Physico-Chemical and Geochemical Analysis of Major Waste Dumpsite in Ikere-Ekiti, Southwestern Nigeria

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ABSTRACT

Ikere-Ekiti, a fast-developing town in southwestern Nigeria, hosts a major waste dumpsite that may serve as a source of heavy metal pollution, organic matter degradation, and groundwater contamination. A total of twenty (20) soil samples from five waste dumpsites within and outside the dumpsite were collected for this study at a depth of 60cm below the ground. The soil samples were collected at random interval from the centre to the outskirt of the study area. The chemical parameters like cations concentrations were determined by using Atomic Absorption Spectrophotometer method (AAS). The anions were determined by the digestion method of the soil. The hydro-chemical analysis of water samples was carried out. The concentration level of cations and anions vary for each of the dumpsites when compared to their control points. The analysis of water quality parameters indicates that while the pH levels of all samples fall within the recommended range for drinking water, several other parameters exceed their respective limits.These findings suggest that the soil in this dumpsite has experienced significant heavy metal and anion accumulation from waste materials. The fifth dumpsite exhibits notable contamination, especially with heavy metals buildup of (Pb, Cd, Cr, As), excess anions, and nutrient imbalances, indicating serious environmental pollution risks.

Key Word: Waste dumpsite; Leachate; Groundwater; soil contamination; Ikere-Ekiti.

INTRODUCTION

In Ikere, Ekiti State, Nigeria, the population has grown quickly, increasing garbage output and creating a large number of waste dump sites. This has really caused recurrent impediments to roads, passageways, and streets. Waste dump sites in Ikere local government of Ekiti State comprises of high levels of metals of different kinds such as lead, cadmium and chromium (Akmal & Jamil, 2021). These metals cannot but filter into the soil and groundwater, exhibiting a threat to the surroundings and public health. Furthermore, all of the dangerous chemicals that leak through a landfill's garbage pile during rainy seasons are known to lead to cancer and other severe health problems. They are often produced by waste breakdown and leachate production, which are trash dump sites with high levels of chemical oxygen demand (COD), biochemical oxygen demand (BOD), and total dissolved solids (TDS) (Agbele et al., 2020; Fatoba et al., 2021; M. Saleh & Koller, 2019; Mepaiyeda et al., 2019; Musa et al., 2020).

In most cases, several of the accidental outcomes of the open dumps is the invasion of leachates into the immediate environment, giving rise to soil and groundwater contamination (Butt et al., 2022; Ogunbiyi et al., 2024; Ogunlana et al., 2024; Timothy Ore et al., 2019). This poses a huge risk to the environment and is the primary source of groundwater contamination(Amodu et al., 2024; Olagunju et al., 2018) . The pH and redox potential of the waste dump sites can affect the mobility and bioavailability of heavy metals. More also, a low pH can increase the solubility of heavy metals, while a high redox potential can enhance their mobility(Ebistu & Minale, 2013; Joe-Ukairo & Oni, 2018; Nava-Martínez et al., 2012). The characteristics and amount of leachate produced at the dumpsite may be impacted by the components, wells, and environment (Fetter et al., 2017; Ojo et al., 2020). There is a significant risk to groundwater when chemicals and leachate are released from landfills(Alslaibi, 2009) . According to reports, almost 80% of water-related or water-borne illnesses are caused by foreign compounds found in water bodies (Adebayo et al., 2015).

The goal of this study work was to give the local government information so they could create pollution prevention and control strategies by using a geochemical and physio-chemical technique to assess the degree of leachate contamination from the Ikere dumpsites.

The effects of waste dump sites in Ikere local government can be assessed using geochemical and physio-chemical approaches. These methods can assist in determining the health and environmental hazards connected to these locations and provide guidance for cleanup and mitigation plans. To reduce the negative effects of trash dump sites on the environment and human health, sustainable waste management techniques such as appropriate garbage disposal, recycling, and composting must be used.

The physico-chemical properties of the waste dump sites, such as the presence of clay minerals and organic matter, can affect the adsorption and desorption of heavy metals. This can influence the mobility and bioavailability of these metals (Kahal et al., 2021).

METHODOLOGY

Geology and Hydrogeology of the Study Area

Ikere-Ekiti is a town in Ekiti State, southwestern Nigeria. It is the second-largest town in the state and serves as an important economic and cultural hub. The study area is Located in Ekiti State, Nigeria, about 10 km south of Ado-Ekiti, the state capital. It Lies between latitude 7°30′N and 7°45′N and longitude 5°10′E and 5°25′E (Aga, 2009; ANDREW, 2016; Ogundare, 2016; Omole et al., 2024) as shown in Figure 1. The town is characterized by undulating terrain with hills and valleys, typical of the Yoruba uplands. The elevation ranges between 250–400 meters above sea level (Omole et al., 2024). It falls within the tropical rainforest zone, experiencing two major seasons, Rainy season (April–October) and Dry season (November–March). Underlain by Precambrian basement complex rocks, including granites, gneisses, and migmatites. Soils are predominantly ferruginous tropical soils, suitable for agriculture (Owolabi, 2019).

The varied geological terrain of Ikere-Ekiti, which is situated in southwest Nigeria, is indicative of the Precambrian Basement Complex. The area is predominantly underlain by crystalline rocks, including migmatite-gneiss-quartzite complexes, older granites, and charnockites (Ayodele & Ajayi, 2016). These formations are interspersed with intrusions such as aplite, dolerite, and pegmatite dykes. Notably, the region features prominent rugged hills, with the Ikere-Ekiti Hills situated to the south, contributing to the area's distinctive topography.

Table 1: Sites of water and soil samples

Locations (coordinates)	Dumpsite	Soil samples	Water samples
7.489103 5.238220	First	S1, S2, S3,S7	W1,W2,W3
7.489105 5.238250	Second	S8,S9,S10,S14	W6,W7,W8
7.489105 5.238248	Third	S15,S16,S17,21	W11,W12,W13
7.488834	Fourth	S22,S23,S24,S28	W21W22,W23

5.230276			
7.488852 5.230279	Fifth	S29,S30,S31, S35	W25,W26

Hydrogeologically, Ikere-Ekiti's groundwater system is influenced by its underlying crystalline geology, which affects aquifer characteristics and water quality (Kayode et al., 2024). Additionally, examinations of shallow wells during dry seasons have revealed issues regarding sanitary conditions and water volume sustainability, underlining the necessity for frequent monitoring and sustainable management measures to maintain safe and adequate groundwater supplies (Talabi et al., 2023).

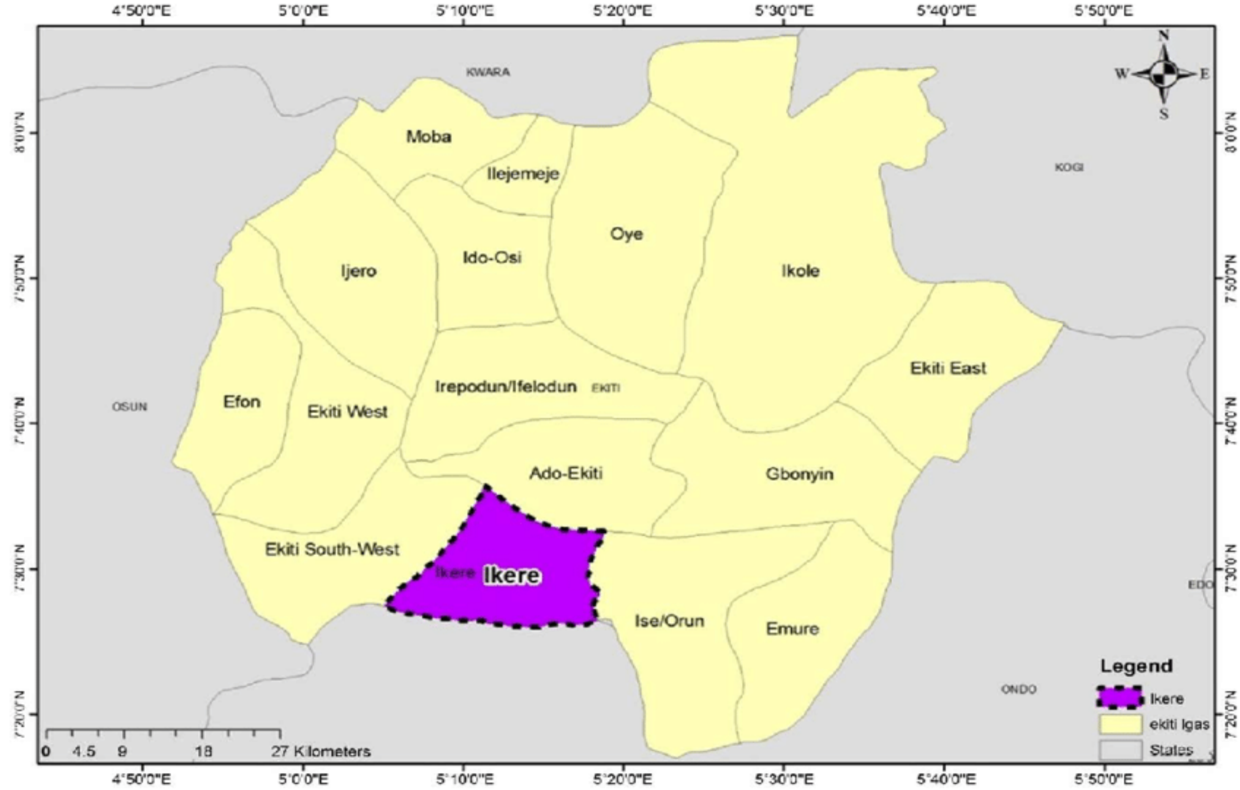

Figure 1: Map of the study area

Samples collection

For this investigation, a total of twenty (20) soil samples were taken from the trash dumpsites both within and outside of them using a hand auger that was buried 60 cm below the earth. At random intervals, soil samples were taken from the research area's centre to its periphery. In December 2024, sampling was conducted on five main waste sites in Ikere-Ekiti. Global positioning systems (GPS) were used to gather measurements at each sample location. The samples were designated as S1, S2, S3, and S4 for the first dumpsite and they were taken at random interval with S4 being the control point at a location far away from the dumpsite. Also, S8, S9, S10, and S14 were taken from the second dumpsite at ransom interval with S14 being the control point at a location for away from the dumpsite, S15, S16 S17, and S21, were taken from the third dumpsite at random interval with S21 being the control point at a location far away from the dumpsite, S22, S23, S24, and S28 were taken from the fourth dumpsite at random interval with S28 being the point at a location far away from dumpsite. And finally, S29, S30, S31, and S35 were taken from the fifth dumpsite at random interval with S35 being the control point at a location for away from dumpsite.

Determining the degree of soil pollution caused by the waste dumpsite is the goal of these. Utilising Atomic Absorption Spectrometry (AAS), the study was conducted at the Federal University Oye-Ekiti, Nigeria's Soil Science laboratory to look for harmful chemicals, metals, and cations.

Water sample collection

For this investigation, fifteen groundwater samples from hand-dug wells (HDW) ranging in depth from 7.0 to 15.0 meters were utilised. The availability of wells in the vicinity of the dumpsites determines which well is utilised for the investigation. The samples were collected at random from the waste zone to the research area's periphery. The water samples were designated as W1, W2 and W3 for three wells found around the first dumpsite, W6, W7 and W8 for three well found around the second dumpsite, W11, W12 and W13 for three wells around the third dumpsite, W21, W22 and W23 for three wells found around the fourth dumpsite, while W25 and W26 for the two wells found around the fifth dumpsite. The site's topography meant that the wells under study varied in depth. Every hand-dug well had a concrete ring lining and was covered. The environmental conditions around the wells varied somewhat.

Soil geochemical analysis

Cations of calcium, magnesium, potassium, sodium, manganese, copper, cadmium, zinc, iron, lead, chromium, nickel, and arsenic are among the chemical characteristics found in the soil that are analysed. Atomic Absorption Spectrophotometer (AAS) technique was used to determine the amounts of cations. To make the soil sample fit through a 0.15 mm sieve, it was air dried and then crushed. Ten millilitres of strong nitric acid were poured to a digest tube containing one gramme of the sieved material, which was then left to soak for half an hour. Once the foaming stopped and the nitric acid had nearly gone, the sample was put on a block digester and cooked to 2500C. After that, five millilitres of strong perchloric acid were added, and the sample was heated until it took on the colour of light straw. This was left to cool. After the sample was filtered into a 100 ml volumetric flask, distilled water was added to make up the difference. The same volume of chemicals used for filtration and digestion were utilised to prepare the blank. Metal concentrations in the digested samples were evaluated using a Buck Scientific Atomic Absorption Spectrophotometer (Model: 210VGP) at various wavelengths of the metals. Quantification of the metals was based upon calibration curves of standard solutions of metals. Each analysis batch contained blanks, and the analytical method's accuracy was assessed using certified reference standards.

The soil digestion technique at the Federal University of Oye, Nigeria, Soil Science laboratory was used to determine the anions concentrations of phosphate, nitrate, sulphate, and chloride.

Using the digestion process, the amount of phosphorus in the soil samples was determined. The Vanado-Molybdo Phosphoric Acid Colorimetric Method was used to measure the amount of phosphate present in the samples. The foundation of this technique is the capacity of an indilute orthophosphate solution of ammonium molybdate to react in an acidic environment to produce a heteropoly acid molybdo-phosphoric acid. A UV visible spectrophotometer was used to evaluate the intensity of the yellow colour, which is related to the phosphate content in the solution, after the technique produced yellow-colored vanado-molybdo-phosphoric acid.

Using the digestion process, the amount of chloride present in the soil samples was determined. A saturated paste can provide soluble Cl in a water extract. Whatman No. 1 filter paper is used to remove any dirt particles from the solution. The pipette 5–10 mL of soil saturation extract in a 150 ml Erlenmeyer flask with a wide mouth Put four drops of the 5% K_2CrO solution in. Titration was performed against 0.01 N AgNO until a persistent reddish-brown hue developed. Two blanks that included all of the reagents but no sol were created and handled just like the samples. Deduct the blank titration reading from each sample's measurements. The AgNO solution used to determine Cl needs to be standardised. The pipette 10 millilitres of a 0.01% NaCl solution in an Erlenmeyer flask with a wide mouth Put four drops of the 5% K,CrO solution in. Titrate against a solution of -0.01 N AgNO until a persistent reddish-brown hue is achieved. After taking the reading, compute the normalcy of AgNO.

Using the Turbidimetric Method, the sulphate concentrations in the samples were ascertained. This technique is predicated on the idea that a sulphate in the presence of (acidified HCl) barium chloride forms barium sulphate in the colloidal form. When glycerol or another organic component is present, the process is improved. A UV visible spectrophotometer may be used to quantify the colloidal solution's absorbance in relation to a standard.

Ten grammes of the soil sample were weighed on a balance and then placed in a 250 ml container to assess the amount of nitrate present. flask of Erlenmeyer. After adding 50 ml of the extraction solution, it was shaken for ten minutes. After adding 0.4 g of Ca(OH)2, the mixture was shaken for a further five minutes. After adding 1 mg of MgCO3, it was shaken for two minutes. The first 10 to 15 millilitres of the filtrate were thrown away after this was filtered. A 100 ml beaker was filled with 25 ml of the clear filtrate, which was then evaporated on a hot plate until it was completely dry. After letting the beaker cool, three millilitres of phenoldisulfonic acid were quickly put in the middle and turned to make contact with all of the salt that was still there. After that, 15 millilitres of distilled water were added, and everything was stirred until all of the residue was gone. After allowing the solution to cool, 6N NH4OH was added until a stable yellow hue developed, indicating that the solution was clearly alkaline. Then an excess of 3 ml was added. Quantitatively, this solution was transferred to a 100 ml volumetric flask, diluted with 100 ml of distilled water, and well mixed by inverting it at least ten times. A spectrophotometer set at 410 nm was used to measure the sample's nitrate level.

Hydro-chemical analysis

The following chemical parameters were measured in the waters in the study area: pH, total dissolved solids (TDS), turbidity, electrical conductivity (EC), alkalinity, acidity, total hardness, and cations concentrations, including doses of iron (Fe), magnesium (Mg), zinc (Zn), manganese (Mn), calcium (Ca), cadmium (Cd), nickel (Ni), chromium (Cr), copper (Cu), lead (Pb), arsenic (As), potassium, and sodium. These were measured using an Atomic Absorption Spectrophotometers (AAS) and the anions concentrations included chloride, sulphate, nitrogen, and phosphate.

Distilled water was filtered through a glass fibre filter to provide turbidity-free water, and the first 200 millilitres of the filtrate were thrown away. Before being used, the next filtrate was gathered and its turbidity assessed. In a volumetric flask, 1.0g of hydrazine sulphate was dissolved in turbidity-free water and diluted to the 100ml mark. In a volumetric flask, 10.0g of hexa-methylene-tetramine was dissolved in water and diluted to the 100ml mark. A 100 ml volumetric flask was filled with 5 ml of solutions A and B.

This was diluted to the 100 ml mark after being corked and left to stand at 250C for 24 hours. This suspension, often known as the stock turbidity suspension, has a turbidity of 400 units. In order to create standards of 0, 5, 10, 20, 30, and 40 units, the proper volume of stock turbidity suspension was measured into a 100 ml volumetric flask and diluted with 100 ml of turbidity-free water. After shaking the sample to completely distribute the solid material, it was transferred into the turbidimeter tube. Straight from the instrument scale, the turbidity was measured.

A Checker pocket-sized pH meter with a replacement electrode was used to measure the water samples' pH as soon as they were collected. A product of WOONSOCKET, RI 02895 HANNA, the meter is. To get precise readings, the meter was initially calibrated using pH 7.00 and pH 4.00 buffers. After inserting the meter's electrode into the water samples, the meter immediately displayed the pH value.

The TDS/conductivity meter METTLERTOLEDOMC126 was used to measure the total dissolved solids (TDS) of the water samples. This average-sized device with two sensitive probes was also utilised to measure the samples' electrical conductivity (EC). To measure the TDS, the instrument was placed on TDS mode while the probes were introduced into each sample and the displayed TDS value was read.

On the other hand, in order to get precise results, the meter was first calibrated using an electrical conductivity solution of 12.88us/cm at 25 C before being switched to EC mode to measure the samples' electrical conductivity. The meter's probes were placed into the water sample so that the water level was above them for every EC analysis. While the EC is measured in siemens (S) or microsiemens (uS), the device measures TDS in either milligrammes per litre (mg/L) or grammes per litre (g/L).

Through the use of complexometric titration, total hardness was measured. Standard EDTA indication produces a blue colour at the end point, while Eriochrome Black T indicator produces a wine colouration when added to a calcium and magnesium solution that has been buffered to pH 10. After measuring 25 millilitres of the sample into the conical flask, 2 millilitres of the buffer solution were added to bring the pH down to 10, and a pinch of the indicator—which gives the flask a crimson tint—was added.

The end point was reached when the mixture in the conical flask changed from a reddish tint to a blue colour after being titrated with a standard 0.01 EDTA solution. It was noted what titre value was utilised for the sample. Total Hardness mg CaCo3/L is calculated by dividing (V x A x 1000) by sample volume, where V is the volume of EDTA used in the sample and A is the amount of CaCo3 (mg) equal to 1 millilitre of EDTA solution.

Chloride is tested using (APHA 4500 - CLB). The sample is titrated with standard silver nitrate in the presence of potassium chromate indicator. The silver nitrate interacts with the chloride present to generate insoluble white silver chloride. A reddish-brown silver chromate precipitate is created when the silver ions react with the excess chromate after all of the chloride has precipitated. After dissolving 16986g of silver nitrate in 1000mL of distilled water, it was placed in an amber container for storage.

A 0.01N standard sodium chloride solution was used to standardise this solution. After dissolving potassium chromate in a little amount of distilled water, drops of silver nitrate solution were added until a distinct red precipitate developed. After 12 hours of standing, the solution was filtered and diluted with 100 millilitres of distilled water. One millilitre of potassium chromate indicator was applied to a conical flask containing 25 millilitres of the sample.

To reach a brick red end point, the liquid in the flask was titrated using a typical 0.01N silver nitrate solution. Both the titre value of the sample and the titre value of the reagent blank were recorded. Chloride, mg/L = (A-B) x N x 35400 divided by V, where A is the sample's titre value, B is the blank's titre value, N is the silver nitrate's normality, and V is the sample volume.

Phosphate was determined by using Tin (II) Chloride Colorimetric Method**.** Orthophosphate ion PO_4^{3-} , combine with ammonium molybdate under acidic conditions to form a yellow complex compound know as ammonium phospho-molybdate. Upon selective reduction using tin (II) chloride solution glycerol, the yellow complex is reduced to a blue coloured compound, due to molybdenum blue or heteropoly blue of uncertain composition. The amount of phosphate in the sample determines how intense the blue hue is. About 500ml of distilled water was mixed with 300ml of concentrated H2SO4 and allowed to cool. One litre was diluted with 4.0 millilitres of concentrated HNO3. 175 millilitres of distilled water were used to dissolve 25 grammes of ammonium molybdate. 280ml of conc H_2SO_4 was added to 400ml distilled water and cooled. After that, one litre of the molybdate reagent was added and diluted. 2.5 fresh tin (II) chloride was weighed out and dissolved in 100ml glycerol. This was water that had been heated while being constantly stirred. Distilled water was used to dissolve 0.2195g of anhydrous potassium dihydrogen phosphate (KH2PO4), diluting it to one litre. 1ml = 0.05mg PO_4**.** 0.5µg, 1.0 µg, 1.5 µg, 2.0 µg, 2.5 µg, standard solution were prepared by using micropipette to transfer 1ml, 2ml,3ml,4ml,5ml respectively of the stock standard solution in 100ml volumetric flask and diluting to the mark with distilled water. To the standard solution and 100ml sample, 4ml of molybdate reagent and 0.5ml of tin II chloride was added and mixed thoroughly and allowed to develop colour while keeping the sample and standard at same temperature. A blank of all the reagents with distilled water was prepared and used to measure read the absorbance of the sample at 690nm. mg/L PO_4 = Reading from curve x 1000 divided by ml of sample.

The Turbidimetric Method was used to determine sulphate. The foundation of this technique is the creation of colloidal barium sulphate in the presence of acidified (HCl) barium chloride. When glycerol or another organic component is present, the process is improved. Using a spectrophotometer, the absorbance of the colloidal solution is measured in relation to a standard. Distilled water was used to dissolve 0.1479g of anhydrous sodium sulphate and dilute it to one litre. 100 ml of the stock standard solution was used to create standard solutions of 0.0, 5, 10, 15, 20, and 25 ppm. The water sample was then measured into a conical flask, and 5 ml of conditioning reagent was added and swirled with a magnetic stirrer. After adding a tablespoon of barium chloride crystal, the mixture was agitated for an additional minute. Using distilled water as a blank, the absorbance of the sample and the standard was measured at 425 nm.

RESULTS

Tables 2 and 3 display the findings of the geochemical investigation of the soil at a significant garbage dumpsite in Ikere-Ekiti, southwest Nigeria. Every dumpsite has a different degree of cation and anion concentration when compared to its control locations. Figures 2 and 3 illustrate the concentration plot of soil samples anion and cation in parts per millions (ppm).

Table2: Soil sample result

Soil Sample (ppm)	**S1**	**S2**	**S3**	**S7**	**S8**	**S9**	**S10**	**S14**	**S15**	**S16**	**S17**	**S21**
Calcium	4092	4165	4052	5120	4280	5624	4820	4122	3980	5240	5200	5678
Magnesium	241	223	216	245	323	322	245	334	234	302	245	278
Potassium	324.5	342.8	322.5	245.6	268.9	246.5	322.8	215.7	267.9	234.8	312.5	236.6
Sodium	84.2	72.5	98.6	98.4	102.4	122.8	76.9	85.8	98.6	125.7	93	122.4
Phosphorus	862.5	584.9	712.4	654.8	572.8	602.9	722.4	454.6	615.4	548.9	546.8	498.2
Nitrate	9.26	7.28	12.42	5.26	12.9	14.88	16.8	7.56	8.96	24.9	6.54	4.56
Sulphate	32.8	34.9	30.9	36.4	42.1	54.8	42.8	34.56	38.9	52.9	33.8	42.9
Chloride	30.65	32.1	42.7	38.9	34.79	54.7	44.9	32.89	38.54	56.8	29.19	44.85
Manganese	201.6	189.2	199.3	198.4	198	224.8	214.5	228.9	215.4	245.9	188.6	201.7
Copper	7.25	8.65	10.9	9.82	8.76	14.89	14.6	8.96	12.4	12.88	8.22	10.85
Cadmium	0.09	0.12	BDL	BDL	0.12	0.28	0.07	0.09	0.22	0.14	BDL	BDL
Zinc	42.19	38.9	32.8	54.88	38.69	62.8	42.1	43.86	52.34	62.54	45.6	49.82
Iron	3109	1589.4	2186.5	1459	2154.8	1981	2170	1765.9	1872.3	2465.9	1875.9	1678.94
Lead	0.12	0.92	0.16	BDL	0.88	6.72	0.09	0.68	2.34	6.89	BDL	BDL
Chromium	0.06	0.11	0.11	0.09	0.14	0.32	0.04	0.18	0.22	0.56	0.08	0.14
Nickel	0.15	0.2	0.22	0.23	0.22	0.37	0.13	0.22	0.28	0.42	0.14	0.29
Arsenic	0.08	0.06	0.05	0.02	0.09	0.08	0.06	0.06	0.1	0.26	0.04	0.06

BDL: Below Detection Level

Table 3: Soil sample result

Soil Sample (ppm)	**S22**	**S23**	**S24**	**S28**	**S29**	**S30**	**S31**	**S35**
Calcium	6412	4210	4724	5420	4980	5124	4872	4862
Magnesium	298	364	226	219	324	345	298	216.8
Potassium	233	214.6	302	301.6	241	208.3	312.5	228
Sodium	89	145.8	65.8	68.9	86.8	112.4	88.43	64.2
Phosphorus	513	502.5	625	590.4	458	542	542	682
Nitrate	14.6	22.4	14.24	3.49	14.5	18.4	12.8	6.12
Sulphate	39.8	62.8	52.9	28.7	42.9	58.9	55.4	36.4
Chloride	48.9	56.9	49.28	28.54	39.8	45.6	48.2	25.4

Manganese	219	268	272.5	188.2	286	274.5	265.4	154.2
Copper	12.5	15.78	9.26	4.12	12.4	16.8	8.76	6.24
Cadmium	0.12	0.21	0.18	BDL	0.28	0.34	0.22	BDL
Zinc	65.9	64.88	52.1	29.8	28.7	34.5	45.25	30.12
Iron	1725	3250	2450	1670	2980	2865	2679	1762
Lead	BDL	8.42	2.45	BDL	6.12	7.21	6.12	BDL
Chromium	0.12	1.22	0.92	BDL	0.54	0.68	1.22	BDL
Nickel	0.23	0.88	0.48	0.06	0.33	0.42	0.78	0.09
Arsenic	0.08	0.23	0.12	BDL	0.08	0.16	0.24	BDL

BDL: Below Detection Level

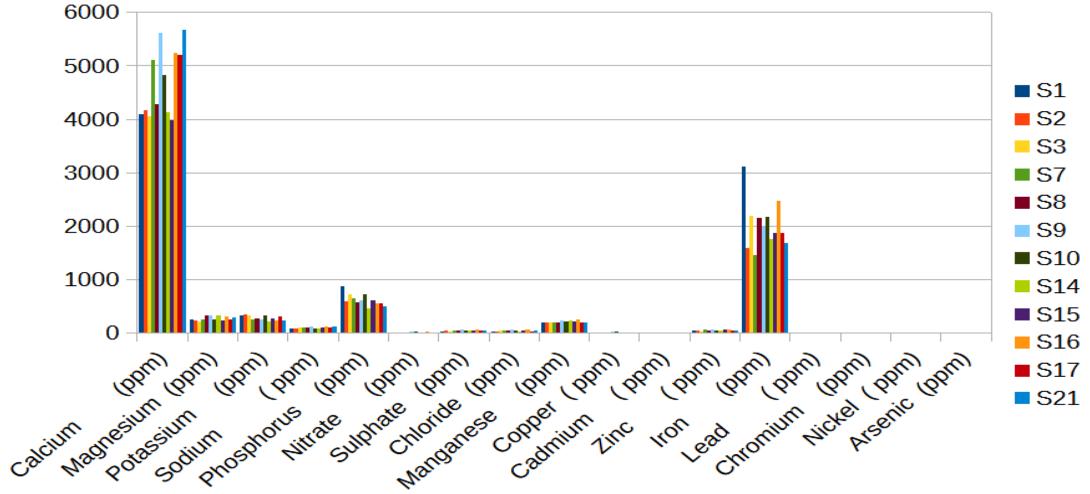

Figure 2: Concentration plot of soil samples

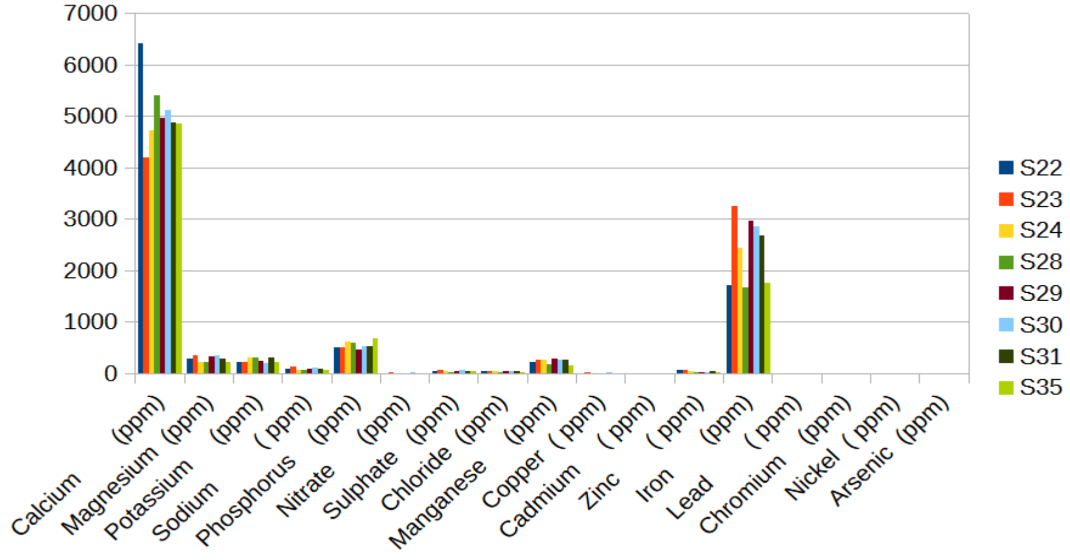

Figure 3: Concentration plot of soil samples

Table 4 displays the temperature, pH, electrical conductivity (EC), turbidity, total dissolved solids (TDS), alkalinity, total hardness, and total acidity of the ground water hand-dug wells that were analysed. Table 5 displays the results of the analysis of anions like magnesium (Mg), zinc (Zn), manganese (Mn), calcium (Ca), cadmium (Cd), nickel (Ni), chromium (Cr), copper (Cu), lead (Pb), arsenic (As), potassium, sodium, and chloride, sulphate, nitrite, and phosphate as well as the concentrations of cations.

Table 4: Physico-chemical Parameters of Water Samples

PARAMETERS	**W1**	**W2**	**W3**	**W6**	**W7**	**W8**	**W11**	**W12**	**W13**	**W21**	**W22**	**W23**	**W25**	**W26**
pH	7.09	6.64	6.61	7.16	7.75	7.21	7.11	6.95	7.24	7.38	6.91	6.94	6.45	7.16
Turbidity (NTU)	8	10	7	9	10	11	10	7	6	11	11	9	10	11
Conductivity µS/cm	209	484	708	214	165	164	178	288	267	1268	1070	386	1343	241
TDS (mg/L)	147.1	345	497	151.2	117	117	125.8	206	190.8	894	755	272	954	170.8
Total acidity (mg$CaCO_3$/L)	12.8	18.9	16.8	6.42	5.12	8.28	6.8	7.24	8.24	4.8	16.7	9.42	12.7	5.68
Alkalinity (mg $CaCO_3$ /L)	46.78	72.8	102.45	26.89	26.7	32.45	28.7	34.89	43.85	146.5	89.76	64.89	168.8	42.9
Total hardness (mg $CaCO_3$/L)	66.75	104.8	134.56	38.7	40.98	56.8	41.24	56.8	65.7	174.9	102.9	82.68	199.8	54.9

Table 5: Concentration of cations and anions in the Ground water sample

PARAMETERS	**W1**	**W2**	**W3**	**W6**	**W7**	**W8**	**W11**	**W12**	**W13**	**W21**	**W22**	**W23**	**W25**	**W26**
Calcium (ppm)	10.2	18.9	14.88	6.24	9.8	4.68	10.45	12.14	9.12	42.49	32.46	21.65	54.9	16.8
Magnesium (ppm)	4.8	3.88	5.12	2.45	4.25	1.65	4.5	3.22	2.14	8.69	12.9	5.64	18.6	4.56
Nitrate (mg/L)	0.28	0.34	0.52	0.31	0.24	0.28	0.34	0.53	0.46	0.82	0.64	0.54	0.98	0.4
Phosphate (mg/L)	0.12	0.18	0.34	0.26	0.16	0.24	0.22	0.26	0.22	0.46	0.42	0.28	0.56	0.28
Sulphate (mg/L)	4.65	6.88	11.08	8.42	5.2	8.2	9.45	7.62	6.86	14.6	12.46	6.8	12.24	5.9
Chloride (mg/L)	11.2	14.82	22.1	18.24	9.86	12.45	10.62	14.8	9.68	35.12	30.08	18.6	26.8	16.75
Potassium (ppm)	2.1	3.6	3.9	2.2	1.8	1.6	1.4	3.4	4.3	9.2	8.4	3.5	8.9	2.8
Sodium (ppm)	8.4	12.7	13.8	8.6	7.4	7.9	5.8	6.4	10.6	12.9	18.2	10.8	20.8	10.2
Manganese (ppm)	0.04	0.02	0.03	0.02	0.01	BDL	0.02	0.02	0.03	0.04	0.06	0.02	0.12	0.05
Copper (ppm)	0.07	0.12	0.09	0.08	0.02	0.1	0.05	0.1	0.06	0.04	0.1	0.06	0.14	0.08
Cadmium (ppm)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.03	BDL	BDL	0.06	BDL
Zinc (ppm)	0.06	0.04	0.09	0.03	0.02	0.05	0.04	0.06	0.08	0.08	0.1	0.05	0.15	0.05
Iron (ppm)	0.35	0.34	0.22	0.17	0.13	0.06	0.15	0.26	0.62	1.45	1.2	0.38	2.14	1.08
Lead (ppm)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.04	BDL

Chromium (ppm)	BDL	0.05	0.02	0.04	BDL	0.07	BDL	BDL	0.04	0.07	0.03	0.04	0.09	BDL
Nickel (ppm)	0.02	BDL	0.08	0.05	BDL	0.03	0.01	BDL	0.04	0.07	0.02	0.03	0.06	BDL
Arsenic (ppm)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.03	BDL

BDL: Below Detection Level

Table 6: Standards for Drinking water (Edition, 2011)

Parameter	WHO (2011)
Temperature (°C)	25
Turbidity (NTU)	5
pH	6.5-9.5
TDS (mg/L)	500
Conductivity µS/cm	1500
Total Acidity (mg CaCO3/L)	NS
Alkalinity (mg CaCO3/L)	4.5
Total Hardness (mg CaCO3/L)	150
Iron (ppm)	0.2
Magnesium(ppm)	NS
Zinc (ppm)	3
Calcium	200
Manganese (ppm)	0.05
Cadmium (ppm)	0.003
Nickel (ppm)	0.07
Chromim (ppm)	0.1
Copper (ppm)	1
Lead (ppm)	0.01
Arsenic (ppm)	0.01
Chloride (mg/L)	Nil
Nitrate(mg/L)	45
Phosphate (mg/L)	NS

Sulphate (mg/L)	250
Nitrite (mg/L)	0.9

DISCUSSION

The first dumpsite, with soil samples designated as S1, S2, S3, and S7 as the control point, the following observations were made from Table 2 about the concentration of cations in the soil samples. Calcium ranges from 4052.0 to 4165.0 ppm which was lower than the control point concentration of 4268.0 ppm, Magnesium ranges from 216.0 to 241.0 ppm and was lower than the control point concentration of 248.3 ppm. Sodium ranges from 72.5 to 98.6 ppm and was lower than the control point concentration of 102.8 ppm. Copper has a range of 7.25 to 10.9 ppm, which was lower than the control concentration of 12.5 ppm. Zinc ranges from 32.8 to 42.19 ppm, which was lower than the control concentration of 46.2 ppm.

Nickel has a range of 0.15 to 0.22 ppm, and it was lower than the control concentration of 0.32 ppm. Potassium ranges from 322.5 to 342.5 ppm and it was higher than the control concentration of 312.8 ppm. Iron ranges from 1589.4 to 3109.0 ppm, it was higher than the control concentration of 1432.0 ppm. Manganese ranges from 189.2 to 201.6 ppm, it was higher than the control concentration of 178.4 ppm. Cadmium ranges from 0.09 to 0.12 ppm, it was higher than the control concentration of 0.08 ppm. Lead has concentration of 0.12 to 0.92 ppm, it was higher than the control concentration of 0.06 ppm. Chromium ranges from 0.06 to 0.11 ppm, it was higher than the control concentration of 0.04 ppm. Arsenic has concentration of 0.05 to 0.08 ppm, it was higher than the control concentration of 0.03 ppm. The For the Anions concentration, Sulphate concentration ranges from 30.9 to 34.9 ppm, which was lower than the control concentration of 36.5 ppm. Chloride ranges from 30.65 to 42.7 ppm, it was lower than the control concentration of 48.2 ppm. Phosphate ranges from 584.9 to 862.5 ppm, which was higher than the control concentration of 521.3 ppm. Nitrate ranges from 7.28 to 12.42 ppm and it was higher than the control concentration of 6.52 ppm.

The analysis of S1-S3 compared to S7 shows that some essential cations (calcium, magnesium, sodium, copper, zinc, and nickel) and anions (sulphate and chloride) have lower concentrations, suggesting possible leaching or depletion at the dumpsite. However, heavy metals like iron, manganese, cadmium, lead, chromium, and arsenic and anions such as phosphate and nitrate have higher concentrations, indicating significant accumulation and potential contamination from waste materials. The higher concentrations of iron, manganese, cadmium, lead, chromium, and arsenic in S1-S3 compared to the control (S7) suggest significant anthropogenic contributions, possibly from industrial waste, electronic waste, or metal scraps at the dumpsite.

Lead contamination is concerning due to its toxic effects on human health, including neurological damage and developmental delays in children. Cadmium, even at trace levels, poses risks for kidney damage and bioaccumulation in crops. Chromium and Arsenic are known carcinogens, raising concerns about long-term exposure and groundwater contamination. For Phosphate and Nitrate, Higher concentrations indicate nutrient enrichment, which may be linked to organic waste decomposition or agricultural runoff. Calcium, magnesium, sodium, and zinc are lower at the dumpsite compared to the control, suggesting that either Leaching is occurring, where rainfall and water movement wash these elements away from the surface soil, Dumpsite soil has altered retention capacity, potentially affecting soil structure and fertility over time or Dilution effects from organic matter decomposition could be lowering certain metal concentrations, while concentrating others (e.g., iron and arsenic).

For the second dumpsite, with soil samples designated as S8, S9, S10, and S14 as the control point, the following observations were made from Table 2, that Calcium (4280.0 to 5624.0 ppm) was higher than the control (4122.0 ppm). Magnesium (245.0 to 323.0 ppm) was lower than the control (334.0 ppm). Sodium (76.9 to 122.8 ppm) showed overlapping trends with the control (85.8 ppm). Copper (8.76 to 14.89 ppm) showing overlapping trends with the control (8.96 ppm).Zinc (38.69 to 62.8 ppm) showed overlapping trend with the control (43.86 ppm). Nickel (0.13 to 0.37 ppm) showed overlapping trend to the control (0.22 ppm). Potassium (246.5 to 322.8 ppm) showed overlapping trend with the control (215.7 ppm).

Iron (1981.0 to 2170.0 ppm) was higher than the control (1765.9 ppm). Manganese (198.0 to 224.8 ppm) was lower than the control (228.9 ppm).Cadmium (0.07 to 0.28 ppm) showing overlapping trend with the control (0.09 ppm).Lead (0.09 to 6.72 ppm) showed overlapping trend with the control (0.68 ppm).Chromium (0.04 to 0.32 ppm) showed overlapping trend with the control (0.05 ppm). Arsenic (0.06 to 0.09 ppm) was higher than the control (0.06 ppm).The Anions concentration of Sulphate (42.1 to 54.8 ppm) was higher than the control (34.56 ppm). Chloride (34.79 to 54.7 ppm) was higher than the control (32.89 ppm).Phosphate (572.8 to 722.4 ppm) was higher than the control (454.6 ppm). Nitrate (12.9 to 16.8 ppm) was higher than the control (7.56 ppm).

Higher concentrations of iron, calcium, arsenic in S8-S10 compared to S14 suggest significant metal accumulation, likely due to industrial and municipal waste. The elevated lead levels pose a concern due to its toxic nature, particularly for children and pregnant women. Slightly elevated cadmium concentrations indicate possible contamination sources, such as electronic waste or industrial runoff. Chromium and Arsenic with Their presence in high amounts raises environmental and health concerns, as both are toxic and can lead to long-term soil and water contamination. Higher phosphate and nitrate indicate increased nutrient levels, possibly from decayed organic matter or fertilizers. While beneficial for plant growth, excessive phosphate and nitrate may contribute to soil degradation and water pollution through eutrophication, leading to harmful algal blooms in nearby water bodies.

For the third dumpsite with soil samples designated as S15, S16, S17 and S21 as the control point, it was observed from Table 2, that the concentrations of calcium (3980 to 5240 ppm) were lower than the control point concentration (5678 ppm). Magnesium (234 to 302 ppm), potassium (234.8 to 312.5 ppm), sodium (93 to 125.7 ppm), manganese (188.6 to 245.9 ppm), copper (8.22 to 12.88 ppm), cadmium (0 to 0.22 ppm), zinc (45.6 to 62.54 ppm), lead (0 to 6.89 ppm), chromium (0.08 to 0.56 ppm), nickel (0.14 to 0.42 ppm), and arsenic (0.04 to 0.26 ppm) all showed overlapping trends with the control point, meaning that some sample values were higher while others were lower. On the other hand, phosphorus (546.8 to 615.4 ppm), nitrate (6.54 to 24.9 ppm), and iron (1872.3 to 2465.9 ppm) were higher than the control point concentrations of 498.2 ppm, 4.56 ppm, and 1678.94 ppm, respectively.For the anions, chloride (29.19 to 56.8 ppm) and sulphate (33.8 to 52.9 ppm) showed overlapping trends with the control point (44.85 ppm and 42.9 ppm, respectively), while phosphate and nitrate had concentrations higher than that of the control point.This pattern indicates variations in contaminant accumulation, with certain heavy metals and anions exceeding control levels, while others remained within or below control concentrations.

For the fourth dumpsite with soil samples designated as S22, S23, S24 and S28 as the control point, it was observed from Table 3 that Calcium (4210.0 to 6412.0 ppm) showed overlapping trends with the control point (5420.0 ppm).Potassium (214.6 to 302.0 ppm) also overlapped with the control point (301.6 ppm).Sodium (65.8 to 145.8 ppm) overlapped with the control (68.9 ppm).Magnesium (226.0 to 364.0 ppm) was higher than the control (219.0 ppm).Iron (1724.9 to 3250.0 ppm) was higher than the control (1670.0 ppm).Manganese (218.9 to 272.5 ppm) was higher than the control (188.2 ppm).Copper (9.26 to 15.78 ppm) was higher than the control (4.12 ppm).Cadmium (0.12 to 0.21 ppm) was higher than the control (0.0 ppm).Zinc (52.1 to 65.9 ppm) was higher than the control (29.8 ppm).Lead (0.0 to 8.42 ppm) overlapped with the control (0.0 ppm).

Chromium (0.12 to 1.22 ppm) was higher than the control (0.0 ppm).Nickel (0.23 to 0.88 ppm) was higher than the control (0.06 ppm).Arsenic (0.08 to 0.23 ppm) was higher than the control (0.0 ppm).Sulphate (39.8 to 62.8 ppm) was higher than the control (28.7 ppm).Chloride (48.9 to 56.9 ppm) was higher than the control (28.54 ppm).Phosphate (502.5 to 625.0 ppm) overlapped with the control (590.4 ppm).Nitrate (14.24 to 22.4 ppm) was higher than the control (3.49 ppm).The data indicates that several heavy metals (iron, manganese, zinc, nickel, chromium, arsenic, cadmium, and lead) have higher concentrations at the dumpsite than at the control point, suggesting possible contamination from waste disposal. Similarly, key anions (sulphate, chloride, and nitrate) also exhibited increased levels compared to the control, reinforcing the impact of pollution. However, some cations, such as calcium, potassium, and sodium, showed overlapping trends with the control point, suggesting variability in accumulation. The significant increase in lead, cadmium, chromium, and arsenic suggests a high level of contamination from industrial or electronic waste.

High lead levels pose a major public health risk, as lead exposure is linked to neurological disorders and developmental issues in children. Cadmium is a highly toxic metal that can cause kidney damage and bioaccumulate in plants, making contaminated soil dangerous for agriculture. Chromium and Arsenic are toxic elements which pose carcinogenic risks and may leach into groundwater sources. Elevated phosphate and nitrate indicate an increase in soil nutrients, likely due to organic waste decomposition or fertilizer runoff. While beneficial for plant growth, excess phosphate and nitrate can lead to soil nutrient imbalance and groundwater contamination, potentially causing eutrophication in nearby water bodies. The lower concentrations of calcium, magnesium, sodium, zinc, and nickel suggest Leaching due to water percolation, where essential minerals are lost from the soil, Dilution effects from organic matter decomposition, altering soil composition and selective retention of heavy metals, where toxic elements accumulate while beneficial cations are depleted.

For the fifth dumpsite, with soil samples designated as S29, S30, S31, and S35 as the control point, the Phosphorus (458.0 to 542.0 ppm) was lower than the control (682.0 ppm). Calcium (4872.0 to 5124.0 ppm) was higher than the control (4862.0 ppm). Magnesium (298.0 to 345.0 ppm) was higher than the control (216.8 ppm). Sodium (86.8 to 112.4 ppm) was higher than the control (64.2 ppm).Iron (2679.0 to 2980.0 ppm) was higher than the control (1762.0 ppm). Manganese (265.4 to 286.0 ppm) was higher than the control (154.2 ppm). Copper (8.76 to 16.8 ppm) was higher than the control (6.24 ppm).Cadmium (0.22 to 0.34 ppm) was higher than the control (0.0 ppm). Zinc (28.7 to 45.25 ppm) overlapped with the control (30.12 ppm).

Lead (6.12 to 7.21 ppm) was higher than the control (0.0 ppm). Chromium (0.54 to 1.22 ppm) was higher than the control (0.0 ppm). Nickel (0.33 to 0.78 ppm) was higher than the control (0.09 ppm). Arsenic (0.08 to 0.24 ppm) was higher than the control (0.0 ppm). Potassium (208.3 to 312.5 ppm) overlapped with the control (228.0 ppm). Nitrate (12.8 to 18.4 ppm) was higher than the control (6.12 ppm). Sulphate (42.9 to 58.9 ppm) was higher than the control (36.4 ppm). Chloride (39.8 to 48.2 ppm) was higher than the control (25.4 ppm).the analysis of S29-S31 compared to S35 shows that most heavy metals and anions (iron, manganese, zinc, nickel, chromium, arsenic, cadmium, lead, nitrate, sulphate, and chloride) have higher concentrations at the dumpsite, indicating potential contamination. Phosphorus was lower than the control, while potassium and zinc showed overlapping trends, suggesting a more stable distribution. These findings suggest that the soil in this dumpsite has experienced significant heavy metal and anion accumulation from waste materials.

Table 4 displays the turbidity, pH, electrical conductivity (EC), total dissolved solids (TDS), total acidity, alkalinity, and total hardness of the ground water (hand-dug wells) that was measured. The general classification of water recommended by world health organization as international standard for drinking water in 2011 is displayed in Table 6. As shown in Table 4, for all the water samples tested, their pH are within the recommended range of 6.5 to 9.5 which is the allowable concentrations for drinking water, the turbidity of all water sample are above the recommended limit of 5 . The conductivity of the water samples are below the recommended limit except for W21,W22,W25 , which are a little bit higher than the recommended limit. The total dissolved solids (TDS) of all water samples examined are below the recommended limit. The total acidity of all water samples is very low, the alkalinity of all water samples is higher than the recommended limit, and Total hardness of all water sample is below the recommended limit except W21, W25 which are a little bit above the limit.

The results of analyzed major cations and anions for water samples are reported in Table 5. The concentration level of calcium for all water samples is very low when compared with the recommended limit. The concentration level of magnesium is high for all water samples when compared with the recommended limit. Potassium level is very low, sodium level is low, manganese concentration level is very low except for W22 and W25 when compared with the recommended limit, copper concentration is very low for all water sample when compared with the recommended limit, calcium is below the detection limit for all samples except for W25 which is slightly higher than the recommended limit when compared. Zinc concentration is very low when compared with the recommended limit. Iron concentration is very low for majority of the samples except for W13, W21, W22, W25, and W26 when compared with the recommended limit. Lead concentration is below detection level except for W25 which is slightly higher than the recommended level. Chromium concentration is below recommended limit for all water samples. Nickel concentration is below the recommended limit for all water samples. Arsenic concentration is below detection level for all samples except for W25 which is slightly above the recommended level.

CONCLUSION AND RECOMMENDATION

The dumpsite (S1-S3) has undergone significant changes in its chemical composition due to waste deposition, leading to higher heavy metal concentrations and nutrient enrichment. However, the decrease in some essential cations suggests possible leaching or altered soil retention properties. The second dumpsite (S8-S10) has undergone notable chemical alterations, with a significant increase in heavy metals and anions, indicating waste accumulation and potential pollution. While nutrients like phosphate and nitrate have increased, essential cations like calcium, iron and arsenic have increased, pointing to possible soil contamination. The third dumpsite (S15-S17) shows significant soil contamination, particularly with heavy metals and excessive anion concentrations. While phosphate and nitrate contribute to nutrient enrichment, the decline in essential cations suggests leaching and soil degradation. The fourth dumpsite (S22-S24) exhibits high contamination levels, especially with toxic heavy metals and excess anions, indicating waste accumulation and potential pollution of soil and groundwater. Heavy metal accumulation (Pb, Cd, Cr, As) indicate Environmental toxicity risks. (Phosphate and nitrate) indicate Soil imbalance & water pollution risks. Depletion of essential cations (Ca, Mg, Na, Zn) indicate Soil degradation and reduced fertility. The fifth dumpsite (S29-S31) exhibits notable contamination, especially with heavy metals, excess anions, and nutrient imbalances, indicating serious environmental pollution risks. Heavy metal buildup (Pb, Cd, Cr, As) will affect human and ecosystem. Nutrient overload (phosphate & nitrate) will lead to Water pollution and soil imbalance. Depletion of essential cations (Ca, Mg, Na, Zn) will lead to Reduced soil fertility.

The analysis of water quality parameters indicates that while the pH levels of all samples fall within the recommended range for drinking water, several other parameters exceed their respective limits. The turbidity of all water samples is above the recommended limit, which may indicate potential contamination or suspended particles. Conductivity is generally within acceptable limits, except for W21, W22, and W25, which show slightly elevated values. Total dissolved solids (TDS) remain within acceptable limits, suggesting minimal dissolved impurities.

Regarding chemical characteristics, total acidity is low across all samples, while alkalinity is higher than the recommended limit. Total hardness is within acceptable levels for most samples, except for W21 and W25, which are slightly above the limit. The major cations and anions analysis reveals that calcium levels are significantly low, while magnesium is high in all samples. Sodium and potassium levels remain low, and manganese levels are only elevated in W22 and W25. Other trace metals, including copper, zinc, and nickel, are present at very low concentrations. However, iron is elevated in W13, W21, W22, W25, and W26, and lead is detected at a slightly higher concentration in W25. Additionally, arsenic is present in W25 at a concentration slightly exceeding the recommended limit.

Recommendations

The soil samples collected from the various dumpsites (S1–S31) exhibit substantial contamination, particularly from heavy metals, excess anions, and nutrient imbalances, all of which pose serious environmental and health risks. . The following strategies are recommended:

1. Immediate and Long-Term Remediation Measures

- Phytoremediation: Introduce metal-accumulating plants (e.g., *Vetiver grass, Indian mustard, Sunflower*) to extract heavy metals like Pb, Cd, Cr, and As from the soil.
- Soil Amendment and Liming: Apply lime ($CaCO_3$) or biochar to:
    - Neutralize soil acidity caused by leaching.
    - Reduce mobility and bioavailability of heavy metals. Restore levels of essential cations (Ca, Mg, Zn, Na).Organic Compost Addition: Enrich the soil with organic matter to improve its structure, nutrient retention, and cation exchange capacity (CEC).

- Engineered Bioremediation: Utilize microbes or microbial consortia that are capable of degrading organic waste and stabilizing metal ions.

2. Pollution Control and Site Management

- Controlled Waste Disposal Practices: Enforce segregation of waste and prevent uncontrolled dumping of hazardous materials. Establish lined landfills to avoid leachate seepage.
- Regular Monitoring: Establish a routine soil and groundwater monitoring program to track changes in heavy metals, anions, and essential nutrients.
- Runoff and Leachate Management: Construct drainage systems and leachate collection points to prevent further migration of pollutants into surrounding soils and water bodies.

3. Agricultural and Ecological Considerations

- Crop Selection and Rotation: In nearby agricultural areas, avoid cultivating edible crops until the soil is remediated. Instead, use non-edible cover crops to stabilize the soil.
- Buffer Zones: Establish vegetative buffer strips around the dumpsites to reduce pollutant runoff and airborne dust.

4. Community Engagement and Policy Enforcement

- Awareness Campaigns: Educate local communities about the risks of waste dumping and the importance of proper waste management and soil conservation.
- Policy and Regulation Enforcement: Collaborate with environmental authorities to enforce solid waste management policies and penalize illegal dumping activities.

For the water samples, the following are recommended:

1. Turbidity Reduction**:** Since all water samples have turbidity above the allowable limit, filtration and sedimentation treatment processes should be implemented before consumption.
2. Magnesium Reduction: Given that magnesium levels are high in all samples, water softening techniques such as ion exchange or lime softening should be considered.
3. Iron and Manganese Removal: Samples with elevated iron and manganese (W13, W21, W22, W25, and W26) may require oxidation and filtration processes to prevent discoloration and potential health risks.
4. Lead and Arsenic Mitigation: The presence of lead and arsenic in W25 calls for immediate action, such as using activated alumina or reverse osmosis filtration, to ensure water safety.
5. Regular Monitoring: Continuous water quality monitoring is recommended to track fluctuations in contamination levels and take preventive actions accordingly.
6. Public Awareness**:** Authorities should inform consumers about the quality of their water sources and encourage the use of appropriate filtration methods for household consumption.
7. Further Investigation: Additional studies should be conducted to identify the sources of contamination and implement long-term corrective measures.

By implementing these recommendations, the water quality can be improved, ensuring safer and healthier drinking water for consumers.

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