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Exploiting Cohesive Geophysical Medium to Weigh the Natural Hit of Solid Waste Dumpsite in Nassarawo-Demsa, Adamawa State, Nigeria.

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Abstract: *Cohesive geophysical medium, namely; magnetic and electrical resistivity methods, were applied along with a geochemical method – atomic absorption spectrophotometry (AAS), to investigate the effect of solid (domestic) wastes dumpsite by means of groundwater contamination on Nassarawo-Demsa Area. The aeromagnetic data used in the present study were extracted from sheet 196 (Numan) which was obtained as part of Nigeria nationwide aeromagnetic survey conducted by the National Geological Survey Agency (NGSA), Abuja. The data were acquired on an average flight elevation of about 80 m in a series of NE – SE flight lines, with a spacing of 500 m. The tie lines occurred at about 2 km. Surfer Version 7.02, a contouring and 2D surface mapping software program was used in processing the aeromagnetic data, basically to investigate fault zones across the study area.Nine hundred and eight (908) datum points, each for the three (3) profiles (stations) of electrical resistivity imaging were recorded to investigate distribution of landfill leachate, and possibly detect groundwater contamination on the study area. ABEM SAS1000 was used to acquire the resistivity data using dipole-dipole configuration, and Res2DInv. exe. software was used in processing the data. Atomic absorption spectrophotometry (AAS) analysis was conducted on fifteen (15) groundwater samples from the study area. Ten (10) samples were Bore Wells (GW1, GW2….GW10) while five (5) were Hand-dug Wells (HW1, HW2…. HW5). The AAS analysis was to determine physicochemical parameters such as turbidity, alkalinity, TDS, EC, DO, sulfate, chloride and nitrate, and some trace elements – Cu, Zn, Fe, Pb, Mn, Cr and Cd - on the groundwater samples.*

The result from aeromagnetic data of the study area revealed high and low magnetic anomaly ranging between 7720nT and 7880nT. In profile one, the inversion process of the electrical resistivity data was carried out using least-squares inversion method and the inverse model resistivity revealed a thin layer of about 3 m and low resistivity variation ranging between 2 Ωm and 16 Ωm. This layer is underlain by a relatively high resistivity layer, ranging between 110 Ωm – 260 Ωm. In profile two, the thin layer of low resistivity occurred at about 4 m depth. The layer has a low resistivity variation from about 4.5 Ωm – 25 Ωm, and underlain by a layer of higher resistivity variation of about 120 – 300 Ωm. From profile three, the thin layer of about 5 m depth, occurred at resistivity variation ranging from about 8 Ωm – 19 Ωm. The layer isalso underlain by a high resistivity layer of about 100 Ωm – 280 Ωm resistivity variation.Physicochemical analysis of the groundwater samples show variation in alkalinity ranging from 167.1 mg/L to 820.0 mg/L. Electrical Conductivity (EC) ranges between 52.8 μmho/cm and 909.2 μmho/cm while pH value of the sample ranges between 7.1 and 7.9. The variation in the Total Dissolved Solid (TDS) ranges between 131.9 mg/L and 2362.7 mg/L. Dissolved Oxygen (DO) of the sample shows variation from 8.4 mg/L to 23.6 mg/L. Variation in Zn concentration ranges from 0.0007 mg/L to 0.4130 mg/L while that of Cu ranges between 0.004 mg/L and 0.028 mg/L. Iron and lead show variation in concentration, ranging from 0.0002 mg/L to 0.046 mg/L, and 0.0005 mg/L to 0.068 mg/L respectively. The concentration of Chromium from the sample ranges between 0.0003 mg/L and 1.993 mg/L while manganese concentration ranges between 0.0001 mg/L and 0.056 mg/L. Cadmium concentration in the sample shows variation from 0.0001 mg/L to 0.009 mg/L. Sulfate concentration ranges from 128 mg/L to 321 mg/L while Chloride concentration ranges between 201 mg/L and 432 mg/L. Fluoride and Nitrate show variation in concentration ranging from 0.3 mg/L to 1.9 mg/L, and 21 mg/L to 88mg/L respectively.

This study concluded that as a result of indiscriminate solid (domestic) wastes dumpsites, most of the groundwater sources in Nassarawo-Demsa area are not suitable for human consumption unless properly drilled to at least 100 m from the surface. Alternatively, groundwater from Nassarawo-Demsa area require treatment before human consumption.

Key Word: *Solid waste dumpsite; Magnetic method; Electrical resistivity;Dipole-dipole; Leachate; Numan.*

I. Introduction

Solid waste is disposed of in tens of dumping grounds right through Nassarawo-Demsa. These dumpsites bear all the waste collected from the area, including chemicals which, ordinarily should be disposed of in hazardous waste landfills. Waste from Auto painting & repair shops, furniture stripping/refinishing and household hazardous product, most at times end up on these dumping grounds, and once there, contaminants (chemicals) can leach into groundwater by means of surface runoff and precipitation. This is mostly common in Africa[1].Just as groundwater percolates, so do contaminants in the form of plume. The speed and size of a plume generally depend on the type of contaminant, its density and solubility, and the velocity of surrounding groundwater. Groundwater contamination can always be the result of human activity, though some sources of groundwater contamination such as manganese, iron, arsenic and sulfates could be natural.

For all that Nassarawo-Demsa is by the Benue River in Northeast Nigeria, majority of its inhabitants depend on groundwater sources for domestic and irrigation purposes. This implies that contamination of groundwater can result in poor drinking water quality and/or potential health problems such as cholera, typhoid and hepatitis. The aim of this research is to harmonize geophysical and geochemical techniques to investigate the level of groundwater contamination in Nassarawo-Demsa. Electrical resistivity, a geophysical method is used in mapping the resistivity variation of a point (the study area) positioned at 10 meters away of a dumpsite in Nassarawo-Demsa. The subsurface mapping is based on the electrical conductivity of leachate which tends to be higher than that of groundwater[2]. This is more so as resistivity technique is suitable for mapping and delineation of leachate contaminant plumes[3,4,5,6]. The geophysical data, by dint of ABEM Terrameter (SAS1000), were processed using Res2DInv Software such that a value of 1.0 means the resistivity is allowed to vary freely during data inversion to estimate the regions above and below sharp boundary. ABEM Terrameter is a state-of-the-art data acquisition system for self-potential (SP), resistivity (RES) and time-domain induced polarization (IP). The instrument has been carefully checked at all stages of production and is thoroughly tested before leaving the factory[7].Different authors used different geophysical tools such as resistivity and magnetism for groundwater exploration[8,9,10]. In particular, the obtained airborne magnetic data in the present research is to be used to investigate magnetic anomaly in order to identify fault zones in and around the study area.

Physicochemical analysis was carried out on 15 samples of groundwater collected from the study area. This was to further identify possible sources of toxic contaminants affecting the portability of the groundwater in and around Nassarawo-Demsa. Polythene cans of 50 cl capacity were used to convey the samples from the study area to the chemistry laboratory for atomic absorption spectroscopy and other physicochemical analysis. Further testing on turbidity, inorganic nutrients and some trace metals were conducted using LaMotte SMART3 Reagent System. This is because the system is designed to minimize most common interferences, and its repeatability is the within-run precision[11].

II. Material and Methods

The research was conducted on Nassarawo-Demsa area of Adamawa State, Northeast Nigeria to investigate the level and/or the negative impact of solid waste mismanagement, with special interest on groundwater contamination.

2.1 Geological Consideration of the Study Area.

Nassarawo-Demsa is located in Numan city of Adamawa, Northeast Nigeria. It is on latitude $9^0$05'00''N and $9^0$46'00''N and longitude $12^0$00'00''E and $12^0$10'00''E. Numan is on elevation of about 158 meter above sea level. It is considered the 3rd biggest city in Adamawa after Jimeta (the State Capital) and Mubi local council. The study area lies on the Upper Benue Trough. In the Upper Benue Trough, the depocenters comprise Pindiga, Gombe, Nafada, Ashaka (in the Gongola Arm) and Bambam, Tula, Jessu, Lakun, and Numan in the Yola Arm[12]. Figure 1 shows the location of Numan on a world map.

Figure 1: Location of Numan on world map (adopted from worldatlas.com)

Figure 2: View of part of Sabob-pegi landfill from south in the Study Area.

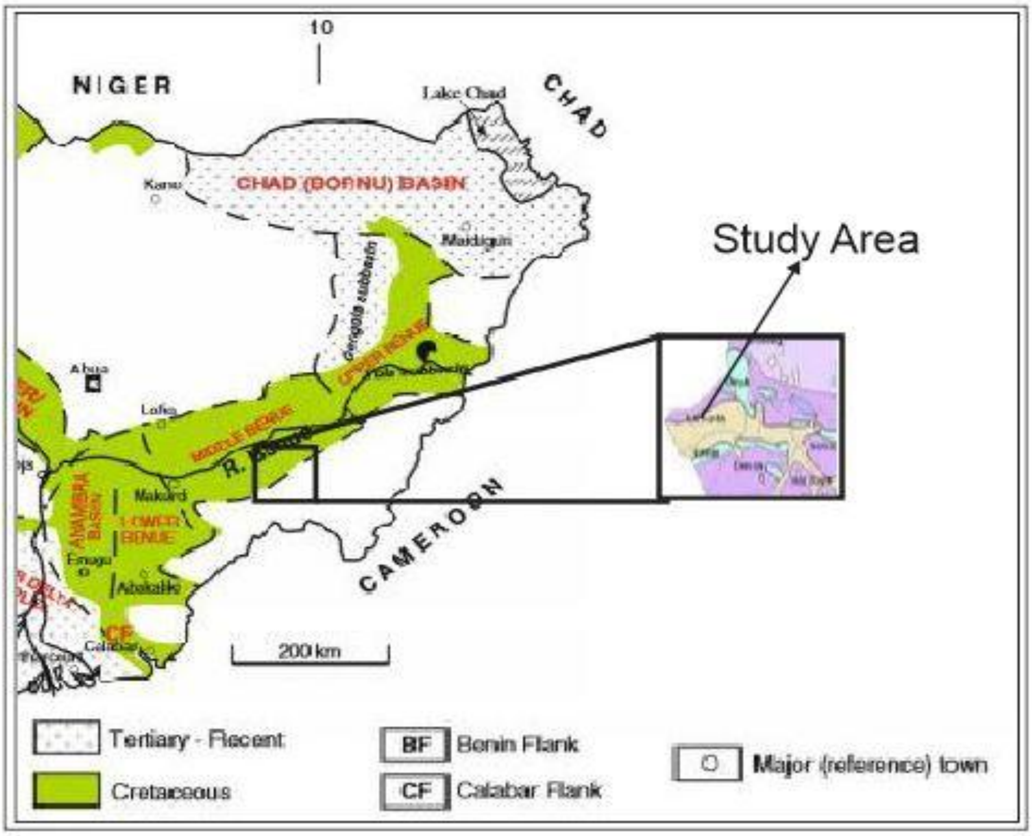

Figure 3: Geological sketch map Sedimentary Basins of Nigeria along the Study Area (modified after Obaje, 2009)

Figure 4: Typical waste particles visible from a hand-dug well in the Study Area.

2.1.1 Hydrology

The study area is situated along the confluences of the two major rivers in Nigeria, namely; rivers Benue and Gongola. The area receives about 8mm of rainfall annually out of which 80% is lost through surface runoff and evapotranspiration while 20% goes to recharge the groundwater system [E. Y. Mbiimbe]. Sources of hand dug wells in the study area are mainly from upper unconfined aquifer of shallow depth ranging between 5 and 15 meters. This is as Bore-wells can go as deep as 250m, though are mostly within the range of 40-120m.

2.1.2 Basic Geochemistry and Heavy Metals

Trace elements such as Pb, Cr, As, Cd and Cu are most common heavy metals found at groundwater contaminated sites[13]. Lead (Pb) naturally occurred a bluish-gray metal in compounds such as $PbSO_4$, PbS, or $PbCO_3$. Lead concentration usually ranges between 10 and 67 mg kg^{-1} in the earth's crust, and of this concentration, about half of Pb tends to be toxic. Lead can cause serious injury to the brain, nervous system, red blood cells, and kidneys[14]. Chromium (Cr) is one of less common of trace elements which does not occur naturally in elemental form, but in compounds. A major source of Cr contamination (in groundwater) is through disposal of Cr containing wastes[15]. The form of Cr commonly found at contamination site is the Chromium(VI).

Arsenic, a metalloid in group VA, period 4 of the periodic table, occurred in wide variety of minerals such as As_2O_3, and in form of arsenate (AsO_4^{3-}) in aerobic environments. Arsenic mobility increases as pH increases in groundwater. The effect of arsenic in groundwater contamination is associated with skin damage, increased risk of cancer, and problems with circulatory system[16]. Cadmium, though very biopersistent, has some toxicological properties which if absorbed by humans, remains resident for many years. This affect several enzymes, resulting in to renal damage (proteinuria). Cadmium also reduces the activity of delta-aminolevulinic acid synthetize, arylsulfatase, alcohol dehydrogenase, and lipoamide dehydrogenase, whereas it enhances the activity of delta-aminolevulinic acid dehydrogenase, and pyruvate dehydrogenase[17]. Aside tobacco smoking, contaminated groundwater intake is a major route through which Cd enters human body.

Copper, Cu, is the third most used metal in the world[18]. It is an essential micronutrient for growth in both plants and animals. It helps in hemoglobin production in human blood. However, cooper can cause liver and kidney damage when taken from contaminated groundwater in high doses.

Zinc, a transition metal occurred naturally in soil (about 70 mg kg^{-1} in crustal rocks).

In essence, presence of toxic metal in groundwater can severely inhibit the biodegradation of organic contaminants. Heavy metal contamination of groundwater poses risk and hazards to humans in particular, and to the ecosystem in general. It also causes food insecurity and land tenure problems[19,20,21].

2.2 Study Duration.

The research was conducted throughout eight months, starting from September 2019 to April 2020, approximately 217 days. Literature review was conducted through 13 days while community relations, site plan, and field work/data collection were conducted through 2, 3, and 28 days respectively. Groundwater samples collection from across the study area was carried out through 5 days and physicochemical analysis takes a period of 28 days.

Table 1: Location/Name of groundwater samples across Nassarawo-Demsa

S/No.	Location/Name of Sample	S/No.	Location/Name of Sample
BW1	Sabon-pegi	**BW9**	Pare 2
BW2	Gwaidamalam	**BW10**	Sakato
BW3	Kwata	**HW1**	Dakata
BW4	Gindin Kuka	**HW2**	Kwahalinga
BW5	Dowaya	**HW3**	Gadina 1
BW6	Numan 1	**HW4**	Gadina 2
BW7	Numan 2	**HW5**	Nassarawo Central
BW8	Pare 1		

2.2.1Sample size

Groundwater samples from the study area were collected in a way and manner to reflect the solid waste dumping grounds across the area. A total of ten Bore Wells (BW1-BW10) and five Hand-dug Wells (HW1-HW5) were strategically selected to fall with the radius of 500 meters from the point of the electrical resistivity mapping. Table 1 gives the location/name of groundwater samples, strategically distributed over Nassarawo-Demsa.

2.3 Data Acquisition and Analysis

Two geophysical methods- magnetic and resistivity were employed identify fault zones and landfill leachate contamination respectively. Atomic Absorption Spectrophotometric (AAS) analysis, a geochemical method was used in the determination of physicochemical and trace elements on groundwater samples from the study area.

2.3.1 Magnetic Method.

The aeromagnetic data used in the present study were extracted from sheet 196 (Numan) which was obtained as part of Nigeria nationwide aeromagnetic survey conducted by the National Geological Survey Agency (NGSA), Abuja. The data were acquired on an average flight elevation of about 80 m in a series of NE – SE flight lines, with a spacing of 500 m. The tie lines occur at about 2 km. Surfer Version 7.02, a contouring and 2D surface mapping software program was used in processing the aeromagnetic data to investigate fault zones across the study. Figure @ shows the aeromagnetic map from the magnetic values plotted (contoured) at 10nT interval. The map reveals a high magnetic anomaly of about 7880nT occupying the northeast, southeast and southern parts of the study area, while the low magnetic anomaly of about 7780nT occupies the southern parts.

2.3.2 Resistivity Method.

Three (3) profiles (stations) of electrical resistivity imaging were recorded to investigate distribution of landfill leachate, possible for groundwater contamination on the study area. ABEM Terrameter, SAS1000 was used to acquire the resistivity data, and Res2dInv. exe. software was used in processing the data. Figures 6, 7, and 8 show the 2D Measured Apparent Resistivity Pseudo-sections, Calculated Apparent Resistivity Pseudo-sections, and the Inverse Model Resistivity Sections. These give the distribution of resistivity across the three profiles.

2.3.3 Geochemical Method

Atomic absorption spectrophotometric (AAS) analysis was conducted on fifteen (15) groundwater samples from the study area. Ten (10) samples are Bore Wells (GW1, GW2….GW10) while five (5) of the total samples are Hand-dug Wells (HW1, HW2…. HW5) as in Table 1. The AAS analysis was to determine physicochemical and trace elements on the groundwater samples. LaMotte Smart3 Colorimeter was used in the analysis of physicochemical parameters such as turbidity, alkalinity, TDS, EC, DO, sulfate, chloride and nitrate. The LaMotte Smart3 Colorimeter is an EPA-Accepted instrument. EPA-Accepted means that the instrument meets the requirements for instrumentation as found in test procedures that area approved for the National Primary Drinking Water Regulation (NPDWR) or National Pollutant Discharge Elimination System (NPDES) compliance monitoring programs [LaMotte Manual].

III. Results

*Magnetic data:*The magnetic values were contoured at 10nT interval to plot the aeromagnetic map of the study area the separation was carried out at a wave number cut-off of 0.0000287, after magnetic data were reduced to the north magnetic pole.

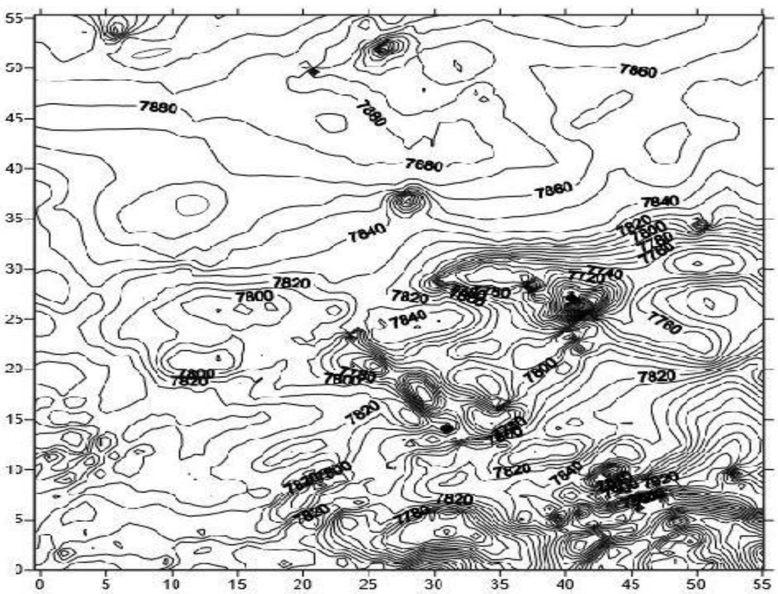

Figure 5: Aeromagnetic Map of the Study Area, contoured at 10nT

The aeromagnetic map of the study area (Fig 5) above reveals magnetic anomaly ranging between 7720 and 7880nT. This is the aeromagnetic data recorded on sheet 196, as on the Nigeria index map. It was recorded during nationwide aeromagnetic survey over Nigeria, on flight line trend of 135 degrees and tie line trend of 45 degrees. On some of the plotting specifications, the aeromagnetic data was projected on the basis of Universal Transverse Mercator, with X-Bias, Y-Bias and Grid Mesh Size stand at 500 000 meters, 0 meters, and 50 meters respectively.

Resistivity data: The distribution of resistivity variation obtained from the study area, as processed using the Res2DInv exe software, along the three (3) profiles are presented in figures 6, 7 and 8, for profiles one, two and three respectively. A total number of 908 datum points were measured in apparent resistivity with electrode spacing of 1.00 m using dipole-dipole array.

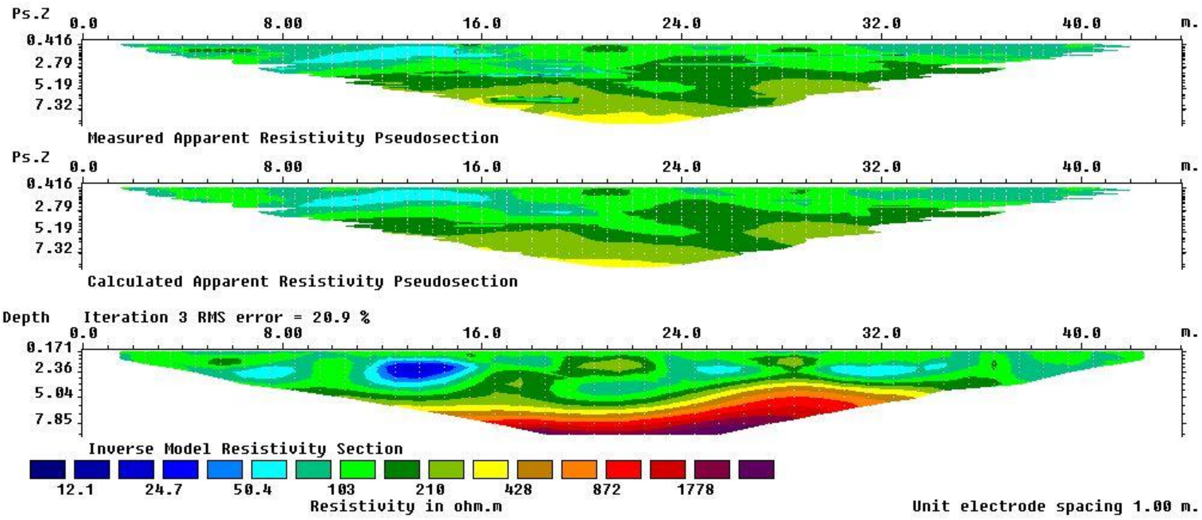

Figure 6: Resistivity distribution along profile one.

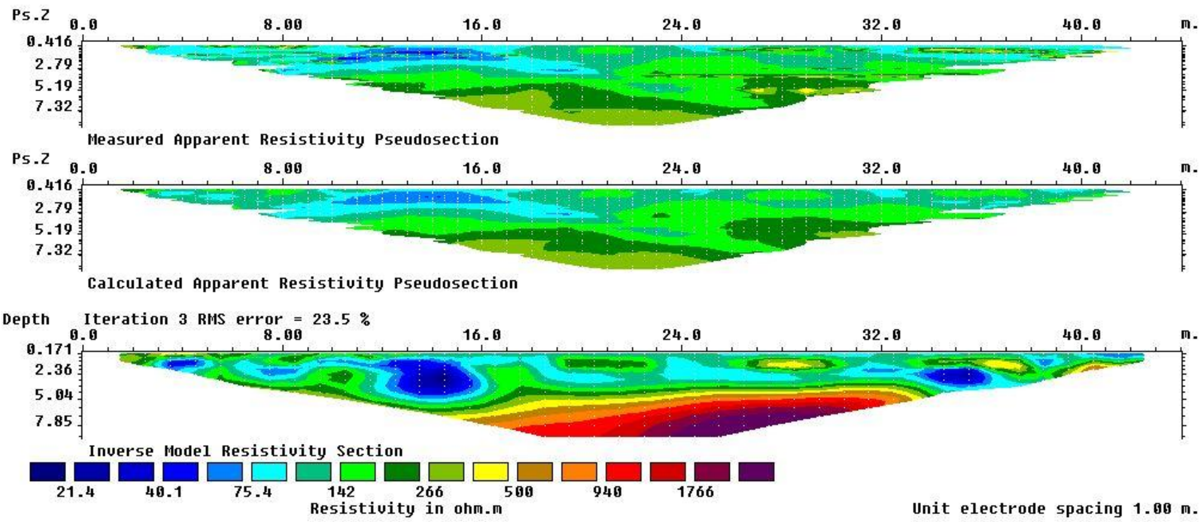

Figure 7: Resistivity distribution along profile two.

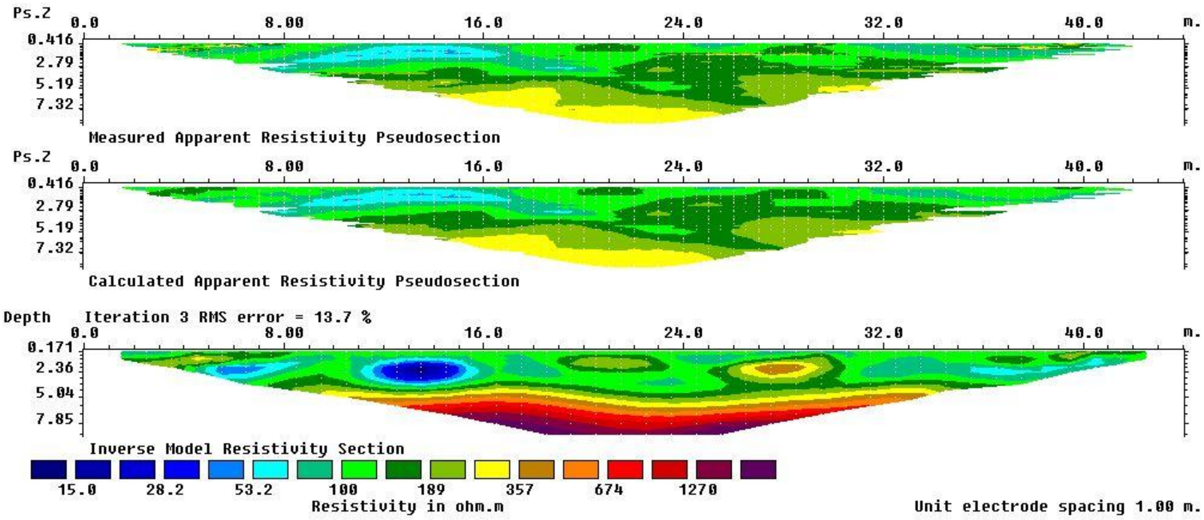

Figure 8: Resistivity distribution along profile three.

Total number of data levels is 35 while total number of electrodes is 45. Minimum and maximum electrode locations are 0.00 and 44.00 m. In each of the three profiles, 3 inverted resistivity images – upper, middle and lower – represent the measured apparent resistivity pseudo-section, the calculated apparent resistivity pseudo-section and the inverted model resistivity section respectively. The upper pseudo-section is a plot of the observed measured apparent resistivity data against depth (vertical distance from the surface of the earth). The middle pseudo-section is a plot of the calculated apparent resistivity data against depth, while the lower section, the interpretation section, is a plot of the inverse model resistivity against depth.

The inversion process was carried out using the Least-squares inversion method and the inverse model resistivity sections reveal a thin layer of about 3 m and low resistivity variation ranging between 2 – 16 Ωm. This layer is underlain by a relatively high resistivity layer, ranging between 110 – 260 Ωm. In profile two, the thin layer of low resistivity occurred at about 4 m depth. The layer has a low resistivity variation from about 4.5 – 25 Ωm, and underlain by a layer of higher resistivity variation of about 120 – 300 Ωm. From profile three, the thin layer of about 5 m depth, occurred at resistivity variation ranging from about 8 – 19 Ωm. The layer is underlain by a high resistivity layer of about 100 – 280 Ωm resistivity variation.

Table 2a: Physicochemical characteristics of the groundwater samples

Sample	Alkalinity (mg/L)	Electrical Conductivity (µmho/cm)	pH	TDS (mg/L)	DO (mg/L)
GW1	261.0	889.6	7.1	1850.9	10.5
GW2	318.0	711.2	7.2	1480.8	8.4
GW3	250.0	727.6	7.9	1514.4	8.6
GW4	167.1	847.6	7.8	2202.8	12.5
GW5	231.3	909.2	7.2	2362.7	13.4
GW6	324.0	52.8	7.6	2149.2	12.2
GW7	311.1	105.5	7.5	131.9	11.0
GW8	301.0	84.4	7.8	263.8	12.8
GW9	287.2	86.3	7.7	211.0	17.7
GW10	322.4	100.7	7.8	215.8	18.1
HW1	560.1	107.9	7.9	251.7	12.2
HW2	680.0	195.2	7.8	269.9	13.1
HW3	543.0	390.4	7.2	487.9	23.6
HW4	820.0	312.4	7.2	976.0	13.1
HW5	598.0	319.4	7.6	780.9	9.3

Table 2b: Concentration of trace elements.

Sample	Zn (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Cr (mg/L)	Mn (mg/L)	Cd (mg/L)
GW1	0.0165	0.016	0.013	0.0005	0.0003	0.056	0.003
GW2	0.0231	0.015	0.011	0.026	1.631	0.023	0.004
GW3	0.2213	0,023	0.0002	0.0008	0.012	0.011	0.002
GW4	0.0466	0.022	0.0003	0.005	1.136	0.013	0.009
GW5	0.4130	0.016	0.024	0.006	1.265	0.016	0.004
GW6	0.0301	0.017	0.0004	0.009	1.328	0.019	0.008
GW7	0.0007	0.028	0.0005	0.0006	1.876	0.027	0.006

GW8	0.0054	0.022	0.032	0.019	1.654	0.001	0.001
GW9	0.0101	0.023	0.031	0.027	0.982	0.0002	0.001
GW10	0.0376	0.004	0.0007	0.023	1.993	0.0001	0.002
HW1	0.0162	0.012	0.007	0.016	0.776	0.026	0.004
HW2	0.2030	0.011	0.011	0.022	1.532	0.051	0.006
HW3	0.0201	0.021	0.010	0.056	1.743	0.007	0.005
HW4	0.1000	0.024	0.046	0.068	0.883	0.009	0.008
HW5	0.1083	0.025	0.026	0.016	1.323	0.006	0.007

Table 3: Concentration of inorganic nutrients.

Sample	Sulfate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Nitrate (mg/L)
GW1	132	432	0.6	87
GW2	128	210	0.8	43
GW3	280	211	1.0	34
GW4	217	431	1.3	68
GW5	263	220	1.8	23
GW6	178	265	1.9	27
GW7	193	313	0.8	57
GW8	320	345	1.0	88
GW9	318	376	1.7	32
GW10	243	321	0.8	36
HW1	233	217	0.9	41
HW2	256	201	0.4	76
HW3	321	322	0.4	71
HW4	238	331	0.3	33
HW5	220	226	1.5	21

Geochemical data: Table 2a, 2b and 3 show the physicochemical characteristics, concentration of trace elements, and concentration of inorganic nutrients obtained over the cause of atomicabsorption spectrophotometric (AAS) analysis on some fifteen (15) groundwater samples from the study area. The sample contains ten (10) bore-wells – GW1, GW2, …GW10, and five (5) hand-dug wells – HW1, HW2, …HW5. Physicochemical analysis of the sample show variation in alkalinity ranging from 167.1 mg/L to 820.0 mg/L. Electrical Conductivity (EC) ranges between 52.8 μmho/cm and 909.2 μmho/cm while pH value of the sample ranges between 7.1 and 7.9. The variation in the Total Dissolved Solid (TDS) ranges between 131.9 mg/L and 2362.7 mg/L. Dissolved Oxygen (DO) of the sample shows variation from 8.4 mg/L to 23.6 mg/L.

Concentration of trace elements –Zn, Cu, Fe, Pb, Cr, Mn and Cd – is give in table 2a. The variation in Zn concentration ranges from 0.0007 mg/L to 0.4130 mg/L while that of Cu ranges between 0.004 mg/L and 0.028 mg/L. Iron and lead show variation in concentration, ranging from 0.0002 mg/L to 0.046 mg/L, and 0.0005 mg/L to 0.068 mg/L respectively. The concentration of Chromium from the sample ranges between 0.0003 mg/L and 1.993 mg/L while manganese concentration ranges between 0.0001 mg/L and 0.056 mg/L. Cadmium concentration in the sample shows variation from 0.0001 mg/L to 0.009 mg/L.

Table 3 shows the concentration of some inorganic nutrients, namely; Sulfate, Chloride, Fluoride and Nitrate, which were geochemically analyzed from the groundwater samples.Sulfate concentration ranges from 128 mg/L to 321 mg/L while Chloride concentration ranges between 201 mg/L and 432 mg/L. Fluoride and Nitrate show variation in concentration ranging from 0.3 mg/L to 1.9 mg/L, and 21 mg/L to 88mg/L respectively.

IV. Discussion

Cohesive geophysical medium, namely: magnetic, resistivity and a geochemical method (AAS) were exploited to weigh the natural hit, in terms of groundwater contamination,due tosolid waste dumpsite (landfill leachate)in Nassarawo-Demsa, Adamawa State, northeast Nigeria. Magnetic method was adopted to investigate major fault zones around the study area to ease the application of resistivity method in order to identify layers of acidic leachate within underground water. The geochemical method was employed to analyse the physicochemical property, concentration of trace elements and that of inorganic nutrients to possibly weigh the natural hit of landfill leachate on groundwater contamination, around the study area. Figure 5 shows the reduced to pole (RTP) aeromagnetic map of the study area. The quantitative interpretation of the RTP map shows that, the zones of high gradient and with closely spaced contour lines are, likely, indicators of major fault zones. The trends of this fault zones include three sets, oriented in eastern, southeast and south direction, and that is the region around, where electrical resistivity imaging was carried out.Figures 6, 7 and 8 present the 2D inverted resistivity distribution along the three profiles, one, two, and three. In all, these three profiles exhibit tight trough in apparent resistivity, which after the inversion process, the resistivity drops at the water table to an extremely low resistivity layer of about 3 – 7 m depth. These layers of low resistivity from all the three profiles suggest, in each profile that the layer contains groundwater possibly contaminated by acidic leachate, a result of landfills around the study area.

From the AAS analysis of the groundwater samples, Table 2a gives the results of physicochemical analysis of these samples. Electrical conductivity (EC) of the samples ranges between 52.8 μmho/cm and 909 μmho/cm. About 53 percent of these samples exceeded the domestic water standards of about 300 μmho/cm prescribed by the World Health Organization (WHO). This can indicate possible groundwater contamination which is capable of imposing natural hit, health consequence inclusive, on the study area. High electrical conductivity values (in groundwater content) indicate high concentrations of ionic constituents in the groundwater bodies of the study area, and can further suggest pollution by domestic wastes [5-Thillai]. Alkalinity from the samples show variation ranging from 167.1 mg/L to about 820.0 mg/L. this suggests contamination as the alkalinity value of the analyzed samples exceeds the WHO permissible limit of 120 mg/L. The pH value of this study's samples ranges between 7.1 and 7.9, which suggests that all the samples are alkaline. This is so because according to the Nigeria Standards for Drinking Water (NSDW), the limit of pH value for drinking water ranges between 6.5 and 8.5. Total dissolved solids (TDS) of the samples ranges between 131.9 mg/L and 2362.7 mg/L which suggest contamination of the groundwater bodies in and around the study area, because water containing more than 500 mg/L of TDS is not all that safe for drinking purpose. That is according the World Health Organization. Dissolved oxygen (DO), the index of groundwater sanitary, is recommended by the World Health Organization to ranges between 4 to 6 ppm for domestic purposes. From the present study, the total dissolved oxygen ranges between 8.4 mg/L and 23.6 mg/L which shows that the samples indicate slight increase of dissolved oxygen above WHO's recommendation.

Table 2b shows the results of concentration of some trace elements from the groundwater samples. The results, however, revealed that from all the samples, Cu, Fe, Zn, Mn, Pb and Cd fall within the permissible limits by the World Health Organization. Copper has permissible limit of 1 mg/L, Iron is 0.3 mg/L, Zinc is 5 mg/L, Manganese is 0.1 mg/L, Lead is 0.05 mg/L and Cadmium is 0.001 mg/L. The analysis of these trace elements suggests absence of chemical hazard from the groundwater bodies, although, Chromium content suggested otherwise. The concentration of Chromium ranges between 0.0003 mg/L and 1.993 mg/L. This exceeded the WHO's permissible limit of 0.05 mg/L, and therefore suggested some level of contamination.

The results of the concentration of some inorganic nutrients from the groundwater samples is given in Table 3. All of the samples exceeded the World Health Organization permissible limit of 200 mg/L of Chloride. This is as the chloride concentration in the present research ranges between 201 mg/L and 432 mg/L. Sulfate concentration form the present research revealed range, from 128 mg/L to 321 mg/L. On the average, the samples' results suggest contamination as some of the samples exceeded the World Health Organization permissible limit of 200 mg/L. Fluoride concentration of the groundwater samples is mostly less than 1 mg/L, except for a number of samples. This can be interpreted, a slight contamination of this water bodies for domestic purposes. Nitrate concentration from the samples in the present research ranges between 21 mg/L and 88 mg/L. Few of these samples have therefore exceeded the WHO's permissible limit of about 45 mg/L and suggested slight contamination of the groundwater bodies of the Study Area.

V. Conclusion

The magnetic method, the resistivity method, and the Atomic absorption spectrophotometric results from the present research jointly conclude that there are two aquifers in and around Nassarawo-Demsa area of Adamawa State, Northeast Nigeria. The first aquifer is at shallow depth of about (3.5 m to 65 m), and depends on the topographic surface. The lithology of this layer consists of sandstone, and generally contaminated by landfill leachates, due to indiscriminate disposal of solid (domestic) wastes. The second aquifer is mostly occurring at layer of thickness, ranging from (16 m to 148 m). The lithology of this aquifer consists of sandy clay, and generally safe for domestic consumption. The authors of this research concluded that the quality of the drinking water in the study area is unfit for human consumption, as majority of groundwater sources in the area fall within the first aquifer (of shallow depth). People living on the study area are exposed to significant natural hit of groundwater contamination which is largely the result of open domestic wastes disposal. It is therefore recommended that suitable groundwater quality management is highly essential to avoid further contamination, and it attendant health consequences on Nassarawo-Demsa.

From the data generated in the present research, and the foregoing discussion, the authors of this study concluded that most of the groundwater sources in Nassarawo-Demsa area are not suitable for human consumption unless properly drilled to at least 100 m from the surface. Groundwater from Nassarawo-Demsa area require treatment before human consumption.

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