SEASONAL ANALYSIS OF WATER QUALITY IN TWO SETTLEMENTS OF WUKARI LOCAL GOVERNMENT AREA, TARABA STATE, NIGERIA

Supported by tetfund
TERTIARY EDUCATION TRUST FUND

C. Andrew[1]*, M. O. Aremu[1], O. J. Oko[1] and G. A. Shenge[2]

[1]Department of Chemical Sciences, Federal University Wukari, PMB 1020, Taraba State, Nigeria

[2]Benue State Water Board, Makurdi, Benue State, Nigeria

*Corresponding author: chrysantus@fuwukari.edu.ng

Received: February 02, 2017 **Accepted:** March 27, 2017

Abstract: In the present study, some physico-chemical parameters and heavy metals content in water samples collected from three sources (wells, boreholes and river) at two different areas (Kente and Hospital Ward) in Wukari local government area were analyzed using standard methods in order to ascertain its quality. The study was conducted during dry season (2015) and rainy season (2016). The physico–chemical parameters of interest that were investigated include temperature, turbidity, suspended solids, total dissolved solids (TDS), conductivity, pH, phosphate, chloride, alkalinity, hardness, chemical oxygen demand (COD), dissolved oxygen (DO) and biological oxygen demand (BOD) while that of metals were cadmium, lead, arsenic, iron, copper, mercury and manganese and the results compared with standard values as prescribed by Standards Organization of Nigeria (SON). The results of the study revealed that the mean amounts of metals analyzed were within the allowable limit as set by SON except that of lead in all water samples from the river irrespective of the season. Most physico-chemical parameters results fall within SON guidelines and some were above the SON limit. In conclusion, the results indicate that seasonal change did not bring significant alteration in the parameters analyzed.

Keywords: Heavy metals, physico-chemical parameters, water quality

Introduction

Water is a basic necessity for the existence of living things. Therefore, its quality is of paramount importance to human physiology and man's continued survival depends very much on its availability (FAO 1997). According to Edet *et al.* (2012), quality water is one that is free from diseases causing microorganisms and chemical substances harmful to human health. However, pure, clean and safe water only exists briefly in nature and is immediately contaminated through various human activities (Kolade *et al.,* 1992). Most sources of water therefore are rendered unfit for immediate consumption and must be treated prior to their use.

Pathogens (bacteria, viruses), heavy metals, nitrate and salts are the major water contaminants and several studies have shown that they are harmful to humans once their contents are high in water sources (Geldreich, 1981). Any drinking water should be free from any microorganisms that is pathogenic since their presence can be taken as an indicator of potential danger of health risks (Ryu *et al.,* 2005)

A number of scientific studies have been carried out across Nigeria to ascertain the quality of water used for various purposes especially drinking and the findings have reveal gross contamination by disease causing microorganisms along with other harmful physical and chemical materials (Aremu *et al.,* 2011, Abimbola *et al.*, 2002, Akaahan *et al.*, 2010, Emmanuel, 2011, Adekunle *et al.*, 2007, Obasi *et al.*, 2001, Akogwu *et al.*, 2015, Achadu *et al.*, 2013). Therefore, it is imperative that periodical water analysis is conducted to determine the quality of water used by human.

Thus, the specific objective of this research work was to investigate the seasonal quality of water from three sources in Kente village and Hospital ward all in Wukari LGA. Water samples from the different sources are analyzed for their physico-chemical and heavy metal contents in order to identify potential contaminants.

Materials and Methods

Study area

The two study areas, Kente town and Hospital Ward are located in Wukari LGA in the southern part of Taraba State which lies on the co-ordinates 7.850°N 9.783°E covering an area of 4,308 km^2 having a total population of 241,546 based on the 2006 census (Oko *et al.*, 2014) (Fig. 1). The vegetation of the study area is that of savannah zone and has two climatic seasons wet (April - October) and the dry season (November - March).

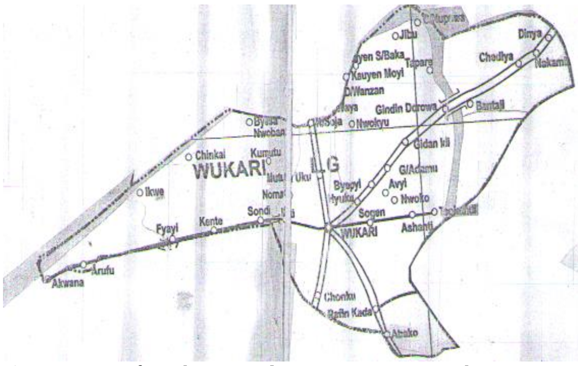

Fig. 1: Map of Wukari Local Government Area showing sample locations

Sampling and analysis

Seven samples of water (three wells, three boreholes and a river) each from the study areas were collected during the dry season of 2015 and rainy season of 2016. Prior to sampling, all sample bottles were cleaned with distilled water and finally with water samples to be analyzed and the collected samples were properly labeled and transported to the laboratory for analysis. The water samples were analyzed for turbidity, suspended solids, TDS, conductivity, pH, phosphate, chloride, alkalinity, hardness, COD, DO and BOD according to standard methods described in APHA (1998). The temperature of the water samples were recorded at the site of collection using calibrated thermometer. Analyses were carried out in triplicates and the mean values are reported. The elemental analysis was determined by using atomic absorption spectrophotometer (UNICAM 929).

Results and Discussion

The heavy metal concentrations (ppm) in the water samples (wells, boreholes, river) are presented in Tables 1 and 2. Metal concentrations were found to slightly vary from water sources and seasonally. For instance, it was observed that the mean metal levels in the Hospital Ward well samples were high during dry season than the rainy season (Table 1). This was however contrary to the result of metal concentrations of water samples in the Hospital Ward River where it was high during the rainy season than in the dry season. This seasonal change can be attributed to surface run-off and erosion which carry lot of wastes containing different metals into the water source during the rainy season. The mean copper concentration determined during both dry and rainy season is less than the findings reported by Akogwu *et al*. (2015). Though copper is known to be toxic even at a low concentration, the observed level is within the limit stipulated by SON. In all the water samples, the mean amounts of lead (Tables 1 and 3) exceeded the maximum tolerable limit of 0.010 mgL^{-1} for drinking water except in the borehole water samples. Similar high lead contents were reported by Aremu *et al*. (2012) in their analysis of ground and stream water in Doma LGA of Nasarawa state. Lead is one of the most extensively studied toxic element and its adverse health effects have been well documented in children and adults (Brown and Marolis, 2012, WHO, 2010). Low levels of lead exposure may results in different neurological and developmental outcomes while at extremely elevated levels it can cause seizures and ultimately death (Bellinger, 2011).

Table 1: Metal concentration (ppm) in water samples from Hospital Ward wells, boreholes and river

Wet Season

Mineral	HWS1	HWS2	HWS3	Mean Value	HBHS1	HBHS2	HBHS3	Mean Value	HRS	SONStandard
Cd	0.0026	0.0026	0.0024	0.0025	0.015	0.015	0.0018	0.0106	0.0027	0.003
Pb	0.0174	0.0169	0.0177	0.0173	0.0046	0.0044	0.0046	0.0045	0.2317	0.010
As	0.0021	0.0022	0.0020	0.0021	0.0009	0.0008	0.0009	0.0009	0.0043	0.010
Fe	0.0442	0.0428	0.0438	0.0436	0.0301	0.0296	0.0294	0.0297	0.0771	0.300
Cu	0.0015	0.0019	0.0017	0.0017	0.0006	0.0005	0.0005	0.0005	0.0057	1.000
Hg	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0005	0.001
Mn	0.0236	0.0234	0.0228	0.0233	0.0103	0.0097	0.0102	0.0101	0.0385	0.200

Dry Season

Mineral	HWS1	HWS2	HWS3	Mean Value	HBHS1	HBHS2	HBHS3	MeanValue	HRS	SONStandard
Cd	0.0030	0.0031	0.0028	0.0030	0.0011	0.0012	0.0016	0.0013	0.0024	0.003
Pb	0.0192	0.0176	0.0214	0.0194	0.0042	0.0038	0.0041	0.0040	0.1963	0.010
As	0.0027	0.0029	0.0029	0.0028	0.0006	0.0010	0.0007	0.0008	0.0039	0.010
Fe	0.0452	0.0437	0.0446	0.0445	0.0284	0.0261	0.0263	0.0269	0.0684	0.300
Cu	0.0021	0.0025	0.0024	0.0023	0.0004	0.0003	0.0003	0.0003	0.0049	1.000
Hg	0.0002	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0004	0.001
Mn	0.0247	0.0248	0.0229	0.0241	0.0094	0.0083	0.0086	0.0088	0.0362	0.200

HWS= Hospital well samples; HBHBS= Hospital borehole samples; HRS= Hospital river samples

Table 2: Levels of physicochemical parameters in the water samples from Hospital Ward wells, boreholes and river

Wet Season

Parameter	HWB1	HWB2	HWB3	MeanValue	HBHB1	HBHB2	HBHB3	MeanValue	HRB	SONStandard
Tempt. (ºC)	28.0	28.0	28.1	28.03	28.2	28.2	28.0	28.13	28.6	25
Turbidity (NTU)	0	0	2	0.67	0	1	0	0.33	7	**5**
Suspended solids (mgL^{-1})	0	0	1	0.33	0	0	0	0.00	2	
TDS (mgL^{-1})	26.0	28.7	25.1	26.60	37.8	41.6	37.1	38.83	30.1	**500**
Conductivity (μScm^{-1})	71.8	74.8	70.6	72.40	84.2	92.8	80.7	85.90	74.1	**1000**
pH	6.64	8.00	7.14	7.26	8.24	7.88	6.84	7.65	7.60	**6.5-8.5**
NO_3-N (mgL^{-1})	28.6	29.0	24.8	27.47	28.4	38.80	29.80	32.33	34.8	**50**
Phosphate (mgL^{-1})	1.04	0.84	0.64	0.84	1.42	1.44	1.16	1.34	1.04	
Chloride (mgL^{-1})	27.9	29.1	25.2	27.40	47.1	49.1	39.1	45.10	41.1	**250**
Alkalinity (mgL^{-1})	7.20	10.80	8.40	8.80	10.20	9.60	8.40	9.40	9.20	
Hardness (mgL^{-1})	100	120	80	100.00	140	160	140	146.67	80	**150**
COD (mgL^{-1})	80	104	60	81.33	68	78	60	68.67	132	
DO (mgL^{-1})	4.7	4.0	3.9	4.20	4.3	3.9	4.3	4.17	4.9	
BOD (mgL^{-1})	40	52	53	48.33	34	38	30	34.00	66	

Dry Season

Parameter	HWB1	HWB2	HWB3	MeanValue	HBHB1	HBHB2	HBHB3	MeanValue	HRB	SONStandard
Tempt. (ºC)	29.1	29.6	29.1	29.27	29.0	29.1	29.0	29.03	30.4	25
Turbidity (NTU)	0	0	1	0.33	0	1	1	0.67	450	
Suspended solids(mgL^{-1})	0	0	0	0.00	0	0	0	0.00	640	
TDS (mgL^{-1})	26.4	29.6	26.8	27.60	38.0	42.1	37.2	39.10	162.8	200
Conductivity (μScm^{-1})	77.0	75.1	71.4	74.50	84.2	90.7	81.0	85.30	1168.4	10
pH	6.94	7.00	6.00	6.65	8.41	8.00	7.26	7.89	8.84	6.5-8.5
NO_3-N (mgL^{-1})	24.4	25.0	20.1	23.17	24.6	37.6	27.1	29.77	98.4	
Phosphate (mgL^{-1})	1.28	0.90	0.72	0.97	1.50	1.47	1.18	1.38	2.68	45
Chloride (mgL^{-1})	31.0	30.1	27.8	29.63	50.9	50.1	40.0	47.00	114.7	200
Alkalinity (mgL^{-1})	8.40	8.00	7.40	7.93	10.00	10.80	9.80	10.20	10.80	200
Hardness (mgL^{-1})	140	140	80	120	160	180	160	166.67	200	100
COD (mgL^{-1})	62	76	52	63.33	60	62	44	55.33	178	10
DO (mgL^{-1})	5.1	4.5	4.4	4.67	4.6	4.5	5.2	4.77	3.3	
BOD (mgL^{-1})	31	38	36	35.00	30	32	22	28.00	88	10

HWS= Hospital well samples; HBHBS= Hospital borehole samples; HRS= Hospital river samples

Therefore, the water samples analyzed with high lead content require treatment so that the level conforms to the standard guideline to make it safe for use. The mean cadmium levels in all the water analyzed are less than the maximum limit stipulated by SON except in water that was sampled from Hospital Ward borehole. Cadmium exposure can impact nearly on all human system and high exposure may give rise to renal, pulmonary, hepatic, skeletal, reproductive effects and cancer (Nordberg, 2003). The elements manganese and iron are found in water and their quantities depend to some extend in the geology of an area. The mean manganese concentrations in the water samples from Hospital Ward area and Kente village both at the dry and rainy seasons were low in comparison to the standard limit set by SON. High exposure to manganese results in decrease in fetal weight retardation, DNA damage, neurotoxic effect and Parkinson-like syndrome (Adekunle *et al.*, 2007; Aremu *et al.*, 2012). The lowest mean value of iron (0.0257 ppm) was obtained from Kente borehole sample and the highest mean value recorded was 0.0785 ppm from Kente borehole. Other values obtained did not exceed the 0.3 mgL^{-1} level recommended by SON for iron in drinking water. Mercury had the least amount of metal analyzed from all the water samples in the area under study. The mean arsenic levels in all the water analyzed do not exceed the standard limit. Generally, the amount of metals in the water samples increased in the order: River > well > borehole. This clearly shows that water samples from river are prone to pollution with metals while the boreholes and well samples are of high quality. The high level of metals in river samples is suggested to be due to rampant dumping of wastes into the river directly or its tributaries containing various metals thereby increasing its concentration.

The results of the physico-chemical parameters for all the water samples analyzed are presented in Tables 2 and 4. The pH of sampleis a measure of the acidity/alkalinity of a solution and is a function of dissolved materials. It is an important parameter which determines the suitability of water for various uses. According to Pawar *et al.* (2012), any water which has pH value of more than 9 or less than 4.5 is rendered not suitable for use. In the present study, the mean pH values in all the water samples analyzed fluctuated in the range of 6.65 – 8.80 were most of the samples are slightly alkaline and some have a level of acidity. However, the pH values obtained are within the SON specification. The pH results obtained compare favourably with the findings of Aremu *et al*. (2012a), Oko *et al.* (2014) and Akogwu *et al.* (2015). Alkalinity refers to the quantity of ions in water that will react to neutralize hydrogen ions. Large quantity results in imparting bitter taste to water. The mean alkalinity values obtained for both the wet and dry seasons in this work conform well to the SON recommended maximum value of 200 mgL^{-1} for drinking water. Excessive alkalinity has been found to cause eye irritation in human and chlorosis in plants (Sisodia and Moundiotiya, 2006). Temperature of water is an important parameter that needs to be ascertained because it can affects aquatic biochemical reactions (Chandaluri *et al.*, 2010). The mean temperature results for both Hospital Ward and Kente water samples are above the SON permissible limit of ambient temperature (25 ºC). Turbidity is the cloudness of water samples. The mean turbidity and suspended solids values were generally low during the wet and dry season in the samples of water from Hospital Ward wells and boreholes. The mean values of the turbidity of well and borehole water samples from Kente indicate higher value compared with the standard limit set by SON. In fact an abnormal result of suspended solids and turbidity values (640 and 450 mgL^{-1}) were obtained in the Hospital Ward river samples during the dry season. These abnormal values may probably be due to unnecessary discharge of sewage in addition to presence of inorganic solids such as clay and silt into the hospital river. Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are vital parameters normally used in assessing the contamination of both ground water and surface water (Aremu *et al.*, 2011b; Asuquo and Etim 2012). Clearly, the mean values obtained in this study are higher than the WHO recommended standards.

Table 3: Metal concentration (ppm) in water samples from Kente wells, boreholes and river

Wet Season

Mineral	KWS1	KWS2	KWS3	Mean value	KBHS1	KBHS2	KBHS3	Mean value	KRS	SON Standard
Cd	0.0023	0.0022	0.0022	0.0022	0.0016	0.0018	0.0016	0.0017	0.0029	0.003
Pb	0.0193	0.0188	0.0191	0.0191	0.0049	0.0054	0.0057	0.0053	0.2718	0.010
As	0.0025	0.0024	0.0024	0.0024	0.0010	0.0011	0.0009	0.0010	0.0051	0.010
Fe	0.0421	0.0408	0.0416	0.0415	0.0288	0.0304	0.0314	0.0302	0.0785	0.300
Cu	0.0018	0.0017	0.0018	0.0018	0.0008	0.0007	0.0070	0.0028	0.0062	1.000
Hg	0.0003	0.0003	0.0002	0.0003	0.0001	0.0001	0.0001	0.0001	0.0007	0.001
Mn	0.0219	0.0224	0.0216	0.0220	0.0102	0.0106	0.0102	0.0103	0.0405	0.200

Dry Season

Mineral	KWS1	KWS2	KWS3	Mean value	KBHS1	KBHS2	KBHS3	Mean value	KRS	SON Standard
Cd	0.0027	0.0025	0.0024	0.0025	0.0014	0.0016	0.0011	0.0014	0.0031	0.003
Pb	0.0211	0.0194	0.0204	0.0203	0.0044	0.0046	0.0047	0.0046	0.2845	0.010
As	0.0034	0.0028	0.0027	0.0030	0.0009	0.0012	0.0010	0.0010	0.0048	0.010
Fe	0.0462	0.0428	0.0421	0.0437	0.0204	0.0282	0.0285	0.0257	0.0683	0.300
Cu	0.0017	0.0023	0.0014	0.0018	0.0006	0.0005	0.0041	0.0017	0.0053	1.000
Hg	0.0003	0.0005	0.0001	0.0003	0.0001	0.0001	0.0001	0.0001	0.0005	0.001
Mn	0.0241	0.0235	0.0225	0.0234	0.0097	0.0101	0.0092	0.0097	0.0385	0.200

HWS= Hospital well samples; HBHBS= Hospital borehole samples; HRS= Hospital river samples

Table 4: Levels of physicochemical parameters in the water samples from Kente wells, boreholes and river

Wet Season

Parameter	KWB1	KWB2	KWB3	Mean value	KBHB1	KBHB2	KBHB3	Mean Value	KRB	SON Standard
Tempt. (ºC)	28.0	28.10	28.20	28.10	28.3	28.3	28.0	28.20	28.9	25
Turbidity (NTU)	1	6	24	10.33	5	12	1	6.00	68	
Suspended solids (mgL^{-1})	0	4	10	4.67	2	5	0	2.33	44	
TDS (mgL^{-1})	29.7	29.9	30.00	29.87	20.8	26.4	24.8	24.00	28.4	200
Conductivity (μScm^{-1})	76.00	77.00	78.00	77.00	61.4	70.6	72.8	68.27	70.9	10
pH	7.50	7.40	7.46	7.45	7.88	7.10	7.22	7.40	6.62	6.5-8.5
NO_3-N (mgL^{-1})	27.6	28.40	29.60	28.53	20.6	27.8	29.4	25.93	30.4	
Phosphate (mgL^{-1})	0.80	0.92	1.04	0.92	0.54	0.66	0.74	0.65	0.88	45
Chloride (mgL^{-1})	28.90	29.10	29.90	29.3	27.1	28.4	25.6	27.03	37.4	200
Alkalinity (mgL^{-1})	10.40	9.80	10.00	10.07	9.80	8.80	9.00	9.20	7.80	200
Hardness (mgL^{-1})	100	100	100	100.00	60	100	100	86.67	60	100
COD (mgL^{-1})	64	98	102	88.00	40	40	56	45.33	142	10
DO (mgL^{-1})	5.00	4.80	4.70	4.83	4.5	4.4	4.5	4.47	5.6	
BOD (mgL^{-1})	32	49	51	44.00	20	20	28	22.67	71	10

Dry Season

Parameter	KWB1	KWB2	KWB3	Mean value	KBHB1	KBHB2	KBHB3	Mean value	KRB	SON Standard
Tempt. (ºC)	29.00	29.10	29.20	29.10	30.0	31.0	29.0	30.00	30.1	25
Turbidity (NTU)	15	4	16	11.67	3	10	0	4.33	10	
Suspended solids (mgL^{-1})	7	1	12	6.67	1	4	0	1.67	4	
TDS (mgL^{-1})	30.10	30.70	30.50	30.43	23.0	27.1	25.0	25.03	28.7	200
Conductivity (μScm^{-1})	77.00	78.10	80.10	78.40	63.9	73.0	73.1	70.00	71.0	10
pH	7.81	7.22	7.41	7.48	6.60	7.00	7.18	6.93	6.00	6.5-8.5
NO_3-N (mgL^{-1})	24.00	28.80	26.20	26.33	18.0	22.4	25.2	21.87	20.8	
Phosphate (mgL^{-1})	0.87	0.98	1.12	0.99	0.61	0.70	0.78	0.70	0.91	45
Chloride (mgL^{-1})	29.70	30.00	30.10	29.93	29.0	29.7	25.7	28.13	39.7	200
Alkalinity (mgL^{-1})	11.00	10.80	10.20	10.67	9.20	8.60	8.80	8.87	7.60	200
Hardness (mgL^{-1})	120	100	120	113.33	80	100	120	100.00	100	100
COD(mgL^{-1})	68	82	112	87.33	32	36	44	37.33	84	10
DO (mgL^{-1})	5.4	5.00	5.10	5.17	5.6	4.5	4.8	4.97	5.8	
BOD(mgL^{-1})	34	41	56	43.67	16	18	22	18.67	42	10

HWS= Hospital well samples; HBHBS= Hospital borehole samples; HRS= Hospital river samples

Consequently, the water samples are polluted with respect to BOD and COD. Hence it is possible that the water samples will have bad odour with reduced oxygen content for aquatic organisms. Hardness is a property of water which can hinder formation of lather with soap due to precipitation of insoluble calcium and magnesium salts. The mean hardness values in the current study areas during both dry and wet seasons were mostly higher than the prescribed limit of 100 mgL^{-1} by WHO. Hardness in water is majorly caused by ions of calcium, magnesium, bicarbonate, chloride, sulphates and carbonate. Chloride concentration is widely used as a parameter in assessing water quality and higher values of indicating higher degree of organic pollution (Chandaluri *et al.,* 2010). In the present investigation, the mean amount of chloride ranged from 27.03 – 114.7 mgL^{-1} and the values are within the SON guidelines. Conductivity of water refers to its current carrying capacity and is directly related to the concentration of ionized salts in water. According to SON guidelines, the maximum desirable limit of conductivity in drinking water is 1000 μScm^{-1}. This shows that the mean conductivity values obtained are within recommended standards. The mean total dissolved solids (TDS) in the water samples analyzed ranged between 25 – 162.1 mgL^{-1} and the values are within the recommended standards. Akogwu *et al.* (2015) analyzed some borehole water samples in Wukari and obtained TDS values which are higher than in the present study. High value of TDS in drinking water is as a result of sewage and urban run-off and chemical used during water purification (Asuqou and Etim, 2012).

Conclusion

The present work is based on investigation of the heavy metal contents and physico-chemical parameters of three water sources (boreholes, wells and river) from Kente and Hospital Ward areas all in Wukari LGA, Taraba state, Nigeria. The study has revealed heavy metals (Cd, Pb, As, Fe, Cu, Hg, Mn) in the water samples at various level of concentrations. The concentrations of the metals analyzed were found to be higher in all water samples from river than that of metals in the borehole and well samples. Thus, we suggest that water from the river sources studied will not be suitable for domestic use and therefore render such water unfit for direct consumption unless it is treated. Furthermore, the results revealed that some metals and physico-chemical parameters analyzed are above the SON limit for drinking water. Therefore, the findings in this research work will be important for both government and academia consultation in monitoring the water quality against any breakout of water borne diseases in the studied areas.

Acknowledgement

Authors are grateful to the Tertiary Education Trust Fund (TETFund) through their Employer, Federal University Wukari for the financial support given them to carry out this study.

Conflict of Interest

The authors declare that there are no conflicts of interest.

References

Abimbola AF, Odukoya AM. & Adesanya OK 2002. The environmental Impact assessment of waste disposal site on ground water in Oke, Ado and Lagos, southwestern Nigeria. Proceedings 15th Annual conference Nigerian Association of Hydrogeologists Kaduna, Nigeria, p. 42.

Achadu OJ, Ako FE & Dalla CL 2013. Quality Assessment of Stored Harvested Rainwater in Wukari, North-Eastern Nigeria: Impact of Storage Media. *J. Envtal. Sci., Toxicol. & Food Techn.*, 7(5): 25-32.

Adekunle IM, Arowolo TA, Ndahi NP, Bello B & Owolabi DA (2007) Chemical characteristics of humic acids relations to lead, copper and cadmium levels in contaminated soil of South west Nigeria. *Annals of Environmental Sci.*, 1: 23–34.

Akaahan TJ, Oluma HOA & Sha'Ato R 2010. Physicochemical and bacteriological quality of water from shallow wells in two rural communities in Benue State. *Pak. J. Anal. Environ. Chem*. 11(1): 73-78.

Akogwu SA, Goler EE, Ochefu AA & Awudu VN 2015. Assessment of Ground Water Quality of some Boreholes in Wukari Township, Taraba State, Nigeria, *Global J. Biosci. & Biotech.*, 4(2): 168-171.

Aremu MO, Opaluwa OD, Nghargbu K & Yahuza AH 2012. Analysis of ground-water and stream for physic-chemical parameters in Doma LGA of Nasarawa State, Nigeria. *NSUK J. Sci. & Techn.*, 2(1&2): 217-225.

Aremu MO, Gav BL, Opaluwa OD, Atolaiye BO, Madu PC & Sangari DU 2011. Assessment of physicochemical contaminants in waters and fishes from selected rivers in Nasarawa State, Nigeria. *Res. J. Chem. Sci.*,1(4): 6-17.

Asuquo JE & Etim EE 2012. Physico-chemical and bacteriological analysis of borehole water in selected areas in Uyo metropolis. *Int. J. Modern Chem.*, 2(1): 7-14.

APHA 1998. Standard methods for the examination of water and waste water, (20th edtition). American Public and Health Association, pp. 1270.

Bellinger DC 2008. Lead Neurotoxicity and Socioeconomic Status: Conceptual and Analytical Issues. *Neurotoxicology*, 29(5): 828-832.

Brown MJ & Margolis S. 2012. Lead in drinking water and human blood lead levels in the United States. Centres for Disease Control and Prevention. Morbidity and Mortality Weekly Report. Supplement 61. August 10, 2012.

Chandaluri SR, Sreenivasa RA, Hariharann VLN & Manjula R 2010. Determination of water quality index of some areas in Guntur district Andhra Pradesh. *IJABPT*, 1: 79-86

Edet EJ, Etim EE & Titus OM 2012. Bacteriological and physic-chemical analyses of streams water in Nduetong Oku community, Uyo, Akwa Ibom state, Nigeria. *Int. J. Modern Chem.*, 3(1): 65-73.

Emmanuel SA 2011. Ground water quality assessment of some sampled boreholes in five rural communities of Misau local government area of Bauchi State, Nigeria. *Int. J. Envtal. Issue*s, 8(2): 45–51.

Food & Agricultural Organizaion (FAO) 1997. Chemical Analysis Manual for Food and Water, 5th ed. FAO Rome, 1: 20-26.

Geldreich D 1981. *E. coli* detection from river water. Environmental science publication. *Springer Netherlands J.*, 43: 139-145.

Kolade OA 1992. Shallow Wells and Supplementary Sources of Water in Nassarawa. M.Sc. Thesis of Jos, Nigeria, pp. 8-11.

Morokov, VV 1987. Assessment of river pollutant source. *Journal of Water Resources*, 14, 1027-1041.

Oko OJ, Aremu MO, Odoh R, Yebpella G & Shenge GA 2014. Assessment of water quality index of borehole and well water in Wukari town, Taraba State, Nigeria. *J. Envt. & Earth Sci.*, 4(5): 1–9.

Pawar RD, Waghulade GP & Patil AK 2012. *AJCER*, 5(1-2): 71-73.

Ryu H, Alam A & Abbaszadegan M 2005. Microbial characterization and population changes in Non-portable reclaimed water distribution systems. *Environ. Sci. Technol*., 39:8600–8605.

Sisodia R & Moundiotiya C 2006. Assessment of the water quality index of wetland Kalakho Lake. Rajasthan. *India. J Environ Hydrology*. 14(23): 1.

Standards Organization of Nigeria (SON) 2007. Nigerian standard for drinking water quality.

World Health Organization (WHO) 2010. Guidelines for drinking water quality, WHO Geneva.