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# Investigation on Leachate Transport on Groundwater Contamination using Vertical Electrical Sounding (VES) at dumpsite in Ogale Community, Eleme Local Government in Rivers State.

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***Abstract-*** *With increasing population comes the concern for waste disposal with open dumpsites as their only source of waste disposal. The leachate formed from the decomposition of waste materials find its way into the groundwater. This study investigated the geoelectric characteristics and the groundwater quality of boreholes around an open dumpsite in Ogale Community, Eleme Local Government in Rivers State. Four (4) borehole locations with varying distances and depth 50, 100 and 150m including the control location of 2000m apart were employed using Schlumberger configured vertical electric sounding (VES) to determine leachate effect on groundwater contamination, subsurface aquifer protective capacity and lithology corrosively. Sub-surface water samples were collected at the dumpsite at borehole depth (BH D) D50, D100 and D150 representing 50m, l00m and 150m respectively, and a control sample. Results of the selected borehole water samples around the dumpsite showed that pH, temperature and dissolved oxygen (DO) were outside the World Health Organisation (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) maximum allowable limits (MAL). The results on leachate from BH D50 and BH D100 that were close to the dumpsite had high chlorides (10.8 and 10.5mg/l) among other metals analyzed like Iron <0.002mg/l, Lead <0.009mg/l, and cadmium <0.002 across distances covered. Total Hardness 11.6, 12.5, 16.4mg/l were considerably lower compare to the control sample 16.9mg/l. The results on microbial content including Coliform count (<1.8MPN/l00ml), and Total Heterotrophic Bacteria (THB) (7.80 and 7.20 x104 cfu/ml) were high in BH D50 and BH D100 and as the distances increase the bacteria count reduces BH D 150 (5.0 x104 cfu/ml. The regression model of R2 = 0.9743, 0.9962 and 0.9981 cross borehole depth shows high level of corrosively of metal. The level of contamination of groundwater was determined using the weighted arithmetic water quality index (WQI) method. The WQI of boreholes indicated 67.7, 67.6 and 68.1 respectively indicating that the water quality is poor and not potable for drinking. This was consistent with the secondary result obtained from the VES analysis which showed weak to moderate aquifer protective capacity. Therefore, due to the corrosive nature of the soil, metal pipes that are prone to corrosion should not be used instead plastic pipes should be used for water conveyance There is also a need for adequate and proper planning, design, construction, and strategic management disposal of waste, as well as the adoption of solid waste re-use and recycling. Also, the implementation of a better sustainable environmental sanitation practice should be implemented.*

***Indexed Terms-*** *Electrical Resistivity Tomography, ERT, Oil Contamination, Contamination Plumes, Resistivity Model, Geophysical Methods, Environmental Assessment, Remediation Planning, Subsurface Contamination, Hydrocarbon Pollution*

## I. INTRODUCTION

Water is the basis of life; about 70% of the human body and about 60-70% of plant cells is made up of water (Smith & Edger, 2006). There is no life without water, and as a result it is one of the major determinants of human settlement, existence and activities on the earth. In addition, water is the most abundant environmental resource on earth. It covers 71% of the earth surface (USGS, 2014). However, potable water is scarce with about 97.4% of earth's water being salt water (96.5% in oceans and 0.9 in other saline water) and only 2.6% freshwater. About 68.7% of the earth's fresh water is tied up in polar ice caps and glaciers, and a further 30.1% is underground as groundwater, most of which are not available for use (Gleick, 1996), while the remaining 1.2% is in surface and other freshwater including atmospheric moisture, 0.03% and soil moisture 0.05%. Atmospheric water as precipitation falls and forms a part of these surface and ground water sources.

Groundwater plays a vital role for urban and agricultural water supply. It accounts for about 0.5% of the total hydrosphere, and is approximately 6.73 x $10km^3$ in volume (Ayoade, 2003). It constitutes a major portion of the earth's water circulatory system known as hydrological cycle and occurs in permeable geologic formation known as aquifers. Aquifers are formations having structure that can store and transmit water at rates fast enough to supply reasonable amounts to wells (Afolayan *et al.,* 2012a). Groundwater is less prone to contamination Compared to surface water because of the overlaying materials' filtration and adsorption capacity (Ayoade, 2003). When groundwater gets contaminated, diseases may spring up rapidly and spread beyond human expectation because of its flow mechanism (Afolayan *et al.,* 2012b) and dumpsite leachate is one of the major sources of groundwater contamination.

Dumpsites have served many years as a disposal site for all types of waste; municipal solid waste, industrial sewage and hazardous waste. Physical, chemical and biological processes interact simultaneously to bring about the overall decomposition of the wastes. One of the by-products of this mechanism is chemically laden leachate. Leachate is produced by the action: of rainwater aiding bacteria in the process of decomposition. Leachate is typically composed of dissolved organic matter, inorganic macro components (such as chlorides, iron, aluminium, zinc and ammonia), heavy metals and xenobiotic organic compounds such as halogenated organics (Kostova, 2006). Other chemicals including pesticides and solvents may also be present. Leachates are potentially hazardous waste from dumpsites, if not dealt with properly they can cause pollution to groundwater, health problems to fauna and flora and affect the environment. It is therefore important that leachates are treated and contained to prevent these occurrences (Kostova, 2006).

Engineered landfills are designed to minimize air, water and soil pollution as well as risks to man and animals. A standardized landfill system involves carefully selected location, placing waste in lined pit or a mound (Sanitary landfills) with appropriate means of leachate and landfill gas collection and control (Alloway & Ayres 1997; Eludoyin & Oyeku 2010). However, the practice of landfill system as a method of waste disposal in many developing Countries is usually far from standard recommendations as most of these landfills are mere 'holes in the ground" which do not qualify as sanitary means of solid waste disposal. (Mull, 2005; Adewole, 2009; Eludoyin & Oyeku, 2010).

### 1.2 Statement of the Problem

As urbanization stretches into per urban areas in Rivers State, residential buildings are constructed closer and closer to inactive and active open dumpsites. In most parts of Nigeria, the government is not responsible for provision of potable water to its citizenry, individual residents provide water for themselves through borehole drilling. The drilling of boreholes close to inactive and active dumpsite presents a high tendency of groundwater contamination by dumpsite leachates. Such contamination of groundwater resource poses a substantial risk to residents and to the natural environment. Although, the impact of dumpsite leachate on groundwater has given rise to a number of studies in recent years (Mor *et al.,* 2006), most of these studies were carried to access groundwater quality in line with safety standards.

However, there is need to evaluate the lithology, groundwater flow, and aquifer protective capacity of the area as to ascertain the vulnerability of aquifers close to dumpsite leachate contamination and portability of groundwater within such areas.

### 1.3 Aim of the Study

The aim is to determine the water quality index of groundwater within the vicinity of an active dumpsite.

### 1.4 Objectives of the Study

The objectives of this study are:

i. Determine the aquifer protective capacity, lithology and the groundwater flow around active dumpsite using Vertical Electric Sounding (VES) survey.
ii. Examine the physiochemical and microbial characteristics of groundwater with varying distance from dumpsite.
iii. Compare the water quality index of the groundwater with relevant standards.

## II. GROUNDWATER CONTAMINATION BY DUMPSITE LEACHATE

Dumpsite leachates are normally composed of organic and inorganic substances that permeates into groundwater systems leading to change in physical and chemical properties of groundwater quality (Vasanthi *et al.,* 2008) The greatest contamination threat to groundwater comes from land filled leachates of industrial waste originated with toxic substances Longe & Omole (2008) However, it has been widely reported that leachates from landfills for non-hazardous waste could contain biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia, chloride, sodium, potassium, hardness, boron, complex organic compound, chlorinated hydrocarbons and metals at concentrations which pose a threat to groundwater quality (Claret et a!., 2015).

Landfill leachates composition and volume vary with time of production and age of landfill. Taylor & Allen, (2006) stated that the condition within a landfill often varies over time, from aerobic to anaerobic thus allowing different chemical reactions to take place, and producing different chemical products. Longe & Enekwechi, (2007) reported that the volume of leachate depends principally on the area of the landfill, the meteorological and hydrogeological factors and effectiveness of capping. The volume of leachate generated is therefore expected to be very high in humid regions with high rainfall and high runoff resulting in high tendency of contamination of groundwater with shallow water table in such areas (Justin *et al.,* 2009). Consequently, the geology and hydrogeology of any potential landfill site has major bearing on the level of natural protection for groundwater contamination by landfill leachate.

### 2.2 Leachate Transport and Groundwater Quality

Waste deposited in landfills or open dumps immediately becomes part of the prevailing hydrological system (Taylor & Allen, 2006). Therefore, landfill has high risk of polluting the underlying soil and groundwater due to leachate production and transportation. Leachate production and composition depend on a number of factors such as solid waste composition, cover design, compaction, interaction of leachate with environment and landfill design operation, particle size, degree of compaction, hydrology and hydrogeology of site, age of landfill, moisture and temperature condition, and available oxygen (Papadopoulou *et al.,* 2007; Longe & Balogun, 2010; Bidhendi *et al.,* 2010). On the other hand, leachate transport depends on the waste type, climatological conditions, physical, chemical and biological processes of the soil profile and the nature of the contaminant disposed at the landfill (Kitanidis, 1993; Jensen *et al.,* 1999; RaptiCaputo *et al.,* 2006).

Leachate attenuates during its travel to the water table through the unsaturated zone. The ability of the unsaturated zone to attenuate leachate depends on its unsaturated hydraulic conductivity, its lithology and its thickness (Slack *et al.,* 2007). Naveen *et al.* (2018) outlined physical, chemical and biological factors that could attenuate the chemical composition and concentration of leachate between the ground surface and the vadose zone. The factors include; filtration, sorption, advection, dispersion, oxidation-reduction, adsorption-desorption, Precipitation dissolution, ion-exchange, hydrolysis and microbial degradation. Besides leachate attenuation through the vadose zone, landfill leachates have also been reported to affect soil electrical resistivity. Zaini *et al.* (2019) in their forensic assessment of landfills leachate using electrical resistivity imaging (ERI) observed that ERI could detect chemical contaminant in the soil based on the electrical resistivity of the contaminant. It was reported that the presence of high concentration of soluble ions in dumpsite leachate, will result in lower resistivity of a soil medium contaminated with such leachate due to enhanced flow of electrical current by the soluble ions. Abdullahi *et al.* (2011) using electrical resistivity/induced polarization imaging of soil in combination with physiochemical analysis observed that as the ion concentration decreased with soil depth, chargeability decreased while electrical resistivity increased for a municipal solid waste dumpsite such that the geophysical data from the electrical resistivity/induced polarization damaging of the soil complimented the water quality analysis data Wijesekara *et al.* (2014) m their study explained that the low resistivity of the new soil surface was due to the leachate plume within the shallow overburden thickness

### 2.3 Assessment of Groundwater Quality

Groundwater quality assessment is often based on the physical, chemical and biological properties temperature, colour, taste, turbidity and odour make up the list of physical water quality parameters (Harter, 2003), while the chemical properties include; alkalinity, acidity, pH, total hardness, total dissolved solids, organic and inorganic elements/compounds and heavy metals. Biological properties include pathogenic and non-pathogenic microbial counts. More attention is focused on chemical and biological quality since groundwater is usually tasteless, odourless and Colourless. Among the chemical properties, contamination with heavy metals is of major concern because of their toxicity and threat to human life and the environment. According to Kholoud *et al.* (2009) heavy metals are good indicators of contamination in urban soils and street dust. They are present in gasoline car components, oil lubricants, industrial emissions, incinerator emissions, d municipal wastewater discharge. Longe & Enekwechi, (2007) stated that heavy metals such cadmium, arsenic, chromium are found to be in excessive level in groundwater due to landfill.

Determination of allowable levels of contaminants in water is by comparison with national or international standards such standards in Nigeria include the Nigerian Standard for Drinking Water Quality (NSDWQ) and the World Health Organisation standard (WHO). The Nigerian Standard for Drinking Water Quality (NSDWQ) was approved by the Council of the Standards Organization of Nigeria in 2007 specifying upper and lower limits of contaminants known to pose risk to the wellbeing of individuals (NIS, 2007). Table 2.1 provides a comparison of the World Health Organization's standard of water quality with that of the Nigerian Standard for Drinking Water Quality. From Table 2.1, minor differences exist between World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ), in the standards of measuring the minimum and maximum concentration of water quality.

Table 2.1 Water Quality Variables and their Standard Limits

| S/N | Parameter | Units | WHO | NSDWQ |
|---|---|---|---|---|
| 1 | Temperature | $^0$C | 25 | NS |
| 2 | pH | NS | 6.5-8.5 | 6.5-8.5 |
| 3 | Electrical Conductivity (EC) | ($\mu$Scm $_{-1}$) | 1000 | 1000 |
| 4 | Total Suspended Solid (TSS) | Mg/L | 3.0mg/l | NS |
| 5 | Total Hardness (TH) | Mg/L | 100mg/l | 150mg/l |
| 6 | Chloride (Cr) | Mg/L | 250mg/l | 250mg/l |
| 7 | Nitrate ($N0_3$) | Mg/L | 10mg/l | 50mg/l |
| 8 | Dissolved Oxygen ($0_2$) | Mg/L | 2.0mg/l | NS |
| 9 | Iron (Fe) | Mg/L | 0,03mg/l | 0.3mg/l |
| 10 | Lead (Pb) | Mg/L | 0.01 | 0.01mg/l |
| 11 | Total Acidity | Mg/L | NS | NS |
| 12 | Total Alkalinity | Mg/L | 200mg/l | NS |
| 13 | Sodium (Na) | Mg/L | 200mg/l | NS |
| 14 | Phosphate ($P0_4$) | Mg/L | 5mg/l | NS |
| 15 | Sulphate($SO_4$) | Mg/L | 250mg/l | 100mg/l |
| 16 | COPPER (Cu) | Mg/L | 0.5mg/l | 1mg/l |
| 17 | Calcium (Ca) | Mg/L | 200mg/l | NS |

Source: Nigerian Industrial Standard (2007)

### 2.4 Water Quality Index

There are several methods for evaluating water quality. However, these methods cannot clearly express the water pollutant categories. Yeh *et al.* (2008) attempted to develop a cost-effective programme for monitoring the quality of groundwater by sampling existing wells in order to obtain useful information. Water Quality Index method (WQI) provides the mechanism for presenting a cumulatively derived numerical expression defining a certain level of water quality. One of the major advantages of WQI is that, it incorporates multiple water quality parameters into a 'mathematical equation that rates the health of water quality with a number (Yogedra & Puttaiah, 2008) Water Quality Index (WQI) method uses a rating system to determine the influence of individual quality parameters on the overall quality of water. A general WQI approach is based on the under listed factors (Fernandez *et al.,* 2012)

i. Parameter selection
ii. Determination of a Quality Function Curve
iv. Sub-indices aggregation with mathematical expression

Water Quality Index was developed by Canadian Council of the Ministers of the Environment (CCME) in (2001) using ten (10) of the most commonly measured water quality variables such as dissolved oxygen, pH, coliforms, specific conductance, alkalinity and chloride. Horton's method of water quality assessment is now widely used across Africa, Asia and Europe. Since then several Water quality indices have been formulated by different international organizations. Studies have shown Water Quality Index to be one of the most effective tools to communicate information on the Overall quality status of water to the users and policy makers within each community (Saxena & Kaur, 2003; Yogedra & Puttaiah, 2008, Yeh *et al.,* 2008, Fernandez *et al.,* 2012, Jinwal *et al.,* 2008).

There are four most common methods for calculating the WQI namely;

i. NSF-WQI (National Sanitation Foundation-Water Quality Index)
ii. OWQI (Oregon Water Quality Index)
iii. Weighted Arithmetic Water Quality Index Method
iv. The Canadian Council of Ministers of the Environment Index (CCME-WQI).

2.4.1 Arithmetic Water Quality Index Method

This method provides information regarding the quality evaluation of a body of water. This method uses the most commonly measured water quality parameters (pH, BOD, COD, DO, P-$PO^{3-}$, N- total, N-$N0^{3-}$, N-$N0^{2-}$, N-$NH^{4+}$, $SO^{2-}{}_4$, Cl-, Cr-total, $Pb^{2+}$, $Cd^{2+}$, $Ni^{2+}$, Fe-total, Mn-total, $Zn^{2+}$ $As^{2+}$) and it is calculated according to the following formula (Chatterji & Raziuddin, 2002):

$$WQI = \frac{\Sigma wiqi}{\Sigma qi} \qquad (2.1)$$

where: WQI has a value between 0 and 100 which indicates the quality of the water; qj represents a relative value of the water quality, specific to each parameter; i represents the number of parameters taken into consideration; Wi is a factor which measures the importance of a parameter in the calculation of the WQI index referred to as relative weight. qj is calculated by applying the formula below (Chatterji & Raziuddin, 2002):

$$qi = 100\ x\ \frac{v_i - v_0}{s_i - v_0} \qquad (2.2)$$

Where: Vi represents the value experimentally determined for the ith analysed parameter; Vo represents the ideal value of that parameter; Si represents the standard, legally accepted, value for the water category in which the analysed water sample was included. W1 factor is calculated by using the formula below (Chatterji & Raziuddin, 2002):

$$W_i = \frac{K}{s_i} \qquad (2.3)$$

Where K is a constant which can result from applying the formula below (Chatterji & Raziuddin, 2002):

$$K = \frac{1}{\Sigma(\frac{1}{si})} \qquad (2.4)$$

Based on the value obtained for the Weighted Arithmetic WQI method, the water quality status may be determined, as illustrated in Table 2.2.

Table 2.2: Water Quality Rating as per Weight Arithmetic Water Quality Index Method

| WQI Value | Water quality |
|---|---|
| 0-25 | Excellent |
| 26-50 | Good |
| 51-75 | Poor |
| 76-100 | Very poor |
| >100 | Unsuitable for drinking |

Source: (Chatterji & Raziuddin, 2002)

2.4.1.1 The Advantages of Weighted Arithmetic Water Quality Index Method

i. It encompasses the values of various physicochemical parameters of water quality into a mathematical equation, which indicates the water ecological state
ii. It reflects the importance that each parameter has in the evaluation and management of Water quality

iii. It can be used to describe the suitability of both surface and underground water sources for human consumption.

#### 2.4.1.2 The Disadvantages of Weighted Arithmetic Water Quality Index Method

i. This index may not provide enough information about the real situation of the water quality;
ii. This index does not include all the parameters which can describe the quality of a body of water
iii. This index only quantifies the direct effect of pollution on a body of water

### 2.5 Aquifer Protective Capacity and Determination

An aquifer is an underground layer of water-bearing permeable rock. Permeable rocks that tend to make the best aquifers include sandstone, limestone, gravel and, in some cases, fractured volcanic rocks such as columnar basalts make good aquifers while rocks such as granite are poor aquifers because they have low porosity, however, highly fractured rocks are good aquifers. Aquifer protective capacity has been defined as the capacity of the overburden unit to impede and filter percolating ground surface polluting liquid into the aquiferous unit, it is a measure of the ability of an earth medium to retard and filter percolating fluid (Olorufemi, 1999; Adeniji *et al.,* 2014). The protective capacity of an overburden layer is directly proportional to its thickness and inversely proportional to its hydraulic conductivity (Oladapo, 2004). Permeable materials such as sand and gravels have high permeability, high resistivity, high hydraulic conductivity, and low longitudinal conductance, while impermeable material such as clay and shale have high longitudinal conductance values due to their low resistivity values (Abiola et al., 2009).

#### 2.5.1 Aquifer Properties

Once a contaminant reaches the water table saturated conditions prevail. The water table is defined as the point where the pressure head is zero, i.e. the pressure is equal to atmospheric pressure. Water movement in the saturated zone is governed by Darcy's Law which may be stated mathematically as (Adenji *et al.,* 2014):

$$v = -K\frac{dh}{dt} \qquad (2.5)$$

where v is the specific discharge with the dimensions of velocity, K is the hydraulic conductivity, dh/dl is the hydraulic gradient or head gradient. The negative sign indicates that flow is in the direction of decreasing head and unlike transport in the unsaturated zone is predominantly horizontal. The hydraulic conductivity takes a range of values for different geological materials being high for coarse grained granular deposits, e.g., for a gravel a typical value is 10.2 rn/sec while for a clay a value of 10 rn/sec is common. These values are for the rock matrix, but fractured rock situations are very common and flow can take place in both the fractures and through the matrix. Such a condition can be expected in limestones and jointed sandstones. Intuitively the flow rate through a fractured rock is higher than its homologue. Clearly the hydraulic conductivity of the geological host rock plays a key role in determining transport rates in the saturated zone.

#### 2.5.2 Longitudinal Conductance

The aquifer protective capacity characterization is based on the values of the longitudinal unit Conductance of the overburden rock units in the area, this is because the earth medium acts as a natural filter to percolating fluid. Its ability to retard and filter percolating ground surface polluting fluid is a measure of its protective capacity (Oladapo, 2004). The Longitudinal conductance (S) is a secondary geoelectric parameters which can be derived from the two primary geoelectric parameters which are layer thickness and resistivity. The total longitudinal conductance of an overburden can be obtained from equation 2.6 (Zohcly *et al.,* 1974).

$$S = \frac{h_1}{p1} + \frac{h_2}{p2} + - - - - - + \frac{h_{n-1}}{p_{n-1}} = \sum_{i=1}^{n} \frac{h_i}{pi} \qquad (2.6)$$

Where h is the layer thickness, Pi is layer resistivity of the ith layer while the number of layers ranges from the surface top soil downward to the basement from i= 1 to n and n is the number of layers The total longitudinal umt conductance values can be used to deduce the protective capacity of the aquifer in a geological location because the protective capacity is considered to be proportional to the longitudinal conductance (S) (Olorufemi *et al.,* 1999; Oladapo *et al.,* 2004). Therefore, the higher the overburden longitudinal conductance of an area, the higher its protective capacity (Oladapo, 2004). Longitudinal conductance has been used by many researchers to assess the protective capacity of the overburden units (Henriet,1976; Oladapo *et al.,* 2004; Adeniji *et al.,* 2014; George *et al.,* 20 14;Obiora *et al.,* 2015; Bayewu *et al.,* 2018) and based on the longitudinal conductance values, overburden units can be classified into excellent, very good, good, moderate, weak and poor aquifer protective capacity as shown in Table 2.3.

Table 2.3: Modified Longitudinal Conductance/Protective Capacity Ratings

| WQI Value | Water quality |
|---|---|
| >10 | Excellent |
| 5-10 | Very good |
| 0.7-4.9 | Good |
| 0.2-0.69 | Moderate |
| 0.1-0.19 | Weak |
| <0.1 | Poor |

Source: (Oladapo *et al,* 2004; Ogungbemi *et al.,* 2013)

### 2.5.3 Transverse Resistance

The total transverse resistance (T) is one of the parameters used to define target areas of good groundwater potential. It has a direct relation with transmissivity and the highest T values reflect most likely the highest transmissivity values of the aquifers or aquiferous zones and vice versa Kumar *et al.,* 2001). Transverse resistance is related to transmissivity. Braga *et al.,* (2006) stated t high transverse resistance translates to high transmissivity, high permeability to water movement and high yield production of aquifers. Tahama *et al.* (2018) categorized T values less 10,000$\Omega^2$ as very low and T values greater than 10,000$\Omega m^2$ as indicative of fresh water aquiters. The total transverse resistance (T) for each geoelectric sounding (VES) stations is computed as follows;

$$T_R = p_i h_1 + p_2 h_2 + - - - + p_{n-1} h_{n-1} = \sum_1^n p_i h_i$$

Where T is the total transverse resistance, is summation sign, $h_l$ is the thickness of the ith layer, n is number of layers and layers and i is the resistivity of the ith layer. Generally, the earth medium acts as a natural filter to percolating fluid. Its ability to filter percolating ground surface polluting fluid is referred to as the longitudinal conductance and is utilized in evaluating protective capacity of the aquifer within an area (Oladapo et al., 2004).

### 2.5.4 Electrical Anisotropic Coefficient [λ), Reflection Coefficient (K) and Fracture Porosity ($\varphi$)

Electric anisotropic coefficient is secondary geoelectric parameters used to delineate the magnitude of variation between the transverse and longitudinal resistivity of subsurface layers in a given area. Flathe (1995) as cited by Khan *et a!.* 2019 stated that transverse resistivity (Pt) is always greater than longitudinal resistivity (p1). Also Zohdy et al. (1974), reported that the electrical anisotropic coefficient of most geological conditions ranges between 1 and 2. High values (A.> 1) means more fracturing of rocks in all the directions with different degrees of fracturing which results in greater water holding capacity (Kumar et al., (2014). The anisotropic coefficient was determined using equation 2.8

A = (2.8)

$$\lambda = \sqrt{\frac{pt}{pt}} \qquad (2.8)$$

The degree of fracturing as presented by the coefficient of reflection was estimated using equation 2.9 (Khan et al., 2019).

$$k = \frac{p_n - p_{n-1})}{(p_n + p_{n-1})} \qquad (2.9)$$

Where K is the reflection coefficient and is defined as the interface separating two subsurface layers Of Varying resistivity values. It is a non-dimensional unit that ranges between -l and +1. When the last layer [nth layer] is less permeable than the layer just above it, the k value is expected to be -1, conversely when the last layer is more impermeable than the layer just above it, the k value becomes +1. According to Olayinka, 1996 as cited by Khan et al., (2019), lower k values implies fractured basement rocks and hence high water holding capacity. Fracture porosity (q.') was calculated using equation 2.10 as shown (Khan et al., 2019).

$$\varphi = \frac{3.4x10^4(N-1)(N^2-1)}{N^2 C(p_{max} - p_{min})} \qquad (2.10)$$

Where N is the vertical anisotropy and C is electrical conductance of groundwater in mS/cm while p, and Pmin are maximum and minimum apparent resistivity respectively. But N = λ, for Schlumberger 1-D data. Thus, equation 2.10 is rewritten as

### 2.6 Vertical Electric Sounding (VES)

In groundwater exploration, various geophysical methods have been employed to locate suitable points for productive boreholes. One of such methods commonly used is the electrical resistivity method in which VES and Horizontal Profiling (HP) are commonly carried out (Omosuyi *et al.,* 2008). The VES method is a depth sounding galvanic method and has proven to be very useful in groundwater studies due to simplicity and reliability of the method. The electrical resistivity of rock is a property which depends on lithology and fluid contents. The number and thicknesses of the geoelectric units as determined from VES measurements at a locality may not necessarily be the same as the geological ones (Emmanuel *et at.,* 2011). The ultimate objective of VES at some locality is to obtain a true resistivity log similar to the induction log of a well at the locality, without actually drilling the well (Hamill & Bell, 1986).

The electrical resistivity technique proved to be one of promising tool in groundwater 1tamination studies. Its major application includes waste disposal studies to locate contaminant.

## III. RESULTS AND DISCUSSION

### 3.1 Results

The investigation on the vertical electric sounding (VES) locations for underground water contamination was considered and the results obtained are presented in Tables and Figures as demonstrated below:

### 4.1.1 Electrical Resistivity

Table 4.1 shows the lithology of soil with different resistivity, thickness and depth employed by VES locations. VES 1 and 2 were delineated with 5 geo-electric layers while VES 3 was delineated with 4 geo-electric. The 5 geoelectric layered VES points 1 and 2 gave HAK and AAK curve types respectively the 4 geoelectric layered VES point 3 gave an AK curve type.

Table 4.1: Geoelectric Layers with Respect to Lithology

| VES | Layers | Resistivity ( $p.\Omega m$) | Thickness (h,m) | Depth (d, m) | Lithology |
|---|---|---|---|---|---|
| 1 | 1 | 145.2 | 1.259 | 1.259 | Clay/surface soil |
| | 2 | 16.56 | 0.5889 | 1.848 | Clay |
| | 3 | 360.74 | 3.2919 | 5.067 | Sand |
| | 4 | 946.7 | 21.47 | 26.53 | Coarse sand |
| | 5 | 444.3 | - | - | |
| 2 | 1 | 11.04 | 1.800 | 1.800 | Clay/surface soil |
| | 2 | 148.5 | 0.15658 | 1.973 | Clay |
| | 3 | 183.8 | 14.14 | 16.11 | Fine sand |
| | 4 | 526.6 | 13.5 | 29.61 | Coarse sand |
| | 5 | 385.207 | - | - | |
| 3 | 1 | 11.08 | 1.826 | 1.826 | Clay/surface soil |
| | 2 | 188.6 | 16.52 | 8.36 | Sand |
| | 3 | 887 | 11.26 | 29.61 | Sand |
| | 4 | 277.2 | - | | |

### 4.1.2 Ground Water Potential around VES 1

HAK curves as shown in Figure 4.1 are generally characterized by a top layer with a higher resistivity than the second layer which is followed by a progressive increase from the third to the fourth layer and then decreases at the fifth layer while the depth of the layers increases progressively from the first to the fourth layer with coefficient of determination $R^2$ 0.9742 corresponding to 97.42%. The resistivity and depth sequences are given as Pi > P2 <3 <4 > p5 and d4 > d > d > d respectively. Ground water potential increases with the presence of fractured layers as ground water is held between fractured layers (Prabhu & Sivakumar, 2018). The very low resistivity value (p2=16.56Ωm) of the second layer is an indication of the presence of highly weathered rocks in this layer supported by the lithology and thickness of the layer, which was a thin clay as shown in Table 4.1. The sudden jump in resistivity from the third to the fourth layer with 150 percent increase in resistivity between the 3rd and 4th layer explains the presence of fractured rocks in the 4th layer. Hence, around the VES 1 area, the 4th layer was identified as the aquifer layer, the depth from the top soil to the aquifer layer is 8.174m while the aquifer resistivity and thickness were 946.7Ω2m and 21 .37m, respectively. The decrease in resistivity at the 5th layer (p5=444.3Ωm) is attributed to the emergence of interconnected fractures capable of yielding moderate groundwater since the resistivity is up to 200 Ωm (Prabhu & Sivakumar, 2018).

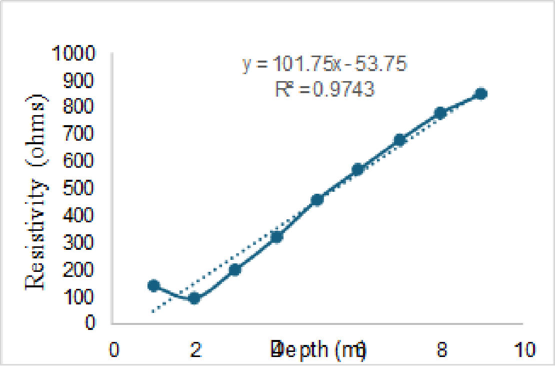


Figure 4.1: Geoelectric Layered VES Point 1

4.1.2 Ground Water Potential around VES 2

Figure 4.2 shows the interpretation of the curve characterized by the resistance and depth sequence of p1 <P2 <3 <p4> p5 and d4 > d > d2 > d respectively. This explains a progressive increase in resistivity with depth among the first four layers followed by a decrease at the fifth layer. The very low resistivity of the top soil (Pi = 11.0411m) is an indication of the presence of highly weathered d rock particles with clay contents which is supported by the lithology of the top soil as displayed in Table 4.1. With resistivity less than 200 Ωm for the 2nd and 3'd layers, much less weathered particles would have been encountered. The 4th layer with a sudden jump in resistivity by 186.5 percent from the 3id layer resistivity authenticates the 4th layer as the fractured layer with coarse sand with coefficient of determination $R^2$ 0.9981 as shown in Figure 4.2. This implies that the 4th layer is the aquifer layer with the depth from the top soil to the aquifer layer been 19.883m while the aquifer resistivity and thickness are 526.6 $p.\Omega m$ and 13.5m respectively. Again the 5th layer with a lower resistivity of 3 85.207Ωm is attributable to the emergence of interconnected fractures capable of yielding moderate groundwater since the resistivity is up to 200m. (Prabhu & Sivakumar, 2018).

The very low resistivity of the top soil (Pi = 11.0411m) is an indication of the presence of highly weathered d rock particles with clay contents which is supported by the lithology of the top soil as displayed in Table 4.1. With resistivity less than 200Ωm for the 2 and 3 layers, much less weathered particles would have been encountered. The 4th layer with a sudden jump in resistivity by 186.5 percent from the 3id layer resistivity authenticates the 4th layer as the fractured layer with coarse sand as shown in Table 4.1. This implies that the 4th layer is the aquifer layer with the depth from the top soil to the aquifer layer been 19.883m while the aquifer resistivity and thickness are 526.6Ωm and 13.5m respectively. Again the 5th layer with a lower resistivity of 3 85.207Ωm is attributable to the emergence of interconnected fractures capable of yielding moderate groundwater since the resistivity is up to 200 m. (Prabhu & Sivakumar, 2018).

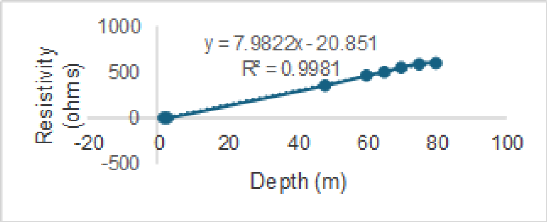


Figure 4.2: Geoelectric Layered VES Point 2

4.1.3 Ground Water Potential around VES 3

Figure 4.3 shows the interpretation of the curve derived from a 4-layer geophysical investigation characterized by a resistivity and depth sequences of $p_1 < P_2 < 3 > p_4$ and $d_3 > d_2 > d_1$ respectively. Similar to the VES 2, the resistivity sequence explains a progressive increase in resistivity with depth from the first to the third layer which was followed by a decrease at the fourth layer. The very low resistivity of the top soil (Pi = 11. O8 Ωm) is an indication of the presence of highly weathered rock particles with clay contents which is supported by the lithology of the top soil as displayed in Table 4.1. With resistivity less than 200 Ωm for the 2nd layer and a sudden jump in resistivity by 407.4 percent from the 2 to 3 layer authenticates the 3rd layer as the fractured layer with coarse sand with coefficient of determination $R^2$ 0.9962. This implies that the 3rd layer is the aquifer layer with the depth from the top soil to the aquifer layer been 10.1 86m while the aquifer resistivity and thickness are 887m and 11 .26m respectively. The sequence ending with a layer of lower resistivity of 27.2Ωm is also attributable to the emergence of interconnected fractures capable of yielding moderate groundwater since the resistivity was up to 200 Ωm. (Prabhu & Sivakumar, 2018).

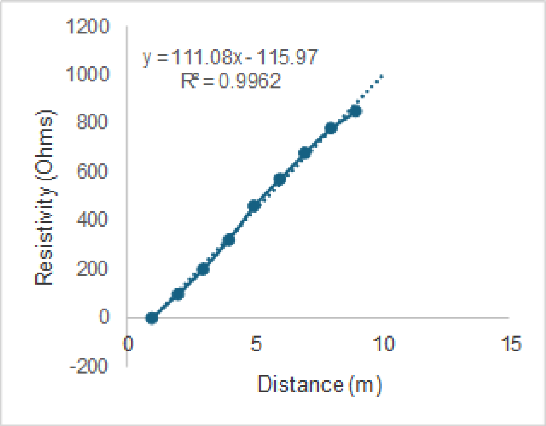


Figure 4.3: Geoelectric Layered VES Point 3

### 4.1.4 Electrical Anisotropic Coefficient (A) and Reflection Coefficient (K)

The transverse resistivity (Pt), longitudinal resistivity and anisotropic coefficient (A) of subsurface layers in this study are as displayed in Table 4.2. It was observed that Pt > P for all VES points I A was within the expected range of most geological conditions. The high $\lambda$ values (A> 1) signify diverse degree of fracturing in the transverse and longitudinal directions of NS-SW for 2 and 3 and N-S direction for YES 1. The high A values also implies that the extensions of fractures in these directions results in high water holding capacity of the entire study area. While the variation between the transverse and longitudinal resistivity explains the non-uniformity medium. It was observed that though the anisotropic coefficient of VES points 2 and 3 the aquifer thickness (H) and the longitudinal conductance (S) for VES points 2 and 3 were similar Table 4.2. The dissimilar values of for VES points 2 and 3 is attributable to the vary number of layers at these VES points. (Braga & Dourado 2006).

Table 4.2: Anisotropic Coefficient of VES Points

| | H | T | S | Pt | Pi | $\lambda$ | k | $\varphi$ |
|---|---|---|---|---|---|---|---|---|
| VES 1 | 34.704 | 27157.95 | 0.162 | 782.54 | 213.78 | 1.91 | -0.36 | 0.692 |
| VES 2 | 29.60 | 9751.16 | 0.27 | 329.47 | 110.99 | 1.72 | -0.16 | 0.901 |
| VES 3 | 29.61 | 13123.52 | 0.27 | 443.27 | 111.68 | 1.99 | -0.52 | 0.823 |

The reflection coefficient (k) values of the 3 VES points were all negative. This means that the last layer of each VES point was dominated by fractured rocks resulting in the high fracture porosity $(\varphi)$ values ranging between 0.692 and 0.901 as shown in Table 4.2. The high porosity suggests that the fractured rocks are likely to possess water with better water holding capacity. It was also observed that VES 3 with the least k value showed the highest value of $\lambda$ while VES 2 with the highest value of k showed the least value of $\lambda$ (see Table 4.2). This is in agreement with the fact that the degree of fracture is inversely related to the anisotropic coefficient (Olayinka, 1996 as cited by Khan et al. (2019). The fracture porosity in this k did not correlate with the anisotropic values ($\lambda$).

### 4.2 Aquifer Protective Capacity, Longitudinal Conductance and Transverse Resistivity

calculated longitudinal conductance (S) values as shown in Table 4.2 ranged from 0.162 to 0.27. Measuring these values against the standard aquifer protective capacity rating as shown in table 2.3, it was observed that there is spatial variation of the protective capacity of the 3 VES points. VES point 1 had a weak aquifer protective capacity while VES points 2 and 3 had moderate aquifer protective capacity. This implies that the overburden impermeable layer constitutes less amount of clay as such the groundwater around the study area is prone to dumpsite leachate contamination (Ayolabi & Peter 2005). Results of transverse resistance (T) as shown in Table 4.2 explains that VES 1 and 3 fell in the high T category(T> 10,000 Qm2) meaning that groundwater within this vicinity should be freshwater with low electrical conductivity while VES 2 fell in the low T category (T < 10,000 Qm2) implying that groundwater within this vicinity has moderate to high electrical conductivity. (AYolabi & Peter 2005)

### 4.3 Effect of Dumpsite Leachate on Selected Physicochemical Properties of Groundwater Contamination

Figure 4.4 to 4.7 shows the pH results of ground water samples at various distance 50m, l00m, 150m, including the control which was away from the dumpsite labelled BH D50, BH Dl00, BH D150 and BH Control respectively showed that water sample were within the acidic range 4.67 – 4.98. The pH level at various distance were within the threshold of WHO and NSDWQ recommendation. However, there was a decreased with increased distance from the location of dumpsite. Figure 4.5 shows the dissolved oxygen (DO) for all water samples within 50m to 150m distance from the dumpsite were far higher than the WHO guideline of 2mg/I. DO decreased as the distance from dumpsite increased. Figure 4.6 shows the temperature ranges across borehole location from dumpsite were within 25.7 to 25.9°C seen be within the WHO guideline of (25°C). Figure 4.7 show the level of THB along contaminated groundwater. While coliform count and THF were similar irrespective of distance, THB decreased with distance from dumpsite as shown in Appendix A.

The spatial variation of pH, DO and microbial counts suggests the possibility of groundwater contamination by dumpsite leachate. With a description of weak to moderate aquifer protective capacity of the study area as presented by the VES points 1-3, the groundwater around the study area is prone to dumpsite leachate contamination. However, the level of heavy metals such as lead, cadmium, chromium and iron as well as nitrate and chloride being found to be within the safe limits of drinking water by WHO, the dumpsite is suspected to be saturated with high organic waste content. This is attributable to the fact that the dumpsite receives little or no industrial waste and local scavengers pick up plastic, metal, and even electronic wastes that could have been the source of heavy metal contamination (Ugbebor & Brownson 2019).

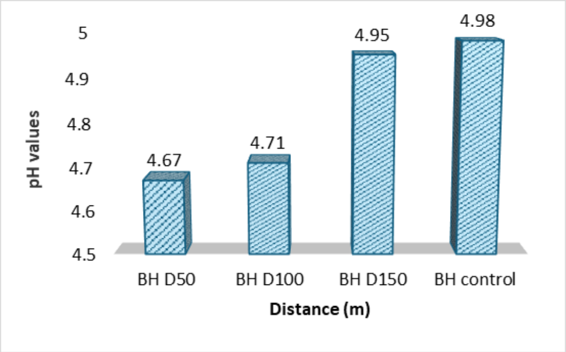


Figure 4.4: pH Values of Groundwater at different Distance from Dumpsite

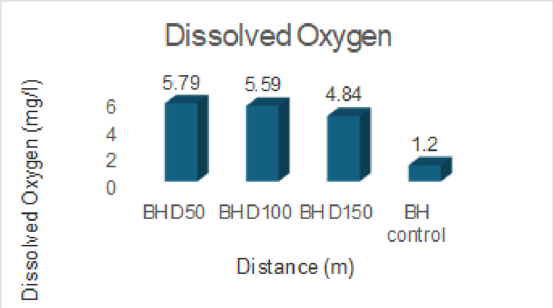


Figure 4.5: Dissolved Oxygen of Groundwater at different Distance from Dumpsite

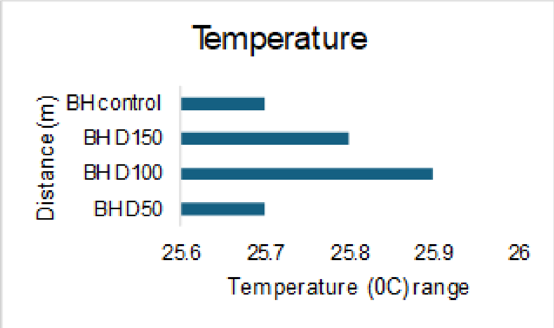


Figure 4.6: Temperature of Groundwater at Varying Distance from Dumpsite

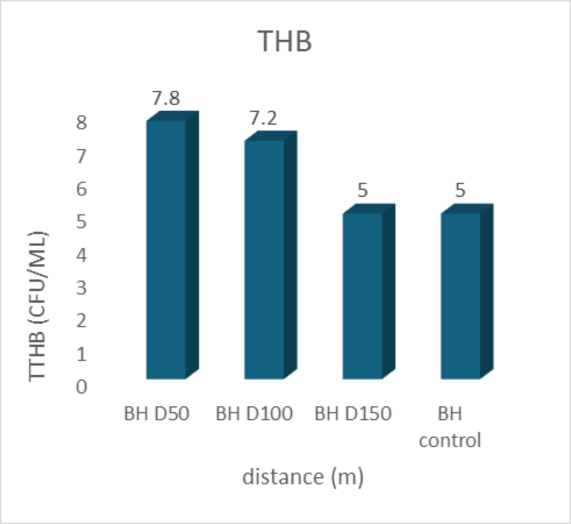


Figure 4.7: Total Heterotrophic Bacteria of Groundwater at Distance from Durnpsite

## 44 Water Quality Index

The water quality index from dumpsite suggests the possibility of groundwater contamination with a description of poor water quality presented in Figure 4.8. The groundwater around the study area is prone to dumpsite leachate contamination. The dumpsite is suspected to be saturated with high organic waste content. This is attributable to the fact that the dumpsite receives little or no industrial waste and local scavengers pick up plastic, metal, and even electronic wastes that could have been the source contamination (Ugbebor & Brownson 2019). The water quality of the boreholes within the Ogale, Eleme dumpsite was evaluated using four different boreholes at significant distances from the dumpsite (see Appendix A). This was carried out with the motive of establishing the degree of pollutant characteristics of the groundwater attributed to improper management of dumpsites. The weighted arithmetic water quality index served as statistical instrument for rating water quality of sampled boreholes. The study showed that the borehole water within and nearby Ogale,

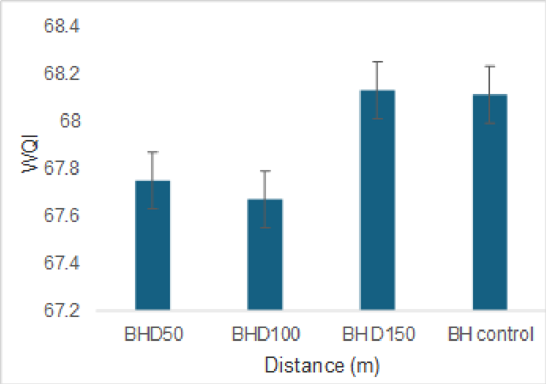


Figure 4.8: Water Quality Index of Boreholes within Dumpsite Location.

## 4.5 Effect of Dumpsite Leachate on Soil Geochemistry

### 4.5.1 Soil Corrosively and pH

Since utility pipes for conveying water are buried within the topmost layers of the soil, the resistivity values of these layers were used in the evaluation of the Corrosivily potential. From the VES results within a depth of I .8m, soil resistivity range between 11.06 —16.56 L2m which implies that the soil within the study area was moderately corrosive (see Table 4.5).

Table 4.5: Soil Corrosively Ratings of Soil Samples

| Soil Resistivity (Ωm) | Soil Corrosively | Sample Description |
|---|---|---|
| <10 | Very strongly corrosive (VSC) | NIL |
| 10-60 | Moderately corrosive (MC) | VES 1,2 and 3 |
| 60-180 | Slightly corrosive (SC) | NIL |
| >180 | Practically non corrosive (PNC) | NIL |

The soil pH at the top soil surface ranged from 4.31 to 4.93 while the soil pH 3m from the soil surface ranged from 4.22 to 4.98 (Figure 4.9).

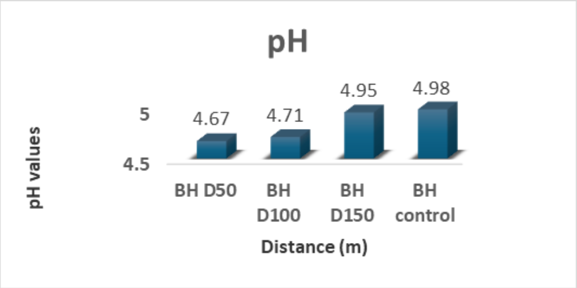


Figure 4.9: Soil p11 at Varying Depth and Distance from Dumpsite

From the soil corrosively classification based on soil pH as displayed in Appendix 3, the soil pH corroborates the fact that the soil was corrosive. However, the corrosivily decreased with distance from dumpsite as soil pH increased with distance from dumpsite and depth.

With respect to depth (3m below the topsoil), soil pH was lower at the dumpsite and at 50m away from dumpsite than at the surface at both depths (soil surface and 3m below the soil surface). The lithological characteristic of the top soil which was clay at the soil surface and sand at 3m depth as shown in Table 4.6 explains the phenomenon.

Table 4.6: Soil Sample Lithology

| Sample | Longitude | Latitude | Elevation | Colour | Lithology |
|---|---|---|---|---|---|
| D1(surface) | $6^{0}98$’E | $4^{0}90$’N | 23.4M | Black | Clay |
| 1m | | | | Reddish black | Clay |
| 2m | | | | Reddish | Clay |
| 3m | | | | Reddish white | Clay |
| D50(surface) | $6^{0}57$’E | $4^{0}90$’N | 23.3M | Black | Clay |
| 1m | | | | Reddish black | Clay |
| 2m | | | | Reddish | Clay |
| 3m | | | | Reddish white | Clay |
| D100(surface) | $6^{0}57$’E | $4^{0}54$’N | 23.2M | Black | Clay |
| 1m | | | | Reddish black | Clay |
| 2m | | | | Reddish | Clay |
| 3m | | | | Reddish white | Clay |
| D150(surface) | $6^{0}57$’E | $4^{0}45$’N | 23.07M | Black | Clay |
| 1m | | | | Reddish black | Clay |
| 2m | | | | Reddish | Clay |
| 3m | | | | Reddish white | Clay |
| Control (surf) | $6^{0}99$’E | $4^{0}89$’N | 15.10M | Black | Clay |
| 1m | | | | Reddish black | Clay |
| 2m | | | | Reddish | Clay |
| 3m | | | | Reddish white | Clay |

Generally, sand has a lower pH than clay, so it is expected that the soil pH at 3m depth should be lower than soil pH at the surface. However, moving further away from the dumpsite, sand pH increased above clay pH. This suggests that the infiltration of the leachate was restricted to less than 3m in the soil because of the less permeable nature of clay. Also, the corrosive nature of the soil suggests that metal pipes that are prone to corrosion should not be used within this area for water conveyance, rather plastic pipes should be used for water conveyance.

### 4.5.2 Soil Electrical Conductivity

The soil electrical conductivity of soil as shown in Figure 4.10 ranged between 906 and 1561 $\mu$S/cm. The classification of the soil based on its electrical conductivity as shown in Appendix J reveals that electrical conductivity at the dumpsite falls between average and harmful to germination (ISSS, 1993). However, electrical conductivity at the surface increased at 50m away from the dumpsite and decreased and stabilized from 100m away from the dumpsite to control.

The increase at 50m can be attributed to the presence of materials containing metal scraps found the area. On the other hand, below the soil surface (at 3m depth) electrical conductivity also increased at 50m away from the dumpsite while at l00m away till the control point, a decrease in electrical conductivity was observed (see Fig. 4.10). This indicates that the soil electrical conductivity was affected by the leachate from the dumpsite as the electrical conductivity of leachate at dumpsite was observed to be extremely high at D50m and D100m 46.00 and 43.00 $\mu$S/cm distance.

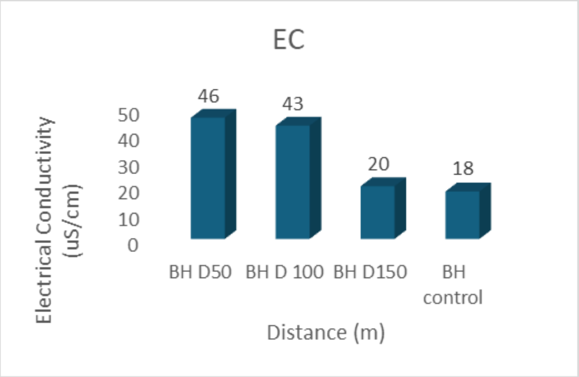
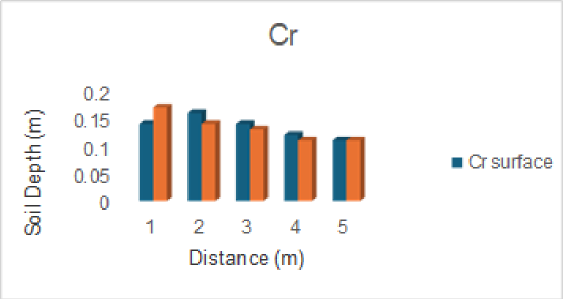


Figure 4.10: Soil Electrical Conductivity at Varying Depth and Distance from Dumpsite

The soil electrical conductivity of soil as shown in Figure 4.10 ranged between 906 and 1561 $\mu$S/cm. The classification of the soil based on its electrical conductivity as shown in Appendix J reveals that electrical conductivity at the dumpsite falls between average and harmful to germination (ISSS, 1993). However, electrical conductivity at the surface increased at 50m away from the dumpsite and decreased and stabilized from 100m away from the dumpsite to control. The increase at 50m can be attributed to the presence of materials containing metal scraps found the area. On the other hand, below the soil surface (at 3m depth) electrical conductivity also increased at 50m away from the dumpsite while at l00m away till the control point, a decrease in electrical conductivity was observed (Fig. 4.10). This indicates that the soil electrical conductivity was affected by the leachate from the dumpsite as the electrical conductivity of leachate at dumpsite was observed to be extremely high with a value of 46.00 uS/cm.



### 4.5.3 Effect of Dumpsite Leachate on Soil Heavy Metal Content

From the field experiment of dumpsite leachate on Pb from surface to 3m depth ignited concentration of 0.009 to 0.1mg/kg as shown in Figure 4.11. These were observed to be with the permissible limit of lead in loam. These heavy metals include chromium, cadmium, lead and iron. The chromium content in soil in this work ranged between 0.11 to 0.1 7mg/kg as shown in Figure 4.11 was observed to be within the permissible limit of heavy metals in soils 100mg/kg (Osmani et al., 2015).

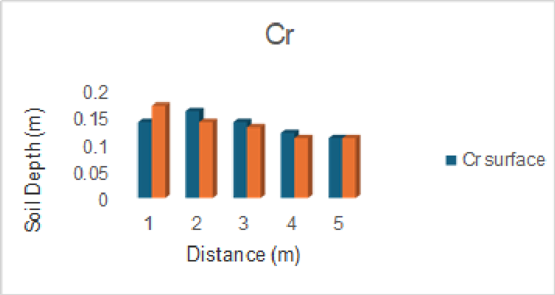


Figure 4.11: Soil Chromium at Varying Depth and Distance from Dumpsite

The chromium content at the surface at 50m away from the dumpsite was the highest but decreased and remained steady from l00m away from the dumpsite till control. This was attributed to the presence of metal scraps of iron found in the area. On the other hand, below the soil surface (at 3m depth) chromium was found to be the highest at the dumpsite but decreased at 50m away from the dumpsite till l00m away and remained steady from 150m away till control (see Fig. 4.11). This indicates that the soil chromium was affected by the high level of iron content in the soil. On the other hand, soil cadmium and lead were constant irrespective of distance and depth and the contents were insignificant in the soil (see Fig 4.12).

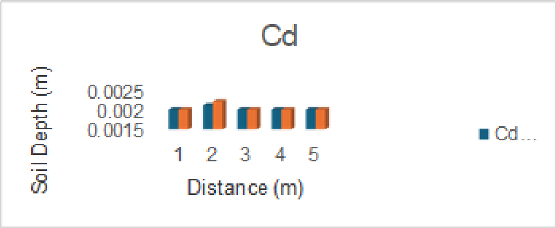


Figure 4.12: Soil Cadmium and Lead at Varying Depth and Distance from Dumpsite

The at the surface increased at 50m away from the dumpsite but decreased and remained constant an l00m away from the dumpsite till control. The increase at 50m can be attributed to the presence of metal scraps found in the area. On the other hand, below the soil surface (at 3m depth) iron was found to be the highest at 50m away from the dumpsite but decreased at l00m away from the dumpsite and remained steady till control (see Fig. 4.13). This indicates that the soil iron was affected by the leachate from the dumpsite as the iron of leachate at dumpsite was observed to be extremely high.

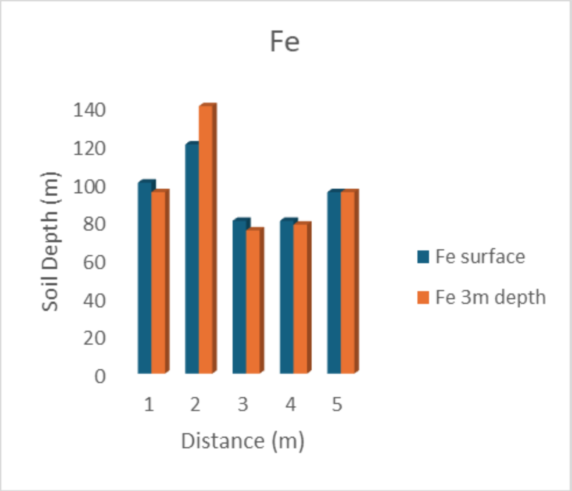


Figure 4.13: Soil Iron at Varying Depth and Distance from Dumpsite

### 4.5.4 Effect of Dumpsite Leachate on Soil Nitrate and Chloride

Nitrate and chloride are two common pollutants of ground water sources from dumpsites. It was observed that nitrate at the surface increased at 50m away from the dumpsite and increased further a l00m away from the dumpsite but had a slight decrease at 150m away from the dumpsite till control. On the other hand, below the soil surface (at 3m depth) nitrate decreased at 50m away from the dumpsite but had an increase and remained steady at l00m away till control (see Fig. 4.14). This indicates that the soil nitrate was affected by the acidity from the dumpsite as the pH at dumpsite was observed to be highly acidic (Olness et al., 2001). Also that nitrate did not percolate to the groundwater table but may have be leached out as surface runoff. Similarly, chloride at the surface decreased at 50m away from the dumpsite but increased and remained steady from l00m away from the dumpsite till control.

On the other hand, below the soil surface (at 3m depth) chloride was found to be the highest at 50m away from the dumpsite but eased at l00m away from the dumpsite and remained steady till control (see Fig. 4.15). This indicates that the soil chloride was affected by the leachate from the dumpsite as the chloride of leachate at dumpsite was observed to be extremely high. Also chloride percolated downwards.

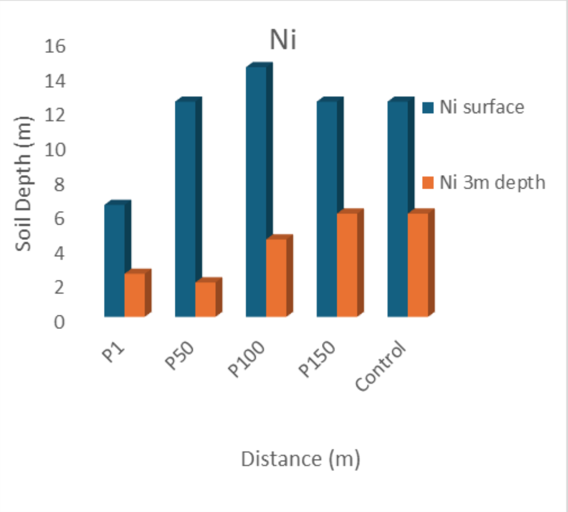


Figure 4.14: Soil Nitrate at Varying Depth and Distance from Dumpsite

## V. CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusion

The migration of leachate from open dumpsite to ground water table is a point source of ground water pollution. The weighted arithmetic water quality index method and vertical electric sounding served as a statistical instrument for rating bore hole water samples and unravelling the groundwater potential, subsurface aquifer protective capacity and lithology corrosively. The study concluded that the borehole water within the Ogale, Eleme dumpsite were laden with. increased acidity and microbial activity, the aquifer protective capacity was weak and the soil was corrosive.

Therefore. with these indices, the study concluded that the borehole water at the dumpsite and the to it were not fit for consumption until they undergo adequate water treatment.

### 5.2 Contribution to Knowledge

This study showed that the aquifer protective capacity is dependent on pollutant type because despite the weak to moderate aquifer protective capacity, it was strong enough to prevent heavy metal percolation into the groundwater but was not able to prevent the percolation of microbes.

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