Geophysical and Hydrogeochemical Investigation of Odolomi Dumpsite in Supare-Akoko, Southwestern Nigeria.

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ABSTRACT

Studies have shown that urban and rural waste management has been a serious problem in Nigeria. This work aims at investigating the effect of waste dumps on the groundwater in Odolomi area of Supare Akoko, south-western Nigeria using resistivity sounding method (dipole-dipole) and laboratory water sample analysis.

Ten (10) hand-dug well water samples and one (1) spring water sample which serves as a control were collected in the study area and analyzed for hydrogeochemical and microbial characteristics to know their quality and usability. The result of the analysis shows that elements like K, Na, Ca, and Pb are found in excess in the groundwater of the study area and more so, there is presence of micro-organisms like Enterococci, Coliform in the study area. The result of the analysis was then compared to the WHO (2010) standard for drinking water and it is evident that the groundwater is contaminated. The geophysical investigation shows that the area is highly conductive which implies that the water in the area is susceptible to contaminations.

It is evident that the study area is contaminated and not potable. This calls for necessary treatment and advanced water scrutiny.

(Keywords: Supare-Akoko, hydrogeochemical, microbial, contamination, groundwater, potable)

INTRODUCTION

Studies have shown that urban and rural waste management has been a serious problem in Nigeria. The concept of promoting better public health dates back to 1860, which naturally gave emphasis on safe water supply and the management of faeces and refuse. The major concern is the increasing volumes of refuse which is generated when the following biological, chemical, and physical processes like biological decay of organic materials, dissolving and leaching of organic and inorganic material by water. When refuse is dumped, it decays and the organic matters give rise to fungi and micro-organisms, while decaying animal tissue and waste yields bacteria which pollute water.

A refuse dump, which is highly rich in organic matter and serves as a reservoir of trace elements can increase the availability of pollutants after decomposition. After decomposition they are leached into the soil or run-off water. During this decomposition, certain organic acids (particularly carbonic acids) are found or formed, which dissolves soil minerals and other residues (Taylor and Allen 2001).

Some components of this waste including food, paper, etc., which consume oxygen thereby changing the redox potential of the liquid present. Percolating groundwater provides a medium through which wastes, particularly organics, can undergo degradation into simpler substances through biochemical reactions involving dissolution, hydrolysis, and the oxidation/reduction process. This leachate drains from the dump, and contains mainly organic carbon largely in the form of fulvic acids (Taylor and Allen, 2001). These in turn migrate downward and contaminate the groundwater. Each year about two million people die as a result of poor sanitation and contaminated water, ninety percent (90%) of the victims are children (Anon, 2009).

The assessment of hydrogeochemical and microbial contamination and characteristics of surface and groundwater in some areas in south-western Nigeria were analyzed for the occurrence and exploration of groundwater in Nigeria basement complex rocks with a lot of water generated from the rocks (Elueze et al., 2004; Tijani and Ayodeyi, 2001.).

Certain minerals are also toxic such as the heavy metals. Although, some of the heavy metals such as zinc, manganese, nickel, and copper act as micro-nutrients at lower concentrations, they can become toxic at higher concentrations. Health risks due to heavy metal contamination of water through soil have been reported extensively in the literature (Eriyamremu et al., 2005; Muchiweti et al., 2006; Singh et al., 2001; Udom and Esu, 2004). Therefore, auditing and monitoring of physico-chemical, minerals, and microbial quality of drinking water as fast becoming an essential aspect of water quality studies.

However, the quality of groundwater does not only depend on the source but on the environment where groundwater is found. Ordinarily, higher concentrations of dissolved constituents are found in groundwater than in surface water because of greater exposure to soluble material in geologic strata.

The indiscriminate dumping of these materials (natural and anthropogenic) has called for attention and this project tends to evaluate the quality of water around the dump site since people still live close to them, also to evaluate the spatial and the geophysical distribution of pollutant in the soil and in the water.

LOCATION AND GEOLOGY OF THE STUDY AREA

The Salvation Army dump site Oke-Ogbon located in Supare-Akoko, Ondo State of Nigeria, lies between latitudes N 07^0 26.897^1 ,N07^0 26.874^1 and Longitude E005^0 41.448^1 , E005^0 41.432^1. It covers an estimated area of about 100m by 100m. It has an approximated elevation of about 340m.

Supare town is situated in the humid tropical region of Nigeria with rainfall of over 1500mm annually and the southwesterly wind blows most of the year. The rainy seasons lasts from March to October every year.

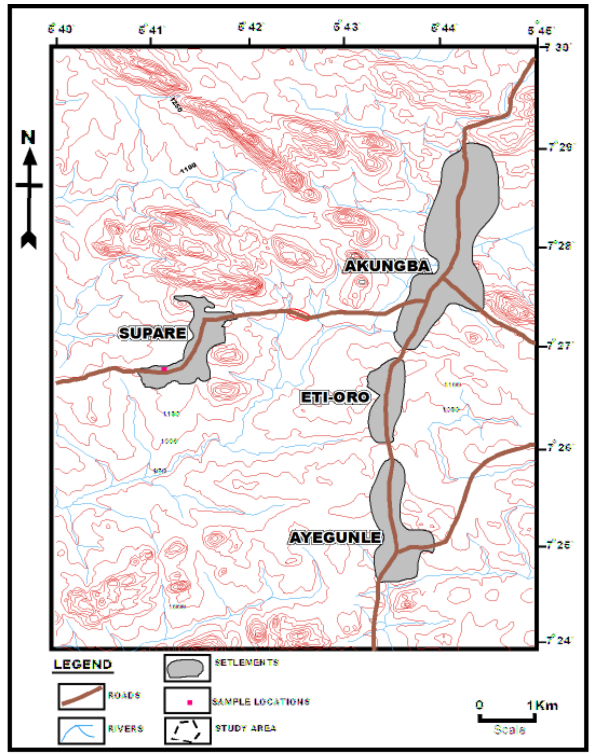

Figure 1: Topographic Map of the Study Area.

The study area falls within the basement complex of south western Nigeria. It is located in Supare-Akoko Ondo- State. A regional geological map of the province published by the geologic survey of Nigerians is shown in Figure 1. The dominant rock type in the area is mainly granite with minor occurrence of migmatites gneiss. They are typically fine to medium to course grained rock, strongly foliated and dark in color, the granite is used for construction and ornamentation by a company known as Crushed Rock Ind. Nig Ltd. Also, beneath the sites, there is a presence of fresh bedrock, a boulder or a partially weathered igneous or metamorphic rock in the area.

Hydrogeology

The study area falls within the hard rock terrain in the hard rock area, partially, weathered/ weathered rocks and fractured zones form aquifer units/system. The groundwater storage capacity depends upon the thickness of the weathered and fractured zones. The study area has rocks of low porosity and permeability.

Weathering aided by fractures and joints have imparted a secondary porosity, hence groundwater in this area is governed primarily by the thickness of the weathered zones and the extent of size openness and inter connections of the fractures and lineaments at sub-surface. However, groundwater system resources through streams, rivers, spring, etc., are not only reliable but are scarce. Only one stream, Odolomi stream, was found flowing dendritically at the lowland area of the site. The major river in the study area is River Odolomi. The river and stream channel in the area display dendritic pattern. The direction of flow of the river is topographically controlled (i.e., down gradient flow).

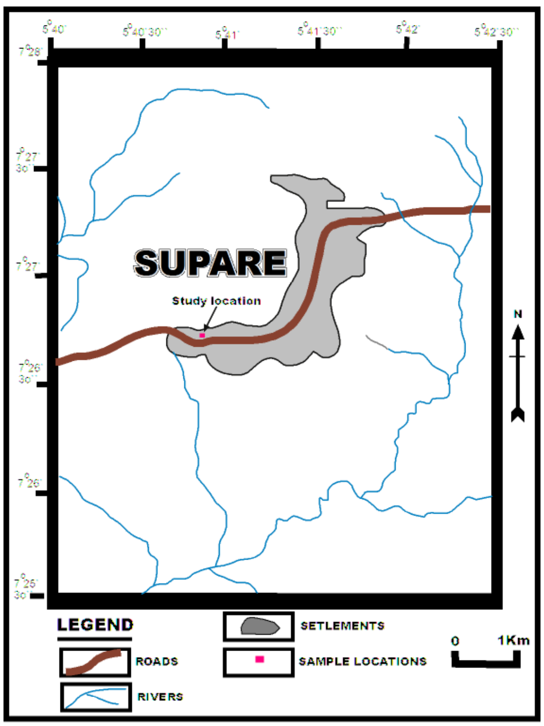

Figure 2: Drainage Pattern of the Study Area.

METHODOLOGY

The methods used in this study are: hydro geochemical, geophysical, and microbial analysis of groundwater in Odolomi dump site which include: reconnaissance survey of the study area, borehole inventories, geophysical survey investigation, and laboratory analysis for the hydro geochemical parameters.

Geochemical Analysis: Chemical parameters analyzed in IITA laboratory are: Cations (Ca, Mg, K, and Na), Anions (Fe, Cu, Mn, and Zn) and some heavy metals (Pb, Cr, Ni, Co, Se, and Cd).

Microbial Analysis: This is a laboratory analysis of water to estimate the numbers of bacteria present and to find out the typical microbes. The biological quality of the water was gotten by determining the bacteriological and the microbial counts.

Geophysical Investigation: The geophysical characteristics and the apparent pictures of the subsurface were gotten through geophysical survey from the resulting pseudo-sections.

Sampling Techniques

Eleven (11) borehole samples of water were collected from different locations within the study area. The water sample includes ten (10) samples from hand-dug wells and one (1) sample from spring water which serves as a control. The samples were taken from borehole of average depth 20-35m. All samples were collected in sterile plastic bottles (1 Liter), stored and transported in a cool box at a very low temperature into laboratory, and microbial analyses were conducted immediately. Labeling is ensured in respect to water sample (locality 1, 2, 3 . . . 11). Samples were then kept in a cool dry place and promptly transferred to International Institute for Tropical Agriculture (IITA) Ibadan and microbiological laboratory Adekunle Ajasin University, Akungba Akoko (AAUA) for chemical and microbial analysis, respectively.

For the determination of mineral concentrations, 10ml of the sample was digested using 50ml conc. H_2SO_4 and $HClO_4$ at the rate 1:1 on a digestor (Foss Tecator digestor) Model 210 at 250^0C for one hour. The clear solution was filtered into a 100ml volumetric flask and filled to the mark with deionized water Deionized water was used as a blank to zero the equipment for the analysis.

Atomic Absorption Spectrophotometer (Buck Scientific Model 210A) was used for the analysis of metals. Standards for each element under investigation was prepared in part per million (ppm) and the limit standard concentration for each element was adhered to according to the BUCK Scientific instructions and used for the calibration. Air/acetylene flame was used, the standard solutions were aspirated and the graph obtained. The concentrations of various metals in the samples were done against metal standard solutions.

Sample Location

During sampling, Global Positioning System (GPS) values of each sample point were taken and recorded on the field note. The table below shows the GPS value for all the sample points. The map shows the elevation and locations of dump site which is gotten from the values of GPS of each sample points within the dump sites. From the maps, it shows that the study area is slightly elevated above the normal terrains; it is evident from the northwesterly extension of the sites. I.e. the north and west of the site are elevated above the other area whereas; the south-eastern parts are depressed. In the same vein, groundwater flows from those elevated region to the depressed region and are contaminated by both natural and anthropogenic.

Geophysical Survey

Geophysics can be defined as the application of methods and techniques of physics to the study of the Earth. It is the study of the properties of matter and energy of the Earth and earth-materials with a view of knowing the nature of the sub-surface. This properties include among others, density, pressure, temperature, resistivity, velocity and conductivity. It involves taking measurement at or near the earth surface influenced by the internal distribution of the physical properties.

Geophysical survey is generally classified into two categories:

- Those that rely on natural field and
- Those that require input to the ground of artificially generated energy are referred to as active method and it involves the generation of local electrical and electromagnetic field that can be used analogously to natural fields.

Geophysical methods are sensitive and are influenced by certain operative physical properties, the types of physical properties to which a method responds determine it range of application, the methods are magnetic method, electrical resistivity method, seismic reflection method, etc.

Dipole-Dipole Method In Investigation Of The Subsurface

Geophysical resistivity techniques are based on the response of the Earth to the flow of electrical current, with an electric current passed through the ground and two potential electrodes to record the result at potential difference between them.

Electrical profiling known as constant separation traversing (CST), uses collinear arrays to determine lateral resistivity variations in the shallow subsurface at a more or less fixed depth of investigation.

Table 1: Table Showing the Field Measurement Carried out in the Study Area Using GPS 3D- Differential.

LOCATION NO	RESOURCE TYPE	LATITUDE (N)	LONGTITUDE (L)	ALTITUDE (M)
1	HDW	$07^{0}26.897^{1}$	$005^{0}41.414^{1}$	292.4
2	HDW	$07^{0}26.912^{1}$	$005^{0}41.420^{1}$	339.6
3	HDW	$07^{0}26.949^{1}$	$005^{0}41.437^{1}$	354.1
4	HDW	$07^{0}26.929^{1}$	$005^{0}41.448^{1}$	394.4
5	HDW	$07^{0}26.900^{1}$	$005^{0}41.457^{1}$	354.0
6	HDW	$07^{0}26.885^{1}$	$005^{0}41.453^{1}$	654.2
7	HDW	$07^{0}26.878^{1}$	$005^{0}41.439^{1}$	651.2
8	HDW	$07^{0}26.874^{1}$	$005^{0}41.432^{1}$	348.4
9	HDW	$07^{0}26.869^{1}$	$005^{0}41.413^{1}$	339.0
10	HDW	$07^{0}26.892^{1}$	$005^{0}41.414^{1}$	358.8
11	SPR	$07^{0}26.869.8$	$005^{0}41.424$	352.2

LEGEND
HDW - Hand-dug well
SPR - Spring

The current and potential electrodes are moved along a profile with constant spacing between electrodes. The two most common array types used for CST are the dipole-dipole and pole-dipole arrays, where a dipole is a pair of current or potential electrodes.

The dipole-dipole resistivity techniques consists of a collinear array with current dipole separation of length a, with a total distance between the dipoles of length na. It shows where the apparent resistivity value calculated from the measured potential difference is plotted to aid later interpretation. The apparent resistivity value is plotted to aid later interpretation. The apparent resistivity value is plotted along intersecting 45 degree line centered on the dipoles. The geometric factor for the dipole-dipole array is G® = N (n+1 (n+2) a.

The dipole-dipole technique records the largest anomalies in comparison to other arrays, but its low signal-to-noise ratio limits its applications. Finding small changes in resistivity at great depth would be difficult (Ward, 1990)

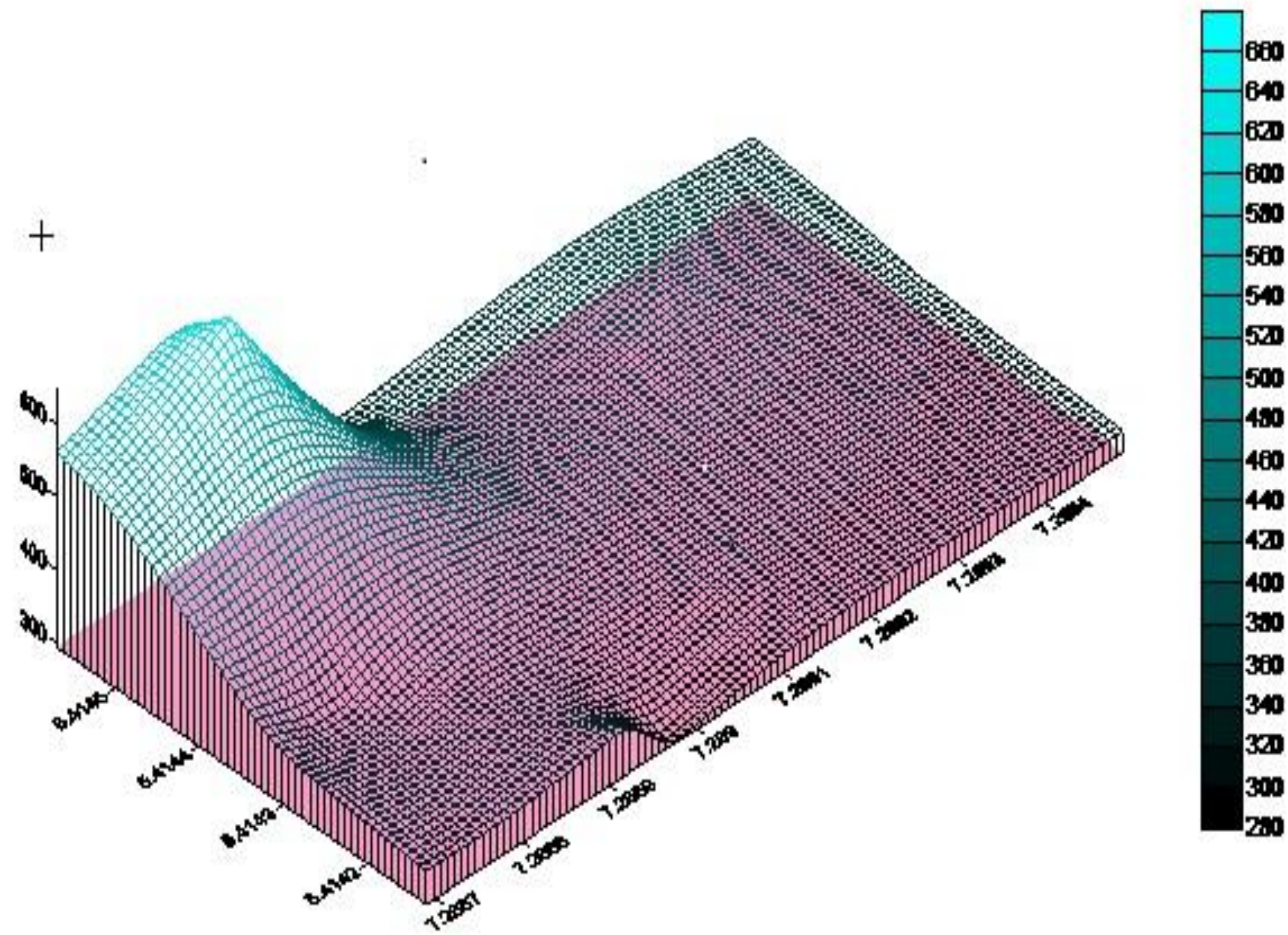

Figure 3: 3D-Map showing the Elevation and Location of the Dump Site.

Geophysical Survey of the Study Area

The geophysical survey of the area, Salvation Army dump site Oke-Ogbon Located in Supare-Akoko, Ondo State of Nigeria was carried out using dipole-dipole method and the subsurface geology was gotten and plotted in a pseudo-section.

RESULTS AND DISCUSSION

The results of the chemical, microbial and geophysical survey of the area are presented. The geochemical data analysis of the study area is presented in table below. The results were compared to World Health Organization (WHO 2010) guidelines for Drinking Water Standards.

Interpretation of Results

From the results shown in Tables 2-4, the chemical and biological qualities of groundwater are determined. They are also compared to the WHO standards for drinking water. The geochemical analysis result as shown are to be used to determine the groundwater quality of the area. Comparing the WHO (2010) standard for drinking water, it is seen from the table, the maximum and minimum permissible level of drinkable water and that, any increase in the amount of the concentration will lead to health hazard. In the geochemical result table it is evident that potassium (k) which has a maximum permissibility level 50mg/l on the WHO (2010) standard for drinking water is the major chemical elements that contaminate the groundwater of the study area, thus the value of k gotten from the analysis is greater than that posited by WHO (2010) standard.

Additionally, The World Health Organization proposed that any good quality groundwater should be devoid of any heavy metals like lead, selenium, cadmium, etc. But some of the water samples in the study area contain some concentration of heavy metals like lead and zinc.

The result of the microbial analysis have shown that all the water samples in the area is not fit for drinking i.e. they are contaminated. WHO (2010) microbial standards posited that a good groundwater should not contain or have any micro-organisms in it.

Table 2: Table Showing the Geochemical Analysis of the Water in the Study Area.

Locations	ppm Ca	ppm Mg	ppm K	ppm Na	ppm Mn	ppm Fe	ppm Cu	ppm Zn	ppm Pb	ppm Ni	ppm Co	ppm Cd	ppm Se	ppm Cr
Hdw 1	64.55	15.26	3.82	38.91	0.00	0.00	0.00	0.05	0.02	0.00	0.00	0.00	0.00	0.00
Hdw 2	142.54	22.41	1.74	30.83	0.36	0.00	0.00	0.08	0.02	0.00	0.00	0.00	0.00	0.00
Hdw 3	34.59	7.34	45.51	23.51	0.00	0.00	0.00	0.07	0.02	0.00	0.00	0.00	0.00	0.00
Hdw 4	39.85	12.80	73.96	18.69	0.04	0.00	0.00	0.08	0.02	0.00	0.00	0.00	0.00	0.00
Hdw 5	38.09	10.39	64.81	37.49	0.00	0.00	0.00	0.08	0.02	0.00	0.00	0.00	0.21	0.00
Hdw 6	38.97	10.93	64.40	34.96	0.00	0.00	0.00	0.08	0.02	0.00	0.00	0.00	0.00	0.00
Hdw 7	53.65	12.80	110.62	40.31	0.00	0.00	0.00	0.07	0.02	0.00	0.00	0.00	0.00	0.00
Hdw 8	54.55	13.25	111.46	40.29	0.00	0.00	0.00	0.07	0.02	0.00	0.00	0.00	0.00	0.00
Hdw 9	50.51	17.94	71.51	37.85	0.00	0.00	0.00	0.05	0.02	0.00	0.00	0.00	0.00	0.00
Hdw 10	58.63	15.14	101.61	38.56	0.00	0.00	0.00	0.08	0.02	0.00	0.00	0.00	0.00	0.00
Spr	155.40	26.89	76.41	35.10	0.17	0.00	0.00	0.10	0.02	0.00	0.00	0.00	0.00	0.00

Key:
Hdw= Hand-dug well
Spr= spring (control)
ppm= parts per million

Table 3: Table Showing World Health Organization WHO (2010) Standards for Drinking Water.

PARAMETER	MAX PERMISSIBLE LEVEL
Color	50
Turbidity	25
pH	6.5-9.2
TOTAL DISSOLVED SOLID (MG/L)	1500
Total hardness (mg/l)	500
Electrical conductivity (ohm km)	1000
Mg (mg/L)	150
Ca (mg/L)	200
K (mg/L)	50
Na (mg/L)	200
Fe (mg/L)	0.03-0.1
Cu (mg/L)	2.0
Mn (mg/L)	0.1-0.2
Zn (mg/L)	3.0
Pb (mg/L)	0.1
Cr (mg/L)	50
Ni (mg/L)	20
Co (mg/L)	20
Se (mg/L)	10
Cd (mg/L)	5.0

Table 4: Table Showing Microbial Analysis Results.

Water Sample	No. of Colonies	Dilution Factor	Colonies forming unit/ml
1	26	10^{-2}	0.26cfu/mg x 10^{-2}
2	800	10^{-2}	8cfu/mg x 10^{-2}
3	400	10^{-2}	4cfu/mg x 10^{-2}
4	63	10^{-2}	0.63cfu/mg x 10^{-2}
5	80	10^{-2}	0.8cfu/mg x 10^{-2}
6	600	10^{-2}	6cfu/mg x 10^{-2}
7	46	10^{-2}	0.46cfu/mg x 10^{-2}
8	9	10^{-2}	0.09cfu/mg x 10^{-2}
9	1	10^{-2}	0.01cfu/mg x 10^{-2}
10	40	10^{-2}	0.4cfu/mg x 10^{-2}
11 (Spring)	76	10^{-2}	0.76cfu/mg x 10^{-2}

Table 5: Table Showing Microbial Standard for Drinking Water.

s/n	Parameters	Conc. or Value Max	Units of Measurement	Point of Compliance
1	Enterococci	0	Number/100	Consumer taps
2	*Escherichia coli* (E. coli)	0	Number/100	Consumer taps
3	Coliform (bacteria)	0	Number/100	Service reservoirs and water treatment work

This is shown from the WHO microbial analysis result in the table above.

From the above results and interpretations, it is imminent that the elements tested for are the cations, anions and the heavy element. Some of the ionic concentration tested for are within the limits of portability (Sample 2), the pH value of the groundwater samples are weakly acidic and the acidic nature may be due to the soil condition or organic acid from decaying vegetation (Ajayi and Umoh, 1998). The water in the study area is generally hard which is caused primarily by the presence of cations such as calcium and magnesium. However, water hardness has no known adverse effect but evidence indicates its role in heart disease. Hardness is unsuitable for domestic use in the study area.

The concentration levels of the major cations (Na, Mg, Ca, and K) and anions (Fe, Cu, Mn, and Zn) in the groundwater samples are less than the recommended limits for domestic purpose (WHO, 2010), in the same vein, the presence of heavy element in the water samples indicates that it is not safe for drinking because of the possible danger of lead poisoning (Tijani, 1994). The groundwater is presently contaminated due to leachate associated with sewage, domestic waste, and industrial waste materials which was due to the relatively low concentration of nitrate in the water sample.

The suitability of groundwater for irrigation purpose depends upon its mineral constituents. The general criteria for judging the quality are (1) total salt concentration as measured by electrical conductivity (EC); (2) relative proportion of sodium to other principal cations; (3) bicarbonate; and (4) boron. A majority of the water samples in the study area are good for irrigation purpose which is evident from the concentration of each element.

Unsafe levels of Zn can lead to respiratory system damage, stress, and inhibition of normal growth and maturation (Weatherley et al., 1988). From all these water analysis, it can be deduced that the most abundant cations are potassium (K), followed by calcium (Ca), then by sodium, and lastly magnesium (i.e., K > Ca >Na >Mg).

Moreover, it is observed that the groundwater in the study area is contaminated because of its high conductivity value. The breakdown of excess organic matter in the waste dump does not only consume energy but also release a variety of compounds into the groundwater among them, nitrates, phosphates, and sulphates and this is known as eutrophication (Carla, 2000; Barker, 1972; Amadi, 1987, Ariyo et al., 2005; Akpokodje, et al., 2005; Carrol, 1960).

Older leachates from open dumps usually contain biological and chemical constituents. Organic matter decomposing under aerobic conditions produces Carbon (IV) Oxide which reacts with the leaching water to form carbonic acid. Dumps generate leachate plumes which travel kilometers in more permeable environment (Moody, 1996; Ajayi, 1998; Abdul Nassir et al., 2000; Adepelumi et al., 2008) the conductivity is high confirming the result obtained from the geophysical sounding.

Therefore, the water sample in the study area is characterized with some bacteria and microorganism which shows that the water is not safe for drinking.

Geophysical Survey Interpretation

In Figure 4 the geophysical survey interpretation (in 2-D) of the study area is as follows, looking at the pseudo-section, it is imminent that the study area has an increasing resistivity and decreasing conductivity.

The bluish region represents a low resistivity which increases and ranges from BLUE to GREEN to YELLOW to RED and finally to PURPLE (from the key) which represent the order in which the resistivity in that area increases.

On the other end, the conductivity of the study area decreases in that order i.e. as resistivity increases, conductivity decreases. Succinctly put, the most conductive portion in the section is the bluish region i.e. conductivity increases from PURPLE to RED to YELLOW to GREEN and most conductive at the bluish region.

Furthermore, the increase in resistivity may be due to the presence of a fresh bedrock, a boulder or a partially weathered igneous or metamorphic rock in the area, The presence of a rock in an area makes resistivity increases and decreases conductivity (igneous or metamorphic).whereas, the portion with low resistivity may be due to the degree of fracturing and the percentage of the fractures filled with groundwater. Sedimentary which usually, are more porous and have higher water content, normally have lower resistivity values.

Moreover, there are pockets of conductive portion in the section which is due to the fracturing of the rocks and weathering, the created void are now filled with water, as even a non-geophysicists will know that water is highly conductive.

In Figure 5 from Section1-6 and a depth of about 14m, it has a low resistivity and high conductivity (i.e., the bluish region).

TRAVERSE 1

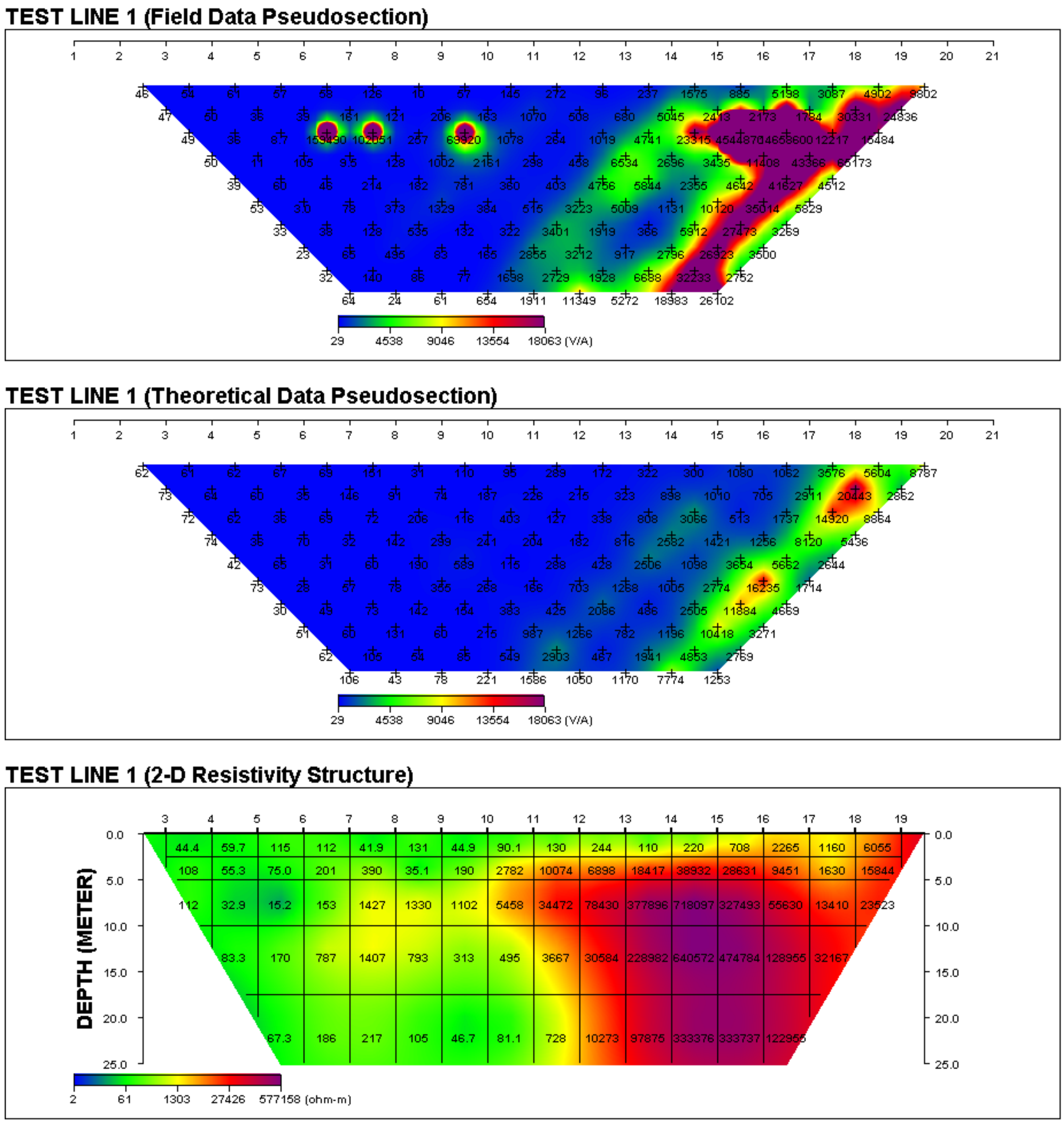

Figure 4: Picture Showing 2D-resistivity Pseudo-section of Traverse 1.

TRAVERSE 2

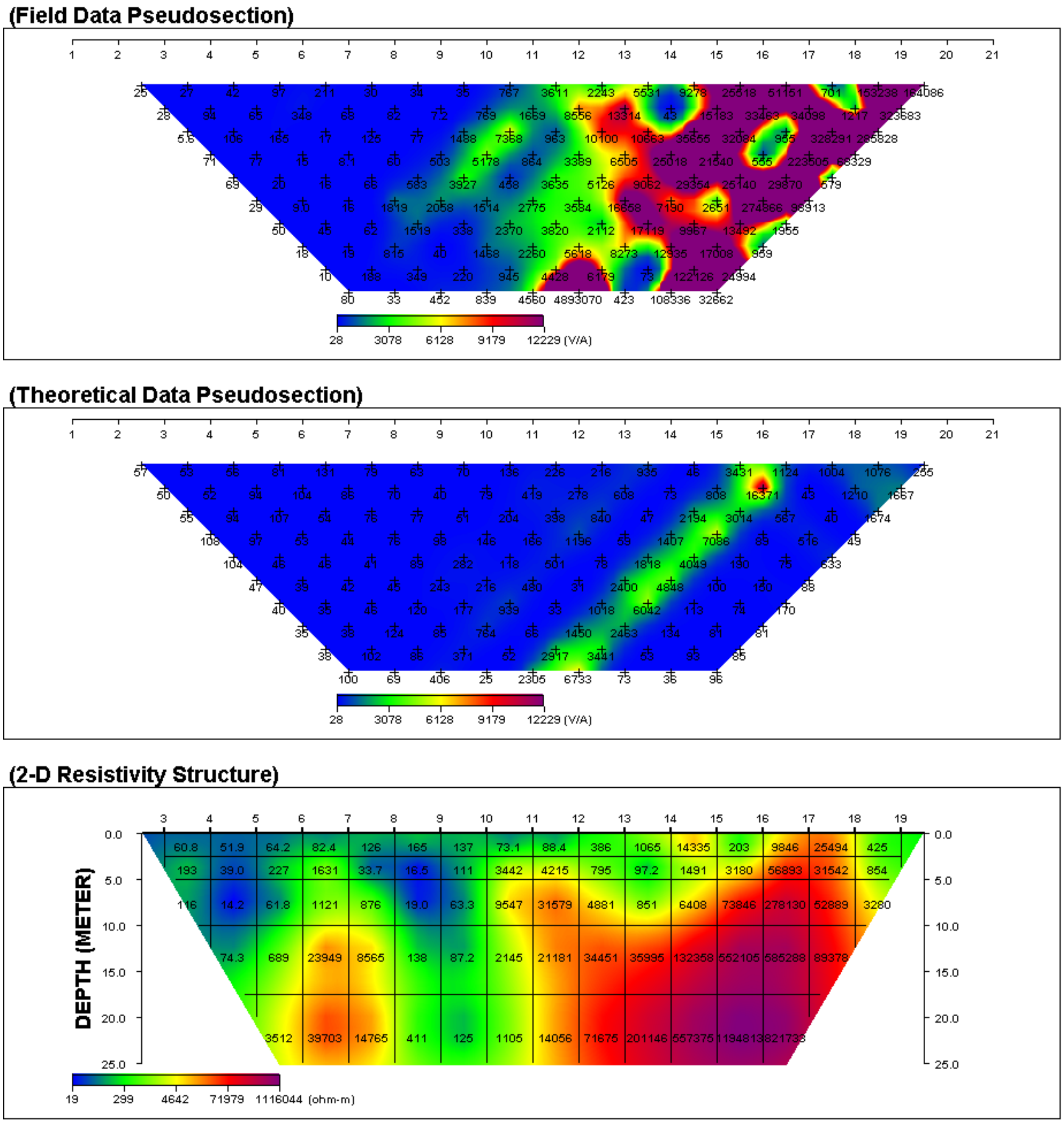

Figure 5: Picture Showing 2D-Resistivity Pseudo-Section of Traverse 2.

From Section 6-7 and a depth of about 15m, resistivity increases and conductivity decreases and at a depth of about 25m in the same section, resistivity increases.

From Section 7-10 and a depth of 15m, resistivity decreases and at higher depth, it increases again at the green portion.

From Section 10 -16, and at a depth of about 7m, resistivity slightly increases and become increases more at about 25m depth.

From Section 16-18, resistivity increases from thin yellow to red and maximum at purple region which is the most resistive and less conductive at a depth of about 25m, in the same section.

From 18 onward, and a depth of about 5m, it is also slightly resistive (greenish region). Having known the resistivity and conductivity potential of the site, it is possible to believe that, the pseudo-section of the traverse helps us to deduce the 3-D pictures of the site.

There may be appearances of fresh bedrock underneath the sites which is evident from traverse 2, and that contaminants were flown down from that area down to the region of low resistivity. After all, it is widely accepted that portions of low resistivity value are contaminated to portions of high resistivity.

From this perspective, contaminants from low resistivity portions are transported or moved through water and porous materials (sand) to the high resistivity portions which now contaminate the groundwater.

Although, the pseudo-section does not give us the true picture of the subsurface but serves as an initial guide for further quantitative interpretation.

CONCLUSION

Solid wastes are mainly disposed of at dump sites because it is the simplest, cheapest, and most economical method of disposing of solid wastes. In most low- to medium-income developing nations (e.g., Nigeria), almost 100% of generated wastes goes to land fill and waste dumps. Because of this, landfill and dumpsites are likely to remain a relevant source of groundwater contaminations for the foreseeable future. Considering the nature and the geology of Odolomi dumpsite Supare-Akoko, the permeability of the top formations causes the movement of contaminants (calcium, lead, zinc, micro-organisms, etc.) from the formation to the groundwater.

The results from subsurface geophysical surveys have enabled us to detect points and passageways by which the groundwater within the study area gets contaminated. As it is known, that area with high resistivity has low conductivity and those regions with low resistivity are easily contaminated than portions with high resistivity.

From the pseudo-section, it is found that, within Region 1-6 and a depth of about 14m, presents low resistive and high conductivity (i.e., bluish region). Also, at Section 7-10 and a depth of about 15m, the resistivity is low and at higher depths, resistivity increases slightly (i.e., blue to green region).

To be succinct, Odolomi area of Supare Akoko is more contaminated in the bluish region followed by the greenish region, then by yellowish portion and by red and purple regions, respectively. As resistivity increases, conductivity decreases and the level of contamination also decreases. From all these facts, one can validly infer that the groundwater in the study area get contaminated right from the low resistivity area to other regions.

The chemistry of groundwater is strongly dependent on the geologic stratum of the area; the geological and climatic factors have determined either directly or indirectly, the type and content of the chemical constituent of the water in the study area as well as their distribution. However, the chemistry of rainfall which is the primary source of groundwater will change as it passes through the geologic stratum of the area (aquifer), by adding some minerals to it which now make up the chemistry of the ground water.

Water in the study area has a poor biological quality as compared to WHO, 2010 standard; it has some bacterial which might have originated from contamination of the water resulting from poor construction of the wells in the area or contamination by biological activities.

From all these interpretations and discussions, it has been shown that the groundwater in the study area is contaminated and polluted; therefore, it should be considered non-potable.

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