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Spatial Distribution of Iron (Fe^{2+}) and Hydrogen Sulphide (H_2S) in Exploited Groundwater of Obubra, South Eastern Nigeria

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Abstract

This study focused on detecting the distribution and presence of Iron and hydrogen sulphide in the exploited groundwater of Obubra to assess its quality for drinking and other domestic purposes. Groundwater samples were collected from fifteen different locations. The samples were analyzed and results show that more than eighty five percent of the exploited groundwater is below NDWQS/WHO standard. The wide distribution of Iron and hydrogen sulphide in the groundwater could be attributed to the subsurface geology. However, results show that groundwater samples of S1 and S9 meet the NDWQS/WHO standard. Coincidentally, S1 and S9 have the highest elevation in the study area. Sample 4 (S4) with concentration of 25.8 mg/l has the highest iron concentration in the area. Though, sample 11 (S11) was collected from an artesian well, it did not meet the required standard for drinking. Most of the groundwater has objectionable taste and odour. In most of the areas, the Iron concentration of groundwater indicates that the water will not be suitable for laundry.

Keywords: Iron; Hydrogen sulphide; Groundwater; Subsurface-Geology; Odour; Taste; Objectionable

Introduction

Obubra is located in Cross River State, Southeastern part of Nigeria. It is within the tropical climate with predominantly wet and dry seasons. It lies within latitudes $5^0 50^{11}$ N to $6^0 065^1$ N and longitudes $8^0 15$ E to $8^0 30^1$ E. In Obubra several boreholes have been drilled with the hope of exploiting portable groundwater for steady and reliable supply to meet the high demand, since surface water pollution is on the increase [1-3].

More than 60% of the boreholes have been abandoned in the area, due to yield of poor water quality from the boreholes. Knowledge of the cause of poor water quality and the extent of distribution is yet unknown as there have been little or no research on the groundwater quality in the area. Since groundwater makes up about 21% of the world's fresh water supply [4], more boreholes are still been drilled in the area with the expectation of accessing quality groundwater. However, little or no reasonable success is recorded, resulting in the waste of resources. The above necessitated this research.

Water samples were collected in good quality screw-caped polyethylene bottles at different hand pump wells and borehole locations. The samples were analyzed in the laboratory. The presence of iron and hydrogen sulphide were suspected in the field due to the rotten egg smell in the water samples and red-brownish colour seen on the base of most boreholes and storage tanks.

Results show that there is wide distribution of iron and hydrogen sulphide in the exploited groundwater of the area. From the results, over 75% of the boreholes in the area yield groundwater below WHO standard for drinking water. The iron content ranges from 0.1 mg/l to 25 mg/l and hydrogen sulphide from 0.05 mg/l to 1.14 mg/l. The high values of Fe^{2+} and H_2S (above 0.3 mg/l and up to 1.8 mg/l) in the exploited groundwater has made it deleterious as it impacts a stringent odour and metallic taste to water if the concentration is above 1.8 mg/l [5].

The above could be as a result of the complex subsurface geology of Obubra.

Area of Study

The study area lies within latitudes $5^0 50^{11}$ N to $6^0 065^1$ N and longitudes $8^0 15$ E to $8^0 30^1$ E. The study area hosts the former IBB College of Agriculture, National Youth Service Camp (NYSC), DLCM camp ground (Figure 1). The area is between Ikom–Calabar highway and therefore easily accessible through the said highway [6].

The clastic beds in the study area can be ascribed to the Ezillo Formation. The Ezillo Formation comprises mostly dark gray shales with fine sandstone and siltstone intercalations in the lower part, and an upper unit that is highly bioturbated with fine medium sandstone, similar to the sandstone of the Amasiri Formation. However, in Ohana, there are black, baked, slaty shale that is intruded by dolerite sills. The sills contain spherules of magmatic rock, as exposed in an abandoned quarry occupied by a green pond all year round. Only the top of the shale sequence with siltstone/sandstone intercalations are observable at the top of the quary, because of the pond. The Ezillo Formation between Appiapum and Ikom is deposited in a deltaic coastal plain, in brackish marshes and inter-distributary bays [7]. A major river (Cross River) exists in the study area into which the streams empty their loads. The said streams often dry up during drought (dry season). The topography of the study area is undulating.

Materials and Methods

Groundwater samples from different hand pump wells and boreholes

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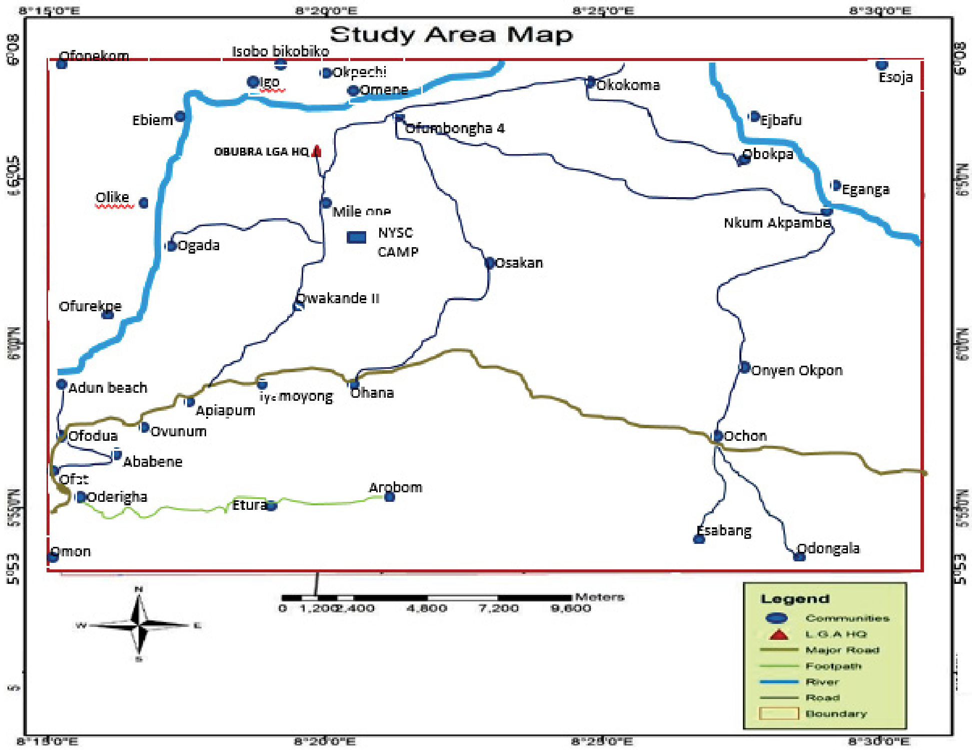

Figure 1: Map of study area.

of fifteen sampling points from Samples were collected in good quality screw capped polyethylene bottles of one liter capacity. Sampling was carried out without adding any preservatives in rinsed bottles directly to avoid any contamination and brought to the laboratory in minimum period of time.

The Wagtech WTD Photometer was used to test for Iron and for hydrogen sulphide in the samples collected.

The Fe^{2+} test was carried out simply by adding a reagent containing thioglycollate to a sample of the water under taste.

$$2HSCH_2COOH+Fe^{3+} \longrightarrow Fe\,(HSCH_2COO)_2+2H^+$$

The thioglycollate reduces ferric iron to ferrous iron and this, together with any ferrous iron already present in the sample, reacts to give a pink colouration. The intensity of the colour produced is proportional to the iron concentration and was measured using the Wagtech WTD Automatic Wavelength Selection Photometer.

The hydrogen sulphide was determined by first testing for sulphide. A simplified method for the determination of sulphide, based on a reagent containing diethyl-p-phenylene diamine (DPD) and potassium dichromate was used. Sulphide reacts with this reagent in acid solution to produce a blue coloured complex. In the absence of sulphide the reagent produces a pink colour. Chlorine, and other oxidizing agents which normally react with DPD, do not interfere with the taste. The reagents are provided in the form of two tablets and the taste is simply carried out by adding one of each tablet to a sample of the water. The colour produced is indicative of the sulphide concentration and is measured using the Wagtech WTD Automatic Wavelength Selection Photometer. To convert from mg/l S to mg/l H_2S, the result was multiplied by 1.06.

Results are compared with Nigeria Drinking Water Quality Standard/World Health Organization (NDWQS/WHO).

Results and Discussion

From the results, Fe^{2+} content in the exploited groundwater in the area is above the NDWQS/WHO except for three wells. Sample 4 (S4) with concentration of 25.8 mg/l has the highest percentage of Iron concentration in the area. Other sample points with very high concentrations of Iron includes S2, S3, S5, S7, S8, S10, S12, and S23 with percentage concentrations of 13.4 mg/l, 18.7 mg/l, 18.6 mg/l, 17.6 mg/l, 10.8 mg/l, 16.0 mg/l, 21.6 mg/l and 23.4 mg/l respectively. The overhead tanks close to sample 2 and in sample 3 and 10 locations are coated with brownish red colouration that is unmistakably a result of oxidation of Fe^{2+} to Fe^{3+}. The case is not different in sample points such as S4, S5, S12, and S23 as the concrete base around the well casing; the casing projections and the drains are coated with same brownish red colouration. Sample points S6, S11 and S13 have concentration values of 6.2mg/l, 0.5mg/l and 9.8mg/l. The sample points that meet the maximum permissible requirement for drinkable waters are those of S1, S9, and S15 with concentrations of 0.1 mg/l, 0.3 mg/l and 0.2 mg/l. The said sample points are located in Mile-one, Iyamoyong and Ofumbongha 4. However, in Ofumbongha 4 many boreholes drilled have been abandoned with lasting evidence of brownish red colouration around the boreholes. In some of them, corrosion occasioned by high iron content have weakened the fabrics of mild steel structures used in their construction and pump installation resulting in sand pumping and pump drop and a reduction of their life span [5]. The borehole drilled in S11 is actually an artesian well located in a community called Ochon. However, the groundwater has putrid odour, even though the Iron content is a little above the NDWQS/WHO permissible standard, this could be as a result of the high content of H_2S in the water. All the sample points have H_2S above the permissible standard with sample point 3 being the highest and sample point 12 having the lowest value. Sample points 1 and 9 are surprisingly totally devoid of detectable taste and odour. Sample 15 has an ignorable taste that may be difficult to detect (Table 1).

From the contour maps of Iron and Hydrogen sulphide above, it is observed that the areas with low iron contents also have relatively low hydrogen sulphide contents (Figure 2). The said areas represent the locations of the communities with exploited groundwater that meets the NDWQS/WHO standard in terms of iron and nearly meets the standards in terms of hydrogen sulphide (Figure 3) [5].

From Figure 4, it is observed that the areas with low iron and hydrogen sulphide content coincide with areas of high elevation (relief) values. This could mean that the distribution of iron and hydrogen sulphide in the groundwater exploited in the study area may be due to the stratification of the layers (geology of the subsurface).

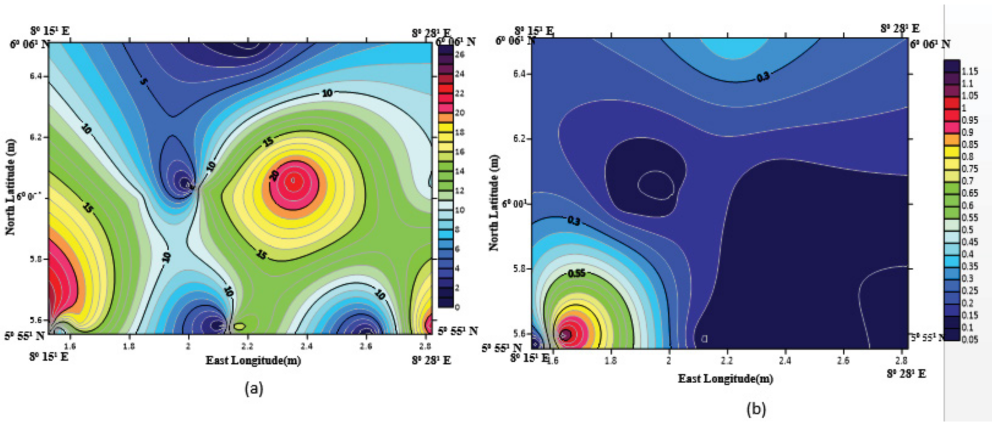

Figure 2: Iron and Hydrogen Sulphide content distribution map.

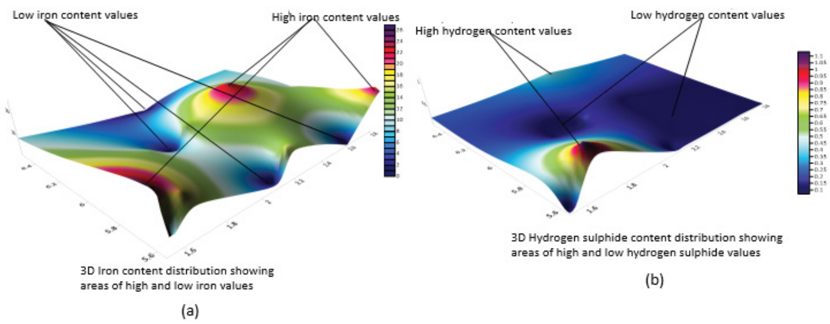

Figure 3: 3D Iron and Hydrogen Sulphide content distribution map.

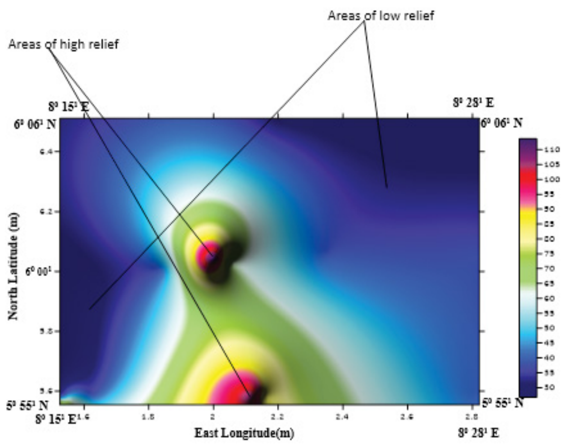

Figure 4: Map showing from points of sample collection.

S/N	NDWQS/WHO SAMPLES	Fe^{2+} (Mg/l)	H_2S (Mg/l)	Elevation (m)
		0.3	0.05	
1	S1	0.1	0.07	118
2	S2	13.4	0.19	64
3	S3	18.7	1.14	36
4	S4	25.8	0.15	31
5	S5	18.6	0.1	32
6	S6	6.2	0.07	64
7	S7	17.6	0.11	70
8	S8	10.8	0.12	38
9	S9	0.3	0.08	109
10	S10	16	0.14	85
11	S11	0.5	0.12	52
12	S12	21.6	0.15	40
13	S13	9.8	0.14	37
14	S14	23.4	0.11	38
15	S15	0.2	0.14	33

Table 1: Results of Fe^{2+} (Mg/l) and H_2S (Mg/l) test from groundwater samples.

Conclusion

The exploited groundwater in the area is generally below the maximum permissible standard in the country, except for groundwater in sample point 1 and 9. Most of the groundwater exploited is objectionable. For an artesian well in the study area to yield groundwater that has a high putrid odour and iron content above the permissible standard, it points to the fact that the occurrence of Iron may be related to the subsurface geology of the area and aquifer strata units. Exploited groundwater in the area must therefore be treated for it not to be objectionable so it can be fit for human consumption and domestic use.

The Iron content can be treated with alkaline hydrogen peroxide. It is one of the surest ways of removing Iron from groundwater. The method is fast, cost effective and environmentally friendly and does not require external coagulant.

To treat the water for Hydrogen sulphide, several methods can be used. Methods such as continuous chlorination and filtration, oxidizing filters with silicates such as zeolite can be used. Packed-bed anion exchange technology can also be used in removal of hydrogen sulphide from groundwater. It is recommended that further studies be carried out in the area to determine physio-chemical parameters as the groundwater may have other related challenges other than Iron and Hydrogen Sulphide only.

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