Special Conference Edition, November, 2017
http://dx.doi.org/10.4314/bajopas.v10i1.88S

Bayero Journal of Pure and Applied Sciences, 10(1): 455 - 561
ISSN 2006 – 6996

INCIDENCE OF HEAVY METALS IN KANO METROPOLIS DRINKING WATER SOURCES

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ABSTRACT
Contamination of Kano metropolis drinking water sources with excessive heavy metals was evaluated using standard laboratory procedures. A total of 72 samples comprising of 24 each of Borehole, Tap and Well water from 8 municipal LGAs (namely; Dala, Fagge, Gwale, Kano municipal, Kumbotso, Nassarawa, Tarauni and Ungogo) were analyzed for the presence of heavy metals (viz; Chromium, Iron, Lead and Zinc). Chromium and Lead concentrations for the samples evaluated (Borehole, Tap and Well) were found to exceed the World Health Organizations (WHO) limits of 0.05 and 0.01mg/l respectively which might be attributed to corrosion of brass fittings of certain submersible pumps and pipes used in borehole and taps specifically. The contamination of well with heavy metals might be due to seepage of sewage into these sources as domestic sewage might be of kitchen and toilet origin heavily accumulated with soaps of heavy metals constituents. Heavy metal contamination with Chromium and Lead calls for serious public health implications for the effects of heavy metals contamination in drinking water.
Keywords: Drinking water, Kano, Chromium, Lead, Iron and Zinc.

INTRODUCTION

Water is essential to life as emphasized by the World Health Organization (WHO, 2008) therefore, its provision in adequate, safe and qualitative condition is important for public health (WHO, 2017) lack of which could pose a serious challenge to sustainable development (Deutch Welle, 2017). About half a billion individuals have no access to safe drinking water mostly those in developing countries (WHO, 2017; Deutch Welle, 2017). This leads to various water borne infections. Rapid urbanization, industrialization and growing population are the cause for discharge of pollutants into the environments and into water bodies and drinking water sources (OCHA, 2010). Water pollution has been a major challenge which requires ongoing evaluation (Okonko *et al.*, 2008).Presence of excessive amounts of heavy metals such as Pb, Cr, and Fe causes chronic poisoning of water (Ellis 1989) resulting in a number of hazards to humans (Vaishaly *et al.*, 2015). One of the major serious health problems is the contamination of water resources available for household and drinking purposes with these metals (Guptaa 2008). Previous work on ground water from Kano, (Garba *et al.,* 2014) has reported high concentration of some heavy metals. This present work was set to explore a wider scope of the various sources of drinking water in all the Municipal Local Government Areas to include well, borehole and tap waters.

Sample Collection and Handling: Physicochemical Analyses

Water samples were collected from selected boreholes, taps and wells of the eight (8) local government areas namely: Dala, Fagge, Gwale, Kano municipal, Kumbotso, Nassarawa, Tarauni and Ungogo).Prior to this, the study area was surveyed to identify functional water sources frequently used. Water samples (250ml) were collected in amber bottles. The collection was carried out following standard procedures (Cheesbrough, 2009).Bottles were tightly closed, labeled accordingly and preserved in cooler in ice and transported to the laboratory for analysis. Water samples collected for analyses were preserved in (1%) nitric acid and placed in ice for transport to the laboratory. Temperature, pH and electric conductivity were analyzed at sampling points using standard analytical method ((APHA, 1992)). The temperature reading was measured using mercury in glass thermometer. The thermometer was rinsed with distilled water and it was then dipped into the water and the reading was recorded (APHA, 1992). PH meter (JENWAY MODEL No. 3530) was used to determine the pH unit of the water samples. The meter was switched on, the electrode of the meter was dipped into distilled water to standardize the electrode. The electrode was then dipped into the water sample and values were recorded (APHA, 1992).

This was measured using digital conductivity meter (JENWAY MODEL No. 470). The meter was switched on and then standardized using 0.1N KCl. The electrode was then immersed into the water sample and the conductivity reading was recorded (APHA, 1992). The total dissolved solid was determined using a conductivity meter (JENWAY MODEL No. 470). The programme menu of the meter was switched to total dissolved solids option. The electrode was standardized using distilled water and the electrode was then immersed into the water sample as the total dissolved solid was recorded (APHA, 1992). Fifty (50) ml of the sample water was poured into a beaker. The electrode of the D.O meter was rinsed with the sample water and dipped into the water. The dissolved oxygen (D.O) value was recorded as ($D.O_1$) and was taken again after five days ($D.O_5$). The B.O.D was obtained by deducting the value of the fifth day reading ($D.O_5$) from the first value ($D.O_1$) (APHA, 1998).

Chloride determination (Agumetric method):
Preparation of Reagents

Potassium Chromate Indicator: Five (5) mg of K_2CrO_4 was dissolved in distilled water and saturated solution of $AgNO_3$ was added. The solution was filtered and dissolved to 100ml using distilled water.Standard silver nitrate solution (0.05M):Silver nitrate (8.49gm) was dissolved and diluted to 1 liter distilled water.

The titration was done using the prepared solutions. Fifty (50) ml of the water was used and Silver nitrate was used for the titration using Potassium chromate as indicator (Bingham, 1982).

Phosphate Determination:
Preparation of Reagent A

Twelve (12g) of ammonium molybdate was dissolved in 250ml of distilled water. Into 100ml distilled water, 0.2908g of antimony potassium tartrate was added. The two dissolved reagents were added to 100ml 2.5M H_2SO_4 .It was then mixed thoroughly and made to 2 liters. The mixture was stored in Pyrex glass vessel in a dark cool compartment.

Preparation of reagent B

Ascorbic acid (1.056g) was dissolved in 200ml of reagent A and stirred.

Five (5) ml of the water sample was pippetted and introduces into 50ml volumetric flask. Distilled water was added to bring up the volume to 40ml and 8ml of reagent B was mixed thoroughly. The absorbance of the solution was observed at 882nm after 30minutes (Heand Honeycutt 2005).

Determination of Heavy Metals Using Atomic Absorption Spectrometry (AAS) Method:
Digestion of Water Samples

Five (5) ml of nitric acid HNO_3 was added to 100 ml of the water sample and heated until about 25ml of the solution remains. The solution was filtered and made to 100ml using distilled water.

Lanthanum Stock Solution

Fifty (50) ml of distilled water was used to wet 59.65g of La_2O_3 and 250ml of concentrated HCl was slowly added to the solution under a fume hood. The solution was diluted to 1 liter with distilled water.

Procedure: Two (2) ml of azomethine-H reagent was added to the solution and mixed thoroughly. The absorbance was read at 240nm after 30 minutes (Perkin-Elmer Corp. 1968).

RESULTS

Results for the physicochemical analysis are presented in Table 1.0. All the physical parameters of the three sources evaluated were found to be within the WHO and NSDWQ standard. Mean values for temperature and pH were very close for all the sources. However, Electric conductivity mean values showed marked variation with the tap water having the lowest values of 115.88µs/cm as compared to that obtained for the borehole (643.13µs/cm) and well water (753.38 µs/cm). This was also true for T.D.S with tap water having the least as compared to the other two sources with 429.38 mg/l and 372.38mg/l for well and tap waters respectively. This observation confirms the influence of Total Dissolved Solids on Electric conductivity. Chloride concentrations were within the WHO and NSDWQ standards of (250 mg/l). Chloride mean value showed marked variation with well water with the highest value (32mg/l) compared to that of borehole and tap waters (23.22mg/l and 23.71mg/l) respectively. Phosphate mean values exceeding the WHO and NSDWQ limits (5mg/l) were that of tap and well waters (7.57mg/l and 5.66mg/l) respectively with tap water having the highest mean value while borehole water has the least mean value (2.76mg/l). Two water sources (well; 0.53mg/l and tap; 0.68mg/l) have mean values for Manganese higher than the recommended value (0.5mg/l). Well water has the least mean value (0.49mg/l) relatively very close to the WHO and NSDWQ standard of 0.5mg/l. iron mean values for the three water sources were all within the WHO and NSDWQ standard (0.3mg/l). Borehole water had the highest mean value (0.28mg/l) followed by tap water (0.24mg/l) while well water had the lowest mean value (0.22mg/l). It can be observed that there is no wide variation within the mean values of the three sources.

Zinc mean values however showed marked variations. Borehole, tap and well water sources had values within the WHO standard (3mg/l) at 1.27mg/l, 0.37mg/l and 0.13mg/l respectively with borehole water with the highest mean value (1.27mg/l). Chromium and Lead mean values for all the three water sources were found higher than the WHO standards (0.05mg/l and 0.01mg/l) respectively. Chromium mean values for borehole, tap and well waters were found to be (0.88mg/l, 0.68mg/l and 0.13mg/l) respectively while lead mean values for borehole, tap and well were found to be (0.28mg/l, 0.27mg/l and 0.19mg/l) respectively. Borehole and tap water sources for chromium and lead mean values showed close variations (borehole; 0.88mg/l and tap; 0.68mg/l). This is also similar for lead mean concentrations in both borehole and tap water sources (borehole; 0.28mg/l and tap; 0.13mg/l) respectively. However, well water chromium and lead mean values showed close variation at 0.13mg/l and 0.19mg/l respectively with least mean values for both parameters.

Mean physicochemical parameters results for the eight Kano metropolis Local Government Areas (LGAs) are as presented in Table 2.0. Nassarawa and Ungogo LGAs have mean temperature values above the WHO and NSDWQ standard (27-28°C) at 28.03°C and 28°C respectively. Tarauni LGA had the least mean value (27.17°C). Hydrogen ion (pH) mean values for the eight LGAs were all within the WHO standard (6.5-8.5 pH unit). Tarauni LGA however had the highest mean value (7.83 pH unit) while Gwale LGA had the least mean value (6.90 pH unit). It is also observed that the pH units for the eight LGAs ranged from 6.90-7.86 pH units with a mean value of 7.37 pH units and a standard deviation of 0.25 as there is no marked variation within the mean values of the eight LGA waters evaluated for pH concentration. The mean electric conductivity (E.C) value for all the LGAs were all within the WHO and NSDWQ standard (1000µs/cm). Fagge LGA had the highest mean value (597µs/cm) while Tarauni LGA had the least mean value (427.67µs/cm). All E.C mean values had a mean value (504.13µs/cm) and a range of (427.67 µs/cm-597 µs/cm) with a standard deviation of 53.54 signifying a marked variation within the mean values of the eight LGA. The Total Dissolve Solids (T.D.S) like the E.C mean values were all within the WHO standard (500mg/l) with Ungogo LGA with the highest mean value (456.33mg/l) while Gwale LGA had the least mean value (147mg/l). Dissolved Oxygen (D.O) mean values for all the LGAs were within the WHO standard (7.5mg/l). Kano municipal LGA had the highest mean value (3.3mg/l) while Kumbotso LGA had the least mean value (2.62mg/l). The D.O mean values for the eight LGAs have a range of (2.62 mg/l - 3.3 mg/l) and a mean of (2.93mg/l) with a standard deviation (0.23), there is no marked variation within the D.O mean values. Biological Oxygen Demand (B.O.D) mean values were all within the WHO standard (2-4mg/l) and a range of (0.75-1.03mg/l) with Tarauni LGA having the highest mean value (1.03mg/l) and Fagge LGA with the least mean value (0.75mg/l). The LGAs had a mean of (0.93mg/l) and a standard deviation of (0.09), variations in mean values were found to be relatively close. The mean values for all the eight LGAs were found to be within the WHO standard for chloride (250mg/l). Nassarawa LGA had the highest mean value (28.25mg/l) while Tarauni LGA had the least mean value (25.11mg/l). Phosphate mean values were all within the WHO standard (5 mg/l). Gwale LGA had the highest mean value (4.96 mg/l) while Tarauni and Kumbotso LGAs have the least mean values (4.75 mg/l). All the LGAs have Manganese mean values above the WHO standard (0.5mg/l) except for Fagge LGA (0.43mg/l) with the least mean value while Dala LGA had the highest mean value (0.66 mg/l). However, Iron and Zinc mean values are within the WHO standard (0.3 mg/l and 3 mg/l) respectively. Kano municipal LGA had the highest Iron mean value (0.37 mg/l) while Nassarawa LGA had the least Iron mean value (0.16 mg/l). Gwale LGA had the highest Zinc mean value (0.92 mg/l) while Dala LGA had the least Zinc mean value (0.12 mg/l). Chromium and Lead mean values had mean values above the WHO standard (0.05 mg/l and 0.01 mg/l). Ungogo LGA had the highest chromium mean value (0.92 mg/l) while Ungogo had the least mean value (0.54 mg/l). Fagge LGA had the highest lead mean value (0.30 mg/l) while Ungogo LGA had the least mean value (0.15 mg/l).

Table 1.0 Mean Physicochemical Constituents for Kano Metropolis Drinking Water Sources

Parameters	Borehole water	Tap water	Well Water	Mean±S.D	Range	WHO Standard
Temperature (°C)	27.79	27.71	27.57	27.69±0.09	27.71-27.79	27-28
p^H	7.1	7.43	7.64	7.30±0.22	7.1-7.64	6.5-8.5
EC (μs/cm)	643.13	115.88	753.38	504.13±278.19	115.88-753.38	1000
T.D.S (mg/l)	643.13	65.34	429.38	1056.71±1154.19	65.34-2675.38	500
D.O (mg/l)	2.85	2.59	2.47	2.64±0.16	2.47-2.85	7.5
B.O.D (mg/l)	1.14	0.43	1.21	0.93±0.35	0.43-1.21	-
Cl^- (mg/l)	23.22	23.71	32	26.31±4.03	23.22-32	250
PO_4^{3-}(mg/l)	2.76	7.57	5.66	5.33±1.98	2.76-5.66	5
Mn (mg/l)	0.54	0.68	0.49	0.57±0.08	0.49-0.68	0.5
Fe (mg/l)	0.28	0.24	0.22	0.25±0.02	0.22-0.28	0.3
Zn (mg/l)	1.27	0.37	0.13	0.59±0.49	0.13-1.27	3
Cr (mg/l)	0.88	0.68	0.13	0.56±0.32	0.13-0.88	0.05
Pb (mg/l)	0.28	0.27	0.19	0.25±0.40	0.19-0.28	0.01

Key: EC = Electric conductivity; TDS = Total dissolved solids; DO = Dissolved oxygen; BOD = Biological oxygen demand; Cl- = Chloride ions; PO_4^{3-} = Phosphate ions; Mn = Manganese; Fe = Iron; Zn = Zinc; Cr =Chromium and Pb = Lead.

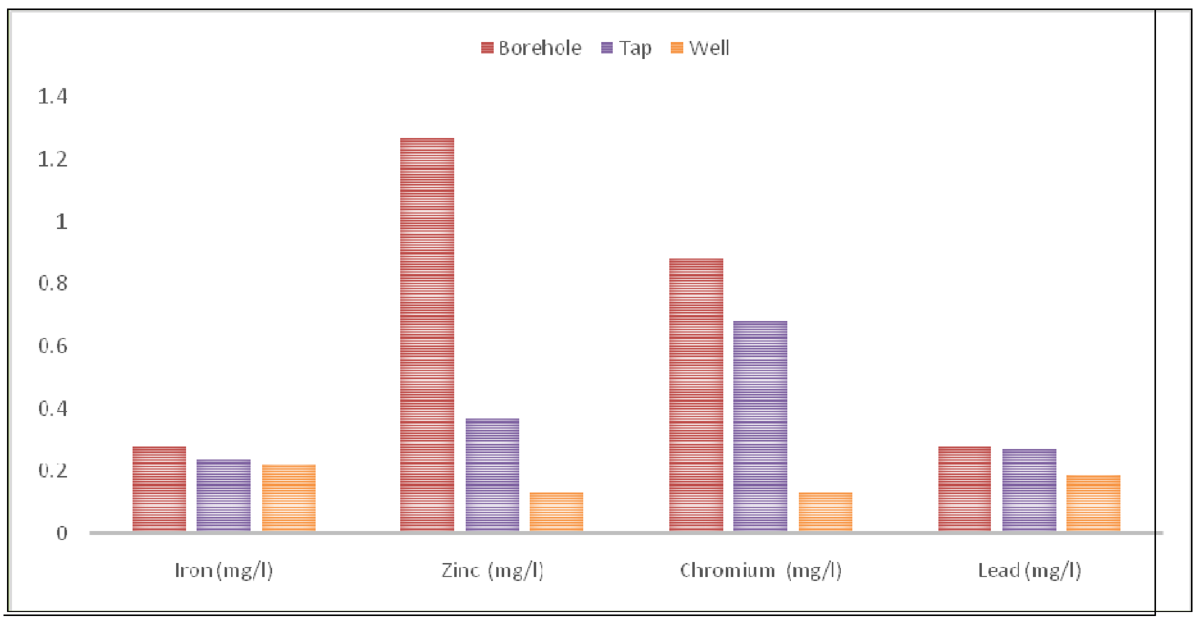

Figure 1.0 Mean Heavy Metals Concentrations in Kano Metropolis Drinking Water Sources

Table 2.0; Mean Physicochemical Constituents of Drinking Water for Kano Metropolis in LGA

Parameters	Dala	Fgg	Gwl	Kbt	Kmc	Nsr	Trn	Ugg	Mean±S.D	WHO Std.
Temp. (°C)	27.3	27.93	27.3	27.8	27.98	**28.03**	27.17	**28**	27.69±0.34	27-28
pH	7.3	7.2	6.9	7.33	7.5	7.5	7.83	7.36	7.37±0.25	6.5-8.5
E.C(µs/cm)	530.67	597	467	484	447.67	527.67	427.67	551.33	504.13±53.54	1000
T.D.S (mg/l)	335.96	322.86	147	295.9	358.5	429.67	327.3	456.33	334.19±87.54	500
D.O (mg/l)	3.17	3.17	2.69	2.62	3.31	2.92	2.86	3.08	2.98±0.23	7.5
B.O.D (mg/l)	0.91	0.75	0.92	1.04	0.88	0.88	1.03	1.01	0.93±0.09	2.0-4.0
Cl^- (mg/l)	25.77	25.21	27.77	26.7	27.05	28.25	25.11	23.93	26.22±1.38	250
PO_4^{3-}(mg/l)	**5.7**	**5.84**	4.96	4.76	**5.15**	**5.43**	4.76	**5.96**	5.32±0.45	5
Mn (mg/l)	**0.66**	0.43	**0.63**	**0.52**	**0.59**	**0.58**	**0.54**	**0.55**	0.56±0.06	0.5
Iron (mg/l)	0.2	0.26	0.25	0.26	**0.37**	0.16	0.19	0.26	0.25±0.06	0.3
Zinc (mg/l)	0.12	0.35	0.92	0.79	0.36	0.84	0.94	0.39	0.59±0.29	3
Cr (mg/l)	**0.72**	**0.93**	**0.54**	**0.85**	**0.85**	**0.58**	**0.74**	**0.98**	0.77±0.15	0.05
Lead (mg/l)	**0.28**	**0.3**	**0.2**	**0.26**	**0.17**	**0.26**	**0.16**	**0.15**	0.22±0.05	0.01

Key: EC = Electric conductivity; TDS = Total dissolved solids; DO = Dissolved oxygen; BOD = Biological oxygen demand; Cl- = Chloride ions; PO_4^{3-} = Phosphate ions; Mn = Manganese; Fe = Iron; Zn = Zinc, Cr =Chromium and Pb = Lead.Kbt = Kumbotso; Kmc = Kano Municipal; Nsr = Nasarawa; Trn = Tarauni and Ugg = Ungogo; .

As stated in table 1.0, Iron concentration was found highest for borehole water sources (0.28mg/l), tap water had (0.24mg/l) while well water had the least concentration (0.22mg/l). Zinc concentrations were all found within the WHO with borehole water having the highest concentration (1.27mg/l), tap water sources had (0.37mg/l) while well water had the least (0.3mg/l). Concentrations for Chromium and Lead for all the water sources exceed the WHO limit (0.05mg/l and 0.01mg/l respectively). However, the highest chromium concentration was recorded for borehole water sources (0.88mg/l), well water sources had the least concentration (0.13mg/l) while tap water sources had (0.68mg/l). Lead concentrations were relatively close with borehole water sources also with the highest concentration (0.28mg/l), tap water had (0.27mg/l) while well water had the least concentration (0.19mg/l).

DISCUSSION

Except for Nassarawa LGA with a temperature mean value slightly exceeding upper limit of 28.03°C, all the mean temperature values recorded for all samples studied in this work are within the WHO and NSDWQ limits which is 28.00°C.Highest mean temperature value recorded in this work (28.03°C) is slightly higher than the finding of Amadi (2014), who studied the bacteriological and physicochemical quality of well water from villages in Edati, Niger State, North-central Nigeriawho reported mean temperature of 28.00°C.

Mean pH values for this research were all within the WHO and NSDWQ limit. High pH units might be attributed to the presence of Iron in water, as corrosion rates increases with pH (Nwachukwu *et al.,* 2014).

The highest mean value of electric conductivity (753.38µs/cm) for this research from well water is slightly below the finding of Ehiowemwenguan *et al.* (2014) (775µs/cm) as well as higher than the finding of Amadi *et al.* (2014) at (347 µs/cm). Total dissolved solids (T.D.S) highest value was observed from Ungogo LGA (456.33 mg/l) is slightly lower to the finding of Sa'eed *et al.* (2014) who determined some physicochemical parameters and some heavy metals in boreholes from Fagge L.G.A of kano metropolis Kano State- Nigeria and reported a mean total dissolved solids of 475.15 mg/l. All chloride mean concentrations for this work were within the WHO and NSDWQ standards of (250 mg/l). Highest chloride mean value (32mg/l) for this research is slightly below to the finding of Amadi *et al.* (2014) at (24.25mg/l).

It is also not in conformity to the findings of Ehiowemwenguan *et al.* (2014) at (220mg/l) and Afandigeh *et al.* (2011) at (180mg/l).

Tap water sources recorded the highest manganese concentration (0.68mg/l), which is higher (0.0mg/l) to the findings of Amadi *et al.* (2014) who worked on the bacteriological and physicochemical analysis of well water from villages in Edati, Niger State, North-central Nigeria and that of Amori*et al* (2013) (0.4mg/l) who evaluated the quality of groundwater in Akwa, Anambra State, Nigeria.

The highest mean iron value for this study (0.37mg/l) is exactly similar to the finding of Amori *et al.* (2012) (0.37mg/l) and slightly higher to the finding of Ehiowemwenguan *et al.* (2014) (0.30mg/l).

Zinc highest mean value (1.27mg/l) is higher to the finding of Garba *et al.* (2014) who analyzed heavy metals contamination in Kano River (Upstream, Midstream and Downstream) and obtained (0.41mg/l) as the highest mean zinc concentration which is relatively closer to the finding of Amori *et al.* (2013) (1.73mg/l).

Highest chromium and lead mean values for this research were obtained at (0.88mg/l and 0.28mg/l) respectively. The chromium mean value was higher to the finding of Sa'eed *et al.* (2014) at (0.45mg/l) while the highest lead mean value was lower to the same author's finding (0.31mg/l) who determined the some physicochemical parameters and heavy metals in boreholes from Fagge LGA of Kano metropolis, Kano state Nigeria. Garba *et al.* (2014) highest chromium lead value (0.42mg/l) is lower to the chromium highest mean value in this work. Amori *et al.* (2013) lead concentration finding was higher compared to the finding in this work who obtained the concentration of lead from borehole water (0.95mg/l). It was also reported that heavy metals concentrations in drinking water might be attributed to corrosion of brass fittings of certain types of submersible pumps used in ground water. The contamination of well with heavy metals might be due to seepage of domestic sewage into these sources as domestic sewage might be of kitchen and toilet origin heavily accumulated with soaps of heavy metals constituents (Tam and Elefsiniotis, 2009). The health implication of these metals over a long period of time includes toxicity of nervous system, organ damage, high blood pressure, and delay in physical and mental development in children (Tchounwou *et al.*,2012; Hellandendu, 2017).

CONCLUSION

Chromium and lead had been detected in quantities that exceed the WHO standard acceptable limits for heavy metals concentration in drinking water.

Recommendations

1. Further research should be carried out to determine the possible means of remediating heavy metals concentrations in our drinking water.
2. There is need for routine monitoring of our drinking water sources for heavy metals to curve the incidences of outbreaks caused by chronic ailments caused by heavy metals.

REFERENCES

Afandigeh, A.I., Njar, G.N., Ewa, E.E., Eli, H.D., Iwara, A.I (2011) Assessment of water quality status of borehole in calabar south local government area, Cross River State *International Journal of Bioscience* (IJB) **1(5):** 71-76.

Amadi, A.N.,Ameh, I.M., Ezeagu, G.G (2014) Bacteriological and Physicochemical Analysis of Well water villages in Edati, Niger State, North Central Nigeria. *International Journal of Engineering Research and Development***10**(2):10-16.

APHA (1992)*Standard Methodology for the Examination of Water and Waste Water*: 18th edition, American Public Health Association and Water Environment Federation. Washington DC.

Amori AA, Oduntan OO, Okeyode IC, Ojo SO (2013). Heavy metal concentration of groundwater deposits in Odeda region, Ogun State, Nigeria. *Journal of Environmental Research and Management***4(5):**253-259.

Bingham, F. T. (1982) Bromine, Chlorine and Fluoride In: Methods of Soil Analysis *Agronomy,* **9:** 449 – 483 Soil Science Society, Madison, Wiscon USA

Cheesbrough, M. (2009) *District Laboratory Practice in Tropical Countries* (3rd edition), United States of America: Cambridge University Press, New York.

Deutch Welle (2017) *Charity: Half a billion people have no clean drinking water* *http://p.dw.com/p/2ZhFt*Accessed: 16/08/2017.

Eawag, (2011) *Putting geogenic contamination on the map,* Eawag news. http://www.eawag.ch/en/consulting/knowledge-and-technologytransfer/publications-for- practitioners/eawag-news-archive/

Ehiowemwenguan, G., Iloma, A.O., Adetuwo, J.O. (2014) Physicochemical and Bacteriological Quality of Borehole water in Eyean community Area of Edo State, Nigeria. *International Journal of Basics and Applied Sciences* **3(2):**60-68.

Ellis, K.V., (1989)*Surface Water Pollution and its Control* Macmillan press Ltd, Hound mill, Basingstoke, Hampshire and London, 3-18, pp 97,100,101 and 208.

Garba, I., Alagbe, S.A., Danbatta, A.U., (2014) Analysis of Heavy metals Contaminations in Kano River (Upstream, Midstream and Downstream) *Journal of Environment and Health Science* 4(17):1.

Guptaa, D. P., Sunita and J. P. Saharan, (2009) Physiochemical Analysis of Ground Water of Selected Area of Kaithal City (Haryana) *India Researcher*, 1(2), pp 1-5.

Hellandendu, J. M. (2017) Health Implications Of Water Scarcity In Nigeria. *European Scientific Journal* August edition vol. 8, No.18 ISSN: 1857 – 7881 (Print) e - ISSN 1857- 7431. P: 111 - 117

Nwachukwu, R. E., Ihedioha, J. N., Eze, I. S. and Agbazue V. E. (2014)Health Risk Assessment in Relation to Heavy Metals in Water Sources in Rural Regions of South East Nigeria. *International Journal of Physical Sciences* **9(6):** 109 - 116

Office for the Coordination of Humanitarian Affairs for the UN, OCHA (2010): *Water Scarcity and Humanitarian Action: Key Emerging Trends and Challenges* Occasional Policy Briefing Series Brief No. 4. P 1 – 15.

Okonko IO, Ogunnusi, TA, Adejoye OD, Shittu OB. 2008. Microbiological and Physicochemical Analysis of Different Water Samples Use for Domestic Purposes in Abeokuta, Ogun State and Ojota, Lagos State, Nigeria. *African Journal of Biotechnology* [AJB] 7 (5):617-621.

Radulescu, C. Dulama D., Stihi, C., Ionita ,I., Chilian, A., Necula, C. and Chelarescu E. D. (2014) Determination of Heavy Metal Levels in Water and Therapeutic Mud by Atomic Absorption Spectrometry. Romanian. *Journal of Physiology*. Vol. **59**, Nos. **9-10**, P. 1057-1066,

Sa'eed, M.D., Mahmoud, A.M. (2014) Determination of Some physicochemical parameters and Heavy metals in Boreholes from Fagge LGA of Kano metropolis Kano State, Nigeria *World Journal of Analytical Chemistry* 2 (2):42-46.

Sinha S.N and Biswas, M. (2011), Analysis of Physico-Chemical Characteristics to Study the Water Quality of a Lake in Kalyani,West Bengal, *Asian Journal of Experimental Biologica Sciences*, 2(1), pp 18-22.

TamY. S. and Elefsiniotis, P. (2009) Corrosion control in water supply systems: Effect of pH, alkalinity, and orthophosphate on lead and copper leaching from brass plumbing. *Journal of Environmental Science and Health, Part A:*Toxic/Hazardous Substances and Environmental Engineering **44**: 1251-1260.

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., and Sutton, D. J. (2012). Heavy Metals Toxicity and the Environment. *EXS*, *101*, 133–164. http://doi.org/10.1007/978-3-7643-8340-4_6

Vaishaly A. G., Mathew B. B. and Krishnamurthy, N.B. (2015) Health effects caused by metal contaminated ground water- Review Article. *International Journal of Advances in Scientific Research* ISSN: 2395-3616 (Online:www.ssjournals.com) Journal DOI: 10.7439/ijasr. P 61 – 64.

WHO (2008) *Guidelines for Drinking-water Quality, Incorporating 1st and 2nd Addenda, Volume 1, Recommendations, 3rd ed.* WHO: Geneva, Switzerland.

WHO (2017) Drinking-water. Fact sheet, Updated July 2017 http://www.who.int/mediacentre/factsheets/fs391/en/Accessed: 16/08/2017.

He, Z. and Honeycutt, C. W. (2005) A Modified Molybdenum Blue Method for Orthophosphate Determination Suitable for Investigating Enzymatic Hydrolysis of Organic Phosphates. *Communications in Soil Science and Plant Analysis,***36**: 1373–1383