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Hydrochemistry; Compliance And Comparative Case Study of Public Water Works In Enugu And Ebonyi States, Southeast of Nigeria.

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Abstract
The compliance and comparative case study of public water works in Enugu and Ebonyi State of Nigeria was carried out in this study. The water samples were collected at Ajali water treatment plant Enugu State (Sample A), 9 Works road GRA, Enugu State (Sample B), Ezilo water Scheme Ebonyi State (Sample C) and Ameke in Ezilo Ebonyi State (Sample D). Ten physicochemical parameters and water like- metals such as SO_4^{2-}, Cl^-, NO_3, Mg^{2+}, Ca^{2+}, Na^+, Pb, Ni, Cr, and Al were determined in rainy season in for one year. The results shows that chloride (Cl^-), (A = 97 mg/l, B = 121 mg/l, C = 97 mg/l, D = 119 mg/l); nitrate, (A = 3.11 mg/l, B = 1.29 mg/l, C = 1.10 mg/l, D = 0.70 mg/l); total phosphate, (A = 1.97 mg/l, B = 0.26 mg/l, C = 0.32 mg/l, D = 0.42 mg/l); Biological oxygen demand (BOD), (A = 0.25 mg/l, 6.00 mg/k, C = 1.10 mg/l, D = 7.40 mg/l); Chemical oxygen demand (COD), (A = 50.67 mg/l 10.67 mg/l, C = 30.39 mg/l, D = 26.67 mg/l); Electrical conductivity (EC), (A = 100 µs/cm, B = 30 µs/cm, C = 200 µs/cm, D = 250 µs/cm); and pH, (A= 7.60, B = 6.62, C = 5.50, D = 5.90) mostly conform to the WHO set standard for drinking water. While TS, TDS, and TSS were (A =205, B =535, C =151, D =183 mg/l), (A =,60 B =555, C =121, D =128 mg/l) and (A =145, B =280, C =30, D =55 mg/l) respectively. Further more, the results of the heavy metal analysed showed that; Lead (Pb) was not detected in all water samples; Nickel (Ni) was observed to be 0.07 mg/l in the water sample collected from Sample A; Sample B contained 0.03 mg/l; Sample C not detected while in Sample D, it was 0.04 mg/l;. Chromium (Cr) was observed to be 0.01 mg/l in Sample A, it was not detected in both water samples B and C but was 0.02 mg/l in Sample D; which means that all the water samples studied conform to the WHO set standard for chromium in drinking water. Aluminium (Al) was observed to be 0.05 mg/l, 0.01 mg/l, Not detected and 0.03 mg/l in water sample A, Sample B, Sample C and Sample D. There is a variation in the Mg^{2+} in Ebonyi water. Hpwever, It was observed that the physical parameters of the water samples analysed were within the World Health Organisation (WHO) set standard for drinking water.

Keyword: *Hydrochemistry, Compliance, Cations, Abakiliki, Ajalli and Evaluation.*

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I. Introduction

Water is one of the most abundant and essential resources of man, and occupies about 70% of earth's surface. About 97% of this volume of earth's surface water is contained in the oceans, 21% in polar ice and glaciers, 0.3-0.8% underground, 0.009% in inland freshwaters such as lakes, while 0.00009% is contained in rivers; Eja, M. E. (2002). According to Rylander, R. (2008), more than 97% of earth's water is in the oceans and ice caps, and glaciers account for another 2%. Also, the ocean comprises 97%, while 3% of the earth's water is fresh water as stated by Kulshneshtha; (1998). Water in its pure state is acclaimed key to health and the general contention is that water is more basic than all other essential things to life. Man requires a regular and accessible supply of water which forms a major component of the protoplasm and provides an essential requirement for vital physiological and biochemical processes. Man can go without food for twenty eight days, but only three days without water, and two third of a person's water consumption per day is through food while one third is obtained through drinking. Muyi; (2007).

Apart from the essential role played by water in supporting human life, it also has, if polluted, a great potential for transmitting a wide variety of diseases. According to Ogbulie, J. N *et al.* (2010), in most developing countries like Nigeria where dangerous and highly toxic industrial and domestic wastes are disposed

of by dumping them on the earth; into rivers and streams with total disregard for aquatic lives and rural dwellers, water becomes an important medium for the transmission of enteric diseases in most communities. Poisonous chemicals are known to percolate the layers of the earth and terminate in ground waters thereby constituting public health hazards. In Enugu and Ebonyi states, share certain anthropogenic activity like the improper waste disposal, ineffective and low function-ability of the state water boards etc. This areas suffers from non-provision of potable water supply as the government at the various levels of leadership has failed consistently in the provision of potable water, thereby, making the inhabitants of the states to depend largely on private borehole water supply which is of doubtful quality.

From time immemorial, researches have focused on the evaluation of water quality status for domestic and industrial use (Carolyn, E (2010). Many of these articles focused on the measurement of water pH, chloride (Cl^-), nitrate (NO^{3-}), bicarbonate (HCO^{3-}), total alkalinity, total hardness, total dissolved solids (TDS), sulphate (SO_4^{2-}), iron (Fe^{2+}), biochemical oxygen demand (BOD), micro-organisms, among other water quality indices. In this direction, World Health Organization (WHO) set an international reference point as standard for drinking-water safety WHO (2006). The standard prescribed "good-water" as a term described as being wholesome and palatable. To be wholesome, water must be free from disease causing organisms, poisonous substances and excessive amount of minerals and organic matter. To be portable, it must significantly be free from colour, turbidity, taste, and must be well aerated, this is according to Hillary, *et al*; (2021). This study therefore, aims to study the compliance and comparative case study of public water works in Enugu and Ebonyi states, south east of Nigeria.

Physiography and climate of the locations

Two main seasons exist in the climatic region within Ajalli water scheme (Enugu state) and Ebonyi state (Abakaliki) area, the dry season which lasts from November to March and the rainy season which begins in April and ends in October with a short period of reduced rains in August commonly referred to as "August break". Temperature in the dry season ranges from 20 to 38°C,and results in high evapotranspiration, while during the rainy season temperature ranges from 16 to 28°C, with generally lower evapotranspiration. The average monthly rainfall ranges from 31 mm in January to 270 mm in July, with the dry season experiencing much reduced volume of rainfall unlike the rainy season, which has high volume of rainfall. Average annual rainfall varies from 1,500 to 1,650 mm. These climatic conditions are responsible for the development of thick lateritic soils in the area Aghamelu *et al*, (2011).

Study Area

Abakaliki, Ebonyi State of Nigeria is situtated in 6^0 041N, 06° 651E with mean annual rainfall of 1700 mm, distributed between April and November and farming is the major activity in the area. Other activities of the area include small scale industries and informal services. The dry season is within December – March while the minimum and maximum temperatures of the area are 27°C and 31°C, respectively Ofomata G.E, (1975). The relative humidity is 30–45% during dry season and 60 – 65% during raining season. The soil of the area belongs to the order Ultisoil classified as Typic Haplustult FDALR, (1985).

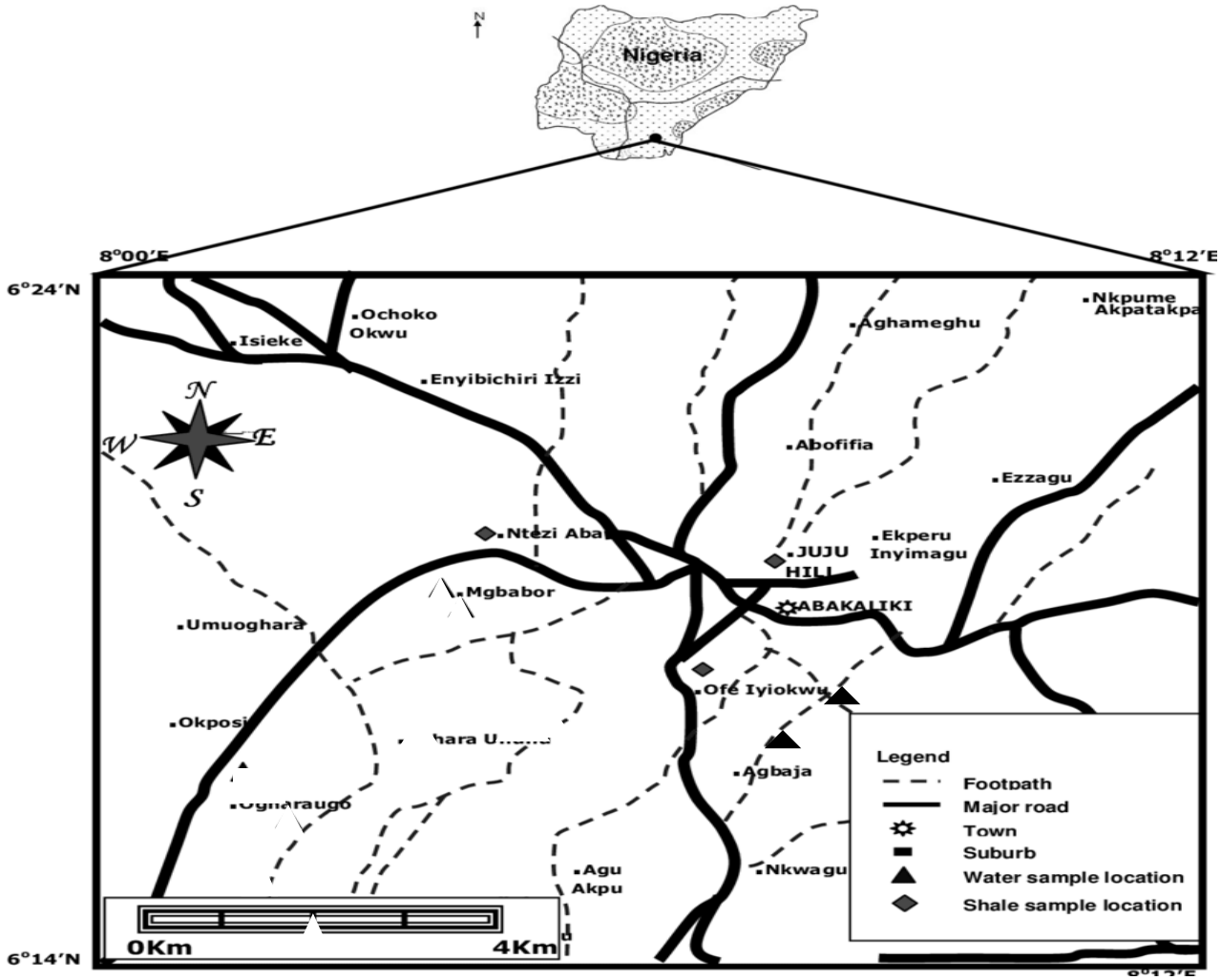

Figure 1. Map of Abakaliki area showing areas of sample collection (Enlarged from map of Nigeria)

Figure 2. Map of Ajalli water scheme

While River Ajali, lies Udi and Ezeagu axis of Enugu State. River Ajali is a stream of running water moving to a lower level channel on land along Umumba village in Ezeagu local government area. Its coordinate is 6° 25′ N and 7° 15′ E, which covers an area of about 633km^2. The Ajali River Aguobu-Umumba watershed is predominantly underlain by Ajali and Nsukka Formations at upland and Mamu Formations in the lowlands. The poorly sorted Ajali sandstones are easily washed away by concentrated runoff from prolonged and torrential rainfall. The soil of the study area is sandy with small percentage of silt/clay (Nweke 2015). The Ajali sand- stone formation is considered a good aquifer, and there is existing groundwater exploitation.

II. Materials And Methods

Sample Collection and Preparation

Water samples were collected from four sites of the areas under study (Figure 1 and 2). Sixteen grab samples were collected for each season from the four sites. Dry season (December to March) and wet season (April to November). Water samples were collected in 1000 cm^3 polyethylene sterilized bottles (cleaned with metal-free soap, washed with distilled water, soaked in 10% nitric acid for 24 hours and finally rinsed with ultra pure water).The temperature and pH were taken immediately on the spot. The samples were then transported to the laboratory in ice-cooled container and delivered to the laboratory on the same day. All the samples were stored in a refrigerator at 4 °C for further the determination of other parameters. Table 1.0 shows the description of the areas under study where the samples were collected.

Table 1.0: Description of the areas under study where the samples were collected

Sampling point	Latitude/Longitude	Area Description
Point A	6° 20′ 36.964″ N 7° 16′ 15.909″ E	Water from water supply pipe after treatment along Umumba community in Ezeagu at various seasons.
Point B	6° 20′ 13.410″N 7° 15′ 53.703″ E	Water sample collected from a tap water at 9 works road GRA, Enugu at various seasons.
Point C	06^0 04'N, 06° 65E 08^0 12'E	Water sample collected from Ezilo water Scheme in Ebonyi state
Point D	6° 14′ N, 8^0 00E 8° 12' E	Water sample collected from a tap in Ameke, Ezilo in Ebonyi state.

III. Results And Discussion

Table 2: The results of physicochemical parameters determined in the analysed samples compared with WHO Standard.

Parameters	pH	Conductivity (µs/cm)	TS (mg/l)	TDS (mg/l)	TSS (mg/l)	BOD (mg/L)	COD (mg/L)	Colour
WHO Standard	**6.50-7.50**	**300.00**	**500**	**500**	**-**	**25.00**	**80.00**	**Colourless**
A	7.60	100.00	205	60	145	0.25	50.67	Colourless
B	6.62	30.00	435	555	280	6.00	10.67	Colourless
C	5.50	200.00	151	121	30	1.10	30.39	Colourless
D	5.90	250.00	183	128	55	7.40	26.67	Colourless

Key: A = Water sample collected at Ajali water treatment plant.
B = Sample collected from a tap at 9 Works road GRA, Enugu.
C = Water sample collected from Ezilo water Scheme.
D = Water sample collected at Ameke in Ezilo.

Table 3: The results of the water-like anions and cations determined in the samples under study compared with WHO standard

Parameters	Cl^- (mg/L)	NO^{3-} (mg/L)	PO_4^{3-} (mg/L)	Pb (mg/L)	Mg^{2+}	Ca^{2+}	Na^+	Ni (mg/L)	Cr (Mg/L)	Al (mg/L)
WHO Standard	**200.00**	**10.00**	**2.00**	**0.01**	**50.0**	**76.0**	**10.0**	**0.05**	**0.05**	**-**
A	97.00±0.20	3.11±0.46	1.97±0.10	ND	3.9±0.16	51.2±0.2	1.7±0.15	0.07±0.01	0.01±0.02	0.05±0.04
B	121.00±0.18	1.29±0.21	0.26±0.16	ND	3.3±0.11	49.7±0.2	2.8±0.13	0.03±0.05	ND	0.01±0.-3
C	107.00±0.11	1.10±0.43	0.32±0.19	ND	66.0±0.09	56.2±0.3	5.3±0.22	ND	ND	ND

D	119.00±0.15	0.70±0.27	0.42±0.22	ND	62.2±0.19	49.6±0.16	4.7±0.11	0.04±0.1	0.02±0.2	0.03±0.01

IV. Discussion

The result of the water samples under study are shown in Table 2 and 3., it was observe that the physical parameters of the water samples analysed were within the World Health Organisation set standard for drinking water; the p^H of water collected from Ajali water scheme and Government Reserved Area in Enugu State was observe to be 7.60 and 6.62 respectively which were within the WHO;(2006) set standard for drinking water and is also applicable to water samples collected from Ezilo water scheme and Ameke all in Ebonyi State was observed to have p^H of 5.50 and 5.90. Drinking water with pH value above the range has been reported to cause nutritional imbalance in the man WHO; (2005). The total hardness of Ajali River water samples varied from 30.00 to 145.00 mg/L which is within the WHO;(2006) standard for drinking water. On this basis, Ajali water scheme is fresh-water indicating its suitability for drinking purposes. The presence of dissolved ions in water is indicated by the electrical conductivity (EC) of the water, and it increases with increase in the ionic concentration. In this study, the EC ranged from 30 to 250 µS/cm with an average value of 102.5 µS/cm. This goes to show that the water scheme in Enugu and Ebonyi state with respect to its EC are suitable for drinking. Biological oxygen demand (BOD) was between 0.25 to 7.40 mg/l for all the water samples under study and were within WHO set standard for biological oxygen demand of drinking water which was set at 25 mg/L, Chemical oxygen demand (COD) was within 10.67 to 50.67 mg/L and was within WHO set standard for chemical oxygen demand of drinking water which was set at 80 mg/l. More so and very important, all the water samples collected were colourless and odourless at ambient temperature.

The results of the study of Cl^-, NO^{3-}, PO_4^{3-},Pb, Mg^{2+}, $Ca^{2+,}$ Na^+, Ni, Cr, and Al are shown on Table 3. The order of increase in Cl^- was B >D > C > A with the highest value of 121.00±0.18 while the lowest value of Cl^- was recorded in A (97.00±0.20). The lowest and highest NO^{3-} values are 0.70±0.27 mg/l and 3.11±0.46 mg/l were observed in A and D, respectively while B and C recorded 1.29±0.21 and 1.10±0.43 mg/l of NO^{3-} , respectively. The $Cl^-$and NO^{3-} in all the water sources studied were within the acceptable limit. According to WHO; (2005), any water with the concentration of Cl^- and NO^{3-} above 200 and 10 is unfit for drinking. Phosphate was within 1.97 mg/L and was within WHO set standard for phosphate in drinking water which was set at 2 mg/L. Table 3 shows also, the concentration of Pb, Ni, Cr, and Al. Pb in the entire water scheme in both state. Nickel (Ni) was observed to be 0.07±0.01 mg/l in the water sample collected from Ajali water scheme which is above the recommended standard, 0.03 mg/l in water sample collected from Government Residential Area in Enugu State, Not detected in the water sample collected from Ezilo water scheme but 0.04 mg/l of nickel was observed in water sample collected from Ameke. Chromium (Cr) was observed to be between 0.02±0.20 to 0.01±0.20 mg/l in all the water samples, although, it was not detected in both water samples collected from GRA and Ezilo water scheme. Aluminium (Al) was observed to be 0.05±0.04 to 0.01±0.03 mg/l in all the water sample collected but was not detected in water sample from Ezilo water scheme; aluminium analysis was inconclusive as no set standard was obtainable from WHO set standard for aluminium in drinking water. Meanwhile, all the above results indicate that all the water samples studied conformed to the WHO set standard for in drinking water.

$Mg^{2+}$and Ca^{2+} which are micronutrient that plays an important role in human nutrition especially in the development of teeth, bones, blood sugar regulations, protein synthesis etc are between 3.3±0.11 to 36.0±0.09 and 49.6±0.16 to 56.2±0.3 respectively. $Mg^{2+}$and Ca^{2+} are at higher value compared to water samples in Enugu. According to Rylander and Amaud (2004), drinking-water containing 403 mg/l hydrogen carbonate was found to reduce the blood pressure in a group of 20 subjects with mild hypertension; while the risk for health infraction was lower with levels of hydrogen carbonate higher than 110 mg/l Rubenowtiz, E; (1996). However, one of the foremost reports demonstrating relation between water quality, other than microbial contamination, and health risks came from Japan. Na^+ is ranges between 1.7±0.15 to 5.3±0.22 mg/l in all the water samples with highest value from water sample collected in Ebonyi state. This result is in tandem with many literature which opined the reaction of Na^+ with Cl^- in most rivers in Ebonyi State

V. Conclusion

From the result of this research study it can be concluded that almost all physicochemical parameters analysed conforms to the WHO (2006) set standard for quality of drinking water. It is evidence that although, the water samples from Ebonyi state met the minimum drinking water standard, the parameter values are almost at the upper limit. Suggesting that drastic measures should be taken to forestall unintended situation.

Conflicts of interest: There is no conflict of interest in this work.
The authors have no relevant financial or non-financial interests to disclose.
All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Okenwa C.J, Ikeyi A.P, Owoh E.N Chinyere E.E, Nnonah C.C and Onunze E. C.

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