, making it susceptible to contaminant leaching.

3.2 METHODOLOGY

3.2.1 SAMPLING

Clean plastic bottles of 500 ml capacity were used to collect samples of both leachate and groundwater. Prior to collecting samples from the sampling points, the bottles were thoroughly rinsed. From December 2022 and January 2023, five leachate samples are taken around the Bhalswa landfill site, and ten groundwater samples are taken between the Bhalswa landfill to Delhi Technological University. Groundwater samples were collected with the help of handpumps found in homes, businesses, temples, or nearby areas, each location of the groundwater sample is depicted in Figure 3.3. The location of leachates is depicted in Figure 3.4. Groundwater sampling was done at various lateral distances from the dump site shown in Table 3.1 and after sample collection samples were delivered to the lab of the environment at Delhi technology university for physicochemical analysis.

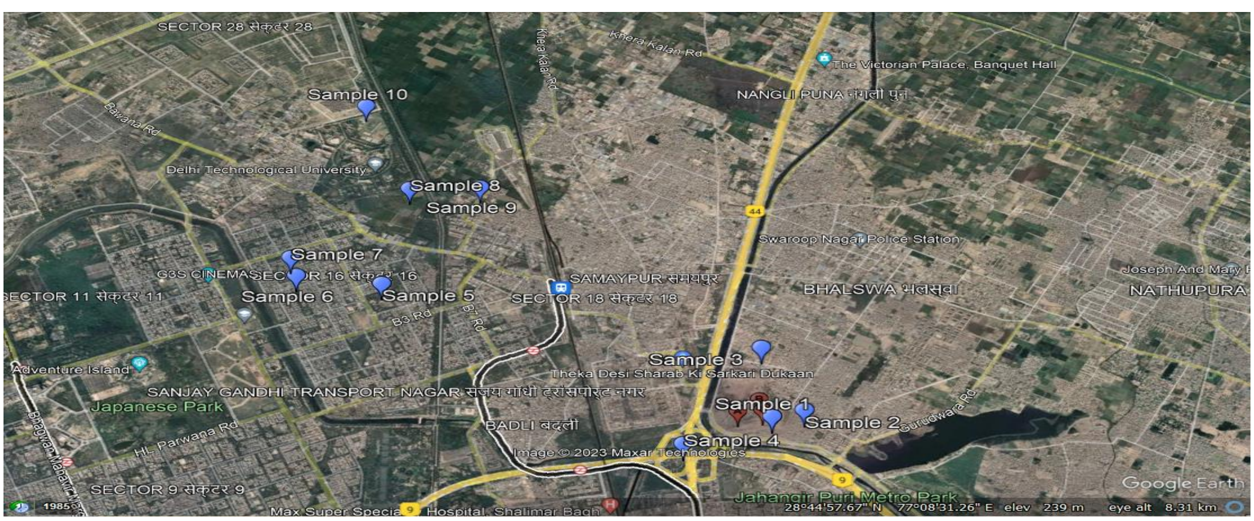

Figure 3.3 Location of groundwater samples

Figure 3.4 Location of leachate samples at Bhalswa landfill site

3.2.2 SAMPLES ANALYSIS

The entire analysis process was carried out as per the central pollution control board recommended methods in the environment lab at Delhi Technological University (CPCB Manual for water and wastewater analysis). The physiochemical properties of each sample of leachate and groundwater were studied. The samples of leachate were investigated for Total Dissolved Solids (TDS), pH, Total Hardness, Alkalinity, Electrical Conductivity (EC), Chloride (Cl), Sulphates (SO4), Nitrate (NO3), Total Phosphate (TP), Magnesium (Mg) and Calcium (Ca).

Figure 3.5 Leachate samples collection at Bhalswa landfill site

Similarly, the investigation for groundwater was done for the parameters like Total Dissolved Solids (TDS), pH, Total Hardness, Alkalinity, Electrical Conductivity (EC), Chloride (Cl), Sulphates (SO4), Nitrate (NO3), Total Phosphate (TP), Magnesium (Mg) and Calcium (Ca).

Figure 3.6 Groundwater samples collection

Table 3. 1 Show the lateral distance of the groundwater samples collected from Bhalswa landfill site

Sample no.	Lateral distance of groundwater sample from Bhalswa Landfill site
Sample 1	366.82 m
Sample 2	443.14 m
Sample 3	557.09 m
Sample 4	679.07 m
Sample 5	2890 m
Sample 6	3220 m
Sample 7	3510 m
Sample 8	3630 m
Sample 9	4240 m
Sample 10	4290 m

The following Table 3.2 categories the parameters studied along with the equipment used and the recommended methods to assess the data from the samples:

Table 3.2 Shows the methods and equipment’s used for the analysis of different parameters.

Parameters	**Methods**	**Equipment used**
pH	Electrometric	Multielectrode water quality meter
Conductivity	Electrometric	Multielectrode water quality meter
TDS	Electrometric	Multielectrode water quality meter
Salinity	Electrometric	Multielectrode water quality meter
Sulphate	-	UV spectrophotometer
Nitrate	-	UV spectrophotometer
Phosphate	-	UV spectrophotometer
Chloride	Titration	-
Total hardness	Titration	-
Calcium	Titration	-
Alkalinity	Titration	-
Magnesium	Titration	-

Figure 3.7

Figure 3.8

Figure 3.9

Figure 3.10

Figure 3.11

Figure 3.7 - Sample preparation

Figure 3.8 - pH determination by using a multiparameter water quality meter.

Figure 3.9 - Conductivity, resistance, and TDS determination by using a multiparameter. water quality meter

Figure 3.10 - Titration for determination of chloride, total hardness, and calcium concentration

Figure 3.11 - UV Spectrophotometer for phosphate, nitrate, and sulphate determination

CHAPTER 4

RESULTS AND DISCUSSION

4.1 LEACHATE ANALYSIS

Precipitation and the type of waste present in the landfill both affect how the leachate behaves. The average value for each parameter is evaluated and compares these results to the general guidelines for the discharge of environmental contaminants into inland surface water bodies given by the Central Pollution Control Board, New Delhi. The outcomes of the laboratory tests carried out to examine the parameters are shown in Table 4.1.

Table 4.1 Shows Bhalswa leachate samples physicochemical characteristics

Parameters	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean	CPCB limit
Conductivity, µS/cm	4610	12320	44900	65600	69900	39466	-
TDS, mg/l	2340	6110	24400	32700	34900	20090	100
pH	5.22	5.32	5.69	5.20	6.8	5.64	5.5-9
Chlorides, mg/l	4260	1775	3195	3550	4970	3550	-
Phosphate, mg/l	1891	1174	2083	2237	1883	1853.6	5
Nitrate, mg/l	19527	10059	22056	23456	25487	20117	10
Sulphate, mg/l	908	42	262	82	66	276	-
Total Hardness, mg/l as $CaCo_3$	3000	2000	2000	2000	3000	2400	-
Calcium, mg/l as $CaCo_3$	1603	1202	801.6	1603	2806	1603.12	-
Magnesium, mg/l as $CaCo_3$	1397	798	1198.4	397	194	796.88	-
Alkalinity, mg/l as $CaCo_3$	700	800	700	500	600	660	-

pH

The mean pH value of leachate samples is 5.64, which is acidic. This mean pH indicates that the leachate was young and at an acidic stage when waste was disintegrating (Lo et al., 1996). if the pH value is basic in nature, then it indicates that the final stage of the landfill's biological processes has been reached, and the organic material there has now entirely stabilized. The pH range recommended by the CPCB is 5.5-9. According to the current research, the pH range is safe for the discharge of leachate into inland surface water bodies.

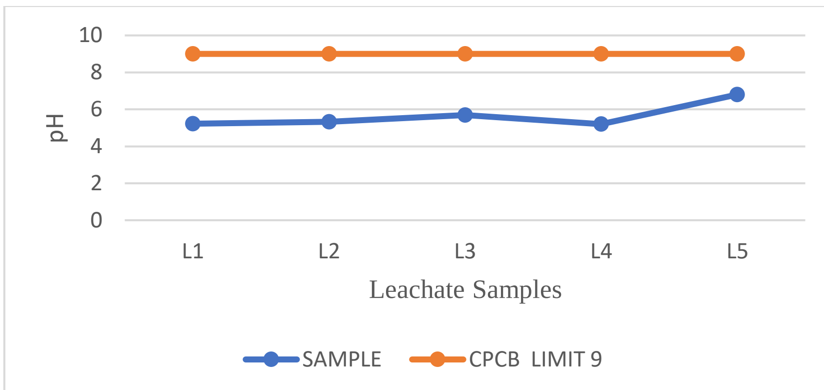

Figure 4.1 Show a comparison of pH with the CPCB limit

TDS & EC

In the present study conductivity ranged between 4610 and 69900 µS/cm with a mean value of 39466 µS/cm. The average value of total dissolved solids, which ranges from 2340 to 34900 mg/l, is 20090 mg/l. The TDS standard recommended by the CPCB is 100 mg/l therefore according to the current research, the TDS exceeds the standard recommended by the CPCB.

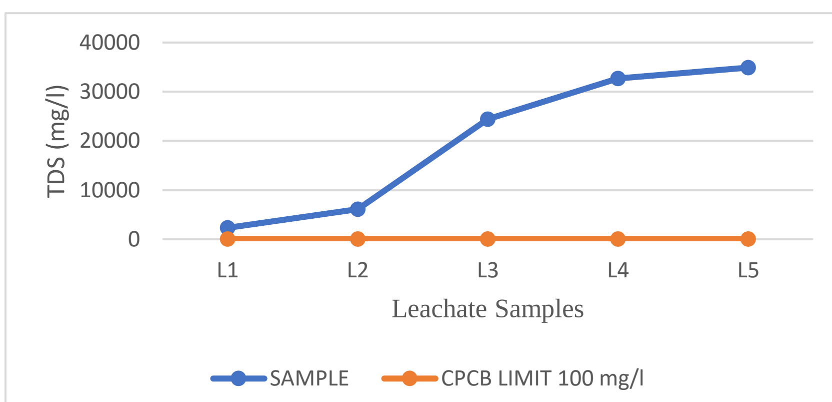

Figure 4.2 Show comparison of TDS with CPCB limit

CHLORIDE

One of the anions examined in the leachate samples was chloride. According to Hem et al. (1971), the presence of chloride in leachate is a result of an ion exchange mechanism between the infiltrating water and the rock, which aids in groundwater renewal. The concentration of chloride in the leachate was determined in the range of 1775 mg/l to 4970 mg/l with a mean value of 3550 mg/l.

NITRATE

It is a form of nitrogen that is commonly found in wastewater, indicating the final product of aerobic waste decomposition. The presence of nitrate indicates the presence of organic matter in the waste composition, which can lead to nitrate poisoning or methemoglobinemia. The Central Pollution Control Board (CPCB) established standards for discharge in 2001, setting a maximum limit of 10 mg/L for nitrate in inland surface waters. In the present study, the nitrate content was found in a range from 10059 to 25487 mg/L with a mean value of 20117 mg/L.

PHOSPHATE

Phosphates are divided into two types, orthophosphate, and organic phosphate. Orthophosphates enter in the waste through agricultural waste and fertilizers, whereas organic phosphate is formed primarily through biological processes. In the present study, the total phosphate content in the leachate samples of dumpsite was found in the range of 1174- 2237 mg/l with a mean value of 1853.6 mg/l.

TOTAL HARDNESS

The total hardness in the leachate samples of the dumpsite was found in the range of 2000- 3000 mg/l with a mean value of 2400 mg/l since this hardness is due to the multivalent cation of magnesium and calcium. In the present study, the calcium and magnesium content in the leachate sample was found in the range of 801.6-2806 mg/l and 194-1397 mg/l with a mean value of 1603.12 and 796.88 mg/l respectively.

ALKALINITY

The value of alkalinity in the current study is caused solely by the presence of bicarbonates. The current study determines that the value of HCO_3 (bicarbonate) in the range of 500-800 mg/l with a mean value of 660 mg/l.

SULPHATE

In the current study the value of sulphate content in leachate samples was found in between 42 and 908 mg/l with a mean value of 276 mg/l. However, CPCB does not recommend any limit for sulphate.

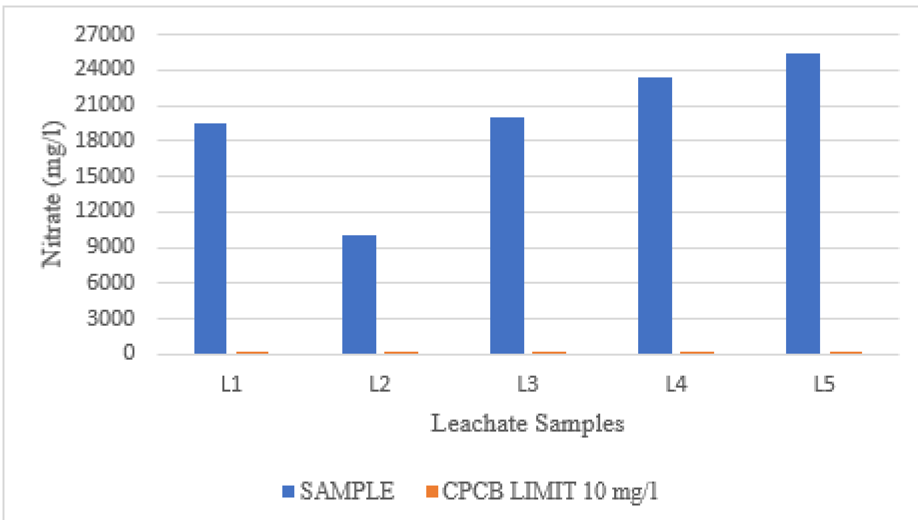

Figure 4.3 Show comparison of Nitrate with CPCB limit

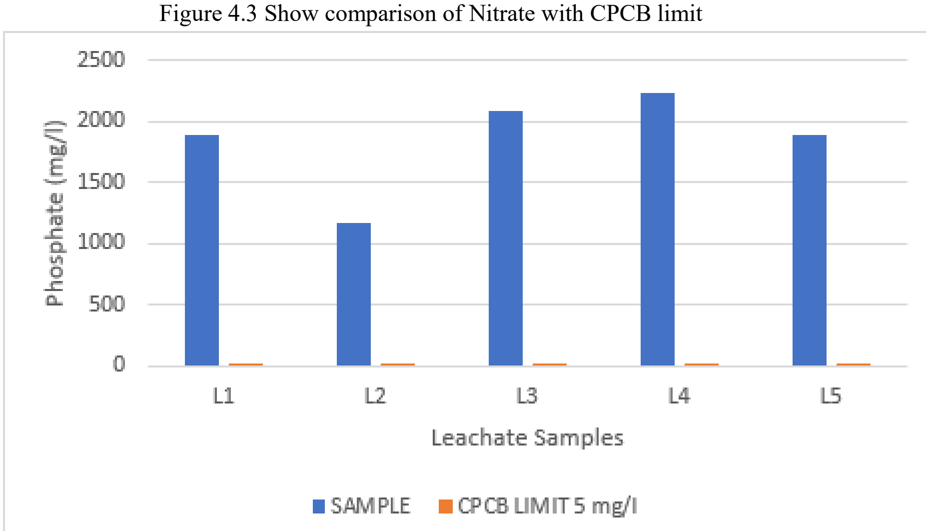

Figure 4.4 Show comparison of Phosphate with the CPCB limit

4.2 GROUNDWATER ANALYSIS

The groundwater in the study region is used for, drinking water, cleaning washing and other household chores. The handpumps are used to gather all the water samples. The physicochemical properties of the samples were investigated. The outcomes of the laboratory examination of groundwater samples are shown in the following Table 4.2.

Table 4.2 Show different physicochemical parameters in various groundwater samples

Parameters	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	BIS LIMIT
Conductivity, µS/cm	6610	3557	3354	3727	869.5	765.4	799.8	372	341.6	275.4	-
TDS, mg/l	3239	1744	1644	1827	527	476	392	1163	461	136	500
pH	6.81	6.87	6.91	6.95	7.06	7.11	7.04	6.91	7.17	6.74	6.5-8.5
Chlorides, mg/l	124.3	63.90	53.25	85.20	14.2	17.75	17.75	49.70	10.65	10.64	250
Phosphate, mg/l	0.0008	2.1465	_	1.6018	_	0.5051	0.4511	_	0.8663	0.0052	-
Nitrate, mg/l	21.048	170.87	16.64	13.07	9.36	7.09	5.86	68.56	3.12	2.84	45
Sulphate, mg/l	160.28	131.02	65.02	137.26	44.92	54.56	53.91	107.80	71.74	42.19	200
Total Hardness, mg/l as $Caco_3$	1210	930	710	900	350	280	420	700	290	190	200
Calcium, mg/l as $Caco_3$	432.9	336.7	212.4	308.6	56.11	40.08	92.18	252.5	72.14	20.04	75
Magnesium, mg/l as $Caco_3$	777.1	593.3	497.6	591.4	293.9	239.9	327.8	447.5	69.9	89.7	30
Alkalinity, mg/l as $Caco_3$	1700	1200	1100	700	600	600	700	600	700	300	200

pH

Any aqueous liquid's acidity or basicity can be determined by looking at its pH. It gauges the hydrogen ion's activity. The sample is regarded as neutral if the pH is 7. A value under or over 7 denotes an acidic or basic nature, respectively. In the present study, the pH was found to be between 6.74 and 7.17. therefore, the groundwater sample is almost neutral Although pH has no negative effects on health, a value less than 4 produces a sour taste, while a value greater than 8.5 produces an alkaline taste. The pH range recommended by the BIS is 6.5-8.5. According to the current research, the pH range is safe for drinking water.

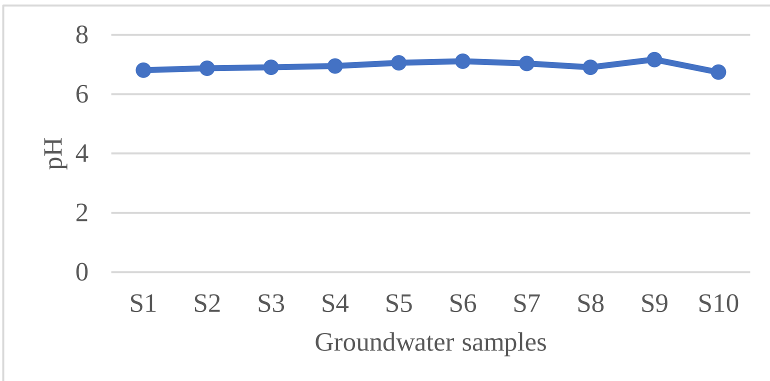

Figure. 4.5 Shows the pH in various samples of groundwater

EC & TDS

Electrical conductivity is used to calculate the total dissolved solids in water. It stands for the water's resistance to an electric current. It is a reliable indicator of the water's overall salinity. TDS accounts for both the organic matter and inorganic salts that are dissolved in water. Water's flavor may change when dissolved solids are present in high concentrations. TDS can have a dull taste and still be harmful to human health at low concentrations. The relationship between TDS and EC values is usually proportional. It was discovered that the studied area's electric conductivity ranges from 275.4-6610 µS/cm. According to BIS 2012, The desirable value of TDS is 500 mg/l and the acceptable maximum value for TDS is 2000 mg/l. If TDS in water exceeds 500 mg/l, it may irritate the digestive tract. TDS was discovered in the present study, ranging from 136-3239 mg/l.

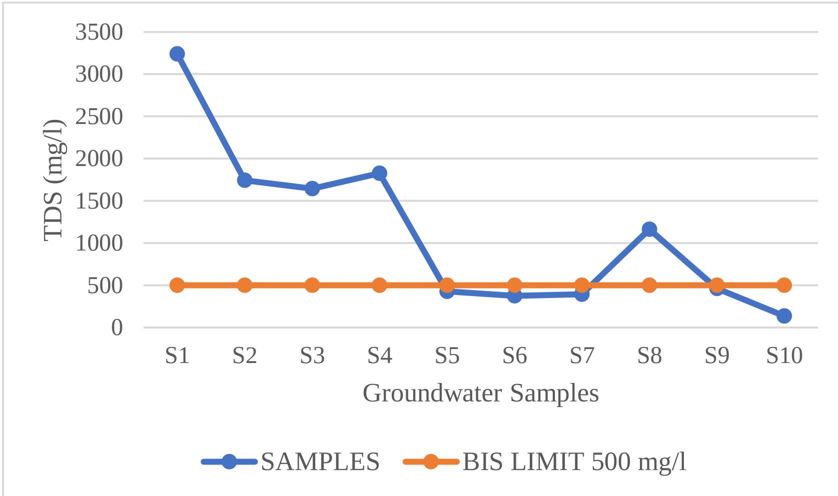

Figure 4.6 Show a comparison of TDS content in groundwater samples with BIS limit

SULPHATE

The maximum and minimum values of sulphate in the current study are 44.92 mg/l and 160.28 mg/l, respectively. As per the IS code 10500: 2012 (BIS code). The maximum allowable content of sulphate in drinking water is 200 mg/l. Therefore, sulphate content in all samples lies within the range recommended by the Bis code.

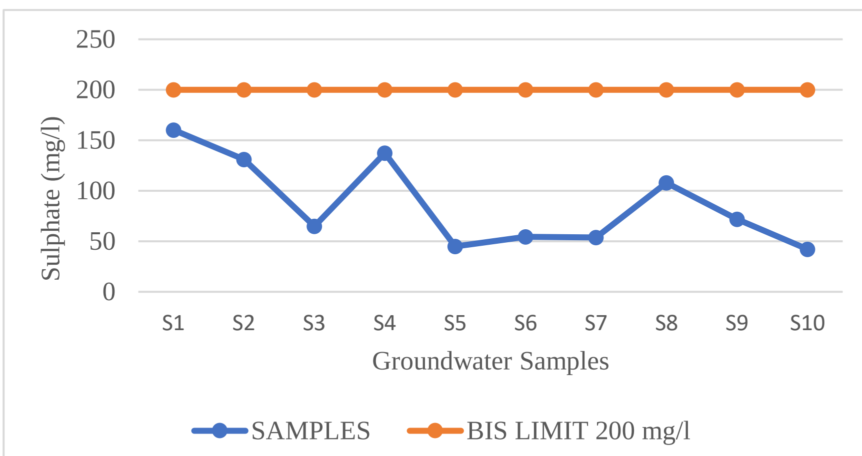

Figure 4.7 Show a comparison of Sulphate content in groundwater samples with the BIS limit

NITRATE

Domestic sewage, and runoff from agricultural fields, are the primary sources of nitrate in groundwater (Srivastava & Ramanathan, 2008). Nitrate concentrations in the vicinity of the Bhalswa landfill ranged from 2.84 to 170.87 mg/l. According to BIS (2012), nitrate levels in water should not be greater than 45 mg/l. In the current study, the result indicated that the nitrate concentration is significantly lower than the standard except in sample 2 and sample 8 which is shown in Figure 4.8.

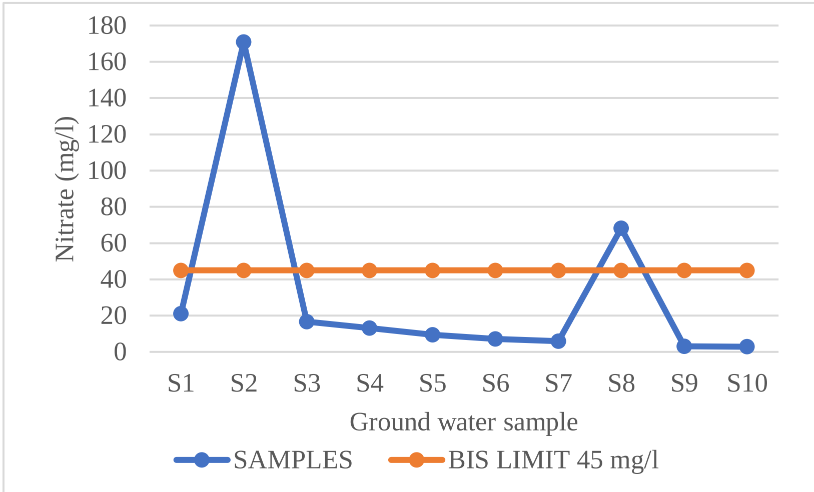

Figure 4.8 Show a comparison of Nitrate content in groundwater samples with the BIS limit

ALKALINITY

According to BIS, 200 mg/l is the maximum desirable value for alkalinity. The value of alkalinity in the current study is caused solely by the presence of bicarbonates. The current study determines that the value of HCO_3 is between 300 and 1700 mg/l. Figure 4.9, illustrates how the bicarbonate ion value exceeds the desired limits.

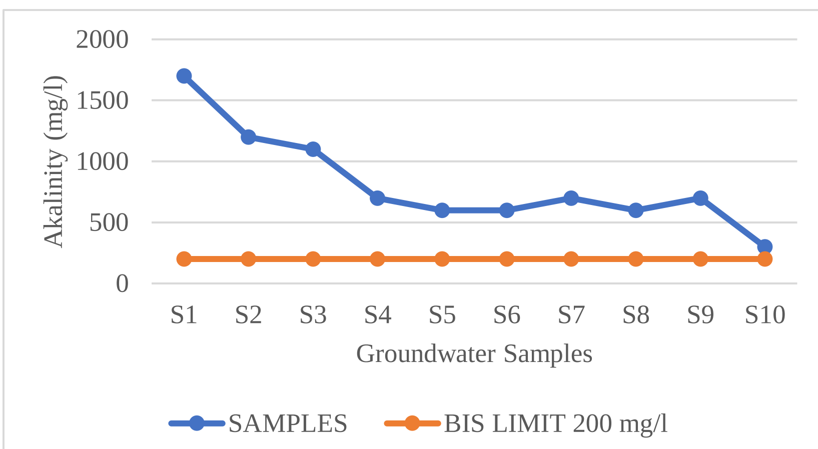

Figure 4.9 Show a comparison of Alkalinity in groundwater samples with BIS limit

CHLORIDE

According to WHO, Natural sources of chlorides include the salts of sodium, potassium, and calcium. Samples of leachate frequently have an abundance of chloride ions. The biochemical reaction occurring in the site or the natural decomposition reactions involving leachate as it passes in the vadose zone has no effect on chloride because it is a conservative contaminant. The minimum and maximum desirable values for chloride content in water according to BIS are 250 mg/l and 1000 mg/l, respectively. Chloride levels in the water samples found in the present study ranged from 10.64-124.6 mg/l.

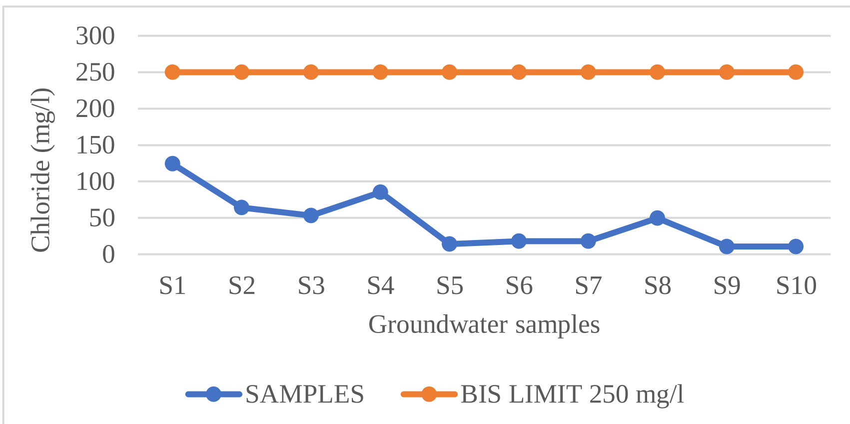

Figure 4.10 Show a comparison of Chloride in groundwater samples with the BIS limit

PHOSPHATE

Phosphates are divided into two types, orthophosphate, and organic phosphate. Orthophosphates enter the waste through agricultural waste and fertilizers, whereas organic phosphates are formed primarily through biological processes (WHO). In this study, phosphate concentrations in groundwater samples were much lower than other parameters. In comparison to all other parameters, the values obtained were the lowest. The lowest total phosphate value was 0.0008 mg/l in sample1 and the highest was 2.1465 mg/l in sample 2. The Indian government has not established any standards for phosphate content in drinking water standards.

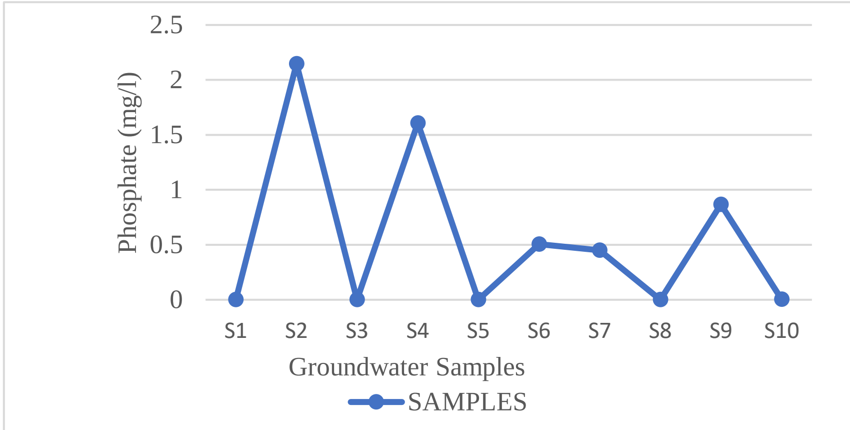

Figure 4.11 Shows Phosphate in various samples of groundwater

TOTAL HARDNESS

Natural water frequently contains significant amounts of multivalent cations, mainly calcium, and magnesium. They quickly precipitate and interact with soap scum, which is very challenging to remove. Calculating hardness involves adding up all the calcium and magnesium ions equivalent to $CaCO_3$. As per BIS 2012, the maximum desirable limit for total hardness in water is 200 mg/l, while the acceptable limit is 600 mg/l. In this study, the total hardness value ranges from 190 to 1210 mg/l. Calcium values 20.04-432 mg/l and Magnesium values are 69.9-777.1 mg/l as CaCO3, respectively. According to BIS standards, the maximum permitted values for calcium and magnesium are 75 mg/l and 30 mg/l, respectively.

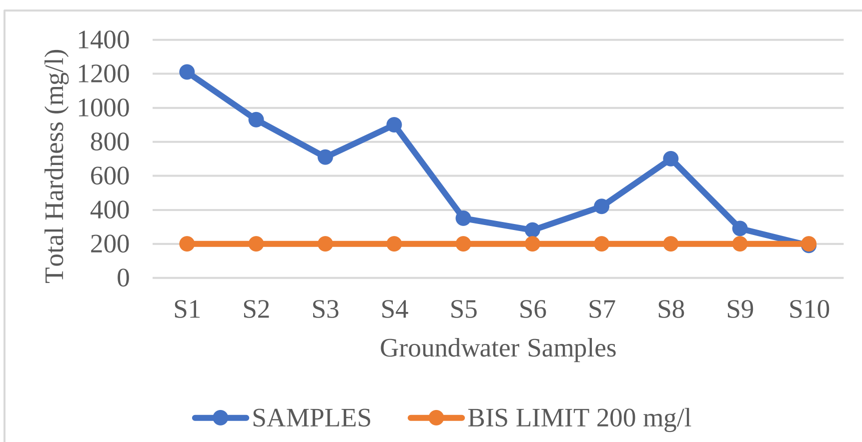

Figure 4.12 Show a comparison of the Total Hardness in groundwater samples with the BIS limit

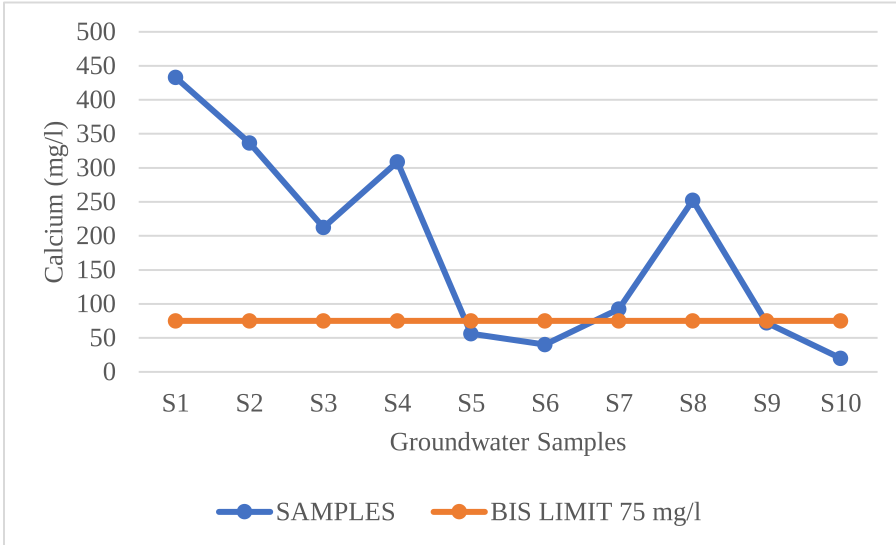

Figure 4.13 Show a comparison of the Calcium content in groundwater samples with BIS limit

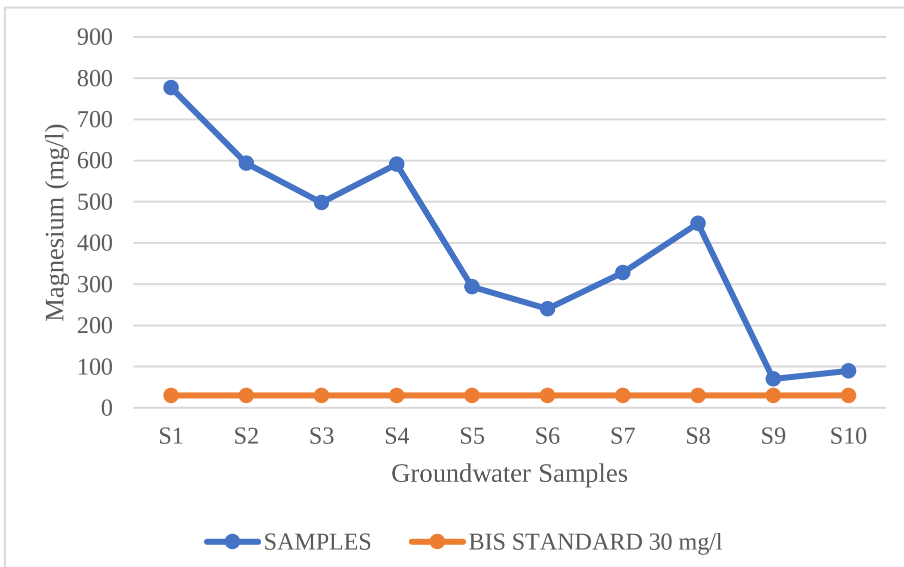

Figure 4.14 Show a comparison of the Magnesium content in groundwater samples with BIS limit

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The National Capital Territory (NCT) of Delhi has a population that is greater than its carrying capacity, which has led to a high demand for essential services like safe drinking water. The environmental balance has been upset by widespread pollution brought on by population growth. Monitoring the generation and disposal of solid waste is the main task facing the government**.** The creation of landfill leachate and its detrimental impact on the quality of groundwater in the surrounding areas are the main topics of this study. The study comes to a number of conclusions regarding the topic being discussed.

- The pH of leachate produce at Bhalswa landfill has a mean value of 5.64 which is acidic. This mean pH indicates that the leachate was young and at an acidic stage when waste was disintegrating.
- The physiochemical parameter like pH, total dissolved solids (TDS), alkalinity, sulphate, nitrate, electrical conductivity, chloride, Hardness, and phosphate in groundwater up to the lateral distance of 3220 m from Bhalswa landfill exceeds the permissible limit recommended by BIS code. and thus, drinking this groundwater may cause diseases like kidney failure, hypertension, and stomach pain.
- The groundwater at 4290 m (around Delhi technological university) is fit for drinking and domestic purpose since all the parameters listed above lie within the BIS code's range.
- Organic waste at the Bhalswa landfill continuously decomposes, releasing gases into the atmosphere that pose a serious threat to both local and global environments. Since methane is released due to the degradation of waste in the landfill, which increases the greenhouse effect.

5.2 RECOMMENDATIONS

India, a developing nation, is still in the early stages of developing engineered landfill design. An engineered landfill is a location created to hold solid waste while reducing negative effects on the neighborhood. Experts construct landfills to provide total isolation from the environment, limit damage to property and life, and increase capacity. Proper hydrogeological techniques are used to ensure the isolation, and the base of the landfill is lined with a substance known as a liner. Leachate is prevented from seeping down to the landfill's base and coming into contact with soil and groundwater by liners used in constructed landfills, which can be made of natural or synthetic materials. Facilities for the collection and treatment of leachate are part of an engineered landfill design. The supervision of landfill operations is the responsibility of a group of knowledgeable and experienced staff.

The Indian government has made progress in implementing engineered landfills in various locations, such as Auda (Gujarat), Puttur (Karnataka), Surat (Gujarat), Karwar (Karnataka), Pune (Maharashtra) and many more. However, the lack of engineered landfill facilities in the capital remains a significant issue. To address this, alternatives such as using natural liners like compacted clay can be considered. Compacted clay is an effective liner that is easily accessible, cheap, and requires no specialized supervision, making it ideal for small villages and towns. Several recommendations can be made to improve the current situation.

- Untreated leachate which is produce by landfill can pollute water bodies if it is released into them. This problem may be avoided by forming an effective leachate-collecting system at the discharging body's outlet and sending the collected leachate to treatment facilities.
- A suitable liner should be employed to stop the ongoing leaching of contaminants and the subsequent contamination of water qualities.
- In order to limit leachates from the Bhalswa landfill, proper management should be implemented to separate out or eliminate hazardous solid wastes before dumping.
- It could be best to close the active landfills as soon as possible to stop creating new pollutant sources.

5.3 FUTURE SCOPE OF THE STUDY

- Seasonal factors, such as pre-monsoon and post-monsoon periods, can also be considered during sampling. By doing so, a more accurate determination of the exact contamination can be obtained.
- To create a suitable model that can forecast the future amount of toxins likely to be present in the groundwater surrounding landfills.

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