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Geology and Hydrogeology of Part of Suleja North Central Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author OJA did all the fieldwork to generate primary and secondary data for the study, prepared the thin section and also did the typesetting. Author AIN did all interpretations of the chemical parameters and water level and potentiometric maps. Author SHW interpreted the thin section microscopy and identification of the minerals.

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ABSTRACT

A study on the geology and hydrogeology of part of Suleja north central Nigeria was carried out using geological and hydrogeological mapping and Electrical Resistivity method of geophysical surveys. The study area was divided into portions of almost equal parts to aid easy identification naming and identification of samples. Rock samples were collected and thin sections were produced from three of these samples. Thirty six (36) hand dug wells were examined for static water level measurements while only fifteen of the water samples were examined in the laboratory for chemistry and bacteriological content. Sixty four (64) Vertical Electrical Soundings (VES) were also carried out using the Schlumberger array. Two major rock types were identified in the area and they are Gneiss and Granite. The water chemistry test showed little dissolution of the rock constituent in the water but rather the effect of sewage, pit latrines and wastewater sources situated around the wells in some areas. Also, the Vertical electrical Sounding (VES) results revealed good groundwater potentials in the larger portions of the study area. The area underlain

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by Granite have the lowest groundwater yield in hand dug wells and as well as from the result of Vertical electrical Sounding. Groundwater occurrence and flow in the area is generally controlled by the topography.

Keywords: Groundwater; geology; hydrogeology; Suleja; Nigeria; basement complex.

1. BACKGROUND

Groundwater occurs in the subsurface and forms an important part of the hydrologic cycle. About 95% of the freshwater in the world apart from the glaciers and ice caps is found beneath the earth. Groundwater support and gives the steady, base flow of rivers and wetlands. Modern man like his primitive ancestors is heavily dependent on water for his sustenance, the use of groundwater as the major source of potable water in both urban and rural areas in Nigeria has assumed such a high proportion that attention has turned fully to it [1]. Water scarcity issue will become an unresolved one in the future for different reasons linked to each other like uneven precipitation distribution all over the world which leads to great reduction in the groundwater recharge thereby affecting the availability of water resources worldwide [2]. Nigeria is just waking up to the responsibility of water resources management as great need is arising for it. An understanding of the geology and hydrogeology of part of Suleja will help in no small way in determining conditions affecting water availability now and in the near future. In a country like Nigeria, a large volume of drinking water is extracted from earth, so its occurrence, and the control geology has on its protection is of utmost importance and this gives the reason why the geology of an area of exploitation must be well understood. Suleja sits on crystalline Basement rocks which commonly serve as groundwater aquifer due to their wide extent though they are usually of low yields which results into drying up of borehole and well during drought [3].

The likelihood of igneous and metamorphic rocks to act as aquifers can be related to the occurrence of fracture intersecting each other, and to highly weathered granite rock, which acts as a porous medium [4].

2. STUDY AREA DESCRIPTION

The area of study is part of Suleja and it is a major satellite town close to the Federal Capital Territory densely populated by the low income earners of about two hundred and fifteen thousand people (National population census, 2006). The indigenes here are the Gbagys.

The portion this research work covers lies between Latitude 9° 11' 36"N and 9° 13' 59.9"N and Longitude 7° 9' 30" E and 7° 11' 36"E with an aerial extent of about 19 km^2, Fig. 1.

Climatic condition comprises of two seasons which are the dry and wet season. Relative humidity is 72% in rainy season and very low during dry season. July and August usually have the highest rainfall while the mean annual rainfall is about 1334 mm^2. March usually have the highest temperature of about 30℃ and lowest in the month of august at about 25℃ due to the frequency of rainfall. The vegetation is savannah mainly dominated by shrubs, grasses and light vegetation sparsely populated by trees of moderate height and sizes.

Soil weathered from rock in Suleja is very rich in humus and favoured production of crops like guinea corn, maize, melon and groundnuts with yam and rice which can all serve as cash crops and food crops.

2.1 Geology and Hydrogeology of Suleja Area

Nigeria is basically underlain by crystalline rocks of the Basement Complex system and the Sedimentary rocks occurring in seven basins, one of which is prolific in petroleum resources. The rocks underlying Suleja belongs to the Basement Complex system and comprises of the Migmatite-gneiss complex and the older granite. They are identified to be older than the late Proterozoic metasediment [5,6], which forms part of the Nigerian Basement Complex but was not found occurring at Suleja. The Migmatite – Gneiss Complex is generally considered as the basement complex sensu stricto [7,8]. The Migmatite-Gneiss Complex also termed by some workers as the "migmatite-gneiss-quartzite complex" makes up about 60% of the surface area of the Nigerian basement [9]. These rocks record three major geological events [10]; the earliest, at 2,500 Ma, involved initiation of crust forming processes. The granite bodies are wide spread and range in sizes from sub elliptical plutons to masses of batholiths [11]. Older Granite as introduced by [12]. They are generally

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Groundwater commonly occurs in structural units known as aquifers, in crystalline rock terrain such as one underlying Suleja area, groundwater occurs in the weathered portion overlying the fresh rock and also in fracturing occurring within the rocks. Weathering profile is quite shallow in the area, groundwater therefore occurs mostly within the fracturing in the rock, hand dug wells are mostly dry at the onset of the dry season.

3. AIM AND OBJECTIVES

The work is aimed at assessing groundwater occurrence and quality of Suleja area based on geological and hydrogeological factors.

The objectives include:

I. To study the geology of the area
II. To study the hydrogeology and groundwater quality of Suleja environs
III. To determine the health implications of the water of this area.
IV. To produce geological and hydrogeological maps of the area.
V. To determine safe groundwater abstraction methods and groundwater potential of Suleja and environs

4. METHODOLOGY

The research work was carried out in three phases; preliminary studies, fieldwork and laboratory analysis.

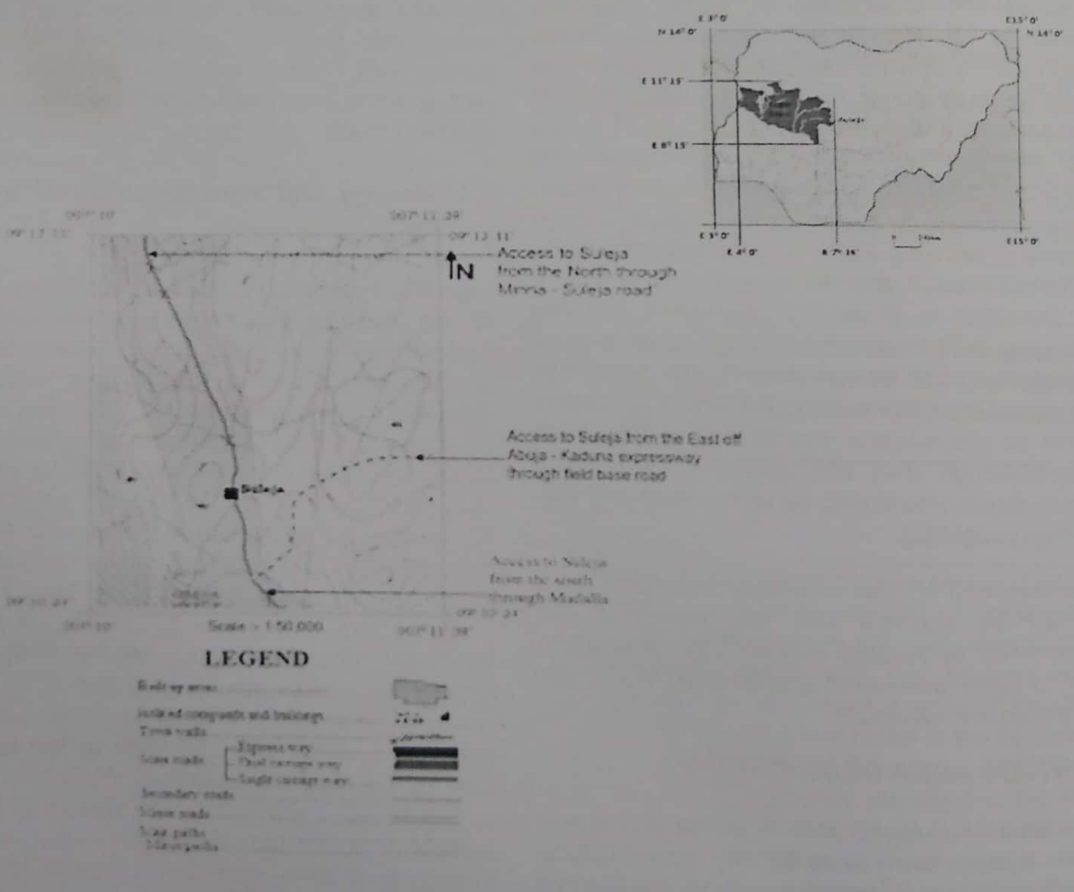

Fig. 1. Map of Suleja in Niger state (inset is the map of Nigeria showing Suleja)

4.1 Preliminary Studies

Preliminary studies involved gathering of related materials and reconnaissance visit to Suleja and environs.

4.2 Fieldwork

Fieldwork was conducted using the topographical map of Abuja Sheet 186 South West on a scale of 1:10,000. Geological traverse method was employed. The area was divided into rows A to H of equal portions as well as column from 1 to 8 for easy reference and identification of samples and portions. Hydrogeological mapping involved measurement of static water level data from hand-dug wells as well as determining the in-situ water physical parameters like pH, salinity and temperature of the water.

Geological mapping was done such that rock types were noted and represented on the base map as they outcropped on the earth surface using the geographical positioning system and Samples were collected from the rock bodies with the use of hammer for laboratory analysis. Geophysical survey was carried out using electrical resistivity meter. Electrical Resistivity survey method adopted involved conducting Electrical Resistivity Profiling (ERP) along seven profile lines running N-S and E-W covering the entire area with each profile line been five hundred meters long. Five Electrical Resistivity Sounding (VES) points were established at one hundred meters intervals along each profile line to get the vertical variations in resistivity.

Fourteen water samples were taken using the one litre capacity sampling bottles and labelled using a permanent marker. Table 1 shows the locations where the various data used for the studies were taken while Fig. 2 is the map of the study area showing water sampling points, the contour lines represent elevation above mean sea level.

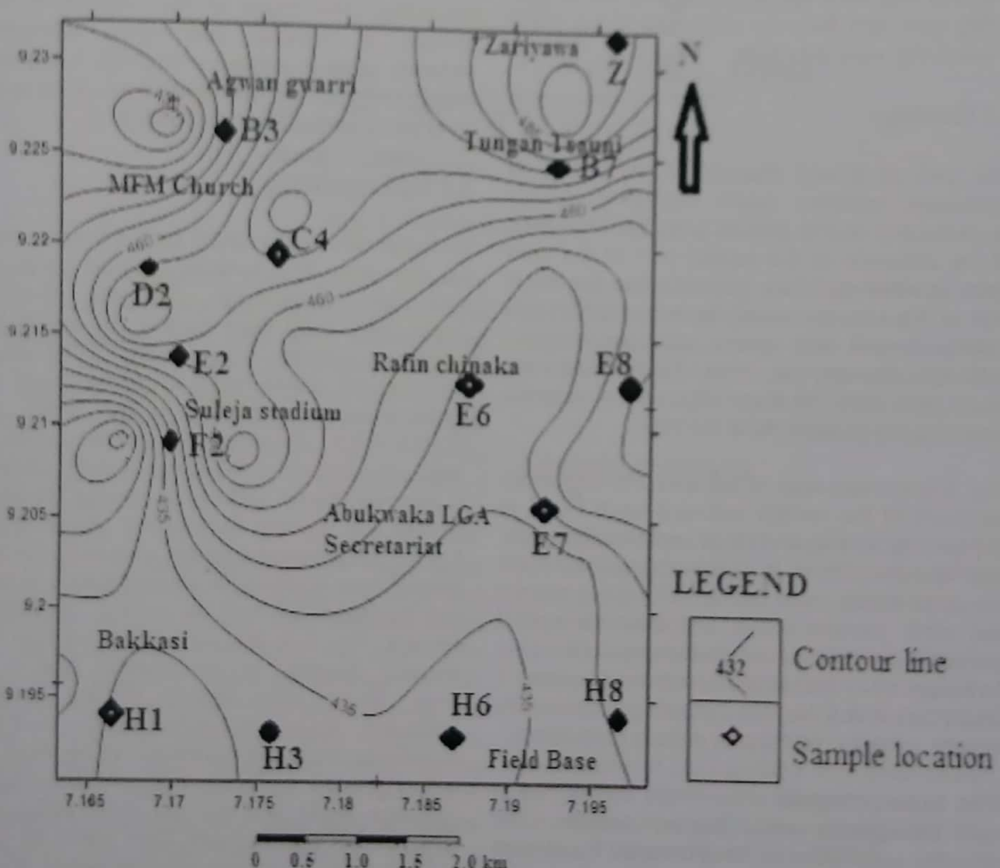

Fig. 2. Map of Suleja area showing locations of the water samples

Table 1. Water sample, location and descriptions of locations

S/no	Sample ID	Sample type	Location latitude longitude		Description
1	Z	Borehole	09°14'27"	07°11'49.2"	Entrance of Zariyawa community
2	B3	Well	09°13'36.7"	07°10'11"	Agwan Gwarri
3	B7	Well	09°13'37"	07°11'35"	Tungan Tsauni
4	C4	Well	09°13'18"	07°10'34"	Around MFM church
5	D2	Well	09°12'56"	07°10'3"	By the river opposite Kwamba pry sch
6	E2	Well	09°12'33.7"	07°10'0.8"	Around Ambest bakery
7	E6	Well	09°12'44.4"	07°11'30"	Rafin Chinaka
8	E8	Well	09°13'39.7"	07°10'92"	Off tungan Tsauni rd, opp Rafin Chinaka
9	F2	Well	09°12'28"	07°10'3"	Behind Suleja stadium
10	F7	Well	09°12'24.8"	07°11'38'	-----
11	H1	Well	09°11'45"	07°09'48"	Down the depressio n, Bakkasi road
12	H3	Well	09°11'39"	07°10'6"	Uphill, Bakkasi road
13	H6	Well	09°11'40"	07°11'21"	Behind Berger rd, field base area
14	H8	Well	09°11'46"	07°11'48"	Close to field base second gate

5. RESULTS AND DISCUSSION

Below are the results of the measurements and analyses that were carried out during the course of this work and they are presented in the order in which the work was done.

5.1 Geology

The part of Suleja mapped is composed of Basement complex rocks consisting mainly gneisses and coarse grained granites. The peaks of the elevation at the central part of the area have its lithology to be granitic while the lower part of the area are mostly gneiss weathered to different levels with quartz veins on different outcrops through the area. Gneiss outcrops found here show the linear alignment of minerals depicting the gneissocity of the rock.

Fig. 3 is the fact map of the area showing exact locations of the various outcrops while Fig. 4 is the geological map and cross section of the area, the contour lines in both cases represent elevation above mean sea level. Granites occupy the north eastern corner and also the central portion. Gneiss is the most widespread rock type in Suleja area. Thin sections of the rock, plates 1 and 2, show that the rock contains predominantly quartz, mica and feldspar in various proportions.

The basic geological units in this part of Suleja are the granite and Gneiss complex. The granites were found to have intruded the Gneiss complex and thereby causing an increase in the metamorphism. The granites were found as rugged ridges almost at the centre portion of study area and towards the right hand corner at the portions B7 and B8. The Gneiss complex is found all over the place at different stages of weathering. They are also found with geological structures. The rocks of the area have high content of feldspar and when feldspathic minerals come in contact with water, it weathers readily [14] and this weathered zone gives space for water storage in the subsurface.

5.2 Hydrogeology

Measurements were taken from the wells using the dip meter and portable physical parameter such as temperature, pH and Electrical Conductivity (EC) were carried out in the field using a portable field meter, YOKOGAWA Personal pH meter (used to measure pH and temperature of samples) Model PH82 and YOKOGAWA Personal SC meter (used to measure electrical conductivity and temperature of samples) Model SC82 produced by Yokogawa Denkiki K.K. Electric Corporation, Japan. Figure 5 is the groundwater potential map of Suleja area derived from water level measurements in wells and boreholes as well as surface geophysical surveys. Fig. 6 is the water level contour map showing direction of groundwater flow in the area. Areas with closely spaced contours represent areas of groundwater discharge suitable for wells and boreholes, while areas with widely spaced contours represent groundwater recharge areas and are not quite suitable for groundwater development. Care would be taken in such areas to prevent effluents getting into the groundwater system from poor urban infrastructural development.

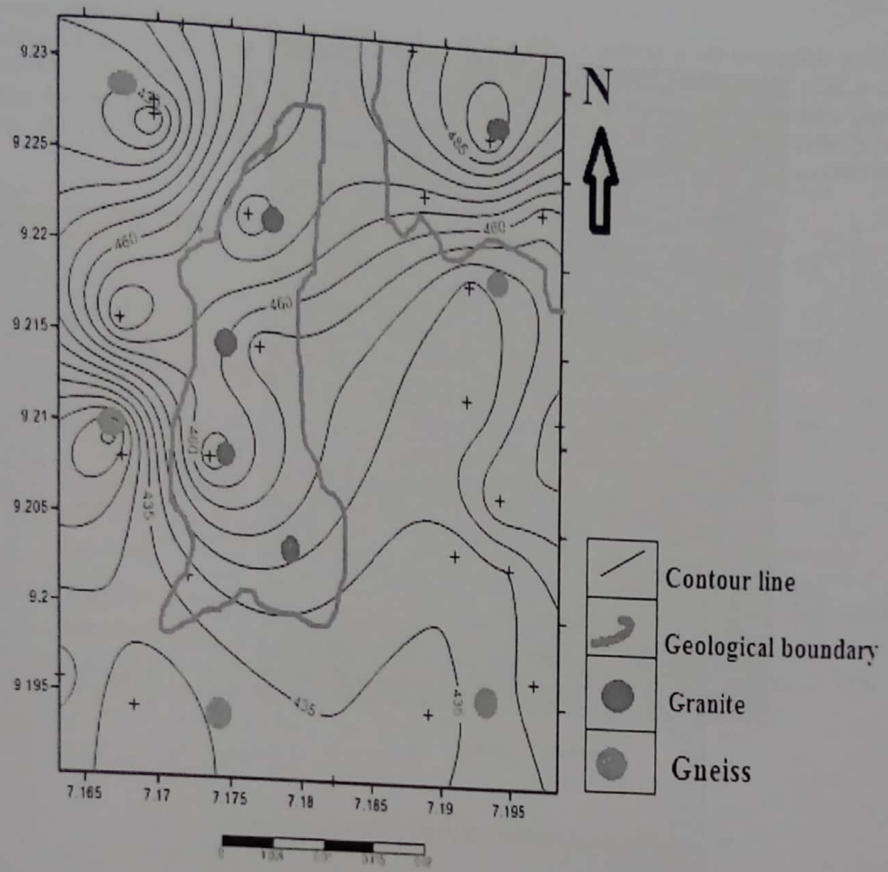

Fig. 3. Fact map of part of Suleja

From the measurement taken across the study area, it was observed that the average depth of wells are about 6 m with some wells having depth as low as 1.6 m and some as deep as 7.9 m and the major source of the recharge is through the regolith. It was observed that water availability or productivity of the well is mostly determined by the elevation of the site where it was dug relative to the elevation of the adjacent areas. Wells at point at G4, G5, G6, G7, G8, H5,H6 and H8 have extremely low depth since they were located around the foot of a slope and this allow the groundwater from adjacent points of higher altitude to recharge the point. This shows the structural control the geology has over groundwater availability. The areas having the best groundwater yield in the area mapped are those having their subsurface rocks to be metamorphic rock (Gneiss complex) with better geological structures and yield tend to reduce towards the area with igneous rock. A comparison of the elevation maps (Fig. 2) and the water level contour map (Fig. 6) shows that groundwater elevation and flow direction are a direct reflection of the elevation of the area. Groundwater occurrence and flow direction is therefore a factor of the surface elevation of the area.

5.3 Hydrochemistry

Hydrochemistry is the qualities of chemical substances present in a sample of water and making up its composition chemically [15]. Physico-chemical composition of the water samples were examined in order to be able know the quality of water and ascertain its usability for domestic, agriculture, industry and recreational purposes. Table 2 below show chemical parameters of both surface and groundwater in Suleja area. The mean measurement of all the parameters from the field and laboratory are as follows, temperature is 26.7℃, the total dissolved solute is 0.20 ppt, pH is 6.4 while conductivity is 320 µS/cm.

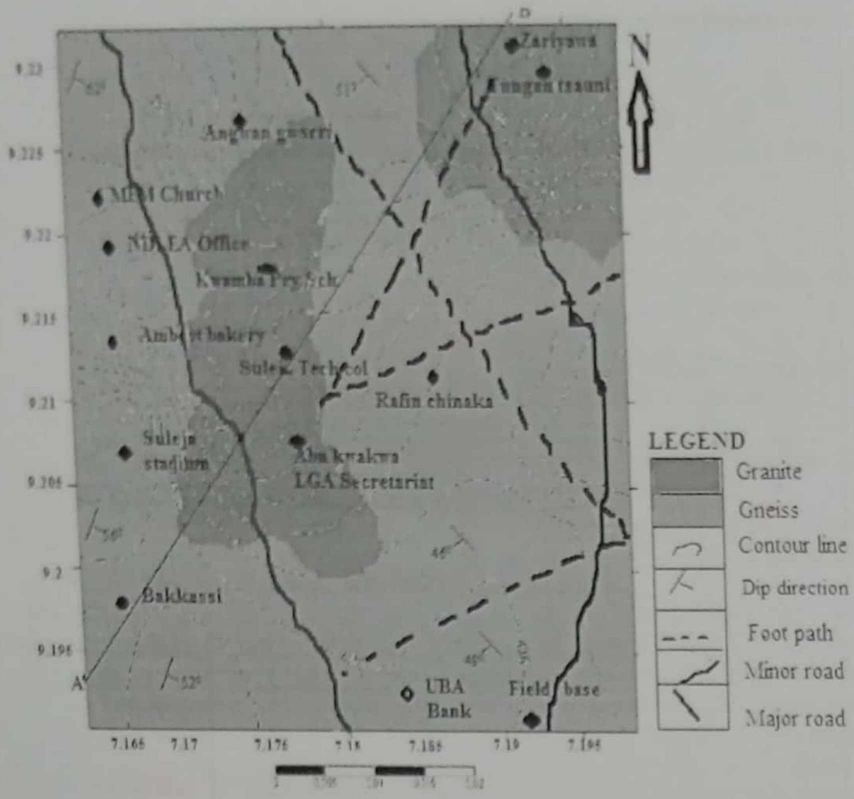

Fig. 4a. Geological map of the study area

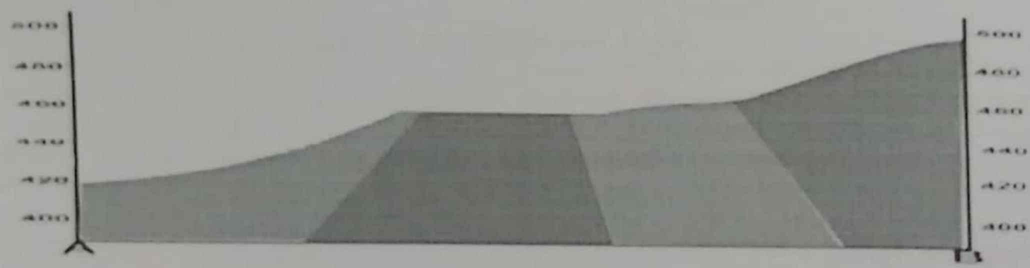

Fig. 4b. Geological cross section of the study area

Fig. 7 is the map of Suleja showing areas with high nitrate concentration while Fig. 8 is the graph of mean concentration of measured parameters of groundwater and Fig. 9 is the Piper diagram that was used to characterise the water as a calcium-magnesium-sulphate water. Nitrate was isolated because of the slightly higher concentration and also been an indicator of pollution from poor sanitary conditions. In characterising the water using Piper, Nitrate was added to chloride to give a sulphate – chloride – nitrate combination.

Impurities can enter into the groundwater through many ways like soil leaching, rock weathering, and some anthropogenic sources such fertilizer application in agricultural practices, poor hygiene and mining activities [16]. In the study area, the major cause of contamination can be traced to poor hygienic practice. Reasonable distance was not considered in locating their hand dug wells, sewage and pit latrines.

From the test results, it can be deduced that the dominant chemical constituent of the waters tested are defined by the rocks. From the Piper diagram, water sample also show sulphatic as main water type and this could be inferred to the relative proximity of groundwater to sewage disposal systems. Some trace elements can also be observed almost crossing the boundary of Nigerian Standard for Drinking Water Quality. There are few instances of some water points having their Nitrate content to be very high and some are still very low but with very high probability of getting it contaminated in the next few years. In almost all the wells, soak away and pit latrines were not given reasonable gaps from each other and this gives the reasons why all may be contaminated by the wastes with time.

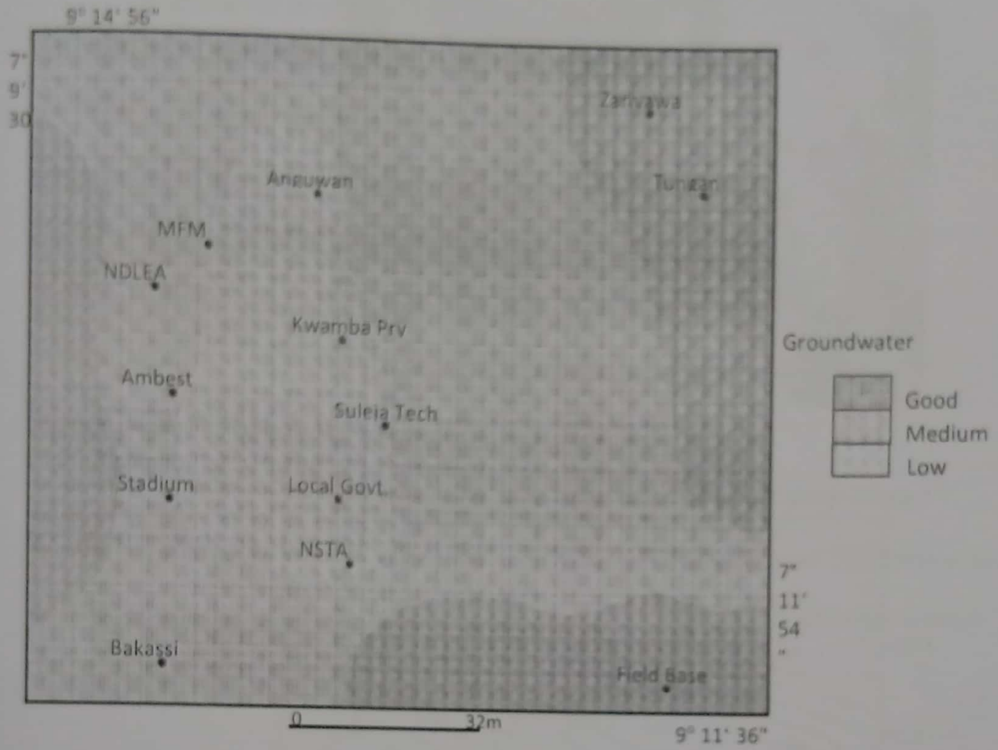

Fig. 5. Groundwater potential map of parts of Suleja

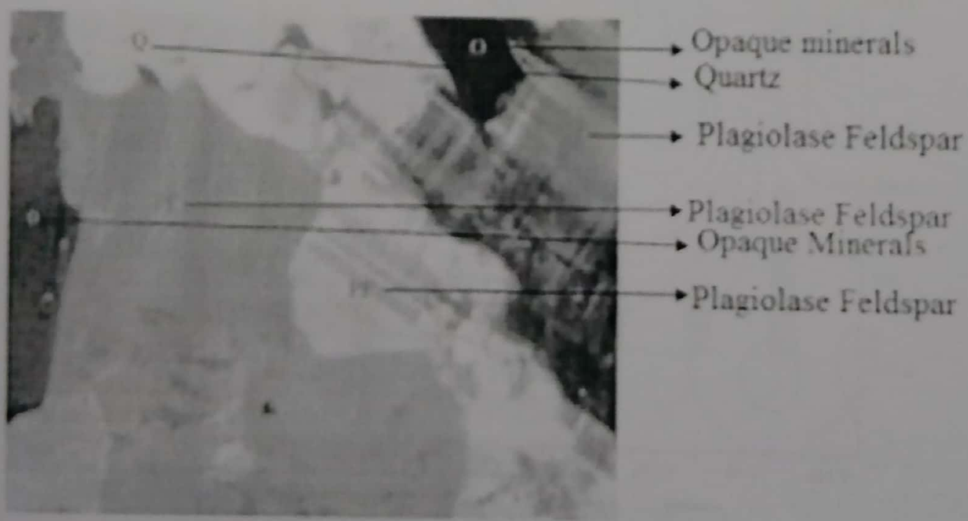

Plate 1. Photomicrograph of gneiss complex (Sample F7)

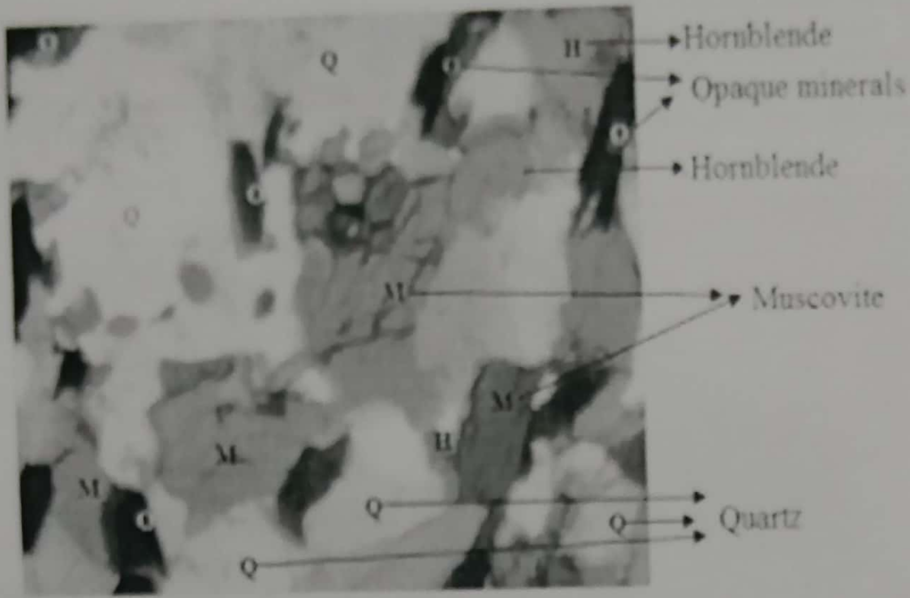

Plate 2. Photomicrograph of granite (sample C4)

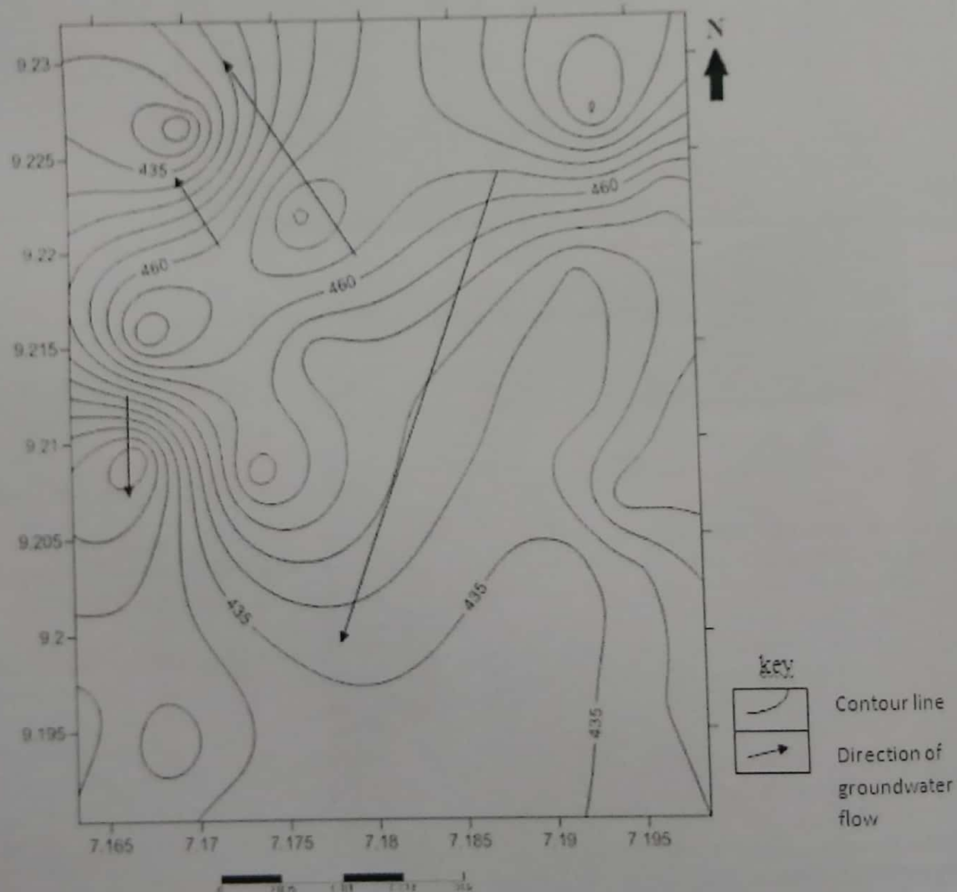

Fig. 6. Water level elevation contour map showing direction of groundwater flow

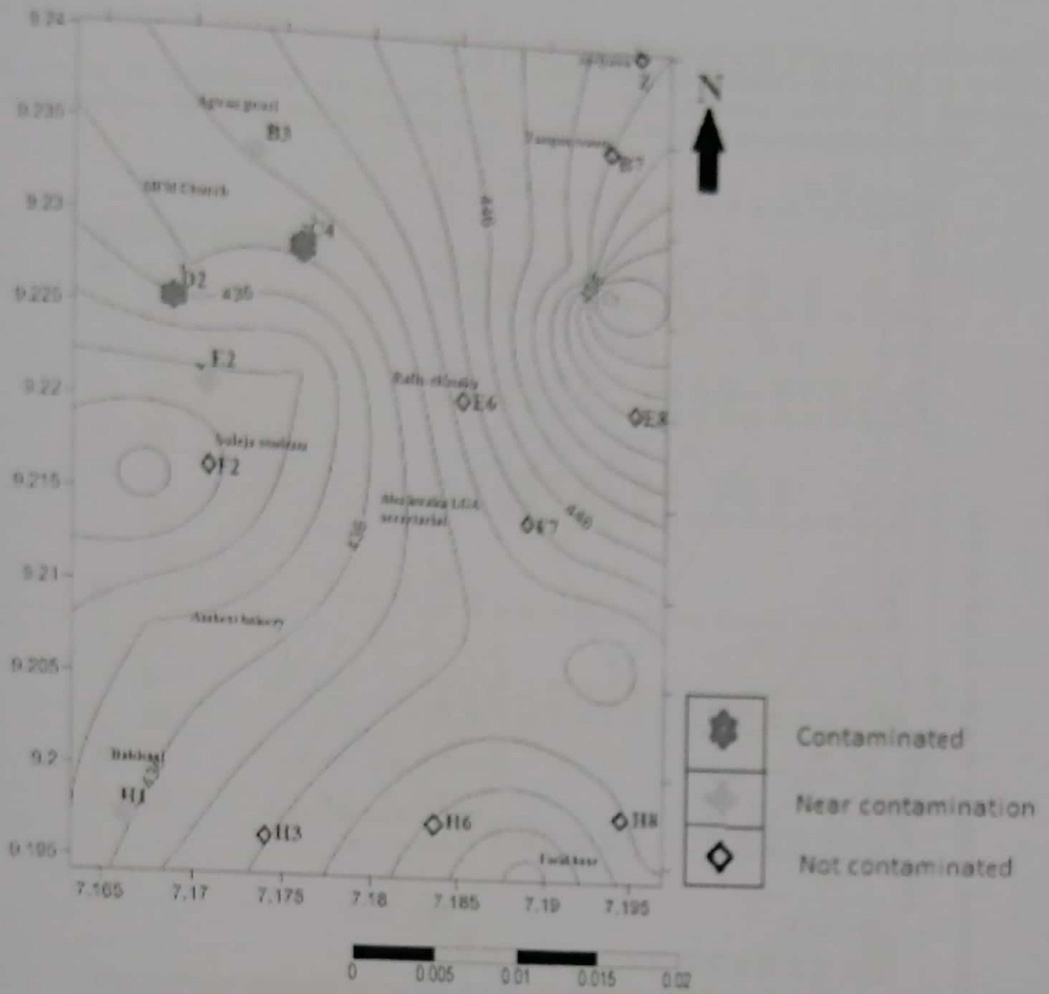

Fig. 7. Map of part of Suleja showing wells with high nitrate content

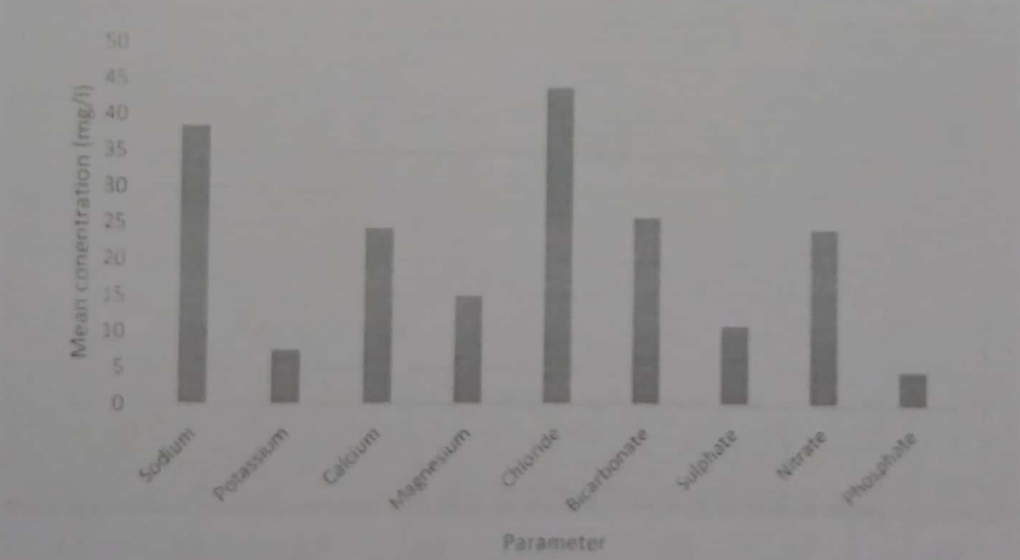

Fig. 8. Mean concentration of measured parameters in Suleja area

Table 2. Results of chemical analysis of water in Suleja area

Sample ID	Cations (mg/l)				Anions (mg/l)						Trace elements (mg/l)			
	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}	NO_3^-	PO_4^{3-}	F^-	Fe^{2+}	Cr	Zn	P
Z	24	3	24.8	8.3	24	21	10	11.1	4	0.81	0.01	0.07	3.5	1.3
B3	60	10	32.8	23.42	69	20	12	44	2	0	0.05	0	3.95	0.65
B7	25	7	23.2	11.73	32	14	10	11.7	2	0	0.11	0.03	3.8	0.65
C4	58	6	14.4	38.06	66	36	10	51.2	6	0.88	0.08	0	5	1.95
D2	116	8	20.8	44.41	150	46	13	58.1	9	0.58	0.1	0.02	4	2.93
E2	57	8	16	29.77	63	27	12	45	4	0.21	0.05	0.01	4	1.3
E6	10	3	16	7.81	15	15	12	6.87	2	0	0.09	0	3.8	0.65
E8	20	20	17.6	13.18	10	36	11	8.5	2	0.02	0.07	0.02	5	0.65
F2	48	8	27.2	18.06	49	21	12	30.1	9	0.34	0.11	0.01	5	2.93
F7	8	4	35.2	1.95	9	22	14	4.27	3	0.67	0.17	0.06	3	0.97
H1	30	8	74.4	1.95	47	48	11	43.7	5	0.06	0.08	0	5	1.63
H3	27	11	12	8.3	30	18	10	10.8	7	1.19	0.04	0.02	4	2.18
H6	24	4	16	2.44	29	13	12	8.3	8	0.49	0.1	0.01	4	2.61
H8	32	6	40	2.44	32	31	10	13.6	5	0.27	0.15	0.08	3.5	1.63
Total	539	106	370.4	211.82	625	368	156	347	68	5.52	1.11	0.33	57.55	22.03
Mean	38.5	7.57	26.46	15.13	44.64	26.28	11.14	24.8	4.86	0.4	0.08	0.02	4.11	1.57

5.4 Geophysical Survey

The results of geophysical survey using the vertical electrical sounding method along profile lines A-H are shown below in Table 3. Fig. 10 is the geo-electric section while Fig. 11 is the map of Suleja showing overburden thickness as determined from geo-electrical surveys.

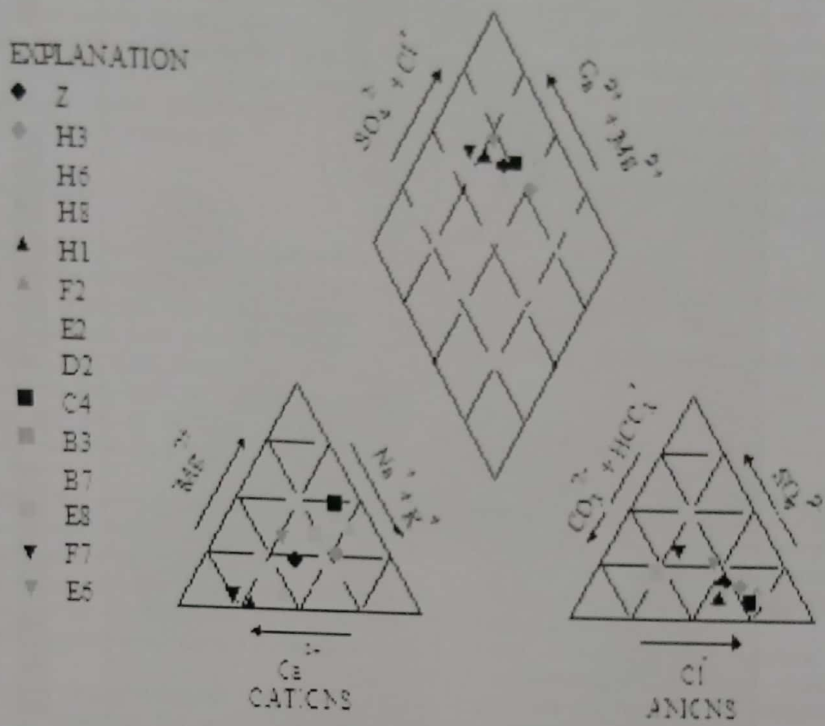

Fig. 9. Piper diagram showing the water types (modified after Piper, 1944)

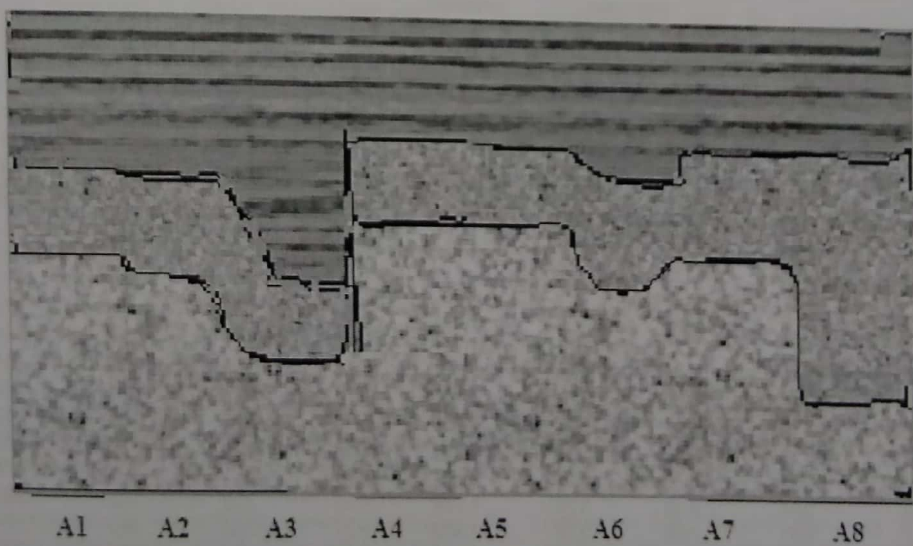

Fig. 10. Geoelctric section for profile line A

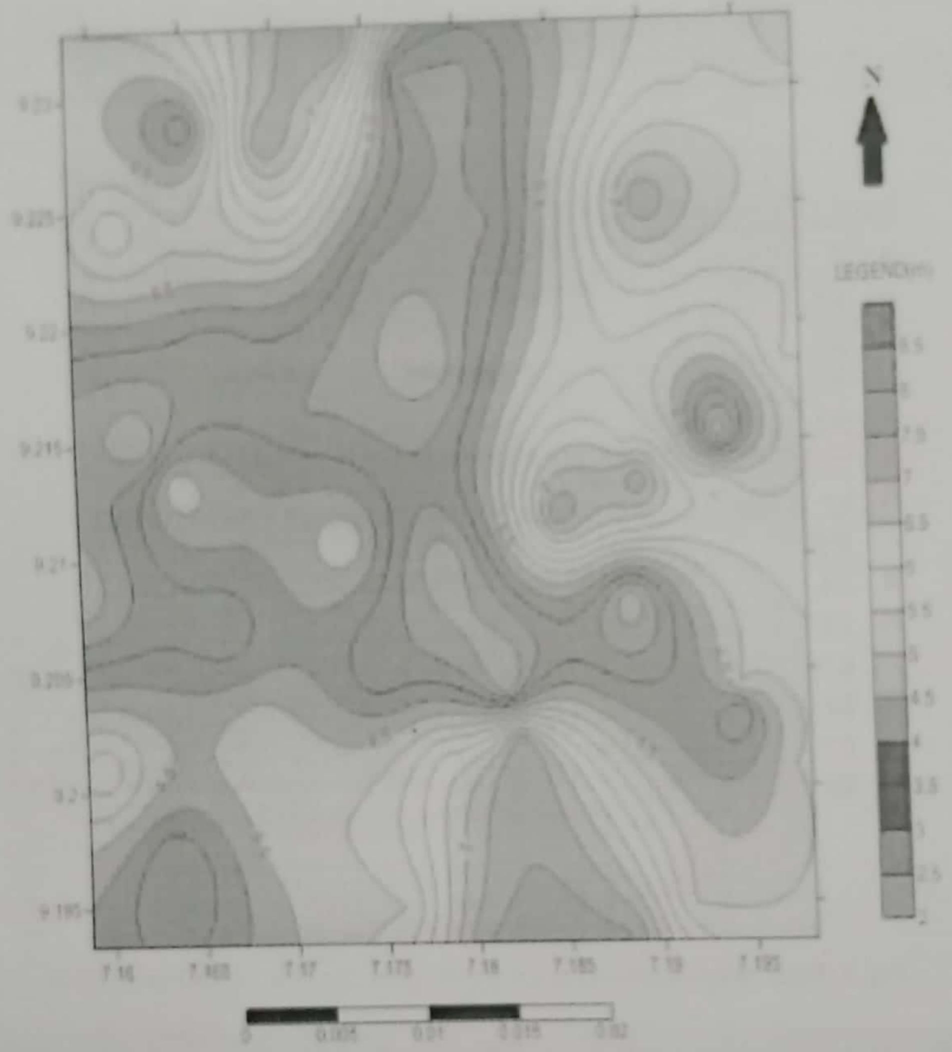

Fig. 11. Map of Suleja showing overburden depth

Table 3. Results of vertical electrical sounding along profile line A

AB/2	A1	A2	A3	A4	A5	A6	A7	A8
1	438	286	348	411	426	315	90	106
2	401	247	266	331	374	271	118	104
3	374	174	184	284	334	214	131	127
5	298	123	141	386	384	194	152	177
6	326	156	109	421	426	211	173	178
8	381	162	98	486	491	297	246	195
10	314	196	191	524	532	332	318	191
15	386	215	224	639	574	315	373	184
20	346	239	267	742	556	341	301	243
25	420	246	301	801	581	310	336	270
30	382	226	311	942	620	292	328	278
35	364	210	314	1126	746	322	328	321
40	401	284	320	1350	824	366	487	374
50	416	344	379	1780	963	424	295	397
60	474	456	467	1864	1106	674	347	394
70	568						348	446

It was observed that wells with thicker overburden layer perform better in groundwater yield than those with shallow overburden except those at the valley of slope. It was also established that yield of a well differs from one point to another mindless of how close they may be. Geophysical surveys carried out in the area reveal that there are reasonable geological structures (fractures) in the subsurface rock that may support a good groundwater yield if borehole are drilled in these area.

6. CONCLUSION

Groundwater occur in all places but with different yields due to the structural control the geology has over it and the continual change in geological conditions from point to point on the earth surface and subsurface. The rock type, grain size, and the level of weathering in the subsurface are set of factors that determine storage and transmisivity of groundwater.

When feldsparthic minerals come in contact with water, it weathers readily [14] the rocks are also highly fractured and faulted as earlier mentioned. The relative high rainfall the area witnesses aids in the weathering of the rocks leading to the formation of regolith which serves as aquifers.

Groundwater move through fissures and fractures of rocks in the subsurface thereby dissolving the rock constituents that are more soluble and continually carry them as it move until its movement is altered through the use of borehole or hand dug well. During the movement of the groundwater through the fissures of rocks, it tend to dissolve the rocks through which it passes thereby changing the chemistry of the water to the chemistry of the rocks or near chemistry of the rocks through which it moves and hence the type of water obtainable.

Groundwater can be polluted and the major source of pollution which eventually alter the chemistry of the water in Suleja and environs is the poor design of sanitary systems and sewage lines. Elevated nitrate concentration noticed in two locations (C4 and D2) was as a result of the proximity of the water sources to unlined pit latrines and poorly designed septic tanks. Groundwater pollution in the area is mainly as a result of anthropogenic factors. Chemical elements/compounds with high concentration are sodium, chloride and nitrate, these are indicators of pollution that often arises from poor waste disposal including human and food waste as well as application of nitrogen fertiliser to soils for agriculture.

Based on the geology and studies that was carried out in Suleja and environs, it is recommended that groundwater can best be developed in this area through the use of well-designed boreholes. Results of the geophysical survey reveal high probability of success in reasonable larger portion of the area and strict laws should be passed by the government dictating or stating specifically the distance that should be between boreholes and pit latrines, soak away.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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