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Microbiological and physico-chemical analyses of hand dug well-water near pit latrine in a rural Area of Western Nigeria

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Contamination of water from feacal sources can lead to major outbreaks of water-borne diseases when such water is consumed without proper treatment. The microbiological and physicochemical analyses of well-water sample collected near pit latrines in Oko, Oyo State, Nigeria were carried out during rainy and dry seasons. Microbiological analysis was carried out by using Most Probable Number (MPN) technique while physico-chemical parameters of the well-water samples were determined by standard procedures. Thermotolerant coliforms were present in all the well-water analysed during both seasons, while total coliform ranged from 350 to 160,000 and 110 to 160,000 MPN/100 ml in rainy and dry season respectively. Results obtained showed that seasonal changes had a significant impact on water quality and that some of the chemical, physical, biological and trace metal parameters analyzed in the samples from study locations were above the acceptable standards for portable water. Water samples from these wells were unsafe for human consumption without proper treatments.

Key words: Hand dug well, thermotolerant coliform, physico-chemical parameters, Most Probable Number.

INTRODUCTION

The development of water resources has often been used as a yardstick for the socio-economic and health status of many nations. However, pollution of water often negates the benefits obtained from the development of these water resources. Water is extremely abundant on the earth's surface, but access to portable water can be restricted. When safe portable water is not available at the right time or at the right place for human or ecosystem use, the well-being of the local population is at risk (Karikari and Ansa-Asare, 2009).

Water pollution and reduction in quality is a major contributor to global freshwater scarcity, stressing the need for more integrated water management and monitoring (Dahunsi et al., 2014). Li and Jennings (2017a) also conducted a study on worldwide regulation of drinking water quality and pointed out that many

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global nations are in lack of drinking water that meet quality standards, which is also an important factor affecting the global drinking water crisis. The provision of portable water to both rural and urban population is necessary to prevent communicable diseases that might accompany the consumption of faecally contaminated water. Moreover, before water can be described as 'portable', it has to comply with certain physical, chemical and microbiological standards, which are designed to ensure that the water is portable and safe for drinking. Therefore, portable water is defined as water that is free from disease producing microorganisms and chemical substances that are deleterious to health (Okonko et al., 2007).

Pit latrines are used for defecation in the rural areas including some parts of urban areas, and it has been estimated that over 1.77 billion people around the world used pit latrines (Graham and Polizzotto, 2013). Structures like pit latrines remain a potential source of pollution to hand dug wells when sited indiscriminately. Pit latrines and seasonal variations (that is, changes from rainy to dry seasons) are widely recognized as a threat to the safety and reliability of drinking water and sanitation supplies, particularly in low-income countries (WHO/UNICEF, 2006). Accordingly, the status of water quality is examined by two approaches: the water is subjected to tests by bacteriologists to ensure safety for human consumption, while physio-chemical parameters should conform to standard regulations (Adebayo and Bashire, 2002; Ahmed, 2002; Awalla, 2002; Egbulem, 2003; Akpabio and Ebong, 2004).

As a result of the increasing usage of both pit latrine structures and indiscriminate location of hand-dug wells near pit latrines in Oko town, there is concern that the well-being of the hand-dug well users might be compromised leading to a serious public health problem. Despite the fact that groundwater is one of the major sources of water supply for majority of the Nigerians, there is no integrated ground water quality monitoring scheme in Nigeria (Adebola et al., 2013). The present study is therefore carried out to examine the microbiological status and qualitative analysis of some physical, chemical parameters and trace metals of hand dug well water samples in the study area.

Study area

Oko in Oyo State, Nigeria lies between latitudes 7° 57' 7'' North to 7° 57' 18'' North and longitudes 4° 20' 24'' East to 4° 20' 37'' East, and is situated at an average elevation of 392 m above mean sea level (MSL). The justification for selecting the study area was based on the high usage of pit latrine in the community. The main method of excreta disposal is through the use of traditional pit latrine. Some of which are reasonably separated from a domesticated hand dug well, while some are few meters away from the well. The topography of the area is of gentle low land in the south, rising to the plateau of about 40 m. The town has an equatorial climate of dry and raining seasons, and relatively high humidity. The dry season is mostly at its peak in February while the raining season peak is always observed around August / September. Average daily temperature ranges from 25 and 35°C almost throughout the year. Geographical location of study area is shown in Figure 1.

MATERIALS AND METHODS

Sample collection

The sampling locations consist of hand dug wells having a distance of 8 to 30 m to the pit latrines. Ground water samples were collected from eleven (11) wells at various locations within the study area during dry and rainy season respectively. The collected water samples were labeled as K1, K2, K3 to K11. The sampling covered both dry (December to March) and rainy (April to October) season. Samples for physico-chemical parameters analysis were collected in duplicate in plastic container to avoid unpredictable changes in characteristics as per standard procedure (APHA, 1998). Samples for bacterio-logical analyses were collected into sterilized plain glass vials according to world health organisations (WHO) sampling procedure (WHO, 2006). All samples were stored in an icebox at 4°C, and transported to Research Laboratory for analyses within 6 h of sampling.

Microbiological analyses

Most probable number (MPN) techniques for isolation of total coliform and total thermotolerant coliform

Multiple-tube method according to WHO (1997) was used for total coliform count, three rows of five test tubes each containing a sterilized inverted Durham tube and MacConkey broth culture medium was arranged on test tube racks, the tubes in the first row (F1) holds 10 ml of double strength of MacConkey broth culture medium while tubes in second and third rows (F2 and F3) contains 10 ml of single strength of MacConkey broth culture medium. A sterile pipette was used to dispense 10 ml test portion of the water samples to each of the five tubes in row F1 while 1mL of the water samples was also dispensed to each of the five tubes in row F2, and finally 1 mL of 1:10 diluted water sample was dispensed to each of the five tubes in row F3. The tubes were shaken gently to mix the content, all sample test tubes were incubated at 35±1.0°C for 24 h. The same procedure was observed for total thermotolerant coliform but was incubated at 47±1.0°C for 24 h, each tube showing gas formation is regarded as "positive result" since the gas indicates the possible presence of coliforms (WHO, 2006). The most probable number (MPN) of bacteria present was estimated from the number of tubes inoculated and the number of positive tubes obtained using specially devised statistical tables (WHO, 2006).

Physicochemical and heavy metal analyses of the hand dug well water samples

The collected samples were analyzed for different physicochemical

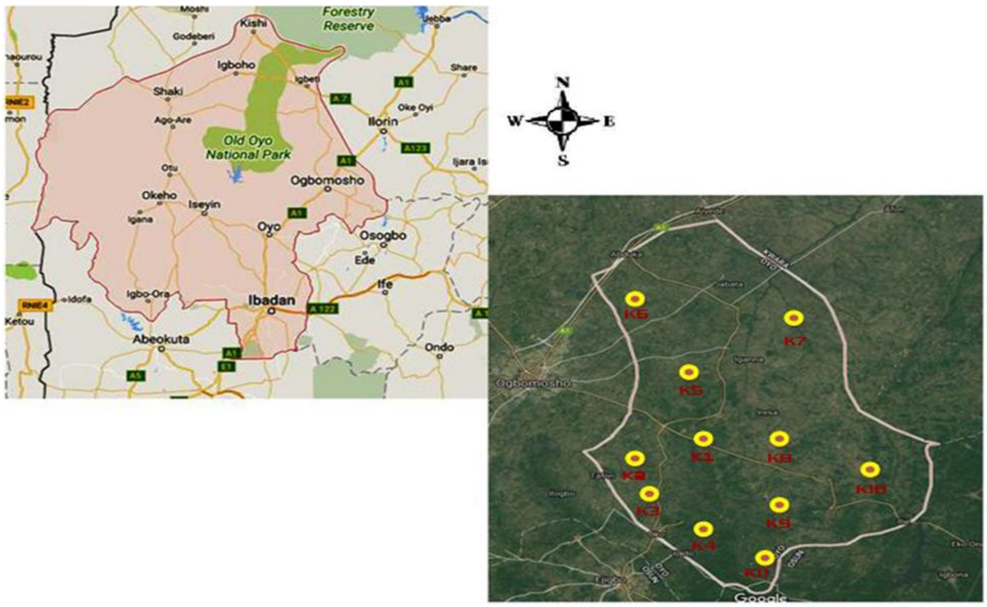

Figure 1. Map showing the geographical location of the study area and collection points.

parameters such as pH, electrical conductivity, total dissolve solids, total hardness, temperature, dissolve oxygen, biochemical oxygen demand, total alkalinity, phosphate, magnesium, chloride, nitrate, lead and iron with standard methods (APHA, 1998). pH was measured immediately the water samples were drawn from the sampled wells. Temperature and pH were measured in situ, using a temperature probe and portable pH meter (Eijkelkampod pH meter, model No. 3.36) respectively. Dissolved oxygen (DO) was determined by DO meter (Eijkelkampod DO meter, model No. 18.36). Other parameters were analyzed in the laboratory according to standard method of American Public Health Association (APHA) (1998).

Statistical analysis

The Statistical Package for Social Scientist (SPSS) 16.0 model was used for the statistical analysis. The t-test analysis of mean was used to establish the significant differences between the dry and the rainy seasons for the microbial and physicochemical quality of the studied well water at $p < 0.05$.

RESULTS

Determination of bacteriological qualities

The mean values of both thermotolerant coliform counts and total coliform counts were shown in Table 1. The most probable number (MPN) for total thermotolerant coliform count of the water samples in rainy season ranged from 13000 to 160000 MPN/100 ml (Table 1), Sampling point K1 and K10 had the highest loads (160000 MPN/100 ml) followed by K4 and K7 (35000 MPN/100 ml) while that of dry season ranges from 33000 to 28 MPN/100 ml. It was observed that a statistically significant difference exists between the two seasons for both thermotolerant and total coliforms counts. High counts of thermotolerant bacteria were observed during the rainy season as compared to dry season with the exception of K6 and K11 that had the counts of 28,000 and 16,000 respectively. The total coliforms count of water samples ranged from 350 MPN/100 ml in K2 to 160000 MPN/100 ml in K5, K8, K9 and K11 as indicated in Table 1.

Determination of physico-chemical and heavy metal analyses of the studied well water samples

The results of physical parameters observed in the studied well during dry and rainy seasons were presented in Tables 2 and 3, while chemical parameters observed in the studied wells during dry and rainy seasons are presented in Table 4. Lead and iron ranged from 0.005 to 0.043; 0.011 to 0.059 mg/L and 0.057 to 0.086; 0.030 to 0.108mg/L in rainy and dry season respectively (Figure 2).

DISCUSSION

The mean values of total coliform counts showed no satstitical significant difference ($p<0.05$) during rainy and dry seasons, while there was a significant difference between the Total Thermotolerant counts for both seasons (Table 1). The WHO and Nigeria Standard of

Table 1. Most probable number for both total thermotolerant and total coliforms.

Sampling point	T-Rain	T-Dry	C-Rain	C-Dry
K1	160000[f]	34[a]	54000[d]	920[ab]
K2	13000[a]	350[c]	350[a]	160000[g]
K3	28000[cd]	1600[e]	920[b]	54000[e]
K4	35000[e]	350[c]	92000[e]	54000[e]
K5	17000[ab]	33[a]	160000[f]	92000[f]
K6	13000[a]	28000[f]	54000[d]	17000[c]
K7	35000[e]	920[d]	35000[c]	350[a]
K8	22000[bc]	350[c]	160000[f]	54000[e]
K9	17000[ab]	350[c]	160000[f]	160000[g]
K10	160000[f]	170[b]	92000[e]	110[a]
K11	24000[bc]	16000[g]	160000[f]	35000[d]

*Values were calculated with MPN per 100 ml.
T = Thermotolerant coliform; C= Total coliform.
Values with the same alphabet are not significantly different.

Drinking Water Quality (NSDWQ) standard for coliforms count in portable water is 0 in 100 ml but none of the sample analyzed complied with this standard. This showed that a change in season (from rainy to dry) had a significant impact on the bacteriological qualities of all the examined hand dug well water samples. Although a number of factors might be responsible for the gross contamination of the well: such factors include:

(1) Distance of the well to pit latrine which may result in cross contamination by the well users.
(2) Topography of the land (well located along sloppy water table are more prone to contamination than those cited in a hilly environment), and
(3) Hygienic condition of the hand dug well environment.

The results obtained showed that all the studied well water was heavily contaminated during the rainy season when compared with the dry season. This was also observed by Jeje and Kamar (2013) and Nwachukwu and Otokunefor (2006) in their work.

Salim et al. (2014) also recorded highest total counts during the winter season as compared with other seasons used in their work at both 35 and 22°C. While Onuigbo et al. (2017) also reported increase in bacterial population during rainy season than dry season. However, contrary to what was obtained in this study, Salim et al. (2014) in their own study observed high coliform counts in autumn compared to other seasons used in their work. The high total coliform counts observed might be an indication of poor sanitary handling and/or environmental conditions affecting the wells. Groundwater is usually contaminated due to improper construction, shallowness, animal wastes, proximity to toilet facilities, sewage, natural soil-plant-bacteria contact, refuse dump sites and various human activities around the wells (Bitton, 1994; EPA, 2003; Shittu et al., 2008).

According to Fakayode (2005), the pH of a water body is very important in the determination of water quality since it affects other chemical reactions such as solubility and metal toxicity. Most of the pH observed during the rainy season fall within the WHO standard but the pH of the water samples during the dry season was below the standard, it is highly acidic; this can result in low quality of water available during this season. Water with low alkalinity has little capacity to buffer acidic inputs and is susceptible to acidification (low pH) (Gopala et al., 2015). However, the results obtained in this study is contrary to what was observed by Shaikh and Mandre (2009) and Shittu et al. (2008) where they reported low pH during the wet season.

Temperatures observed in this study fell within the acceptable standard of 28 to 30°C (Tables 2 and 3) (NSDWQ, 2007; WHO, 2011). Although temperature generally influences the overall quality of water (physico-chemical and biological characteristics) but, there are no general guidelines values for drinking water in many parts of the world (Palamuleni and Akoth, 2015). Total dissolved solids (TDS) is another important parameter for drinking water, water with high solid content will have low palatability and may produce unfavourable reactions from consumers (Basavaraddi et al., 2012).

TDS also include most of the inorganic salts that are dissolved in water, the concentration of TDS in drinking water vary based on local geology and geography (Jimmy et al., 2012). TDS values observed in this study ranged from 42 – 465 mg/l. All water samples studied fell within the acceptable range of 1000mg/l (WHO, 2011). But Rao (2006) and Srinivasamoorthy et al. (2009) reported high values of TDS in their work, which is contrary to what was obtained in this study.

Total suspended solids (TSS) is a parameter used in water quality and is also known as non –filtrable residue (NFR). TSS gives a measure of turbidity of water and it causes the water to be milky or muddy looking. A significant difference ($p<0.05$) exist between the TSS in K3 which is having the highest value of 1252.25 and the TSS values recorded for the other water samples in the dry season (Table 2). While in rainy season, result shows no significant difference in the TSS of the samples with K6 having 12.89, 18.35 for K7 and 22.46 for K8 which were of low values but are different significantly from 381.98 of K1, 98.53 of K2, 120.76 of K3, 81.17 of K4, 38.71 of K5, 674.68 of K9, 214.09 of K10 and 442.49 of K11 (Table 3). Water high in suspended solid may be aesthetically unsatisfactory for bathing (WHO, 2007).

The higher amount of total solids in the present study with comparison to WHO standard might be due to the fact that the concerned wells are not ringed and also drawer could be responsible for aggittation during

Table 2. Physicochemical characteristics of the studied well during dry season.

Sample	pH	TSS	TDS (mgl^{-1})	Temp^{0}C	E.C (µs cm^{-1})	D.O (mgl^{-1})	BOD (mg O_2l^{-1})	Total hard. ($mgCaCO_3l^{-1}$)	Total ALK ($CaCO_3$ mgl^{-1})	PO_4^{3-} (mgl^{-1})	Mg^{+2} (mgl^{-1})	NO_3 (mgl^{-1})	Pb (mgl^{-1})	Fe (mgl^{-1})	Cl (mgl^{-1})
K1	5.42^{b}	7.53^{b}	55^{a}	29.1^{a}	77^{a}	9.90^{a}	3.80^{d}	27.37^{a}	17^{ab}	0.79^{a}	0.100^{e}	19.41^{a}	0.050^{g}	0.087^{c}	298.77^{g}
K2	4.08^{a}	480.05^{h}	415^{fg}	29.0^{a}	640^{e}	9.62^{a}	1.66^{a}	153.68^{f}	18^{bc}	4.38^{e}	0.103^{f}	107.46^{g}	0.046^{e}	0.081^{b}	317.18^{j}
K3	5.55^{bc}	1252.25^{k}	378^{f}	29.1^{a}	659^{ef}	9.85^{a}	1.60^{a}	184.21^{g}	20^{cd}	3.79^{e}	0.085^{c}	92.90^{f}	0.059^{h}	0.094^{e}	143.08^{b}
K4	6.00^{bcd}	642.56^{i}	442^{g}	29.8^{a}	741^{f}	10.41^{a}	1.40^{a}	101.05^{cd}	30^{f}	5.43^{g}	0.117^{i}	133.12^{k}	0.048^{f}	0.100^{f}	299.01^{h}
K5	6.30^{cd}	18.12^{c}	218^{de}	29.3^{a}	396^{cd}	9.93^{a}	3.45^{bc}	181.05^{g}	61^{h}	2.42^{b}	0.128^{j}	83.89^{d}	0.044^{d}	0.104^{g}	310.22^{i}
K6	6.47^{d}	78.15^{e}	132^{c}	29.0^{a}	242^{b}	10.28^{a}	3.77^{d}	98.94^{c}	31^{f}	3.70^{e}	0.100^{e}	90.82^{e}	0.045^{de}	0.093^{e}	270.54^{e}
K7	6.34^{cd}	387.47^{g}	120^{bc}	29.2^{a}	228^{b}	10.03^{a}	2.90^{bc}	111.58^{d}	46^{g}	5.32^{g}	0.092^{d}	130.34^{j}	0.039^{b}	0.091^{d}	252.54^{c}
K8	5.76^{bcd}	909.13^{j}	66^{ab}	29.0^{a}	135^{a}	10.22^{a}	3.41^{bc}	35.79^{a}	26^{e}	4.81^{f}	0.082^{b}	115.34^{h}	0.049^{fg}	0.108^{h}	371.10^{k}
K9	6.15^{bcd}	2.16^{a}	42^{a}	28.5^{a}	70^{a}	10.37^{a}	4.65^{e}	33.68^{a}	15^{a}	3.31^{d}	0.113^{h}	81.12^{c}	0.041^{c}	0.101^{f}	283.32^{f}
K10	6.26^{bcd}	51.99^{d}	261^{e}	28.9^{a}	445^{d}	10.34^{a}	2.72^{b}	137.89^{e}	31^{f}	5.17^{g}	0.105^{g}	126.88^{i}	0.050^{g}	0.100^{f}	136.85^{a}
K11	5.88^{bcd}	95.18^{f}	181^{cd}	28.4^{a}	347^{c}	10.10^{a}	3.58^{cd}	74.73^{b}	22^{d}	3.08^{c}	0.033^{a}	75.57^{b}	0.011^{a}	0.030^{a}	260.24^{d}
WHO	6.5-8.5	500	1000	28-30	400	5.0-7.0	-	300	120	-	-	50	0.01	0.1-1.0	250
NSDWQ	6.5-8.5	-	500	Ambient	1000	-	-	150	-	-	0.20	50	0.01	0.3	250

Values = Mean, values followed by the same alphabets in the columns are not significantly different according to Duncan's multiple range test ($p \leq 0.05$).

Table 3. Physicochemical characteristics of the studied well during rainy season.

Sample	pH	Temp^{O}C	TDS (mgl^{-1})	TSS	EC (µs cm^{-1})	D.O (mgl^{-1})	BOD (mg O_2l^{-1})	Total.ALK ($CaCO_3mgl^{-1}$)	Total Hardness ($mgCaCO_3l^{-1}$)	Mg^{2+} (mgl^{-1})	PO_4^{3-} (mgl^{-1})	Cl (mgl^{-1})	NO_3^- (mgl^{-1})	Pb (mgl^{-1})	Fe^{3+} (mgl^{-1})
K1	6.42^{b}	28.5^{a}	381.0^{d}	381.98^{e}	647^{i}	10.7^{j}	2.84^{d}	57^{c}	139.08^{k}	0.089^{f}	2.140^{c}	231.54^{k}	14.33^{a}	0.043^{g}	0.086^{g}
K2	6.27^{a}	29.0^{a}	367.0^{d}	98.53^{bc}	620^{h}	4.8^{b}	0.12^{a}	76^{e}	59.32^{f}	0.101^{g}	3.470^{d}	143.27^{f}	84.19^{h}	0.030^{cd}	0.058^{a}
K3	7.40^{e}	28.5^{a}	216.0^{bc}	120.76^{c}	367^{de}	7.6^{i}	0.45^{b}	78^{f}	46.49^{b}	0.056^{c}	0.038^{b}	122.05^{b}	72.63^{e}	0.038^{f}	0.069^{d}
K4	8.18^{g}	29.0^{a}	215.3^{bc}	81.17^{abc}	359^{d}	7.4^{h}	2.63^{c}	142^{h}	48.10^{c}	0.087^{f}	0.023^{ab}	127.63^{c}	107.35^{k}	0.023^{b}	0.073^{e}
K5	8.10^{g}	28.5^{a}	205.0^{b}	38.71^{ab}	339^{c}	5.9^{e}	5.05^{h}	63^{d}	104.21^{j}	0.098^{g}	0.029^{b}	210.30^{j}	65.88^{d}	0.029^{cd}	0.078^{f}
K6	7.82^{f}	29.0^{a}	138.0^{a}	12.89^{a}	233^{b}	5.5^{d}	3.80^{f}	50^{b}	44.09^{a}	0.065^{d}	0.033^{b}	112.04^{a}	77.37^{f}	0.033^{de}	0.060^{ab}
K7	7.38^{e}	30.0^{a}	254.0^{bc}	18.35^{a}	435^{f}	5.9^{e}	5.25^{i}	84^{g}	52.50^{d}	0.062^{d}	0.027^{b}	130.51^{d}	101.60^{j}	0.027^{c}	0.057^{a}
K8	7.38^{e}	28.5^{a}	212.0^{b}	22.46^{a}	369^{e}	4.7^{a}	5.96^{j}	64^{d}	76.49^{i}	0.047^{b}	0.030^{b}	165.78^{h}	80.61^{g}	0.030^{cd}	0.071^{de}
K9	7.34^{e}	29.0^{a}	117.0^{a}	674.68^{f}	206^{a}	5.0^{c}	2.93^{e}	186^{i}	72.95^{h}	0.088^{f}	0.035^{b}	158.99^{g}	62.46^{c}	0.035^{ef}	0.065^{c}
K10	7.18^{d}	28.5^{a}	277.0^{c}	214.09^{d}	479^{g}	6.6^{g}	10.4^{k}	62^{d}	57.72^{e}	0.081^{e}	0.032^{b}	138.69^{e}	90.95^{i}	0.032^{de}	0.059^{a}
K11	6.82^{c}	28.5^{a}	465.0^{e}	442.49^{e}	767^{j}	6.0^{f}	4.14^{g}	18^{a}	68.94^{g}	0.035^{a}	0.005^{a}	169.45^{i}	50.23^{b}	0.005^{a}	0.063^{bc}
WHO	6.5-8.5	28-30	1000	500	400	5.0-7.0	-	120	300	-	-	250	50	0.01	0.1-1.0
NSDWQ	6.5-8.5	Ambient	500	-	1000	-	-	-	150	0.02	-	250	50	0.01	0.3

Values = Mean, values followed by the same alphabets in the columns are not significantly different according to Duncan's Multiple range Test ($p \leq 0.05$).

Table 4. Mean Concentration of the Chemical parameters observed in the studied wells during both dry and rainy season.

Variable		K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11
Phosphate	D	0.79±0.01	4.38±0.01	3.79±0.02	5.43±0.01	2.42±0.01	3.7±0.01	5.32±0.02	4.81±0.01	3.31±0.01	5.17±0.01	3.08±0.01
	R	2.14±0.01	3.47±0.03	0.038±0.01	0.023±0.01	0.029±0.01	0.033±0.01	0.027±0.02	0.03±0.01	0.035±0.01	0.032±0.03	0.005±0.03
Magnesium	D	0.100±0.01	0.103±0.01	0.085±0.02	0.117±0.01	0.128±0.01	0.100±0.01	0.092±0.01	0.082±0.01	0.113±0.01	0.105±0.01	0.033±0.02
	R	0.089±0.01	0.101±0.01	0.056±0.01	0.087±0.01	0.098±0.01	0.065±0.01	0.062±0.01	0.047±0.02	0.088±0.01	0.081±0.01	0.035±0.01
Chloride	D	298.77±1.11	317.18±1.10	143.08±1.08	299.01±1.12	310.22±1.22	270.54±1.11	252.54±1.11	371.1±1.09	283.32±1.16	136.85±1.23	260.24±1.22
	R	231.54±1.09	143.27±1.09	122.05±1.11	127.63±1.11	210.3±1.14	112.04±1.11	130.51±1.09	165.78±1.08	158.99±1.12	138.69±1.14	169.45±1.32
Nitrate	D	19.41±0.01	107.46±0.03	92.9±0.03	133.12±0.01	83.89±0.03	90.82±0.02	132.34±0.01	115.34±0.01	81.12±0.02	126.88±0.03	75.57±0.03
	R	14.33±0.03	84.19±0.02	72.63±0.03	107.35±0.02	65.88±0.02	77.37±0.02	101.6±0.01	80.61±0.01	62.46 0.03	90.95±0.02	50.23±0.03

Values = Mean, values followed by the same alphabets in the columns are not significantly different according to Duncan's multiple range test ($p \leq 0.05$).

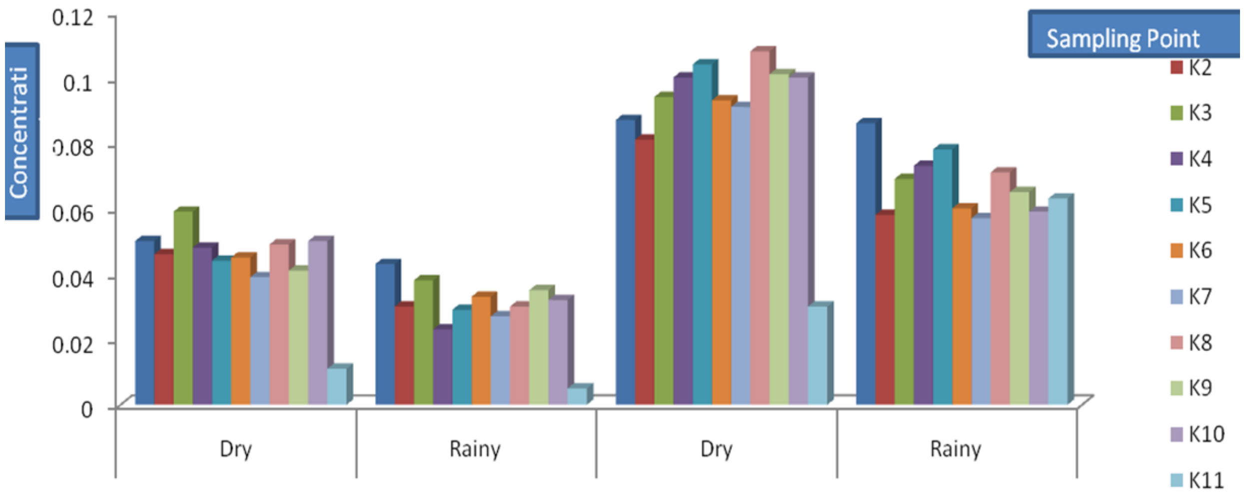

Figure 1. Mean comparative studies of trace metals observed in both dry and rainy season.

abstraction. Mahananda et al. (2010) confirms these similarities in their report by concluding that higher concentration of this parameter is an index that the wells are grossly polluted. In natural waters, there is a close relationship between alkalinity and hardness. Total hardness is the sum of calcium and magnesium hardness, in mg/L as $CaCO_3$. High levels of hard water ions such as Ca^{2+} and Mg^{2+} can cause scaly deposits in plumbing, appliances, and boilers (Shinde and Nagre, 2015). The results obtained showed that 44.09 mg/L which was the lowest value was found in K6 while 139.08 mg/L the highest value, was obtained in K1. The WHO (2011) indicates that hardness above 200 mg/L result in scale deposition, particularly on heating while soft waters with a hardness of less than about 100 mg/L have a low buffering capacity and may be more corrosive to water pipes.

No health-based guideline value has been proposed for hardness but however, the degree of hardness in water may affect its acceptability to the consumer in terms of taste and scale deposition. Contrary to what was obtained in this study, Sanusi and Akinbile, (2013) observed higher values of total hardness during the wet season in their own work. Water samples with high alkalinity values are considered undesirable because of excessive hardness and high concentrations of sodium salts. Electrical conductivity is a measure of water's ability to conduct an electric current, and it is related to the amount of dissolved minerals in the water, but it does not give an indication of the element present. Higher value of conductivity is a good indicator of the presence of contaminants such as sodium, potassium, chloride or sulphate (Orebiyi et al*.,* 2010).

Results of the analysis showed that the range of conductivity values obtained in samples ranged from 206 to 767 µS/cm in rainy season, while the highest value was observed in K3 (659 µS/cm) and the least was found to be 70 µS/cm in K9 during the dry season. The results obtained corresponds to that of Jayalakshmi et al. (2011) and Singh et al*.* (2010) who reported different ranges of electrical conductivity as a good and rapid method to measure the total dissolved ions which is directly related to the total solids in the water sample. While Sanusi and Akinbile (2013) observed no difference in electrical conductivity values obtained during the two seasons used in their study. Heavy deposition of the dissolved oxygen (DO) by the pollutants was noticed and this showed that the wells were unsafe for consumption. 9.1 and 63.6% of the water samples during the rainy and wet seasons respectively fall below the NSDWQ (2007) standard for DO. Efe et al. (2005) also observed high values in DO during the dry season as compared to rainy season.

The value recorded for the two seasons for biological oxygen demand (BOD) analysis was significantly different from each other. The result obtained from the BOD test revealed the measure of the amount of oxygen consumed by microorganisms in breaking down the organic matter. Igbinosa and Okoh (2009) reported high turbidity and BOD in their work, while Jihyun et al*.* (2013) also reported that water BOD often increases during periods of heavy rain and high river flows - as organic matter are washed in from surrounding lands and drainage channels.

Though, phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problem could occur from extremely high level of phosphate (Kumar and Puri, 2012). Comparative study of the two seasons shows a statistical significant difference between the recorded values of the samples because rainfall can cause varying amounts of phosphates in well water. Chloride concentrations in excess of about 250 mg/L can give rise to detectable taste in water. When it is above 250 mg/L the water is unsuitable for human consumption (WHO, 2011).

Graham and Polizzotto (2013) have reported positive correlation between chlorides and water temperature. In addition, numerous studies have confirmed that ground water inputs also tend to increase the concentration of chlorides (Cengiz Koc, 2010). Previous report in similar research confirmed nitrate as the largest chemical concerns from excreta deposited in on-site sanitation systems (BGS, 2002; Fourie and Vanryneveld, 1995; Pedley et al., 2006).

High concentrations of nitrogen in water sample makes it an excellent indicator of faecal contamination, nitrate has been the most widely investigated chemical contaminant derived from pit latrines. Consumption of high concentrations of nitrate in drinking water is known to cause methemoglobinemia associated with cancer in humans (Fewtrell, 2004; WHO, 2011). Fatombi et al*.* (2012) also associated the presence of nitrates in groundwater to waste water from domestic source and from leaking septic tanks built near wells.

Although, all the studied well water samples conformed with the recommended standard for iron, yet their presence in such small concentration is a clear indication of the presence of toxic wastes in those hand dug wells, the maximum permissible level of iron content in drinking water is 0.3 mg/L, a level above this concentration makes the water unsafe for domestic consumption. High level of iron makes the water turbid, discoloured and imparts unpalatable taste to water (Trivedi et al., 2010). However, Lead must not be more than 0.01 mg/L as the water becomes poisonous if present in higher concentration. Some of the values obtained were higher than the desired concentrations for domestic water consumption, hence making it unfit for use as portable water. High concentration of iron in domestic water samples from well water have also been reported (Dissanayake et al., 2010; Ogedengbe and Akinbile, 2007; WHO, 2006). Values above the standard pose danger to consumers when such water is consumed. Generally, groundwater quality varies from place to place, sometimes dependent on seasonal changes (Vaishali and Punita, 2013), the types of soils, rocks and surface through which it moves (Seth et al., 2014; Thivya et al., 2014).

Currently, worldwide nations including Nigeria are in lack of drinking water quality regulations (Li and Jennings, 2017a) and ingestion of contaminated drinking water is one of the major exposure pathways to hazardous chemicals and diseases (Li and Jennings, 2017b). Thus, it is necessary for nations to provide strict maximum concentrations level of hazardous substances to protect public health. And considering the level of pollution observed in this study, groundwater quality monitoring and testing is of paramount importance both in the developed and developing countries.

Local authorities and public health practitioners should be mandated to carry out house to house inspection for the concerned communities and major treatment of water from these wells should be encouraged before its domestic consumption either by disinfection of wells water or other forms of treatment such as chlorination, sedimentation and filtration.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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