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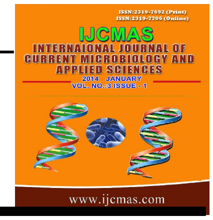

Original Research Article

Assessment of the Quality of Water Resources of Ahaba and Ovim Areas, Isuikwuato Southeastern Nigeria

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A B S T R A C T

Assessment of the quality of water resources of Ahaba and Ovim areas of Isuikwuato has been carried out with the aim to give out information on the physical, chemical and microbial properties of the water resources in the area in order to appreciate the impacts of natural and anthropogenic activities on the water quality. Ten (10) water samples from rivers, springs and boreholes were analyzed using standard methods. The results of the chemical analysis show that water resources of the area are generally acidic (pH range of 5.2 -6.0), soft (total hardness range of 4.00 – 43.00 mg/l), fresh (TDS range of 55.80 – 73.16 mg/l) and excellent for Agricultural purposes (SAR range of 0.63-1.73). The acidic nature of the water resources renders it unfit for industrial uses. The Piper Trilinear diagram delineated two dominant hydrochemical facies: Ca-(Mg)-Na-HCO_3 and Ca-Mg ($S0_4$)-HCO_3. The former facies group has appreciable amount of $NaHCO_3$ which is an indication of cation exchange water. The Ca-Mg ($S0_4$)-HCO_3 type falls within normal alkaline water and is predominantly hydrogen carbonate sulphate. The microbiological analysis result shows that the mean total heterotrophic bacterial count (THBC) were 3.0×10^5 and 4.5×10^5cfu/ml for SPA and SPB respectively, while 3.0×10^5 and 1.4×10^5 as well as 0.0×10^5 and 1.0×10^5cfu/100ml represent the total coliforms count(TCC) and feacal coliforms counts (FCC) for the spring waters (SPA and SPB). The THBC of the boreholes ranged from 1.6×10^5–3.5×10^5cfu/ml while those of TCC and FCC were 4.0×10^5–8.0×10^5 and 1.0×10^5–3.0×10^5cfu/100ml respectively. The organisms isolated include *Klebsiella* sp (20%), *Staphylococcus* sp (20%), *E. coli* (80%), *Streptococcus* sp (20%), *Salmonella* sp (20%), *Bacillus* sp (20%) and *Pseudomonas* sp (20%). The occurrence of the total bacterial isolates from each sample showed SPA (28.6%), SPB (42.9%), BH1 (28.6%), BH2 (14.3%), and BH3 (28.6%). The study revealed obvious microbial and chemical contamination of these water sources, probably by domestic, sewage and industrial wastes. Water from these sources should be treated before consumption, while comprehensive public healthsurvey is recommended before boreholes are sited

Keywords

Feacal coliforms; Geochemistry; Isuikwuato; Pollution; Spring; Water Facies.

Introduction

Drinking water has always been a major issue in many developing countries. In Nigeria, many of the rural populace do not have access to adequate water and therefore, depend on other alternatives like wells and surface water sources for domestic use. There is no substitute for water in any of its uses. However, as much as water is important in life, where and when it is available, it must be kept safe and free of contamination and pollution for the survival of mankind. Rivers are the most important freshwater resource for man. Unfortunately, river waters are being polluted by indiscriminate disposal of sewage, industrial waste and plethora of human activities, which affect their physico-chemical characteristics and microbiological quality (Koshy et al., 1999). Pollution of the aquatic environment is a serious and growing problem. Increasing numbers and amounts of industrial, agricultural and commercial chemicals discharged into the aquatic environment have led to various deleterious effects on aquatic organisms. Aquatic organisms, including fish, accumulate pollutants directly from contaminated water and indirectly *via* the food chain (Hammer 2004, Mohammed 2009).Groundwater quality depends, to some extent, on its chemical composition (Wadie et al., 2010) which may be modified by natural and anthropogenic sources. Rapid urbanization, especially in developing countries like Nigeria, has affected the availability and quality of groundwater due to waste disposal practice, especially in urban areas. Once groundwater is contaminated, its quality cannot be restored by stopping the pollutants from source (Ramakrishnaiah et al., 2009). As groundwater has a huge potential to ensure future demand for water, it is important that human activities on the surface do not negatively affect the precious resource (Sarukkalige 2009). Groundwater quality is mainly controlled by the range and type of human influence as well as geochemical, physical and biological processes occurring in the ground (Zaporozec 1981). It therefore becomes imperative to regularly monitor the quality of different water bodies and device ways to perfect it (Yisa et al., 2010).

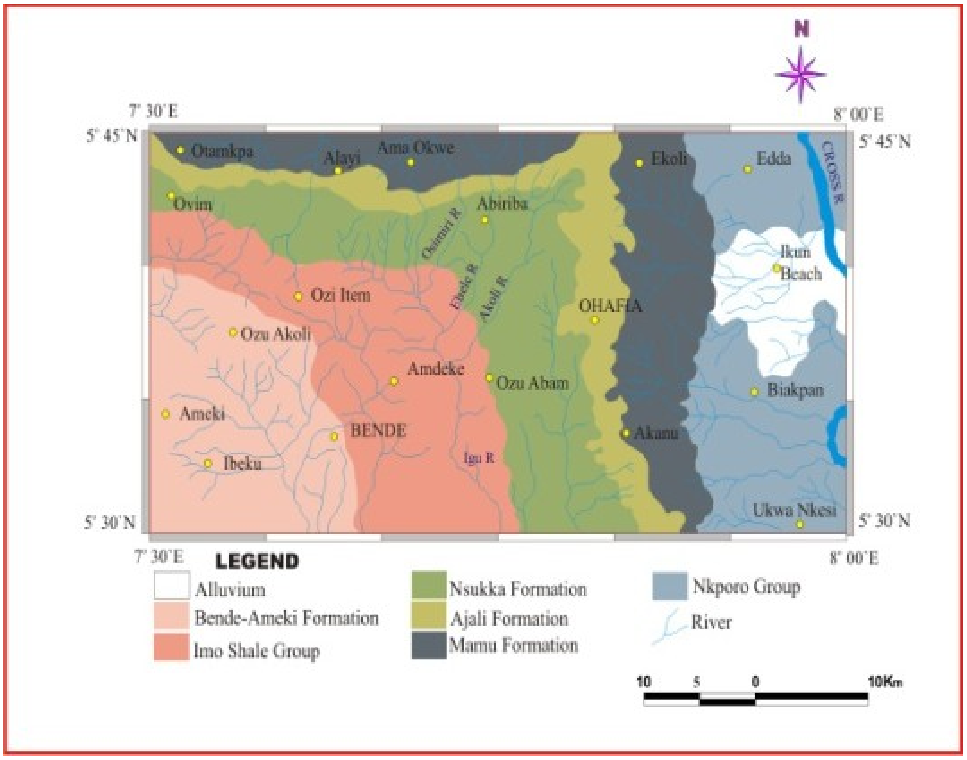
The objective of this work is to give out information on the physical, chemical and microbial properties of surface and groundwater systems in the area in order to appreciate the impacts of anthropogenic actions on the quality of the water resources of Ahaba and Ovim areas.

The study area

The study area comprises of Ahaba and Ovim axis, Isuikwuato Local Government Area of Abia state, located in the southeastern part of the country and lies within latitudes $5^o40'$N – $5^o49'$N and longitude $7^o 29'$ E -$7^o 37'$ E. It is bounded in the East by Bende L.G.A, North by Ozara town, West by Amaba town and South by Akoli Imenyi (figure 1). This area is accessible through diverse road networks. The flat landscape of the area is drained by the Isuikwuato River which has a southeastern flow direction and empties loads of clay/silt into the ocean, thereby helping to broaden the flood plain of the Nsukka, Ajali, and Mamu Formations through constant deposition of debris on the existing plain and building up levees. Discharge is normally very low during dry seasons. The river increases in turbidity with increase in water volume especially during raining seasons. The study area possesses rain forest type of vegetation.

The different Geologic Formations that outcrop within the study area comprises of three Formations namely: Nsukka Formation (formally referred to as the upper coal measure). Ajali Sandstone (formally called the false bedded sandstone) and Mamu

Figure.1 Geological map of Isuikwuato showing the study area



Formation (which has the lower coal measure as its old name) (figure 1). The Nsukka Formation, age Danian, has its type locality at Nadu River 14km north of Nsukka. It consists of an alternating succession of sandstone, dirty shale and sandy shale with thin coal seam at various horizons. The basal sandstone of the Nsukka Formation has a thickness of about 15m and is present throughout Nsukka and most of Udi division (Reyment, 1965). The Ajali Sandstone, age upper Maastrichtian, has its type section at Ajali River Enugu area. It consists of thick friable, poorly-sorted sandstones, typically white in colour but sometimes iron-stained. Large scale cross beding characterizes this formation with dip up to 20^{o}. The Mamu Formation, age lower Maastrichtian/Upper Senonian, has its type section at Mamu River Enugu district. It contains distinctive assemblages of sandstone, shale, mudstone and sandy shale, with coal seams at several horizons. Well bedded fine to medium sandstones that are white or yellow in colour. Generally, these do not allow easy flow of runoff waters in the area and thus streets/roads which do not have adequate drainage system are always flooded.

Materials and Methods

Data was acquired from libraries, field work and laboratory investigations. Topographic and geologic maps on a scale of 1: 250,000 were obtained from Nigeria geological survey department, Enugu. The ground water samples were collected near the well head of each of the sampled boreholes before the water went through tanks/treatment units. One (1) liter of water was collected from each borehole. Prior to all sample collection, the wells were pumped for about three to five minutes. This was to ensure collection of representative samples. Samples were collected in three (3) labeled, well drained plastic containers tightly corked. The choice of plastic containers is to minimize contamination that could alter the water constituents. The first container was 250ml for microbial test. The second (1 litre container) was acidified with two (2) drops of concentrated Nitric acid (HNO_3) for cations determination in order to homogenize and prevent absorption/adsorption of metals to the wall of the plastic container. Acidification equally stops most bacterial growth, inhibits oxidation reactions and precipitation of cations. The third plastic container (1 litre) was used for anion determination. Similarly too, surface water samples were collected in triplicate by complete immersion method and corked under water. These samples were preserved in cool boxes to keep the temperature below 20^{o}C for eventual transfer to the laboratory for analysis within 24 hours of collection. Sample Collection for the microbiological analysis was done as described by Cheesbrough (2004).

Sampling was done only in good weather condition to avoid rainwater contamination, as this would affect the quality of the samples collected. A three-in-one pH meter was used to determine the pH and TDS of the water samples while conductivity meter was employed for the determination of electrical conductivity (EC). These parameters were determined in situ. HACH DR 2800 Spectrophotometer was used in the determination of different hydro geochemical properties such as Na, K, HCO_3, Cl, NO_3, and SO_4. Other analyses such as the determination of Mg and Ca concentrations were done by complexometric titration method. Details of analytical procedures are reported in Omidiran (2000). The analytical data quality was evaluated by computing the sum of the equivalents of the cations with the sum of the equivalents of the anions (Hounslow 1995). A positive result means that both an excess cations or insufficient anion exists, and a negative result means the opposite. For freshwater, ionic balance is assumed to be good if it lies within the range of ±10% (Celesceri 1998). In this study, ionic balance values ranged from -0.84 to + 0.57%. For microbiological analysis, Sterilization of media was carried out by moist heat sterilization method using autoclave at 121^{o}C, 15psi for 15 minutes. Heat stable materials were sterilized using hot air oven at 161^{o}C for one hour as described by Cruickshank et al., (1982). Heat liable materials were asceptically rinsed with alcohol and distilled water. The water samples were asceptically subjected to ten-fold serial dilutions as described by Fawole and Oso, (2000). Spread plate technique as described by Dubey and Maheshwari (2004) was adopted for the inoculation of the samples. The inoculated duplicate agar plates were incubated at 37^{o}C for 24 hours for heterotrophic bacterial count (THBC) while total and feacal coliform counts (TCC and FCC) were determined after incubation at 45^{o}C for 24 hours in MacConkey agar. Identification of isolates was based on the scheme described by Cheesbrough (2004).

Results and Discussion

Physico-Chemical Results

The result of the physico-chemical analysis carried out on the samples obtained from the study area along with the World Health Organization Standard (WHO 2006) is presented on Table 1.

The data was represented graphically using bar charts and line plots. All the measured parameters conform to the

World Health Organization (WHO 2006) standard except for pH generally and Colour in some sampling locations (Table 1). Water resources in the study area are generally acidic as indicated by pH range of 5.2 -6.0. This general low pH range shows the absence of carbonate in solution, as carbonates usually occur in solution at pH of 8.2 and above (Ahiarakwem et al., 2002). The borehole at Chief Ekwe's compound (BH3) has the highest concentration of most of the physical parameters like Total Suspended Solids (TSS), Colour, Total Disolved Solids (TDS) and Conductivity (Figures 2 and 3). From the plots of the cation concentration of the different water bodies in the area it was observed that potassium ion dominates in all the surface and spring water sources whereas calcium ion is the dominant cation in the boreholes sampled (Figures 4 and 5). The presence of potassium in water may be due to agricultural activities. High concentration of calcium in water leads to scale formation and hardness (Ibeneme et al., 2013). The anion concentrations of all the water bodies show predominantly trioxo carbonate (Figures 6 and 7).

The total hardness of water from the study area ranges from 4.00 – 43.00 mg/l (Table 1). This result shows that the water is soft based on the classification after Hem 1985 (Table 2).

The TDS of water resources in the area ranges from 55.80 – 73.16 mg/l (Table 1), which shows that the water is fresh when compared with table 3.

The water quality for agricultural use is determined on the basis of its specific conductance (expressed as TDS), sodium content and boron concentration. Sodium content of water is mainly used to classify its suitability for agricultural purposes because sodium's reaction with soil reduces the soil's permeability. The parameter used is the Sodium Absorption Ratio (SAR).

$$SAR = \frac{[Na^{+}]}{[Ca^{2+} + Mg^{2+}]^{1/2}} \qquad \text{…………..(1)}$$

After determining the SAR, a table adapted from Etu-Efeotor (1981) (Table 4) was used to classify the SAR value so as to determine the water class for agricultural purposes

The SAR range of 0.63-1.73 suggests that the water falls within the excellent range (0-10), indicating that the water is very good for agricultural purposes.

The quality of water can be classified for various industrial uses on the basis of its TDS, Total hardness, pH and silica contents. Table 5 shows the classification of the studied water bodies based on AWWA 1991 standard.

Thus for the water resources of the area to be used for industrial purposes, the acidity must be reduced through processes, like introduction of lime, that increase pH values. The water resources of the area were found to have two dominant hydrochemical facies according to the Piper Trilinear diagram (Figure 8). These include Ca-(Mg)-Na-HCO_3 and Ca-Mg ($S0_4$)-HCO_3. According to Lohnert 1973, the former facies group has appreciable amount of $NaHCO_3$ which is an indication of cation exchange water. One of the characteristics of this water type is the higher carbonate hardness as compared to the total hardness. This in effect means that there is more HCO_3 than the available

Table.1 Result of the Physico-Chemical Parameters of the water samples

Sample Code	Cations				Anions				Other Physical/Chemical Parameters								
	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	HCO_3^- (mg/l)	Cl^- (mg/l)	NO^{3-} (mg/l)	SO_4^{2-} (mg/l)	Conductivity, (µmhoscm^{-1})	T.S.S (mg/l)	T.D.S (mg/l)	Ph@2 3^{o}C	Fe (mg/l)	Mn (mg/l)	T.H .(mg/l)	Turbidity NTU	Colour TCU
SW1	2.0	ND	3.5	3.49	18.3	ND	0.27	1.8	102.0	25.0	63.24	5.8	0.08	0.02	4.0	2.0	3.0
SW2	1.2	2.67	-	3.45	15.25	ND	0.066	ND	98.0	10.0	61.25	5.2	0.09	0.025	14.0	1.5	NIL
SW3	4.0	0.97	2.28	3.54	27.45	ND	0.221	1.0	98.0	20.0	60.27	5.7	0.08	ND	14.0	NIL	NIL
BH1	7.2	2.67	-	3.12	16.78	0.75	0.132	1.0	118.0	5.0	73.16	5.5	0.11	0.015	29.0	3.5	NIL
BH2	2.4	2.43	2.39	3.48	27.45	0.5	0.11	2.5	97.0	18.0	60.63	5.5	0.14	ND	16.0	NIL	NIL
BH3	9.6	4.62	-	5.04	41.18	ND	0.221	13.8	112.0	160.0	70.0	5.2	0.03	0.001	43.0	3.2	140.0
SPA	1.6	1.22	2.9	2.71	13.73	4.15	0.20	0.8	91.0	15.0	56.42	5.7	0.08	ND	9.0	5.0	50.0
SPB	1.6	1.46	1.1	3.68	13.73	ND	0.133	5.0	98.0	5.0	60.75	5.5	0.15	0.02	10.0	2.0	2.0
SPC	1.2	1.7	-	2.94	7.63	ND	0.044	0.6	105.0	5.0	65.10	5.5	0.10	ND	10.0	NIL	NIL
SPD	2.0	2.19	-	2.82	18.3	0.5	0.155	0.5	93.0	25.0	55.80	6.0	0.03	0.02	14.0	NIL	NIL
WHO (2006)	75	20	200	200	500	200	10	250	1000		500	6.5-8.5	0.3	0.01	100	5	15

Note: ND=Not detected, **Nil**=None, **SW**=Surface Water, **BH**=Borehole, **SP**=Spring Water.

SPA= Ngeleoyiri Spring (Ovim), **SPB=** Erimano spring (Ahaba), **SPC=** Source spring (Amaba), **SPD=** Iyisukulu spring (Ovim), **SW1=** Emeamiyi River (Ahaba), **SW2=** Nnuocha stream (Umukogbuo), **SW3=** Iyiagbagidi River (Ahaba), **BH1=** Borehole at Eze Nwachukwu's compound (Ahaba), **BH2=** Borehole at Oriendu Market (Ovim), **BH3=** Borehole at Chief Ekwe's compound (Ahaba).

Figure.2 Concentrations of the Physical Parameters of the water samples presented in bars.

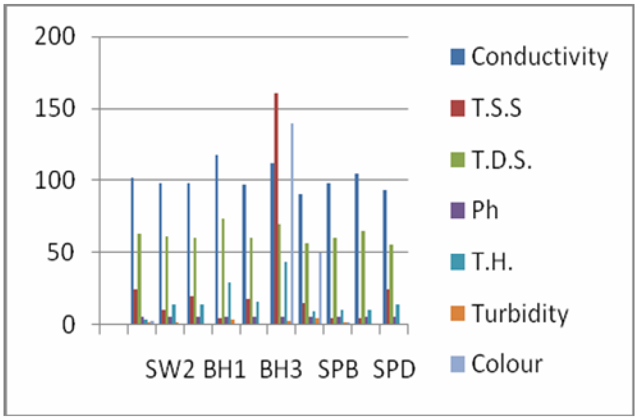


Figure.3 Concentrations of the Physical Parameters of the water samples presented as a line plot

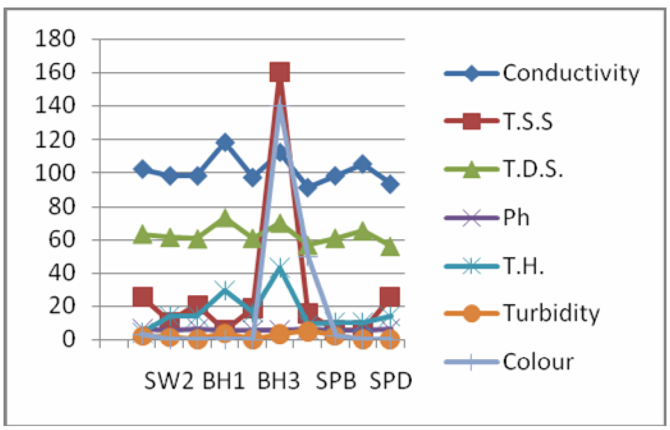


Figure.4 Cations concentration of the water samples presented in bars

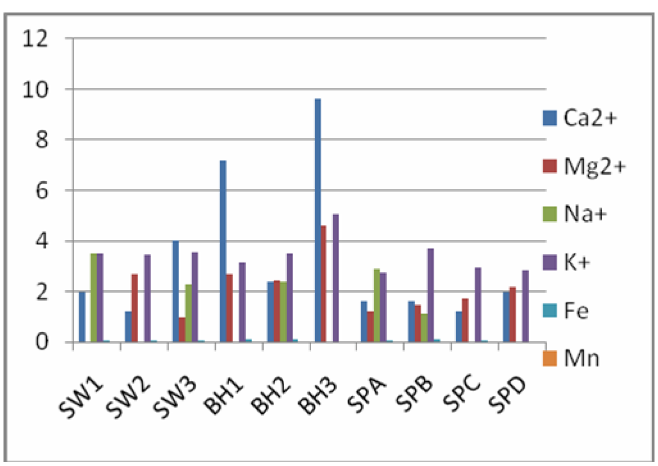


Figure.5 Cations concentration of the water samples presented as a line plot.

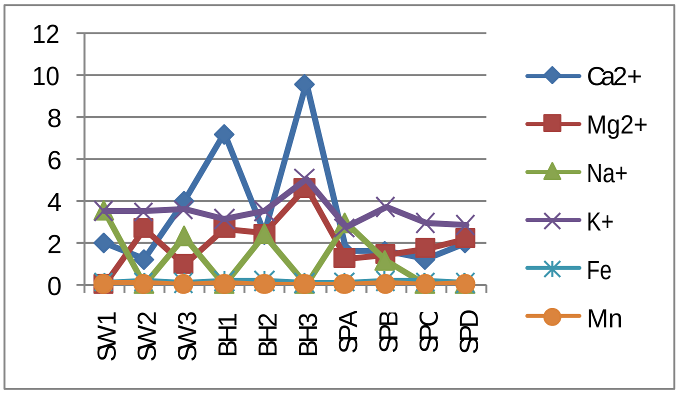


Figure.6 Anions concentration of the water samples presented in bars.

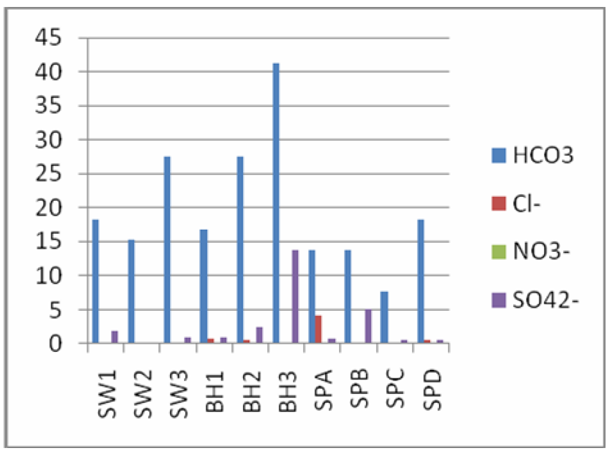


Figure.7 Anions concentration of the water samples presented as a line plot.

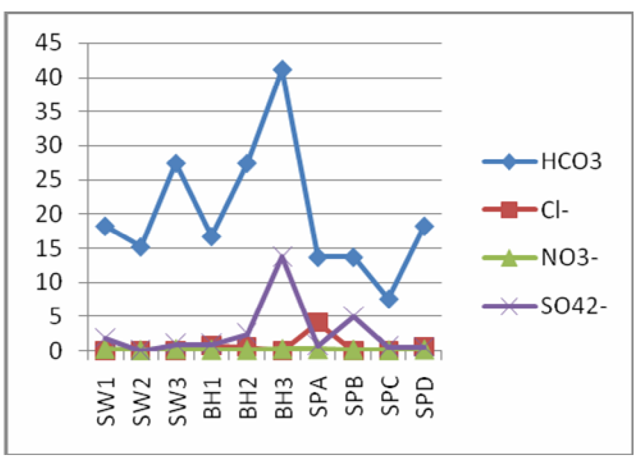


Table.2 Water quality classification on the basis of Total Hardness (mg/l) as $CaCO_3$ (after Hem, 1985)

HARDNESS (mg/l)	WATER CLASS
0-60	Soft
61-120	Moderately Hard
121-180	Hard
180	Very hard

Table.3 Water quality classification based on TDS (after Carol, 1962).

CATEGORY	TDS mg/l
Fresh water	0 – 1000
Brackish water	1,000 – 10,000
Saline water	10,000 – 100,000
Brine water	100,000

Table.4 Water Classification for Agricultural purposes (Adapted from Etu-Efeotor 1981)

SAR	WATER CLASS (for agricultural purposes)
0 - 10	Excellent
10 – 18	Good
18 – 26	Fair
26	Poor

Table.5 Classification of the studied water bodies based on AWWA 1991 standard.

Parameters (mg/l)	Measured values in the study area			AWWA accepted Standard (mg/l)
	Mean SW	Mean BH	Mean SP	
TDS	61.58	67.98	59.52	50.1-500
Total Hardness	10.67	29.33	10.75	0-250
Iron	0.082	0.093	0.09	0.1-10
pH	5.57	5.4	5.66	6.5-8.3
Cl^-	ND	0.625	2.33	20-250
Mn	0.023	0.008	0.02	0-0.5

Figure.8 Piper Trilinear plot of the water samples

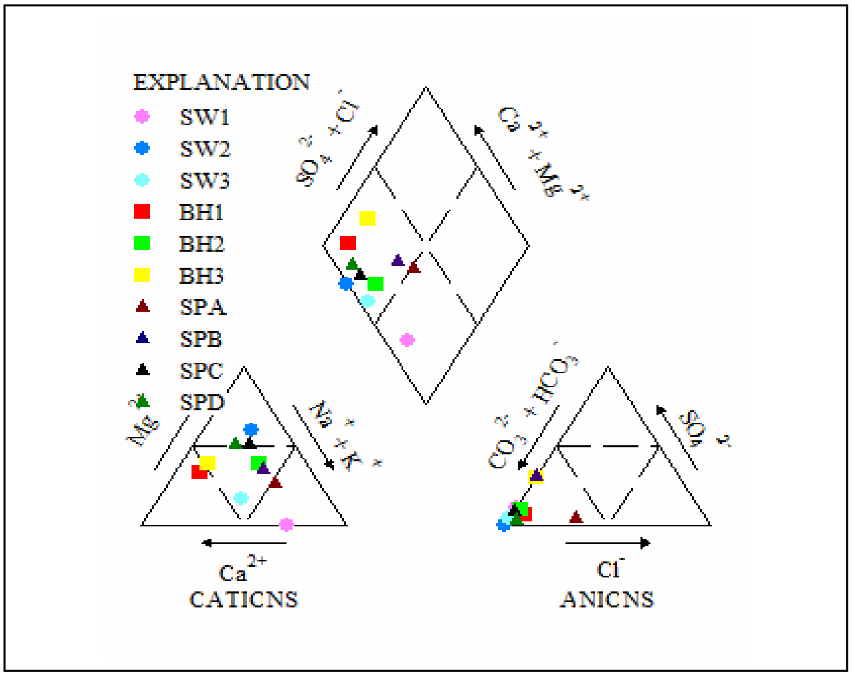


Table.6 Mean Total Heterotrophic Bacterial and Coliform Counts of the Spring and Borehole Waters

Sample	THBC (cfu/ml)	TCC(cfu/100ml)	FCC(cfu/100ml)
SPA	$3.0x10^5$	$3.0x10^5$	$0.0x10^5$
SPB	$4.5x10^5$	$1.5x10^5$	$1.0x10^5$
BH1	$3.5x10^5$	$6.0x10^5$	$2.0x10^5$
BH2	$1.6x10^5$	$8.0x10^5$	$1.0x10^5$
BH3	$2.3x10^5$	$4.0x10^5$	$3.0x10^5$

Table.7 Distribution of Bacterial Isolates from the Spring and Borehole Waters

Isolate	SPA	SPB	BH1	BH2	BH3	% Occurrence[b]
Klebsiella	+	-	-	-	-	20
Staphylococcus	+	-	-	-	-	20
E. coli	-	+	+	+	+	80
Streptococcus	-	+	-	-	-	20
Salmonella	-	+	-	-	-	20
Bacillus	-	-	+	-	-	20
Pseudomonas	-	-	-	-	+	20
% Occurrence[a]	28.6	42.9	28.6	14.3	28.6	

a = % Occurrence of total isolates from each sample
b = % Occurrence of individual isolates across the sample
+ = Positive, - = Absent

alkaline earth metal ions (Ca^{2+} and Mg^{2+}) in equivalent concentration (Lohnert 1970). These excess bicarbonate ions then release the alkaline (notably Na^{+}) into the solution by exchange reaction with the cation exchangers such as clay minerals. The Ca-Mg ($S0_4$)-HCO_3 type falls within normal alkaline water and is predominantly hydrogen carbonate sulphate.

Microbiological Results

The mean result of the total heterotrophic bacterial count (THBC) as well as total and feacal coliforms counts for the spring (20%), *Bacillus* sp (20%) and *Pseudomonas* sp (20%). The occurrence of the total bacterial isolates from each sample showed SPA (28.6%), SPB (42.9%), BH1 (28.6%), BH2 (14.3%), and BH3 (28.6%).

The presence of *Klebsiella*, *Staphylococcus*, *Escherichia coli*, *Streptococcus*, *Salmonella*, *Bacillus* and *Pseudomonas* species in some of the ground water sources analyzed is indicative of the poor sanitary quality of the water sources. All the water sources except Ngeleoyiri spring, recorded both total coliform and feacal coliform counts high above the limits of USEPA Maximum Contamination Levels of < 100cfu/ml in drinking water (USEPA, 2003). The high feacal coliform in most of the water sources studied is indicative of possible pollution by human excreta. This agrees with reports by Duru *et al*., (2012) and Okechi *et al*., (2013).

The World Health Organization recommended one *E. coli* colony per 100ml of water sample to be normal (WHO, 2006). However, this indicator organism was found in large numbers at Erimano spring and all the borehole water and borehole waters are as shown in Table 6. The TBHC were $3.0x10^5$ and $4.5x10^5$cfu/ml for SPA and SPB respectively, while $3.0x10^5$ and $1.4x10^5$ as well as $0.0x10^5$ and $1.0x10^5$cfu/100ml represent TCC and FCC for the springs. The THBC of the boreholes ranged from $1.6x10^5$–$3.5x10^5$cfu/ml while those of TCC and FCC were $4.0x10^5$–$8.0x10^5$ and $1.0x10^5$–$3.0x10^5$cfu/100ml respectively. Table 7 shows the percentage distribution of the bacterial isolates from different spring waters and boreholes. These organisms include *Klebsiella* sp (20%), *Staphylococcus* sp (20%), *E. coli* (80%), *Streptococcus* sp (20%), *Salmonella* sp samples studied, with a prevalence rate of 80%. The presence of this indicator bacterium suggests the possible presence of pathogens causing cholera, typhoid and gastroenteritis, thus calling for initial treatment before such waters are consumed.

Streptococcus sp which also depicts possible feacal contamination recorded 20% prevalence rate, having been isolated in Erimano spring. According to Cheesbrough (2004), feacal streptococci may sometimes be of value in confirming the feacal nature of water pollution. *Klebsiella* and *Salmonella* species are human enteric pathogens. Both recorded prevalence of 20%, having been isolated in either of the two spring waters. *Salmonella* species have been implicated in various forms of salmonellosis. The typhoid and paratyphoid species cause typhoid and paratyphoid fever, which can be fatal and can spread through contaminated drinking water (Greenwood et al., 1992). *Staphylococcus* species was isolated from Ngeleoyiri spring. The organism being a normal flora of the human body, its presence in water suggests poor human handling. *Pseudomonas* and *Bacillus* species occurrence can be attributed to their widespread distribution in aquatic and soil ecosystems as reported by Rogers *et al*., (1977).

Conclusion

Water resources of the study area are generally acidic, soft, fresh and excellent for Agricultural purposes. Some parts of the area do not permit adequate ion exchange reaction between the soil and percolating rainfall, at shallow depth. This can be attributed to the high concentration of Mn^{2+} in this water samples from boreholes within these localities. For the water resources of the area to be used for industrial purposes, the acidity must be reduced through processes, like introduction of lime, that increase pH values. The boreholes sampled at Ahaba contain more physical and chemical parameters as well as microbiological isolates than that of Ovim. This could be as a result of anthropogenic activities occasioned by population increase at Ahaba than Ovim. The study revealed obvious microbial contamination of these ground water sources, probably by domestic, sewage and industrial wastes. Water from these sources should be treated before consumption, while comprehensive public health survey is recommended before boreholes are sited.

References

Ahiarakwem, C.A. and Ejimadu, O.G.2002. Geochemical properties of Ground water in Orlu area, Imo State, Southeastern Nigeria. Water Resources Journal, 13, 19-22.

AWWA 1991. American Waste Water Association, 14.

Carol, D., 1962. Rain water as a chemical agent of Geologic process. A review US Geological Survey of Water Supply paper 1535-G,18.

Celesceri, L. Greenberg A.E. and Eaten A.D. 1998. Standard method for the examination of water and waste water, American Public Health Association, Washington, 134.

Cheesbrough, M. 2004. District Laboratory Practice in Tropical Countries, Part 2. Cambridge University Press, Cambridge.140.

Cruickshank, R., Dugauid, J.P. Marmoin, B.P. and Swain, R.H.A. (1982). The Practice of Medical Microbiology. 13th Ed. Churchill Livingstone, Edinburgh, 273-284.

Dubey, R.C. and Maheshwari, G. 2004. Methods for Study of Microorganisms. Practical Microbiology. 2nd Ed. S. Chand and Company Ltd, Ram Nogar, New Delhi, 19-301.

Duru, C. N., Okechi, R.N., Ukagwu, N., Ibe, I.J and Ahumibe, N.C. (2012). Bacteriological Quality of Municipal Borehole waters in Imo State, Nigeria. Journal of Biodiversity and Environmental Sciences 2(11), 18-22.

Etu-Efeotor, J.O. 1981. Preliminary Hydro geochemical investigation of subsurface waters in parts of the Niger Delta, Jour. Min. Geol. 18(1), 103-106.

Fawole , M. O. and Oso, B.A. 2000. Laboratory Manuel of Microbilogy. 2nd Ed. Spectrum Books Ltd, Ibadan. 1-115.

Greenword, D., Slack, R.C.B. and Peutherer, J. F. 1992. Medical Microbiology. A Guide to Microbial Infection Pathogenesis, Immunity, Laboratory Diagnosis and Control 14th Ed. Church Livingstone, Uk, 420.

Hammer, M.J. 2004. Water and Wastewater Technology. 5th ed. Practice-Hall Inc.; Upper Saddle River, NJ, USA, 139–141.

Hem, J. D. 1985. Study and Interpretation of the Chemical characteristics of natural water. Geological survey water supply paper, Washington DC: New York US, 397.

Hounslow A.W. 1998. Water Quality data analysis and interpretation Lewis, New York.

Ibeneme, S.I., Ukiwe, L.N. Selemo, A.O., Okereke, C.N., Nwagbara, J.O., Obioha Y.E., Essien A.G., Ubechu B.O., Chinemelu E.S., Ewelike E.A. and Okechi R.A. 2013. Hydrogeochemical study of Surface water Resources of Orlu, Southeastern Nigeria. International Journal of Water Resources and Environmental Engineering 5(12), 670-675.

Koshy, M., Nayar, T.V. 1999. Water quality aspects of River Pamba. Pollut. Res. 18, 501–510.

Lohnert, E.P. 1973. Austauschwaesser In H Schneider (Hrsg) Die Grunwasserchliessung 2nd Edition, Vulkan Verlag Essen,138-144.

Lohnert, E.P. 1970. Grundwasserchemismus und kationentaush im norddeutschen Flachland Z dt geol Ges, Sonderheft. Hydrgeol Hydrogeochem, Hannover, 139-159.

Mohammed, F.A.S. 2009. Histopathological studies on *Tilapia zilli* and *Solea vulgaris* from lake Quran, Egypt. World J. Fish Mar. Sci. 1, 29–39.

Omidiran, P.C. 2000. Fundamentals of geology 3rd ed. W.B. standards company, Philadelphia 230.

Okechi, R.N, Onyekere, J.A, Azuwike, C.O, Nnokwe, J.C., Ibe, I. J. and Ukagwu, N. 2013. Groundwater Quality of Boreholes located Around Cassava Processing Mills. Journal of Research in Public Health 2(11), 056-062.

Piper, A.M. 1953. A Graphic Procedure in the Geochemical Interpretation of water Analysis. US Geol. Survey. Washington D.C ISBN ASIN: B0007H2Z36.

Ramakrishnaiah, C.R. Sadashivaiah, C. and Ranganna, G. 2009. Assessment of Water Quality Index for Groundwater in Tumkur Taluk, Karnataka State, India. E-Journal of Chemistry. 6(2), 523-530.

Reymet, R.A. 1965. Aspec,ts of Geology of Nigeria. Ibadan University press. 145pp.

Rogers Y.S, Edavid A. A. and John L. I. 1977. General Microbiology. 4th Ed. Macmillan Publishers Ltd, London, 595-596.

Sarukkalige, P.R. 2009. Impact of land use on groundwater quality in Western Australia. Improving Integrated Surface and Groundwater Resources Management in a Vulnerable and Changing World. Proc. of JS .3 at the Joint IAHS and IAH Convention, Hyderabad, India, IAHS Publ, 136-142.

USEPA (United State Environmental Protection Agency) 2003. Drinking Water Quality Standars. Edstrom Industries, Waterfood, Wisconsin, 12.

Wadie, A.S.T and Abduljalil, G.A.D.S (2010). Assessment of hydrochemical quality of groundwater under some Urban areas within Sana'a Secretariat. Ecletica quimica. www.SCIELO.BR/EQ. 35(1), 77-84.

World Health Organistion .2006. Guidelines for Drinking water. First Addendum to the 1st Ed. Vol. 1 Recommendations, Geneva, 595.

Yisa, J. and Jimoh, T. 2010. Analytical Studies on Water Quality Index of River landzu. Ame. J. Appl. Sci. 7(4), 453-458.

Zaporozec, A. 1981. Groundwater pollution and its sources. Geo. J., 5(5), 457-471.