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Assessment of Leaching Pollutants in Subsoil and Ground Water Quality near Municipal Solid Waste Dump Site in Lucknow

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Abstract - *Rapid population growth, urbanization, and industrial expansion, many countries are experiencing increased environmental pollution, which negatively impacts both quality of life and ecological systems. These pollutants often enter the soil through various channels, such as improper waste disposal, industrial and urban wastewater discharge, sewage sludge, pesticides, fertilizers, and unauthorized dumping of household waste. The use of untreated solid waste and sewage effluent in agriculture is a significant source of toxic metal and organic pollutant contamination in soils. This issue is particularly pressing in developing countries, where the disposal of untreated municipal solid waste (MSW) poses a major threat. The presence of hazardous pollutants in this waste can have serious consequences for both human health and the environment. This study focuses on assessing the impact of leaching pollutants from municipal solid waste on the quality of sub-soil.*

Key Words: MSW, Leaching Pollutants, Water Quality and Toxic Metals, soil.

1.INTRODUCTION

Development often significantly impacts the environment, affecting ecology, water resources, and plant life. Rapid urbanization and population growth have further stressed groundwater resources and increased municipal solid waste (MSW) production. Leachate, a liquid produced from decomposing MSW, poses a major threat to water resources, human health, and sanitation. This highly concentrated mixture of organic matter, inorganic compounds, and heavy metals forms during the acidic phase of waste decomposition, with its composition varying based on waste type, depth, moisture, and age (Kjeldsen et al., 2002). MSW is also known as garbage. MSW is the combination of commercial waste, construction waste, demolition waste, agricultural waste. It includes trash, grass cutting, food scraps, disposable, appliances, kitchen waste, common household waste, synthetic waste, leather, waste from destruction of building, road, bridges, or other structure (Archana et al., 2014).

In 2022, the MSW collection system in Lucknow city followed a structured process with the use of various vehicles to collect and transport waste across the city's 110 wards. Here is an outline of the data related to waste collection and the vehicles used. Door-to-door collection was implemented in 57 wards using rickshaw trolleys and hand carts. In 53 wards, residents disposed of waste directly into nearby dhalaos (waste storage points) or road bins. Total Waste Generated: Approximately 1600-1700 metric tons per day (MTD). MSW is transported by vehicles owned by Lucknow Nagar Nigam (LNN), with no use of private vehicles. LNN operates a fleet consisting of 22-23 dumpers, 6-10 tractors, 48-54 trucks, and around 100 Chhota haathi vehicles to transfer waste from primary and secondary collection points to landfill sites (Rawat et al., 2022).

Groundwater, a primary source of drinking water, accounts for over 90% of the world's fresh water and is a critical reservoir of clean water. Compared to surface water, groundwater is generally less polluted and its suitability for various uses depends on its quality (Singh, et al., (2011). Monitoring water quality is essential for maintaining human health and the stability of aquatic ecosystems. In India, MSW is frequently disposed of in low-lying areas without proper precautions, resulting in open dumps that are called landfill sites. This unregulated disposal negatively impacts the environment and human health, particularly through groundwater contamination. The waste decomposes and produces leachate a toxic liquid with various harmful chemicals that can seep into groundwater if no protective measures are in place (Archana et al., 2014; Singh and Uchimura, 2023; Kumar and Kumar Rana, 2024). MSW is complex refuse consisting of various materials with different properties. Some of the components are stable while others degrade because of biological and chemical processes (Gupta et al., 2013; Amano et al., 2021).

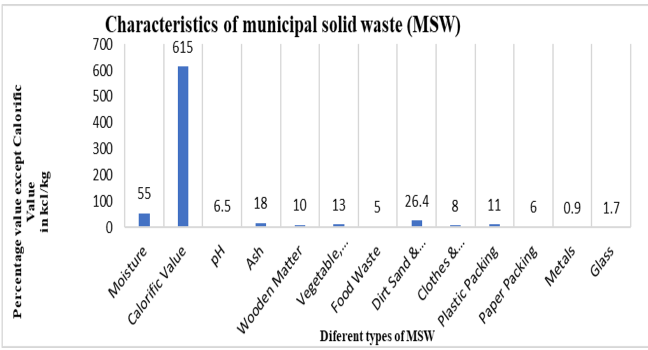

Figure-1: Characteristics of municipal solid waste (LNN)

2. LITERATURE REVIEW

Urooj et al., (2019) assessed water quality near landfill sites and found high turbidity, electrical conductivity, and pH levels outside WHO's permissible limits, indicating significant contamination. Dehghani et al. (2021) found that water sources near landfill sites had high cadmium levels, making them unsafe for drinking. The acidic pH in these waters was linked to decomposed organic material from the landfill, which lowers the pH and increases the solubility and toxicity of heavy metals. Singh and Tripathi, (2023) highlighted that solid waste disposal in water bodies leads to significant pollution, necessitating proper waste management practices to protect public health. Magna et al., (2018) found that water near waste dumping sites had poor quality, with high turbidity and contamination from leachates, making it unsuitable for domestic use. (Chhipa and Nandwana, 2014; Saralakumari, et al., 1993) emphasized that MSW dumping contaminates groundwater with high chloride and fluoride levels, posing health risks like fluorosis. Wickramasinghe et al. (2018) observed that soils near waste dumping sites were acidic, while groundwater showed elevated levels of nitrates, sulphates, and heavy metals due to leachate contamination. (Ali and Singh, 2018; Pillai et al. 2014) examined soil beneath waste dumps and found that contamination from leachates alters its geotechnical properties, reducing its strength and increasing the risk of groundwater pollution. Singh and Tripathi, (2023) concluded that industrial contamination significantly deteriorates soil properties, making it more plastic, compressible, and less permeable. Special considerations are necessary for construction on such soils, with geomembranes suggested to mitigate contamination effects.

3.STUDY SITE

The land fill site is on bank of Gomti river from Hardoi Road. The land is filled by garbage of varying depth of 1.00m to 5.00m at various length of bank. This site is discontinued since 2007. Lucknow is situated in the centre of UP. It lies between 26°55' north latitude and 80°59' east longitude. It is closed on 2007. It is very necessary to know the composition of waste of the dump site. (Rawat et al., 2022).

Figure-2: Municipal solid waste dump site at Dubagga (Source site visit 2022).

4.METHODOLOGY

Lucknow covers an area of 2,528 square kilometers and had a population of approximately 4.580 million according to the 2011 Census of India. Lucknow generates about 1,600 tons of MSW daily, with organic waste making up a significant portion (46-55%) of this total. Waste disposal in the city commonly involves open dumping in low-lying areas without protective liners or leachate collection systems (Final City Sanitation Plan for Lucknow, 2011). There were around 23 municipal solid waste dumping sites in Lucknow, all sites are closed both old and new, with Dubagga being the primary one. The Dubagga landfill is located at and to the west of Lucknow. This low-lying area is close to the fish market and bank of Gomti river. This landfill site remains after 2007 it is not in use. It spans an area of approximately 61,420.08 square meters, and has a height of 4 to 5.5 meters (Ali and Singh, 2018).

4.1.Collection of soil and subsurface water (ground water) Samples

Five soil sample locations were chosen nearby the Dubagga municipal landfill site. The soil was spread on clean surface, debris were removed from the soil sample. The soil sample containing lumps was broken into small pieces. It was air dried and sieved through 2 mm IS: sieve. IS: 1904-1978 specifies that all foundations should extend to a depth of at least 50 cm below the natural ground surface (Arora, 1988), therefore, samples from different locations of the area were collected from this depth. The tools like trowel, spade, auger, etc. were used for samples collection. Sampling tubes made up of steel were used for the collection of bulk density samples. The collected samples kept into thick quality polythene bags were labeled, sealed, and brought to the laboratory for analysis. Soil sample were collected from the base of dumping site designated sample 1,2,3, 4 and 5 was taken. All the samples were collected at the same day, the 5th samples were taken from outside of dumpsite near the Dubagga at 100 meters distance and labeled as sample 1, 2, 3, 4 and 5. The all-soil samples were collected from 100 meter from each other.

Ground water sample were collected from surrounding the dumping site designated samples was collected from opposite of green corridor, near a house of Lucknow green corridor road, M.C. Saxena college mod and nearby the agriculture land was taken. All the samples were collected at the same day, a 500 meters radius and labeled as sample GW1, GW2, GW3 and GW4.

4.2.Physiochemical Properties of Soil

For determining the suitability for crop production, the physical properties of soil play important role. The physical properties of the soil are interconnected to the characteristic like ability to support and bear, cultivation practice, moisture storage capacity and its availability to plants, drainage, maintain the plant nutrient. For Plant growth soil should also be physically fertile. Plants are supported by soil which is the mixture of solids, liquid, gases which is called three phase system. The important physical properties of soil are (Fatima and Tripathi, 2022). Soil color depends on the presence of organic matter and mineral present in it (Indian Standards, 1972, 1973).

Cation-exchange capacity (CEC) is the maximum quantity of total cations that a soil can hold, at a given pH value, available for exchange with the soil solution. It is expressed as centi-mol of Hydrogen per kg (cmolc/kg or 100 meqc/100g). Measurement of acidity or alkalinity of the soil is done by pH. More precisely, it is a measure of hydrogen ion concentration in an aqueous solution and ranges in soils from 3.5 (very acid) to 9.5 (very alkaline). The effect of pH is to remove from the soil or to make available certain ions. Soils with high acidity (<5.5) tend to have toxic amounts of aluminium and manganese. Soils with high alkalinity (>8.5) tend to disperse. (of Indian Standards, 1987, 1972). Leaching refers to the downward movement of pollutants through permeable soil, which can contaminate groundwater and soil. Contaminants from municipal solid waste, including non-biodegradable and hazardous materials, can leach into the soil. This contamination reduces soil quality (Indian Standards, 1972). Soil samples were air-dried, sieved through a 2 mm IS sieve, and analyzed for moisture content, electrical conductivity, pH, organic carbon, available nitrogen, phosphorous, and potassium. Standard methods as per IS codes were followed. The sample was collected and were analyzed for their physio-chemical properties by various methods which are listed here. pH from pH meter, moisture content from oven drying method, electrical conductivity (µ mhos/cm) from electrical conductivity meter, organic carbon percentage from titrimetric method (Walkley and black, 1934), available nitrogen as N (mg/kg) from micro Kjeldhal method, phosphorous as P_2O_5 (mg/kg) from spectrophotometric method and potassium as K(mg/kg) from flame photometer method.

5.RESULT AND DISCUSSION

The analysis of soil samples from different sites figures 3(a) to 3(d) along with a controlled sample provides valuable insights into the soil characteristics in terms of pH, moisture, electrical conductivity, organic carbon, available nitrogen, phosphorus, and potassium, here are the key points derived from the data.

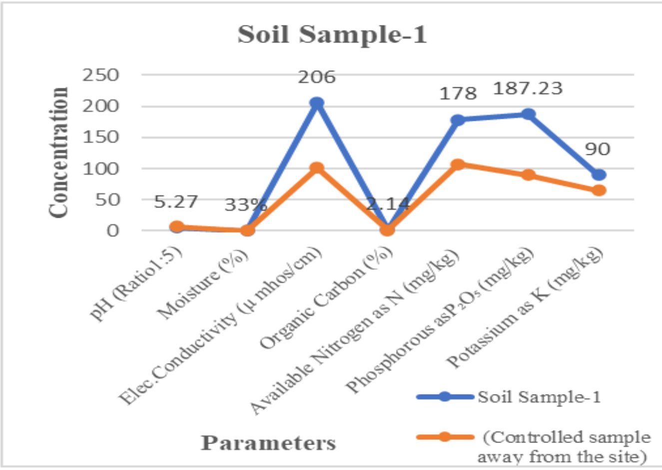

Figure-3 (a): Soil Sample-1.

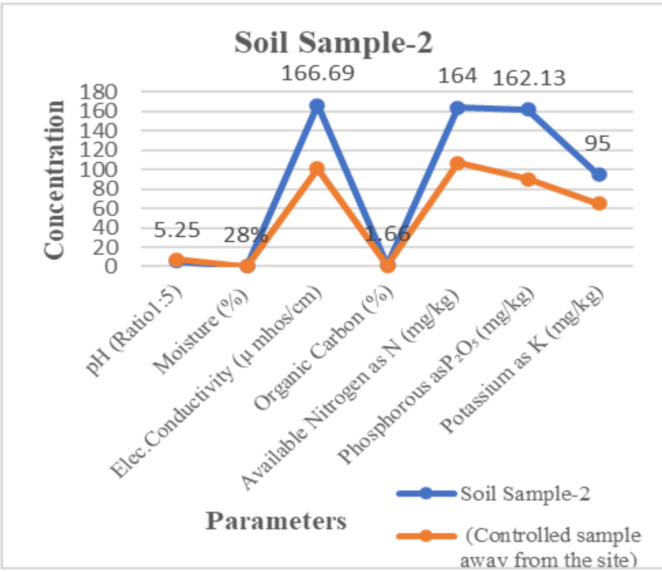

Figure-3 (b): Soil Sample-2.

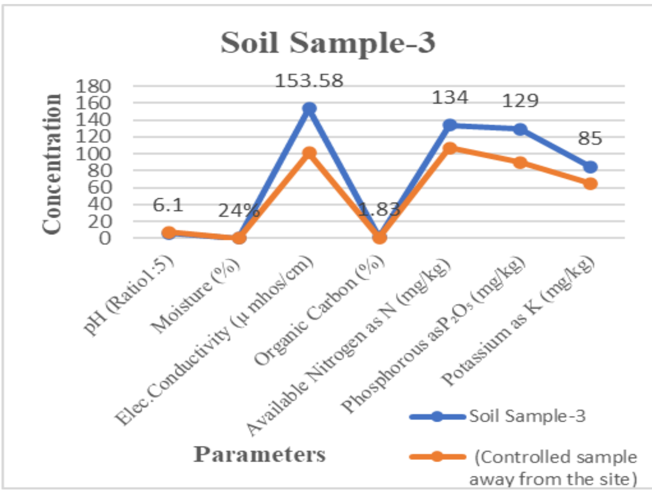

Figure-3 (c): Soil Sample-3.

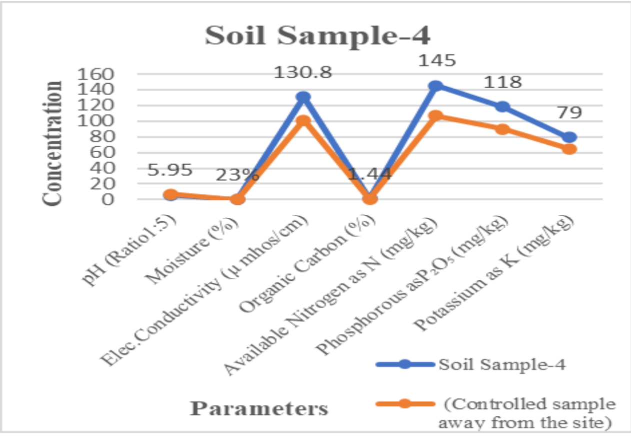

Figure-3 (d): Soil Sample-4.

The pH values of the soil samples range from 5.25 to 6.1, indicating mildly acidic soil conditions. The controlled sample, with a pH of 7.21, is neutral, suggesting that the site-specific soil samples are more acidic, likely due to site-specific factors (e.g., proximity to waste materials or industrial activities). The higher acidity (lower pH) in the site samples can affect nutrient availability, particularly for elements like phosphorus. The moisture content decreases from figure 4(a) (33%) to figure 4(d) (23%). The controlled sample has the lowest moisture content at 21%. Higher moisture in site samples could be due to water retention from organic content or proximity to water sources. It indicates that the soil in the site area retains more water compared to the control, potentially affecting microbial activity and plant growth. Electrical conductivity (EC) values show a declining trend from figure 4(a) (206 µmhos/cm) to figure 4(d) (130.8 µmhos/cm), with the control sample at 101.32 µmhos/cm. The elevated EC levels in the site samples suggest a higher concentration of soluble salts, which could be a result of leachate from nearby waste or contaminants. Higher salinity can impact soil health and plant growth negatively by limiting water absorption. Organic carbon content is highest in figure 4(a) (2.14%) and decreases progressively to figure 4(d) (1.44%). The controlled sample has a significantly lower organic carbon content (0.98%). The elevated organic carbon levels in the site-specific samples suggest higher organic matter decomposition, possibly due to organic waste accumulation. Organic carbon is essential for soil structure and fertility, promoting microbial activity and nutrient retention. Available Nitrogen (N) levels are relatively higher in figure 4(a) (178 mg/kg) and decrease through figure 4(d) (145 mg/kg), with the controlled sample having the lowest level (107 mg/kg). The increased nitrogen content in site samples may indicate nutrient enrichment due to waste deposits or fertilizers. However, excessive nitrogen can also lead to nutrient imbalances and affect plant health. Phosphorus (P_2O_5) levels are highest in figure 4(a) (187.23 mg/kg) and decrease to 118 mg/kg in figure 4(d), with the control sample having a phosphorus level of 90.01 mg/kg. High phosphorus content in the site samples suggests possible accumulation from waste materials or fertilizers. Excess phosphorus can lead to water contamination through runoff, leading to eutrophication of nearby water bodies. Potassium (K) levels show a similar trend, with higher values in the site samples (90 mg/kg in figure 4(a), reducing to 79 mg/kg in figure 4(a) compared to the control (65 mg/kg). Potassium is essential for plant growth, but its higher levels in the site samples might indicate leaching or accumulation from external sources Bureau of Indian Standards (BIS:10500-2012).

5.1.Physicochemical Analysis of Ground Water

Groundwater samples were analyzed for parameters such as pH, total dissolved solids (TDS), total hardness, alkalinity, calcium, magnesium, chloride, nitrate, sulphate, and fluoride. Methods included pH meter readings, digital TDS meter, titration methods, and spectrophotometric analysis. WQI was calculated using the weighted arithmetic index method, considering parameters like pH, TDS, nitrate, fluoride, chloride, sulphate, alkalinity, and total hardness. The standards used were prescribed by the BIS:10500-2012.

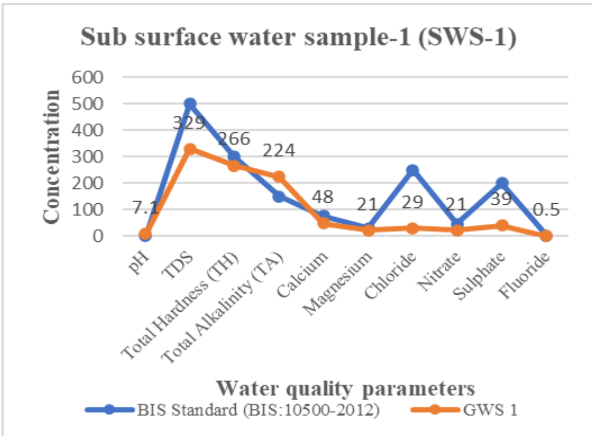

Figure-4(a): Sub Surface Water Sample-1.

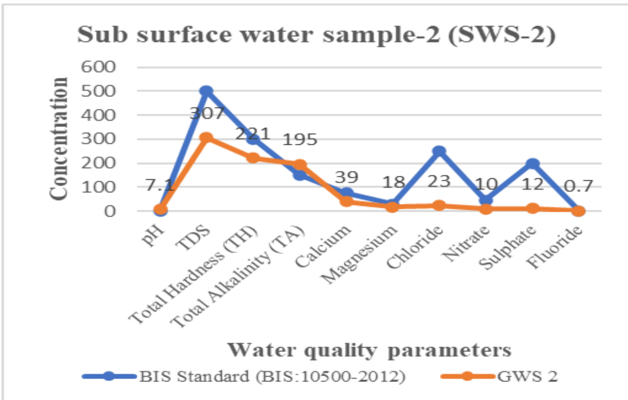

Figure-4(b): Sub Surface Water Sample-2.

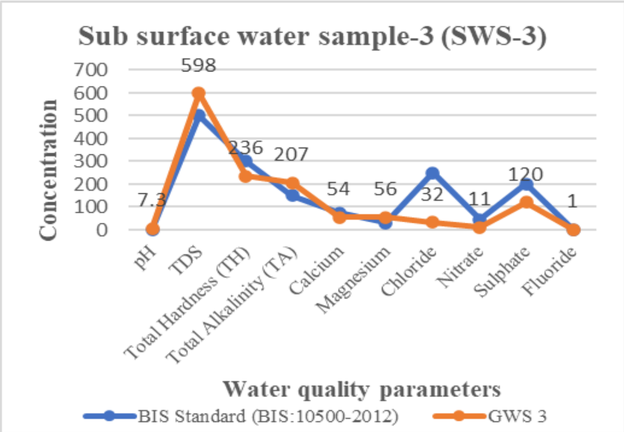

Figure-4(c): Sub Surface Water Sample-3.

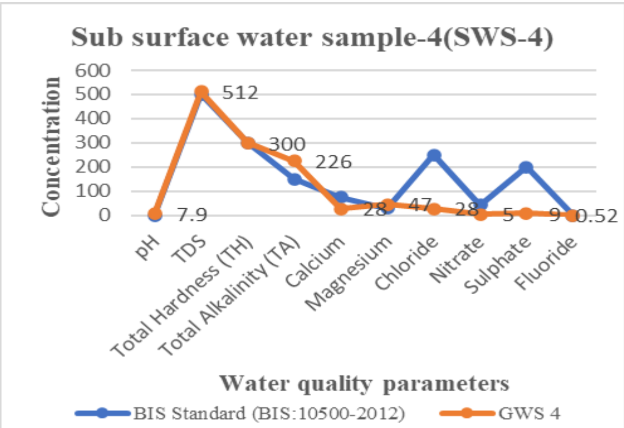

Figure-4(d): Sub Surface Water Sample-4.

The ground water (GW-1 to GW-4) in above figure 5(a) to 5(d) were analyzed for various physicochemical parameters and compared with the BIS Standard for drinking water. Here is a detailed discussion based on the results

The pH values of all groundwater samples range between 7.1 and 7.9, which falls within the acceptable BIS range of 6.5 to 8.5. This indicates that the sub surface water samples are slightly alkaline, which is suitable for drinking water and poses no significant risk in terms of acidity or alkalinity. Total. The BIS standard for TDS is 500 mg/L, with figure 5(a) (329 mg/L) and figure 5(b) (307 mg/L) within this range, while in figure 5(c) (598 mg/L) and figure 5(d) (512 mg/L) exceed the permissible limit. The elevated TDS levels in figure 5(c) and figure 5(d) may indicate the presence of dissolved salts, which can affect water taste and may require treatment before consumption. The BIS limit for total hardness is 300 mg/L, with all samples except figure 5(d) (300 mg/L) falling below this threshold. While figure 5(d) reaches the upper limit, the other samples have acceptable hardness levels, making the water safe for consumption. Hard water can lead to scaling in pipes and may cause problems for those with sensitive skin. The BIS standard for alkalinity is 150 mg/L. However, all sub surface water samples exceed this limit, with values ranging from 195 mg/L figure 5(b) to 226 mg/L figure 5(d). High alkalinity levels suggest the presence of carbonate and bicarbonate ions, which could affect the taste of water and may require treatment to balance the water chemistry for long-term use. The BIS limit for calcium is 75 mg/L, and all sub surface water samples fall within this range (28 mg/L to 54 mg/L). The calcium content in the water is suitable for drinking and does not pose any significant health risks. The magnesium levels in sub surface water samples range from 18 mg/L to 56 mg/L, exceeding the BIS limit of 30 mg/L in figure 5(c) (56 mg/L) and figure 5(d) (47 mg/L). High magnesium concentrations can contribute to hardness and may cause gastrointestinal issues for sensitive individuals. The BIS standard for chloride is 250 mg/L, and all sub surface water samples have chloride levels well below this threshold (23 mg/L to 32 mg/L). Low chloride levels indicate that the water is free from significant contamination from chloride salts, which could otherwise affect the taste or cause corrosion in pipes. The BIS limit for nitrate is 45 mg/L, and all sub surface water samples are well within this range (5 mg/L to 21 mg/L). Nitrate levels in drinking water are safe, with no risk of nitrate contamination, which is crucial for preventing methemoglobinemia (blue baby syndrome) in infants. The BIS limit for sulphate is 200 mg/L, and all sub surface water samples have sulphate levels within this limit (9 mg/L to 120 mg/L). Sulphate levels are acceptable for drinking, with figure 5(c) showing the highest concentration (120 mg/L), which is still below the threshold. The BIS standard for fluoride is 1 mg/L. figure 5(a) (0.5 mg/L), GW-2 (0.7 mg/L), and figure 5(d) (0.52 mg/L) fall below this limit, while figure 5(c) (1 mg/L) is at the permissible limit. Fluoride levels are safe and pose no risk of fluorosis, a condition caused by excessive fluoride consumption.

6.CONCLUSION

After analyzing the physico-chemical characteristics of both contaminated and uncontaminated soil samples, the results demonstrate the adverse effects of pollutants from MSW due to leaching, leading to a loss of soil fertility compared to the control samples. The test results highlight notable changes in the geotechnical properties of contaminated soils when compared to the parent (uncontaminated) soil. The introduction of acidic and basic contaminants alters the soil pH. Contaminated soils exhibit increased electrical conductivity due to the presence of more free ions. The soil pH ranges from 7.35 to 8.10, indicating a slightly alkaline nature, which can cause corrosive damage to plant stems and root systems. Contaminants increase the soil plasticity due to chemical interactions with soil particles. Contaminated soils become more compressible, while the decrease in the coefficient of consolidation indicates reduced permeability.

The analysis of groundwater samples indicates that the water quality is generally within safe limits according to the

BIS standards, but TDS levels in figure 5(c) and figure 5(d) exceed the BIS limit, which may require treatment to remove excess dissolved solids for improving taste and reducing potential scaling. Total alkalinity exceeds the permissible limit in all samples, suggesting that the water may need treatment to reduce alkalinity for long-term use. Magnesium levels are high in figure 5(c) and figure 5(d), which could contribute to water hardness and may cause health issues for sensitive individuals. Overall, the groundwater is not suitable for consumption without treatment needed to address the high alkalinity, TDS, and magnesium levels in some samples. Regular monitoring of these parameters is recommended to ensure continued compliance with drinking water standards.

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