Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2015, 7(11):6-11

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Physicochemical and colorimetric determination of arsenic concentrations in some selected boreholes in Abakaliki and Ebonyi Local Government Areas, Ebonyi State, Nigeria

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ABSTRACT

Water samples from borehole in twelve strategic locations within Ebonyi and Abakaliki L.G.A in Ebonyi State Nigeria were assessed for its portability using standard methods. The range of results obtained were; pH (7.1-8.6), Temp. (28.3-29.2^oC), Dissolved Oxygen (9.3-10.2 mg/L), Total Dissolved Solids (273-446 mg/L), Electrical Conductivity (474-973 µS/cm), Total hardness (55 – 262 mg/L), Total Alkalinity (36.2 -106.2 ppm), PO_4^{3-} (0.08-0.13 mg/L), Cl^- (63.16 – 188.95 mg/L), SO_4^- (42.88-52.91 mg/L), NO_3^-(0.07-1.21) and Arsenate (V) 0.02 - 0.06 µg/L. The results showed that all the physicochemical parameters analysed were below the World Health Organization(WHO) and Standard organization of Nigeria (SON) acceptable limit for drinking water. However, these results does not indicate adverse pollution rather, it indicated a trace level of arsenic contamination in the sampled boreholes as uncontaminated water usually have below 0.001 µg/L. Measurement difficulties of arsenic and its removal in underground water could also could also be a contributing factor. It therefore provides an avenue or need for further studies and monitoring so as to establish a fact both for policy makers, industries and general public.

Keywords: Physicochemical parameters, Arsenic, Borehole water, Pollution and Monitoring.

INTRODUCTION

Just as it is crucial to check the human health status from time to time, it is very important to routinely conduct studies on the water quality parameters. This sterns from the fact that the health quality of a people in no small measure, depends on the quality of portable water available to them[1]. Water constitutes about 70% of the planet earth, and the major component of every living thing, including human being [2]. Natural water contains some traces of impurities whose nature and amount vary with the source, environment and economic lifestyle of the inhabitants[3].While it is agreed that water is one of the most important resources with great implications for African development, the freshwater situation in Africa is unfortunately not encouraging [1].

Groundwater is the water that exists below the surface of the ground in the spaces between particles of rock or soil, or in the crevices and cracks in rocks. Most groundwater is within 100 meters of the surface of the Earth [4]. Good drinking water supply to Nigerian's teeming populace has been a perennial problem that has defied various solutions. As such, it has often attracted rhetorical commentaries with little or no practical solutions [5]. Although it is the major source of life, it is also the major contributor of several ailments including; typhoid fever, cholera, diarrhoea, dysentery etc[6].

The seasonal variation of the physicochemical characteristics of natural waters, be it surface or underground, calls for routine study and monitoring so as to know when any of the variables gets above permissible limit. It is also key to alert the public of the impending challenges that might occur as result of the changes and as well proffer solution for ameliorating the scourge [7]. Arsenic is chemically very similar to its predecessor in the group (phosphorus), so much that it will partly substitute for it in biochemical reactions and is thus poisonous. It is often higher in concentration in underground water as compared with surface water [8].

Abakaliki and Ebonyi Local Government Areas constitute Ebonyi state capital city, with a high population density and the hub of economic and industrial activities in the state. Portable water is water used for drinking, washing, and other domestic purposes. It impacts on the health of the people especially when used for drinking or cooking. Portable water from Ebonyi state government (through the Water Board) are either insufficient, epileptic or non-existence in some areas (including the study areas). As a result, many people/areas within the capital city depend on streams, boreholes or wells for their portable water need. This general trend possess danger to the people's health from water-borne diseases [6].This study is therefore imperative as it will provide a baseline information for further studies, effective monitoring and implication of long-time accumulation of toxicants.

EXPERIMENTAL SECTION

Sample Location

The sampling area was geologically located between latitude 60^o 15", 60^o 20" and longitude 80^o 05", 80^o 10", covering a total area of about 81 Km^2. The map below showed the 13 local government areas including Abakaliki and Ebonyi local government areas (the sample areas).

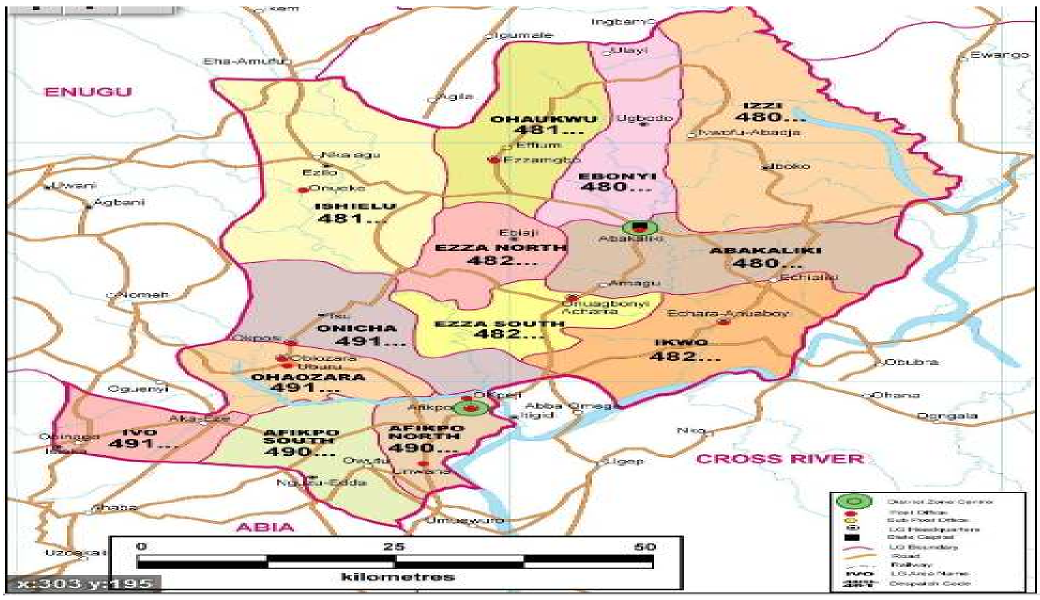

Fig. 1: Map of Ebonyi State showing the studied local government areas

Sampling Method:

Six water samples each, were collected in two local government areas namely of Ebonyi State, Nigeria. The boreholes were made up of hand-pumped and motorized boreholes. Hence, a total of twelve (12) samples selected and spaced to monitor the variation of the samples from each other. The samples were collected in the rainy season (in the month of April), within a duration of six days, all in the morning. Table 1 shows the sampling points and sources of ground water.

Table 1: Sampling Points

S/N	Sampling Point Name	Source of Underground Water
1	Abakaliki Local Government Head Quarters	Motorized Borehole
2	Fmr. Timber Shed	Hand- Pumped Borehole
3	Ochudo city	Motorized Borehole
4	Hausa Quarters	Motorized borehole
5	Agbaja,St. Michael	Hand-Pumped Borehole
6	Odunukwe Street	Motorized Borehole
7	Olisaemeka Street	Motorized Borehole
8	Kpirikpiri	Motorized Borehole
9	St. Joseph Lodge	Motorized Borehole
10	Mile 50	Motorized Borehole
11	Liberation Estate	Motorized Borehole
12	Amike-Aba at Unity Fm	Motorized Borehole

Analytical Procedures

All reagents were analytical grade and were used without further purification while Distilled water used for the preparation of reagents were double distilled. The chemical and physicochemical parameters determinations were carried out according to standard methods viz:

Temperature, pH, turbidity, total dissolved solid (TDS), DO and EC were all determined at site using appropriate probes (all made by Hach Company, Loveland Colorado, USA).

Samples were first filtered appropriately to remove dirts and other particles and divided into parts for both nutrients and arsenate (V) determination. Chloride ion was determined by Mohr's method using 0.02 M silver nitrate solution as titrant and potassium chromate as indicator [9].Total Hardness(Ca^{2+} and Mg^{2+}hardness), were determined by standard complexometric titrimetric methods[10] at pH 10 and 12 respectively while total alkalinity (TA) was determined by acid titration using methyl-orange as an indicator [11]. Meanwhile, nutrients like nitrate (NO_3^-), sulfate SO_4^{2-} and phosphate (PO_4^{3-})was evaluated using brucine and turbidimetric methods, and were determined spectrophotometrically at 410, 495 and 820 nm respectively [7].

Arsenic was determined colorimetrically as arsenate (V). This was based on the reaction of arsenate (V) with potassium iodide in the presence of sulphuric acid and the subsequent release of an equivalent amount of iodine which thus imparts a pink colour to the carbon tetrachloride which is was extracted and the colour measured at a predetermined wavelength of 515 nm. The amount of As (V) in the unknown sample was obtained from the graph of absorbance of iodine in carbon tetrachloride versus the concentration of arsenic (V) in the standard [12]. The detection limit of this method was 0.0005 mg/L. Below is the equation of reaction.

$$AsO_4^{3-} + 2I^- + 2H^+ \rightleftharpoons I_2 + AsO_3^{3-} + H_2O$$

RESULTS/DISCUSSION

Table 2: Physicochemical Parameters of the twelve (12) Boreholes Samples

S/N	Location	pH	Temp. °C	DO mg/L	TH mg/L	TA ppm	TDS mg/L	EC µS/cm	Turbidity NTU
1	**Abakaliki LG HQ**	8.6	28.5	10.2	107	62.2	322	696	0
2	**Fmr.Timber Shed**	7.1	28.7	9.8	187	102.2	282	474	0
3	**Ochudo city**	8.6	28.5	10.1	262	139	420	904	0
4	**Hausa Quarters**	8.2	29.1	9.7	65	41.2	390	787	0
5	**Agbaja, St. Micheal**	8.1	28.7	9.7	101	59.2	349	760	0
6	**Odunukwe Street**	7.8	28.9	9.4	192	104.7	399	844	0
7	**Olisaemeka St.**	8.1	28.9	9.7	55	36.2	366	799	0
8	**Kpirikpiri**	7.9	29.2	9.3	187	102.2	323	943	0
9	**St. Joseph Lodge**	8.1	29.0	9.8	165	91.2	398	800	0
10	**Mile 50**	7.8	28.8	9.8	195	106.2	403	843	0
11	**Liberation Estate**	8.6	28.3	10.2	206	111.7	273	605	0
12	**Amike-Aba**	7.9	28.9	9.7	289	153.2	446	973	0
	WHO [12]	**6.5 - 8.5**	**Ambient**	**8.0**	**500**	**400**	**500**	**1000**	**0-5**
	SON [13]	**6.5 - 8.5**	**Ambient**	**8.0**	**150**	**-**	**500**	**1000**	**0-5**

***WHO** = World Health Organisation, **SON** = Standard Organisation of Nigeria, **DO** = Dissolved oxygen, **TH** = Total hardness, **TA** = Total Alkalinity*

The result of the nutrient loads and trace metal concentrations in the studied underground Water is given in Table 3

Table 3: Chemical composition of the Borehole water samples

S/N	Location	PO_4^{3-}(mg/L)	Cl^- (mg/L)	NO_3^- (mg/L)	SO_4^{2-} (mg/L)	As (µg/L)
1	Abakaliki LG HQ	0.11	127.89	0.63	31.29	0.06
2	Fmr.Timber Shed	0.11	113.68	0.07	41.78	0.02
3	Ochudo city	0.10	135.79	0.52	24.88	0.03
4	Hausa Quarters	0.13	123.16	0.41	47.77	0.03
5	Agbaja, St.Micheal	0.08	135.26	0.42	52.91	0.02
6	Odunukwe Street	0.11	63.16	0.70	47.66	0.06
7	Olisaemeka St.	0.13	94.74	0.37	42.62	0.02
8	Kpirikpiri	0.10	118.95	1.21	36.64	0.02
9	St.Joseph Lodge	0.10	188.95	0.49	52.18	0.05
10	Mile 50	0.12	121.58	0.87	36.64	0.04
11	Liberation Estate	0.07	131.05	0.25	33.81	0.06
12	Amike-Aba	0.09	171.05	1.08	44.09	0.03
	WHO [12]	**-**	**250**	**50**	**100**	**10**
	SON [13]	**-**	**250**	**50**	**100**	**10**

Table 4: The mean values of physicochemical parameters of studied site in comparison with other published values

S/N	Location	pH	Temp. (°C)	DO (mg/L)	TH mg/L	TA ppm	TDS mg/L	EC µS/cm	Turbidity NTU
	WHO Standard [11]	6.5 - 8.5	Ambient	8.0	500	400	500	1000	0-5
	SON [12]	6.5 - 8.5	Ambient	8.0	150	-	500	1000	0-5
1	Abakaliki/Ebonyi LGAs	8.2	28.8	9.8	167	92.4	364.3	785.7	0
2	Umuahia South[14]	5.27	29.5	-	35.1	15.5	4.5	88.5	5
3	Calabar South [15]	5.5	28.8	-	26.3	-	-	324.2	0
4	Kano Metropolis[16]	7.28	-	7.25	-	80.5	286.59	860	10.5
5	Rumuogwuna[17]	5.4	29.0	-	-	-	14.25	30.95	0.50

Results of Table 2 indicated that all the boreholes sampled were alkaline, with their pH values ranging from 7.1 to 8.6, little above the WHO and SON standards of 8.5. This could be linked to the presence of carbonates and bicarbonates as sampled areas are highly mineralized. Ochudo city and Liberation Estate, both in Abakaliki and Ebonyi local governments respectively have same pH value of 8.6, above the WHO and SON limits for underground water. The higher pH values of the samples indicated high conductivity of water [18].Temperature is a biologically significant factor which plays an important role in the metabolic activities of organisms. The temperatures of the sampled boreholes ranged from 28.3 to 29.2 °C during the study periods. This may be due to chemical and or activities of micro-organism.

Dissolved oxygen (DO) is an important parameter in water quality assessment as it reflects the physical and biological processes prevailing in the water. The DO values indicate the degree of pollution in water bodies. The DO values of the sampled water varied from 9.3 to 10.2. This is well above the WHO and SON regulatory standard of 8.8 for drinking water, although not detrimental. Natural waters with consistently high dissolved oxygen levels are most likely healthy and stable, capable of supporting a diversity of aquatic organisms and also the solubility and availability of nutrients [18,19]. Its low levels can result in damages to oxidation state of substances from the oxidized to the reduced form thereby increasing the levels of toxic metabolites. High mean DO value of the studied boreholes (Table 4) in comparison with other published works showed a less microbial activities, hence qualifying the water good for drinking and other domestic uses.

Hardness in water is mostly due to the natural accumulation of salts from contact with soil and geological formations or it may enter from direct pollution by industrial effluents. Hardness of water mainly depends upon the amount of calcium or magnesium salts or both [20]. It is the property of water which prevents the lather formation with soap and increases the boiling points of water [18]. The total hardness of all the samples analyzed were in the range of 55 to 289 mg/L $CaCO_3$, which agrees with the WHO limit of 500 mg/L $CaCO_3$for drinking water whereas, only three samples from Olisaemeka Street, Hausa Quarters and Agbaja, St. Michael (see Table 2) are within the limit of SON standard of 150 mg/L for drinking water.Although, the values of total hardness of all the samples are below the permissible limit, depending on the interaction of other factors, such as pH and alkalinity, water with hardness above approximately 200 mg/L may cause scale deposition in the treatment works, distribution system and pipe work and tanks within buildings. Also, soft water, with a hardness of less than 100 mg/L, may, have a low buffering capacity and so be more corrosive for water pipes[10].

Total Alkalinity of water is its capacity to neutralize acidic nature and is characterized by the presence of hydroxyl ions. It may be due to the presence of domestic sewage disposal and the presence of soluble chlorides from rocks [21]. The values of total alkalinity(ppm) of the samples are in the range of 36.2 to 153.2 which agrees well with the recommended value of 400 ppm by WHO for underground water.

High concentrations of total dissolved solids (TDS) or total mineralization may cause adverse taste effects. They are products of run offs. They increase with increased rainfall and have adverse effect on dissolved oxygen and carbon dioxide. The values of TDS in the analyzed samples are in the range of 322 to 446 mg/L which is well within the WHO approved standard of 500 mg/L for drinking water. Suspended solids in water are directly proportional to the dissolved solids. Dissolved solids could directly influence water conductivity, the higher the dissolved solids the higher the conductivity [20].

Electrical Conductivity (EC) is the capacity of water to convey electric current. It indicates the amount of total dissolved salts [22]. In this study, the values of the electrical conductivity of all the boreholes studied are in the range of 605 to 973 mg/L (Table 2) which are below the stipulated guideline for WHO and SON for drinking water. This indicated that there are not much dissolved inorganic materials in the boreholes and also indicated low salinity.
Turbidity is the relative clarity of water, be it surface or underground water. It is often caused by suspended and colloidal matters such as clay, silt, organic and inorganic matter, plankton and microscopic organisms. All the borehole samples analyzed in this study all have zero (0) turbidity. This indicated the relative clarity of the samples which makes it suitable both for consumption and other domestic uses.

Results of the nutrient loads (phosphate, chloride, sulfate and nitrate, Table 3) were found to be within prescribed limits (0.07 to 0.13, 63.16 to 188.95, 24.88 to 52.91 and 0.07 to 1.21 all in mg/L. However, accumulation of the nutrients over time will eventually result in eutrophication. Nitrogen (N) and phosphorus (P) species are notable characteristic pollutants for eutrophication of natural waters [23-25].
In water, arsenic is mostly present as arsenate, with an oxidation state of 5, if the water is oxygenated [11]. All the boreholes sampled are within the acceptable limits with values ranging from 0.02 to 0.06 µg/L, which is below 10.00 µg/L according to the WHO guideline.

Although the values are all within the prescribed standards, it calls for further routine studies and monitoring to ensure that it does not escalate with time as a result of mineral exploitation or by anthropogenic activities[8].

CONCLUSION

The need for periodical or routine study of the physicochemical parameters of underground water (Boreholes and Well Waters) in Ebonyi State cannot be over-emphasized.

Underground water in Abakaliki/Ebonyi local government areas harvested through boreholes as portable water are often contaminated with impurities (gases, salts, acids, organisms etc.) often generated from anthropogenic activities (agriculture, industrial activities etc.).

However, from our study, the level of the contaminants were within acceptable limits of portable water (SON and WHO) except for the trace amounts of arsenate (V),as uncontaminated water usually contain less than 0.001 µg/L of arsenic [26].

Effective routine monitoring of pollutant generation and handling will minimize its concentration in water samples hence safeguard people’s health. This study therefore provides a baseline information on environmental monitoring in this highly populated area of Ebonyi State.

Acknowledgements
We wish to most sincerely acknowledge the efforts of the Laboratory technologists in the Department of Industrial Chemistry, Mr. Ogbuand Mr. Nwonu Micheal, for their assistance throughout the period of the research. The efforts of Dr. O.N Omaka, Dr. F.I. Nwabue and Dr. Elom, N. cannot be overemphasized, you have all done noble. May God bless you all.

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