ISSN No:-2456-2165

Hydro- Geochemical and Geoelectrical Investigation of MUBI and Its Environs in Adamawa State, Northeastern Nigeria

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Abstract:- Thirty (32) sources of water samples collected from various hand- dug wells, boreholes, streams and rivers in the study area were hydro geochemically analyzed and the results revealed that most of the samples' physical parameters (pH, EC, TH, TDS) are within permissible range of World Health Organization (WHO, 2017) Standard for drinking water and domestic purposes except for few cases (samples at Lokuwa, Wuro- patuji, Police Barracks and Kofar Sarki) that have values exceeding the permissible limit. The mean temperature of all the water samples is 29.12^{0}C and all the samples showed no presence of E-coli and total coli form bacteria. The mean results of the hydro geochemical analysis of the cat ions and anions revealed that K^{2+}, Ca^{2+}, Mg^{2+} have values within the permissible limit by (WHO, 2017)for drinking water and domestic uses; However, Na^+ concentration in samples from the study area was found to exceed the maximum permissible limit of 200mg/L except for samples from Barama and Digil that have values within the maximum permissible limit by (WHO, 2017); Cl^- , $SO_4{}^{2-}$,$PO_4{}^{3-}$, $CO_3{}^{2-}$,$N0_3{}^-$) in samples from the study areas have values within the permissible limit according to (WHO, 2017) with exception of $HCo_3{}^-$ that has a value exceeding the permissible limit apart from sbample in hand dug well at Digil. For boreholes and hand dug wells with high sodium and bicarbonate concentration, the water can be treated before using. Reverse osmosis or distillation can also be used to remove high concentration of sodium before using the water for drinking. Bicarbonate concentration can be reduced by treating the water with addition of lime water and alum. Schlumberger array of seventeen (17) vertical electrical soundings (VES) of maximum electrode separation of AB = 320m (i.e. AB/2 = 160m) were carried out in the study area with a view of establishing differences in subsurface geoelectric layers and characteristics of aquifereous units. Curve matching with the Orellana-Mooney master curves and 2-D forward modeling with IP12 WIN software was used to interpret subsurface layering. The curves in the area revealed 3-4 layers and they are mostly KAH type curves. The first layer is top soil (loosed sand) with mean thickness of 0.86 m and average resistivity value of 136.58 Ωm. The second layer is flow top basalt with mean thickness of 0.82 m and average resistivity value of 337.75 Ωm. The third is weathered/fractured basement and has a mean thickness of 3.15 m and average resistivity value of 1,773.74 Ωm. The fourth layer is layer of fresh bedrock with a mean thickness of 7.58 m and average resistivity value of 11,615.56 Ωm. The aquifer thickness ranges from 1.3 – 22.1m and the depth to water table also ranges from 1.34 to 33.5 m. Hydraulic conductivity and transmissivity of aquifers in the study areas were computed and found to have range of values between 2.0-66.4 m/day for K and 6.1 – 377.8 m^2/day for T respectively.

***Keywords**:- Hydrogeochemical, Geoelectric Layer, Aquifer, Transmissivity, Hydraulic Conductivity.*

I. INTRODUCTION

The study area is located within Mubi North and Mubi South Local Government Areas which falls within the Basement Complex of North eastern part of Nigeria between Latitudes 10°12^1 N and 10°21^1 N and longitudes 13°10^1 E and 13°21^1 E and an aerial expanse of about 78.75km^2 (Fig 1).

ISSN No:-2456-2165

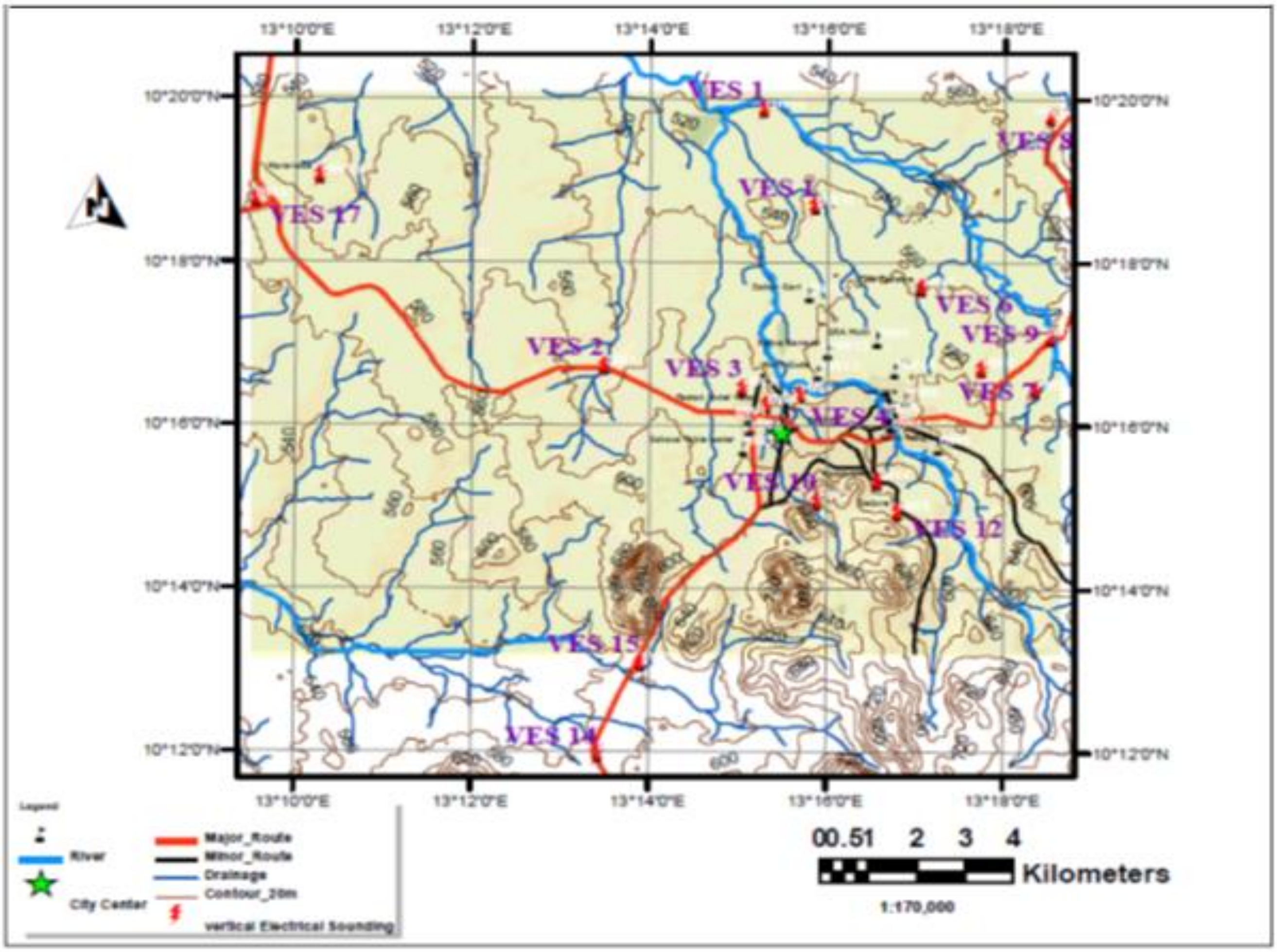

Fig 1:- Topographic Map of the Study Area showing VES points (FSN, 1970 Uba Sheet 156 Map Superimposed): FSN = Federal Surveys, Nigeria

Water is one of the most important natural resources and because of the ever-increasing population, the requirements for its supply for various purposes have increased in demand (Yassah, 2014). The various purposes to be served by water are determined by water quality standards set by the World Health Organization (WHO) and other agencies concerned with the safe use of water for its various uses.

Water is an essential commodity but often taken for granted because of its natural abundance all over the earth. It has numerous uses depending on its quality. Water is rendered useless or harmful when its unique properties are altered by foreign substances. Common sources of contaminants come from domestic, industrial, agricultural, chemical and engineering activities which consume and or generate them, namely insecticides, fertilizers and industrial waste (Bawuro, Umar and Onyirioha, 2007)

Water is used for agricultural, industrial, household, recreational and environmental purposes all over the world. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization (Ramakrishnaiah, 2009). The quality of water is vital for mankind since it is directly linked with human welfare (Umoh, 2012). In the Study area for example, most of the population depend on ground water as the only source of drinking water supply. Potable water is the water that is free from disease producing micro-organisms and chemical substances that are hazardous to health (Lamikarand and Shittu, 2008). Disease causing micro-organisms such as coli form bacteria can be introduced into water supply system during well construction, pit-latrines and household wastes. Faecal coli forms are indicators of anthropogenic contamination affecting the quality of water to be used for drinking purposes (Olasehinde and Virloka, 1998). Bacteriologic ally polluted water is potentially dangerous to health because of possible out breaks of typhoid, dysentery or cholera epidemics (Okuofu et al., 1990).

Because of high grazing in Mubi and its envrons, the application of manure and chemical fertilizers on farm lands, nitrates and phosphates may infiltrate to ground water. A high concentration of nitrate in drinking water is also believed to be health hazard because it may cause methaemoglobinemia in human infants; a potentially fatal syndrome by which oxygen transport in the blood stream is impaired (Appelo and Postma, 1993). Sulphate, if present in sufficient quantities will impart a bitter taste to water and may also be cathartic (Todd, 1980). Fluoride at high Concentration levels can cause Skeletal Fluorosis (WHO, 1984).Phosphate occurrence in water may be linked with period of low biological decomposition (Ishaku and Ezeigbo, 2000). Water receiving raw sewage or treated industrial waste may contain significant concentration of phosphate.

The largest available source of freshwater is the underground water (Ariyo et al., 2005) which accounts for about 98% of freshwater globally (Bouwer, 2002). Availability of groundwater in basement complex area depends on the thickness of aquiferous overburden and presence of water bearing fracture (Eduvie et al., 1999). However, the quality of groundwater supply required depends on its purpose of exploitation (Olayinka and Olorunfemi, 1992 and Ige, 2013). Globally, human system requires 3 litres of water to maintain body fluid per day (Feiters, 2001). Olugboye (2008) linked population increase, urbanization/commercialization and high living standard as major contributors to high water demand. Domestic water supply in Mubi and its environs comes largely from ground water, much of this is taken from hand dug wells and boreholes hence, the need to optimize the quantity and quality of water available for consumption in growing towns such as Mubi, Adamawa state of Nigeria is desirable.

In the present study, status of water quality is given in terms of important selected indicators namely nitrate, chloride, alkalinity, pH-value, TDS, TH, turbidity, sulphate, phosphate, electrical conductivity and the associated cat ions of K+, Na+, Ca+, Mg2+. Thus, the study also aims at investigating the variation of depth; determine the thicknesses and continuity of the aquifer(s) in Mubi and its environs and to recommend possibly best sites for drilling bore-holes for potable, and quantity of available water.

II. GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

The area, Mubi and its environs is located within the Northeast Basement Complex of Nigeria. The rocks are of pre pan Africa orogeny (gneisses and migmatites) or older granites and occupy mainly the lowlands as small outcrops. They are banded, foliated with felsic and ferromagnesian minerals forming the light and dark bands respectively. This mineral differentiation imparts the foliation to the rocks. The older granites which are younger are intrusive to the gneissic and magmatic rocks (Adebayo, 2010). The oldest rocks of the area, the gneisses which are believed to be of birrimian age (Oyawoye, 1970) are overlain by recent alluvium resulting from the weathering and erosion of hills and decomposed rock material. They cover a large part of the crystalline basement rocks. The geologic structures predominant in the area are dykes, quartz veins, folds, shear zones etc. The dominant tectonic directions are NW-SE marking pre pan African episode (750+ 150 m.y) (Bassey, 2004). Basic extrusive rocks belonging to the Cameroun Volcanic line are found in the area but are minor in spatial occurrence. They are tertiary-recent in geologic age (Adebayo, 2010).

Separating the G. R.A and the northern area of Mubi from the southern area is the Yedseram River which flows north from the Mandara range. It is in continuous channel as far as Bama where it breaches the Bama ridge. Thereafter, its flow is diffused into the Bama Deltaic Complex. The lower reaches of the river is a region of extensive flooding, high evaporation and net water loss. Smaller tributaries drain the western slopes. The river and the tributaries depend on the seasonal rainfall in the moutains and its upper reaches (Buchanan and Pugh, 1973).

Artesian and other water sources exist in the study area, much of which is underlain by basement complex with an overlying thin layer of weathered rock, colluvial material and iron pan. This mantle has an average thickness of about 16m but extends to a depth of 61m in some areas. Joints are better developed in the granite and quartzite than the gneisses, migmatites and schist. Ground water occurs either in the weathered mantle or in the joints and fractures in the unweathered rocks. The basement complex rocks generally form a poorer reservoir of water than the overlying thick mantle. The average depth of the water table is about 37m, and wells if carefully sited, could provide sufficient water for small village. This water is replenished after rain (Buchanan and Pugh, 1973).

III. METHOD

Thirty (32) water samples collected from different hand-dug wells, bore-holes, streams and rivers within Mubi and its environs, their locations and positions taken with GPS (Fig1.1). All the samples collected in plastic containers previously washed with distilled water and taken to the laboratory within 24 hours. Parameters such as total dissolved solids (TDS), electrical conductivity (EC), temperature and pH were measured at the field immediately using TDS/ conductivity meter (HATCH KIT), thermometer and colour comparator for pH. The chemical analyses were carried out using Spectrophotometer Kit, titration and flame-photometer. All the water samples were bacteriologic ally analyzed according to specification of the World Health Organization (WHO) standards. Before the analysis, all the materials were sterilized for 15 minutes and samples analyzed within 24 hours of collection. The essence of bacteriological analysis was to detect the presence of coli form bacteria, however no attempt was made to identify bacterial type through microscopic studies.

17 Vertical Electrical Sounding (VES) were undertaken using a terrameter SAS 3000B with a 320m spread Schulumberger electrode array. The data were subjected to computer iteration using Win Resist software in order to determine geoelectric layers (the variation of depth to aquifer, the thickness and continuity of the aquifers) and to recommend appropriate points for drilling boreholes.

IV. RESULTS AND DISCUSSION

Table 1and 2 shows the results of the water samples collected from the study area. The mean temperature of all the water samples is 29.120C and all the samples showed no presence of E- coli and total coli form bacteria. The results revealed parameters such as pH ,Ec , TDS, TH, Alkalinity, Sodium, potassium, Calcium, Magnesium, Chloride, Sulphate, Phosphate, Carbonate, bicarbonate and nitrate are almost present in all of the water samples within the permissible range of world Health Organization(WHO, 2017) standard for drinking water and domestic use except in few cases where the values exceeded the permissible limits.

The water was tested for faecal contamination by isolating Escherichia coli form from the water samples and the results showed that sanitary conditions of the hand dug wells and boreholes in the study area are clean. Other reasons attributing to lack of contamination by E-coli and other coli forms are the considerable depths of the wells and boreholes in the study area with an average depth of about 55m (Ijostem et al, 1977), suggested that only shallow wells or bore holes are susceptible to contamination by surface and soil micro-organisms and almost all of the hand dug wells and boreholes are far away from pit latrines, obeying minimum distance required by sanitary conditions from latrines.

Computed results of the 17 VES field measurements are presented in table 3 and 4 respectively. The values of all the 17 VES points were plotted on x-axis (abscissa) while the apparent resistivities (ρa) were plotted on the Y-axis (ordinate of a log-log graph sheet). The curves were smoothening and the numbers of layers were noted and quantitatively interpreted using a computer software program IP12WIN 2003 MODEL.

The interpreted result in table 3and 4 showed that the study area has a minimum of three layers (VES9) and maximum of five layers (all the remaining VES points obtained in the study area). VES9 with only three (3) layers has RMS or fitting error = 1.32% where as in the category of those VES with five (5) layers have RMS or fitting error ranging from 0.04 to 0.99% .The average value of each thickness and resistivity of each layer is calculated and the values are given as follows: h1 = 0.86m, h2 = 0.82m, h3 = 3.15m, h4 = 7.58m, and h5=30.11m. The average resistivity values of the layers are ρ1 =136.23Ωm, ρ2 =357.75Ωm, ρ3 = 1,773.74Ωm, ρ4 = 11,615.56Ωm, ρ5 = 10,973.31Ωm and ρ6 = 600.17Ωm. Other geo electric parameters such as longitudinal conductance, S and Transverse resistance, T were computed from the values of thickness and resistivities of each layer. Longitudinal conductance was calculated using the following formula: Longitudinal Conductance, Si = Σ hi/ρi and Transverse resistance, Ti was calculated using formula: Transverse resistivity, Ti = Σ hi xρi ; Where h represents the thickness, ρ represents resistivity and i, the subscript indicating the position of the layer. The results of these two parameters are presented in table 3. The average value of the longitudinal conductance of each layer is given as: S1 = 6.O3 X10-1 siemen, S2 = 3.1X 10-1siemen, S3 = 9.4 X10-1 siemen, S4 =4.8 X101 siemen, S5= 1.02X102 siemen and S6=0 siemen and the transverse resistivity value to be T1= 2.28X103Ωm, T2= 4.48X102Ωm, T3=1.6X102Ωm, T4=3.6X 102Ωm, T5=1.71X103Ωm and T6= 0.

The quantitative interpretation of the vertical electrical sounding has helped in delineating the aquiferous zones and thicknesses of the rock layers in Mubi and its environs. The VES interpreted results are summarized in table 3 and 4. From the analysis of interpreted results obtained from the study area (Mubi and its environs), four distinct layers may be recognized as follows: the first layer is the surface unit of the top soil sand and it is identified as the loose sand with mean thickness o.86m and an average resistivity value of 136.23Ωm. The second layer is interpreted as a layer of flow top basalt with a mean thickness of 0.82m and an average resistivity value of 357.75 Ωm. This layer is found throughout the study area. The third layer which is interpreted to be a layer of weathered/fractured basement (consisting of migmatite-gness) has an average resistivity value of 1,773.74Ωm with a thickness of 3.15m, this layer is also found to be present throughout the study area and these results are confirmed by the results of geo electric and geologic correlation sections and borehole litho logic profiles. The fourth layer is interpreted as a layer of fresh bedrock and it is found to be present and continuous down the subsurface in the study area. The interpreted results showed that this layer has a mean thickness of 7.58m and with an average resistivity value of 11,615.58Ωm. The above results agreed with data of existing boreholes in the study area which suggested that the depth of water bearing zone in the study area range from12m to 60m.

LLocatiLLocation	Sample NO	Tempre-Ture (◦c)	Ph	Alkanity (PPm)	Electricai-Conductivity (µs/Cm)	Turbidity (NTU)	TH (ppm)	E-COLI (CFU)
Shagari-	HW1	29.80	8.70	98.00	249.00	0.00	136.00	**0.00**
Lowcost Lamurde	HW2	29.60	7.40	62.00	872.00	0.00	278.00	**0.00**
Sabon pegi	HW3	30.80	7.10	54.00	417.00	0.00	84.00	**0.00**
Lokuwa	HW4	28.10	7.30	248.00	3788.00	12.00	200.00	**0.00**
Sebore	HW5	28.30	7.40	80.00	195.00	0.00	78.00	**0.00**
Mayanka	HW6	29.10	8.00	360.00	1447.00	0.00	200.00	**0.00**
Fed Poly-Mubi	HW7	28.40	7.10	32.00	359.00	0.00	24.00	**0.00**
Barama	HW8	28.50	6.10	104.00	129.00	0.00	100.00	**0.00**
Mugulvu	HW9	29.60	7.50	144.00	314.00	0.00	132.00	**0.00**
Digil	HW10	30.70	6.60	20.00	359.00	21.00	80.00	**0.00**
Wurogude	HW11	29.50	7.40	144.00	914.00	0.00	80.00	**0.00**
Wuropatuji	HW12	30.50	7.10	NM	1952.00	NM	NM	**NM**
Police –Barrack	HW13	30.00	7.30	104.00	1671.00	0.00	90.00	**0.00**
Shuware	HW14	32.00	6.10	60.00	1083.00	0.00	180.00	**0.00**
Mararraba	HW15	30.60	8.10	182.00	1420.00	0.00	268.00	**0.00**
Vimtim	HW16	29.10	8.60	124.00	837.00	8.00	128.00	**0.00**
Sabonpegi	BW1	29.10	7.20	54.00	249.00	0.00	84.00	**0.00**
Starling- Motel	BW2	28.50	6.00	120.00	664.00	0.00	78.00	**0.00**
Sahaba T/Water	BW3	32.60	7.10	64.00	860.00	0.00	80.00	**0.00**
Kwarhi B/School	BW4	30.60	7.50	152.00	754.00	0.00	192.00	**0.00**
Wuropatuji	BW5	29.30	7.20	64.00	3724.00	0.00	180.00	**0.00**
Kofar Sarki	BW6	29.60	6.30	158.00	3916.00	0.00	260.00	**0.00**
Festac Hotei	BW7	30.90	7.20	120.00	1234.00	0.00	180.00	**0.00**
GRA Mubi	BW9	28.00	6.00	60.00	917.00	0.00	70.00	**0.00**
Digil	BW10	30.50	6.90	48.00	508.00	94.00	28.00	**0.00**
Sabon Gari	BW11	29.10	7.40	48.00	718.00	0.00	48.00	**0.00**
Arahan Kunu	SW1	29.00	6.80	44.00	156.10	10.00	58.00	**0.00**
Kogin Gada	SW2	34.70	7.90	40.00	171.00	135.00	24.00	**0.00**

Bladega	SW3	31.90	7.80	58.00	165.00	23.00	72.00	**0.00**
Narawo	SW4	29.70	7.60	192.00	388.00	6.00	132.00	**0.00**
River Yezarem	SW4	32.80	8.10	38.00	414.00	142.00	140.00	**0.00**
Mean		29.12	7.30	91.00	1017.50	11.00	113.50	**0.00**
WHO,2011 (MPC)		25.00	6.5-8.5		1250.00	5.00	500.00	--

Table 1:- Results of Geochemical Data Of Thirty Two (32)Water Samples From The Study Area (Physical Parameters)

KEY: HW = Hand dug well; BW = Borehole water; SW = Stream water; NM = Not Measured; ND = Not Determined; MPC = Maximum Permissible Concentration.

Location	Sample No	Na^{+}	K^{2+}	Ca^{2+}	Mg^{2+}	Cl^{-}	SO_4^{2-}	PO_4^{3-}	CO_3^{2-}	HCO_3^{-}	NO_3^{-}
Shagari-Lowcost	HW1	215.85	3.00	16.10	2.58	40.00	14.00	1.50	ND	732.00	0.232
Lamurde	HW2	232.50	14.00	2.72	2.55	108.00	38.00	0.20	-	610.00	0.119
Sabonpegi	HW3	210.00	10.00	0.90	2.21	40.00	17.00	0.20	-	427.00	0.203
Lokuwa	HW4	210.00	10.00	1.76	2.50	112.00	49.00	0.00	300.00	2440.00	0.189
Sebore	HW5	219.00	12.00	ND	0.54	18.00	12.00	0.00	-	610.00	0.131
Mayanka	HW6	214.00	4.00	3.07	2.60	40.00	5.00	1.70	180.00	3294.00	0.203
Fed Poly-Mubi	HW7	204.75	17.50	0.18	1.10	20.00	11.00	0.00	-	122.00	0.275
Barama	HW8	193.95	21.50	6.53	2.02	20.00	4.00	0.60	-	793.00	0.099
Mugulvu	HW9	204.00	7.00	1.06	1.29	12.00	9.00	0.10	180.00	793.00	0.189
Digil	HW10	180.30	17.50	0.13	1.50	20.00	9.00	0.30	-	61.00	0.296
Wurogude	HW11	240.00	6.00	13.02	2.72	48.00	25.00	0.60	180.00	1830.00	0.142
Wuropatuji	HW12	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Police-Barack	HW13	244.50	23.00	3.38	2.59	42.00	25.00	1.20	-	732.00	0.131
Shuware	HW14	212.40	8.50	3.07	2.60	40.00	5.00	1.70	180.00	427.00	0.203
Mararaba	HW15	240.00	29.00	1.86	ND	40.00	48.00	0.00	240.00	1403.00	0.131
Vimtim	HW16	210.00	12.00	0.51	2.25	38.00	13.00	0.00	120.00	1098.00	0.176
Sabon Pegi	BW1	210.00	32.50	1.25	2.56	24.00	7.00	0.60	360.00	183.00	0.203
Starling-Motel	BW2	216.75	4.50	9.56	1.41	60.00	34.00	0.90	240.00	1647.00	0.131
Sahava T/Water	BW3	204.45	6.00	2.21	2.59	20.00	6.00	1.50	ND	427.00	1.091

Kwarhi	BW4	220.50	11.00	0.03	0.92	28.00	8.00	0.00	300.00	1281.00	0.176
Wuropatuji	BW5	219.60	59.00	22.43	2.99	100.00	49.00	0.50	-	427.00	0.142
Kofar Sarki	BW6	235.95	34.00	26.11	2.84	84.00	60.00	0.90	ND	1220.00	0.119
Festac Hotel	BW7	210.00	9.00	14.22	2.73	80.00	38.00	0.60	180.00	1098.00	0.142
GRA	BW9	213.00	18.00	1.31	2.39	52.00	6.00	1.30	-	305.00	0.131
Digil	BW10	178.65	6.00	0.08	1.46	20.00	6.00	3.70	-	183.00	0.066
Sabon Gari	BW11	213.15	21.00	0.36	1.85	16.00	18.00	1.00	-	366.00	0.142
Arahan Kunu	SW1	218.70	3.00	0.89	2.30	20.00	4.00	1.30	-	244.00	0.309
Bakin Gada	SW2	217.00	38.00	ND	0.02	12.00	2.00	0.8	-	305.00	0.539
Bladega	SW3	232.50	33.00	ND	0.26	16.00	7.00	0.00	-	427.22	0.119
Nassarawo	SW4	220.50	24.00	0.74	1.69	36.00	14.00	0.30	180.00	1891.00	0.142
River Yezeram	SW5	211.80	4.00	0.07	0.82	16.00	6.00	0.00	ND	122.00	0.292
Mean		194.75	17.00	4.96	1.93	20.73	18.30	0.72	88.00	849.93	0.220
WHO,2011 (MPC)		200.00	12.00	75.00	50.00	200.00	250.00	250.00	<120.00	600.00	0.50

Table 2:- Results Of Geochemical Data Of Thirty Two (32) Water Samples From The Study Area (Chemical Parameters In Mg/L)
KEY: HW=Hand-dug well; NM=Not Measured; ND=Not Determined; MPC=Maximum PERMISSIBLE CONCENTRATION.

ISSN No:-2456-2165

Location	VES NO	Thicknesses of Layers (m)						Depth d (m)	Resistivity of LAYERS (Ohm-m)					
		h_1	h_2	h_3	h_4	h_5	h_6		ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6
Digil	1	1.48	1.25	0.04	3.04	6.58		12.40	245.00	962.00	2.87	93.20	16020.00	23.50
Arhan Kunu	2	0.50	0.7o	2.48	12.70	71.5		16.4	99.40	734.00	10.00	1066.00	234.00	10.20
Shagari Lowcost	3	0.50	1.05	0.05	9.36	22.10		33.50	2.17	205.00	16.40	3.27	75.40	1.05
Mayanka	4	1.77	0.90	8.18	32.20	14.70		57.80	31.30	4.45	109.00	20.30	2.99	16.10
Yelwa	5	0.50	0.17	3.00	3.09	39.60		46.40	217.00	8.73	479.00	11.70	44.40	2725.00
Fed. Poly Mubi	6	o.51	0.27	1.03	3.92	10.1		15.80	370.00	73.00	1218.00	123.00	9214.00	286.00
Barama	7	0.50	0.60	0.06	10.80	59.90		11.90	88.40	21.20	4032.00	182.00	4473.00	5829.00
Vimtim	8	0.50	0.10	4.06	2.42	23.70		31.60	410.00	2354.00	2354.00	16387.00	33081.00	336.0
Kogin Gada	9	1.34	2.60	5.58				9.52	31.40	31.40	20148.00	536.00		
Lamode	10	1.19	1.45	0.79	2.91	30.70		37.10	91.70	38.50	1130.00	104673.00	982.00	243.00
Madanya	11	0.50	0.10	8.33	1.64	1.62		12.20	51.90	3.44	75.40	939.00	100369.00	43.70
Sebore	12	0.50	0.83	3.87	1.85	16.90		24.00	31.00	1105.00	61.10	920.00	8279.00	82.79
Nassarawo	13	0.71	1.87	2.04	11.20	101.00		15.80	314.00	52.9	183.00	21104.00	598.00	78.00
Mugulvu	14	0.96	1.32	4.52	10.30	9170		17.10	34.20	282.00	52.90	6301.00	26.40	39.30
Bladega	15	0.51	0.66	3.10	8.52	8.20		21.00	29.3	109.00	282.00	43499.00	12878.00	484.00
Mararraba	16	1.10	0.03	6.46	11.8	6.96		26.4	21.00	5.18	297.00	1606.00	109.00	3.18
Kulp B/School	17	1.48	1.25	0.04	3.03	6.03		12.4	245.00	962.00	2.87	93.20	16o20	2.00
Mean		0.86	0.82	3.15	7.58	30.11		23.58	136.23	357.75	17773.74	11615.56	10973.3	600.17

Table 3: Result of computed geo-electric Parameters from the Study Area
(Source: Field Survey).

ISSN No:-2456-2165

Table 4: Results of Computed Secondary Geo- electric Parameter

Location	VES NO	Longitudinal conductance (µs/cm)						Transverse Resistance (Ohm-m)						Fitting error (%)
		S_1	S_2	S_3	S_4	S_5	S_6	T_1	T_2	T_3	T_4	T_5	T_6	
Digil	1	$6.09x10^{-3}$	$1.30x10^{-3}$	$1.46x10^{-2}$	$3.26x10^{-2}$	$4.1x10^{-4}$		$3.63x10^{2}$	$1.2x10^{3}$	$1.21x10^{1}$	$2.83x10^{2}$	$1.05x10^{5}$		0.42
Arhan Kunu	2	$5.03x10^{-3}$	$9.58x10^{-4}$	0.25	$1.19x10^{-2}$	$3.06x10^{-1}$		49.70	516.00	24.80	$1.35x10^{4}$	$1.67x10^{4}$		0.81
Shagari Lowcost	3	0.23	$5.12x10^{-3}$	$3.12x10^{-3}$	2.86	0.29		1.09	215.25	0.84	30.61	$1.67x10^{3}$		0.10
Mayanka	4	0.06	0.20	0.08	1.59	4.92		55.40	4.10	891.62	653.66	43.95		0.24
Yelwa	5	$2.3x10^{-3}$	$1.96x10^{-2}$	$6.26x10^{-3}$	0.26	0.89		108.50	1.49	1437.00	36.15	1758.24		0.19
Fed. Poly Mubi	6	$1.37x10^{-3}$	$3.68x10^{-3}$	$8.5x10^{-4}$	$3.19x10^{-2}$	$1.09x10^{-3}$		187.59	19.64	1254.54	482.16	93061.40		0.06
Barama	7	$5.66x10^{-3}$	$2.82x10^{-2}$	$1.48x10^{-5}$	$5.93x10^{-2}$	$1.34x10^{-2}$		44.2	12.66	2403o.72	327.60	267932.70		0.31
Vimtim	8	$1.22x10^{-4}$	$2.5x10^{-6}$	$2.48x10^{-4}$	$1.48x10^{-5}$	$7.2x10^{-3}$		205.00	$3.7x10^{3}$	9557,24	39656.54	784019.70		0.17
Kogin Gada	9	$4.27x10^{-2}$	$1.54x10^{-5}$	$2.77x10^{-1}$	0.00	0.00		4.21	$4.37x10^{5}$	112425.84	0.00	0.00		1.32
Lamorde	10	$2.29x10^{-2}$	$3.76x10^{-2}$	$7.00x10^{-5}$	$2.80x10^{-5}$	$3.13x10^{-2}$		109.12	55.82	894.96	304598.00	30147.40		0.05
Madanya	11	$9.63x10^{-3}$	$2.94x10^{-2}$	0.11	$1.74x10^{-3}$	$1.6x10^{-5}$		25.95	$3.47x10^{-1}$	628.08	1539.96	1.62597.78		0.99
Sebore	12	$1.61x10^{-2}$	$7.52x10^{-4}$	$6.33x10^{-2}$	$2.01x10^{-3}$	$2.41x10^{-3}$		5.6	919.36	236.46	1.70	139915.10		0.05
Nassarawo	13	$2.29x10^{-3}$	$1.4x10^{-3}$	$1.11x10^{-2}$	$5.31x10^{-4}$	$1.17x10^{-1}$		$2.24x10^{2}$	$2.5x10^{3}$	$3.73x10^{2}$	$2.36x10^{2}$	$6.04x10^{4}$		0.05
Mugulvu	14	$2.80x10^{-2}$	$3.4x10^{-3}$	$8.54x10^{-2}$	$1.63x10^{-3}$	3.47		32.76	512.16	239.11	649.00	2.42x103		0.11
Bladega	15	$1.74x10^{-2}$	$4.82x10^{-4}$	$1.10x10^{-2}$	$1.95x10^{-4}$	$1.89x10^{-3}$		14.91	914.33	874.2	3.72x102	1.06x102		0.04
Mararraba	16	$5.23x10^{-2}$	$5.54x10^{-3}$	$2.18x10^{-2}$	7.35x10-3	$6.39x10^{-2}$		23.10	0.15	$7.85x10^{3}$	0.19	$7.59x10^{2}$		0.08
KulpB/School	17	0.12	$1.3x10^{-3}$	$1.45x10^{-2}$	$3.25x10^{-2}$	$4.1x10^{-4}$		362.60	1.2x103	0.12	$2.82x10^{2}$	$1.05x10^{5}$		
Mean		$6.03x10^{-1}$	$3.1x10^{-1}$	$9.4x10^{-1}$	4.80	10.2		$2.28x10^{3}$	$4.48x10^{2}$	$1.61x10^{2}$	$3.63x10^{2}$	$1.71x10^{3}$		

(Source: field survey)

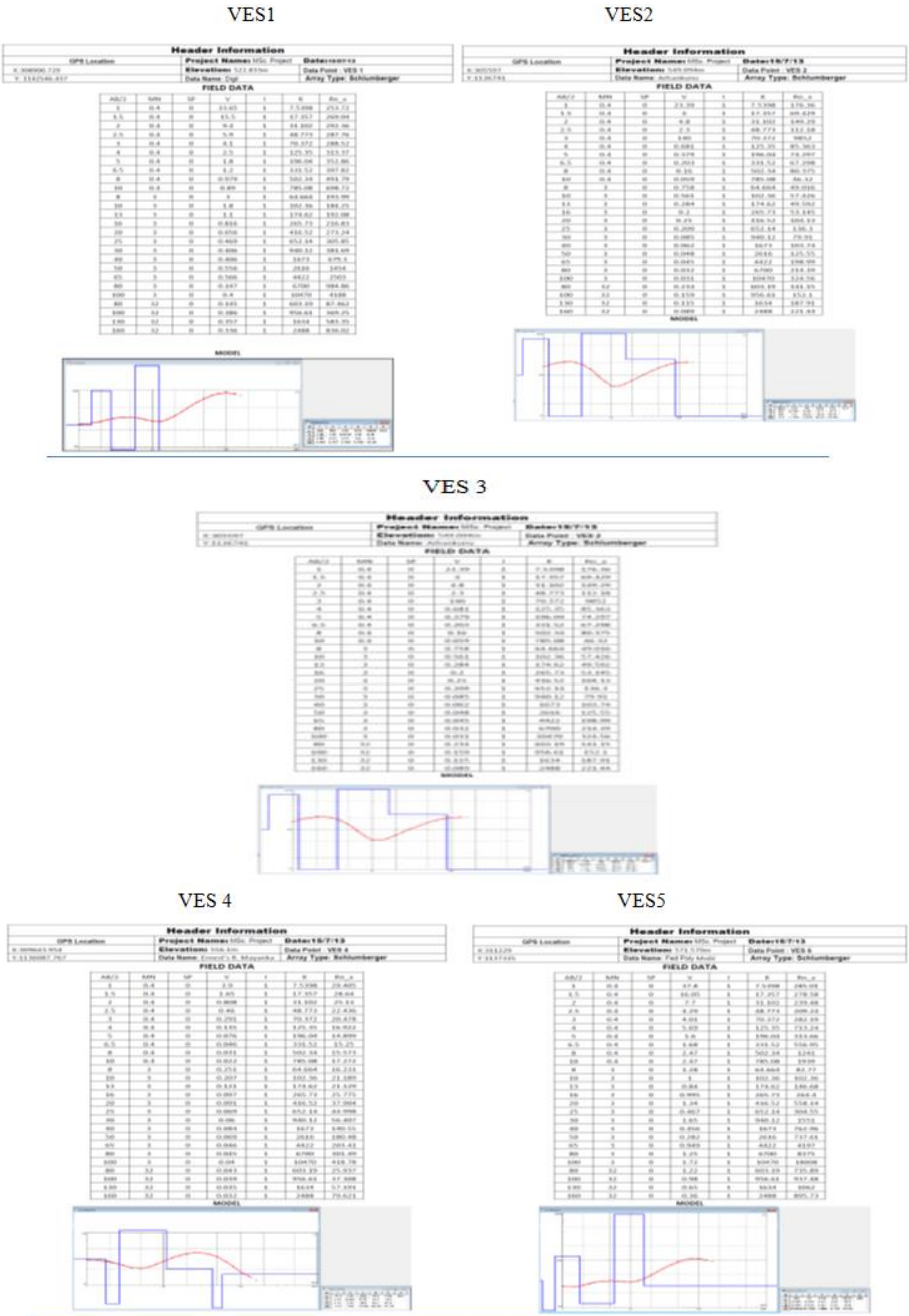

Fig. 2: SOME SELECTED FIELD DATA WITH VES CURVES OBTAINED FROM THE STUDY AREA
Source: Field Survey

ISSN No:-2456-2165

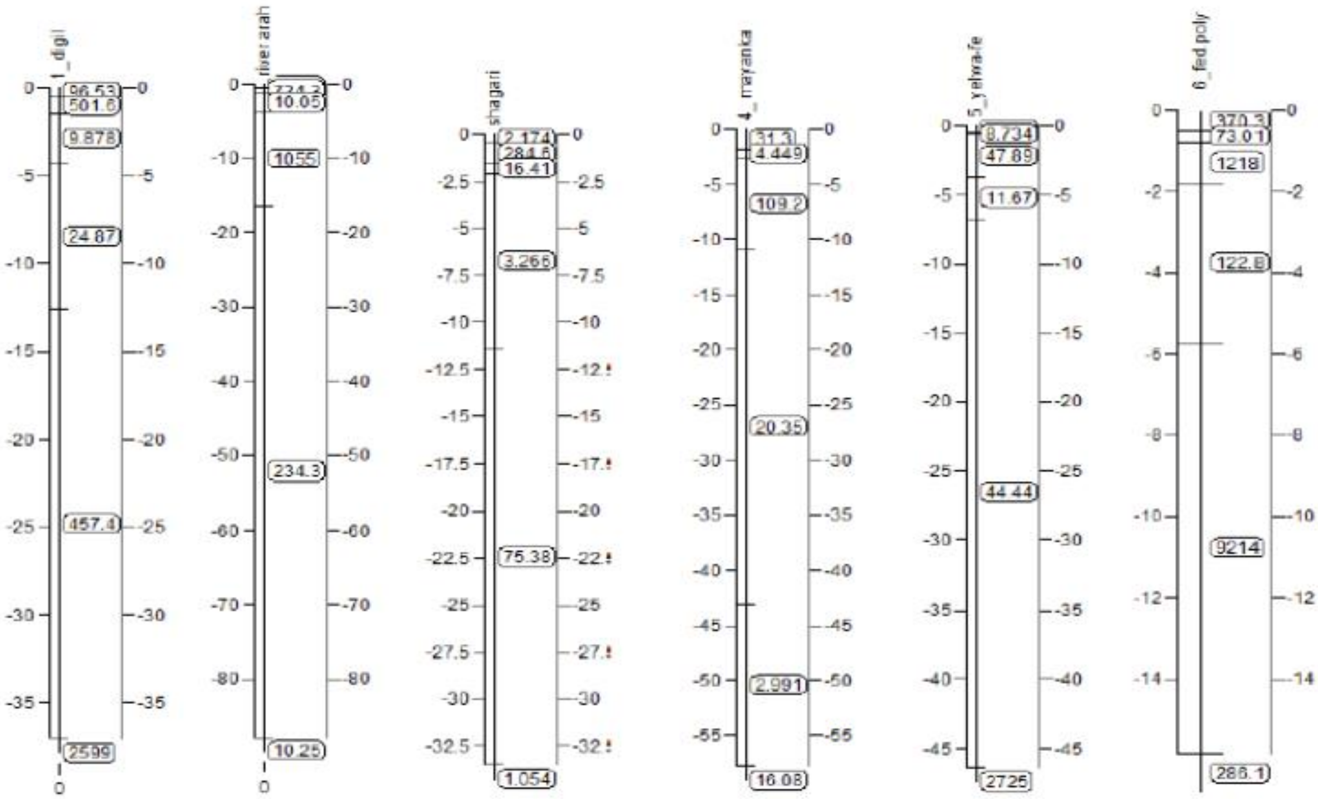

Fig. 3:- Geoelectric Sections Of Some Selected Ves Results Obtained From The Study Area
Source: Field Survey.

Geo electric sections shown in Fig. 3: were obtained using the interpreted results at various VES points in the study area. Each section represents the distribution of resistivity layers of different lithologies within each point down the subsurface. The vertical scale indicates the depth of each resistivity layer and the number of each representative layer resistivity is also indicated. Five distinct geo electric layers are found to be present in all the geo electric sections of the VES points.

V. PSEUDO AND RESISTIVITY SECTIONS

The pseudo and resistivity sections shown in Fig. 4: represent different anomalies at the VES points and the corresponding resistivity distributions of the different lithological sequences down the subsurface of each VES point in the study area. The red colour represent high resistivity anomalies i.e, points where water cannot be found and points with dark colour represent low resistivity anomaly indicating where water can be obtained.

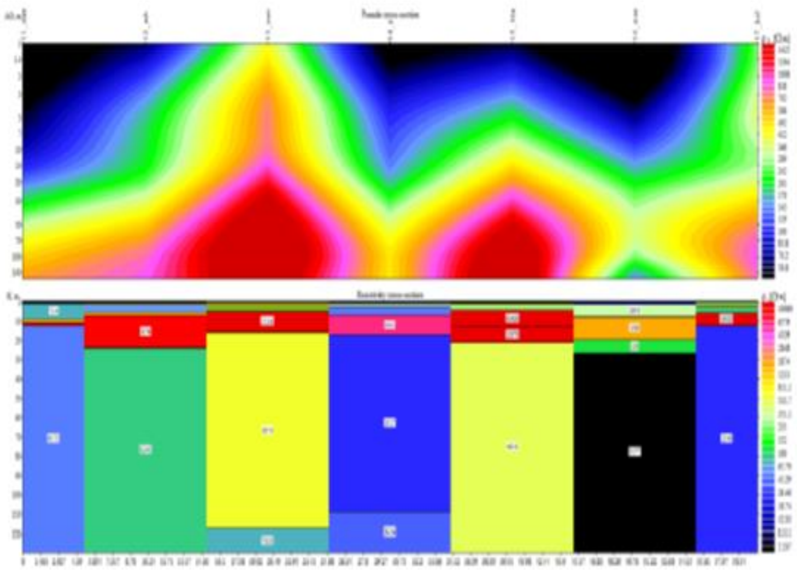

Fig. 4: A Typical Pseudo and Resistivity Section from the Study Area.
SOURCE: Field Survey

REFERENCES

[1]. Adebayo, A.A. (2010): Geology, Relief and Drainage, Mubi Region- A Geographical Synthesis.

[2]. Appelo, C.A.J and Postman, D. (1993): Geochemistry, Groundwater and Pollution. A. A. Balk man Rotterdam, Netherlands. P 536.

[3]. Ariyo, S. O, Adeyemi, G. O and Odukoya, A.M (2005): Geochemical Characterization of aquifers In the basement complex-sediment transition zone around Ishara, South -western Nigeria, Water Resources Journal of Nigeria Association of Hydro geologists, 16, 31-38.

[4]. Bassey, N.E. (2004): Personal Communication Based on an On-going Research on the-Geology of Hauwal Basin.

[5]. Bawuro , A. A., Umar, B. A. and Onyirioha, N. N (2007): Analysis of Heavy and Essential Metals in Water sources around Ashaka Cement Factory.

[6]. Bouwer, H (2002): African recharge of groundwater, Hydrology and Engineering, Hydrology Journal, vol. 10, No. 1, pp 121-142.

[7]. Buchanan, K.M., and Pugh, J.C. (1973): Land and People in Nigeria, Relief and Geology of Mubi Town; Report of Ministry of Education, North Eastern State of Nigeria, 1973.

[8]. Eduvie, M.O., M0gekwu, E.A and Adanu, E.A (1999): Aquifer Assessment and Borehole Characteristics in parts of Kaduna environs, Water Resources Journal of Nigeria Association of Hydro geologists, vol. 16, pp 38-45.

[9]. Feiters, C.W (2001): Applied Hydrogeology, 4th edition, Prentice Hall, New Jersey, 597p. Ige,O.O (2013): Groundwater Development Challenges: Way Forward. Proceedings of the 1st Regional Workshop Organized by National Water Capacity Building Network, North Central Regional Centre, University of Ilorin,held on 3rd and 4thDecember,2013.

[10]. Ijostem, J.L., Young, J., Hollen, C. and Elson, I.R. (1977): Bacteria and nitrate contermi - nation of well water in North-east Iowa. Proceeding of Iowa Academy of Sciences Vol. 84. pp 14-39.

[11]. Ishaku, J.M.,and Ezeigbo, H.I.(2000): Water Quality of Yola Area, Northern Nigeria. Water-Resources Journal of NAH, Vol.11, p.39.

[12]. Lamikarand, A., and Shittu, O. B. (2008): Physiochemical Analysis and Bacteriological Analyses of Water Used for Drinking and Swimming purposes in5 Abeokuta, Nigeria, African –Journal of Biomedical Research, vol.11, pp.285-290.

[13]. Okuofu, A. C. Echafona, N. O and Ayeni, O. G (1990): Bacteriological and physiochemical Examination of well waters in Ahmadu Bello University (Main Campus Zaria Nigeria. Water Resources. NA H Vol. 2 pp. 111 – 115.

[14]. Olasehinde, P. I and Virloka, E. A (1998): Preliminary results of Hydrogeochemical Investigation in Ilorin Area, South Western Nigeria – Quality of Hydrogeo chemical analysis, Water Resources – Journal of NAH Vol. 9 pp. 51– 61.

[15]. Oyawoye N. E. (1970): The basement Complex of Nigeria. In: Dessauvagie, T. F. J. and Whiteman A. Y. (Ed), African Geology, University press, Ibadan, Nigeria pp.91– 97.

[16]. Ramakrishnaiah, C.R. (2009): Assessment of Water Quality Index for the Groundwater in Tukur Taluk, Karnataka State, India, E-Journal of Chemistry, Vol. 6, no 2 ,pp 523- 530.

[17]. Todd, D. K. (1980): Ground Water Hydrology 2nd edition J. Wiley andsons,NewYork.

[18]. WHO (1984): Guidelines for drinking water quality Vol. I. Recommendations. World Health Organization.

[19]. WHO (1993): Guidelines for drinking water quality, Vol. 2, World Health Organization Recommendations, Geneva, Swith Zerland, 1993.

[20]. WHO (1997): Guidelines for drinking water quality. Vol. 3: surveillance and control of Community supplies. World Health Organization Geneva

[21]. WHO (1998): Environmental and Health research for Europe, World Health Organization.

[22]. YASSAH, H. N. (2014): Geoelectrical Investigation of Groundwater Potential and Water Quality Assessment of Mubi and its Environs in Adamawa State, Nigeria. An-Unpublished MSc Thesis, University of Nigeria Nsukka.