Groundwater Quality in Lekwesi / Umuchieze Area, Southeastern Nigeria

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ABSTRACT

The Lekwesi/Umuchieze area of Nigeria is a rural community dependent on groundwater as their source of water supply for domestic and agricultural use. The area is underlain in most parts by shaley/clayey bedrock that has been deeply weathered.

There are no boreholes in Lekwesi/Umuchieze but the existence of several springs suggest a shallow water table in the bedrock. Water samples from ten (10) springs in the area have been analyzed and studied in order to assess the quality of the groundwater, principally as the major source of potable water and also as it affects the occupational activities of this agrarian community. The result of the chemical analysis of the groundwater samples compares favorably with the World Health Organization, (WHO) 1984 standard for drinking water.

The bacteriological analysis of the samples, however, reveals that the aquifer/groundwater has very high concentrations of Coliform bacteria, varying between 20 and >2400MPN/100ml of water. The WHO (1984) standard stipulates 0/100ml for drinking water. The high population of Coliform bacteria indicates poor sanitary conditions in the study area, arising from poor handling of domestic wastes, especially garbage and sewage. The aquifer is thus contaminated and the groundwater, therefore, is not potable without treatment.

The groundwater is, however, good for agricultural use, having %Na and SAR values that vary between 9 and 24 and 0.12 and 0.26 respectively. The study further reveals that the groundwater is soft, and also that it is a mixed type of HCO_3^- and $SO_4^{2-} + Cl^-$, both of which are rich in Mg^{2+}.

(Key words: springs, potable water, Coliform, agrarian, rural community).

INTRODUCTION

The project area is dominated by rural dwellers that mainly use water for domestic and agricultural purposes. The area lies between latitude 5°55'N and 6°00'N and longitude 6°25'E and 6°30'E. It covers such areas as Lokpanta, Lekwesi Umuchieze, Lokpaukwu, etc. and occupies an area of about 79.2km^2 (Figure 1). Sources of water supply to the inhabitants of the area are mainly by stream, contact spring, or shallow hand- dug wells. Irrespective of the fair distribution of the sources of water, provision of potable water remains an unsolved problem because of the unhygienic behavior of this rural community.

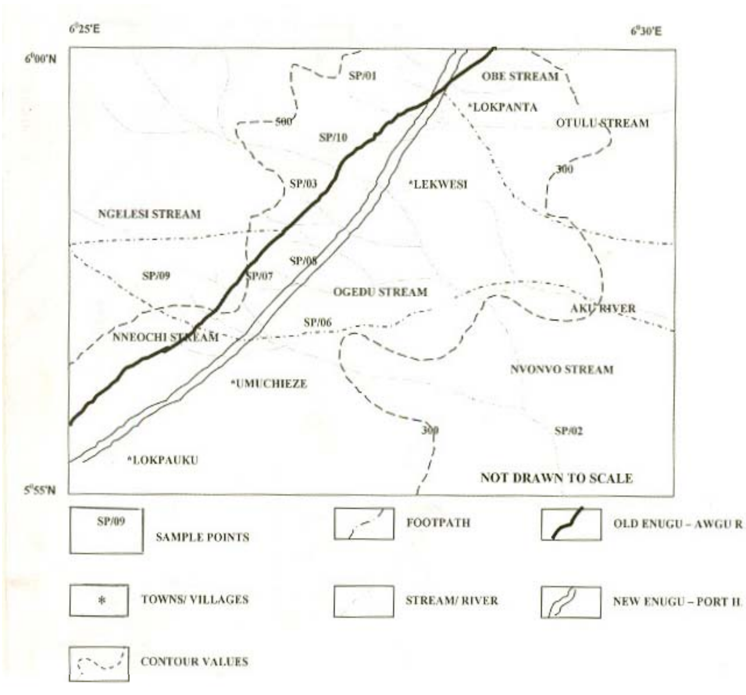

Figure 1: Sketch map of the study area showing accessibility, drainage and sampling points.

Previous research work on the aspects of hydrogeology and hydrogeochemistry of the southeastern part of Nigeria have been carried out by numerous researchers including Egboka

(1983 & 1986), Uma & Egboka (1986), Amadi (1987), Ezeigbo (1988), Ezeigbo & Okogbue (1990), Okonny (1991), Nwankwo (1995), Ahueke (1999), and Ahiarakwem (2004). Therefore, the focus of this study is to determine the potability of the spring water in the area by comparing the chemistry with the WHO (1984) limits for drinking water, determine the hydrochemical facies distribution of the spring water, and finally, determine if the spring water can be harnessed and used for agricultural purposes such as irrigation, feeding of livestock, etc. The distance between the springs is not more than 250 meters apart.

GEOLOGY/LITHOSTRATIGRAPHY

The study area is located in the southeastern part of the lower Benue Trough. The Benue Trough is located at a major re-entrant in the latest African continent. It occupies an intra-continental position and has a thick, compressionally-folded Cretaceous supracrustal fill (Murat, 1970; Catchley and Jones, 1975; Olade, 1975; Petters, 1978; Hoque and Nwajide, 1984).

The study area is underlain by the Awgu and Nkporo Shales. The Awgu Shales are fissile, finely laminated, dark bluish grey to black carbonaceous, richly fossiliferous, pyretic, and gypsiferous shales (Reyment, 1965). The Agbani sandstone member forms an unconfined aquifer system in the Awgu Shale.

The Nkporo Shales consist of dark shales and mudstone with occasional thin beds of sandy shales and sandstone (Reyment, 1965). Figure 2 shows a generalized stratigraphic profile of the study area based on outcrop studies.

PHYSICAL FEATURES OF THE SPRINGS

The study area is drained by the Cross river system. This system may be related to structural controls, inequalities in rock hardness/texture, recent diatrophism, and the geology/geomorphic history (Igbozurike 1975). The project area consists of springs and streams which emerge from the escarpment and descend towards the valley. The streams maintain a parallel course, perpendicular to the dip of the strata. Some of the streams encountered in the area include 'Otulu', 'Nvonvo', 'Nneochi', etc., while some of the springs observed include 'Owu julius', 'Iyi Rufus', 'Mbian', etc. Figure 3 shows a picture of one of the springs (Iyi Rufus).

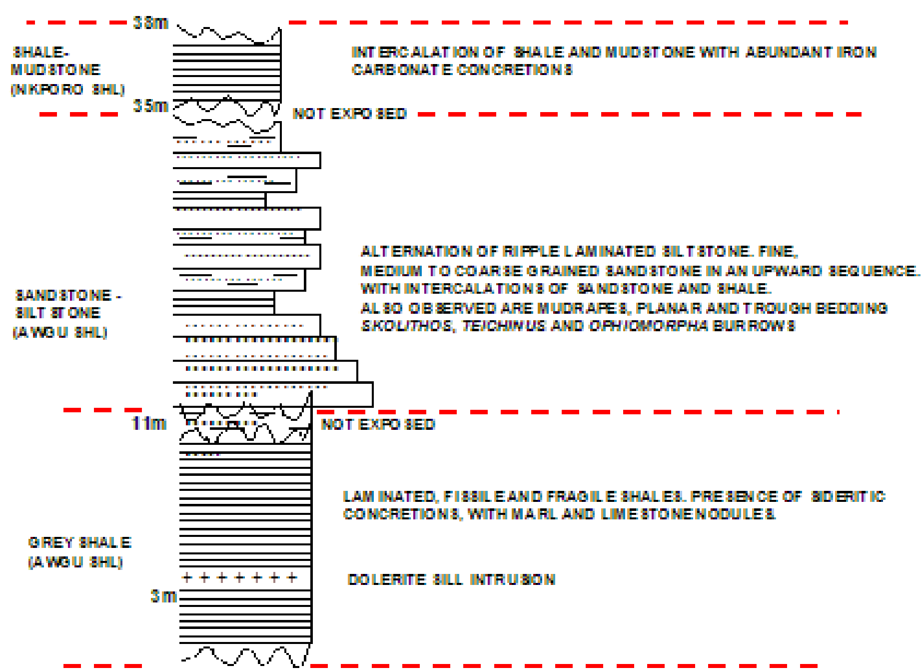

Figure 2: Composite stratigraphic profile of outcrops within the study area.

The streams are not fast flowing and deposits of coarse sandstones and pebbles along the valley floor were observed. Some of the springs are perennial while some are seasonal (ophemeral). Their drainage form is dendritic.

Figure 3: Picture of one of the springs in the study area (Iyi Rufus).

METHODOLOGY

The methods employed for this study are field investigation/sampling and laboratory analysis. A detailed field sampling exercise was carried out in the month of March 2004, while laboratory analyses of the water samples were carried out within 12 hours after sampling at Anal Concept Laboratories, Port Harcourt. The samples were collected in sterilized white plastic containers, pH was analyzed using a pH meter, while color was measured against a standard solution in Nessler tubes. Cations were analyzed using an atomic absorption spectrophotometer (Perkin – Elemer AAS3110), while Anions were analyzed using the colorimetric method with the UV, visible spectrophotometer WPAS110. Total dissolved solids (TDS) were analyzed using the gravimetric method. Analysis of Coliform was carried out using the multiple tube/most probable number technique (MPN). Aliquots of 100ml of each were used for the analysis (Cheesbrough 1999).

The quality assurance measure taken in carrying out the analysis was the "multiplicity of samples" approach. With all obtained results only very little variation was observed. This implies that the analysis was honestly carried out by the laboratory technologist. However, the ionic balancing method is another type of quality assurance measure that can be carried out, this is based on Domenico and Schwartz (1990) standards. Most laboratories accept ±0.05 as standard error which must not be exceeded.

The formulae employed in estimating %Na, SAR and Trilinear plot are:

%Na = (Na +K) 100/Ca + Mg + Na + K
(Todd, 1980)

where: %Na = Percentage Sodium
Na = Sodium
K = Potassium
Ca = Calcium
Mg = Magnesium

SAR = Na/ (Ca + Mg)/2
(Todd, 1980)

where: SAR = Sodium Absorption Ratio
Na = Sodium
Ca = Calcium
Mg = Magnesium

All ionic concentrations in mg/l are expressed in meq/l.

A trilinear plot was carried out by first converting each ionic concentration (mg/l) to (meq/l). The percent of each of the values was then plotted on the triangle diagrams. The position of the points is projected parallel to the magnesium and sulphate axes until they intersect in the center field (Fetter, 1980). Note: in calculating values to be used in the trilinear plot, the total equivalents of cation with anions may not exactly balance each other. This may be due to analytical error and unreported minor constituents.

RESULTS

Ten (10) springs were sampled and analyzed for various physical-chemical parameters. Results show that the concentration of color was between 20 and 45^{o}H; pH ranged between 6.2 and 6.8; total hardness (T.H.) ranged between 2 and 36mg/l; and total dissolved solids (TDS) ranged between 4 and 280mg/l.

For the Cations the values for Na^{2+} ranged between 1.4 and 4.8mg/l, K^{2+} ranged between 0.4 and 2.4mg/l, Fe^{2+} ranged between 0.1 and 0.9mg/l, Ca^{2+} ranged between 0.8 and 11.2mg/l, and Mg^{2+} ranged between 4.8 and 19.5mg/l.

For the Anions the values for PO_4^- ranged between 0 – 0.14mg/l, NO_3^- ranged from 0 – 3.1mg/l, SO_4^{2-} ranged from 0 – 12.0mg/l, Cl^- ranged between 1.0 – 8.0mg/l, CO_3^{2-} was 0 mg/l and HCO_3^- ranged from 2 – 20mg/l.

The Coliform bacteria count ranged between 20 and >2400MPN/100ml (Table 1). The obtained results were compared with the WHO (1984) highest desirable and maximum permissible limits for drinking water to establish if the springs are fit for human consumption (Table 2).

Estimates of %Na are between 9 and 24, while SAR is between 0.12 and 0.26 respectively (Table 3). The percentage hardness of the spring water is presented in Table 4.

A Schoeller semi-logarithmic plot of the water samples SP_1 – SP_5 and SP_6 – SP_{10} is presented in Figures 4 and 5, while the trilinear diagram plot for the water samples is given in Figure 6.

Table 1: Hydrochemical data from the study area

S/No	Sample	pH	Color (^oH)	Na^{2+} Mg/l	K^{2+} Mg/l	Fe^{2+} Mg/l	TDS Mg/l	Ca^{2+} Mg/l	Mg^{2+} Mg/l	PO_4^- Mg/l	T.H Mg/l	NO_3^- Mg/l	SO_4^{2-} Mg/l	Cl^- Mg/l	CO_3^{2-} Mg/l	HCO_3^- Mg/l	Coliform MPN/100ml
1	SP/01	6.5	45	3.1	1.3	0.9	140	2.4	4.9	0.14	2	0	10.3	1.0	0	20	150
2	SP/02	6.2	20	1.4	0.9	0.3	40	1.6	4.9	0.05	2	0	9.4	2.0	0	4	210
3	SP/03	6.8	35	2.4	0.9	0.9	20	4.0	9.7	0.03	20	0	11.2	5.0	0	10	1100
4	SP/04	6.4	30	2.4	0.7	0.3	20	2.4	9.7	0.03	6	0	8.6	6.0	0	10	>2400
5	SP/05	6.5	30	3.8	0.9	0.3	60	4.0	9.7	0	20	1.8	1.9	8.0	0	20	43
6	SP/06	6.5	35	1.4	0.4	0.4	4	3.2	4.9	0.03	4	0	12.0	3.0	0	10	>2400
7	SP/07	6.5	30	4.8	0.6	0.3	120	11.2	19.5	0.03	36	3.1	9.5	3.0	0	10	1100
8	SP/08	6.5	25	1.4	0.4	0.3	40	0.8	4.9	0	4	0	0	1.0	0	10	1100
9	SP/09	6.5	25	1.9	2.4	0.1	60	1.6	4.8	0	4	1.1	0	4.0	0	2	20
10	SP/10	6.5	20	1.4	0.6	0.1	280	0.8	4.8	0.05	6	0	0	3.0	0	4	28

TDS = Total dissolved solids
T.H = Total hardness

Table 2: Range values of physical-chemical parameters WHO (1984) Standards for drinking water.

S/No	Concentration level	Highest desirable level	Maximum permissible level
1	pH	7 – 8.5	6.5 – 9.2
2	Color (oH)	5	50
3	Total dissolved solids (TDS) Mg/l	500	1500
4	Total hardness (T.H) Mg/l	100	500
5	Na2+ Mg/l	-	-
6	K2+ Mg/l	-	-
7	Ca2+ Mg/l	75	200
8	Mg2+ Mg/l	50	150
9	Fe2+ Mg/l	0.1	1.0
10	PO4- Mg/l	-	-
11	NO3- Mg/l	45	50
12	SO42- Mg/l	200	400
13	Cl- Mg/l	200	600
14	CO32- Mg/l	-	120
15	HCO3- Mg/l	-	-
16	Coliform MPN/100ml	0/100ml	0/100ml

Table 3: Estimates of % Na, SAR and Hardness for this study.

S/No	Samples	Na	SAR	Water Cls	Hardness Class
1	SP/01	24	0.26	Good	Soft
2	SP/02	15	0.12	,,	,,
3	SP/03	11	0.15	,,	,,
4	SP/04	12	0.15	,,	,,
5	SP/05	16	0.23	,,	,,
6	SP/06	11	0.12	,,	,,
7	SP/07	9	0.20	,,	,,
8	SP/08	14	0.13	,,	,,
9	SP/09	23	0.17	,,	,,
10	SP/10	15	0.13	,,	,,

%Na = Percentage Sodium
SAR = Sodium Absorption ratio
Water Cls = Water Class for SAR based on the US Department of Agriculture (1954) Classification.
Hardness class based on Freeze & Cherry (1979)

Table 4: Percentage hardness of the water samples (Freeze and Cherry, 1979).

Hardness ($Ca^{+} Mg CO_3^{2-}$) mg/l	Water Classification	% Result of this Study
0 – 75	Soft	100
75 – 150	Moderately hard	-
150 – 300	Hard	-
>300	Very hard	-

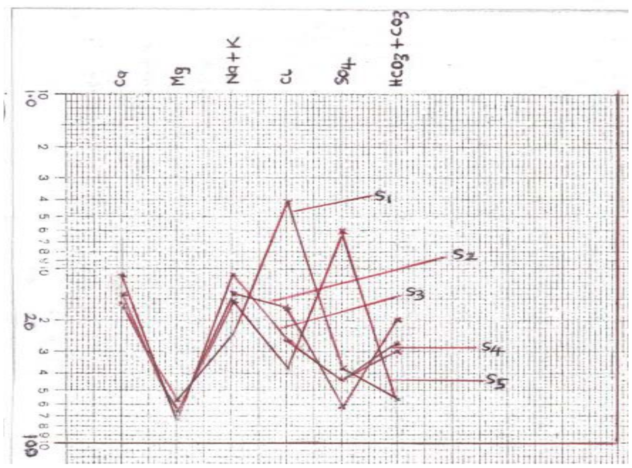

Figure 4: Schoeller semi-logarithmic plot of the water samples SP_1 – SP_5

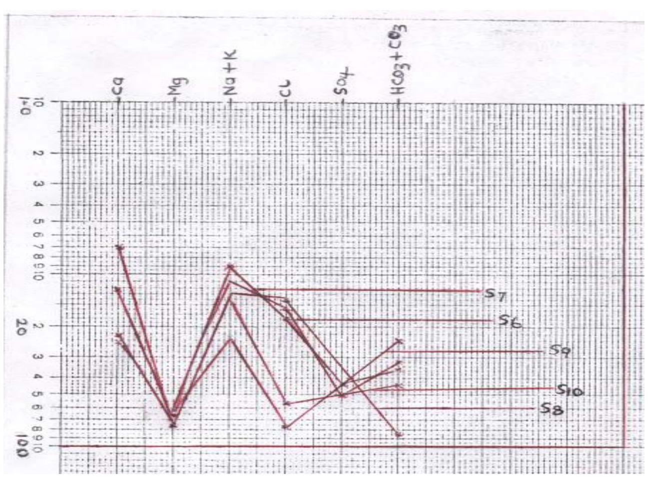

Figure 5: Schoeller semi-logarithmic plot of the water samples SP_6 – SP_{10}

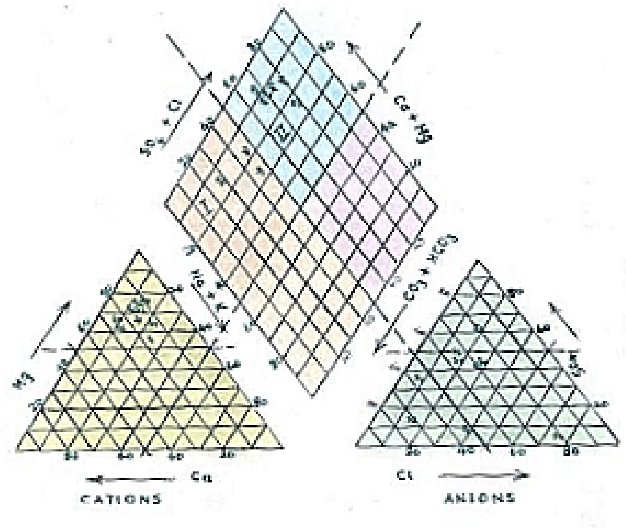

Figure 6: Trilinear diagram plot of the water samples.

DISCUSSION OF RESULTS

The physical parameter measured (color) falls within the WHO maximum permissible limit for drinking water, thus implying good water quality. Measured pH concentrations fall within the WHO maximum permissible limit, also indicating good water quality. The total dissolved solids (TDS), total hardness (T.H), Fe^{2+}, Ca^{2+}, Mg^{2+}, NO_3^{-}, SO_4^{2-}, Cl^{-} and CO_3^{2-} concentration levels all fall below the WHO (1984) highest desirable and maximum permissible limits, indicating good water quality. However, the Coliform count is excessively high at >2400MPN/100ml.

The WHO limit for potability is 0/100ml (Table 2). Possible reasons for the high Coliform bacteria count may be pollution from sewage effluents, human and animal waste, and solid waste discharge. Coliform analysis was carried out essentially to detect the bacteriological pollution in groundwater and surface water. The presence or absence of Coliform bacteria helps in the determination of water quality and potability. The springs in the study area are quite shallow and possibility of bacteriological contamination exits.

Estimates of %Na values ranged between 9 and 24. Based on the water classification of Doneen (1950) and Wilcox (1985), the spring water quality in the study area is good. The principal agricultural effects of sodium in water are a reduction in soil permeability and a hardening of the soil. They are caused by the replacement of calcium and magnesium ions by sodium ions in the soil clays and colloids. When high sodium water is applied to a soil, the number of Na^+ ions combining with the soil increases and an equivalent quantity of Ca^{2+}, or other ions, is displaced. This reaction causes deflocculation and a reduction of permeability (Fetter, 1980).

The sodium absorption ratio (SAR) is between 0.12 and 0.26. The SAR limits recommended by the salinity laboratory of the US Department of Agriculture (1954) directly reflects the degree of absorption of sodium by soil. The SAR values (Table 3) for the study area show that the spring water is excellent for irrigation and suitable for industrial use, this is based on the American water works association (1971) standards.

Percentage hardness (as in Ca + Mg CO_3^{2-}) of the groundwater reveals that the water is 100% soft (Table 4); this is on the basis of water hardness classification of Freeze & Cherry (1979). A Scholler semi-logarithmic plot was carried out to determine the relationship between the chemical constituents in the different water samples. Nearly all the samples show similar trend/signature except for samples 9 and 10, (Figures 4 and 5).

The trilinear plot was basically carried out to determine the hydrochemcial facies distributions of the samples. Hydrochemical facies is a term used to describe the variation in chemical composition of groundwater aquifers. The variation in the chemistry of the groundwater is a function of lithology, solution kinetics and flow pattern of the aquifer (Fetter, 1980). Hydrochemical facies analysis of the samples revealed a mixed type of HCO_3^- and SO_4^{2-} + Cl^-, both of which are rich in Mg^{2+}.

CONCLUSION

Results of this study show that spring water from Lekwesi/Umuchieze areas compares favorably with the WHO (1984) limits for domestic drinking water. Bacteriological analysis of the samples revealed high Coliform counts between 20 and >2400MPN/100ml. The high population of Coliform bacteria indicates poor sanitary conditions in the study area. The spring water is fit for human consumption after treatment for Coliform has been effected (e.g. Chlorination). The groundwater is, however, good for agricultural purposes due to the low concentration of %Na and SAR. The hardness class of the groundwater is soft and hydrochemical facies analysis revealed that the springs in the area are dominated by magnesium rich (Cation) facies and bicarbonate – sulfate – chloride (Anions) facies.

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