



GEOCHEMICAL APPRAISAL OF OBUDU RANCH SPRING SOUTH -EASTERN NIGERIA

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ABSTRACT

Contamination is becoming a threat to spring water in Nigeria especially the Obudu Cattle Ranch spring. This ground water resource is the major source of potable water for both the inhabitants and the agrarian society of the community. This work is part of continuous appraisal of Obudu Cattle Ranch spring. This is to identify the extent of possible contamination and infer the potability of the water. Routine analysis was conducted on the spring water samples to check for the physical, chemical and bacteriological constituents which include the pH, temperature, turbidity, conductivity, alkalinity, magnesium and others. Therefore, the geochemical status of Obudu Cattle Ranch spring in Calabar was assessed for a period of nine years at the peak period of the dry season (in March); using atomic absorption spectrometry (AAS). The result obtained show that, the pH value ranges from 5.7 to 7.3 signifying slightly acidic to neutral water. Turbidity also range from 0.045-2.47, Electrical conductivity 5.4-25u/cm³ Calcium 16.0 to 18.0mg/l, and Iron 0.1 to 0.72% respectively. The bacteriological analysis result indicates that the coliform present is numerous to count which is contrary to WHO and NAFDAC standard of 1cfu/100L of water sample. The presence of high level of bacteriological load revealed in the analysis signifies that the spring water is not safe as potable water and can pose serious danger to human and animal health. Therefore, due to the yearly quality variations and fluctuations observed in the analytical results, the spring water is recommended for treatment before it can be used for domestic purposes.

Keywords: Contamination, Bacteriological, Turbidity, Spring, Obudu, Fluctuations

INTRODUCTION

A spring is a component of the hydrosphere, it is any natural situation where water flows to the surface of the earth from underground. It can otherwise refer to as a site where the aquifer surface meets the ground surface. According to Lamoreaux and Tanner (2001) and Talabi (2013), spring arises where groundwater naturally emerges from the earth's subsurface in a defined flow which could form a pool or stream-like flow. Freshwater from the spring could be directly discharged onto the ground surface, into the beds of rivers or streams or the ocean below sea level.

From the studies conducted it was observed that spring water bottling company is making waves in Nigeria (Ikogosi warm spring and Swam water bottling in Jos). This has become a source of revenue generation both to the state of domicile and the country at large.

Terrestrial waters are essentially solutions of few salts, and other chemical characteristics (WHO, 2006) that depends on the nature and proportion of the substances they contained. The interpretation of the chemical characteristic of water from analysis is not satisfactory, based on the amounts of the radicals. Hence, water analysis should be framed with respect to the chemical nature and the proportional amounts of the radicals present in a solution of mixed salts.

Non-pathogenic bacteria are as important as the pathogenic ones; these include the sulphur and iron bacteria. Among them are the sulphate reducers which produce elemental sulphur from sulphate and iron bacteria which frequently present in ground waters posing those subjects to a degree of organic pollution. They obtain energy for their metabolism by oxidation of the ferrous and manganese ion. Pathogenic and non-pathogenic micro-organisms (bacteria, fungi, viruses) are hazardous environmental pollutants to the hydrological environment. They enter the environment from waste disposal and treatment area, sewage lagoon, barnyards and mine area (Knox and Canter, 1985).

This study is to appraise the chemical properties of the spring water, and determine the suitability of the water for domestic and industrial uses and as well identify the possible water treatment facilities to be installed to make it suitable for various uses if necessary. Overtime, the communities within this locality have depended on this untreated water which has resulted in series of water borne diseases such as typhoid fever, thus affecting a greater number of the inhabitants. The result from the appraisal obtained will be used to ascertain the geochemical nature of the spring, possible treatment plant facilities that could be installed and the flow course of the spring could be determined. The geochemical variations in geochemical composition with time between from 2002 and 2011 are being evaluated to predict the possible future occurrence or change in quality.

Regional Geological Evolution of the Study Area

Obudu Plateau, otherwise called Obudu cattle ranch

lies within the Precambrian crystalline Basement complex of Southeastern Nigeria. Although series of works had been carried out by various authors in this Basement complex among whose are Ekwueme, 1991 and 2004; Adeyeye, 2004; Akinyulli, 2003; Ephraim, 2005); Ekwueme and Kroener, 1997: but not much had been done on the hydrology and hydrogeology of this study area. According to Ekwueme (2004), the Obudu plateau is more rugged and forms a part of the Bamenda massif which stretches from the Cameroon Republic to Easting Nigeria, it lies within latitude 6° 24' N and 9° 24' East, with 1.576m elevation of above sea level and of luxuriant with good temperate and climate. Viable methods should be intensified for the treatment of polluted water to become potable, acceptable for human consumption. Some natural influences may however pollute water quality for domestic uses. When surface run-off passes through density marshy lands, there may be tendency for the colour impartation on the water due to the presence of humic acid (Degremont, 1989). Adeyeye (2004) opined that potable water supplied through pipes laying for drinking, those pipes when broken, water may pass from the leaking sewage line carrying organism and bacteria into the drinking water. Well and other sources of underground water can be contaminated by badly sited septic tanks, manure heaps or garbage dumps. This could be made potable when properly treated to prevent diseases. Pathogenic micro-organisms are present in ground-waters, especially in the vicinity of facilities that discharge sewage effluents, contaminated surface water, new septic tanks, agricultural waste and refuse tips.

The nearer these sources of pollution of ground-water sources, the greater the change of successful seepage of these micro-organisms. This makes it difficult to isolate pathogenic micro-organism from ground-water sources. Therefore, the ability to detect facial contamination at low level is the main safeguard in preserving the portability of water supply. Rivers are also affected by indiscriminate dumping of solid waste into the water. Waste disposed on land near the river is leached into the water thereby causing contamination and rendering it undrinkable (Hoko, 2005).

Waste effluents could be directly or indirectly discharged into water under man's control, whereas some get leached into water in form of chemical substance. This could be during mining operations, industrial wastes, agricultural waste, and animal husbandry effluents when not properly controlled (Balogun, 2010). The cause of water pollution in Obudu may be natural or man-made. They could have resulted from agricultural and human activities. The Agricultural activities might have contributed to the contamination of Obudu Ranch Spring. The use of agriculture chemical, such as fertilizers, herbicides and pesticides and detergent, are washed into the river causing water contamination. While Human activities like the use of chemicals and washing could make the water undrinkable, hence, it poses a threat to human life.

Geological settings of Southeastern Nigeria

The geology of Southeastern Nigeria is dominated by Cretaceous-Tertiary sediments which make up the lower Benue Trough which consists the Calabar Flank, the Mamfe Embayment, the Anambra Basin, Afikpo syncline, Abakaliki Anticlinorium and the Niger Delta. These cretaceous-Tertiary sediments lie unconformably on rocks of the crystalline basement (Oban-Obudu massif) which are Precambrian in age. These have been extensively studied by (Reyment,1965: Crathley and Jones,1965: Peters,1991: Whitman,1982: Ekwueme *et al.*, 2005 and Nton,1999) among others (Figure 1).

The lower Benue trough is among the coastal basins of central West Africa. These basins are believed to be vestiges of the fragmentation and dispersal of Gondwanaland (Peters, 1991). This involved crustal uplift, rifting and Africa continent separation. In the Gulf of Guinea, the bifurcating rift became the site of a triple junction. Two of the arms opened into an ocean with marginal basins while limited opening occurred along the third arm known as aulacogen (Benue Trough) containing a thick folded sedimentary pile and an aulacogen delta (Niger Delta) at its re-entrant (Peters 1991). The Mamfe Embayment and Yola rifts are minor bifurcations along the main axis of the Benue Trough. They contain thinner and non-marine sedimentary rocks. A maximum depth to basement of about 4km has been suggested for the southern flank of the Mamfe rift and filled with cretaceous fluvialelastic sequence. Basaltic rocks are associated with sedimentary rocks of Mamfe rift while the Satonian (older beds) in the lower Benue Trough were folded, faulted, intruded and uplifted. This resulted in the formation of Abakaliki Anticlinorium flanked in the west by the Anambra Basin and in the east by the Afikpo syncline.

Location of the Study Area

Obudu Ranch resort is located in Northern part of Cross River State, Southwestern Nigeria). It is located on the Obudu Mountain in Obanliku Local Government Area between latitude 6° 21' 30" and 6° 22' 30" N and longitude 9° 22' 0" and 9° 22' 45" E respectively. It covers an area of 104km² with an estimated height of about 1576m above sea level (NCF, 2017). Obudu Mountain Resort is bounded in the North by Benue state, North-East by the Republic of Cameroon, to the South-East by Boki Local Government Area in Cross River State of Nigeria (Figure 2).

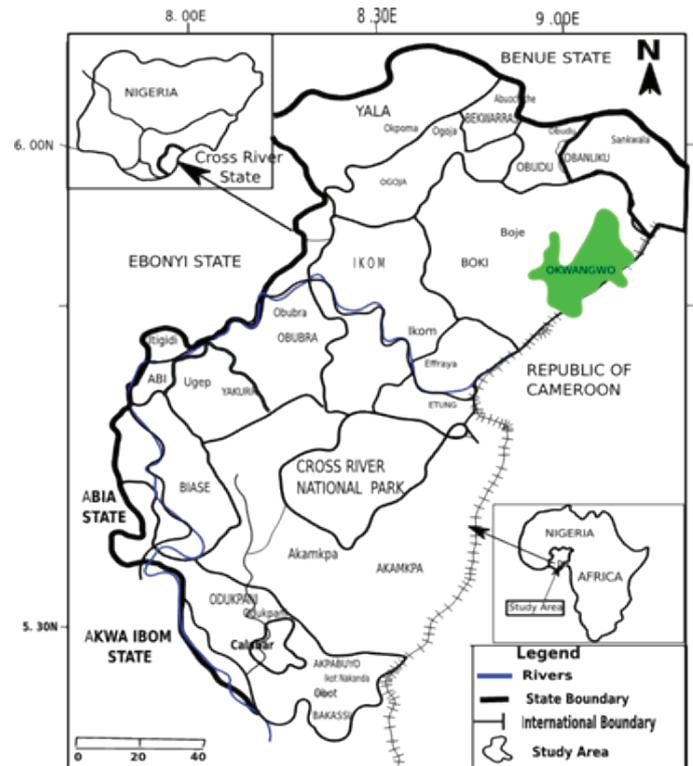


Figure2: Map of Obudu Township (Modified after Ekwueme *et al.* 1995)

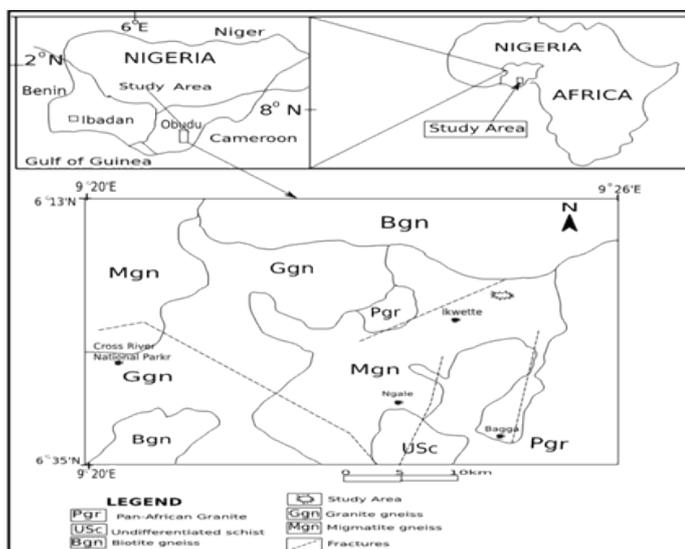


Figure1: The Geologic map of Cross River State and Obudu Environs (Modified after Ekwueme, 2004).

The Obudu plateau is flanked on the South/East by the Cameroon volcanic line and on the South/West by the Benue Trough (Ekwueme, 2004). Lithologically, the basement complex is made up of the schist, granite and pegmatite, migmatitic gneiss, Aplites and Quartz veins and Dolerites. The Schist consists of quartz, biotite, chlorite, muscovite, oligoclase (An₂₈), k-feldspar sillimanite. The granites are porphyritic and weakly foliated. They contain quartz, orthoclase and muscovite. They may also contain biotite, pyrite and garnet. Aplitic dykes and quartz veins are associated with pegmatites. The dolerites are fine to medium-grained and composed dominantly of labradorite, pyroxene and olivine. Banded and homogenous schists occur in the Ranch area. Igneous bodies like granites, dolerites, charnockites and diorites intrude into this dominantly gneissic and schistose complex [Umeji, 1988, Ekwueme, 1990a, 1994a, 1994b] as shown in Fig. 2 the local geology of Ikwette, Obudu L.G.A.

From geotectonic settings, Obudu plateau (Ekwueme, 1990a, 1994a, 1994b, 1998) lies within the reactivated Precambrian Basement of Nigeria. This forms a portion of the pan-African Tectonothermal belt located between the West African Craton, to the west and the Gabon-Congo Craton, to the east.

MATERIALS AND METHODS

One hundred (100) water samples from Obudu cattle ranch springs were collected and analysed with the assistance from Ortech Consulting Engineers, a company contracted on a private public partnership on water projects with the state government. The samples were collected between span of the years (2002 and 2011) of which the correspondence author was on the project as the plant manager of the company. The samples were carefully collected in a sterilized plastic can that was rinsed with the spring water before final collection. The physical parameters such as pH, Electrical conductivity, and temperature were conducted in situ using the necessary equipment before taken to the laboratory for further analysis. The analysis was conducted in triplicate using Atomic Absorption Spectrophotometer (alpha 4 analytical equipment) in order to detect possible error. Critical studies were conducted on the geochemical analytical results of the water sample using statistical and correlation analyses.

RESULTS AND DISCUSSION

The result of the geochemical analysis of the water samples from Obudu Spring Ranch that (Tables 1) spanned through a period of nine years revealed variation in the physicochemical parameters which include pH, Electrical conductivity, temperature, hardness Ca, Fe among others.

The pH ranges from 5.7 to 7.3 with an average value of 6.4 ± 0.1 respectively. It was observed that 37.2 percent of the sample has pH that falls within the WHO (2006) permissible level of 6.5 - 8.5, while 62.8 percent of the water samples have pH lower than 6.5 (Figure. 3), the lowest permissible level of drinking water standard. The slight acidic character of the water at these periods might either be due to the deposition of some organic matters from run-off or through the mineralogical composition of the source rock through spring water flows.

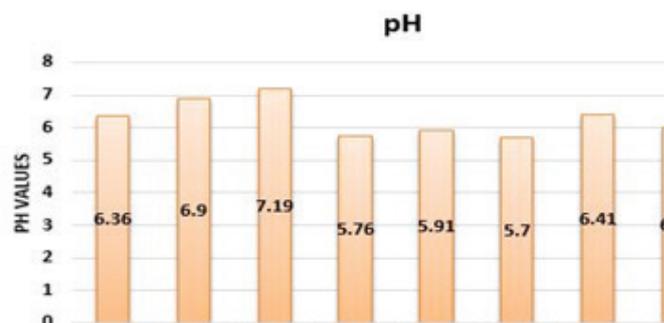


Figure3: pH values versus varied years

Decomposition of organic matter by fungi and bacteria has been recognized to produce various organic acids that are capable of lowering the pH of aqueous solution as observed in coastal water (Asaolu, 2005, and Bowen, 2006). This might have occurred being a major factor that influenced acidity of the water.

The temperature of the water ranges from 24°C to 26°C (Table 1 and Fig. 4). The temperature of water mainly depends on the ambient conditions, hot water is not generally palatable, but it may affect the state and level of other parameters including conductivity and Bacteriological activity in the water. Balogun (2010) states that warm water temperature gives rise to accelerated bacterial activity thereby creating potentials for odour development through depletion of oxygen resulting from bacterial oxidation of organic and nitrogenous compounds that may be present in water.

Further indication shows/revealed river that a river/stream whose temperature rises above 33°C is generally considered unsuitable for public water supply. The temperatures in the spring are within the recruited standard of W.H.O (2006) and NAFDAC (2007).

Temperature exerts a marked effect upon the pollution characteristics of a stream because the amount of oxygen that a stream can carry is inversely proportional to the temperature of the stream signifying variables effects on the BOD and COD of the water. Adeyeye (2004) reported that in the spring water, temperature and dissolved oxygen play vital roles in the rate of chemical reaction and the nature of biological activities, since these govern the assimilate capacity of aquatic system.

Table 1: Physical and chemical analysis of Obudu compared with WHO and NAFDAC

Parameter /Unit	2003	2004	2005	2006	2007	2008	2009	2010	2011	NAFDAC (2007)	WHO (2006)
Temp	26	25.3	23.20	25.0	21.9	24	24.5	25.1	24.8	No guideline	No guideline
pH	6.4	6.9	7.2	5.8	5.9	5.7	6.4	6.0	7.3	6.5 - 8.5	6.5 - 8.5
Turbidity	2.47	2.30	0.21	0.04	0.06	1.48	0.96	0.73	1.5	0.03	0.30
Conductivity (uS/cm)	9.9	25.0	11.90	11.6	5.4	8.8	14.02	7.2	8.2	27	30
Total Hardness (mg/l)	28.2	18.0	35.0	47.0	54.0	30.0	25.0	54	50.0	-	-
Nitrate (mg/l)	ND	2.45	2.20	2.50	0.85	0.11	0.6	0.11	ND	2.9	3.0
Calcium (mg/l)	16.0	18.0	18.0	16.0	18.0	17.3	16.2	18	70	30	75
Magnesium (mg/l)	30.0	-	-	31.00	36.0	-	-	36	30	1.0	1.0
Potassium (mg/l)	-	-	-	0.09	-	-	-	-	-	0.6	0.5
Iron (mg/l)	0.38	0.40	0.50	0.32	0.1	0.53	0.72	0.1	0.30	0.3	0.3
Manganese (-	0.3	-	0.32	-	1.35	0.78	-	0.05	2.0	1.8
Ammonia (mg/l)	ND	1.3	0.5	ND	1.0	-	0.23	1.0	0.50	2.5	2.5
Ammonium (mg/l)	ND	0.08	0.19	ND	0.16	0.21	0.63	0.16	ND	1.9	1.9
Chloride (mg/l)	ND	4.92	3.15	-	2.52	-	-	-	2.5	500	500
TDS (mg/l)	59.04	32.5	-	6.96	4.15	5.3	8.52	5.7	0.05	60	60
TSS (mg/l)	0.06	1.20	0.02	1.10	0.44	1.31	-	0.15	0.05	-	1.5
TCC/100ml	TNTC	TNTC	TNTC	58	TNTC	TNTC	24	TNTC	TNTC	-	-
FCC/100ml	TNTC	TNTC	TNTC	16	TNTC	TNTC	9	TNTC	TNTC	-	-

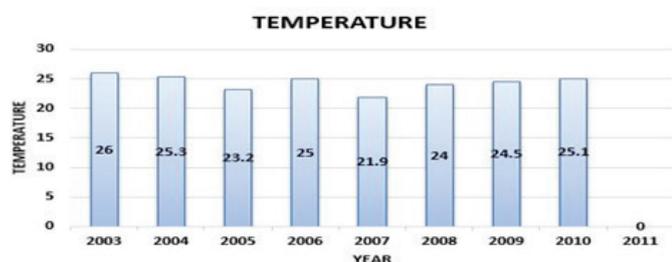


Figure4: Temperature and versus varied years

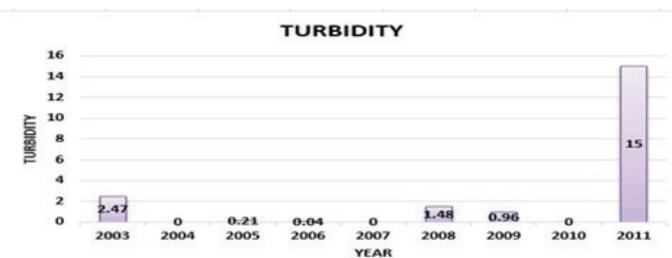


Figure5: Turbidity versus varied years

The turbidity level of the spring ranges from 0.04 to 2.47 with a mean value of 1.08, far above the recommended level of NAFDAC (2007) and WHO (2006). The highest turbidity rate was recorded in 2003 (Figure 5), while the least occurred in 2006. This must

have resulted from changes recorded in rain downpour (NCF, 2007). Also the effect of construction works, human activities and increased rainfall caused the increase in year 2011.

The turbidity effect can be controlled with water treatment facilities to enable its potability.

Calcium concentrations in the samples range from 16 – 70mg/l, only the samples taken in 2011 fall above the NAFDAC (2007) permissible standard of 30mg/l, but below the (W.H.O 2006) recommended level of 75mg/l (Table 1 and Figure. 6), an indication that the water when consumed will not be harmful. Calcium provides a certain taste in water depending on its specific salt present. It has a relevant physiological action on bone formation and also on nerve integrity and transformation. The calcium concentration values in the samples fall below 75mg/l, indicating its potability with WHO (2012).

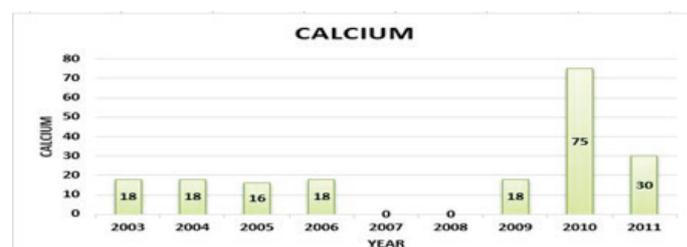


Figure.6: Calcium and versus varied years

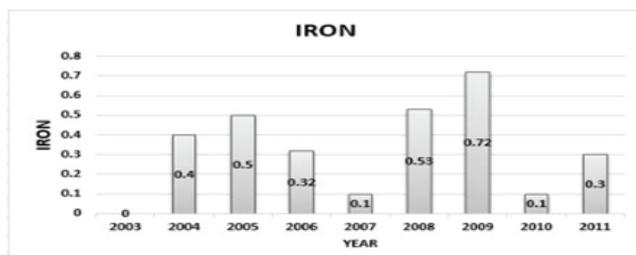


Figure. 7: Iron concentration versus varied years

Water hardness, alkalinity and free CO_2 reflect the quantity of dissolved solutes and wastes in different phases of a natural aquatic system. These chemical parameters with respect to their interrelationship enhance or suppress the general geochemical conditions prevailing in the water system. This plays significant roles in the distribution of contaminants.

According to Adeyeye (2004), the environmental protection agency established the recommended limit for total dissolved solids (TDS) in drinking water at 500 mg/l. While that of lower warm spring, is found to be 895 mg/l. The geochemical analysis of the water samples from the springs compared with the WHO (2006) standard indicates that the water samples fall within the stipulated range of acceptability.

Iron concentration in the samples range from 0.1 to 0.72mg/l with an overall mean of 0.37mg/l. About 75% of the samples have values greater than the permissible standards of WHO (2012) and NAFDAC (2007) respectively (Figure. 7), while the other 25% falls within the limits. The presence of iron might have resulted from many igneous and metamorphic rocks and clay minerals through which the spring water has either taken their sources or flow through. The spring must have either taken its source from a source rock of the basement complex, and or from wastes and dead plants along through which it flows. Apart from the results of samples of years 2007, 2010 and 2011, which fall within the WHO permissible limits of 0.3mg/l, all other samples are slightly high or high in composition. According to WHO (2006), any water with iron concentration above 0.3mg/l causes staining of laundry materials. The high concentration levels of the Fe and Mg could have been either from the ferro-magnesium minerals in the source rock and other rock types along the flow course or series of human activities thereby releasing waste and sewages effluent into the stream either directly or indirectly.

Magnesium concentration as revealed in Table 2 range from 30 – 36mg/l with the mean value of 3.33mg/l, as against the approved WHO (2012) and NAFDAC (2007) permissible standard of 1.0mg/l. the occurrence of high concentration magnesium in water may lead to bitter taste and may cause a laxative effect to consumers.

Hardness is one the properties of water that indicates the presence of carbonate, bicarbonate and magnesium mineral compounds. This may be as a result of dissolved calcium and magnesium from soil and rock materials.

Hard water is beneficial to health, however, high concentration of it can cause lime buildup (scaling) in pipes and water heaters.

The total hardness in Obudu Spring water range from 18.0mg/l - 54.0mg/l throughout the period of sampling. This falls below the permissible standard of 60mg/l set by WHO (2006) and adjudged to be very soft. Naturally soft water can have aggressive properties due to the piping material (WHO, 2012) through which it is distributed. This could be avoided when the water is conditioned or stabilized, by increasing the alkalinity and/or adding corrosion-inhibiting substances such as phosphates. WHO (2012) classified water hardness into low, moderate and high ranges and said further that drinking such water will enhance the incidences of heart disease, degenerative heart disease, hypertension, sudden death of cardio-vascular origin or a combination of these.

According to McGowan (2000), hardness is most commonly expressed as milligrams of calcium carbonate equivalent per litre. Water containing calcium carbonate at concentrations below 60 mg/l is generally considered as soft; 60–120 mg/l, moderately hard; 120–180 mg/l, hard; and more than 180 mg/l, very hard. He declared further that although hardness is caused by cations, it may also be discussed in terms of carbonate (temporary) and non-carbonate (permanent) hardness.

The total dissolved solids (TDS) of water in Obudu Ranch Spring ranges from 0.05 to 59.0mg/l (Figure 8), Electrical conductivity (5.4 to 25.0 $\mu\text{S}/\text{cm}$) and Turbidity (0.04 to 2.47mg/l), all falls within the permissible level of World Health Organization (WHO,2006).

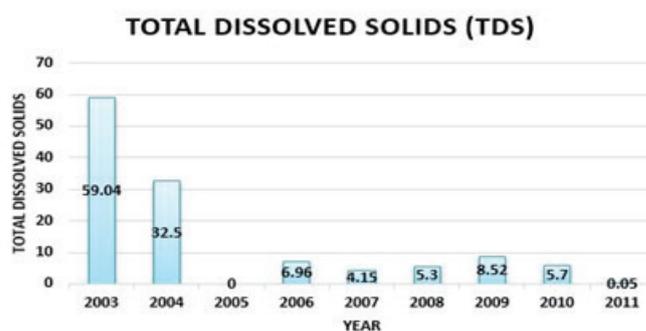


Figure. 8: Total dissolved solid versus varied years

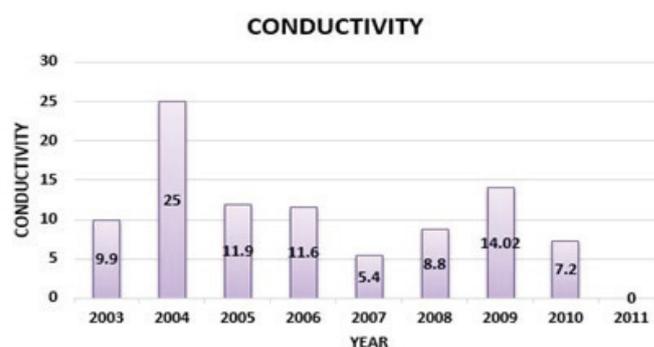


Figure 9: Electrical conductivity versus varied years

Although the level of Cl^- is below the permissible level of potable water, but higher concentrations may get into such spring through discharge and run offs from road salt, fertilizer, animal or other wastes. Chloride is not toxic, but may contain salty taste at 250 mg/L. Water with high chloride may indicate high concentration of sodium.

Electrical conductivity concentration ranges 5.4 ($\mu\text{S}/\text{cm}$) to 25 ($\mu\text{S}/\text{cm}$) with an average concentration value of 11.34 $\mu\text{S}/\text{cm}$ although the value is below the lowest permissible level recommended by WHO (2006) and NAFDAC (2007). The figure 9 below shows the graphical below variation experienced in electrical conductivity over nine years.

The result of the microbiological analyses of the water samples show they are too numerous to count which indicates that they are far higher than the set standard permissible limits of NAFDAC (2007) and WHO (2006) as shown in table 1. In this study area it is observed that the possible contaminants might have either entered through fractures in the bedrock close to the surface, or in areas with coarse sand and gravel soils.

The organisations in their different opinions said that in any intended water for drinking the faecal and total coliform count must be 0 respectively, in any 100ml sample of the said water. The springs can only be made potable when subjected to thorough treatment and stabilization of all the constituents in it

CONCLUSION

The results of the geochemical analysis of the water in Obudu Ranch Spring in Cross River State indicate that majority of the parameters analyzed are within the permissible level standards of drinking water according to NAFDAC (2007) and WHO (2006). The major exceptions are the elements such as Magnesium (Mn, 35.75mg/l), and Iron (Fe, 0.50mg/l,) which are higher than the permissible limits set by both organizations.

The high concentration levels of the Fe and Mn could have been either from the ferro-magnesium minerals in the source rock and other rock types along the flow course or series of human activities thereby releasing waste and sewages effluent into the stream either directly or indirectly. Caution should be taken towards further discharge of sewage effluents, and refuse into the water regime. The Government should sensitize the communities living around this spring

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on the danger involved in drinking the water without treated. A simple water treatment plant is suggested to be installed in the community which would involve treatment with aeration processes.

The impurities in the water resulting from the dissolution of iron-oxide (Fe_2O_3) could be reduced either by boiling and distillation or by the use of water softening chemicals such as $\text{Ca}(\text{OH})_2$ and Na_2CO_3 . It is recommended that Environmental health Officers and sanitary inspectors should be properly trained and educated on the need to regularly check water pollution in these environments. Considering the bacteriological analysis result the water needs to be treated/ chlorinated before it can be used for domestic activities.

On the other hand, some of the constituent values are gratifying because the water contains reasonable levels of beneficial elements such as: Na, K, Mg, and Ca in the spring water. It is also recommended that there should be a constant monitoring of the study area by the concerned ministries and agencies, so that human activities in the spring could be controlled. Proper treatment and chlorination be conducted before the water can be used for domestic and industrial purposes. Government should provide and install a water treatment plant for the communities living on the plateau to avoid epidemics. The ministry of environment and natural resources through the state house of assembly could enact laws against any form of water pollution to restrict discharge to a sewer into the springs, stream, rivers or any water source in the state. Environmental health education should be encouraged through proper training and education of the community populace. Agencies like water and sanitation project WATSAN and UNICEF should be involved through collaborative training of experts for proper and adequate knowledge on how to combat water pollution.

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