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Quality Assessment of Borehole Water used in the Vicinities of Benin, Edo State and Agbor, Delta State of Nigeria

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ABSTRACT

This study was aimed at determining water quality parameters in borehole water from the University of Benin, Benin City, Okobi and Eluemelor vicinities of Agbor respectively in order to access the quality of the borehole water from the three boreholes. Water samples were collected three times at monthly intervals between December 2009 and February 2010 for the three sampling points, respectively. Parameters for quality check includes; pH, temperature, electrical conductivity, biochemical oxygen demand, dissolved oxygen, chloride, sulphate, nitrate, ammonium, sodium, calcium, magnesium, lead, cadmium, copper, zinc, chromium, iron, arsenic, nickel and manganese. Physicochemical characteristics were determined using their respective standard methods of analysis while heavy metal levels were determined using Atomic Absorption Spectrophotometer. Parameters determined gave results which fell within the World Health Organisation (WHO) and federal environmental protection agency (permissible limit for portable water except for calcium and manganese which gave elevated values as against their corresponding WHO limits of 75 and 0.05 mg L^{-1}, respectively. The pollution index values for calcium and manganese indicated significant degree of pollution by the two metals in all the borehole water samples studied. The overall results from this study showed that water samples from the boreholes studied were found to be safe for drinking and other domestic activities considering the parameters which fell within the allowable limits. However, proactive measures must be taken to check the levels of calcium and manganese to avert severe contamination and protect our precious ground water resource. It is therefore recommended that the borehole water from the three boreholes studied be subjected to treatment processes to reduce calcium and manganese levels before exposure to public use.

Key words: Water quality parameters, pollution index, borehole water, proactive measures

INTRODUCTION

Contamination of water bodies has increasingly become an issue of serious environmental concern. Clean water is a priceless and limited resource that man has began to treasure only recently after decades of pollution and waste (Silderberg, 2003). Potable water is an essential ingredient for good health and the socio-economic development of man (Udom *et al.*, 2002), but it is lacking in many societies. All natural waters contain many dissolved substances. Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges, and over-use of limited water resources (Singh and Mosley, 2003).

The major sources of pollution in streams, rivers and underground water arises from anthropogenic activities largely caused by the poor and uncultured living habit of people as well as the unhealthy practices of factories, industries and corporate bodies; resulting in the discharge of effluents and untreated wastes. Pollution in water affects not only water quality but could also be dangerous to aquatic life (Sunnudo-Wilhelmy and Gill, 1999). Ground water pollution could be avoided when borehole wells are located far from any source of potential pollution. Good well design is also important in the prevention of underground water pollution. During the construction process of a borehole, drilling fluids, chemical casings and other materials may find their way into the well thereby polluting the water. An open hole during the construction stage can also be a direct route for contaminants from the surface to the aquifer thereby providing an ideal opportunity for chemical and bacteriological pollution to occur. Lasting damage can be avoided if the well is completed, disinfected and piped within a short space of time. The possibility of contamination increases if there is a lengthy delay in completing the well. Even if no sources of anthropogenic contamination exist, there is potential for natural levels of metals and other chemicals to be harmful to human health. This was highlighted in Bangladesh where natural levels of arsenic in groundwater were found to be causing harmful effects on the population (Anawara *et al.*, 2002). Unfortunately, this problem arose because the groundwater was extracted for drinking without a detailed chemical investigation. Monitoring the quality of water is very essential for environmental safety. The natural water analyses for physical and chemical properties including trace element contents are very important for public health studies (Kot *et al.*, 2000). These studies are also a main part of pollution studies in the environment.

Borehole water serves as the major source of drinking water in the local population of Nigeria, since only very few can afford and rely on purified and treated bottled water for consumption. Owners of boreholes capitalise on this opportunity to commercialize their boreholes which many resort to buying the bore hole water for drinking, since it is cheaper for them to afford.

Therefore, this brings the imperativeness of examining the water quality parameters of borehole water with special interest study on Agbor town in Delta State and Benin City in Edo State respectively with a view to accessing their level of purity. This study tends to x-ray and estimate the levels of heavy metals, ion contents, biochemical oxygen demand, dissolved oxygen as well as other parameters such as temperature, pH, conductivity with a view to comparing them with international allowable standards as this will guide our decision on the quality and purity assessment of the bore holes.

MATERIALS AND METHODS

Study area: Geographically, the study area comprises of Edo and Delta state, respectively. Borehole water was collected from the borehole in the University of Benin, Benin City, Edo State as well as two different locations in Agbor town, Delta State. The two locations in Agbor were borehole was obtained are Okobi Street, Boji-Boji Owa and Eluemelor, Agbor Urban. These areas were specifically chosen for the study because of the very low water table observed and lack of nearness to industrial facilities and potential ground water pollution sites such as urban solid waste dump sites.

Sample collection treatment and preservation: Two sample points were located in Agbor (Fig. 1) while one located in Benin. Borehole water samples for the study were collected three times at monthly intervals between December 2009 to February 2010 for the three sampling points,

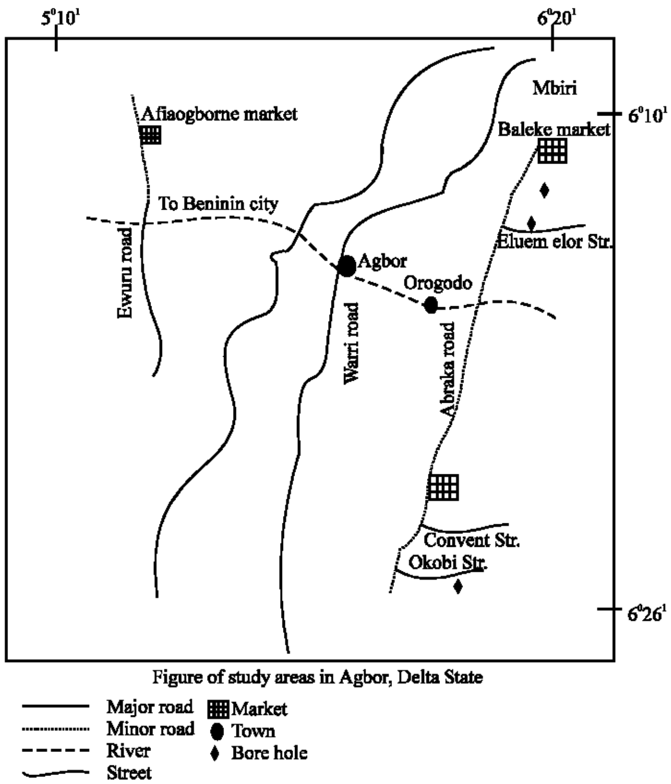

Fig. 1: Map of agbor showing study area

respectively. Water samples were collected directly from the taps in the borehole into clean white polyethylene stoppered bottles which have been washed with soap solution, rinsed three times with pure water and then rinsed again three times with 1% HNO_3 after which they were rinsed with the bore hole water to be collected. The water samples were stoppered and labelled.

The samples were filtered by passing water through a 0.45 mm millipore membrane filter placed in an all glass millipore filtering system. The membrane filters have been washed with 1% HNO_3 followed by rinsing in high purity water prior to filtration (Meranger *et al.*, 1979). Samples were there after refrigerated at 4°C in the laboratory prior to analysis.

Sample analysis: Samples for Dissolved Oxygen (DO) and Bological Oxygen Dmand (BOD) were determined using Winkler method by treating with manganesous sulphate solution, alkali-iodide azide solution and 1.00 mL concentrated sulphuric acid by inserting the can for several times. The samples were then allowed to stay for five minutes after the formation of brown precipitates. The DO was immediately determined in-situ using a multi-parameter water quality model (model 6000 UPG), the remaining treated solution was well stoppered and incubated prior to five days later before BOD analysis. BOD was determined using iodometric method (USEPA, 1986; Young *et al.*, 1981). Analysis for heavy metal determination was achieved by measuring 100 mL of each water sample into a beaker and 5 cm^3 of concentrated HNO_3 was added. The solution was evaporated to near dryness on a hot plate, making sure that the sample does not boil. The beaker containing the residue was cooled. 5 mL of conc. HNO_3 was further added and returned to the hot plate until digestion was completed (Ahn *et al.*, 1996; Anonymous, 1995). Two millilitter of conc.

HNO_3 was added and the beaker warmed slightly to dissolve the residue. The digested sample was filtered and the filtrate made up to 50 cm^3 mark with deionized water. The solutions were stored in a refrigerator prior to metal analysis using atomic absorption spectrophotometer. Blanks were also prepared using the same procedure of digestion of the samples. Parameters such as pH, temperature, electrical conductivity, BOD, DO and ion contents (Cl^-, NO_3^-, NH_4^+, Na^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}) were all determined by standard methods (Ademoroti, 1986; Anonymous, 1995; APHA, 1992; Chapeon, 1992; Franson, 1995). The temperature, pH and electrical conductivity were determined with zeal thermometer (0-300°C), P107 digital consort pH meter and K 120 digital consort electronic conductometer respectively. Metal concentrations were determined using atomic absorption spectrophotometer (210VGP model). Procedural blank and standard solutions were prepared following method described by Franson (1995).

Quality control: Triplicate analyses were performed on the samples to yield a mean which was used to determine trueness (Valcarel, 2000). Procedural blanks and standard solutions were prepared and included for analytical quality control to assure the accuracy and reproducibility of the results.

RESULTS AND DISCUSSION

All parameters determined were detected in this study. The mean and range of results obtained from the three months study for the borehole water parameters in the three sampling sites as well as their World Health Organization (WHO) guideline standards are presented in Table 1 and 2.

Pollution index (Pi) is expressed as a function of the concentration of individual parameter as against the baseline standard. It is given as:

$$\text{Pollution index (Pi)} = \frac{\text{Concentration}}{\text{Standard}}$$

It shows the relative pollution contributed by each item. The critical value is 1.0 values greater than 1.0 indicates significant degree of pollution while values less than 1.0 shows no pollution.

Pollution index values obtained for calcium and manganese in all samples studied indicated that the boreholes are polluted with the water showing a higher degree of pollution in manganese than calcium. The water therefore needs to be treated before use. However, the results of the other parameters studied were considered low when compared with the WHO (1983) and FEPA (1991) for drinking water hence did not indicate pollution because their levels were below the limits for portable water. A similar trend was observed in the parameters determined for the samples from the two boreholes studied in Agbor since no significant variation was observed in their results. This shows a very strong peculiarity in the physiochemical properties of water from the boreholes studied. Strong variation in results were observed for some of the parameters studied between the sampling site in Benin and Agbor which can be attributed to the difference in geographical location.

The results when compared with similar studies investigating the physicochemical characteristics of borehole water in warri and environs as reported by Okonkwo *et al.* (2008); Rim-Rukeh *et al.* (2008) shows that pH was higher in this study indicating that the borehole water are slightly alkaline as against those in warri which were slightly acidic (5.32-5.34 and 4.50-5.20). Temperature values were lower in this work when compared to boreholes studied in warri (27.74-28.83 and 26.0-27.0°C). Conductivity values were found to be significantly higher

Table 1: Mean and range of results of borehole water samples

Parameters	Sampling sites S1 Mean	S1 Range	S2 Mean	S2 Range	S3 Mean	S3 Range	WHO maximum allowable levels
Temperature (°C)	22.91	21.50-24.58	23.19	22.21-24.12	24.43	24.10-25.42	25°C
pH	6.75	6.48-6.99	6.71	6.62-6.80	6.45	6.34-6.56	6.50-8.50
Elect. Conduct (μs cm^{-1})	32	30-34	32	30-34	29	28-30	1400
Biochemical Oxygen Demand (BODs) (mg L^{-1})	1.3	1.2-1.4	1.4	1.2-1.6	1.3	1.1-1.4	>6.0
Dissolved Oxygen (mg L^{-1})	5.65	5.5-5.8	5.55	5.4-5.7	5.9	5.6-6.2	>30
Chloride (mg L^{-1})	17.75	17.60-17.80	35.55	35.0-36.1	159.75	158.45-159.95	25°C
Nitrate (mg L^{-1})	0.45	0.35-0.55	0.16	0.15-0.17	0.24	0.15-0.33	10
Ammonium (mg L^{-1})	2.31	2.20-2.42	3.93	3.81-4.05	5.50	5.41-5.59	10
Sodium (mg L^{-1})	0.07	0.06-0.08	0.06	0.04-0.08	0.10	0.08-0.1	200
Calcium (mg L^{-1})	144.17	143.15-145.19	128.15	127.14-129.16	126.15	125.12-127.18	75
Magnesium (mg L^{-1})	19.44	18.40-20.48	18.22	17.21-19.23	26.73	25.70-27.76	30
Sulphate (mg L^{-1})	0.13	0.12-0.14	0.19	0.17-0.20	0.36	0.34-0.37	250
Lead (mg L^{-1})	0.014	0-013-0.015	0.013	0.012-0.014	0.015	0.014-0.016	0.05
Cadmium (mg L^{-1})	0.005	0.004-0.006	0.003	0.001-0.005	0.006	0.005-0.007	0.01
Copper (mg L^{-1})	0.06	0.05-0.07	0.04	0.038-0.042	0.045	0.033-0.057	1.0
Zinc (mg L^{-1})	0.11	0.09-0.12	0.12	0.10-0.14	0.10	0.9-0.11	5.0
Chromium (mg L^{-1})	0.007	0.006-0.008	0.008	0.007-0.009	0.005	0.0049-0.0061	0.05
Iron (mg L^{-1})	0.06	0.05-0.07	0.05	0.045-0.065	0.07	0.06-0.08	0.3
Arsenic (mg L^{-1})	0.041	0.030-0.052	0.04	0.03-0.05	0.03	0.02-0.04	0.05
Nickel (mg L^{-1})	0.007	0.006-0.008	0.045	0.035-0.055	0.02	0.01-0.03	0.05
Manganese (mg L^{-1})	0.12	0.09-0.14	0.14	0.12-0.16	0.13	0.10-0.15	0.05

(62.6-158.40 and 370-410 μs cm^{-1}) in warri borehole waters than that reported in this work. Values for dissolved oxygen was very similar to those reported by Okonkwo *et al.* (2008) (5.52-5.68 mg L^{-1}) and Rim-Rukeh *et al.* (2008) (4.9-5.9 mg L^{-1}) in warri. A comparison of the metals and ion contents in both study shows that nitrate (1.046-4.13 and 18-38 mg L^{-1}), sulphate (5.40-15.68 and 68-170 mg L^{-1}) and iron (0.23-0.24 and 13.80-19.32 mg L^{-1}) determined in borehole from warri had values higher than reported in this study while zinc (0.002-0.013 mg L^{-1}), lead (0.008 mg L^{-1}), cadmium (0.002 mg L^{-1}), manganese (0.022-0.062 mg L^{-1}), chloride (9.40-17.4 mg L^{-1}) and ammonium (0.006-1.81 mg L^{-1}) reported by Okonkwo *et al.* (2008) gave values that were lower than those reported in this study. However, values for BOD (14-21 mg L^{-1}), lead (0.10-0.5 mg L^{-1}) and zinc (0.56-0.98 mg L^{-1}) reported from the work of Rim-Rukeh *et al.* (2008) exceeded those reported in this study while the concentration of nickel (0.01-0.02 mg L^{-1}) was very similar to that in this study. A comparative evaluation of the present study and those reported by Okonkwo *et al.* (2008) as well as Rim-Rukeh *et al.* (2008) showed that their results are highly correlated except for pH and conductivity which showed significant differences as well as the concentration levels of nitrate, sulphate, iron and BOD reported by Rim-Rukeh *et al.* (2008) in warri borehole water which were in orders of magnitude greater than those reported in this study. The low level observed for most of the parameters investigated in this work as against the studies conducted in warri could be due to the low level of industrialization, lack of proximity to possible source of contaminants and very far reaching water table observed in the study areas. Since the water table is very low in the

Table 2: Computation data of pollution index for the three sampling points

	S1	S2	S3
Parameters	Pollution index	Pollution index	Pollution index
Temperature (°C)	0.92	0.93	0.98
pH	0.9	0.86	0.89
Elec Conduct (µs cm^{-1})	0.023	0.023	0.021
B.O.D (mg L^{-1})	0.22	0.23	0.22
Chloride (mg L^{-1})	0.071	0.142	0.639
Nitrate (mg L^{-1})	0.045	0.016	0.024
Ammonium (mg L^{-1})	0.231	0.550	0.393
Sodium (mg L^{-1})	0.00035	0.0003	0.0005
Calcium (mg L^{-1})	1.92	1.71	1.68
Magnesium (mg L^{-1})	0.648	0.607	0.891
Sulphate (mg L^{-1})	0.00052	0.00076	0.000144
Lead (mg L^{-1})	0.28	0.26	0.30
Cadmium (mg L^{-1})	0.5	0.3	0.6
Copper (mg L^{-1})	0.06	0.04	0.045
Zinc (mg L^{-1})	0.022	0.024	0.02
Chromium (mg L^{-1})	0.14	0.16	0.10
Iron (mg L^{-1})	0.2	0.17	0.23
Arsenic (mg L^{-1})	0.82	0.80	0.60
Nickel (mg L^{-1})	0.14	0.90	0.40
Manganese (mg L^{-1})	2.40	2.80	2.60

study areas, presence of numerous soil layers will act as natural filters which will reduce contaminant concentration to a large extent. This could stem from the fact that sand bed (soil profile) is a natural filter where processes such as filteration, adsorption, biodegradation, ion exchange and dispersion may reduce concentration of contaminants to a great extent (Okokoyo and Rim-rukeh, 2004). Low levels of ions and metals in this work when compared with the studies in warri could be due to the non acidic nature of the water because (Etu-Efiofor and Odigi, 1983) reported that in an area with a pH less than 5, the solubility of heavy metals is permissible. Similar study on the assessment of dry season surface, ground and treated water quality in the Cape Coast municipality of Ghana revealed exceedances to some health-based drinking water guidelines for various water samples on pH, Fe, Mn, SO_4^{2-}, Cu and Zn (Quagraine and Adokoh, 2010) as against the results obtained in this work. However, the results from this study when compared with a study on the assessment of drinking water quality of canal, shallow pumps, dug wells and water supply schemes from the administrative districts of Thatta, Badin and Thar in Southern Sindh (Pakistan) shows that the limits for electrical conductivity, sodium and iron exceeded World Health Organization standards but other parameters as pH, copper, manganese and zinc were within standard permissible limits of World Health Organization (Memon *et al.*, 2010).

A total assessment of the overall water quality parameters shows that ground water from the three boreholes studied are safe for drinking and other domestic activities by parameters which fell within the allowable WHO (1983) and FEPA (1991) limits, however values obtained for calcium and manganese exceeded the recommended standard. This agreed with the results obtained for the measurements of various water quality parameters carried out on groundwater samples of dug wells, bore wells and hand pumps at the northern Indo-Gangetic alluvium region (Singh *et al.*, 2006).

Non treatment of borehole water can bring deadly illness such as typhoid (Mathew, 2003). Hence proactive measures should be taken to advert severe contamination so as to protect our precious ground water resource.

It is therefore advised that the borehole water be subjected to treatment processes to reduce the concentration of calcium and manganese before exposure to public use.

CONCLUSION

Water quality parameters in borehole water of University of Benin, Benin-City. Edo State and vicinities around Agbor, Delta State were assessed to evaluate the level and degree of purity of the borehole water. All parameters determined were found. The borehole water were found to be safe in the parameters studied except for calcium and manganese which exceeded acceptable world health limits. Parameters such as pH, temperature, conductivity, BOD, DO, Chloride, Nitrate, Ammonium, Sodium, Magnesium, Sulphate, Lead, Cadmium, Copper, Zinc, Chromium, Arsenic, Iron, Nickel were below pollution levels when compared with the WHO and FEPA maximum allowable levels for drinking water. However, the pollution index for calcium and manganese indicated that the borehole waters are polluted in these metals. It is therefore suggested and advised as a matter of National health importance that the water from the borehole be subjected to purification and treatment processes to reduce calcium and manganese levels before exposure to public use.

RECOMMENDATION

It is recommended that appropriate regulatory agencies should carry out quality assessment of existing boreholes to ascertain their quality level of the water before allowing for public utilization.

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