Int. J. Chem. Sci.: 12(1), 2014, 23-38
ISSN 0972-768X
www.sadgurupublications.com

PHYSICO–CHEMICAL AND BACTERIOLOGICAL QUALITIES OF GROUND WATER RESOURCES IN EZINIHITTE MBAISE LOCAL GOVERNMENT AREA OF IMO STATE, NIGERIA

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ABSTRACT

Physico-chemical studies and bacteriological assay of borehole waters in Ezinihitte Mbaise Local Government Area of Imo State, Southeast Nigeria, were carried out to provide baseline data and to evaluate the portability of the rural water supplies. Water samples were collected from eleven boreholes located in different towns in the Local Government Area for analyses, using various standard methods. The values of chemical parameters in triplicate analyses of the various water samples showed ranges in mg/L as follows with exception of pH, 4.56 to 6.36; and conductivity, 10.89 to 57.40 μs/cm; thus, total solids,10 to 90; total dissolved solids, 6.4 to 34.5; nitrate, 0.6 to 2.9; phosphate, 0.01 to 0.02; sulphate, 0.05 to 0.13; total acidity, 0.76 to 40.32; total alkalinity, 0.5 to 24.5; total hardness, 12.0 to 38.0; chloride, 0.5 to 9.5; sodium, 5 to13; potassium, 1 to 4; calcium, 4 to 32; magnesium, 2 to 7. Lead, cadmium and chromium were not detectable in all the water samples. Detectable levels of other trace metals were: copper, 0.01 to 0.19 mg/L; nickel, 0.1 mg/L; iron, 0.01 to 0.25 mg/L and zinc, 0.01 to 0.15 mg/L. Total viable count for bacteria showed heavy growth of *E. coli* in eight boreholes. The range was from 0.12 x 10^2 to 2.56 x 10^2 cfu/100 mL. Compared with WHO guideline values for drinking water, pH range 4.56-6.36 fell below the range of 6.5-8.5. The heavy metals did not exceed the stipulated guideline values, but the growth of bacteria impairs the quality of the water in eight boreholes. However, for assurance of safety, water needs to be boiled before drinking.

Key words: Borehole waters, Low pH, Low ionic content, Bacterial pollution, WHO guideline values.

INTRODUCTION

Around the world, water pollution is a serious and costly problem. Groundwater, especially, once contaminated is very expensive to clean up and made usable again. In some cases, it could lead to loss of borehole or well water and polluted aquifer could transport contaminants into nearby rivers and lakes[1]. In urban areas, sources of pollution of under-

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ground water include solid waste dumps, soakway pits and industrial effluents[2], as well as rain, organic action in the soil and mineralization of the rocks through which the water flows[3].

Ezinihitte Mbaise Local Government Area is one of the local administrative units in Imo State, Nigeria. It is a rural area, with subsistence agriculture, petty–trading and artisan works as the major activities. Agricultural and domestic wastes are still disposed in the traditional way, using those that decay as manure in the gardens, and burning those that cannot easily decay. Great majority of the people source water for domestic use from boreholes. The sale of borehole water by tankers is a thriving business in the area.

The most likely source of water pollution in rural area is fertilizers, pesticides and herbicides, which have become of effective use in Nigerian modern agriculture. Furthermore, most people use pit toilets, which can equally pollute groundwater. There are also the activities of motor vehicle technicians and metal workers who dispose metal-laden wastes such as disused lead-acid batteries indiscriminately.

There is evidence of baseline data obtained, where the boreholes which were either provided by communities, non-governmental organizations (NGOs), or individuals, were dug. Hence, we analysed the water from this area with the aims of providing baseline data on physico-chemical and bacteriological parameters and to evaluate the quality and potability of the rural water resource.

EXPERIMENTAL

Sampling

Water samples were collected from eleven boreholes from different towns in Ezinihitte Mbaise Local Government Area of Imo State Nigeria, as shown in Fig. 1, namely: Akpodim, Amumara, Chokoneze, Eziudo, Ihitte, Itu, Obizi, Oboama, Okpofe, Onicha and Umunama.

The samples were collected in new 2-Litre polyethylene cans, previously, washed with foamless detergent, rinsed with tap water, followed by Analar grade 1 : 1 HCl (BDH, England), and then copiously rinsed with deionized distilled water[4]. At the collection points, the taps were allowed to flow for some time, and the sample containers were once again rinsed with water to be sampled before filling the cans[4]. The labelled cans were corked immediately and placed into ice before being transported to the laboratory for analysis. The sampling for bacteriological analysis was made in bottles designed for it and which had already been washed and sterilized[4]. The samples for heavy metals analyzed were preserved by adding 5 mL concentrated HNO_3 to prevent metals from adhering to the walls of the containers. The remaining samples were preserved in refrigerator.

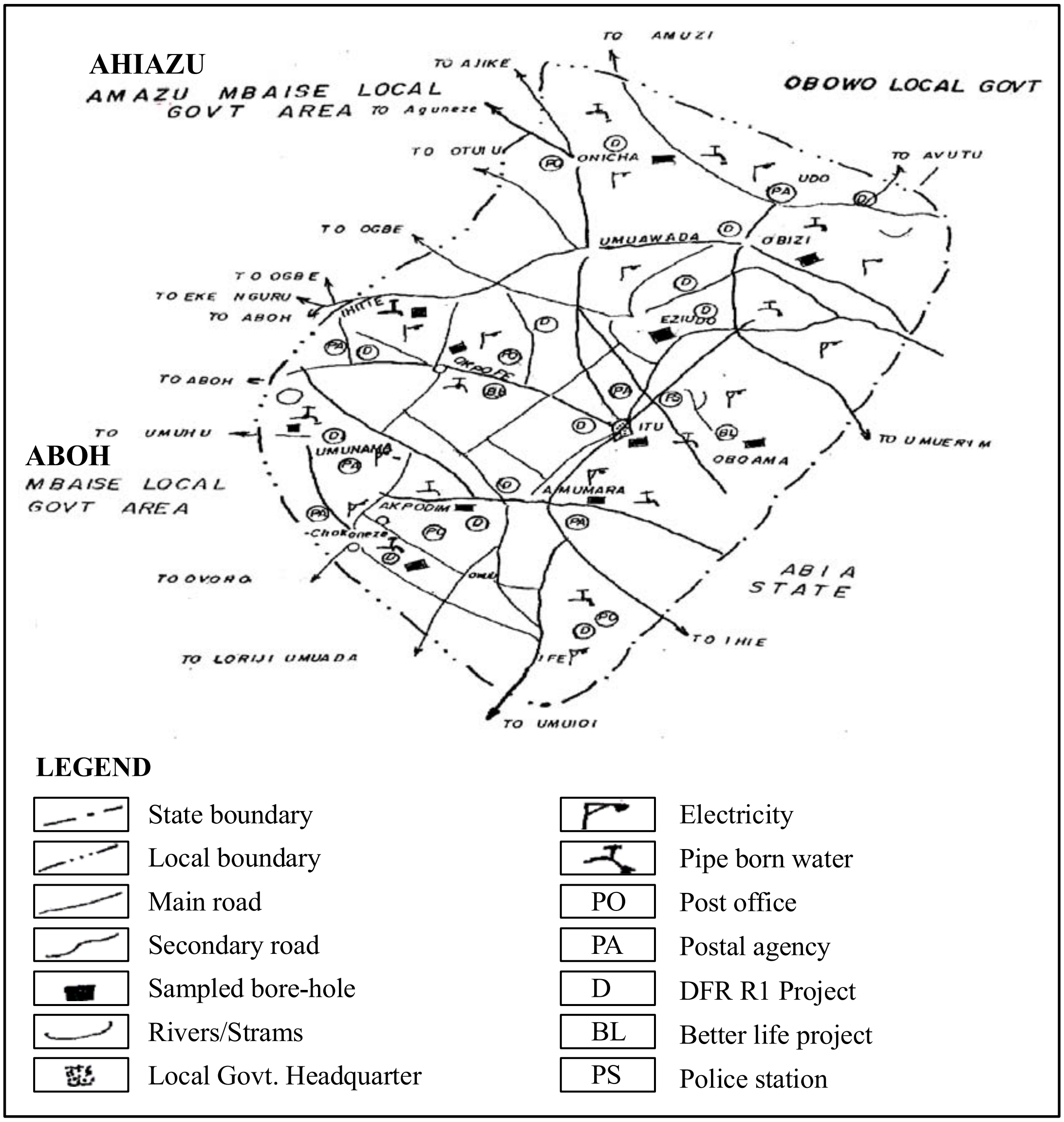

Fig. 1: Map of Ezinihitte Mbaise Local Government Area showing locations of the sampled boreholes

Sample analyses

All reagents used were AR grade. Double deionized water was also used for preparation of solutions. On arrival at the laboratory, pH, conductivity and alkalinity were determined before the remaining samples were preserved by refrigeration. pH was determined using HANNA HI 4212 pH meter. A Jenway 470 conductometer was used to determine conductivity.

Various standard methods[5] were employed in the analyses of the following: total dissolved solids(TDS)–gravimetry, total alkalinity (TA)–potentiometric titration, total acidity-potentiometric titration, and total hardness (TH), calcium and magnesium-EDTA titrations. Chloride was determined by Mohr's Argentometric method, nitrate, by cadmium reduction method, sulphate, by turbidimetric method, and phosphate, by reactive (ortho) phosphate ascorbic acid method. Sodium and potassium were assayed using a Gallen Kamp model 3Y flame analyser. The trace metals: cadmium, chromium, copper, iron, nickel, lead, and zinc were determined using atomic absorption spectrophotometer (Alpha 4, serial no 4200, Chem Tech Analytical Ltd, UK), equipped with air-acetylene flame. All the samples for trace metal analysis were concentrated by evaporating 200 mL of well mixed acid-preserved water to less than 25 mL after acidifying with 10 mL conc. HNO_3, and made up in a 25 mL standard flask. Sample blank for trace metal analysis was prepared by taking the double deionized water through the same process as the samples.

Total viable coliform count was carried out in the Microbiology Department of the Regional Water Laboratory, Federal Water Resources Enugu, Enugu State using membrane lawryl sulphate broth.

RESULTS AND DISCUSSION

Table 1 shows the average values of triplicate determinations of physico-chemical parameters of the various borehole waters. Their metal levels are presented in Table 2 and for comparison; the World Health Organization (WHO) guideline values for drinking water quality are presented in Table 3. The results of bacteriological analysis are shown in Table 4.

Table 1 shows wide variations in some parameters from location to location. The underground water in the studied area is characterized by a relatively close acid pH values. The lowest annual pH, 4.56 was measured in borehole located in Obizi while the highest 6.36 was measured in the borehole located in Onicha. The pH values of the various water samples did not show significant differences ($p > 0.05$). The range of the pH values, 4.56 to 6.36, falls below the WHO permissible range 6.5 to 8.5 for drinking water.

Conductivity values ranged from 10.89 to 57.40 μs/cm; with the lowest determined value in water from Itu. The highest conductivity was measured in the borehole water at Onicha. This borehole showed the highest pH, TDS, alkalinity, hardness, and calcium as shown in Tables 1 and 2.

Table 1: Values of physico-chemical parameters of borehole waters in Ezinihitte Mbaise, LGA. Imo State, Nigeria

	Akpodim	Amumara	Chokoneze	Eziudo	Ihitte	Itu	Obizi	Oboama	Okpofe	Onicha	Umunama	(Mean ± SD)
Temp. (^oC)	28.1	27.7	27.6	27.8	27.7	27.6	27.8	28.0	27.5	21.0	27.8	27.15 ± 2.05
pH	5.05	6.28	4.88	4.76	5.48	6.05	4.56	5.00	4.88	6.36	4.72	5.27 ± 0.66
Conductivity (µs/cm)	20.70	28.50	19.49	22.90	13.25	10.89	23.50	22.70	19.98	57.40	31.30	24.60 ± 12.82
TDS (mg/dm^3)	14.8	17.1	11.7	14.1	7.9	6.4	14.0	13.6	12.0	34.5	19.2	15.03 ± 7.42
SS (mg/dm^3)	5.2	12.9	48.3	45.9	2.1	83.6	16.0	6.4	28.0	35.5	0.8	25.88 ± 25.69
T solids(mg/dm^3)	20.0	30.0	60.0	60.0	10.0	90.0	30.0	20.0	40.0	70.0	20.0	40.91 ± 25.48
Total acidity (mg/dm^3 as $CaCO_3$)	40.32	16.40	12.33	14.26	17.48	9.66	0.76	12.02	12.52	16.15	0.80	13.88 ± 10.45
Total Alkalinity (mg/dm^3 as $CaCO_3$)	1.5	2.5	0.5	0.5	0.5	1.5	ND	1.5	0.5	24.5	ND	3.72 ± 7.82
Cl^- (mg/dm^3 Cl^-)	1.0	4.5	0.5	9.0	1.5	3.2	4.5	9.5	5.0	0.5	3.5	3.88 ± 3.12
NO_3^- (mg/dm^3)	0.7	0.6	1.6	2.1	1.4	0.6	1.3	1.3	0.9	0.0	2.9	1.34 ± 0.73
SO_4^{2-} (mg/dm^3)	0.07	0.08	0.07	0.06	0.05	0.06	0.13	0.07	0.11	0.06	0.06	0.08 ± 0.03
PO_4^{3-} (mg/dm^3)	0.01	0.01	0.01	ND	0.01	ND	0.02	ND	ND	0.01	00.1	0.01 ± 0.01
Total hardness (mg/dm^3 as $CaCO_3$)	12.0	20.0	14.0	24.0	14.0	15.0	18.0	19.0	27.0	38.0	6.0	18.82 ± 8.58

ND = Not detectable

Table 2: Metal concentrations (mg/dm^3) of borehole waters in Ezinihitte Mbaise LGA of Imo State, Nigeria

Borehole location	Na	K	Ca	Mg	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Akpodim	6	4	8	4	ND	ND	0.01	ND	ND	ND	ND
Amumara	8	3	14	6	ND	ND	0.03	0.07	0.01	ND	0.15
Chokoneze	8	3	10	4	ND	ND	0.01	0.05	ND	ND	0.02
Eziudo	10	2	20	4	ND	ND	0.01	ND	0.01	ND	ND
Ihitte	7	1	81	6	ND	ND	019	0.25	0.01	ND	0.01
Itu	5	1	8	7	ND	ND	0.02	0.02	0.01	ND	0.03
Obizi	9	3	12	6	ND	ND	0.01	0.015	0.01	ND	0.03
Oboama	11	12	14	5	ND	ND	0.04	0.01	0.01	ND	0.09
Okpofe	8	1	20	7	ND	ND	0.01	0.03	ND	ND	0.08
Onicha	5	1	32	6	ND	ND	ND	0.06	0.01	ND	ND
Umunama	13	4	4	2	ND	ND	0.04	0.02	0.01	ND	0.01
WHO or EU*	200	10*	75	50	0.003	0.003	2	0.3	0.02	0.01	3
Mean* ± SD	8.18 ± 2.48	3.18 ± 3.16	20.27 ± 21.55	5.18 ± 1.54	-	-	0.04 ± 0.06	0.06 ± 0.08	0.01 ± 0.00	-	0.05 ± 0.06

ND = Not detectable

Table 3: WHO guideline values for drinking water[6]

Parameter	Ingest desirable level	Maximum permissible
pH	7.0-8.5	6.5-8.5
Conductivity µs/cm	-	1000
Nitrate (mg/dm^3)	50	100
Phosphate (mg/dm^3)	15.3 (EU)	-
Sulphate (mg/dm^3)	100	500
Total (Alkalinity (mg/dm^3 as $CaCO_3$)	-	200
Total acidity	0.3	-

Cont…

Parameter	Ingest desirable level	Maximum permissible
Total dissolved solids (mg/dm^3)	500	1000
Total hardness (mg/dm^3 $CaCO_3$)	100	500
Calcium (mg/dm^3)	75	200
Magnesium (mg/dm^3)	50	150
Sodium (mg/dm^3)	200	-
Potassium (mg/dm^3)	10(EU)	-
Cadmium (mg/dm^3)	-	0.003
Chromium (mg/dm^3)	-	0.05
Copper (mg/dm^3)	0.05	2
Nickel	-	0.02
Iron	0.3	1.0
Lead	0.01	0.05
Zinc	3	5

Table 4: Bacteriological assay of borehole waters in Ezinihitte Mbaise L.G.A, Imo State, Nigeria

Sample point	Total coliform count ($cfu/100\ cm^3$)
Akpodim	0.96×10^2
Amumara	0.15×10^2
Chokoneze	0
Eziduo	0
Ihitte	1.90×10^2
Itu	0.12×10^2
Oboama	0.19×10^2
Obizi	0
Okpofe	1.4×10^2
Onicha	0.72×10^2
Umumana	2.56×10^2
Eu Std	0

TDS was considered low for all the water samples. This low level, far below the WHO guideline value for drinking is good. The lowest value was determined in the water sample from Itu, 6.4 mg/L whereas the highest value was measured in sample from Onicha, 34.5 mg/L. Total solids (TS) values ranged from 10 to 90 mg/L with Ihitte borehole water having the lowest value and Itu sample having the highest value.

Values of chloride ranged from 0.5 to 9.5 mg/L. Water samples from Onicha and Chokoneze boreholes had the least values. These are good and meet the WHO guidelines. Nitrate was detectable at very low levels in 10 boreholes, ranging from 0.6 to 2.9 mg/L. These values were far below WHO maximum permissible level of 50 mg/L. Phosphate values were also very low, ranging from 0.01 to 0.02 mg/L and was not detectable in boreholes located in Oboama, Eziudo, Itu and Okpefe. Sulphate levels ranging from 0.05 to 0.13 mg/L were far below the WHO maximum of 500 mg/L. Highest value for total hardness (38 mg/L) was determined in water sample from borehole in Onicha while those from Umunama had the least value (6 mg/L). This indicates that the groundwater in Ezinihitte Mbaise area is mainly soft water. This is because the values fall between 0 and 50 mg/L for sulphate. Values of total alkalinity ranged from 0.5 to 24.5 mg/L. Total alkalinity was not detectable in boreholes in Obizi and Umunama. Total acidity levels ranged from 0.76 to 40.32 mg/L.

The data on metals presented in Table 2 show that the concentrations of sodium, potassium, calcium and magnesium were close to WHO guideline values. Sodium was detected in all the boreholes at very low levels, ranging from 5 to 13 mg/L. Potassium levels ranged from 1 to 12 mg/L. Calcium levels ranged from 4 to 81 mg/L. These are low compared to the WHO guideline values of 75 mg/L. Magnesium was detected in all the water samples, in the range of 2 to 7 mg/L. Borehole waters from Itu and Okpefe had the highest values of 7 mg/L.

Chromium, cadmium and lead were not detectable in any water sample. This could imply that none of the water boreholes is exposed to anthropogenic lead, cadmium and chromium contamination and that the rocks and soils surrounding the areas may have just very low concentrations of these toxic metals. Nickel was not detectable in borehole waters from Akpodim, Chokoneze and Okpofe while in others it was measured at 0.01mg/L, which is lower than WHO guideline value of 0.02 mg/L. The only borehole water that showed no value for copper was that located at Onicha. The maximum value of 0.19 mg/L was obtained in Ihitte borehole. Thus copper had values ranging from 0.01 to 0.19 mg/L while the WHO guideline value is 2 mg/L. Iron with values ranging from 0.01 to 0.25 mg/L occurred in all samples with the exception of samples from Akpodim and Eziudo. All the values fell below the maximum allowable concentration of 0.3 mg/L of iron in drinking water. Zinc was not detectable in boreholes at Akpodim, Eziudo and Okpofe. Its values ranged from 0.01 to 0.15 mg/L, with the maximum value obtained in Amumara borehole water.

Pollution by *E. coli* was observed in eight out of the eleven boreholes in which the number of colony forming units (cfu) ranged from 1.2 x 10^2 to 2.56 x 10^2 cfu/100 mL whereas the European Union Standard is zero cfu/100 mL. Any value of bacteria viable counts other than zero, impairs water quality. The water sample with the highest microbial load of 2.56 x 10^2 was that from Umunama while the borehole water from Itu had the least value of 1.2 x 10^2 cfu/100 mL. Those with 0 cfu, were Chokoneze, Eziudo and Obizi.

Studies have shown that low pH characterize most groundwater resources studied in Nigeria[2,4,7]. The reported values include a range of 4.8 to 5.1 in Onitsha, mean value of 5.56 in Benin[8]; range of 4.3 to 7.8 in Lagos[9] mean of 6.3 in Akure[10]; range of 5.9 to 7.0 in Nsukka, Enugu State[7]; a range of 5.8 to 7.4 in Gboko[2]; and range of 3.7 to 5.5 in Isuikwuato, Abia State Nigeria[4]. The pH values of all the water samples fell below the WHO guideline values of 6.5 to 8.5 for drinking water. Waters with pH lower than 4 possess sour taste and those above 8.5 alkaline bitter tastes. High pH in water could lead to the formation of trihalomethanes, a toxic contaminant of drinking water[6]. The borehole waters have low buffering capacity. Though pH has no direct effect on the human health, all the biochemical reactions are sensitive to variation of pH for most reactions as well as for human beings. pH value of 7.0 is considered best and ideal (WHO). Water samples with low pH ($\leq$ 6.0) could be attributed to the discharge of acidic water into these sources from agricultural and domestic wastes.

The electrical conductivity is a valuable measure of the amount of cations and anions in water. The conductivity values were far below the WHO guideline value of 2500 µs/cm for drinking water. This is directly related to dissolved ions. The borehole in Onicha having the highest value for conductivity indicates that it has most of its salts dissolved in it. The values of total dissolved solids were low compared with the WHO guideline value for drinking water. Total dissolved solids in drinking water has been associated with sewage, urban runoff, industrial waste water and chemical seepage[11], though of aesthetic rather than health hazard[11,12].

The level of total alkalinity in the water samples could be attributed to bicarbonate ions since hydroxide and carbonate alkalinity were completely undetectable in any of the water samples. The result of total hardness obtained shows that the waters were soft. The highest values were less than 50 mg/L. Soft water has been associated with rickets in children[11]. On the other hand, hard water has been associated with rheumatic pains and goiter. Hard water consumes more soap to produce lather; produces deposits and scaling in pipes and steam boilers, hardens vegetables and would not allow it to cook well, and therefore not very good for drinking and domestic uses[7].

Chloride values were very far below the WHO guideline value of 250 mg/L. Chloride is a conservative parameter and has a evapotranspiration factor from rainwater to groundwater[13].

Nitrate levels in all the boreholes were very low compared to the WHO guideline value. Therefore, these waters are safe for consumption both for babies and adults. High nitrate in drinking water leads to methemoglobinemia cases in babies.

Phosphate values were very low and could indicate that there was little or no seepage of domestic sewage, or agricultural leaching or runoff water. Sulphate values were also far below the WHO guideline value. High levels of sulphate cause diarrhea and dehydration[14].

The levels of calcium and magnesium were very low compared to the WHO guideline values of 75 mg/L and 50 mg/L respectively. When there is high content of calcium and magnesium in drinking water, it could result to kidney or bladder stones[14].

Potassium in water is very important in human body. It regulates the water balance and the acid-base balance in the blood and tissue[15]. WHO does not have any fixed health guideline value for potassium present in drinking water which suggests its safety. However, USEPA has set a maximum level of 100 mg/L and EU a guideline value of 10 mg/L. It has been recommended that waters with potassium exceeding 12 mg/L is not good for regular drinking because it could lead to renal stress and possible kidney failure[15]. The borehole water at Oboama showed a potassium concentration of 12 mg/L which is above EU guideline value (12), while the rest showed a range of 1-4 mg/L.

At low concentration of sodium in drinking water, there is no health concern because in healthy people, excess of Na is got rid of via the kidneys. Sodium is considered harmful at high concentrations in drinking water to persons suffering from cardiac, renal and circulatory diseases because of their inability to maintain the required body balance of sodium[14]. The food and National Board of the National Research Council of America recommends that the intake of sodium be limited to not more than 2400 mg per day[15].

Sodium values ranged from 5 mg/L in Onicha borehole water to 13 mg/L in umunama samples, indicating low values against the WHO guideline value of 200 mg/L for drinking water. This implies that all the borehole waters sampled do not have health related issues with respect to sodium concentration. At levels above 200 mg/L, sodium may affect the taste of drinking water. These waters are safe for drinking without having further health implications. Most water supplies contain less than 20 mg/L of sodium whereas in some countries, levels can exceed 250 mg/L[16].

Chromium, cadmium and lead were not detectable at all in all the samples analyzed. This could be attributed to lack of industries such as leather, paints, dyes, explosives, ceramics and paper industries around the locality. Cadmium naturally occurs in ground water when it is found in low concentrations in rocks. Cadmium may enter the water supply from mining, industrial operation and leachates from landfill. Also it may enter the distribution system from corrosion of galvanized pipes. It is inferred that non of these features or factors is associated with the borehole waters assayed.

Copper was not detectable in borehole at Onicha. Others had values far below the WHO guideline value of 2 mg/L for drinking water.

Nickel was not found in Akpodim, Chokoneze and Okpefe borehole waters as shown in Table 2. Others had low levels of nickel. Iron occurred in the borehole waters at very low levels with exception of boreholes in Akpodim, Eziudo and Ihitte. The highest value of 0.25 mg/L is most likely to come from leaching of iron salts from soil and rocks.

Zinc was not detectable in boreholes in Akpodim, Eziudo and Okpefe. It was present in the remaining boreholes with the highest value of 0.15 mg/L obtained from Amumara. All values fell below the WHO guideline value of 3 mg/L for drinking water hence making the water samples fit or safe for drinking.

However, all the samples except those from Chokoneze, Eziudo and Obizi, showed total coliform count above zero. Zero is the EPA and WHO maximum contamination level (MCL) per 100 mL of water[17]. By the EPA and WHO guideline values, any water that has coliforms or *E. coli* is not safe for drinking. Thus the major pollution factor of groundwater resources in Ezinihitte Mbaise Local Government Area of Imo State, Nigeria is bacteriological. This is an impairment, which can however be redeemed by boiling and chlorinating the waters to make it safe for drinking.

Many countries had reported extensively on the analysis of borehole waters for the presence of common inorganic ions and physical parameters. It is of great importance to compare the results obtained from this analysis of borehole waters in Ezinihitte Mbaise Local Government Area, Imo State, South-east Nigeria with those of other nations to know the difference in the composition, suitability for drinking and their deviation from international guidelines outlined for drinking water especially in respect of current world attention to the development of international tourism and the place of packaged water, which in many cases are sourced from ground water. The results from this work have been compared with the composition of borehole waters from twenty countries[18]. From each of these countries the number of samples reported were as follows: Ethiopia, nine samples; Eygpt, five samples; Australia, six samples; Canada, two samples; China, eight samples; France, eight samples; Germany one sample; Hong Kong, five samples; Iceland, one sample; Indonesia, six samples; Italy, three samples; Japan, three samples; Malaysia, three samples; Portugal, two samples; Scotland, two samples; Sweden, one sample; Thailand, two samples; Turkey, one sample; UK, four samples and USA, two samples. The reports show that all these water samples were analyzed for common ions which include Cl^-, NO_3^-, SO_4^{2-}, Na^+, K^+, Mg^{2+} and Ca^{2+}. Table 5 presents the comparison of the results obtained from this research work with those reported results as ranges of the results of all the samples for each ion.

From Tables 5-7, the only impairing factor to the quality of the studied water samples is bacteria and this can be dealt by boiling.

Table 5: Comparison of the results obtained by present study with results from other countries in mg/L of the analytes[18]

Country	Analytes						
	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}
Ezinihitte Mbaise	0.5-9.5	0.0-2.9	0.05-0.13	5-13	1-12	4-81	2-7
Ethiopia	3.57-48.1	0.0-13.9	0.0-9.06	2.77-**195.4**	1.19-**36.3**	1.51-51.4	1.30-21.9
Egypt	11.1-**221.1**	0.1-18.7	10.4-68.12	4.49-**169**	0.11-18.5	1.39-44.8	1.54-23.3
Australia	5.9-47.4	0.6-24.8	0.7-6.8	2.4-34.5	0.7-20.0	0.5-4.6	5.7-38.6
Belgium	5.7-11.4	0.2-1.3	4.0-4.7	7.2-7.9	1.2-1.3	6.0	1.2
Canada	0.0	0.2-1.0	1.7-6.7	0.0-1.5	0.2-6.0	3.0-7.9	0.0-0.7
China	0.0-67.0	0.9-**35.9**	0.5-**177.0**	8.1-31.4	0.4-24.1	0.7-**171.4**	1.0-12.5
France	4.3-**125.3**	0.0-18.3	7.2-**1039.0**	7.5-49.0	5.0-**58.9**	6.5-**468.6**	2.2-21.0
Germany	45.8	1.1	47.0	**227.0**	170.5	113.0	**50.5**
Hong Kong	7.9-80.9	0.0-4.2	0.0-98.7	0.0-44.0	0.0-6.4	2.4-22.0	0.2-**47.3**
Iceland	15.9	0.7	2.6	14.7	1.1	4.7	0.0
Indonesia	0.0-26.4	0.7-**38.1**	1.3-27.2	9.1-40.0	4.3-70.7	2.8-21.4	2.8-10.3
Italy	0.0-19.4	5.1-9.1	4.8-41.5	3.3-30.9	0.5-**26.5**	6.3-40.0	0.8-**48.0**

Cont…

Country	Analytes						
	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}
Japan	3.0-7.8	0.5-1.5	0.4-2.3	7.9-8.4	0.9-2.8	0.4-2.1	0.4-2.1
Malaysia	2.9-22.9	0.0-13.5	0.9-3.2	5.8-30.8	0.0-3.4	4.9-18.3	4.0-5.8
Portugal	8.6-15.8	1.3-1.9	0.7-1.3	7.6-11.8	1.5-13.6	0.0-22.1	3.0-4.3
Scotland	8.6-**138.6**	1.1-4.8	0.8-8.0	8.1-58.0	13.3-17.9	47.7-**110.0**	2.9-3.1
Sweden	26.5	0.7	9.3	**225.0**	0.6	5.5	1.9
Thailand	30.7-**133.2**	0.2-0.4	1.7-33.9	68.0-69.2	0.2-14.9	31.6-38.0	1.5.1-25.0
Turkey	0.0	1.7	3.8	0.4	4.6	31.0	0.1
UK	15.1-33.5	0.3-15.0	3.6-70.0	10.3-30.0	1.4-**26.0**	54.6-**140.0**	0.8-5.0
USA	7.2-**214.1**	0.4-0.6	0.6-106.1	0.0-11.1	0.2-3.7	9.1-79.7	3.8-4.3

Bold fonts indicate values exceeding limit of standard

Table 6: Comparison of results of heavy metals with some national and international guidelines[19-23]

S. No.	Guidelines	Analytes					
		Cd	Cr	Cu	Fe	Pb	Zn
1	WHO[6]	0.003	0.05	2	0.2	0.01	5
2	Australia[19]	0.002	0.05	2	0.3	0.01	3
3	Canada[20]	0.005	0.05	≤ 1	≤ 3	0.01	≤ 5
4	USEPA (Government of Pakistan[21]	0.005	0.05	1	–	0.005	5
5	New Zealand[21]	0.004	0.05	2	–	0.01	–
6	Pakistan[22]	0.003-0.01	0.05-0.1	1-2	–	–	–
7	Codex[23]	0.003	0.05	1	–	0.01	–
(i)	Akpodim	ND	ND	0.01	ND	ND	ND
(ii)	Amumara	ND	ND	0.03	0.07	ND	0.15
(iii)	Chokoneze	ND	ND	0.01	0.05	ND	0.02
(iv)	Eziudo	ND	ND	0.01	ND	ND	ND
(v)	Ihitte	ND	ND	0.19	0.25	ND	0.01
(vi)	Itu	ND	ND	0.02	0.02	ND	0.03

Cont…

S. No.		Guidelines	Analytes					
			Cd	Cr	Cu	Fe	Pb	Zn
	(vii)	Obizi	ND	ND	0.01	0.015	ND	0.03
	(viii)	Oboama	ND	ND	0.04	0.01	ND	0.09
	(ix)	Okpofe	ND	ND	0.01	0.03	ND	0.08
	(x)	Onicha	ND	ND	ND	0.06	ND	ND
	(xi)	Umunama	ND	ND	0.04	0.02	ND	0.01

The limit is not given; ND = Not detectable

Table 7: Comparison of the results on common ions with some national and international guidelines

S. No		Guidelines	Analyte (mg/L)							
			Na^+	K^+	Mg^{2+}	Ca^{2+}	Cl^-	NO_3^-	SO_4^{2-}	PO_4^{3-}
1.		WHO[6]	200	–	150	75	250	50	250	15.3
2.		Australia[19]	180	–	–	–	250	50	500	–
3.		Canada[20]	≤ 200	–	–	–	≤ 250	45	≤ 500	–
4.		USEPA[21]	–	–	–	–		10	250	–
5.		Pakistan[22]	–	–	–	–	250-400	–	–	–
6.		Codex[23]	–	–	–	–	–	50	–	–
	(i)	Akpodim	6	4	4	8	1.0	0.7	0.07	0.01
	(ii)	Amumara	8	3	6	14	4.5	0.6	0.08	0.01
	(iii)	Chokoneze	8	3	4	10	0.5	1.6	0.07	0.01
	(iv)	Eziudo	10	2	4	20	9.0	2.1	0.06	ND
	(v)	Ihitte	7	1	6	81	1.5	1.4	0.05	0.01
	(vi)	Itu	5	1	7	8	3.2	0.6	0.06	ND
	(vii)	Obizi	9	3	6	12	4.5	1.3	0.13	0.02
	(viii)	Oboama	11	12	5	14	9.5	1.3	0.07	ND
	(ix)	Okpofe	8	1	7	20	5.0	0.9	0.11	ND
	(x)	Onicha	5	1	6	32	0.5	0.0	0.06	0.01
	(xi)	Umunama	13	4	2	4	3.5	2.9	0.06	0.01

The limit is not given; ND = Not detectable

CONCLUSION

The results of the physico-chemical analyses in this study have shown that most boreholes in Ezinihitte Mbaise area are not considerably contaminated by chemicals. The parameters assayed were found in most cases far below the stipulated guideline values. This indicates that the aquifers in this area has not been adversely affected either by the geochemical or anthropogenic factors. The data are therefore baseline. However, they have shown a high degree of faecal contamination as depicted in the result of bacteriological analysis. The presence of coliform count makes the water unsafe for drinking. The sources of the faecal pollution should be checked and prevented. Generally, the quality of the waters could be improved in respect to faecal pollution by boiling and chlorination before any use.

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Accepted : 04.10.2013