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PHYSICO-CHEMICAL AND BACTERIOLOGICAL ANALYSES OF DRINKING WATER IN IBENO LOCAL GOVERNMENT AREA OF AKWA IBOM STATE

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Abstract

Physicochemical, heavy metals and bacteriological analysis of drinking water samples from ten (10) geo-referenced points in five communities of Ibeno Local Government Area were conducted to ascertain their quality. Two sampling sessions were carried out in each season; totaling four (4) different sessions for both wet and dry season. Physicochemical and heavy metal parameters were assessed in the drinking water samples and the results were compared with World Health Organization (WHO) and Federal Ministry of Environment (FMENV) standards. Some physico-chemical parameters like pH, temperature, electrical conductivity, alkalinity, total dissolved solids, total suspended solids, dissolved oxygen, nitrate, phosphate, nickel, cadmium and copper showed positive (+), deviation from WHO and FMENV Standards (that is not exceeded the standards), while calcium, zinc, iron, lead and manganese deviated negatively from these standards. Also ten (10) bacterial species isolated were identified as Bacillus subtilis, micrococcus varians, Esherichia coli, streptococcus, faecalis, enterococus faecalis, salmonella typhi, staphylococcus aureus, clostridium perfringens, proteus vulgaris and pseudomonas aeruginosa. The total coliform count of the water samples ranged from 0 cfu/100ml at Mkpanak to 38 cfu/100ml at Ikot Inwang. The most frequently occurring bacteria were, E. Coli (27%) followed by C. Perfringens (20%) while B subtilis (3%), M. varians (3%) and P. vulgaris (3%) were the least. High counts of indicator bacteria also constitute a threat to public health. Bacteriological quality of the drinking water samples in some areas except Mkpanak did not meet the WHO recommended standard. Against the background of the implications of the findings, the study recommends the establishment of good water works for provision of good quality drinking water, modern sanitary and sewage disposal facilities, creation of awareness among the people enforcement by regulatory bodies and regular monitoring of drinking water quality, its compliance with the standards and its impact on the health of the people of Ibeno Local Government Area.

Keywords: physicochemical, heavy metals, water quality, dissolved oxygen, and bacteriological quality

1. Introduction

Globally, water is one of the most abundant and essential commodities of man and occupies about 97 per cent of the earths surface. About 70 per cent of this volume of earth's water is contained in the oceans, 21 per cent in polar ice and glacier, 0.3 to 0.8 per cent in ground water, 0.009 per cent in inland fresh waters such as lakes while 0.00009 percent is contained in rivers [1]. The earth's organisms are made up mostly of water, a tree is about 60% water by weight, and most animals (including human) are about 50-65% water by weight. Each of us needs only a dozen or so cupfuls of water per day to survive while huge amounts of water are needed to supply food, shelter needs and wants. Water also plays a key role in sculpting the earth surface, moderating climate and diluting pollutant [2]. "Surface waters may include reservoirs, dams, oxidation ponds, and man-made lakes according to [3]. Apart from atmospheric water in the form of hail and snow, there abounds in Nigeria all other water resources. Akwa Ibom State in which Ibeno Local Government Area is situated is in the southern part of Nigeria". The study area Ibeno Local Government Area is one of the coastal local government areas as well as an oil producing area in Akwa Ibom State bordered by the Atlantic ocean and has various environmental problems including pollution of available water sources. There are many types of water sources available for domestic, recreational, fishing and industrial uses in Ibeno Local Government Area. These include ponds, streams (shallow wells), boreholes with hand pumps and rain water, but they all are polluted by human and industrial activities in the area.

Water pollution according to Daniels [4] is said to occur when a chemical, physical or biological substance exceeds the capacity of water body to assimilate or break down the substance that can cause harm to the aquatic ecosystem. Generally, pollution may be defined as the release of substances or energy in the wrong amount at the wrong place or at the wrong time by man in quantities that damage either his health or resources. The non-availability of potable water source in most of the town, villages, hamlets and fishing settlements in Ibeno Local Government Area is found to be one of the major environmental problems.

Ibeno Local Government Area is a coastal subregion characterized by abundant water resources. The absence of potable water supply for domestic use in some parts of Ibeno has compelled the population to rely heavily on natural sources of water supply for domestic uses. The quality of most of these sources of water supply are doubtful. Both people in most parts of the area drink from sources and use water without treatment or having regards to the quality except a few sources in Mkpanak where Exxonmobil supplies well treated drinking water. The anthropogenic and natural phenomenon seems to affect water quality in the study area. These include environmental hazards such as gas flaring, oil spillage, washing of material with detergents into water bodies, wastewater and sludge from industrial processes, poor sanitation, storm surges, salt water extrusion and intrusion, sanitary sewer lines, use of unclean vessels to fetch water from wells which is a common practice in the area. One of the most deadly and wide spread pollutants of water is untreated or inadequately treated human waste and sewage released into waterways. This forms the major causes of illness and death in developing countries. Millions of people die every year from illness caused by water pollution which include diarrhea, respiratory diseases, circulatory disorders, typhoid, infectious hepatitis, enteritis, polio, schistosomiasis, amoebiasis (amoebic dysentery), cholera and a lot of others [5] and [6].

The physical reality of life is defined by water [7]. Water is a unique liquid, without which life would be impossible. On a global scale, water abundance is not a problem the problem is water availability in the right place at the right time in the right form [8]. "We live on a planet in which the aqueous environment dominates" [9] and "there would be no life on earth without water and its unique properties".

Pure water has a neutral pH value of 7. It is thus described as neutral to litmus test. The pH can be altered by introduction of impurities such as acids, bases carbonates or bicarbonates. The electrical conductivity of pure water is zero. The conductivity would increase in the presence of ionic species or impurities.

Christopherson [7] reported that precipitation that reaches the earth's surface follows two basic pathways; it either flows overland or soaks into the soil. Water that flows over the ground is often called run-off. The term surface water refers to water flowing in streams and rivers as well as water stored in natural or artificial lakes. Popek [10], defined surface water as water that flows or rests on land and is open to the atmosphere, lake, ponds, lagoons, rivers, streams, ditches, and man-made impoundments are bodies of surface water.

Groundwater is accessed for use through wells, springs, or dug out ponds. Formations from which ground water is derived in the zone of saturation have considerably different characteristics than the soil near the surface (10). Solowowe [11] and Tumwine [12] referred to ground water as phreatic. In addition, Desilva [13], reported that part of the precipitation that falls on the land may infiltrate the surface, percolate downward through the soil under the force of gravity, and become what is known as ground water.

1.1. Microbiological status of water supply

Pure water is completely free from micro-organisms such as bacteria, viruses, fungi and so on. One of the most important attributes of good quality water is that it should be free from disease-causing organisms such as pathogenic bacteria, viruses, protozoa, or parasitic worms [14]. The presence or absence of living organisms In water can be one of the most useful indicators of its quality. In streams, rivers and lakes, the diversity of fish and insects species provides a measure of the biological balance or health of the aquatic environment. A wide variety of different species of organisms usually indicates that the stream or lake is unpolluted. The disappearance of certain species and over abundance of other groups of organisms is generally one of the effects of pollution [14].

A very important biological indicator of water quality and pollution used in environmental technology is the group of bacteria called coliforms. Consequently, water that has been recently contaminated with sewage will always contain coliforms [15] and [16]. A particular species of coliforms found in domestic sewage is called *Eschericha Coli* (*E. Coli*). Coliform bacteria are organisms that hardly survive in water longer than most pathogens. They are also relatively easy to detect. In general, it can be stated that if a sample of water is found not to contain coliforms, then there has not been recent sewage pollution and the presence of pathogens is therefore extremely unlikely. On the other hand, if coliforms are detected, there is a possibility of recent sewage pollution. However, additional tests would be required to confirm that the coliforms are from sewage and not from other sources [17 and 18].

A total coliform test is particularly applicable to the analysis of drinking water to determine its sanitary quality. Drinking water must be free from colforms of any kind. On the other hand, a fecal coliform test is more appropriate for monitoring pollution of natural surface water or groundwater, since a total coliform count would be inconclusive in this case.

1.2. Description of the study area

Ibeno Local government area has a coastal area of over 1,200 square kilometers. It is situated on the eastern flanks of Niger Delta which in turn is part of the gulf of Guinea. It is located at the south end of Akwa Ibom State with latitude 4°321 and 4°341 North of Equator and longitude 7°541 and 8°021 east of Greenwich Meridian. The communities on the west bank of the Qua Iboe River do not have access to the hinterland except by boat through the river and creeks.

Qua Iboe River estuary which lies within the study area coordinates of has Douglas Creek emptying into it. This creek is about 900m long and 8m deep. It is the point where petroleum exploration and production (E & P) waste from the Exxon Mobil Qua Iboe Terminal (QIT) tank farm are transferred to the lower Qua Iboe River Estuary and adjourning creeks through two 24" diameter pipes. The Exxon Mobil oily sludge dumpsite is located adjacent to this creek and the flare stack where gas is flared continuously is also situated a few meters from this creek [19], [20]. Some communities in Ibeno Local government areas are located at the bank of Qua Iboe River while others are located on the Atlantic Littoral. Communities such as Mkpanak, Upenekang, Iwuoachang, are located on the east bank of the Qua Iboe River, Okorutip and Ikot Inwang are on the west bank of the Qua Iboe River while Iwuopom-Opolom, Itak Abasi, Aketa, Okoroitak are located on the Atlantic coastline [21].

2. Materials and Methods

2.1. Description of samples

The study area is coastal and riverine in nature. For the purpose of this study, five communities were randomly selected and sampled, using a table of random numbers. Out of these five communities, two were accessed through boat while three were accessed through the hinterland (onshore). Two sample locations were taken from each of the five communities making up a total of ten water sampling points. The sampling locations designated WS1, WS2, WS3 – WS10 fell within Mkpanak, Upenekang (LGA Headquarters), Iwuoachang, Ikot Inwang and Okorutip. Water samples were taken from drinking water sources located in all the five communities.

For this study, two sampling seasons were employed (wet and dry seasons), taking cognizance of seasonal changes which may occur in certain parameters. Sample collection was done at two different times in each season. The wet season sampling was carried out in July, 2008 and August, 2008 while dry season sample was carried out in December 2008 and January 2009, the results are shown in the Tables (1 and 2).

During the field work activities, a hand-held German GPS Model 12 XL; S/N 84567093 was used to take the coordinates at each sampling points and recorded in a field notebook. After every sampling session, laboratory analysis took place within the confines of the respective "holding time" of the samples collected. Samples collected were analyzed for physiochemical and bacteriological parameters (Table 1,2,3,4,5,6 and 7).

2.2. Data requirement and sources

The research relied heavily on both primary and secondary sources of data sets. The primary data were obtained from observations, careful laboratory analysis of physicochemical and bacteriological parameters of water samples collected. The secondary sources included information obtained from published and unpublished documents as well as internet and library.

2.3. Sample collection and treatment

Sampling containers were pre-sterilizes with hot water. At each location, samples for physicochemical parameters were collected in a sterilized two (2) litres plastics container which was covered and labeled WS1 (water sample 1) to WS10 representative of different sampling locations. Prior to sample collection, the container was thoroughly rinsed with the water to be sampled. The portable meters were calibrated and standardized according to the manufacturers instructions to ensure proper instrument functioning and response. Samples for bacteriological analysis were aseptically collected in a separate similar sampling container.

The water was sampled by first of all rinsing the two (2) litres plastic container with water of the location to be sampled and with an aid of a bailer. Water sample was drawn out of the open wells and hand-dug well which serve as sources of drinking water. For bacteriological samples, the water drawn out with the aid of a bailer was aseptically transferred into the sample container. For water from hand-pumps, boreholes and tap, this was allowed to rush for about 5 minutes then the sample was collected with observation of all the precautions of the water sample collection techniques for both physicochemical and bacteriological analysis. It is important to note that most drinking water sources in the study area are underground water except water supplies at Mkpanak donated by Exxon Mobil to the community. The people of the study area do not have drinkable surface water The ground water temperature values were taken in-situ using mercury-in-glass broth thermometer. Water pH was taken in-situ using portable pH meter, SUNTEX Model TS-2. The procedure of sample collection was repeated at all sampling points with different sample containers used.

In the field, samples collected were all transferred into an ice cube cooler and transported to the laboratory for analysis of bacteriological and physicochemical parameters. In the laboratory, the samples were preserved by refrigeration and were analyzed within the confines of their respective “holding time”.

2.4. Method of data analysis

The underlisted parameters were investigated using the drinking water samples collected.

1. Physical Parameters: temperature, turbidity, pH level and electrical conductivity (Table 1 and 2).
2. Chemical Parameters: Calcium (Ca), tetraoxosulphate (vi) (PO43) dissolved oxygen (DO) Chloride (CL-), total suspended solids (TSS), alkalinity, nitrate (NO3-), total dissolve solids (TDS), total hardness (Tables 3-4).
3. Heavy Metals: Zinc (Zn), Iron (Fe), Lead (Pb), Nickel (Ni), Cadmium (Cd), Manganese (Mn), Copper (Cu), (Tables 3-4).
4. Bacteriological Parameters: Total coliform count.

Standard experimental methods were used to determine the above named parameters (Tables 5-13)

3. Results and Discussion

Tables 1, 2, 3 and 4 show the summary result of all the physicochemical and heavy metals parameters investigated in drinking water samples in Ibeno Local Government Area during wet and dry seasons respectively. Table 3 and 4 show the means of physicochemical and heavy metals parameters investigated in drinking water samples and comparison of this study average with World Health Organization (22, 23) and Federal Ministry of Environment (FMENV) standards respectively.

3.1. Physicochemical and heavy metal analysis

The results of the physicochemical and heavy metal analysis of the drinking water sources sampled with summary description of individual parameters for both wet and dry seasons during the fieldwork are as presented in Tables 1 and 2 respectively. pH the results indicate that there were slight difference in pH values of dry and wet seasons. A maximum pH of 6.80 and a minimum of 6.35 were obtained during the dry season with mean of 6.53 while for wet season, a maximum of 6.70 and minimum of 5.60 with mean of 6.32 were obtained. The pH values of other locations except for WS1, WS2, WS5, WS6, WS9 and WS10 (wet season) and WS1, WS2, WS4, WS5 (dry season) respectively (Table 1 and 2) were below WHO (6.5 – 8.5) and FMENV (6.5) limits. pH is one of the most important measurements commonly carried out in natural water and waste waters to ascertain the quality of the water. pH is the negative logarithm of hydrogen ion (H) concentration. It determines the acidity and basicity of a medium. Hydrogen ion concentration is critical to aquatic ecosystem because it affects the growth, reproduction and abundance of species. Also, it affects virtually all enzymes, hormones and other chemical components of the body which control metabolism, growth and development. A high pH value (¿ 8.5) gives necessary condition for which free ammonia (NH_3) is oxidized to ammonium (NH_4^+) ion and this is toxic to aquatic biota [24]. The mean pH value for wet season was below the WHO and FMENV standards of 6.5 – 8.5 and 6.5 respectively

3.1.1. Temperature

Temperature of water is the degree of coldness or hotness of the water. It is a very important parameter which determines the level of dissolved oxygen and bacterial activity in water. Temperature of a particular water system usually affects the solubility of substances in it; certain substances dissolve significantly in water at high temperature, others do so at low temperature. On the other hand, at low temperature, the rate of sedimentation and filtration decrease thereby adversely affecting the water treatment process. The temperature together with pH measurement serve as stabilization indicators for groundwater wells [10]. The maximum and minimum temperature obtained during the wet season (25.9°C and 25.0°C); respectively with a mean of 25.6°C were within the WHO and FMENV standards. For the dry season, 26.8°C and 25.9°C were recorded as maximum and minimum temperatures respectively with a mean of 26.4°C and this study average of 26.0°C (Tables 3). These values were within the WHO and FMENV limits of 27 – 28°C and 35°C respectively in all water sample locations.

Table 1: Percentage Bogue Compound Composition of Main Compounds in Various Binder Materials.

	POFA 10%	RHA 30%	BPA 10%	AHA 20%	GHA 10%	BGSA 10%	WA 20%	Control
C3S	1.57	-125.04	52.39	-25.70	-20.20	23.31	-35.69	50.7
C2S	31.0	193.81	14.88	90.14	84.22	45.54	92.69	22.5
C3A	8.093	11.14	11.4	10.91	19.74	10.02	22.86	8.6
C4AF	10.114	6.19	7.24	7.54	8.15	7.5	7.5	9.4

* POFA=Palm Oil Fuel Ash, RHA=Rice Husk Ash, AHA=Acha Husk Ash, BGSA=Bambara Groundnut Shell Ash, GHA=Groundnut Husk Ash, BPA=Bone Powder Ash and WA=Wood Ash.

Table 2: Chemical Analysis of Cement Replacement Materials.

Elemental oxides	% Composition						
	AHA	BGSA	BPA	GHA	RHA	WA	C
Fe2O3	2.40	2.16	1.33	4.35	0.95	2.35	2.5
SiO2	40.46	33.36	3.16	54.03	67.30	3.80	20.70
Al2O3	5.50	1.75	6.39	39.81	4.90	28	5.75
CaO	0.84	10.91	28.68	1.70	1.36	10.53	64.0
SO3	0	6.40	0	0.09	2.80	0	2.75

3.1.2. Electrical conductivity

Electrical conductivity can be used as an approximate measure of the total concentration of inorganic substances in water. It is a measure of the ability of a water sample to convey an electrical current and it is related to the concentration of ionized substances in water. From the study the mean values for electrical conductivity were 291.2 μs/cm for wet season and 274.9 μs/cm for dry season. Values of conductivity in all the ten (10) sample locations were within the WHO 1993 standard of 1000 micro siren per centimeter (μs/cm). The FMENV'T standard has no limit for this parameter.

3.1.3. Alkalinity

The required doses of various chemicals depend on the alkalinity level of the water. Very high level of alkalinity unlike acidity indicates the presence of industrial or chemical pollution (Nathanson, 2000). Water with moderate amounts of alkalinity can be consumed without adverse health effect but excessive concentrations would cause objectionable taste because alkaline solutions are bitter. The minimum and maximum values of alkalinity for wet season were 0.5mg/l and 14.0 mg/l; and 0.6 mg/l and 15.0 mg/l for dry season (Table 1 and 2). There is a slight difference in mean values of (6.78 mg/l) for wet season and (7.64 mg/l) for dry season and this study average 7.21 mg/l: all these values as well as values of all the sample locations are below WHO standard of 100-200 mg/l. The FMENV has no limit for this parameter, (Table 3).

3.1.4. Solid Content

The solids investigated in this study show a total dissolved solids (TDS) and total suspended solids (TSS). Separation of dissolved and suspended solids in water was accomplished by means of filtration. High level of solids in water increases water density affect osmoregulation of fresh water organisms and reduces the solubility of gases such as oxygen (Radiojevic and Bashkin, 1998). The maximum and minimum values of 142.8 mg/l and 120.0 mg/l for wet season were obtained for TDS with a mean of 131.0 mg/l. While maximum and minimum values 143.7 mg/l and 120.7 mg/l were obtained for the dry season with a mean of 145.4 mg/l. This study average of 138.2 mg/l is below the WHO standard of 1000 mg/l. The values in all the water samples locations were also lower than WHO limits. There is no TDS standard by FMENv. The maximum, minimum and mean of values 197.4 mg/l, 71.6mg/l and 151.4 mg/l respectively for wet season were obtained for total suspended solids (TSS) (Table 1). For dry season, the maximum and minimum values were 198.1 mg/l and 81.4 mg/l respectively with a mean of 146.0mg/l (Table 3). This study average of 148.7mg/l is lower than those of WHO (250mg/l) and FMENV (600mg/l) standards (Table 4). The values in all the ten (10) water sample locations for both wet and dry seasons were lower than WHO and FMENv standards.

3.1.5. Turbidity

The maximum, minimum and mean values of 28.63mg/l, 2.80mg/l and 18.8 mg/l were obtained for the wet season (Table 1). The maximum and min-

TABLE 1: Physicochemical and Heavy Metals Parameters Investigated in Drinking Water Samples in Ibeno Local Government Area during Wet Season

Sample Points Code	Location/Sources of drinking water	Coordinates	pH	Temp (°C)	Elec. Cond. (μs/cm)	Alk. Alinity (mg/l)	TDS (mg/l)	TSS (mg/l)	Turbity (mg/l)	DO (mg/l)	Total hardness (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Chloride Cl (mg/l)	Ca (mg/l)	Zn (mg/l)	Fe (mg/l)	Pb (mg/l	Ni (mg/l)	Cd (mg/l)	Mn (mg/l)	Fe (mg/l)
WS$_1$	Tap water (Mkanak)	N04°34'16.0" E007°58'12.1"	5.70	25.1	266.7	0.6	126.1	123.4	2.80	0.65	3.3	1.58	0.06	155.0	2.8	0.8	0.20	0.39	ND	ND	0.02	0.03
WS$_2$	Tap water (Mkanak)	N04°34'18.8" E007°58'15.8"	5.60	25.0	264.6	0.5	125	125	3.10	0.80	3.3	1.58	0.07	155.9	2.5	1.2	0.22	0.45	ND	ND	0.02	0.04
WS$_3$	Hand pump (Upenekang)	N04°33'56.9" E007°59'01.0"	6.55	25.7	269.3	0.6	128.5	126.5	8.80	0.98	5.2	1.86	1.2	160.7	4.9	2.5	0.74	2.10	0.01	0.01	0.03	0.05
WS$_4$	Open well (Upenekang)	N04°34'05.6" E007°58'23.9"	6.55	25.9	269.7	0.9	129.7	130.6	26.20	1.01	50.7	6.89	2.95	170.1	10.9	6.1	0.55	4.95	0.04	0.04	0.23	0.09
WS$_5$	Borehole (Iwuachang)	N04°33'808" E008°00'132"	6.45	25.7	298.1	1.0	142.8	71.6	19.20	0.92	4.3	5.10	2.65	164.0	5.7	3.9	0.55	2.95	ND	ND	0.04	0.04
WS$_6$	Swallow well (Iwuachang)	N0°32'809" E008°00'130"	6.35	25.7	293.6	11.7	130.0	195.1	23.20	1.00	613	6.90	3.20	191.5	9.6	7.4	0.75	2.75	0.004	0.004	0.06	0.05
WS$_7$	Hand-dug well (Ikot Inyang)	N04°33'58.9" E007°57'32.1"	6.70	25.9	354.7	12.9	137.7	196.8	27.80	1.63	107.5	10.46	3.55	199.5	12.9	7.6	1.65	5.45	0.06	0.005	0.09	1.15
WS$_8$	Hand-dug well (Ikot Inyang)	N04°32'58.9" E007°57'30.1"	6.60	25.8	358.7	12.6	138.0	197.4	28.63	2.24	109.5	11.87	3.65	215.9	11.9	6.9	1.95	5.85	0.06	0.004	0.08	1.35
WS$_9$	Swallow well (Okoruptip)	N04°33'24.4" E007°56'23.8"	6.20	25.7	251.6	13.0	131.5	169.4	24.20	1.18	80.0	10.1	3.35	199.9	7.9	6.5	1.15	4.75	0.04	0.002	0.06	1.05
WS$_{10}$	Swallow well (Okoruptip)	N04°33'19.0" E007°56'23.8"	6.35	25.5	257.0	14.0	120.0	178.0	24.20	1.13	80.4	10.2	3.15	201.3	9.5	7.3	1.15	3.45	0.03	0.003	0.06	0.95
Mean			6.32	25.6	291.2	6.8	131.0	151.4	18.80	1.15	50.6	6.65	2.38	181.4	7.9	5.0	0.89	3.45	0.002	0.002	0.07	0.48
Minimum			5.60	25.00	251.6	0.5	120.0	71.6	2.80	0.65	3.3	1.58	0.06	155.0	2.5	0.8	0.20	0.39	0.001	0.001	0.02	0.03
Maximum			6.70	25.90	358.7	14.0	142.8	196.8	28.63	2.24	80.0	11.87	3.65	215.9	12.9	7.6	1.95	5.45	0.06	0.06	0.09	1.35

TABLE 2: Physicochemical and Heavy Metals Parameters Investigated in Drinking Water Samples in Ibeno Local Government Area during Dry Season

Sample Points Code	Location/Sources of drinking	Coordinates	pH	Temp (°C)	Elec. Cond. (μs/cm)	Alk. Alinity (mg/l)	TDS (mg/l)	TSS (mg/l)	Turbity (mg/l)	DO (mg/l)	Total hardness (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Chloride Cl (mg/l)	Ca (mg/l)	Zn (mg/l)	Fe (mg/l)	Pb (mg/l)	Ni (mg/l)	Cd (mg/l)	Mn (mg/l)	Fe (mg/l)
WS$_1$	Tap water (Mkanak)	N04°34'16.0" E007°58'12.1"	6.40	26.1	214.2	0.6	126.6	81.8	1.3	0.15	2.7	2.7	1.23	97.5	2.7	1.1	0.06	0.39	ND	ND	0.03	0.04
WS$_2$	Tap water (Mkanak)	N04°34'18.8" E007°58'15.8"	6.35	26.4	205.3	0.6	126.8	81.4	1.6	0.20	3.0	3.0	1.35	102.8	2.5	1.3	0.06	0.44	ND	ND	0.04	0.04
WS$_3$	Hand pump (Upenekang)	N04°33'56.9" E007°59'01.0"	6.55	26.3	262.9	1.2	129.2	127.7	8.7	0.9	5.3	5.3	1.60	161.8	5.0	2.6	0.21	2.13	0.09	0.003	0.06	0.06
WS$_4$	Open well (Upenekang)	N04°34'05.6" E007°58'23.9"	6.45	26.0	289.3	2.1	132.8	132.6	8.7	1.05	47.8	47.8	6.25	170.0	10.5	6.3	0.04	5.20	0.55	0.004	1.02	0.06
WS$_5$	Borehole (Iwuachang)	N04°33'808" E008°00'132"	6.35	26.8	292.8	1.8	143.7	108.6	20.5	1.26	5.0	5.0	5.25	165.2	6.6	4.1	0.44	3.4	ND	ND	0.03	0.03
WS$_6$	Swallow well (Iwuachang)	N0°32'809" E008°00'130"	6.55	25.9	292.7	12.6	125.2	197.2	8.9	1.13	55.3	55.3	6.75	190.6	8.9	7.6	1.15	2.80	0.07	0.004	0.12	0.55
WS$_7$	Hand-dug well (Ikot Inyang)	N04°33'58.9" E007°57'32.1"	6.80	26.7	339.1	14.2	138.2	194.2	19.9	1.59	79.8	79.8	9.50	202.0	12.7	7.7	2.20	6.30	2.00	0.005	0.13	1.39
WS$_8$	Hand-dug well (Ikot Inyang)	N04°32'58.9" E007°57'30.1"	6.75	26.8	351.7	14.5	139.1	198.1	22.8	2.20	80.2	80.2	12.50	215.7	11.7	7.1	2.60	6.90	1.75	0.004	1.00	1.16
WS$_9$	Swallow well (Okoruptip)	N04°33'24.4" E007°56'23.8"	6.50	26.3	245.2	13.8	271.9	163.9	22.4	1.09	75.4	75.4	7.50	189.7	7.7	7.2	2.70	5.20	0.57	0.004	0.08	1.20
WS$_{10}$	Swallow well (Okoruptip)	N04°33'19.0" E007°56'23.8"	6.55	26.2	255.5	15.0	120.7	174.6	22.0	1.1	80.1	80.1	3.03	193.0	9.5	7.4	2.40	6.20	0.05	0.004	0.09	0.25
Mean			6.53	26.4	274.9	7.64	145.4	146.0	33.7	1.07	43.5	43.5	5.50	168.9	7.8	5.2	1.29	3.90	0.051	0.003	0.26	0.68
Minimum			6.35	25.9	205.3	0.6	120.7	81.4	1.3	0.9	2.7	2.7	1.23	97.5	2.5	1.1	0.06	0.39	0.05	0.003	0.03	0.04
Maximum			6.80	26.8	351.7	15.0	143.7	198.	22.8	2.20	80.2	12.5	12.5	202.0	12.7	7.7	2.70	6.20	2.00	0.005	1.02	1.39

TABLE 3: Average Values for Physicochemical Variables and Heavy Metals Levels for both Wet and Dry Season.

Parameter	Units	Mean for Wet Season	Mean for Dry Season	This Study Average Value (Mean for both Seasons)
pH		6.53	6.32	6.43
Temp	^oC	25.6	26.4	26.0
Elec. Cond.	μs/cm	291.2	274.9	283.1
Alkalinity	mg/L	6.78	7.64	7.21
TDS	mg/L	131.0	145.4	138.2
TSS	mg/L	151.4	146.0	148.7
Turbidity	NTU	18.8	13.68	16.2
DO	mg/L	1.15	1.07	1.11
Total hardness	mg/L	50.6	43.5	47.1
Nitrate	mg/L	6.65	5.50	6.08
Phosphate	mg/L	2.38	2.07	2.23
Chloride	mg/L	181.4	168.9	175.2
Calcium	mg/L	7.9	7.8	7.9
Zinc (Zn)	mg/L	5.02	5.24	5.13
Iron (Fe)	mg/L	3.45	1.29	2.37
Lead (Pb)	mg/L	3.45	3.90	3.68
Nickel (Ni)	mg/L	0.03	0.51	0.27
Cadmium (Cd)	mg/L	0.002	0.003	0.003
Manganese (Mn)	mg/L	0.07	0.26	0.17
Copper (Cu)	mg/L	0.48	0.86	0.67

TABLE 4: Comparison of Average Values for Physicochemical Parameters and Heavy Metals Levels with WHO and FMENV'T (FEPA) Standards [2, 17, 25].

Parameter	Units	This Study Average Value	WHO STD	Deviation from WHO STD	FMEN V STD
pH		6.41	6.5-8.5	+2.07	6.5
Temp	^oC	26.0	27-28	+2	35.0
Elec. Cond.	μs/cm	283.1	1000	+716.9	-
Alkalinity	mg/L	7.21	100-200	+192.8	-
TDS	mg/L	138.2	1000	+861.8	-
TSS	mg/L	148.7	250	+101.3	600
Turbidity	NTU	16.2	25	+8.8	-
DO	mg/L	1.11	15	+13.89	-
Total hardness	mg/L	47.1	100	+52.9	-
Nitrate	mg/L	6.08	10.0-50.0	+43.9	-
Phosphate	mg/L	2.23	3.50	+1.27	5.00
Chloride	mg/L	175.2	250	+74.8	-
Calcium	mg/L	7.9	7.5	-0.4	-
Zinc (Zn)	mg/L	5.13	5.0	-0.13	1.00
Iron (Fe)	mg/L	2.39	1.0	-1.39	2.00
Lead (Pb)	mg/L	3.68	5.0	+1.32	<1.00
Nickel (Ni)	mg/L	0.27	5.0	+4.73	-
Cadmium (Cd)	mg/L	0.003	0.005	+0.002	<1.00
Manganese (Mn)	mg/L	0.17	0.10	-0.07	-
Copper (Cu)	mg/L	0.67	1.0	+0.33	-

imum values of 22.8 mg/l and 1.3mg/l respectively with a mean of 13.68mg/L were obtained for the dry season (Table 2). This study average of 16.2 mg/l reveals that this value is lower than the normal range of 25o (11) WHO standard. FMENv has no stipulated limit for turbidity. It is to be noted that the values in water sample locations at Upenekang (WS4) and Ikot Inwang (WS7 and WS8) were higher in wet season than 25 (o11) WHO standard (Table 1).

3.1.6. Dissolved Oxygen

The maximum and minimum values for dissolved oxygen was 2.24mg/l and 0.65mg/l respectively with a mean of 1.15mg/l for wet season. For dry season, the maximum and minimum was 2.20mg/l and 0.9mg/l with a mean of 1.07mg/l were obtained. This study average is 1.11 mg/l (Table 4). This value is within the limit set by WHO (15mg/l). There is no limit set by FMENv.

3.1.7. Total Hardness

The maximum and minimum values of 109.5 mg/l and 3.3mg/l with mean of 50.6mg/l in wet season (Table 4) were recorded while maximum and minimum values 80.2 mg/l and 2.7 mg/l with a mean of 43.5 mg/l were recorded for dry season. The study average value of 47.1 mg/l is lower than WHO (100mg/l) standard. There is no limit set by FMENv. It is to be noted that for water sample locations at Ikot Inwang (WS7, and WS8), the value obtained during wet season were higher than WHO standard see (Table 3).

3.1.8. Nitrate

Nutrients in water are the primary productivity index and give a true indication of species abundance and activity of aquatic life. For the wet season, the maximum value of 11.87mg/l, minimum of 1.58mg/l and mean of 6.65mg/l were recorded for nitrate. During the dry season, the maximum value of 12.5mg/l, minimum of 1.23mg/l and mean of 5.5mg/l were recorded for nitrate. These values are within the WHO values 10-50 mg/l. The phosphate values obtained from this study during wet season are 3.65mg/l (maximum), 0.065mg/l (minimum) and 2.23mg/l (mean). Dry season value are 3.65mg/l (maximum), 0.03mg/l (minimum) and 2.07 mg/l (mean). It is to be noted that maximum value (3.65mg/L) of phosphate recorded for wet and dry season are slightly higher than WHO standard (3.50mg/L) but below the FMENv standard of 5.00mg/l. Also, it is to be pointed out that these high values were recorded for water sample locations at Ikot Inwang (WS7 and WS8). A level of nitrate above the threshold of 45 mg/L is a potential health risk to pregnant women and infants. A high level of nitrate causes methaemoglobinemia. High levels of phosphate in water favours the growth of blue green algae which could release toxic cyanotoxins are detrimental to health. The average levels of nitrate (6.08mg/l) and phosphate (2.23mg/l) in this study were lower than WHO standards of 10.0 50.0mg/l and 3.5mg/l respectively and FMENv gives no standard for nitrate but phosphate level is within the range of (5.00mg/l).

3.1.9. Chloride

The maximum and minimum levels of chlorides in the water sample investigated were 215.9mg/l and 155.0mg/l respectively with a mean of 181.4mg/l for the wet season respectively (Table 1). Also, the maximum and minimum levels 202.0mg/l and 97.5mg/l respectively with mean of 168.9mg/l were recorded in dry season (Table 2). This study average of 175.2mg/l (Table 3) is lower than the WHO limit of 250mg/l standard. FMENv has not set limit for this parameter.

3.1.10. Calcium

The calcium level of the water sample investigated in the study area recorded maximum, minimum and means values of 12.9mg/l, 2.5mg/l and 7.9 mg/l respectively for wet season (Table 1); and 12.7mg/l, 2.5mg/l and 7.8mg/l respectively for dry season (Table 2). This study average of 7.9mg/l was slightly higher than 7.5 mg/l WHO water quality standard. FMENv has no limit for this parameter. It is to be noted that, these values were slightly higher than WHO standard for water sample from Ikot Inwang (WS7 and WS8), and Okorutip (WS9 and WS10) for both wet and dry seasons. The seasonal variation of water quality between dry and wet seasons is very clear as shown in Table 1,2 and 11 respectively. According to the method described by APHA AWWA-WPCF [15]. The reason for the variation of water quality being that surface run-off during rainy (wet) season carries so many particles that cause water pollution compared to the dry season where water particles settle thereby remaining purer.

The health effect of the consumers of this water quality is not safe for the analysis of water from Ibeno Local Government Area. Therefore, alternative supply for the people in the area should be provided by Exxonmobil Qua Iboe Terminal (QIT) or by the Government of Akwa Ibom State.

3.1.11. Heavy Metals

It can be seen from Tables 3 and 4 that all the drinking water samples in the study area contained all the heavy metals investigated at varying concentrations. They were zinc, iron, lead, nickel, cadmium, manganese and copper. Some of these metals are required in minute quantities by plants, animals and man but are toxic in relatively high concentrations. In humans, some of these metals are essential to life in that they are compounds of enzymes, protein, vitamins and other substances, which maintain or regulate vital functions. However, others, such as lead and cadmium serve no known necessary function in any living organism. Even in comparatively small quantities they can cause severe damage to fauna, flora and man. This study average revealed that zinc (5.13mg/l), iron (2.37 mg/l) and manganese (0.17mg/l) did not meet the minimum standards of 5.0 mg/l, 1.0mg/l and 0.10mg/l respectively recommended by WHO (Table 4). Meanwhile, zinc (5.13 mg/l), Iron (2.3mg/l and lead (3.68mg/l) were also higher than FMENv limits of (1.00mg/l), (2.00mg/l) and (¡ 1.00mg/l) respectively. The nickel level (0.27mg/l), cadmium (0.003 mg/l) and copper (0.67 mg/L) were within the WHO (1993) standard of 5.0mg/l, 0.005mg/l and 1.0mg/l respectively (Table 4.). The FMENv do not have limit for nickel, manganese and copper (Table 4). It is pertinent to note that the levels of zinc, iron, lead, manganese and copper investigated at water samples from Ikot Inwang (WS7 and WS8) and Okorutip (WS9 and WS10) were higher than WHO recommended (Tables 1 and 2).

3.2. Bacteriological/microbiological analysis

The results of total coliform count with mean values for both wet and dry seasons and coliform density (Tables 11 and 12) revealed that total coliform count ranged from 0 to 38 cfu/100ml (for both seasons). The highest count (38 cfu/100ml) was recorded at Ikot Inwang while the least (0 cfu/100ml) was recorded at Mkpanak with coliform density range of 0 cfu/100ml at Mkpanak and 38 cfu/100ml at Ikot Inwang (Table 3). Tables 5 – 10 shows the bacterial isolates and their percentage occurrence from drinking water sampled in Ibeno Local Government Area for both seasons. The bacterial isolates for both seasons encountered were Bacilus subtilis, micrococcus varians, Escherichia coli, streptococcus faecalis, Enterococcus faecalis, salmonella typhi, staphy lococcus aureus, clostridium perfringens, proteus vulgaris and pseudomonas aeruginosa. The most frequently occurring organism was *E. coli* (27%) followed by *C. Perfringens* (20%) while the least were *Bacillus Subtilis* (3%), *M. Varians* (3%), *P. Valgaris* (3%) (Table 7).

4. Conclusion and Recommendations

From the physic-chemical and bacteriological analyses of drinking water in Ibeno Local Government Area of Akwa Ibom State, it can be concluded that Ibeno has no good source of drinking water quality and concerned authorities such as Exxon Mobil Qua Iboe Terminal (QIT) and State Government of Akwa Ibom State should provide alternatives for the supply of good quality water in the area, in order to save lives of men and animals living within the area.

TABLE 5: Bacterial Isolates from Drinking Water Samples Investigated in Ibeno Local Government Area in July 2008 (Wet Season) [26]

	Bacterial Isolates									
Sample Points Code	**E.coli**	**S.faecalis**	**E.faecalis**	**P.aeruginosa**	**B.subtilis**	**C.perfringens**	**M.varians**	**S.aureus**	**P.vulgaris**	**S.typhi**
WS$_1$	=	=	=	Seen	=	=	=	=	=	Seen
WS$_2$	=	=	=	=	=	=	=	=	=	Seen
WS$_3$	Seen	=	Seen	=	=	=	=	=	=	Seen
WS$_4$	Seen	=	Seen	=	Seen	=	=	Seen	=	=
WS$_5$	Seen	Seen	=	=	=	=	=	Seen	=	Seen
WS$_6$	Seen	=	Seen	Seen	=	Seen	=	=	Seen	=
WS$_7$	Seen	Seen	=	=	=	Seen	Seen	Seen	=	=
WS$_8$	Seen	=	Seen	Seen	=	Seen	Seen	Seen	=	=
WS$_9$	Seen	Seen	=	=	Seen	Seen	=	=	=	=
WS$_{10}$	Seen	Seen	=	=	=	Seen	=	Seen	=	=

TABLE 6: Bacterial Isolates from Drinking Water Samples Investigated in Ibeno Local Government Area in August 2008 (Wet Season)

	Bacterial Isolates									
Sample Points Code	**E.coli**	**S.faecalis**	**E.faecalis**	**P.aeruginosa**	**B.subtilis**	**C.perfringens**	**M.varians**	**S.aureus**	**P.vulgaris**	**S.typhi**
WS$_1$	=	=	=	=	=	=	=	=	=	=
WS$_2$	=	=	=	=	=	=	=	=	=	Seen
WS$_3$	Seen	=	Seen	=	=	=	=	=	=	Seen
WS$_4$	Seen	=	Seen	=	=	Seen	=	Seen	=	=
WS$_5$	Seen	Seen	=	=	=	=	=	Seen	=	Seen
WS$_6$	Seen	=	Seen	Seen	=	Seen	=	=	Seen	=
WS$_7$	Seen	Seen	=	=	=	Seen	Seen	Seen	=	=
WS$_8$	Seen	=	Seen	Seen	=	Seen	=	=	Seen	=
WS$_9$	Seen	Seen	=	=	Seen	Seen	=	=	=	=
WS$_{10}$	Seen	Seen	=	=	=	Seen	=	Seen	=	=

TABLE 7: Mean Bacterial Isolates from Drinking Water Samples Investigated in Ibeno Local Government Area in July 2008 & August 2008 (Wet Season) [3]

	Bacterial Isolates									
Sample Points Code	**E.coli**	**S.faecalis**	**E.faecalis**	**P.aeruginosa**	**B.subtilis**	**C.perfringens**	**M.varians**	**S.aureus**	**P.vulgaris**	**S.typhi**
WS$_1$	=	=	=	Seen	=	=	=	=	=	=
WS$_2$	=	=	=	=	=	=	=	=	=	Seen
WS$_3$	Seen	=	Seen	=	=	=	=	=	=	Seen
WS$_4$	Seen	=	Seen	=	=	Seen	=	Seen	=	Seen
WS$_5$	Seen	Seen	=	=	=	=	=	Seen	=	=
WS$_6$	Seen	=	Seen	Seen	=	Seen	=	=	Seen	=
WS$_7$	Seen	Seen	=	=	=	Seen	Seen	Seen	=	=
WS$_8$	Seen	=	Seen	Seen	=	Seen	=	=	Seen	=
WS$_9$	Seen	Seen	=	=	Seen	Seen	=	=	=	=
WS$_{10}$	Seen	Seen	=	=	=	Seen	=	Seen	=	=

Note: Total number of organisms isolated in wet season = 36

TABLE 8: Bacterial Isolates from Drinking Water Samples Investigated in Ibeno Local Government Area in December 2008 (Dry Season) [27,28]

	Bacterial Isolates									
Sample Points Code	E.coli	S.faecalis	E.faecalis	P.aeruginosa	B.subtilis	C.perfringens	M.varians	S.aureus	P.vulgaris	S.typhi
WS_1	=	=	=	=	=	=	=	=	=	Seen
WS_2	=	=	=	=	=	=	=	=	=	Seen
WS_3	Seen	=	=	=	=	=	=	=	=	Seen
WS_4	Seen	=	Seen	=	=	Seen	=	=	=	=
WS_5	Seen	Seen	=	=	=	=	=	=	=	=
WS_6	Seen	=	=	=	=	Seen	=	=	=	=
WS_7	Seen	=	=	Seen	=	Seen	=	=	=	=
WS_8	Seen	=	=	Seen	=	Seen	=	=	=	=
WS_9	Seen	Seen	=	=	=	Seen	=	=	=	=
WS_{10}	Seen	Seen	=	=	=	Seen	=	=	=	=

TABLE 9: Bacterial Isolates from Drinking Water Samples Investigated in Ibeno Local Government Area in January 2009 (Dry Season) [13]

	Bacterial Isolates									
Sample Points Code	E.coli	S.faecalis	E.faecalis	P.aeruginosa	B.subtilis	C.perfringens	M.varians	S.aureus	P.vulgaris	S.typhi
WS_1	=	=	=	=	=	=	=	=	=	Seen
WS_2	=	=	=	=	=	=	=	=	=	Seen
WS_3	Seen	=	=	=	=	=	=	=	=	Seen
WS_4	Seen	=	Seen	=	=	Seen	=	=	=	=
WS_5	Seen	Seen	=	=	=	=	=	=	=	=
WS_6	Seen	=	=	Seen	=	Seen	=	=	=	=
WS_7	Seen	Seen	=	=	=	Seen	=	=	=	=
WS_8	Seen	=	=	Seen	=	Seen	=	=	=	=
WS_9	Seen	Seen	=	=	=	Seen	=	=	=	=
WS_{10}	Seen	Seen	=	=	=	Seen	=	=	=	=

TABLE 10: Mean Bacterial Isolates from Drinking Water Samples Investigated in Ibeno Local Government Area in December 2008 & January 2009 (Dry Season)

	Bacterial Isolates									
Sample Points Code	E.coli	S.faecalis	E.faecalis	P.aeruginosa	B.subtilis	C.perfringens	M.varians	S.aureus	P.vulgaris	S.typhi
WS_1	=	=	=	=	=	=	=	=	=	Seen
WS_2	=	=	=	=	=	=	=	=	=	Seen
WS_3	Seen	=	=	=	=	=	=	=	=	Seen
WS_4	Seen	=	Seen	=	=	Seen	=	=	=	=
WS_5	Seen	Seen	=	=	=	=	=	=	=	=
WS_6	Seen	=	=	Seen	=	Seen	=	=	=	=
WS_7	Seen	Seen	=	=	=	Seen	=	=	=	=
WS_8	Seen	=	=	Seen	=	Seen	=	=	=	=
WS_9	Seen	Seen	=	=	=	Seen	=	=	=	=
WS_{10}	Seen	Seen	=	=	=	Seen	=	=	=	=

TABLE 11: Summary of Mean of each Bacterial Isolates from both Seasons (Wets & Dry) from Drinking Water Samples in Ibeno Local Government Area.

S/N	Bacterial Isolates	Wet Season	Dry Season	Mean (Wet and Dry Season)
1.	E.coil	8	8	8
2.	S.faecalis	4	4	4
3.	E.faecalis	4	1	3
4.	P.aeruginosa	3	2	2
5.	B.subtilis	1	=	1
6.	C.perfringens	6	6	6
7.	M.varians	1	=	1
8.	S.aureus	4	=	2
9.	P.vulgaris	2	=	1
10.	S.typhi	3	3	3
	Total	36	24	30

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TABLE 12: Total Coliform Count and Coliform Density Investigated from Drinking Water Samples during July, 2008 & August 2008 (Wet Season) [29]

Sample Points Code	Water Sample/Location	Coordinates	Volume of Water Sample filtered (ml)	Coliform Count (cfu/100ml) in July 2008	Coliform Count (cfu/100ml) in August 2008	Mean Total Coliform Count Wet Season	Coliform Density
WS$_1$	Tap water (Mkanak)	N04^{0}34’16.0” E007^{0}58’12.1”	100	0	0	0	0
WS$_2$	Tap water (Mkanak)	N04^{0}34’18.8” E007^{0}58’15.8”	100	0	0	0	0
WS$_3$	Hand pump (Upenekang)	N04^{0}33’56.0” E007^{0}59’01	100	8	9	9	9
WS$_4$	Open well (Upenekang)	N04^{0}34’05.6” E007^{0}58’23.9”	100	20	22	21	21
WS$_5$	Borehole (Iwachang)	N04^{0}33’808” E008^{0}00’132”	100	8	7	8	8
WS$_6$	Shallow well (Iwuachang)	N04^{0}32’809” E008^{0}00’130”	100	12	14	13	13
WS$_7$	Hand-dug well (Ikot Inyang)	N0$_4$33’58.9” E007^{0}57’32.1”	100	34	38	36	36
WS$_8$	Hand-dug well (Ikot Inyang)	N04^{0}32’58.6” E007^{0}57’30.1	100	38	39	39	39
WS$_9$	Shallow well (Okorutip)	N04^{0}33’24.4” E007^{0}56’23.8	100	16	18	17	17
WS$_{10}$	Shallow well (Okorutip)	N04^{0}33’19.0” E007^{0}56’23.8”	100	18	20	19	19

TABLE 13: Total Coliform Count and Coliform Density Investigated from Drinking Water Samples in December, 2008 & January, 2009 (Dry Season) [30,24]

Sample Points Code	Water Sample/Location	Coordinates	Volume of Water Sample filtered (ml)	Coliform Count (cfu/100ml) in July 2008	Coliform Count (cfu/100ml) in August 2008	Mean Total Coliform Count Wet Season	Coliform Density
WS$_1$	Tap water (Mkanak)	N04^{0}34’16.0” E007^{0}58’12.1”	100	0	0	0	0
WS$_2$	Tap water (Mkanak)	N04^{0}34’18.8” E007^{0}58’15.8”	100	0	0	0	0
WS$_3$	Hand pump (Upenekang)	N04^{0}33’56.9” E007^{0}59’01	100	7	6	7	7
WS$_4$	Open well (Upenekang)	N04^{0}34’05.6” E007^{0}58’23.9”	100	19	17	18	18
WS$_5$	Borehole (Iwachang)	N04^{0}33’808” E008^{0}00’132”	100	7	5	6	6
WS$_6$	Shallow well (Iwuachang)	N04^{0}32’809” E008^{0}00’130”	100	10	11	11	11
WS$_7$	Hand-dug well (Ikot Inyang)	N0$_4$33’58.9” E007^{0}57’32.1”	100	32	36	34	34
WS$_8$	Hand-dug well (Ikot Inyang)	N04^{0}32’58.6” E007^{0}57’30.1	100	36	38	37	37
WS$_9$	Shallow well (Okorutip)	N04^{0}33’24.4” E007^{0}56’23.8	100	16	17	17	17
WS$_{10}$	Shallow well (Okorutip)	N04^{0}33’19.0” E007^{0}56’23.8”	100	17	20	19	19