Scientia Africana, Vol. 7 (No.2), December 2008 pp 81-88
 ISSN 1118 - 1931

CHEMICAL CHARACTERISTICS OF GROUND WATER FROM PARTS OF THE BASEMENT COMPLEX OF OBAN MASSIF AND OBUDU PLATEAU, SOUTH EASTERN NIGERIA.

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Received: February, 2008
Accepted: August, 2008

ABSTRACT
Groundwater samples from 29 boreholes in the Basement areas of Obudu and Oban in Cross Rivers State have been analyzed for their major, minor and trace element constituents and some physical characteristics. The results are evaluated with a view to determining its quality and potability. The Ca^{2+}, Mg^{2+}, NO_3^-, SO_4^{2-} and Cl^- concentration levels of 0.8 – 69.2mg/l, 0.8 – 22mg/l, 0.02 – 1.7mg/l, 0.3 – 22mg/l and 0.3 – 22mg/l respectively, for the water samples are lower than the WHO recommended highest desirable levels of 75, 50 and 200mg/l respectively. Total Iron and Mn^{2+} concentration are 0.02 – 1.6 and 0 – 0.66mg/l respectively. All the water samples, with the exception of some from Okodi and Sankwala for total Iron and Anineje for Mn^{2+} have their concentration levels below the WHO maximum permissible levels of 1.0mg/l and 0.5mg/l. The total hardness (as $CaCO_3$) concentration levels of 10 – 220mg/l are in most cases higher than the WHO maximum permissible levels (of 500mg/l). The pH (5. 0 – 7.5) with the exception of those obtained from Sankwala, fall within the maximum permissible levels of 6.5 – 9.2 units. Generally, these chemical characteristics compare well with those of the groundwater from other basement areas but differ in many respects from those from sedimentary terrains. The water is of good quality and therefore potable.

Keywords: Basement area, concentration level, permissible levels, potable.

Introduction

Ground water is by far more abundant than surface water and its quality is as important as its quantity. Water (be it groundwater or surface water) meant for drinking must therefore meet quality standards. Water quality is essentially determined by its physical, chemical as well as microbiological characteristics. The microbial load of ground water particularly from deep boreholes is significantly low and rarely exceeds the tolerable level mainly as a result of natural filtration the water passes through on its course from the aquifer to the borehole.

In hydrogeochemical determination, the major parameters commonly analyzed for are Ca^{2+}, Mg^{2+}, CO_3^{2-}, SO_4^{2-}, total hardness as $CaCO_3$, Mg-hardness, Ca-hardness and total alkalinity as $CaCO_3$, as well as minor ions including total Iron (Fe^{2+} + Fe^{3+}), NO_3, NH_3 (Nitrate and Ammonia) Nitrogen, Fluoride (F) and trace elements which include Mn, Zn, Cu and Pb. These ions are important determinable parameters because of their sensitive effects on human health. For instance concentration of Mn leads to brain damage, that of Pb causes vomiting and abdominal pains. The deficiency of Zn leads to kidney disease. (Oxford, 2002).

In determining quality characteristics of groundwater from parts of Oban and Obudu areas of South Eastern Nigeria, the results of physical and chemical analysis for samples collected from twenty-nine boreholes are presented and discussed in this paper. The concentration levels of constituents are compared with the WHO (2007) recommended concentration levels in order to establish the potability of the groundwater. This data is also compared with published data from other parts of the Nigerian Basement complex.

The Study Area

The study area covers the whole of Oban in Akamkpa local Government Area and Obudu in Obudu Local Government Area. The area is bounded by longitudes 8^{o}E and 9^{o}E and latitude 7^{o}N and 5^{o}N respectively (Fig. 1)

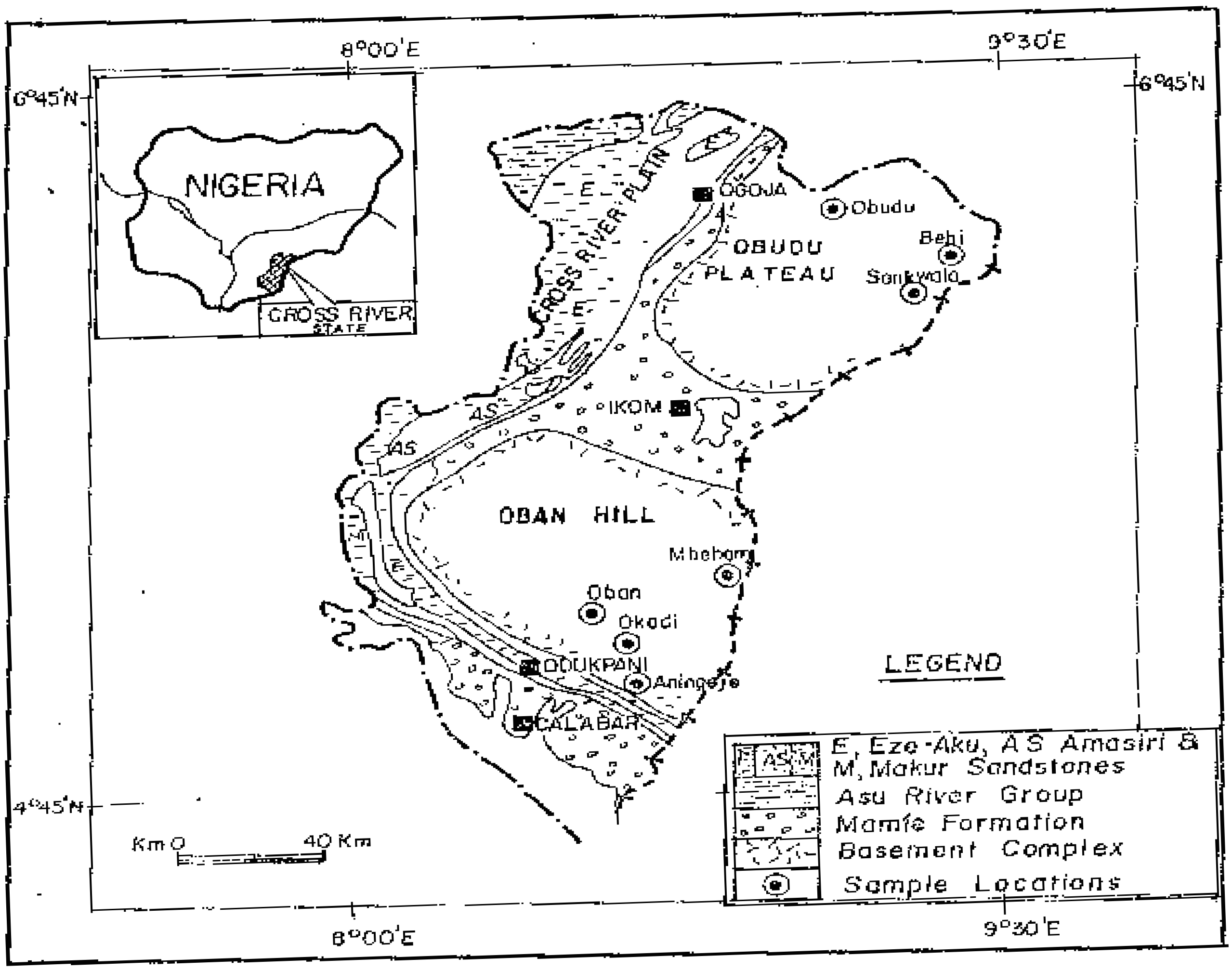

Fig. 1.: Outline Geological Map and Structures of Cross River State indicating Oban and Obudu areas and Sample locations *(Adopted from CINAB 1989).*

 ISSN 1118 - 1931

Physiography and Climate

The areas constitute the two mountainous areas in this part of Nigeria and are separated by the Ikom depression which is an ancient sedimentary basin. The landforms in the areas of study range from hills and boulder inselbergs to smooth inselbergs in Oban (Oyegun 1973) while Obudu is characterized by steep rolling hills and depressions that culminate in the flat topped plateau – the Obudu Ranch in the extreme South.

Both areas experience both wet and dry seasons which are the typical seasons in Nigeria. While other parts may be affected by erratic changes in temperatures, the top of the Ranch is permanently cold (between 16 – 20^{o}C – GNAB, 1989). Giving it a climatic characteristic that can be described as temperate.

The wet season starts from March and ends in October while the dry season begins in November and lasts till about February. The brief period between December and January is hammatan, characterized by the influence of cold dry air (Oyegun 1993). Temperatures range from 23.2^{o}C to 29.5^{o}C and can reach values up to 38^{o}C at mid-day in the hottest periods.

Geology and Hydrogeology

The two areas of Obudu and Oban are underlain by the Precambrian basement complex. Typical rocks in Oban include gneisses, migmatites, amphibolites, quartzites, schists, granites and pegmatites. In addition to the other rock types in the Oban massif, Obodu also has wide occurrences of Charnockites and rocks of the Older granites suite (Ekwueme, 1991).

These rocks have differing aquifer potentials based on their petrological and structural characteristics. The geology also overwhelmingly imposes its chemistry on the ground water making it to acquire similar chemistry to that of the host rock.

The rocks are strongly foliated and show an alignment with other minor and major structures like joints, fault planes, shear zones and fold axes. The joint and fractures aid in the development of extensive weathering profiles in many places. The main aquifer unit in a typical basement area is the weathered zone whose thickness in these areas could range between 5m and 40m or even more. The groundwater is rarely confined and static water levels could be as shallow as 3.5m. (CINAB, 1989).

The older granite inselbergs are erosion resistant and fresh rocks are often easily encountered in their vicinity since the weathered zone is thin or completely absent. However, where joint systems are well developed and thick weathered zones exist, well yields are enhanced. In the migmatite-gneiss and schist zone where foliation and schistocity enhances permeability, significant well yields of between 4 and 11 L/S have been obtained (Olorunfemi et al, 1991).

Sampling Procedures and Laboratory Analysis

The chemical analysis of water samples were carried out at the prodec Fugro Laboratory in Port Harcourt. Water samples were taken at the end of the constant rate pumping tests for each of the boreholes and analyses were done approximately 24 hours after sampling.

The methods used include titrimetry, colorimetry and gravimetry. The chemical parameters Ca^{2+}, Mg^{2+}, Ca Hardness, Mg hardness, alkalinity and iron were analyzed with Titrimetry while Mn^{2+}, NO_3^{2-} and colour were determined with colorimetry and SO_4^{2-} with gravimetry conductivity meter, turbidometer and pH meter were used to determine the conductivity, turbidity and P_H respectively. The chemical parameters used in characterizing the groundwater from the boreholes are pH, conductivity, Ammonia, Nitrogen, Iron, Cr^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, Mn^{2+}, Ca hardness, Mg Hardness, total alkalinity and fluoride. The physical characteristics determined include turbidity and colour. Table 1 gives the result of analyses for these parameters in the different water samples for the 29 boreholes.

Table 1: Data from the chemical analysis

Location/Geology	*Bebi Granite*	*Obudu Town Migmatite gneiss*	*Anineje Migmatite gneiss*	*Oban Migmatite gneiss*	*Okodi Migmatite gneiss*	*Sankwala Migmatite gneiss*	*Mbebam gneiss*
Number of boreholes sampled	4	4	4	5	3	4	5
Concentration levels	Range	Range	Range	Range	Range	Range	Range
Conductivity (umhos/cm)	225–310	250–400	150–300	240–460	200–800	25–70	200–540
Turbidity (N. T. U)	–	–	0–2.5	4.7–15	4.6–32	0.17–6.6	–
Colour (^oH)	–	–	0–20	5–12	5–30	0–15	–
P_H (Units)	6.2–6.7	6.5–7.2	6.7.1	6.7–7.5	6.5–7.02	5.0–5.9	6.9–7.5
Ammonial Nitrogen (Mg/l)	0.05–0.22	0.02–0.05	0.03–0.05	–	–	–	0.01–0.04
Nitrate Nitrogen (Mg/l)	1.0	0.02–2.5	0.05–0.9	0.2–0.5	–	0.5–1.1	0.07–1.7
Fe^{3+} (Mg/l)	–	0.08–0.4	–	–	–	–	–
Total Iron (Mg/l)	0.05	–	0.08–0.3	0.8–1.4	0.2–1.6	0.08–0.5	0.02–0.2
Ca^{2+} (Mg/l)	21.6–39.6	19.6–34	19–40	24–68	–	0.8–9.6	32.8–69.2
Mg^{2+} (Mg/l)	2.3–4.5	20.7–22	6–8.5	4.9–9.9	–	0.8–3.6	2.92–11.4
Cl^- (Mg/l)	0.6–1.2	0.5	0.5–2	0.6–3	–	0.5–8.5	0.3–22
Sulphate (Mg/l)	0–2	0.2–6	2.0	–	03–4	0.4–5	2–7
Mn^{2+} (Mg/l)	–	0.1–0.3	0.2–0.66	0–0.3	–	0.2–0.3	0.15–0.5
Ca Hardness $CaCO_3$ (Mg/l)	34–99	49–85	48–100	61–170	–	2–24	82–173
Mg Hardness $CaCO_3$ (Mg/l)	23–34	85–91	25-35	20-37	–	2.1–10	12–138
Total Hardness as $CaCO_3$ (Mg/l)	87–133	134–174	73–135	98–195	–	10–30	94–222
Total Alkalinity as $CaCO_3$ (Mg/l)	110–160	122–198	52–165	129–235	–	12–29	150–285

 ISSN 1118 - 1931

Results and Discussion

Discussions are done here of the major chemical constituents with emphasis on their concentration levels in relation to the WHO permissible levels:

The pH ranges from 5.0 to 7.5 in Mbebam on the average. Egboka (1986) has pointed out that most ground water in Nigeria have pH values from 5.5 to 6.5 Units. It has however been observed that occasionally pH values of up to 7 units are obtained. The pH levels obtained here are comparable with those from other localities in the Nigerian Basement complex (Ako et al 1986, Nwogute, 1986 and Amadi 1987). The pH levels are within the WHO permissible range of 6.5 and 9.2 Units (table 2). The range of general acceptability is 7.0 – 8.5 units. The Sankwala borehole water with slightly low pH values (5.0 – 5.9) is acidic and this may cause severe corrosion of the borehole casing and metals in the distribution system.

TABLE 2: Standards for drinking water

Characteristics	Highest Desirable Level	Maximum Permissible Level
Colour (^oH)	5	50
Turbidity (N. T. U)	5	25
pH (Units)	7–8.5	(Minimum 6.5) (Maximum 9.2)
Chloride (Cl^-), Mg/l	200	600
Manganese (Mn^{2+}), Mg/l	0.05	0.5
Flouride (F^-), Mg/l	0.7–1.0	0.5
Copper (Cu^{2+}), Mg/l	0.05	1.5
Iron (Fe^{2+}), Mg/l	0.1	1.0
Nitrate (NO_3^-), Mg/l	45	50
Total Hardness		
$CaCO_3$, Mg/l	100	500
Sulphate (SO_4^2), Mg/l	200	400
Zinc (Zn^{2+}), Mg/l	5.0	15
Calcium (Ca^{2+}), Mg/l	75	200
Magnesium (Mg^{2+})	50	150

(WHO, 2007)

In this work only Ca^{2+} and Mg^{2+} concentration levels were determined out of the alkaline earth metals. The concentration ranges are 0.8 – 69.2mg/l for Ca^{2+} and 0.8 – 22mg/l for Mg^{2+}. Both constituents are within WHO recommended concentration levels of 75 and 50mg/l respectively (table 2). These two elements are the main combative agents of hardness of groundwater. The relevant nutrient elements are Ammonia, Nitrogen and Nitrate nitrogen. The concentration levels for both constituents are 0.01 – 0.22mg/l and 0.02 – 11.7mg/l. The WHO recommended concentration limit for Nitrate (as NO_3) is 45mg/l.

The sulphate concentration levels range from 0.3 to 7mg/l. The WHO maximum desirable level is 200mg/l. Ezeigbo (1988) observed that a sulphate concentration of more than 250mg/l is objectionable for some industries while water containing about 500mg/l sulphate tastes bitter.

The chloride (Cl^-) concentration levels vary from 0.3 – 22mg/l. These values are far less than the WHO recommended highest desirable levels of 200mg/l (Table 2).

Manganese, like iron is very significant in assessing potability of water as even minute amounts of the element in water are objectionable. Manganese concentration range of between 0 and 0.66mg/l was obtained in the study area. The highest of 0.66mg/l was got in Anineje South of Oban Town. All other water samples had their Mn levels conforming with the WHO maximum permissible level of 0.5mg/l. Water with higher concentration is likely to have unpleasant taste.

The concentration of total iron from this area range from 0.03 to 1.6mg/l. The WHO maximum level is 1.0mg/l. The samples from Okodi have slightly higher values of total iron of about 1.6mg/l. High concentration of iron could cause staining of laundry and an undesirable taste in beverages. Egboka, 1986 has noted that groundwater from basement areas have total iron contents of less than 1mg/l and rarely exceeding 2mg/l.

The Ca^{2+}, Mg^{2+}, NO_3^-, SO_4^{2-} and Cl^- concentration levels for all the samples of water fall within the WHO acceptable levels. But some few exceptions exist, such as the relatively high (up to 1.mg/l in Okodi waters and the relatively high Mn^{2+} (up to 0.66) in Aninenje water.

Most of the water samples have total hardness (as $CaCO_3$) concentration that are higher than the WHO desirable levels but are still within the maximum permissible level. The groundwater is moderately hard to hard.

The pH values, with exception of those obtained from Sankwala fall within the maximum permissible levels.

Comparison

The waters from the basement areas of Oban and Obudu have chemical qualities that are comparable with those from other basement areas in Nigeria, at least in parameters like pH, total iron, hardness, Ca^{2+}, Mn^{2+}, etc all falling within the potable water levels. But when compared with waters from areas underlain by sedimentary rocks, the lower limit of most parameters are a lot lower than those from the basement areas. For example while Mg^{2+} levels are generally within the range of 0.05 – 1.9mg/l in the Niger Delta, (Udom et al, 2002), the range is between 0.8 and 22mg/l in the study area.

This is largely attributable to the chemical breakdown of some feromagnesium minerals (rich in Fe and Mg) like amphiboles and pyroxenes which form the bulk of these basement rocks. Table 3 shows the details of this comparison.

Table 3: Comparison between values of Parameters from the study areas and those from a sedimentary Basin (Niger Delta).

Parameters	*Range in Study Area (basement)*	*Range from sed. Terrain (Niger Delta Udom & Ushie 2002)*	*WHO (2007) Standards. (Maximum Permeable)*
Colour (°H)	0 – 30	0 – 30	50
Turbidity (NTU)	0 – 32	0 – 32	25
pH (Units)	5.0 – 7.5	6.8 – 7.2	6.5 – 8.5
Chloride (Cl^-)	0.3 – 22	20.2 – 44.9	600
Manganese (Mn^{2+})	0.1 – 0.66	–	0.5
Floride (F^-) Mg/l	–	–	0.5
Total Iron (Mg/l)	0.02 – 1.6	0.01 – 0.12	1.5
Nitrate (NO_3^-) Mg/l	0.02 – 1.7	0.01 – 1.58	10 – 50
Total Hardness ($CaCO_3$)Mg/l	2 – 138	0.22 – 6.24	500
Sulphate (SO_4^{2-}) Mg/l	03 – 7	ND	400
Calcium (Ca^{2+}) Mg/l	0.8 – 69	0.2 – 6.0	200

Based on the above information therefore, it can be concluded that the water from the study area, though with a chemical character peculiar to the basement areas is generally of potable quality.

However, to ensure supply of safe drinking water to the public, routine chemical analysis is recommended to detect on time, incidental or eventual deterioration of water quality especially in the urban areas of Oban and Obudu which are prone to industrial pollution.

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