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HYDRO-GEOCHEMICAL AND QUALITY ASSESSMENT OF GROUNDWATER FROM SEDIMENTARY FORMATION IN THE MIDDLE BENUE TROUGH, NIGERIA

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ABSTRACT
Nasarawa State in Nigeria, is host to several mineral deposits. The groundwater resources in the State plays an important role in the socio-economic life of the people in terms of domestic, industrial and agricultural water supply. The effect of climate change, on the surface and groundwater resources, couple with the anthropogenic and geogenic activities on the quality of the various groundwater sources remained uncertain. Two hundred (200) water samples were collected randomly from boreholes and hand-dug wells from five locations (20 each) in Nasarawa South: Keana, Obi, Lafia and Awe Local Government Areas of the State, referred to as Middle Benue trough. 100 samples were collected during peak of dry season and another 100 during peak of rainy season. Cations, anions and heavy metals were analyzed using atomic absorption spectrometry (AAS); with aim of determining their concentrations in relation to suitability within the tolerance limit. The results revealed that heavy metals such as lead (Pb), manganese (Mn), Magnesium (Mg) and arsenic (As) have concentrations above World Health Organization (WHO 2017) and SON (2015) standards. The high concentrations are mostly associated with the Baryte and Lead-zinc mineralization present in Keana / Awgu formations in the Middle Benue Trough. Zinc (Zn), copper (Cu), cadmium (Cd), and iron (Fe2+) have their concentrations within World Health Organization (WHO 2017) drinking water permissible limits. The cations and anions present in the groundwater in the study areas had varying levels in terms of physico-chemical and bacteriological quality. In some areas bacteriological contamination rendered water sources unfit for human consumption, but suitable for agricultural purposes. Therefore, regular monitoring of the water sources in the affected areas are highly recommended.

Keywords: Benue Trough, Nigeria, Groundwater, Hydrochemistry.

1. INTRODUCTION
Population growth, agriculture and industrialization activities have put a lot of pressure on water resources all over the world. In the developing countries like Nigeria, the conventional water treatment facilities are hardly feasible especially in the rural areas, thus, potable water demands of residents are hardly met. Individuals and groups have resorted to managing their own water supplies and one of such resorts is to develop and harness groundwater resources through drilling of individual boreholes and hand-dug wells.

Groundwater refers to all subsurface water or water beneath the surface of the earth which saturates the pores and fractures of sand, gravel, and rock formations (Hogan, 2012). It is the most preferred and effective source of water for agricultural and domestic uses.

The demand for groundwater in Nigeria increases rapidly every year as it is more risk free from pollution than surface water, less susceptible to bacterial pollution than surface water, because the soil and rocks through which groundwater flows serve as filter removing most of the bacteria (Akpan *et al.,* 2013; Hogan, 2012). But freedom from bacterial pollution alone does not mean that the water is fit for consumption.

The use of contaminated groundwater for drinking and consumption purposes can cause major health problems. According to WHO (2017), about 80% of all diseases in human beings are caused and transmited by water. The application of excessive amounts of herbicides, pesticides and fertilizers, indiscriminate dumping of waste and industrial effluents result in soil and water contamination. These impair soil productivity by affecting plant yields and also cause health hazards by entering into food chain via soil–plant–animal/human route. These heavy metals reach the human system through ingestion in the form of food and water. Exponential growth in population and the resulting demand for water requires careful planning of the management of available water resources. Dissolved mineral constituents in large concentrations can be hazardous to humans, animals and plants (Igwe *et al.*, 2012; Onyeobi and Imeokparia, 2014). Groundwater quality in an area is greatly controlled by the natural processes (e.g., geology, groundwater movement, recharge water quality, and soil/rock interactions with water), anthropogenic activities (e.g., agricultural production, industrial growth, urbanization with increasing exploitation of water resources) and atmospheric input. Therefore, a periodic assessment of groundwater quality is necessary in order to ascertain the quality of water for human consumption, as well as to provide an overall scenerio about the sources of groundwater contamination at both spatial and temporal scales which is imperative for managing this vital resource, especially in water-scarce regions.

2.0 MATERIALS AND METHODS

2.1 Study Area

Nasarawa State is located in central part of Nigeria. Nasarawa State was created on the 1st October 1996 with Lafia as the capital town. Nasarawa State is bordered in the east by Plateau and Taraba State in the north by the Kaduna State, in the south by Benue and Kogi States and in the west by the Abuja Federal Capital Territory. The State has thirteen (13) Local Government Areas with an estimated Land area of 27,107.8km^2 (Figure 1). The State is located on Longitude 8^{0}8' 38" East and Latitude 8^{o}24'17" North. The study areas (Figure 2) cover Doma, Lafia, Obi, Keana and Awe Local Government Areas (referred to as Nasarawa Southern Senatorial Zone)

2.1.1 Climatic and Geographical Location of the Study Areas

The study areas fall within Latitudes 8^{0}20'40''N and 8^{0}25'43''N on its Southern and northern boundaries, and Longitudes 8^{0}48'8''E and 8^{0}55'55''E on its eastern and western boundaries (Figure 3). Climatologically, temperatures are generally high, with gradual increase in from January to March. Relative humidity rises from February to a maximum of about 88% in July.

Steady rains commence in April when the relative humidity reaches about 75%, with a noticeable decline in temperature. The variation in rainfall has significant effect on the groundwater accumulation, yield, recharge and economic activities due to rain-fed agriculture products. Thus, rainfall season spans from April to October with a yearly value ranging from 1100mm to about 2000mm (Yusuf *et al*., 2017)., while November to March is characterized by dryness.

2.2 Collection of Water Samples

2.2.1 Collection during peaks of dry season (March 2020) and rainy season (September 2020).

Water samples were collected from 20 selected boreholes and hand dug wells sites (Figure 3) from the five (5) Local Government Areas, in clean 1 litres plastic bottle for physico-chemical parameters analysis during dry season. A plastic bailer was use for wells while boreholes samples were taken from taps after allowing it to run for a few minutes. The pH, temperature,

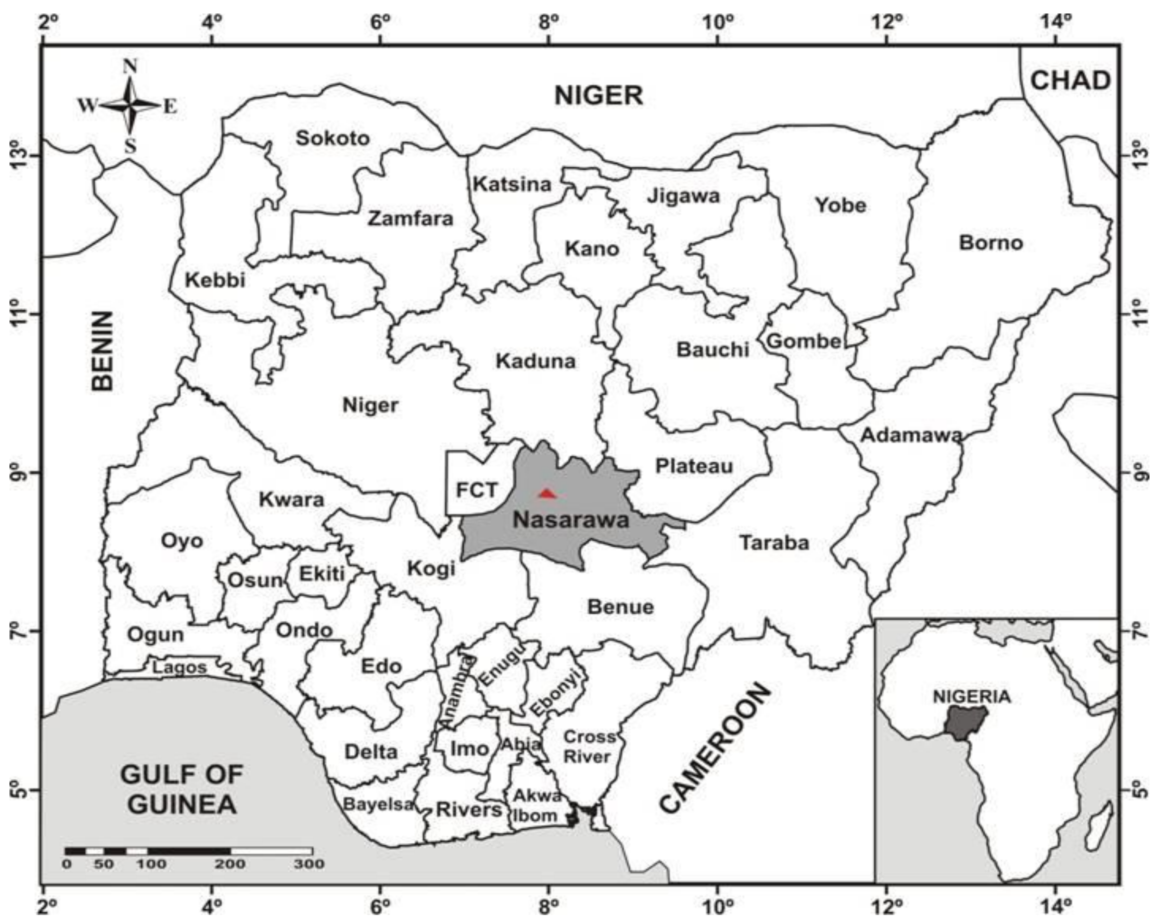

Figure 1: Map of Nigeria showing Nasarawa State.

Source: Nasarawa State Government, (1998).

TDS and conductivity were determined ***in situ*** using pH meter, thermometer and TDS/conductivity meter. Time and date of sampling were noted for each location. Samples for bacteriological analysis were collected in clean 250ml amber reagents bottles. These procedures were repeated for the months of September 2020 as the peak rainy season.

2.2.2 Laboratory Analysis of Samples

(a). The physical, chemical, hydrocarbons and heavy metals were determined at the Federal Ministry of Agriculture and Rural Development NIPFS/FAO/UN laboratory Kaduna, Nigeria. The methods and instruments used are as shown in Table 1.

(b). Samples for bacteriological analysis were done at Nasarawa State University, Faculty of Agriculture Laboratory, Lafia, according to WHO (2017) standards (Table 1).

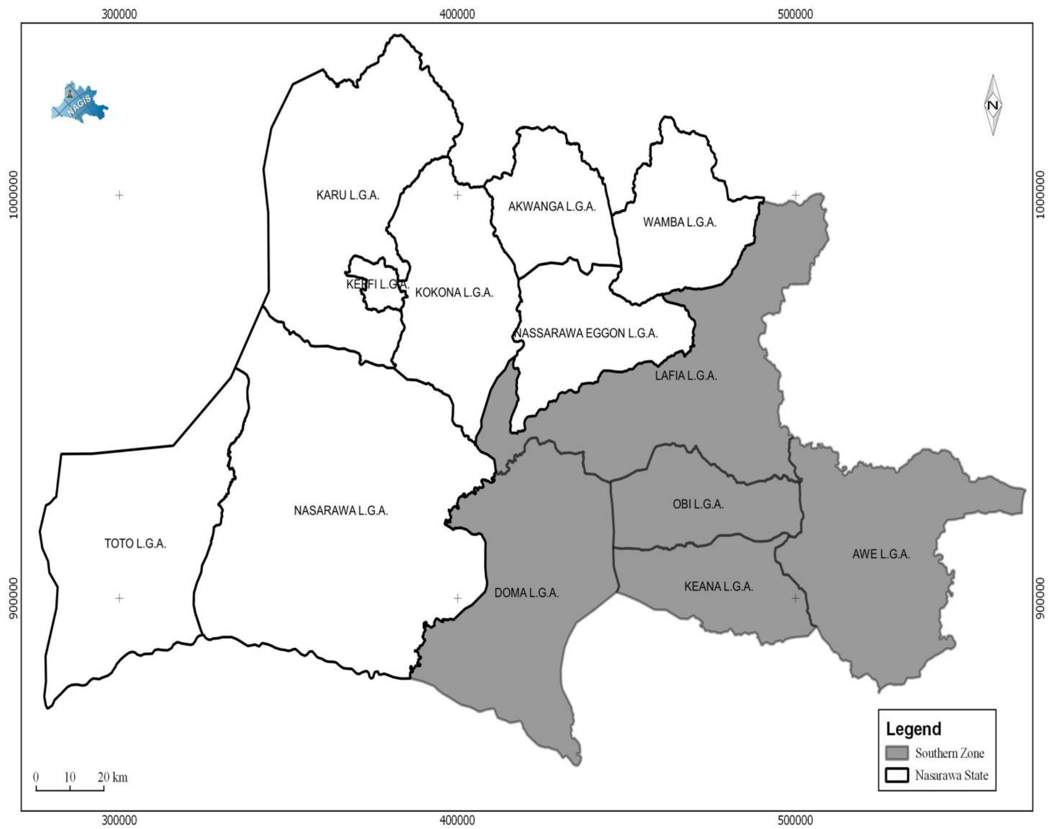

Figure 2: Map of Nasarawa State showing the five Local Government Areas in the Middle Benue Trough surveyed

Source: NAGIS (2020).

3. RESULTS OF ANALYZED GROUNDWATER.

The mean results of the 200 samples analyzed are shown in Tables 2 - 6.

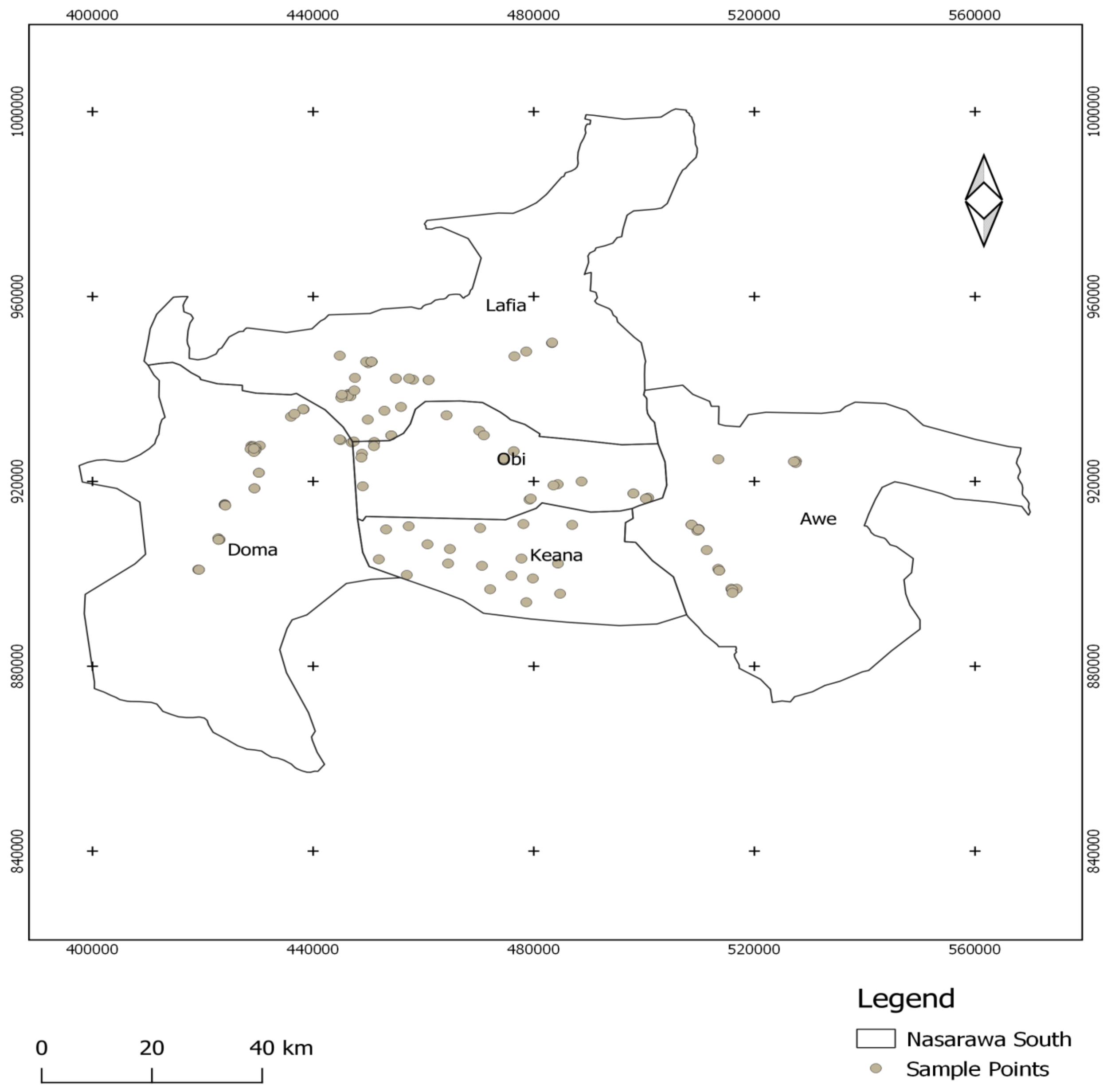

Figure 3: Map of Nasarawa South showing the sample points in the five Local Governments.
Source: Field Study (2020)

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Table 1: Laboratory Methods of Analysis and Instruments used

S/n	Parameters	Units	Methods of analysis	Instruments used
	Physical Parameters			
1	Temperature	^oC	Thermometry	Glass bulb Thermometer
2	Turbidity	NTU	Turbidimetry	Turbidimetre, Current source
3	T D.Solids	mg/l	Gravimetric	Oven, Desiccator, Petri-dish
	Chemical Parameters			
1	pH	(1-14)	Electrometry/ECP	pH Electrode
2	T. Acidity	mg/l	Photometric	Lab. instruments/reagents
3	T. Alkalinity (TA)	mg/l $caco_3$	Photometric	Lab. instruments/reagents
4	T. hardness (TH)	mg/l$caco_3$	Titrimetric/photometric	Photometer
5	E. Conductivity	µS/cm	ECP	Lab. instruments/reagents
6	Sodium (Na^+)	mg/l	Spectrophometry	Colorimeter
7	Potassium (K^+)	mg/l	Spectrophometry	ECP/AAS
8	Calcium (Ca^{2+})	mg/l	Spectrophometry	ECP/AAS
9	Magnesium (Mg^{2+})	mg/l	Spectrophometry	ECP/AAS
10	Chloride (Cl^-)	mg/l	Titrimetric	ECP/AAS
11	Nitrates (NO_3^-),	mg/l	Spectrophometry	ECP/AAS
12	Sulphate (So_4^-)	mg/l	Colometry	Colorimeter
13	Bicarbonate (HCO_3^-),	mg/l	Spectrophometry	ECP/AAS
14	Carbonate (CO_3^-)	mg/l	Spectrophometry	ECP/AAS
15	Fluoride (F)	mg/l	Spectrophometry	ECP/AAS
16	lead (Pb),	mg/l	Spectrophometry	ECP/AAS
17	copper (Cu^{2+}),	mg/l	Spectrophometry	ECP/AAS
18	arsenic (As),	mg/l		ECP/AAS

Vol. 08, No. 01; 2023

ISSN: 2456-8643

19	cadmium (Cd),	mg/l	Spectrophometry	ECP/AAS
20	iron (Fe^{2+})	mg/l	Spectrophometry	ECP/AAS
21	manganese (Mn)	mg/l	Spectrophometry	ECP/AAS
22	Chromium (Cr^{+})	mg/l	Spectrophometry	ECP/AAS
23	zinc (Zn^{2+})		Spectrophometry	ECP/AAS
			Spectrophometry	
	Bacteriological Parameters			
1	T. Bacteria Count	cfu/ml	Membrane filtration	Lab. instruments/reagents
2	E. Coli count	MPN/100ml	Membrane filtration	Lab. instruments/reagents

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Table 2: Mean Results of the Analyzed Hydro-geochemical Parameters of Awe Local Government Area

S/No	Sample Code	Turbidity (NTU)	TDS	Temp. (^{O}C)	pH H_2O	EC (US/cm)	HCO_3^- (mg/l)	NO_3^- (mg/l)	SO_4^{3-} (mg/l)	CL^- (mg/l)	F (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)
1	**A1**	0.00	30	38	8.0	50	0.50	18.81	13.14	7.09	0.21	5.788	2.862	50.0	17.60
2	**A2**	2.00	25	39	7.9	40	0.60	22.44	11.47	7.09	0.23	5.972	2.958	144.0	13.94
3	**A3**	1.00	10	38	7.9	30	0.30	7.27	12.14	0.00	0.12	3.483	2.273	90.20	15.15
4	**A4**	3.00	15	38	8.2	25	0.40	10.43	10.47	0.00	0.18	2.900	0.533	130.00	18.79
5	**A5**	1.00	20	38	7.9	30	0.30	3.17	11.47	0.00	0.08	3.939	0.265	46.21	21.21
6	**A6**	2.00	40	37	8.4	70	0.40	13.60	12.80	7.09	0.19	5.884	2.864	62.00	14.55
7	**A7**	2.00	30	36	8.4	60	0.70	58.93	11.80	7.09	0.22	8.563	3.504	58.06	12.12
8	**A8**	7.00	30	40	8.6	60	0.50	40.80	11.80	7.09	0.16	7.762	3.957	50.02	16.36
9	**A9**	3.00	10	38	8.1	30	0.30	86.13	11.47	0.00	0.24	15.285	6.079	56.41	12.73
10	**A10**	3.00	15	35	7.5	25	0.70	138.27	11.80	0.00	0.21	28.651	6.791	38.10	31.45
11	**A11**	3.00	60	38	7.2	90	0.30	63.46	15.46	14.18	0.19	7.333	4.141	54.00	20.61
12	**A12**	3.00	70	37	7.1	120	0.20	83.87	14.46	14.18	0.22	8.143	5.182	50.10	20.61
13	**A13**	2.00	20	39	7.6	50	0.50	27.20	8.80	0.00	0.16	7.523	4.134	76.34	22.42
14	**A14**	2.00	30	38	7.4	70	1.30	65.73	11.46	7.09	0.22	4.314	3.606	46.50	24.85
15	**A15**	1.00	25	38	7.4	55	0.20	43.06	10.13	7.09	0.17	4.433	3.780	56.00	16.36
16	**A16**	5.00	30	38	7.6	60	0.50	34.00	10.80	3.54	0.19	5.124	3.502	50.23	15.15
17	**A17**	2.00	20	39	7.3	50	0.20	52.13	9.18	7.09	0.21	8.476	5.905	56.00	11.52
18	**A18**	47.00	40	39	6.9	70	0.20	9.29	9.14	3.54	0.16	5.515	4.328	46.80	11.52
19	**A19**	1.00	50	39	7.4	80	0.20	12.24	14.80	3.54	0.13	4.202	4.423	36.28	15.15
20	**A20**	33.00	20	41	7.9	50	0.20	12.01	14.80	0.00	0.18	5.973	5.166	44.40	22.42

A1….A19 = Boreholes

Source: Field work (2020)

Table 2: (Continued)

S/No	Sample Code	Pb (mg/l)	Cr (mg/l)	Cd (mg/l)	As (mg/l)	Fe (mg/l)	Zn (mg/l)	Cu (mg/l)	Mn (mg/l)	CO_3^- (mg/l)	Total Hardness (mg/l)	Total Alkalinity (mg/l)	Total Acidity (mg/l)
1	**A1**	0.090	-0.061	-0.414	0.064	1.998	0.050	0.226	1.523	0.1	3.21	3.4	10
2	**A2**	0.159	-0.084	-0.427	0.008	2.284	0.044	0.290	1.804	0.3	2.80	5.4	10
3	**A3**	0.150	0.077	-0.421	0.007	2.319	0.266	0.262	0.801	0.2	3.21	5.4	10
4	**A4**	0.099	0.082	-0.417	0.016	3.186	0.093	0.336	2.136	0.3	4.01	3.4	20
5	**A5**	0.085	0.115	-0.415	0.000	1.966	0.141	0.215	2.326	0.6	4.01	3.4	10
6	**A6**	0.083	0.138	-0.412	0.011	3.378	0.087	0.298	0.866	0.4	6.41	5.4	20
7	**A7**	0.231	0.087	0.064	0.085	3.614	0.110	0.229	3.656	0.5	2.80	3.4	10
8	**A8**	0.220	0.088	0.051	0.091	4.119	0.183	0.059	3.884	0.6	2.80	3.0	10
9	**A9**	0.226	0.068	0.101	0.107	3.359	0.247	0.302	3.428	0.7	3.21	3.0	10
10	**A10**	0.381	0.099	0.120	0.104	5.778	0.212	0.102	2.188	0.3	3.21	4.6	10
11	**A11**	0.275	0.123	0.076	0.034	3.834	0.236	0.035	2.331	0.6	2.80	4.6	10
12	**A12**	0.440	0.101	0.063	0.056	4.410	0.081	0.274	4.556	0.7	2.80	3.4	10
13	**A13**	0.217	0.096	0.114	0.095	5.033	0.028	0.186	5.010	0.4	4.81	3.4	10
14	**A14**	0.191	0.064	0.050	0.083	3.713	0.104	0.228	6.682	0.6	2.80	4.6	20

15	**A15**	0.102	0.152	0.025	0.024	2.804	0.195	0.182	1.105	0.5	3.21	3.4	10
16	**A16**	0.176	0.436	0.038	0.016	10.102	0.112	0.302	1.349	0.6	3.21	3.0	10
17	**A17**	0.155	0.126	0.013	0.009	5.032	0.182	0.363	4.556	0.7	4.01	3.4	20
18	**A18**	0.308	0.266	0.114	0.066	18.199	0.267	0.340	7.676	0.6	4.01	5.4	10
19	**A19**	0.104	0.166	0.133	0.076	3.778	0.194	0.245	2.828	0.5	2.80	5.4	10
20	**A20**	0.312	0.182	0.152	0.084	7.502	0.246	0.344	3.428	0.3	3.21	3.0	10

A1….A19 = Boreholes

Table 2b: Mean Results of the Analyzed Bacteriological Concentration in Groundwater of Awe Local Government Area

S/N			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sample Code			A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}	A_{17}	A_{18}	A_{19}	A_{20}
Total Coliform	Media	NA Count	0	1	0	1	0	0	0	0	1	1	1	2	0	2	0	2	1	0	2	3
		MCC COUNT	0	0	1	2	3	1	2	3	2	1	2	1	1	0	0	0	2	0	4	3
E. Coli	Media (Emb)	Count	1	1	0	0	1	1	0	0	0	0	0	1	1	1	2	1	2	1	1	0

A1….A20 = Boreholes

Source: Field work (2020)

Table 3: Mean Results of the Average Analyzed Hydro-geochemical Parameters of Doma Local Government Area

S/No	Sample Code	Turbidity (NTU)	TDS	Temp. (^oC)	pH H_2O	EC (US/cm)	HCO_3^- (mg/l)	NO_3^- (mg/l)	SO_4^{3-} (mg/l)	CL^- (mg/l)	F (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)
1	D1	2.00	120	31	6.8	180	1.02	24.93	15.80	14.18	0.64	50.179	6.554	53.20	0.36
2	D2	1.00	80	30	5.8	120	1.38	77.06	11.46	49.63	1.26	49.672	6.555	46.05	0.18
3	D3	2.00	10	32	6.8	15	1.32	31.73	39.80	7.09	0.73	49.843	6.400	55.46	0.18
4	D4	1.00	20	31	6.1	30	1.44	70.26	23.14	7.09	1.12	48.365	5.939	39.24	0.18
5	D5	1.00	10	29	6.4	20	0.92	52.13	15.47	35.45	0.88	48.582	5.835	48.51	0.24
6	D6	2.00	80	33	5.3	120	0.64	77.06	20.14	7.09	1.16	48.376	6.203	51.50	0.18
7	D7	1.00	170	31	4.7	280	0.74	72.53	15.80	14.18	1.10	48.781	6.245	50.12	0.30
8	D8 w	3.00	50	31	5.8	80	0.62	40.80	28.47	21.27	0.79	49.462	6.364	51.60	0.24
9	D9 w	1.00	360	32	5.9	540	1.42	72.53	38.80	35.45	1.14	49.848	6.596	53.00	0.24
10	D10 w	1.00	460	30	6.2	690	1.20	31.73	12.60	35.45	0.78	50.096	6.855	61.44	0.24
11	D11 w	6.00	240	31	6.2	370	0.42	11.33	23.80	49.63	0.46	49.268	6.470	47.07	0.36
12	D12 w	2.00	310	31	6.4	470	0.36	13.60	11.47	56.72	0.53	47.462	6.026	59.02	0.36
13	D13	1.00	50	32	6.4	80	1.20	54.40	24.41	28.36	0.91	49.872	6.550	40.21	0.18
14	D14	5.00	80	32	7.0	120	0.38	29.46	17.46	21.27	0.72	50.218	6.484	50.40	0.18
15	D15	2.00	90	31	6.3	130	0.34	21.31	19.46	14.18	0.66	48.872	6.066	45.00	0.18
16	D16 w	2.00	100	32	6.7	150	0.26	13.82	27.14	14.18	0.52	49.332	6.312	61.70	0.18
17	D17 w	2.00	250	30	6.3	370	0.92	34.0	43.47	42.54	0.78	48.843	6.332	70.30	0.18
18	D18 w	2.00	20	29	6.6	30	0.28	13.15	18.14	7.09	0.54	48.272	5.860	48.92	0.18
19	D19	2.00	10	31	6.8	20	0.18	14.28	18.46	7.09	0.54	50.227	6.346	40.50	0.18
20	D20 w	2.00	10	30	6.2	20	1.22	113.33	27.80	7.09	1.43	47.361	6.058	52.00	0.18

D1…D19 = Boreholes; W = Hand-dug well

Source: Field work (2020)

Table 3 (Continued)

S/No	Sample Code	Pb (mg/l)	Cr (mg/l)	Cd (mg/l)	As (mg/l)	Fe (mg/l)	Zn (mg/l)	Cu (mg/l)	Mn (mg/l)	CO_3^- (mg/l)	Total Hardness (mg/l)	Total Alkalinity (mg/l)	Total Acidity (mg/l)
1	D1	0.103	0.217	0.000	0.180	1.887	0.400	0.258	1.260	0.3	3.21	3.4	10
2	D2	0.471	0.080	0.000	0.165	2.082	0.326	0.228	1.329	0.2	3.21	6.6	20
3	D3	0.395	0.366	0.000	0.094	2.686	0.592	0.294	1.359	0.5	4.01	6.8	10
4	D4	0.399	0.157	0.000	0.018	1.555	0.473	0.265	0.831	0.4	4.01	12.4	30
5	D5	0.518	0.196	0.014	0.220	1.672	0.417	0.228	0.620	0.3	3.21	5.4	10

6	D6	0.566	0.154	0.011	0.212	1.751	0.409	0.264	2.209	0.1	6.41	4.6	30
7	D7	0.000	0.152	0.000	0.016	1.665	0.529	0.341	0.788	0.16	7.21	18.0	40
8	D8 w	0.208	0.261	0.000	0.048	1.867	0.387	0.159	0.273	0.65	4.81	12.0	20
9	D9 w	0.168	0.171	0.000	0.017	1.939	0.380	0.183	0.320	0.8	6.41	11.4	30
10	D10 w	0.196	0.312	0.000	0.067	2.227	0.500	0.458	3.269	0.6	12.02	5.4	10
11	D11 w	0.487	0.237	0.008	0.144	1.836	0.673	0.538	4.312	0.7	6.41	6.6	10
12	D12 w	0.388	0.134	0.000	0.038	1.276	0.375	0.208	0.539	0.6	7.21	6.8	20
13	D13	0.276	0.228	0.000	0.094	1.633	0.671	0.454	1.043	0.3	4.01	9.0	20
14	D14	0.428	0.148	0.004	0.039	1.852	0.501	0.350	0.949	0.4	5.61	3.0	10
15	D15	0.323	0.102	0.000	0.133	1.685	0.454	0.238	0.724	0.6	4.01	3.4	20
16	D16 w	0.006	0.081	0.000	0.019	1.352	0.703	0.549	3.887	0.5	4.01	3.4	10
17	D17 w	0.041	0.121	0.000	0.016	1.782	0.421	0.332	0.900	0.7	12.02	3.0	10
18	D18 w	0.024	0.245	0.000	0.006	1.766	0.453	0.274	0.353	0.8	3.21	5.4	20
19	D19	0.234	0.242	0.000	0.072	1.599	0.523	0.372	0.944	0.9	3.21	4.6	10
20	D20 w	0.353	0.283	0.000	0.086	1.607	0.315	0.195	0.272	0.6	3.21	5.4	10

D1…D19 = Boreholes; W= Hand-dug well

Source: Field work (2020)

Table 3b: Mean Results of the Analyzed Bacteriological Concentration in Groundwater of Doma Local Government Area

S/N			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Sample Code			D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8 w	D_9 w	D_{10} w	D_{11} w	D_{12} w	D_{13}	D_{14}	D_{15}	D_{16} w	D_{17} w	D_{18} w	D_{19}	D_{20} W
Total Coliform	Media	NA Count	0	1	2	1	1	2	103	207	156	164	86	30	60	45	25	25	35	30	20	30
		MCC Count	0	1	1	0	0	4	152	102	301	170	75	40	70	50	30	40	60	40	30	35
E. Coli	Media (Emb)	Count	5	6	6	3	2	3	113	125	40	25	20	10	3	3	6	7	8	10	11	12

D1…D19 = Boreholes; W= Hand-dug well

Source: field work (2020)

Table 4: Mean Results of the Analyzed Hydro-geochemical Parameters of Keana Local Government Area

S/No	**Sample Code**	**Turbidity (mg/l)**	**TDS**	**Temp. (°C)**	**pH H_2O**	**EC (US/cm)**	**HCO_3^- (mg/l)**	**NO_3^- (mg/l)**	**SO_4^{3-} (mg/l)**	**CL^- (mg/l)**	**F (mg/l)**	**Ca^{2+} (mg/l)**	**Mg^{2+} (mg/l)**	**Na^+ (mg/l)**	**K^+ (mg/l)**
1	**K1**	1.00	10	34	7.3	30.00	1.76	145.06	48.73	0.00	1.64	2.755	6.766	224.10	0.30
2	**K2**	3.00	15	32	7.5	40.00	1.88	158.60	37.10	0.00	1.62	2.423	5.552	284.40	0.24
3	**K3**	0.00	20	37	7.1	40.30	0.94	68.00	20.59	0.00	1.24	2.944	6.139	100.10	0.36
4	**K4**	1.00	30	34	7.0	50.10	0.68	63.46	17.33	7.09	0.94	11.511	6.082	70.30	0.42
5	**K5**	0.00	25	39	7.6	45.20	0.78	95.20	17.10	7.09	0.96	8.256	6.439	64.00	0.24
6	**K6**	1.00	20	37	7.5	30.40	0.86	126.93	17.10	3.54	1.21	8.804	7.110	62.00	0.24
7	**K7**	0.00	10	34	7.7	30.00	1.18	131.46	18.03	3.54	1.42	8.228	7.545	74.24	0.24
8	**K8**	1.00	20	32	7.6	40.00	1.14	142.80	19.43	0.00	1.48	5.672	7.474	98.10	0.30
9	**K9**	1.00	10	32	7.1	30.00	1.06	74.80	17.56	0.00	1.54	19.532	7.710	186.30	0.67
10	**K10**	1.00	30	34	7.2	50.00	0.94	83.87	19.66	3.54	1.50	26.273	7.787	134.00	0.42
11	**K11**	1.00	40	37	7.7	80.00	1.24	120.13	14.31	7.09	1.21	2.322	7.563	70.14	0.24
12	**K12**	1.00	30	36	7.3	70.90	0.32	24.90	9.66	7.09	0.63	0.330	2.509	50.00	0.12

ISSN: 2456-8643

13	**K13 w**	9.00	10	33	5.2	30.80	0.06	5.67	8.49	14.18	0.22	0.042	0.000	5.80	0.06
14	**K14**	0.00	20	35	7.4	30.00	1.04	54.40	24.31	0.00	1.26	5.319	3.554	176.00	0.18
15	**K15**	1.00	40	40	8.0	80.00	1.10	131.47	35.94	3.54	1.44	0.375	0.136	278.00	018
16	**K16**	35.00	80	34	5.5	140.70	0.08	4.31	12.69	14.18	0.36	0.400	0.053	10.70	0.12
17	**K17 w**	1.00	50	34	6.5	90.00	0.36	185.87	32.68	7.09	1.66	41.252	6.974	128.00	1.39
18	**K18**	5.00	30	38	6.2	50.26	0.08	9.52	9.89	7.09	0.24	0.217	0.174	4.80	0.12
19	**K19**	1.00	70	34	5.3	150.00	0.08	9.52	9.42	21.27	0.25	0.065	0.116	6.20	0.12
20	**K20 w**	4.00	30	34	5.6	50.00	0.12	12.69	9.19	7.09	0.28	0.123	0.000	4.30	0.12

K1…K19 = Boreholes; W = Hand-dug well

Source: Field work (2020)

Table 4 (Continued)

S/No	Sample Code	Pb (mg/l)	Cr (mg/l)	Cd (mg/l)	As (mg/l)	Fe (mg/l)	Zn (mg/l)	Cu (mg/l)	Mn (mg/l)	CO_3^- (mg/l)	Total Hardness (mg/l)	Total Alkalinity (mg/l)	Total Acidity (mg/l)
1	**K1**	0.147	0.018	0.000	0.091	0.107	0.000	0.132	0.214	0.6	2.80	3.0	10
2	**K2**	0.222	0.035	0.000	0.051	0.100	0.000	0.094	0.211	0.3	3.21	3.4	10
3	**K3**	0.297	0.081	0.009	0.069	0.086	0.000	0.079	0.194	0.7	4.01	4.6	0
4	**K4**	0.386	0.103	0.016	0.101	0.132	0.000	0.198	0.087	0.6	3.21	3.7	0
5	**K5**	0.367	0.080	0.009	0.19	0.102	0.005	0.184	0.222	0.6	2.80	3.4	10
6	**K6**	0.265	0.107	0.014	0.063	0.039	0.017	0.156	0.179	0.4	3.21	3.6	0
7	**K7**	0.036	0.047	0.000	0.077	0.061	0.025	0.140	0.360	0.8	3.21	3.4	0
8	**K8**	0.000	0.108	0.000	0.074	0.007	0.045	0.078	0.085	0.1	5.61	5.4	10
9	**K9**	0.068	0.146	0.000	0.048	0.054	0.014	0.167	0.671	0.2	3.21	6.6	20
10	**K10**	0.100	0.128	0.007	0.019	0.062	0.024	0.183	1.160	0.3	4.01	3.4	10
11	**K11**	0.162	0.077	0.000	0.064	0.000	0.034	0.178	0.273	0.8	4.01	5.4	20
12	**K12**	0.170	0.170	0.006	0.083	0.043	0.015	0.205	0.330	0.6	3.21	6.6	10
13	**K13 w**	0.209	0.057	0.000	0.106	0.231	0.000	0.081	0.173	0.7	7.21	3.0	10
14	**K14**	0.260	0.006	0.000	0.142	0.033	0.000	0.067	0.122	0.6	3.21	3.4	0
15	**K15**	0.179	0.107	0.000	0.085	0.075	0.000	0.112	0.201	0.4	2.80	2.2	0
16	**K16**	0.073	0.070	0.000	0.033	0.064	0.094	0.434	1.329	0.3	12.02	2.0	0
17	**K17 w**	0.342	0.099	0.014	0.106	0.056	0.013	0.184	0.694	0.6	3.21	3.0	0
18	**K18**	0.118	0.065	0.000	0.071	0.042	0.044	0.262	0.270	0.8	3.21	3.4	10
19	**K19**	0.100	0.099	0.000	0.063	0.021	0.036	0.236	0.556	0.6	7.21	3.4	10
20	**K20 w**	0.012	0.132	0.000	0.012	0.039	0.048	0.351	0.714	0.7	6.41	5.1	10

K1…K19 = Boreholes; W = Hand-dug well Source: Field work (2020)

Table 4b: Mean Results of the Analyzed Bacteriological Concentration in Groundwater of Keana Local Government Area

S/N			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SAMPLE CODE			K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}	K_{11}	K_{12}	K_{13} w	K_{14}	K_{15}	K_{16}	K_{17} w	K_{18}	K_{19}	K_{20} w
TOTAL COLIFORM	MEDIA	NA COUNT	0	1	6	7	8	3	8	10	6	7	10	16	11	10	8	7	6	7	8	7
		MCC COUNT	2	4	12	16	13	6	9	15	18	14	21	20	12	13	6	13	25	16	11	8
E. COLI	MEDIA (EMB)	COUNT	2	4	5	2	3	4	7	8	10	2	3	8	6	10	12	10	6	4	2	6

K1…K19 = Boreholes; W = Hand-dug well Source: Field work (2020)

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Table 5: Mean Results of the Analyzed Hydro-geochemical Parameters of Obi Local Government Area.

S/No	Sample Code	Turbidity (mg/l)	TDS	Temp. (^{O}C)	pH H_2O	EC (US/cm)	HCO_3^- (mg/l)	NO_3^- (mg/l)	SO_4^{3-} (mg/l)	CL^- (mg/l)	F (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)
1	O1	0.00	10	35	7.7	30.00	2.74	362.60	13.80	0.00	0.29	0.543	0.776	615.00	0.73
2	O2	0.00	20	35	8.0	40.00	2.32	385.33	21.20	0.00	0.36	0.698	1.086	465.00	0.79
3	O3	0.00	40	34	8.3	71.30	0.50	22.44	8.60	7.09	0.12	4.585	3.065	14.20	0.24
4	O4	16.0	35	34	7.7	53.40	0.28	47.60	9.40	7.09	0.14	2.421	3.229	54.00	0.30
5	O5	0.00	10	34	8.6	30.00	1.00	56.67	17.40	0.00	0.26	12.081	6.417	138.00	0.48
6	O6	0.00	20	34	8.4	40.00	1.34	97.46	26.80	0.00	0.23	7.051	6.051	395.00	0.79
7	O7	0.00	10	36	8.8	34.00	0.24	14.51	7.80	0.00	0.18	1.022	1.035	7.90	0.24
8	O8	0.00	30	41	8.9	47.90	0.24	9.97	8.60	7.09	0.21	0.127	0.776	58.00	0.24
9	O9 w	14.00	10	33	8.2	31.00	0.26	16.09	7.80	7.09	0.15	19.675	6.431	12.50	1.15
10	O10	2.00	20	33	8.6	47.00	0.34	27.20	10.00	0.00	0.23	1.007	2.932	2.00	1.03
11	O11	1.00	15	36	9.0	20.93	0.14	9.52	9.60	0.00	0.24	0.000	0.000	3.40	0.30
12	O12	0.00	10	34	8.4	24.20	0.22	21.99	7.20	0.00	0.17	1.830	2.161	10.80	0.61
13	O13 w	4.00	10	33	6.6	25.00	0.14	29.47	9.40	0.00	0.19	4.707	5.392	3.10	0.79
14	O14 w	10.00	30	34	8.5	60.70	0.20	40.80	8.20	7.09	0.15	11.084	3.505	54.00	1.33
15	O15	2.00	40	36	8.5	81.20	0.26	16.55	8.40	14.18	0.19	0.000	2.250	4.50	0.61
16	O16 w	10.00	30	33	8.2	60.30	0.00	4.76	8.40	7.09	0.09	0.176	0.116	5.50	0.30
17	O17	1.00	10	34	7.6	20.31	0.10	3.17	7.00	0.00	0.07	0.016	0.000	2.80	0.30
18	O18 w	6.00	10	33	8.4	19.87	0.06	16.32	8.20	0.00	0.27	0.276	0.658	3.90	0.48
19	O19 w	48.00	60	37	7.1	109.65	0.06	6.80	8.80	14.18	0.18	1.159	0.000	3.70	0.24
20	O20	0.00	30	41	7.0	55.70	0.06	15.19	8.40	7.09	0.12	0.240	0.000	1.80	0.12

O1…O20 = Boreholes; W = Hand-dug well

Source: Field work (2020)

Table 5 (continued)..

S/No	Sample Code	Pb (mg/l)	Cr (mg/l)	Cd (mg/l)	As (mg/l)	Fe (mg/l)	Zn (mg/l)	Cu (mg/l)	Mn (mg/l)	CO_3^- (mg/l)	Total Hardness (mg/l)	Total Alkalinity (mg/l)	Total Acidity (mg/l)
1	O1	0.018	0.134	0.000	0.015	0.045	0.004	0.186	1.523	0.6	2.80	4.6	0
2	O2	0.142	0.204	0.000	0.036	0.062	0.000	0.141	1.804	0.4	3.21	3.0	0
3	O3	0.218	0.111	0.000	0.074	0.045	0.005	0.153	0.878	0.3	3.21	4.6	10
4	O4	0.185	0.135	0.000	0.066	0.034	0.047	0.160	2.136	0.11	4.01	3.4	10
5	O5	0.315	0.201	0.000	0.122	0.028	0.000	0.171	2.327	0.4	4.01	2.0	20
6	O6	0.237	0.131	0.000	0.072	0.054	0.008	0.098	2.188	0.6	2.80	2.4	10
7	O7	0.043	0.125	0.000	0.018	0.052	0.075	0.159	4.554	0.3	3.21	3.4	0
8	O8	0.225	0.074	0.000	0.052	0.103	0.026	0.183	5.010	0.6	3.21	3.0	0
9	O9 w	0.115	0.118	0.000	0.064	0.087	0.124	0.375	2.206	0.4	2.80	3.0	0
10	O10	0.052	0.242	0.000	0.047	0.098	0.006	0.076	1.341	0.1	2.80	6.6	10
11	O11	0.119	0.085	0.000	0.069	0.000	0.027	0.103	1.261	0.1	4.01	3.0	10
12	O12	0.000	0.168	0.000	0.024	0.000	0.000	0.114	1.471	0.1	3.21	2.0	0
13	O13 w	0.000	0.195	0.000	0.011	0.035	0.035	0.275	1.902	0.02	6.41	2.2	0
14	O14 w	0.000	0.173	0.000	0.000	0.023	0.027	0.272	0.466	0.3	3.21	0	0
15	O15	0.072	0.175	0.000	0.031	0.026	0.000	0.208	0.822	0.4	2.80	0	0

16	O16 w	0.023	0.063	0.000	0.024	0.097	0.000	0.238	1.644	0.3	4.01	0	10
17	O17	0.000	0.128	0.000	0.012	0.000	0.016	0.451	1.358	0.1	4.01	2.2	0
18	O18 w	0.000	0.087	0.000	0.000	0.132	0.000	0.151	0.622	0.1	3.21	2.4	10
19	O19 w	0.000	0.114	0.000	0.000	0.005	0.008	0.177	0.840	0.4	3.21	3.0	0
20	O20	0.029	0.073	0.000	0.009	0.000	0.002	0.196	0.832	0.3	4.01	3.0	0

O1…O20 = Borehole; w = Hand dug well

Table 5b: Results of the analyzed Bacteriological concentration in groundwater of Obi Local Government Area.

S/NO.			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sample Code			O_1	O_2	O_3	O_4	O_5	O_6	O_7	O_8	O_9 w	O_{10}	O_{11}	O_{12}	O_{13} w	O_{14} W	O_{15}	O_{16} w	O_{17}	O_{18} w	O_{19} w	O_{20}
Total Coliform	Media	NA Count	7	5	8	6	8	10	6	11	12	6	11	6	5	8	6	7	8	11	7	8
		MCC Count	6	6	6	3	2	3	1	1	2	3	2	3	1	2	3	1	3	4	3	2
E. Coli	Media (EMB)	Count	6	2	8	9	10	2	6	8	9	2	3	6	7	8	3	4	5	6	7	3

O1…O20 = Borehole; W = Hand dug wells Source: Field work (2020)

Table 6: Mean Results of the Analyzed Hydro-geochemical Parameters of Lafia Local Government Area

S/No	Sample Code	Turbidity (mg/l)	TDS	Temp. (^oC)	pH H_2O	EC (µ/cm)	HCO_3^- (mg/l)	NO_3^- (mg/l)	SO_4^{3-} (mg/l)	CL^- (mg/l)	F (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)
1	L1	1.00	50	34	6.7	105.20	0.10	34.0	8.93	7.09	0.17	9.786	4.263	16.50	1.64
2	L2	1.00	15	35	6.5	30.20	0.08	13.6	7.42	7.09	0.23	1.251	0.641	6.80	0.67
3	L3	1.00	80	35	5.0	115.60	0.16	54.40	7.42	14.18	0.26	14.995	4.379	83.60	1.39
4	L4	2.00	10	34	6.5	32.20	0.22	11.11	6.86	7.09	0.20	0.335	0.171	9.50	0.42
5	L5	2.00	10	35	5.8	33.71	0.06	1.81	7.42	21.27	0.24	0.000	0.000	0.60	0.06
6	L6	1.00	10	34	5.5	17.31	0.08	3.85	7.42	21.27	0.26	0.120	0.000	3.10	0.06
7	L7	1.00	20	33	7.1	45.45	0.06	4.31	7.23	14.18	0.13	0.277	0.000	2.50	0.06
8	L8	1.00	20	34	5.8	37.00	0.18	11.79	6.48	7.09	0.10	2.433	1.292	5.30	0.61
9	L9	13.00	30	34	6.4	76.80	0.08	31.73	7.23	14.18	0.26	2.009	4.798	12.20	1.58
10	L10 w	10.00	25	34	6.5	67.10	0.08	15.19	6.10	7.09	0.18	1.957	4.246	44.00	0.85
11	L11	0.00	70	35	4.9	140.30	0.06	27.20	8.93	28.36	0.12	8.376	4.793	70.00	4.06
12	L12	1.00	30	34	5.0	61.00	0.06	12.69	7.04	35.45	0.10	2.825	2.455	54.00	1.64
13	L13	1.00	35	36	4.7	70.50	0.06	14.51	7.23	28.36	0.04	4.233	2.901	46.00	1.70
14	L14	1.00	20	36	5.7	46.90	0.06	15.87	7.80	21.27	0.06	2.305	2.023	15.50	0.73
15	L15	0.00	30	36	6.2	60.40	0.08	13.37	7.80	7.09	0.15	3.532	2.608	56.00	1.70
16	L16	0.00	50	40	5.1	107.80	0.06	24.93	7.99	7.09	0.17	6.808	4.953	70.00	2.00
17	L17	1.00	20	37	4.9	41.61	0.06	6.35	7.42	14.18	0.15	0.409	0.025	4.50	0.18
18	L18	0.00	40	37	5.8	80.30	0.10	13.60	7.42	7.09	0.12	0.775	0.480	5.90	0.42
19	L19	1.00	140	35	6.4	263.00	0.20	81.60	7.61	14.18	0.18	29.558	6.445	5.60	4.61
20	L20	0.00	50	36	6.5	86.05	0.16	21.76	6.86	7.09	0.17	0.198	0.000	98.00	0.18

Table 6 (Continued)

S/No	Sample Code	Pb (mg/l)	Cr (mg/l)	Cd (mg/l)	As (mg/l)	Fe (mg/l)	Zn (mg/l)	Cu (mg/l)	Mn (mg/l)	CO_3^- (mg/l)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Total Acidity (mg/l)
1	L1	0.000	0.072	0.000	0.014	0.000	0.028	0.208	0.019	0.6	2.80	3.0	20
2	L2	0.000	0.116	0.000	0.021	0.053	0.039	0.238	0.065	0.5	2.80	5.4	10
3	L3	0.000	0.118	0.000	0.036	0.000	0.000	0.460	0.104	0.5	3.21	11.4	20
4	L4	0.058	0.098	0.000	0.064	0.030	0.000	0.350	0.105	0.6	2.80	3.4	10
5	L5	0.000	0.003	0.000	0.000	0.041	0.000	0.228	0.097	0.8	2.80	6.6	20
6	L6	0.097	0.052	0.000	0.047	0.032	0.051	0.159	0.116	0.3	3.21	6.8	10
7	L7	0.091	0.043	0.000	0.046	0.070	0.022	0.176	0.145	0.4	2.80	3.0	0
8	L8	0.257	0.043	0.000	0.079	0.045	0.025	0.166	0.207	0.6	4.81	6.6	0
9	L9	0.262	0.124	0.000	0.066	0.094	0.025	0.244	0.199	0.7	4.81	3.0	10
10	L10 w	0.210	0.076	0.000	0.073	0.080	0.038	0.274	0.331	0.8	3.21	3.4	20
11	L11	0.233	0.068	0.000	0.077	0.011	0.033	0.138	0.087	0.2	3.21	4.6	10
12	L12	0.115	0.087	0.000	0.048	0.033	0.032	0.273	0.371	0.2	4.81	4.6	10
13	L13	0.236	0.075	0.000	0.054	0.035	0.041	0.323	0.388	0.3	7.21	12.0	40
14	L14	0.085	0.076	0.000	0.079	0.053	0.015	0.195	0.122	0.4	3.21	5.4	20
15	L15	0.663	0.128	0.000	0.148	0.070	0.020	0.236	0.169	0.5	2.80	3.0	10
16	L16	0.170	0.000	0.000	0.126	0.030	0.009	0.122	0.136	0.6	7.21	3.4	40
17	L17	0.286	0.055	0.000	0.131	0.034	0.000	0.101	0.091	0.3	12.02	18.0	60
18	L18	0.128	0.011	0.000	0.039	0.010	0.000	0.096	0.084	0.6	5.61	6.6	10
19	L19	0.061	0.075	0.000	0.035	0.036	0.000	0.078	0.070	0.5	4.01	6.8	20
20	L20	0.081	0.026	0.000	0.028	0.027	0.014	0.138	0.122	0.6	3.21	3.4	30

Table 6b: Mean Results of the Analyzed Bacteriological Concentration in Groundwater of Lafia Local Government Area

S/NO.			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sample Code			L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10} w	L_{11}	L_{12}	L_{13}	L_{14}	L_{15}	L_{16}	L_{17}	L_{18}	L_{19}	L_{20}
Total Coliform	Media	NA Count	0	1	0	1	0	0	0	0	1	1	1	2	0	2	0	2	1	0	2	3
		MCC Count	0	0	1	2	3	1	2	3	2	1	2	1	1	0	0	0	2	0	4	3
E. Coli	Media (EMB)	Count	1	1	0	0	1	1	0	0	0	0	0	1	1	1	1	1	2	1	1	0

L10 w = Hand-dug well; L1…L20 = Boreholes

Source: Field work (2020)

4. DISCUSSION OF THE GROUNDWATER ANALYSIS

The results of physicochemical, heavy metals and bacteriological content in the groundwater samples as presented in Tables 2 - 6, are compared with both World Health organization, WHO (2017) and Nigerian Standard for Drinking Water Quality, NSDWQ (2015), Standard Organization of Nigeria (SON 2015).

4.1 Physical Parameters

The groundwater mean values of pH from the 5 study sites ranged from 6.9 to 8.6. This indicates that groundwater in the area is slightly acidic to alkaline in nature. Turbidity ranged from 0.00 at site A1 to 33 NTU in site A20. However, variation above the recommended limit was found at sites A8, A18 and A20. Hardness ranges from 2.80 to 6.41 mg/L which is very low compared to WHO (2017) maximum permitted levels of 500. The electrical conductivity (EC) is a good measure of salinity hazard to crops. Excess salinity reduces the osmotic activity of plant and thus interferes with the absorption of water and nutrients from the soil (Ref). The EC values from the study sites ranged from 25 to 120 µS/cm, which when compared with standards, are safe for consumption. The values of TDS from the water samples range from 10 to 70mg/l, all the values are less than 1000 mg/l, hence are within the non-saline class (Ref). The water samples from the study area can be utilized on all agricultural soils.

4.2 Chemical Parameters

Major Cations: The major cations analyzed in the water samples from the areas of study include sodium, potassium, calcium, magnesium, copper, zinc and iron. Sodium (Na^+) has a mean concentration that ranged from 36.288 to 130.00 mg/l. This falls within the permissible limit according to SON (2015), NSDWQ (2015). Potassium (K^+) has mean concentrations varying from 11.52 mg/l to 31.45 mg/l . Calcium (Ca^{2+}) from 2.972 to 28.651 mg/l, both are within the permissible limit (WHO, 2017). Magnesium (Mg^{2+}) mean concentrations range from 2.862 to 6.791 mg/l which is above permissible limit of SON (2015 and NSDWQ (2015). Copper (Cu) has concentrations range from 0.028- 0.344 mg/l which is within the permissible limit. Zinc (Zn) concentrations ranged from 0.050 - 0.246 mg/l, which is within the permissible limit according to WHO (2017), NSDWQ (2015). Iron (Fe^{2+}) mean concentration ranged from 1.998 to 7.502 mg/l, which are above permissible limit, therefore, not suitable for drinking (WHO, 2017).

major anions, Nitrate (NO_3) mean concentration ranged from 3.17 to 65.06mg/l, this is slightly above the permissible limit as stipulated by NSDWQ (2015). and must be treated before consumption to avoid Cyanosis overtime. (NSDWQ, 2015) when use for drinking. Sulphate (SO_4^{2-}) concentrations ranged from 0.00 to 0.009 mg/l, which is within the permissible limit and suitable for drinking (NSDWQ, 2015).

Heavy Metals: Cadmium (Cd) mean concentrations ranged from - 0.414 to 0.152mg/l. Some boreholes are free of Cadmium (Cd), but some part of Awe has Cadmium slightly above the NSDWQ, 2015). permissible limit. When consumed for a longer time, it accumulates in body system and may lead to cancerous effect (Lena *et al.,* 2014). Lead (Pb) has a mean concentration ranged from 0.090 to 0.440 mg/l which is above the permissible limit of (WHO, 2017) and (NSDWQ, 2015) in Awe and its environment see Table 2. In Doma lead (Pb) mean concentration ranged from 0.006 to 0.566 mg/l which is above the permissible limit of (WHO, 2017) and (NSDWQ, 2015) see Table 3. In keana Local government area, have lead (Pb) mean concentration ranged from 0.073 to 0.386 mg/l above the permissible limit, however, two wells K8 is free from lead and K20w has Pb within the permissible limit of (WHO, 2017) and (NSDWQ, 2015) see Table 4. Obi Local government area have a relative low concentration of Pb ranged from 0.00 to 0.315 mg/l for only a few wells above the permissible limit see Table 5. In Lafia Local government area have Pb mean concentration ranged from 0.00 to 0.663 mg/l see Table 6. However, health impact of Pb includes Cancer, interference with Vitamin D metabolism, affects mental development in infants, toxic to the central and peripheral nervous systems (Sharma *et al.*, 2014**)**. Awe Local Government area have Manganese (Mn) mean concentrations ranged from 0.272 to 4.312mg/l , see Table 2, Doma Local government area have Mn mean concentrations ranged from 0.801 to 7.676 mg/l, see Table 3, Keana local government area have Mn mean concentrations ranged from 0.087 to 1.329 mg/l, see Table 4, Obi Local government area have mean concentrations ranged from 0.466 to 5.910mg/l, see Table 5 and Lafia local government area have Mn mean concentrations ranged from 0..070 to 0.388 mg/l, see Table 6. The health impact of drinking water containing Manganese (Mn) above 0.2mg/l and relatively high doses of manganese affect DNA replication and causes mutations in microorganism and mammalian cells (Lena *et al.*, 2014). In mammalian cells, manganese causes DNA damage and chromosome aberrations. Large amounts of manganese also affect fertility in mammals and are toxic to the embryo and foetus (Lena *et al.*, 2014). Arsenic mean concentration ranged from 0.007 to 0.107mg/l which is slightly above WHO, 2017 standard in some boreholes. The health impact of drinking water containing Arsenic above 0.01mg/l includes dermal disease, cardiovascular disease, skin cancer, bladder cancer, diabetes mellitus and damage to genetic information in genotoxicity which ultimately leads to mutation (Lena *et al.*, 2014**)**.

Fluoride mean concentration ranged from 0.13 to 0.22 mg/l which is within the recommended limit of WHO (2017) and NSDWQ (2015).

Bacteriological analysis: Reveals that coliform count ranged from 0 to 4 and E. Coli from 0 to 2Cfu which is below the recommended limit of NSDWQ (2015). But WHO (2017) recommend 0 tolerant. According to NSDWQ (2015), any water with Total Coliform count above 10Cfu/ml and 1Cfu/100ml is considered a bacteriological contaminated water. Bacteriological contaminated groundwater is associated with water borne diseases such as viral hepatitis, schistosomiasis and cholera (Ishaku *et al* 2015). The quality of groundwater in some section of the study area is bacteriologically contaminated and therefore unfit for human consumption. Pockets of areas containing less than 10 coliform counts occur in Awe, Obi and Lafia local government areas, others must properly for there fitness for drinking purposes.

5. CONCLUSION

Chemical analysis of groundwater from hand-dug wells and boreholes in the study area reveals concentrations of Lead, Arsenic, and Manganese are above the WHO Drinking Water Standards. This situation is cause by the geology of the area, due to the natural occurrence of barite and lead/zinc mineralization in the affected study areas like Keana/Awgu formations in the Middle Benue Trough. The use of such waters for drinking for long-term consumption may have serious health problems. There is need for adequate treatment of the water regularly. However, the water is suitable for both industrial and irrigation purposes with minimal concern.

As a remedy, scientists need to adopt and apply geophysical and geoinformatics techniques, geographical information systems (GIS) and remote sensing technologies to study groundwater contamination due to natural geogenic leaching from rocks and soils and contributions from anthropogenic sources, mainly from agricultural activities and processing plants.

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