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Research Article

SUBSURFACE DELINEATION OF LECHATES IN AN ACTIVE DUMPSITE USING ELECTRICAL RESISTIVITY METHOD AND HYDROGEOCHEMICAL INVESTIGATION

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ABSTRACT

Leachate contamination was assessed using electrical resistivity, and groundwater samples were taken from the area surrounding the dumpsite to examine any potential effects of leachate percolation on the quality of the soil and groundwater. Water samples were tested for concentrations of different physicochemical elements, including SO_4, NO_2, HCO_3, Cl, Mg, Na, K, Ca and Fe. The concentrations in groundwater samples, especially those taken close to landfill sites, were found to be at high levels, possibly indicating that leachate percolation has had a significant impact on groundwater quality. Groundwater quality is reduced by the presence of contaminants, especially close to dump sites, making the aquifer unsuitable for consumption. Although some corrective actions are recommended to lessen further groundwater contamination due to leachate percolation, the current report calls for effective waste management in Yenagoa Local Government area.

Keywords: Leachates, Contamination, Dumpsite, Waste, Groundwater, Resistivity

INTRODUCTION

Waste is anything that is of no use to the disposal. It can also be said to be any material obtained from an activity, which has no immediate economic demand and which must be disposed of (Deborah & Ayobami, 2013). Solid wastes are residual from homes, businesses or institutions and are referred to as trash, garbage, rubbish, discards and throwaways that are of no relevance to the disposer. Based on its origin, purpose, physical characteristics, and potential dangers to the environment, solid waste can be divided into different categories. Broken bricks, shattered glass and bottles, abandoned cans, plastics, papers, battery casings, plantain skins, and nylon are a few examples of solid waste products. On the basis of source which is commonly used, solid wastes are classified as municipal, industrial, agricultural, mining and mineral wastes, construction and demolition, human and animal wastes. Most of the urban solid wastes, irrespective of their classification, are degradable; this aids the rate of leachate formation and migration. The non-biodegradable wastes can last for many years without any sign of decomposition. Therefore, there is possibility of leachate generation, plume extension and migration at the base of urban landfill owing to the composition of discarded materials and frequent surface water ingestion from urban precipitation. Leachate is a liquid associated mainly with open dumps. It is produced when rain water percolates through wastes that are dumped in a disposal site. Trace elements such as lead, iron, copper, zinc, and manganese are also found in leachates. Ground water around the waste disposal site can be contaminated by leachate from the waste deposited (Bernstone & Dahlin, 1996; Hensel & Dalton, 1995).

A long-established method for solid-waste disposal that demands a minimum of effort is the open dumpsite (Montgomery 1951). Drawbacks to such facilities are obvious especially to those having the misfortune to live nearby. Open dumps are unsightly, unsanitary, and can give off unpleasant scents. In addition, they often attract insects and pests like rodents, which creates a fire threat. Trash maybe scattered by wind or water. Some of the gases rising from the dump may be toxic. There is foul odour emanating from the site which is a typical characteristic of waste dumpsite. The waste composition comprises leaves, paper, food waste, tins, glass, and rags. Open dumps are an unsatisfactory means for solid-waste disposal. All in all, the need to develop a long-term wastes management strategy with the objective of achieving a state of sustainable and effective system of waste disposal. The aims of this waste management policy are to protect human health, the environment and natural resources. The dumpsite should be chosen so as to ensure minimal environmental impact in the surrounding areas.

In order to achieve the set out waste management objectives, the Bayelsa Waste Management Board closed the old dumpsite which was located along Tombia-Amassoma road and opened another waste disposal site which is located close to the Shell facility along Etelebo road to Negudo community (Figure 1).

To delineate the potential pollution plume geophysical technique (DC Resistivity method) was applied to study the area. It was used to map the area where conductive materials are concentrated and the direction of migration of the plumes and therefore provided a basis for remediation if the environment is under threat. Due to the rapid and accurate development of six subsurface images using geoelectrical resistivity, the resistivity imaging technique has become more and more common in electrical exploration. According to Dahlin and Zhou's research from 2002, this technique is becoming more and more common. The 2-D geoelectrical resistivity imaging measures the apparent resistivity of the subsurface, which can be inverted to develop a model of the subsurface structure and stratigraphy in terms of its electrical properties (Loke and Baker, 1996b).

Aim and Objectives:

The study aims to delineate subsurface contamination zones around the dumpsite and also reveal the direction of migration

Objectives of this research are:

i. To ascertain the properties of the water samples around the area.
ii. To assess the impact of groundwater contamination from landfill leachate on human health

Figure 1: Showing an area of the waste dumpsite

Study Location and Accessibility:

The study was conducted in Bayelsa state's Yenagoa Local Government Area. Latitude 40 55' 29" N and longitude 60 15' 51" E define the study area's perimeter (figure 2). Its area is 706 km^2, and its elevation is 86 meters above sea level. A number of road networks connect the research area, which is situated in the rain forest vegetative zone. River Nun tributaries drains the entire region.

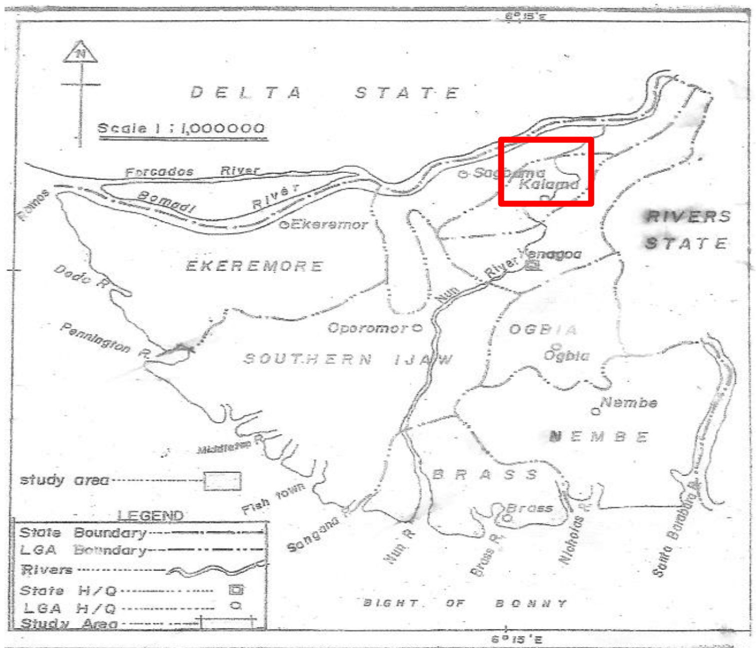

Figure 2: Map of Bayelsa showing study location (modified after Oborie & Nwankwoala, 2012)

Geologic Setting:

The evolution and stratigraphy of the Niger Delta Basin (figure 3) have been extensively discussed by prominent authors (Short & Stauble, 1967; Murat 1972; Nwajide 2013, Wright, 1981; Burke, et. al., 1971). The rifting of the Precambrian basement terrain into the ridge triple junction during the Late Jurassic to Cretaceous Period led to the separation of the African and South American plates, which is related to the tectonic evolution of the basin (figure 3).

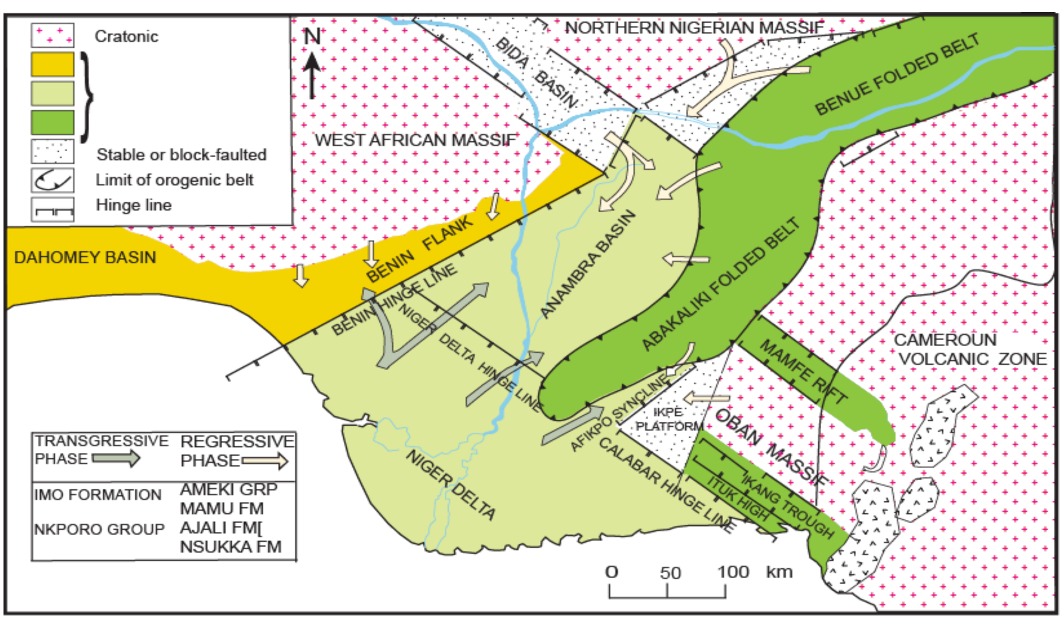

Figure 3: Tectonic map: Campanian to Eocene redrawn and modified after (Murat, 1972).

The Paleogene sequence of the Niger Delta Basin comprises of the Paleocene Imo Formation, the Eocene Ameki Group and the Oligocene Ogwashi-Asaba Formation.

The oldest formation (Palaocene Imo Shale) forms an arched exposure section down the delta frame. They are blue to grey fossiliferous shales with thin bands of sandstones. The Ameki Group of the Eocene comprises of sandstones, calcareous clays and fossiliferous shales; the Ogwashi-Asaba Formation spans from the Late Eocene – Early Oligocene to Recent and contains alternating coarse grained sandstones, light clays and lignite streaks (Kogbe, 1976).

The most recent deposits are the coastal plain sands of the Benin Formation from Miocene to Recent. These formations are age diachronous and grades into the subsurface with their equivalents as the Akata, Agbada and Benin Formations respectively also referred to as the pro delta, delta front and delta top environments (figure 4).

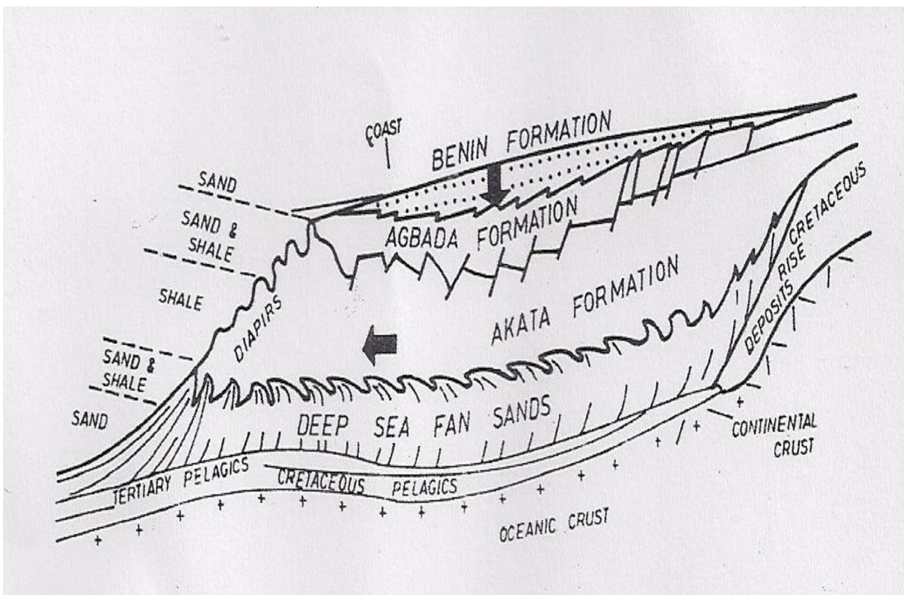

Figure 4: Structure of Niger Delta. (After Asseez, 1976)

Data Acquisition:

i. Acquisition of electrical resistivity data using profiling (Constant Separation Techniques) with ABEM terrameter
ii. Acquisition of four electrical imaging data one for each location with a lateral extent of 200m along the dumpsite.
iii. Acquisition of borehole and hand-dug well water samples for geochemical investigation

Data Analysis:

i. The profile data was presented using depth sounding curves, and the apparent resistivity data was plotted against electrode spacing on a graph. Using this technique, a curve was drawn across the collection of data points that was as precise and supple as feasible.

ii. The profile data were analysed qualitatively involving partial curve matching the computer iterative methods.
iii. The data acquired from detail imaging from the suspected contaminated region/part of the waste dump site were analysed and processed using DIPRO software.
iv. The water samples were subjected to analyses to ascertain the physiochemical properties. The following factors were examined: pH, electrical conductivity, total dissolved solids, chloride ion, bicarbonate, sulphate, nitrate, magnesium, calcium, potassium, sodium, and iron.
v. Interpretation and inference.

Instrumentation and Measurement Procedure:

Instruments Used:

I. ABEM Resistivity Metre:

This is a resistivity metre which is capable of measuring the resistivity of the earth over a range of conditions. With additional hardware, it could be connected to a computer. The instrument is powered by a large recharge battery.

II. Electrodes:

Two pairs of electrodes made from stainless steel were used. One pair as current electrodes and the other as potential electrodes. The electrodes were driven into the earth to ensure good electrical contact. At least two-thirds the length of the electrodes should be below the ground surface. A controlled amount of electrical current (I) flows from the resistivity metre through the current electrodes into the ground while the potential difference (ΔV) across the potential electrodes is measured.

III. Cables:

These were used to connect the electrodes to the resistivity metre. They provide passage for current to flow from the resistivity metre to the electrodes and then into the ground. Four reels of cables were used, two each for current and potential electrode pairs.

IV. Clips:

Four crocodile clips used to connect the cables to the electrode in order to ensure good electrical contact.

Methodology:

To look at the geometry and subsurface conditions of the dumpsite, four Constant Separation Traverses were completed. Three profiles were run along the dumpsite, with each profile having a maximum 200-meter spacing. With electrode spacing of 10 m, 20 m, 30 m, 40 m, 50 m, and 60 m for n=1, 2, 3, 4, 5, and 6, respectively, these profiles made use of the Wenner array. The fourth profile constitutes the control and was carried out about 100m east of the dumpsite.

The ABEM Resistivity metre was used for resistance measurements. The current and potential electrodes were expanded at the same spacing. Tight grip of electrodes with the ground was ensured to prevent leakage of current into the ground through poorly insulated cables. Data collected from the field were referred to as apparent resistivity data and were converted to true resistivity data by multiplying with the geometric factor (k) which is equal to $2\pi a$. These true resistivity data are later plotted on a graph which represents a manual 'pseudo-section'.

RESULTS AND INTERPRETATION

Profile 1:

The result of the 2D resistivity inversion along the dumpsite for location 1 is shown in fig. 5 as 2D inverted resistivity structures. The 2-D geo-electric profile of the line shows a non-uniform lateral distribution of layers. A low resistivity zone was observable from south-western to north-eastern along the profile from 0m to 130m ranging from 21.8Ωm-58.8Ωm. This low resistivity zone reaches a depth of 28m on the south-western end of the profile from 0m to 50m and gradually reduces in depth of penetration along the north-eastern direction to about 5m. This low resistivity zone is due to the effect of contamination plume from the dumpsite as the leachate percolates through the soil. According to Sauck (1998, 2000) and Atekwana et al. (2000), the zone with low resistivity is a result of a high concentration of total dissolved solids in a region with the most active microbial activity. Pitting was carried out between 50m and 60m along the profile and the plumes were observed from 2m depth. Below this low resistivity zone is a slightly higher resistivity zone observable from 30m along the entire profile. This zone reaches a depth of more than 70m on the south-western axis of the profile and reduces in thickness as one move north-eastern to 180m on the profile. On the profile, a zone of exceptionally high resistivity can be seen. It is more noticeable on the north-eastern portion of the profile, which extends from the surface down to 200 meters in depth, however it is less obvious on the south-western portion. On the 2-D profile image, the leachate plume migration can be seen moving along the weak zones and flooding the southwest corner of the profile.

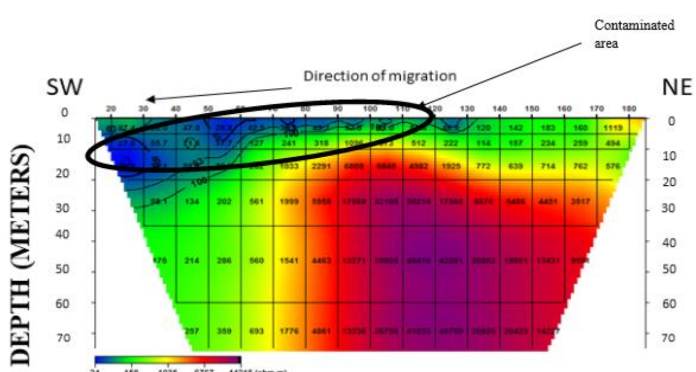

Figure 5: Pseudosection for location 1

Profile 2:

Profile 2 is located 20m south of profile 1. The 2-D geo-electric profile depicted in Fig. 6 shows the lateral fluctuation of sandy soil, which is consistent with the findings of the pitting. At the profile's surface, specifically between 60 and 80 meters, between 100 and 110 meters, and between 130 and 140 meters, a zone of significant resistivity was found. A sandy layer is present in this zone, which has a thickness of around 10 meters. A slightly high resistivity was also observed along the entire profile close to the surface (green). Within this zone is the very low resistivity zone which was as a result of the movement of the plumes through the sandy layer was observed from a depth of 5m to 20m with values ranging from 2.75Ωm -9.35Ωm. This low resistivity area is interpreted as areas where there is accumulation of leachate plumes (Shemang et al 2006).
The migration of leachate plumes observed on the 2-D profile image was observed at much greater depth. This is due to the permeability of the sandy layer.

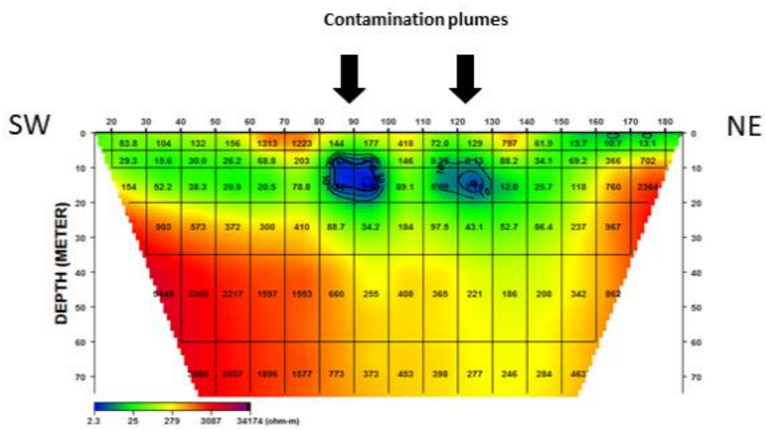

Figure 6: Pseudosection for location 2

Profile 3:

The 2D inverse resistivity section shows a range in resistivity values which varies from 24.3Ωm to 34.3Ωm to a depth of about 30m suggestive of clay/clayey sand. Due to the leaching of the contaminants and presence of moisture, the resistivity values are low which are indicative of leachate plumes, suggestive of the wet part of the waste (Dahlin & Leroux, 2010). The leachate plume is observed along 80m-110m of the profile at a depth of 0m-27m. Pitting was also done at 90m along the profile to buttress the claim and the moisture from the contaminant was seen at about 3m depth. A larger resistivity range, spanning the bottom of the profile from 33.4 m to 53.7 m, denotes the presence of the intermediate layer. At both the southern and north-eastern edges of the profile, a zone of exceptionally high resistivity can be seen beneath this layer.
Here, migration of leachate plume is also limited to shallow depth due to the low permeability nature of the clay close to the surface as observed during pitting.

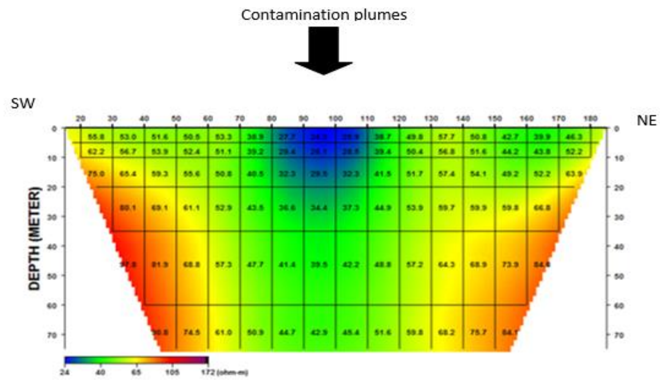

Fig. 4.3: Pseudosection for location 3

Figure 7: Pseudosection for location 3

Profile 4 – Control:

Profile 4 is located 100m east of profile 3. Pseudosection of this area shows that the resistivity values vary from 14.2Ωm to 540Ωm Due to the dryness of the environment as well as the presence of stones and shattered building materials, the area has a high resistance. Furthermore, there is proof that solid garbage is present in the area. No contamination plume was observed here and selected areas were pitted and found to be wide distribution of unsaturated sand beneath artificial building waste material in this region.

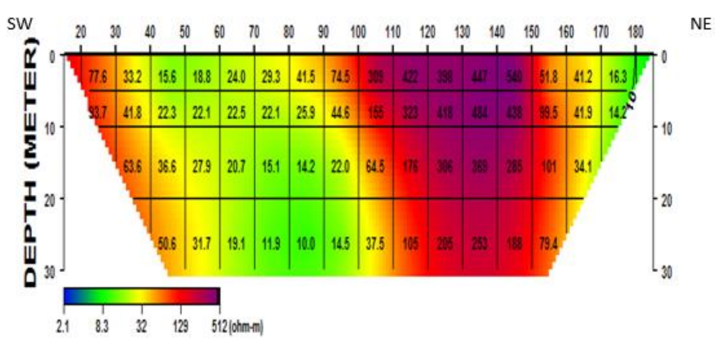

Figure 8: Pseudosection for location 4

Samples	pH	Electrical Conductivity, µs/cm	Total Dissolved Solids	Temperature, ºC
BH1	7.4	513	290	28.1
BH2	5.92	851	424	28.1
W1	6.1	490	400	28.3
W2	5.3	790	505	28.2
WHO	6.5 – 8.5	1000	300	25.70

Table 1: Result of Physiochemical properties of groundwater obtained from boreholes and hand-dug wells around the dumpsite

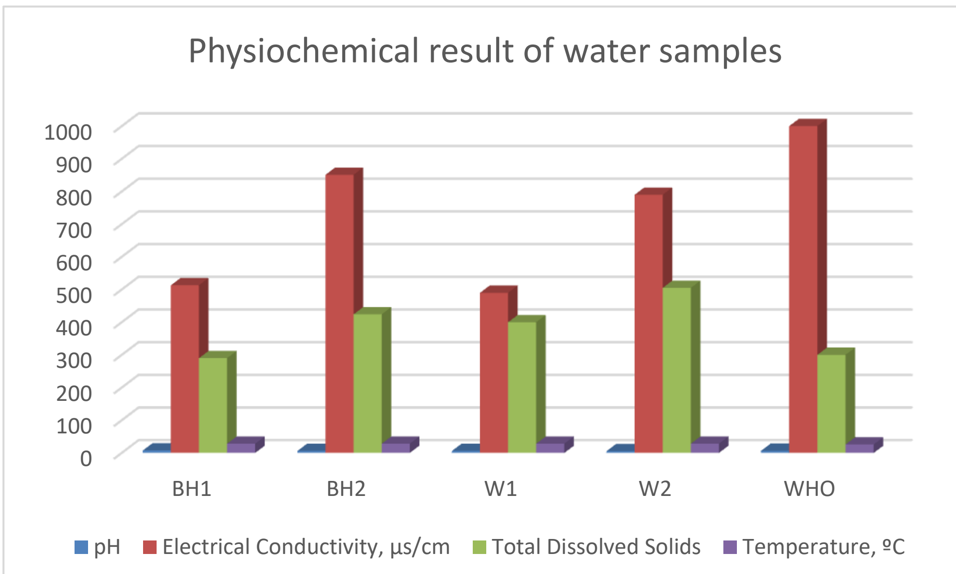

Figure 9: Observed pH, EC, TDS and Temperature values of BH1 & BH2, W1 & W2 in comparison to WHO standard

Samples	Sulphate, mg/L	Nitrate, mg/L	Bicarbonate, mg/L	Chloride, mg/L	Magnesium, mg/L	Sodium, mg/L	Potassium, mg/L	Calcium, mg/L	Iron, mg/L
BH4	57.52	27.21	0.16	16.49	0.79	79.08	1.15	9.19	0.03
BH5	20.48	35.33	0.23	33.99	1.31	89.3	1.91	15.21	0.05
W1	51.3	2.8	0.41	20.12	8.78	0.75	1.1	86.99	0.011
W2	241.37	26.17	0.1	47.3	14.16	1.21	1.77	110.25	0.03
WHO	250	50	350	250	50	200	50	75	0.3

Table 2: Result of Hydro-chemical Parameters of Water Samples

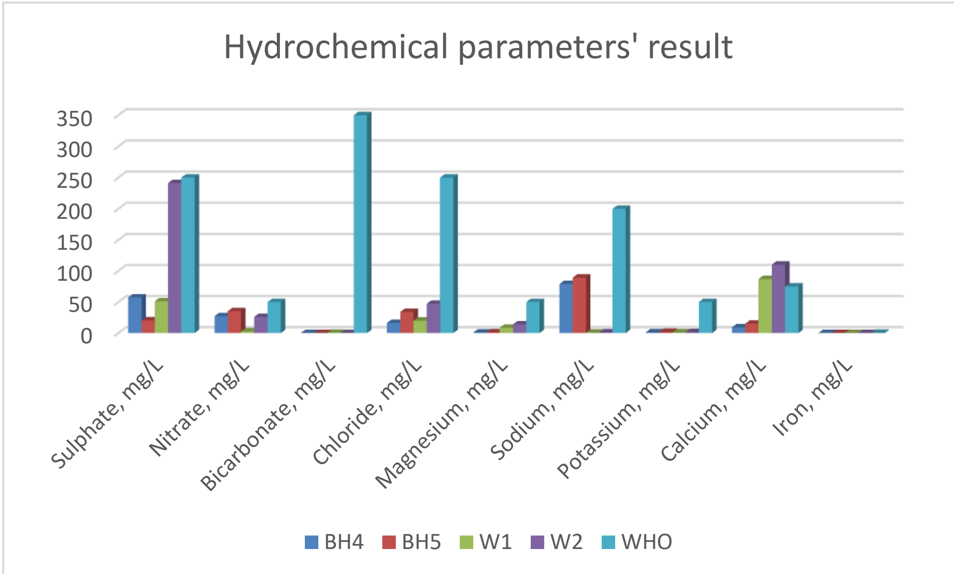

Figure 10: Observed SO_4, NO_2, HCO_3, Cl, Mg, Na, K, Ca and Fe values of BH1 & BH2, W1 & W2 in comparison to WHO standard

Mean electrical conductivity (EC) values of 513 us/cm and 851 us/cm, as well as TDS values of 505 mg/L and 424 mg/L, were greater for the two bore holes that were located 50 m east and 150 m south of the dumpsite, respectively. These values are statistically considerably above the typical ranges. Given the region's extensive industrialization and population, this suggests leachates plumes percolation and pollution from home and industrial waste.

CONCLUSION

The study has revealed that many parts of the dumpsite have been considerably contaminated due to migration of leachate. This is evident from the low values of resistivity obtained from the result. It also showed that contaminants derived from the waste disposal site infiltrate through the soil. Movement of plumes occurs when there are weak zones like fractures or when in contact with very permeable subsurface material.

Resistivity data indicated certain level of leachate contamination from the surface waste dump. This is reflected in the resistivity value of 24Ωm to 58.8Ωm along 0m-130m from the south-western to the north-eastern end of the profile 1, while resistivity values in the underlying layer of 120Ωm to 359Ωm indicated the presence of sandstones. Profile 2 is represented by very low resistivity values (2.75Ωm -9.35Ωm), the low resistivity area shows evidence of contaminant plumes for Profile 3, which covered a depth of around 30 meters from the surface, resistivity values ranging from 24.3 m to 34.3 m were collected. Clays, pollution plumes, and microbial activity are some of the variables that have been linked to the zones of low resistivity shown on Profiles 1 to 3. The control presented as profile 4 reveals an absence of plumes, since it is located

100m east of the dumpsite. Pitting showed that the area is chiefly composed of unsaturated sandstones.

Recommendation:

Detailed geotechnical and geochemical assessments must be performed in order to characterize the subsurface inside and around the waste dumpsite. Since it was not properly designed before being used, this is essential, and more parameters must be found. These parameters to be determined include permeability, compressibility factors, bearing capacity, clay mineral types, consolidation factor, porosity and geochemical analysis.

Geotechnical investigation must be carried out on any proposed waste dumpsite before usage so as to allow easy access to the site for detailed investigation. Geophysical surveys must also be included in the design and monitoring of dumpsites, in order to forestall and checkmate the movement of leachate plumes into shallow surrounding aquifers which could in turn be harmful to the local populace.
All dumpsite should be designed and converted to modern Landfill in compliance to WHO standard.

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