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Preliminary Assessment of Physicochemical Properties of Borehole Water in the vicinity of Public Health Facilities in Nasarawa State, Nigeria

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Abstract: *Water samples were collected from boreholes in the vicinity of public health facilities in Nasarawa State, Nigeria, for the evaluation of physicochemical parameters, using standard methods. Water pH from Keana was acidic (6.01 – 6.91), except at Chiata (9.34). pH values at Kuru (10.15) in Toto, Zalli (10.61) in Wamba, MCWC Obi (10.03) at Obi and Jangwa (10.31) in Awe were above the World Health Organization (WHO) permissible limits, so also nitrate contents in Ayele (11.04 mg/l) at Nasarawa, Chiji (12.14 mg/l) in Toto, Karmo (12.14 mg/l) in Toto, Main Market (12.02 mg/l) at Keffi, Sabo Gari (12.04 mg/l) at Keffi, Angiri (12.06 mg/l) in Lafia, Ugah (13.02 mg/l) in Lafia, and Agwa Sule (13.05 mg/l) in Obi. The highest and the lowest conductivity (EC) values were recorded in borehole water from Nasarawa and Kokona respectively, while the highest phosphate content was recorded at Agyemo in Doma. The hardness level of water was highest at Karu and lowest in Doma, while alkalinity at Toto was highest, and lowest in Keffi. TDS, EC, alkalinity and total hardness levels were within the acceptable WHO and Standard Organization of Nigeria (SON) standards for ground water, which suggested that water from the boreholes were safe.*

Keywords: *Physicochemical properties, borehole, water, health facilities, Nasarawa state*

I. Introduction

The pollution of groundwater has become a major environmental issue, particularly where groundwater represents the main source of drinking water [1-3]. This situation is so common in many lesser developed countries that the security of drinking water supply has been chosen as one of the ten Millennium Development Goals [4].

The challenge of ensuring usable water in sufficient quantities to meet the needs of human and ecosystems emerged as one of the primary issues of the 21st century [5-6]. Inadequate water supply and poor water quality give rise to health and other societal issues, limit agricultural productivity and economic prosperity, and pose national security risk in some countries [7-9]. Problem of this nature have been increasing in scope, frequency, and severity because the demand for water continue to grow while supply of renewable water remain fixed [8].

Water is one of the most important resources with great implications for African development; however, the freshwater situation in Africa is unfortunately not encouraging. Presently, it is estimated that more than 300 million people in Africa live in a water-scarce environment [10-11]. The situation is getting worse as a consequence of population growth, rapid urbanization, increasing agriculture and industrial activities, and lack of adequate capacity to manage freshwater resources [10, 12]. The growing deficit of good quality water in developing countries has spurred the need to utilize other sources of water other than conventional treated waters at maximal risk of microbiological and chemical pollution [13-14].

The quality of groundwater is affected by the characteristics of the media through which the water passes on its way to the groundwater zone of saturation [15-16]. The greater part of the soluble constituents in ground water comes from soluble minerals in soils and sedimentary rocks. The more common soluble constituents include calcium, sodium, bicarbonate and sulphate ions. Another common constituent is chloride ion derived from intruded evapotranspiration concentrating salts, and sewage wastes [17].

The major sources of pollution in underground water arises from anthropogenic activities, largely caused by the poor and uncultured living habit of people as well as the unhealthy practices of some health facilities, factories, industries and agricultural practices; resulting in the discharge of effluents and untreated wastes. Disinfectants, pharmaceuticals, radionuclides and solvents are widely used in health facilities which combine with hospital influents and may be leached into the underground water system [3, 18]. Ground water pollution could be avoided when borehole wells are located far from any source of potential pollution [2].

Borehole water serves as the major source of drinking water in the local population of Nigeria, since only very few can afford and rely on purified and treated bottled water for consumption [2]. Water is drawn from the ground for a variety of uses, principally community water supply farming (both livestock and irrigated cultivation) and industrial processes. Unlike surface water, groundwater is rarely used *in situ* for non-consumptive purposes such as recreation and fisheries, except occasionally where it comes to the surface as springs.

Studies on groundwater pollution have been carried out in different parts of Nigeria [2-9]. Monitoring the quality of water is very essential for environmental safety, thus physicochemical parameters were determined in water from boreholes in the vicinity of some selected public health clinics (PHC) in thirteen (13) local government areas of Nasarawa state, Nigeria, to ascertain the quality of the water for various purposes.

II. Material And Methods

2.1 Study Area

Nasarawa state (Fig. 1) is located centrally in the middle belt region and lies between latitude 7° 45′ and 9° 25N′ of the equator and between longitude 7° and 9° 37′E of the Greenwhich meridian. It shares boundary with Kaduna state in the north, Plateau state in the east, Taraba and Benue states in the south, and flanked by Kogi and Federal Capital Territory in the west [19].

2.2 Sample collection and analysis

Borehole water was sampled from sixty nine (69) boreholes located in some PHC in thirteen (13) local government councils of Nasarawa state (Fig. 1). The water samples were collected from the boreholes into pre-washed two litres polythene containers (Tukura et al., 2012) and transported to the laboratory, treated and preserved for analysis. The physicochemical parameters were determined according to standard methods [20].

2.3 Statistical analysis

Simple statistics such as average and mean were used in the presentation of data. Values in each table are the average values for a given site, whereas the mean values of the physicochemical parameters for each local government area were presented in the form charts.

III. Results And Discussion

Variations in physicochemical parameters for borehole water form Karu, Kokona and Keffi are presented in Table 1. pH ranged between 7.79 and 8.36 at Karu, 7.41 to 8.15 for Kokona and 7.44 to 8.87 at Keffi. The highest pH (8.87) was recorded at Main Market at Keffi, and the lowest (7.74) at Arusu in Kokona. EC varied from from 95 – 203µS/cm at Karu, 93 – 143 µS/cm (Kokona) and 130 – 145 µS/cm at Keffi. TDS at Karu varied from 43 – 101mg/l, 18 – 32 mg/l and 26 - 28 mg/l at Kokona and Keffi respectively. EC and TDS levels were highest in Gurku and Saka, both at Karu. Alkalinity varied in the areas as follows: 18 - 36 mg$CaCO_3$/l (Karu), 18 – 32 mg$CaCO_3$/l (Kokona) and 26 – 28 mg$CaCO_3$/l (Keffi). Nitrate and chloride contents varied from 7.34 to 10.04 mg/l and 80 to 120 mg/l respectively at Karu, 80 – 100 mg/l and 18 – 35 mg/l at Kokona. Higher nitrate (12.04 mg/l) and chloride (120 mg/l) contents in Keffi were recorded at Sabo Gari and Main market areas respectively. Sulphates ranged from 30 – 55 mg/l in Karu, 18 – 55 mg/l at Kokona and between 35 – 44 mg/l at Keffi. Highest phosphate level (0.04 mg/l) was reported at Karu and Kokona, and below detectable limit in other sampling areas.

Physicochemical parameters results for borehole water from Nasarawa and Toto (Table 2) indicated that pH varied from 8.10 to 8.36 for Nasarawa and 6.90 to 10.15 at Toto.Highest EC levels were recorded at Ayele (220 µS/cm) in Nasarawa and Sabo (240 µS/cm) in Toto.TDS ranged from 94 – 111 mg/l at Nasarawa, and 50 - 121 mg/l in Toto. Variation in alkalinity was 18 – 36 and 16 – 30 mg$CaCO_3$/l at Nasarawa and Toto respectively. Results for physicochemical parameters for Akwanga, N/Eggon and Wamba are reported in Table 3.The highest and the lowest water pH was recorded at Zalli (10.61) and Wayo (5.91) respectively, both at Wamba. EC ranged between 45 – 235 µS/cm at Akwanga, 65 – 185 µS/cm for N/Eggon and 83 – 224 at Wamba. The lowest TDS contents were recorded at Nidan (43mg/l) in Akwanga, 31 mg/l at Ogba (N/Eggon) and 41 - 31 mg/l in Kwabe at Wamba. Alkalinity varied from 20 – 24 mg$CaCO_3$/l at Akwanga, 16 – 30 mg$CaCO_3$/l (N/Eggon), and 18 - 24 mg$CaCO_3$/l at Wamba, while nitrate ranged from 5.65 – 10 .04 mg/l (Akwanga), 4.47 – 7.25 mg/l (N/Eggon) and 5.45 – 9.24 mg/l at Wamba.

The lowest chloride content (160 mg/l) was obtained at Kwabe (Wamba) and the highest (180 mg/l) at Galle South in N/Eggon. At Akwnga, chloride levels varied between 80 – 160 mg/l, 28 – 40 mg/l (N/Eggon) and 22 – 38 mg/l at Wamba. Sulphate ranged from 30 - 60 mg/l (Akwnaga), 28 – 40 mg/l (N/Eggon) and 22 – 38 mg/l (Wamba). The highest phosphate level (0.18 mg/l) was recorded at Ogba (N/Eggon). Sulphate (43 mg/l) and chloride (160 mg/l) contents were both recorded at Ayele in Nasarawa. Table 4 reported results from Lafia and Obi. At Lafia, pH ranged from, 6.05 – 9.06, EC: 65 – 216 µS/cm, TDS: 32 – 104 mg/l, alkalinity: 18 – 32 mg/l,

nitrate: 6.77 - 12.06 mg/l, chloride: 60 -160 mg/l, and sulphate: 17 – 45 mg/l. At Obi, the highest water pH (10.03) and EC (260 µS/cm) level were recorded at MCWC Obi and Agwa Sale respectively, while chloride varied from 31 – 130 mg/l and 16 – 26 mg/l for alkalinity. The highest nitrate (13.5 mg/l) and chloride (180 mg/l) levels were obtained at Agwa Sule. Sulphate ranged from 28 – 75 mg/l. Phosphate levels were generally low in all the areas.

From Table 5, pH varied between 7.85 and 10.31 (Awe), 5.31 and 7.89 (Doma), and from 6.01 to 6.91 at Keana. The lowest (74 µS/cm) and the highest (261 µS/cm) EC values were recorded at Alwaza (Doma) and Akuri (Awe) respectively. TDS ranged from 33 – 130 mg/l (Awe), 35 – 103 mg/l (Doma) and 67 – 11 mg/l at Keana. Alkalinity varied from 18 – 30 at Awe, 10 – 20 for Doma, and 14 – 20 mg/l at Keana. Nitrate levels were highest at Jangwa (Awe) and lowest (3.02) at Owena (Keana).

Chloride and sulphate varied respectively from 25 – 140 mg/l and 25 – 54 mg/l at Awe, 80 – 180 mg/l and 14 – 55 mg/l at Doma, 160 – 180 mg/l and 11 – 35 mg/l at Keana. The highest phosphate content was recorded at Agyemo in Doma. Fig. 2 shows the mean variations in pH of the borehole water. pH of the studied areas varied from slightly to moderately alkaline, except at N/Eggon and Doma where the water samples were slightly acidic (< 7).Variations in EC (Fig. 3) indicated that Karu, Nasarawa, Keana and Obi recorded relatively higher values. In comparison, EC values from Toto and Akwanga, and Lafia and Awe were similar. The highest and the lowest EC values were recorded in boreholes water in the vicinity of public health facilities from Nasarawa and Kokona respectively.

Variations in TDS (Fig. 4) show that TDS levels at Nasarwa, Keana and Obi were higher. Relatively low TDS contents were reported at Kokona, and N/Eggon. TDS levels at Keffi, Wamba, Awe and Doma did not show any significant variation. Nasarawa and Kokona recorded the highest and lowest TDS contents respectively.

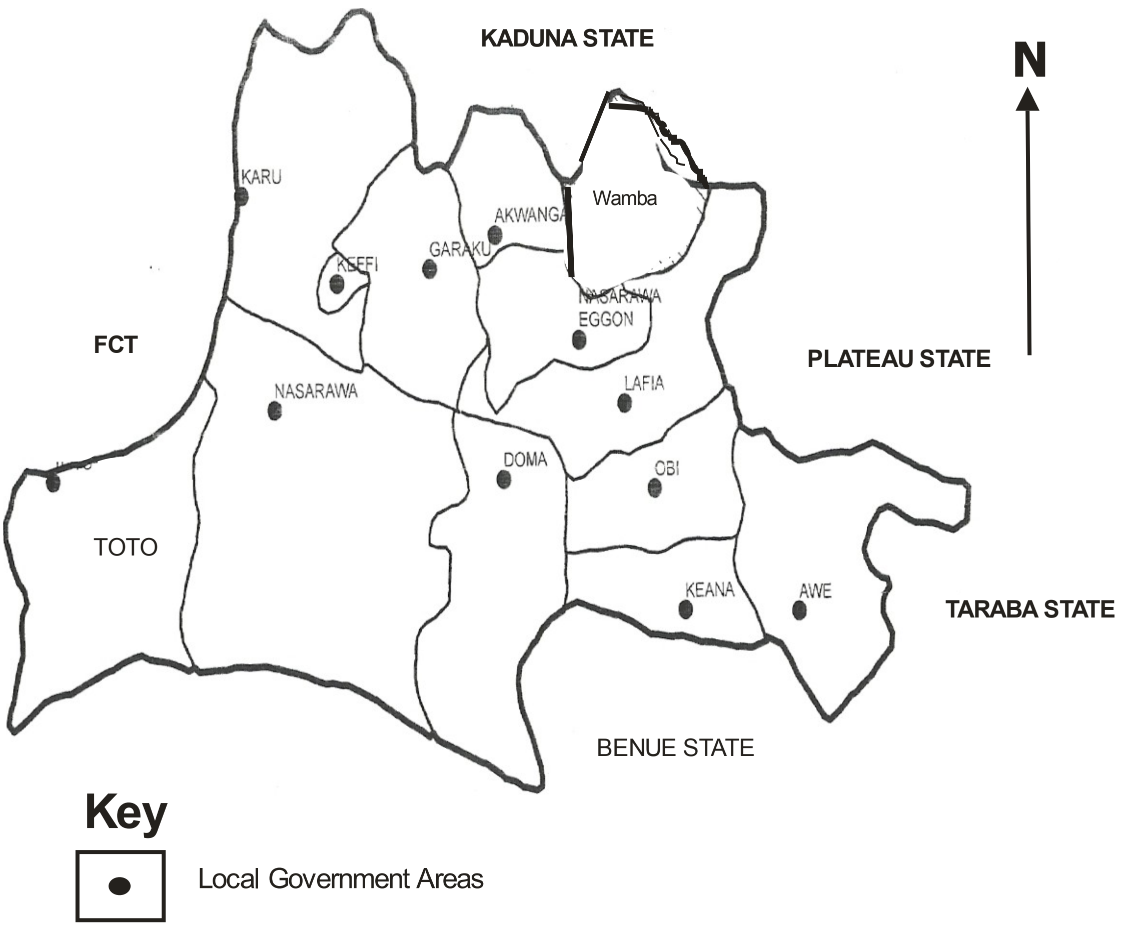

Fig. 1: Nasarawa State showing sampling areas

Table1. Physicochemical properties of borehole water in Karu, Kokona and Keffi public health facilities.

Areas	pH	EC (µS/cm)	TDS (mg/l)	Alkal. ($CaCO_3$/l)	NO_3^- (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	PO_4^{2-} (mg/l)
Karu								
New Karu	8.20	122	61	30	8.05	120	30	0.01
Gurku	8.36	203	101	36	7.34	100	34	ND
Saka	8.36	203	101	18	10.04	120	40	0.02
Karape	7.79	95	43	3	7.34	100	34	ND
Kari	8.11	180	91	20	10.00	80	55	0.04
Kokona								
S/Gari	8.15	93	45	32	8.15	100	55	0.01
M/Market	6.68	143	73	20	12.02	160	18	0.04
Arusu	7.44	96	45	18	6.28	80	42	0.02
Keffi								
S/Gari	7.44	130	63	26	12.04	100	35	ND
M/Market	8.87	145	78	28	10.05	120	44	ND

Names in bold: Local government areas, ND: Not detectable

Table 2. Physicochemical properties of borehole water in Nasarawa and Toto public health facilities.

Areas	pH	EC (µS/cm)	TDS (mg/l)	Alkal. ($CaCO_3$/l)	NO_3^-(mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	PO_4^{2-} (mg/l)
Nasarawa								
Zaka Bello	8.34	190	94	18	9.67	100	30	0.02
Godlinic	8.34	190	94	18	9.67	100	30	0.02
Ayele	8.10	220	111	22	11.04	160	43	0.04
Onda	8.36	203	101	36	7.34	100	34	ND
Toto								
Ukya	7.70	105	50	30	6.19	80	45	0.10
Umesha	6.68	167	92	16	2.97	100	15	0.02
Chiji	7.94	182	98	22	12.14	180	63	ND
Karmo	8.02	60	19	20	12.14	80	38	0.05
Bugga Sabo	6.90	240	121	20	9.05	160	30	0.03
Offu	9.56	200	101	28	10.09	140	58	0.02
Kuru	10.15	53	110	28	11.16	160	45	0.40

Names in bold: Local government areas, ND: Not detectable

Table 3. Physicochemical properties of borehole water in Akwanga, Nsarawa Eggon and Wamba public health facilities.

Areas	pH	EC (µS/cm)	TDS (mg/l)	Alkal. ($CaCO_3$/l)	NO_3^- (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	PO_4^{2-} (mg/l)
Akwanga								
C/School	8.05	77	38	20	10.01	120	48	0.06
Takpir	7.86	218	108	20	10.04	100	30	0.04
Tidde	6.23	235	117	22	5.81	80	40	ND
Anjida	7.86	218	108	20	10.04	100	30	0.04
Nidan	7.41	99	43	24	7.17	160	44	ND
Nunku	9.05	115	53	28	5.65	120	35	0.01
Koko	6.01	45	19	30	8.08	100	60	ND
N/Eggon								
Galle South	6.08	171	84	22	5.56	180	28	ND
Langalaga	6.00	77	38	18	7.13	100	30	ND
Kagbu Error	7.57	90	47	30	4.47	120	30	ND

Ogba	6.38	65	31	16	7.25	80	40	0.18
Angbiggah	7.12	183	94	22	6.09	80	28	0.10
Wamba								
Zalli	10.61	128	65	24	9.24	80	35	0.03
Wayo	5.91	101	50	18	7.30	120	22	ND
Yashi Madaki	8.13	129	66	28	9.10	160	38	ND
Kwabe	8.23	83	41	20	5.45	60	30	0.03
Wamba Kurmin	9.16	224	118	20	9.05	100	26	0.02

Names in bold: Local government areas, ND: Not detectable

Table 4. Physicochemical properties of borehole water in Lafia, and Obi public health facilities.

Areas	pH	EC (μS/cm)	TDS (mg/l)	Alkal. ($CaCO_3$/l)	NO_3^- (mg/l)	Cl^-(mg/l)	SO_4^{2-} (mg/l)	PO_4^{2-} (mg/l)
Lafia								
Ombi Poly	9.06	166	83	26	7.52	60	25	0.02
Agyaragu Y	7.23	216	104	18	6.77	160	40	ND
Angiri	8.23	186	94	22	12.06	140	455	ND
Akunza	6.45	154	76	20	10.12	140	50	ND
Ugah	6.9	166	86	32	13.02	120	17	0.02
Takpa	6.05	65	32	22	9.34	80	34	0.01
Obi								
Ome	9.24	170	97	26	7.85	60	28	0.08
U/suwababa	6.13	167	83	18	7.54	120	75	0.02
MCWC Obi	10.03	213	105	20	7.54	120	50	ND
Akpangwa	7.12	65	31	20	8.12	80	34	ND
Idevi	8.04	142	77	24	8.24	100	30	ND
Agyaragu	7.36	191	98	18	9.05	100	41	ND
Agewu	8.00	170	82	28	8.21	80	36	0.06
Akaleku	7.00	120	61	20	10.01	160	30	0.04
Agwa Sule	7.00	260	131	16	13.05	180	30	0.08

Names in bold: Local government areas, ND: Not detectable

Table 5. Physicochemical properties of borehole water in Awe, Doma and Keana public health facilities.

	pH	EC (μS/cm)	TDS (mg/l)	Alkal. ($CaCO_3$/l)	NO_3^- (mg/l)	Cl^-(mg/l)	SO_4^{2-} (mg/l)	PO_4^{2-} (mg/l)
Awe								
Gidan Ihumer	8.34	130	64	18	7.02	120	40	0.03
Jangara	7.85	70	33	24	10.02	140	43	0.06
Akuri	6.85	261	130	26	9.12	25	25	0.02
Jangwa	10.31	182	130	30	10.05	100	54	0.01
Doma								
Agyemo	7.29	169	101	10	6.45	160	40	0.22
Iwashi	7.89	175	84	20	9.05	100	25	0.02
Alwaza	6.63	74	35	20	8.13	80	55	0.01
Idadu	6.72	78	36	10	6.12	180	14	0.14
Agyema	5.31	225	113	16	7.15	120	33	0.30
Keana								
Agbaragba	6.01	194	111	18	6.12	100	11	0.15
Owena	6.01	135	67	22	3.02	180	25	0.02
Chiata	9.34	176	98	24	4.18	160	35	ND
Kalachi	6.91	202	103	14	4.45	140	15	ND

Names in bold: Local government areas, ND: Not detectable

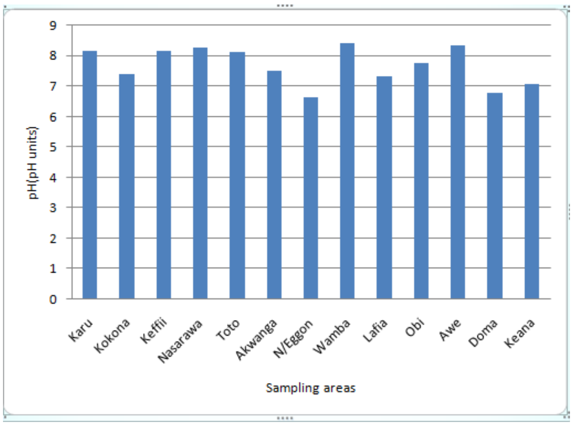

Figure 2 Variation in pH levels of borehole water

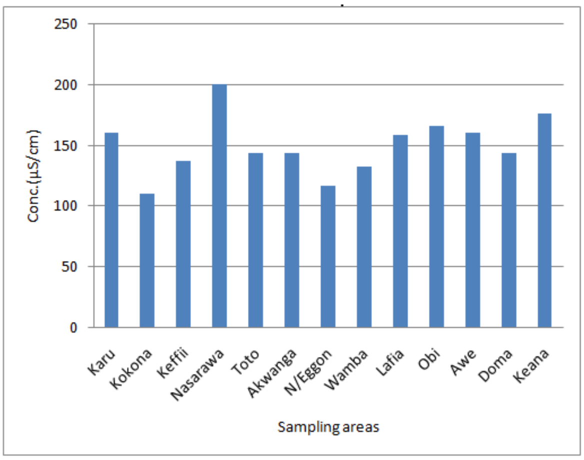

Figure 3 Variations in conductivity (µS/cm) of borehole water.

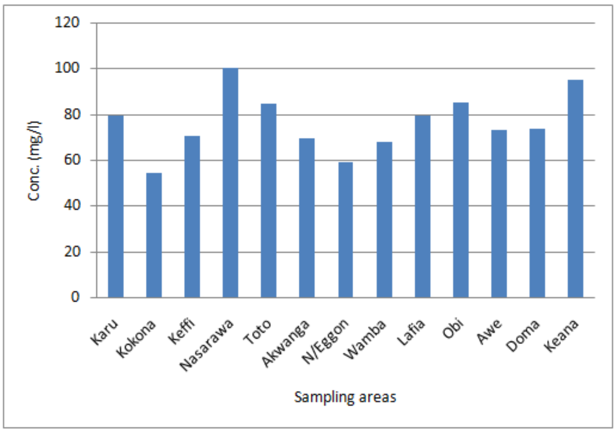

Figure 4 Variations in total dissolved solids (TDS) (mg/l) of borehole water

Mean variations in alkalinity and total hardness are shown in Fig. 5. Water hardness at Karu and Doma was highest and lowest respectively. Mean variation in alkalinity at Toto was significantly the highest and minimum at Keffi. Water hardness and alkalinity generally did not vary significantly across the areas.

From Fig. 6, nitrate contents were similar in all the studied areas and generally low. The highest and lowest chloride levels were observed at Keana and Akwanga respectively, and increases progressively from Karu to Toto, except at Keffi. Sulphate levels at Keffi, Toto, Awe and Obi were not significantly different. Sulphate levels in the borehole water were < 40. Phosphate contents were generally low.

pH is an important indicator of water quality and the extent of pollution in the studied areas. Unpolluted rivers normally show near neutral or slightly alkaline pH. pH of borehole water at Kuru (10.15), Zalli (10.61), MCWC Obi (10.03) and Jangwa (10.31) were higher than the WHO [21] accepted limit (9.20). Water pH levels were higher than the values reported by [3, 11, 15], but within the same range of values reported by [22] for borehole water in Niger state Polytechnic, Zungeru campus. Conductance (EC) qualitatively reflects the status of inorganic pollution and is a measure of total dissolved solid and ionized species in the water. EC levels were higher than the values reported by [2, 10], lower than the levels reported by [22]. Physicochemical parameters results for borehole water from Nasarawa and Toto (Table 2) indicated that pH varied from 8.10 to 8.36 for Nasarawa and 6.90 to 10.15 at Toto. EC values were, however within the WHO [21] acceptable limit (500µS/cm).

The measure of total dissolved solids (TDS) is a good indicator of the mineralized character of the water. High levels of dissolved solids in the water systems increase the biological and chemical oxygen demand, which deplete the dissolve oxygen level in the aquatic system. TDS in drinking-water originate from natural sources, sewage, urban runoff and industrial wastewater [15].

The levels of TDS in abroad sense reflect the burden of aquatic systems [23].TDS of the studied borehole water were within the WHO acceptable limit (500mg/l), but higher than the values reported by [11] for some selected boreholes in Umuahia North Local Government Area, in Abia State**,** and [10] for borehole water in Yenagoa, Bayelsa State, Nigeria. Water TDS contents fall within the range reported by [14] and [8] for borehole water in Okutukutu, Bayelsa State.

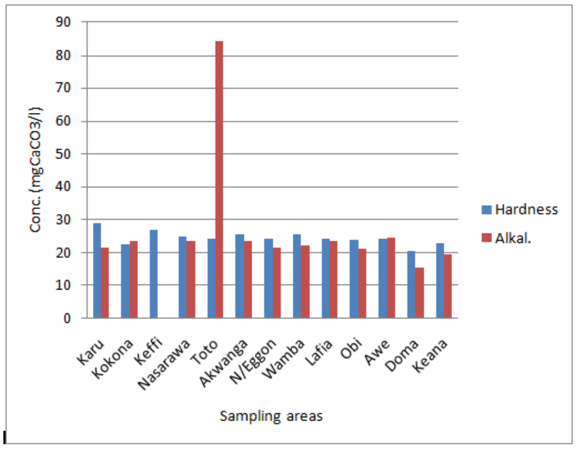

Figure 5 Variations in total hardness ($CaCO_3$/l) and alkalinity ($CaCO_3$/l) of borehole water

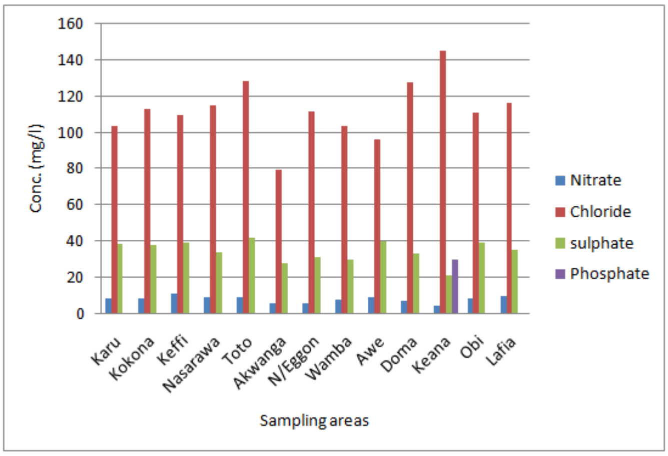

Figure 6 Variations in nitrate, chloride, sulphate and phosphate contents in borehole water

Chloride is present in nearly all natural water with varying concentration, depending on the geochemical condition of the area [23]. Chloride in drinking-water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion. No health-based guideline value is proposed for chloride in drinking-water by WHO and SON standard of drinking water. However, chloride concentrations in excess of about 250 mg/l can give rise to detectable taste in water. Chloride levels in the borehole water were above the levels reported by [16], but within the range reported by [2, 22, 24].

Alkalinity and EC values in this study were higher than those reported by [10-11]. EC is an indicator of water quality and soil salinity, hence the relatively high values observed in some water samples showed high salinity; thus the waters might not be very suitable for domestic and agricultural use. The alkalinity of water may be caused by dissolved strong bases such as sodium or potassium hydroxide (and other hydroxide containing compounds), hydroxide ions are always present in water, even if the concentration is extremely small [16]

Nitrate, the most highly oxidized form of nitrogen, is commonly present in surface and ground waters because it is the end product of the aerobic decomposition of organic nitrogenous matter. Some ground waters may also have nitrate contamination as a consequence of leaching from natural vegetation. Nitrates react directly with hemoglobin in human blood to produce methemoglobin, which destroys the ability of blood cells to transport oxygen. This condition is especially serious in babies under three months of age as it causes a condition known as methemoglobinemia or "blue baby"disease [3, 8]. Nitrate contents at Ayele (11.04 mg/l), Chiji (12.14 mg/l), Karmo (12.14 mg/l), Main Market (12.02 mg/l), Sabo Gari (12.04 mg/l), Angiri (12.06 mg/l), Ugah (13.02 mg/l), and Agwa sule (13.05 mg/l) were above the WHO [21] acceptable limit (10 mg/l). Nitrate levels of the studied areas were higher than the levels reported by [2, 10, 14], lower than the values reported by [8], but in agreement with the results reported by [11, 25].Sulphate levels were higher than the values reported by [2].

IV. Conclusion

Physicochemical properties show some variations according to sampling areas. Water pH at Keana was acidic (6.01 – 6.91), except at Chiata (9.34); but alkaline at Kuru (10.15), Zalli (10.61), MCWC Obi (10.03) and Jangwa (10.31) in Awe. Variation in water pH may affect mobilisation of available heavy metals. At low pH, heavy metals may be remobilised into the water column affecting water quality. Nitrate contents at Ayele (11.04 mg/l), Chiji (12.14 mg/l), Karmo (12.14 mg/l), Main Market (12.02 mg/l), Sabo Gari (12.04 mg/l), Angiri (12.06 mg/l), Ugah (13.02 mg/l) and Agwa Sule (13.05 mg/l) in Obi were above the World Health Organization (WHO) permissible limits. Nitrate can be a natural constituent but high concentration often implies a source of pollution. Farming activities should be regulated around such facilities, since the major source of nitrate might be from fertilizers applied to crops in farms close to boreholes, which is subsequently leached into the ground water. TDS, EC, alkalinity and total hardness levels were within the acceptable WHO and Standard Organization of Nigeria (SON) [25] standards for ground water, which suggested that the borehole water were safe for consumption, agriculture and industrial uses. The low level observed for some parameters may be attributed to low level of industrialization, lack of proximity to possible source of contaminants and possibly far reaching water table in the study areas. Variations in some physiochemical parameters suggest that there is the need for continuous monitoring of the borehole water quality, especially for heavy metal levels which may be affected by change in pH. Microorganisms might also been responsible for the changes in water properties, thus the need for microbial analysis.

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