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Physicochemical Assessment of Ground Water Quality from Borehole and Hand Dug Wells around Obajana Community, Lokoja, Kogi State, Nigeria

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ABSTRACT: The groundwater qualities of Obajana in Kogi State were determined. The study consisted of the determination of some heavy metals and physicochemical properties of drinking water samples. The samples were analyzed for the following parameters iron, copper, manganese, zinc, lead,using AAS Varian AA240FS. Nitrates, sulphate, phosphate, colour, dissolved solids, electrical conductivity, pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), temperature, turbidity, total hardness and total alkalinity using standard method. The data showed the variation of the investigated parameters in samples as follows: temperature 26-30^oC, pH 5.53-7.89, electrical conductivity (EC) 6.210-339.670 µS/cm, total hardness 50.00- 424.20 mg/l, alkalinity 1.10-145.67mg/l, turbidity 0.00-34 FTU, colour 5-15TCU, phosphate 0.02-0.760 mg/l, nitrate 10.24-48.20mg/l, sulphate 24.70-222.13mg/l, dissolved oxygen 0.2-1.8 mg/l, BOD 0.2-1.0mg/l, COD 1.1-3.2mg/l, Cu 0.00.1-0.10mg/l , Fe 0.01-0.060mg/l, Zn 0.029-5.046mg/l, Mn 0.0-0.44mg/l and Pb 0.0348-1.046mg/l. The concentrations of some of the investigated parameters in the drinking water samples from the research region were above the permissible limits of the World Health Organization standard for drinking water quality guidelines. lead was found to exceed 0.01mg/l which is the WHO maximum limit, also zinc and manganese were found to exceed the WHO maximum limit of 3.0mg/l and 0.1mg/l.

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Water is important to take care of and sustain human life, animals and plants (Patil and Patil, 2010), this is often because it constitutes to an outsized extent, the foremost solvent within which many of the body's proteins and other substances are dissolved. It enables many metabolic activities of the body to require place (Ezeribe *et al.,* 2012). Water is crucial for growing food, for domestic uses and as a critical consider industries, tourism and cultural purpose because it helps in sustaining the earth's ecosystem (Mark *et al.,* 2002). Groundwater is of major importance and is intensively exploited for personal, domestic and industrial uses. in line with Ajibade *et al.,* 2011, 90% of the population in Nigeria depends largely readily available dug wells and boreholes. ascension in urban populations, industrial activities, commercial and agricultural developments end in increase within the search of potable water. The preference of groundwater as a source of beverage in rural areas is thanks to its relatively better quality than river water. Pollution of groundwater is an impairment of water quality by chemicals, heat or bacteria to a degree that doesn't necessarily create public health hazards but does adversely affect such water for domestic, farm, municipal or industrial use (Ajibade *et al.,* 2011). Water related diseases are liable for 80% of all illness or death within the developing countries and kill over 5 million people per annum (Roy, 1999).

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The employment of groundwater as a source of potable facility is increasing worldwide, although it will be contaminated because of pollution (UNESCO, 2007). Dust emissions from the factory haven't only affected the environment, but the water from open-wells has visibly suffered surface contaminations from cement dust deposition These wells are the main source of drink and other domestic chores for inhabitants of the realm surrounding the cement factory. this could elicit a priority since the water quality may experience undesirable changes as the result of cement dust intrusion. the standard of water influences the health status of any populace, hence, analysis of water for physical, biological and chemical properties including chemical element contents are important for public health studies (Akhilesh *et al.,* 2009). Furthermore, (Weiss, 1974) had indicated that cement dust is capable of changing salt content of water leading to serious disruption of aquatic communities and also decrease quality of water used for drinking. Thus, the present situation of the wells within the vicinity of the cement factory necessitate a study aimed at evaluating the health risk of the people that depends on water from hand dug wells for drinking and other domestic usage the assembly of cement is increasing by about 3% annually (Ogbonna *et al.,* 2006)and contribution of cement production worldwide to the greenhouse emission emission is estimated to be about 7% of the entire greenhouse emission emissions to the earth’s atmosphere (Obiri-Danso *et al.,* 2009). Calcinations process of cement is heat dependent and contributes to rising global temperature (Chinedu *et al.,* 2011). the target of this present work is to work out the physio-chemical parameters of water within the Obajana immediate community, compare the parameter with WHO standards and established a baseline for future studies.

MATERIALS AND METHOD

Study Area: The cement factory which was founded in 1992, is located on latitude 7°55'0" N and longitude 6°26'0"E has a community located next to the site of the cement plant and truck parking garage in which three communities are surrounding the cement factory. The inhabitants in the area and surroundings obtained their water from hand-dug wells, very few boreholes and the semi-perennial Onyi River system. Obajana lies within the sub-humid tropical zone, and has a mean annual rainfall that range from 1100 to 1320mm (Musa *et al.,* 2013).

Sample Sites: The town was categorized into two suburbs based on the main road network in the town, Obajana 1 and Obajana 2 communities, respectively. Eight (8) boreholes and twelve (12) wells were selected from Obajana community; 6 wells, 4 boreholes from the each of the two suburbs for sampling, which gave a total of twenty sample sites as shown in table 1:

Table 1: Sampling locations and coordinates for sampling sites 1 and 2

S/No	GW Type	Site 1	Coordinates	GW Type	Site 2	Coordinates
1	HW	Obj 1	$6^0$25’37.2”N $7^0$55’19.2”E	HW	Obj 11	$6^0$26’06.0”N $7^0$55’12.0”E
2	HW	Obj 2	$6^0$25’40.8”N $7^0$55’36.6”E	HW	Obj 12	$6^0$25’48.0”N $7^0$54’54.0”E
3	HW	Obj 3	$6^0$25’40.8”N $7^0$55’26.4”E	HW	Obj 13	$6^0$25’55.2”N $7^0$55’04.8”E
4	HW	Obj 4	$6^0$25’40.8”N $7^0$55’19.2”E	HW	Obj 14	$6^0$26’06.0”N $7^0$55’12.0”E
5	HW	Obj 5	$6^0$25’30.0”N $7^0$55’19.2”E	HW	Obj 15	$6^0$26’16.8”N $7^0$55’19.2”E
6	HW	Obj 6	$6^0$25’33.6”N $7^0$55’15.6”E	HW	Obj 16	$6^0$26’09.6”N $7^0$55’19.2”E
7	BH	Obj 7	$6^0$26’06.0”N $7^0$55’12.0”E	BH	Obj 17	$6^0$26’06.0”N $7^0$55’12.0”E
8	BH	Obj 8	$6^0$25’26.4”N $7^0$55’22.8”E	BH	Obj 18	$6^0$26’13.2”N $7^0$55’15.6”E
9	BH	Obj 9	$6^0$26’09.6”N $7^0$55’19.2”E	BH	Obj 19	$6^0$26’02.4”N $7^0$55’12.0”E
10	BH	Obj 10	$6^0$25’30.0”N $7^0$55’12.0”E	BH	Obj 20	$6^0$25’48.0”N $7^0$55’44.4”E

**Key BH = Borehole, HW = Hand dug well*

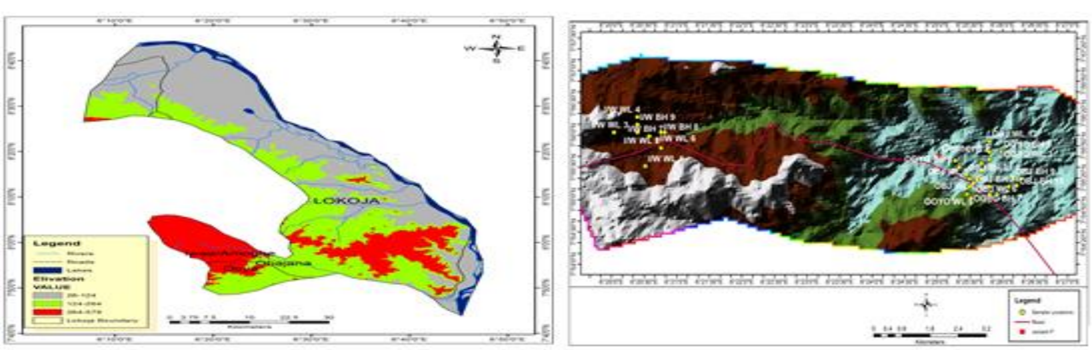

Fig 1 (a) and Map of Lokoja showing Obajana and surrounding communities Source: Adapted and modified from the google map of Kogi State and SRTM image, 2013 obtained in August, 2013. Fig. 1(b) Map of Obajana and its environs showing cement factory and sample locations Source: Adapted and modified from the google map of Kogi state and SRTM image obtained in August, 2013

Sample collection: Groundwater samples were collected according to standard procedures by (Malhota, 2002). They were obtained directly from the water pump after allowing the water to run for at least five minutes and each sample bottle and its cap rinsed three times with the water sample. These samples were subsequently stored at 4°C for as short a time as possible before analysis to minimize physicochemical changes. Parameters with extremely low stability such as pH, electrical conductivity, turbidity and temperature, were measured immediately.

Physicochemical analysis: The temperature of the water samples resolve in-situ using mercury in glass thermometer (Sheppard and Socolow, 2007). The pH of the water samples decided employing a portable pH meter after being standardized with buffers of pH 4.0 and pH 9.2 (Mehta and Burrows 2001). the color determined by visual comparism using Lovibond colour disc (Pt-Co), during which the disc consists of various colours which is graduated. Conductivity of the surface water and also the underground water samples made up our minds using the quality procedure approved by AOAC (Giddings *et al.,* 2000). The conductivity meter (Hach model CO150) was used. A nephelometer was employed in determining turbidity of the samples. Total hardness resolve by EDTA titration using Eriochrome black T indicator as described by (EC, 2001). The chemical Oxygen Demand (COD) of the surface water and also the underground water samples determined using the quality method described by (Mehta and Burrows, 2001). The azide modification of the Winkler’s method was accustomed determine DO and BOD. 100cm3 of water sample was quantitatively transferred into an evaporating dish that has been previously weighed and dried in an oven for one hour and cooled in desiccators. The content of the dish was evaporated to dryness on a water-bath to a continuing weight. The residue was dried in an oven between 103-105oC for 2 hours, cooled in an exceedingly desiccator and also the difference in weight calculated which was expressed because the Total dissolved solid (WHO, 2003). The HANNA multi parameter logging spectrophotometer (HI83200) was accustomed digitally determine the nitrate, phosphate and sulphate within the surface water and well water samples. Total alkalinity made up our minds by transferring (100ml) of water sample into a conical flask, two drops of phenolphthalein indicator was added and therefore the solution titrated with

H_2SO_4 to the tip point. Again, two drops of acid-base indicator were added to the titrated mixture and titration was continued to azo dye end point, (WHO, 2003, APHA/SMWW, 1998).

Heavy metals analysis: The water was immediately digested after sampling to forestall changes in composition of water samples per standard procedures .The water sample bottles were shaken thoroughly in their plastic containers by use of hand. A volume of 100 mL of the sample was measured employing a 100 mL measuring cylinder and put during a beaker and 5 mL of concentrated aqua fortis was then added. The mixture was heated slowly on a hot plate and evaporated to about 20 mL ensuring that the water doesn't boil. an extra 5 mL of concentrated aqua fortis was added and therefore the beaker was covered with a watch glass while heating continued. aqua fortis continued to be added until the answer appears light coloured and clear. the answer was filtered and therefore the filtrate was transferred to a 100 mL volumetric flask to chill and therefore the filtrate was made up to the mark with H_2O and brought for analysis (Radojavic and Bashkin, 2006). The analysis of 5 heavy metals namely: Copper (Cu), Manganese (Mn), Iron (Fe), Lead (Pb) and Zinc (Zn) were dispensed base on ASTM standard, which are approved by APHA (1998).

RESULT AND DISCUSSION

Physicochemical analysis: pH: The pH results of the samples obtained ranges between 5.53 to 7.89 pH units. With the exception of Obajana 1, 2, 3 and 4 from site 1 and Obajana 5, 6 from site 2 which are slightly acidic. All other samples fell within the WHO range for portable water. The pH values lower than 6.5 are considered to be acidic for human consumption and can cause health problems such as acidosis which could have adverse effects on the digestive and lymphatic systems of human (Jankovic, *et al.,* 2010).

Temperature: Water temperature recorded during the sampling period for the various sites did not differ significantly. Temperatures ranges between 26ºC to 33ºC. With the exception of Obajana 2 in site 1, Obajana 5 in site 2 which are slightly higher compare to the other sites. The temperature values are within WHO (Kano *et al.,* 2000) limit for drinking water.

Conductivity and Dissolved Solids: Conductivity of the water samples ranged from 6.210 – 339.670 µS/cm. All the other values are within the WHO regulatory limit of 8-10,000 µS/cm. Conductivity is related to the concentration of dissolved solids (DS), according to Chapman (1992), TDS may be obtained by multiplying the conductivity by a factor between the ranges of 0.55 to 0.75. Given these low conductivity values, it is not surprising that the DS, which is an index of the number of dissolved solids in water is low. Thus, the DS which ranged between 2.400 to 161.200 mg/L was obtained for the study.

According to the study statistics, the DS is directly an average multiplication factor of 0.5 of the conductivity values measured across all the sampling points investigated. A health-based value has not been proposed by the WHO, however, a DS above 1,000 mg/L may be objectionable to consumers (Kano *et al.,* 2000).

Turbidity: Turbidity values ranged from 0 to 34.0 FTU. The One-way ANOVA test showed that Turbidity level in the four sites significantly differs as its confident level is less than 0.005. Four borehole samples and six well samples showed turbidities between 6.0 and 34.0 FTU from sites 1, 3 and 4. All other samples had their turbidity values between 5.0 FTU. The WHO guideline for turbidity in drinking water is 5 FTU. The high turbidity may be attributed to larger particles such as organic matter and dissolved solids. The greater the turbidity, the higher the risk of gastro-intestinal diseases (APHA/AWWA, 1996).

Total Hardness: The minimum and maximum values for total hardness obtained from the hand dug wells and boreholes water samples at the two different sampling sites in Obajana as shown in Tables 2-3 were 50 – 424.20mg/L which is below the WHO (500 mg/l) permissible limits for drinking water WHO (WHO, 2003).

Colour: The minimum and maximum values for colour obtained from the hand dug wells and boreholes water samples at the two different sampling sites in Obajana as shown in Tables 2-3 were 5 – 15 TCU which is higher than the WHO (3–15TCU) permissible limits for drinking.

Total alkalinity: The minimum and maximum values for alkalinity obtained from the hand dug wells and boreholes water samples at the two different sampling sites as shown in Tables 1-2 ranges from (1.1 – 145.670mg/l). All samples from the two sites were found below the maximum permissible limit of WHO (150 mg/l). This agrees with the findings of (Pasikatan *et al.,* 2001).

Ions and Nutrients: The WHO recommends that values of sulphur higher than 250mg/l should be reported to "the health authorities" due to the problems of gastro-intestinal track (WHO, 2003). However, these high levels of ions and nutrients in water could be traced to the natural or industrial activities. The concentration of sulphate in the subject samples ranged from 24.790 mg/L to a high of 222.130 mg/L which is within WHO limit. The One way ANOVA test showed that nitrates level in the two sites significantly differs as its confident level is less than 0.005. Nitrates levels varied between 10.24 to 48.24 mg/L. these concentration levels are not alarming and therefore the wells were free from organic pollution. The minimum and maximum values for phosphate obtained from the hand dug wells and boreholes water samples at the two different sampling sites in Obajana as shown in Tables 2-3 ranges from 0.02 to 0.760 mg/L. All samples from the two sites were found below the maximum permissible limit by WHO (6.5mg/L). The observation is also in agreement with the findings of other workers in similar studies (Pasikatan *et al.,* 2001).

Table 2: Mean values of physicochemical parameters for wells and borehole water samples compared with WHO standard for Site 1.

Parameter	WHO	OBJ 1	OBJ 2	OBJ 3	OBJ 4	OBJ 5	OBJ 6	OBJ 7	OBJ 8	OBJ 9	OBJ 10
Temp.(ºC)	30.0	30.0	31.0*	30.000	28.0	27.0	26.0	29.0	29.0	30.0	29.0
pH	6.5-9.5	5.65	6.28	6.37	6.50	6.77	7.20	7.40	7.55	7.05	7.60
E.Cond (µS/cm)	8-10,000	52.53	75.30	97.53	106.0	112.30	185.0	129.8	129.8	155.4	219.0
Turb (FTU)	5.0	34.0*	28.0*	0.000	2.0	5.0	3.0	5.0	4.0	1.00	3.0
Alkalinity(mg/l)	150.0	34.0	26.0	14.0	44.0	68.0	83.0	35.0	29.0	24.0	145.67
T.Hard (mg/l)	500.0	50.0	80.500	202.000	206.000	212.000	260.000	212.000	181.800	242.400	333.3
D.O (mg/l)	5.0	1.20	1.400	1.500	1.500	1.500	1.400	0.900	0.200	0.500	0.300
C.O.D (mg/l)	10.0	2.20	1.600	1.800	1.850	1.900	1.500	2.100	1.500	2.300	3.100
B.O.D (mg/l)	3.0	0.70	0.800	0.900	0.600	0.200	0.400	0.900	0.200	0.500	0.300
Sulphate mg/l)	250.0	21.80	42.030	73.470	128.710	100.200	151.700	59.120	86.680	150.300	130.60
D.S (mg/l)	500.0	24.400	30.200	45.800	50.500	53.100	80.500	61.300	61.400	73.700	104.73
Nitrate(mg/l)	50.0	24.240	48.240	27.030	23.020	20.950	18.020	21.070	15.560	13.387	10.240
Colour (TCU)	3-15	5.000	5.000	5.000	5.000	5.000	10.000	5.000	10.000	5.000	5.000
phosphate (mg/l)	6.5	0.320	0.280	0.220	0.320	0.420	0.350	0.250	0.300	0.580	0.720

Dissolved Oxygen, Chemical Oxygen Demand and Biological Oxygen Demand: Dissolved oxygen (DO) measured in milligram/litre ranged between 0.20 and 1.800. The WHO has set a provisional health-based guideline value of 5.0 mg/L for DO which should be adequate to protect public health (EIA, 2004). The measured value was; however, lower than the WHO's standard. Very low DO may result in anaerobic conditions that can cause foul odour in water. Chemical oxygen demand (COD) is one of water quality parameters in determining the oxygen consuming potential of a water resource. COD measured for the water samples ranged from 1.1 to 3.2mg/l. All samples from the two sites were found below the maximum permissible limit by WHO (10 mg/l). Most applications of COD determine the amount of organic pollutants found in surface water, making COD a useful measure of water quality (Morrel, 2006). Biological oxygen demand: The minimum and maximum values for biological oxygen demand obtained from the hand dug wells and boreholes water samples at the two different sampling sites in Obajana and its environs as shown in Tables 2-3 ranges from (0.2-1.0mg/l). Which were found to be below the maximum permissible limit by WHO (3 mg/l). The BOD represents the amount of oxygen needed by microbes to stabilize biologically oxidizable matter.

Table 3: Mean values of physicochemical parameters for wells and borehole water samples compared with WHO standard for Site 2.

S/N	Parameter	WHO	OBJ 1	OBJ 2	OBJ 3	OBJ 4	OBJ 5	OBJ 6	OBJ 7	OBJ 8	OBJ 9	OBJ 10
1	Temp. ºC	30.0	30.0	28.000	27.000	28.0	31.000*	28.000	27.000	26.000	30.0	30.000
2	pH	6.5-9.5	7.75	7.890	7.550	7.450	6.190	5.580	7.690	7.780	7.370	7.180
3	E.Cond(μS /cm)	8-10,000	230.0	286.000	250.000	193.000	100.400	90.200	219.000	339.000	339.670	338.0
4	Turb (FTU)	5.0	2.00	0.000	2.000	3.000	3.000	5.000	3.000	4.000	3.000	0.000
5	Alkalinity(mg/l	150.0	120.0	99.000	80.000	50.000	51.300	43.000	121.000	51.000	119.000	76.000
6	T.Hard (mg/l)	500.0	363.5	323.300	280.000	220.000	373.700	353.300	333.300	373.700	373.700	383.3
7	D.O (mg/l)	5.0	1.30	1.100	1.300	1.500	1.400	0.800	0.900	1.500	0.800	1.600
8	C.O.D (mg/l)	10.0	1.1	3.100	3.050	3.030	2.500	2.800	3.000	2.700	3.200	2.300
9	B.O.D (mg/l)	3.0	0.6	0.300	0.300	0.300	0.900	1.000	0.400	0.700	0.400	0.700
10	Sulphate mg/l)	250.0	80.18	87.650	110.700	200.140	200.500	222.130	110.310	126.840	150.550	180.4
11	Colour(T.C.U)	3-15	10.0	5.000	5.000	5.000	5.000	10.000	5.000	5.000	5.000	10.000
12	Nitrate(mg/l)	50	12.24	7.740	14.490	16.670	6.130	4.480	12.560	7.730	5.460	3.330
13	D.S(mg/l)	500	109.50	136.40	120.3	90.500	80.200	60.500	103.400	161.100	160.700	161.2
14	phosphate (mg/l)	6.5	0.310	0.190	0.210	0.230	0.250	0.300	0.760	0.400	0.400	0.2600

*Key: * were observed to be more than the WHO maximum tolerance limit for drinking water*

The Concentrations of Metal ions in Water compared with the WHO Maximum Permissible Limit: The results obtained for the concentrations of metals ions namely Cu, Mn Fe, Pb and Zn in the water samples collected from different hand dug wells and boreholes, was compared with the WHO maximum permissible limit using the ONE-WAY ANOVA test. The results are presented as a bar chart.

Copper: The minimum and maximum concentrations of copper obtained from the hand dug wells and boreholes water samples at the two different sampling sites in Obajana ranges from 0.001 mg/l to 0.10 mg/l. The maximum permissible limit by WHO is (2.0 mg/l). Our investigation depicts that copper is within the safety limit.

Iron: The test for iron showed it level in the two sites significantly differs as its confident level is less than 0.005. The minimum and maximum concentrations of iron obtained from the hand dug wells and boreholes waters at the two different sampling sites in Obajana ranges from 0.01 mg/l – 0.06 mg/l. The maximum permissible limit by WHO is 0.3mg/l for iron. Our studies depict that iron is within the safety limit.

Manganese: The analysis confirmed that manganese in the two sites do not differ significantly with its confident level being greater than 0.05, however, the minimum and maximum concentration of manganese metal ions obtained from the hand dug wells and borehole waters at the two different sampling sites in Obajana, ranges from 0.0 mg/l – 0.44 mg/l, which is higher than the maximum permissible limit by WHO (0.10mg/l), Manganese impacts a bitter taste to water, stains cloths and metal parts in addition to the formation of precipitate in foods when used for cooking and it also promotes the growth of algae in reservoirs.

Table 4: World Health Organization (2008)

S/no	Metals	Highest desireable limit (mg/l)
1	Copper	2.000
2	Iron	0.300
3	Manganese	0.100
4	Lead	0.010
5	Zinc	3.000
6	Nickel	0.020
7	Chromium	0.050

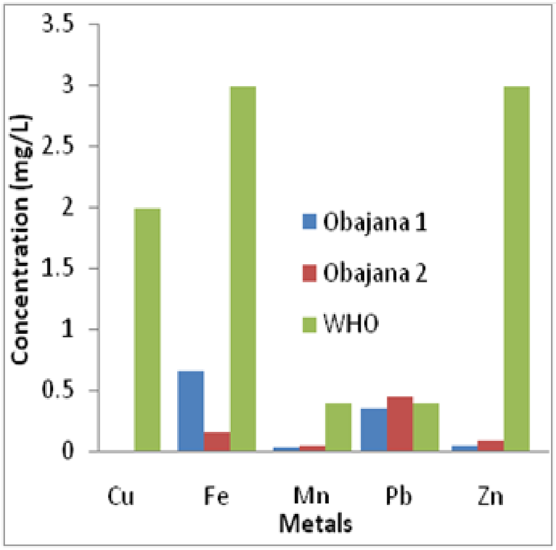

Fig. 2 Comparison of the concentrations of metal ions in water and WHO Maximum permissible limit

Zinc: The calculation showed that zinc level in the two sites significantly differs as its confident level is less than 0.005. The minimum and maximum level of zinc metal ion obtained from the hand dug wells and boreholes water samples at the two different sampling sites in Obajana ranges from 0.029 – 5.046mg/L. The maximum permissible limit by WHO is 4.0 mg/L. The level of dissolved zinc in water may increase as the acidity of water increases.

Lead: The One way ANOVA test showed that lead level in the four sites significantly differs as its confident level is less than 0.005 but lead concentration in the samples range from 0.0348 – 1.046 mg/l which is very high when compared to the 0.01mg/l WHO guideline, the values disagrees with results presented by (Maitera, *et al.,* 2011) but agrees with Environmental Impact Assessment report of (EIA, 2004) which states high level of lead in river sediments in Obajana. These results indicated that the well waters are not desirable for consumption, because Pb alone even at low concentration could be toxic to the human system. It is important to trace the contribution of this contaminants which is affecting the water quality in Obajana. However, the contamination levels are so high enough which implies that that other anthropogenic sources might be responsible.

Conclusion: The result for the above work showed that most physico-chemical parameters were within the acceptable limit of WHO. Pb, Mn, Zn in some sites were found to exceed the permissible limit as recommended by WHO, Rock mineral dissolution could be the possible reason. Drinking water should be treated before use . Heavy metals can be checked also by encouraging the communities to eat foods (seafood, fish, red meat, chicken) which serves as natural chelators(binding agent to hold the metal ion while been discharged by liver or kidney into urine/feaces) of toxic heavy metals.

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