ASSESSMENT OF GROUNDWATER QUALITY IN SHARADA INDUSTRIAL AREA OF KANO, NORTH-WESTERN NIGERIA

Supported by tetfund TERTIARY EDUCATION TRUST FUND

A. O. Amoo[1]*, Y. H. Gambo[1], A. O. Adeleye[1] and N. B. Amoo[2]
[1]Department of Environmental Sciences, Federal University Dutse, Nigeria
[2]Department of Surveying and Geo-informatics, Federal Polytechnics Ede, Nigeria
*Corresponding author: amoschom@mautech.edu.ng

Received: November 11, 2017 **Accepted:** May 13, 2018

Abstract: The current research examined the level of groundwater contamination in Sharada industrial area of Kano, Nigeria. Groundwater samples were collected, examined and analyzed for water quality parameters (physicochemical and heavy metals) and compared with permissible water quality standards (World Health Organisation (WHO); Nigeria Standard for Drinking Water Quality (NSDWQ); and National Agency for Food, Drug and Control (NAFDAC). A random sampling method was employed in collecting the samples from three (3) different locations of Sharada phase I, II and III. Heavy metals were determined using Atomic Absorption Spectrophotometer and titration was employed to determine physicochemical parameters while pH, electrical conductivity (EC) and temperature were measured in-situ. Results obtained from the analysis of the heavy metal in the sampled hand dug wells revealed mean concentration ranges of Cd(0.10-0.20 mg/l), Cr(0.0370-0.0925 mg/L), Pb(0.0650-0.1305 mg/L) and Zn(0.0280-0.0420 mg/L) while the sampled boreholes recorded mean concentration ranges of Cd(0.10mg/L), Cr(0.0925-0.1110 mg/L), Pb(0.0430-0.1085 mg/L) and Zn(0.0560-0.0830 mg/L). In comparison with standards requirement for water quality, it was found that some of the parameters were above the standard quality for water requirements. Analyses also revealed that, the mean concentration of heavy metals like (Cd Cr and Pb) were found to be above standard water quality requirement, while Zn level did not exceed the standard limits. In conclusion, improper discharge of untreated effluents in the environment could have led to the contamination levels by heavy metals and other parameters detected in this study. It is therefore recommended that industrial, domestic and agricultural effluents should be subjected to the required treatment standards and constant monitoring of disposal processes of both industrial and domestic effluents in the study area that would guarantee protection of groundwater resources in the locality should be implored.

Keywords: Heavy metals, groundwater, water quality, Sharada, North-western, Kano

Introduction

Water is an essential commodity that supports all forms of plant and animal life (Vanloon and Duffy, 2005). About 60% percent of human body is water as life began in water and life is nurtured with water (Fasunwon *et al*., 2010). Access to adequate safe drinking water is of prime importance to many governmental and international organizations and without doubt it is the principal component of primary health care and a basic component of human development as well as a pre-condition for man's success to deal with hunger, poverty and death (SOPAC/WHO, 2005). Water is primarily used for industrial, domestic, agricultural activities and necessary for sustainable economic development of an area as it is the next major support to life after air (Pritchard *et al.*, 2008).

The availability of pipe-borne water, borehole water and shallow wells in urban areas is an indication that water is a vital component of human existence. It is generally found from two major natural sources; Surface water such as fresh water lakes, rivers, streams and Ground water such as borehole water and well water (McMurry and Fay, 2004; Mendie, 2005). Provision of adequate and safe water for drinking is important for the development of any country (Pritchard *et al.*, 2008). The quality of water that human beings ingest is critical in determining the quality of their lives (Fetter, 1994). The World Health Organization has frequently insisted that the single major factor adversely influencing the general health and life expectancy of a population in many developing countries is the ready access to potable water (Hoko, 2005). The usefulness of water for a particular purpose is determined by the water quality (Fetter, 1994).

According to Jones (1997), groundwater is used by about 1.5 billion people worldwide. The sources of groundwater contamination are many and the contaminants are numerous. Increasing industrialization has been accompanied throughout the world by the extraction and distribution of mineral substances from their natural deposits. Subsequent to contamination, water sources undergo chemical changes through technical processes, finely dispersed and in solutions by way of effluent, sewage, dumps and dust into the water, the earth and the air and finally into the food chain (Fetter, 1994). It is against this backdrop that this study was conducted to assess the physicochemical quality and the possible presence of heavy metals in Sharada industrial area groundwater with view to compare the results of examined parameters with acceptable standards.

Materials and Methods

Study area

Kano metropolis covers an area of about 600 km^2 located between longitude 8º and 9ºE and latitude 10º and 12ºN. Kano industries are concentrated in three industrial estates which are: Bompai, Challawa and Sharada. The climate area of Kano is the tropical wet and dry type with dry season between for 4 - 5 months and wet season between May and September (Dan Azumi and Bichi, 2010). Sharada is one of the popular industrial areas in Kano which is located in Kano Municipal Local Government and Kumbotso Local Government area of Kano State as shown in Fig. 1.

Water sampling

The water samples were collected from six (6) boreholes and six (6) hand-dug wells. Generally, two (2) samples represented each well at different phases from Sharada industrial area were randomly subjected to heavy metals and physicochemical analysis as depicted in Fig. 1. Random sampling method was adopted in collecting groundwater samples and this was done due to the numerous contaminants that alter the water quality in groundwater of industrial zones. All water samples were taken at a specified time and point to give an indication of the water quality at that point in time and all samples were stored at a cool temperature of 4ºC to inhibit the activities of microorganisms.

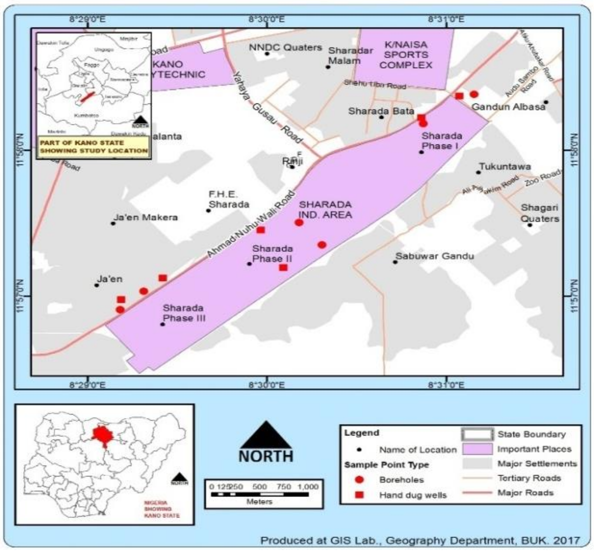

Fig. 1: Map showing the study area and sampling points

Analytical analysis

All the samples were promptly taken to the laboratory and then analyzed for the following physicochemical and heavy metals parameters; Temperature, pH, Electrical Conductivity (EC), Magnesium (Mg), Calcium (Ca), Potassium (K), Sulphate, Chloride, Bicarbonates, Nitrates (NO_3), Cadmium (Cd), Chromium (Cr), Lead (Pb), and Zinc (Zn) were determined using standardized methods (APHA, 1998).

Data analysis

Results of laboratory analyses were subjected to Statistical analysis using Microsoft Excel. Descriptive statistics and One-way analysis of variance (ANOVA) were used to compute the variations in the physicochemical and heavy metals parameters of the water samples between the sampled sites.

Results and Discussion

Analytical results of physicochemical characteristics of groundwater samples from hand-dug wells and bore holes are presented in Table 1. The hand-dug well water samples from SP 1 and 2 had the mean value of 6.41 and 6.34 which are below the allowable limits set-up by the drinking water quality standards. This implies that the water is slightly acidic. The pH value in SP 3 was 6.50. This is within the recommended limits for drinking water quality standards. The results of the borehole water samples from SP 1 to 3 were found to be 5.98, 6.00 and 6.19. These are below the recommended ranges for drinking water standards. The pH values obtained in this current study are contrary to Bello (2013), who reported a pH value range of 6.00 to 9.00 in the same study area. The current change in pH range of the area can be attributed to the acidic constituents/pollutants that must have seeped into the groundwater over the years.

Temperature is one of the most important ecological and physical factors which has a profound influence on both the living and non-living components of the environment, thereby affecting organisms and the functioning of an ecosystem. Based on the results obtained from the study area, the overall mean values of temperature for hand-dug wells were 32.60°C, 31.60°C and 31.80°C while the boreholes recorded overall mean values of 31.60°C, 31.60°C and 32.0°C respectively in Table 1. Interestingly, similar temperature differences have been reported by Mohammed *et al.* (2015) in the same area.

The electrical conductivity (EC) mean values of the collected water samples for hand-dug wells were 468.0, 526.50 and 360.50 µS/cm, respectively; which are within the recommended ranges for NSDWQ drinking water standard (Table 1). Based on the results obtained from the sampled boreholes, the mean values for the samples were 277.0, 228.0 and 322.50 µS/cm, respectively; which are all good and suitable for drinking. Onwughara *et al.* (2013) reported value of 9.32 µS/cm which is below the recommended limit of NSDWQ while Karpagam and Ramesh (2015) also reported value of pre-monsoom from 1050 to 2990 µS/cm and post monsoon from 1320 to 2140 µS/cm, in which all are above the allowable limit set by NSDWQ and also contrary to the results obtained from this research.

The hand-dug wells for SP 1, 2, and 3 had calcium (Ca) mean concentrations of 0.67, 0.75 and 0.67 mg/L, respectively (Table 1) which are below the maximum permissible limit set by NSDWQ, WHO and NAFDAC for potable water. The mean concentrations of calcium (Ca) in the sampled boreholes were 0.50, 0.50 and 0.50 mg/L in SP 1, 2 and 3, respectively. These values are within the recommended ranges set by NSDWQ standard for drinking water and no variation was observed in all the phases as their mean concentration is 0.50mg/L. According to a similar research conducted by Adefemi (2012), reported a mean value of calcium (Ca) which ranged from 3.35 to 26.23 mg/L is obviously below maximum acceptable limits prescribed by drinking water quality.

The sampled hand-dug wells from SP 1, 2, and 3 recorded magnesium (Mg) mean concentration values of 0.60, 0.40 and 0.40 mg/L, respectively which are above the acceptable limit set by NSDWQ and below the limits set by WHO and NAFDAC standards. For the boreholes, the mean concentrations of magnesium (Mg) in the collected water samples are 0.40, 0.30 and 0.50 mg/L for the SP 1, 2 and 3, respectively. These values are above the recommended limit set by NSDWQ standard for drinking water but below WHO and NAFDAC standards. Similar result to the one obtained in this current study has been reported by Onwughara (2012) which had a mean value of 33.6 mg/L, exceeding the acceptable limit of NSDWQ.

The water sampled from SP 1, 2, and 3 (Hang dug wells) had sodium (Na) mean concentration values of 25.00, 22.66 and 21.00 mg/L, respectively which are within the recommended ranges set by NSDWQ standard for drinking water of 200 mg/L. The mean concentrations of Na in the sampled borehole water were 16.335, 14.335 and 21.335 mg/L for SP 1, 2 and 3, respectively; which are within the recommended limit 0.2 mg/L set by NSDWQ standard for drinking water. Therefore, no health based guideline value is proposed. Although, as prescribed by WHO (2012), when the concentrations are in excess of 200 mg/L unacceptable taste may arise.

Based on the study, the hand-dug wells water sampled from SP 1, 2, and 3 had potassium (K) mean concentration values of 9.165, 9.500 and 10.08 mg/L respectively which are above the recommended limit set by WHO and NAFDAC standards for drinking water of 1 – 2 and 1.00 mg/L, respectively (Table 1). For the borehole, the mean concentrations of potassium (K) in the collected water sampled were 7.1700, 11.5800 and 10.4150 mg/L for the SP 1, 2 and 3, respectively which are above the recommended 1 – 2 and 1.0 mg/L limit set by WHO and NAFDAC standards for drinking water. Earlier research conducted by Mohammad *et al.* (2015) recorded between 1.58 and 13.46 mg/L which agrees with the findings in this current study.

The hand-dug wells water sampled from SP 1, 2 and 3 had sulphate (SO_4) mean concentrations of 0.0584, 0.0657 and 0.1241 mg/L, respectively which are below the recommended limits set by NSDWQ standard for drinking water. For the boreholes, the mean concentrations of sulphate (SO_4) were in the range of 0.0511, 0.0803 and 0.1168 mg/L for the SP 1, 2 and 3, respectively are within the recommended 100 mg/L limit set by NSDWQ, WHO and NAFDAC standards for potable water. Similar research study carried out by Kwari (2015) reported a mean value (95.05 mg/L) which is within acceptable limit of drinking water quality standards was contrary to the result reported by Bichi and Bello (2013) that had a mean value of 102.33 mg/L which is above NSDWQ acceptable limit for drinking water quality.

The mean concentration values of Chloride (Cl) for the hand-dug wells in SP 1 and 2 were 292.9000 and 324.850 mg/L, respectively; which are above the recommended limits set by NSDWQ, NAFDAC and WHO standards (250 mg/L) for drinking water with the exception of SP 3 with a mean concentration of 200.600 mg/L which is within the recommended limit. The mean concentrations of Chloride (Cl) for the boreholes in SP 1 and 2 were 232.5500 and 147.3500 mg/L, respectively; which are within the recommended 250 mg/L limit set by NSDWQ and WHO standard for drinking water with the exception of borehole water from SP 3 that had the highest value (477.5000mg/L) which is above the standard for drinking water. However, it has been established by WHO (2008) that chloride concentrations in excess of about 250 mg/litre can give rise to detectable taste in water. Earlier research on ground water quality around cement factory in Ibese Ogun State by Ayedun *et al.* (2012) reported Chloride (Cl) mean value of 259.47 mg/L and also Bichi and Bello (2013) obtained a mean value of 552.87 mg/L which are contrary to the results obtained from this current. Again, these variations may be due to the constituents of the pollutants that seep into the groundwater at the various study areas compared.

The hand dug water sampled from SP 1, 2, and 3 had Nitrate (NO_3) mean concentrations of 0.7005, 0.7005 and 1.0508 mg/L, respectively; which are within the recommended limits set by NSDWQ and WHO standards for potable water. For the borehole, the mean concentrations of sampled water were 1.0508, 1.0508 and 1.0553 mg/L for the SP 1, 2 and 3, respectively, which are within the recommended limit set by NSDWQ and WHO standards for potable water. These results are in line with the finding of Amoo *et al*. (2017) regarding the Nitrate (NO_3) concentration obtainable in Kano and its environs. However, low level of nitrate in the study area may be attributed to the less anthropogenic activity involving nitrate pollution of the groundwater.

Table 1: The results of physiochemical characteristics of groundwater with the standards

Parameters	HWSP$_1$ (mean)	HWSP$_2$ (mean)	HWSP$_3$ (mean)	BHSP$_1$ (mean)	BHSP$_2$ (mean)	BHSP$_3$ (mean)	WHO	NSDWQ	NAFDAC
Coordinate Latitude	04447092 P32	0446563 P32	0444405 P32	0447191 P32	0445182 P32	0443920 P32	ND	ND	ND
Longitude	1323294	1323008	1320142	1322503	1323375	1320845	ND	ND	ND
pH	6.42	6.38	6.50	5.98	6.00	6.19	6.5-8.5	6.5-8.5	6.5-8.5
Temperature(^{0}C)	32.60	31.60	31.80	31.60	31.60	32.00	ND	ND	ND
EC (µS/cm)	468.00	526.50	360.50	277.00	228.50	332.50	1000	1000	ND
Magnesium (mg/L)	0.60	0.40	0.40	0.40	0.30	0.50	150	0.20	30
Calcium (mg/L)	0.67	0.75	0.67	0.50	0.50	0.50	100 - 300	150	75
Sodium (mg/L)	25.00	22.67	21.00	16.34	14.34	21.34	200	200	ND
Potassium (mg/L)	9.17	9.50	10.08	7.17	11.58	10.42	1 – 2	ND	1.0
Sulphate (mg/L)	0.0584	0.0657	0.1241	0.0511	0.0803	0.1168	250	100	200
Chloride (mg/L)	292.90	324.85	200.60	232.55	147.35	477.50	250	250	200
Bicarbonate (mg/L)	396.50	244.00	396.5	335.50	183.00	152.5	ND	ND	ND
Nitrate (mg/L)	0.7005	0.7005	1.0508	1.0508	1.0508	1.0553	50	50	50

HWSP = Hand dug Well Sharada Phase; **BH=** Borehole well Sharada Phase; **EC=** Electrical Conductivity; **ND=** Not Detected

Table 2: Heavy metals characteristics of groundwater in Sharada phase (SP) 1, 2 & 3

Parameters	HWSP$_1$ (mean)	HWSP$_2$ (mean)	HWSP$_3$ (mean)	BHSP$_1$ (mean)	BHSP$_2$ (mean)	BHSP$_3$ (mean)	WHO	NSDWQ	NAFDC
Coordinate	0444702	044653	044445	044711	044512	0443920	ND	ND	ND
Latitude	P32	P32	P32	P32	P32	P32			
Longitude	1323294	132308	132012	132253	132335	1320845	ND	ND	ND
Cadmium (mg/L)	0.20	0.20	0.10	0.10	0.10	0.10	**0.003**	**0.003**	**0.003**
Chromium (mg/L)	0.0370	0.0925	0.0555	0.0925	0.1110	0.0925	**0.05**	**0.05**	**0.05**
Lead (mg/L)	0.0870	0.0650	0.1305	0.0430	0.0870	0.1085	**0.01**	**0.01**	**0.01**
Zinc (mg/L)	0.0975	0.0280	0.0420	0.0695	0.0560	0.0830	**3**	**3**	**3**

HWSP = Hand dug Well Sharada Phase; **BH=** Borehole well Sharada Phase; **EC=** Electrical Conductivity; **ND=** Not Detected

The mean value of Cadmium (Cd) for the hand-dug wells in SP 1, 2 and 3 ranged from 0.10, 0.20 and 0.20 mg/L (Table 2) as compared with the research done by Sankar and Rao (2014). All these values when compared with the standards are above the recommended limits set by WHO, NSDWQ and NAFDAC. However, there was no variation in the mean concentration of Cadmium (Cd) in all the three (3) Phases of Sharada and having a mean concentration of 0.10 mg/l in the sampled boreholes. The high level of Cadmium in the groundwater of the study area might be attributed to the indiscriminate discharge of untreated sewage, industrial effluent or disposal of urban waste on the surrounding land. These results suggest that consumption of water in the study area is not advisable as serious health effects of Cadmium (Cd) have been established by Hodgson and Levi (2001).

The mean concentrations of Chromium (Cr) in the hand dug wells were found to be 0.0370, 0.0925 and 0.0555 mg/L in SP 1, 2 and 3, respectively (Table 2). The mean concentration of Chromium (Cr) in SP 2 and 3 were found to be above the recommended limits set by WHO, NSDWQ and NAFDAC, while it was found below the standards set by WHO, NSDWQ and NAFDAC in SP 1. The mean concentration level of Chromium (Cr) in the sampled boreholes were found to be 0.0925, 0.1110 and 0.0925 mg/L in the three phases respectively and all are above the acceptable limits that should be found in potable water. This implies that, the consumption of water from the study area is not safe since hexavalent Chromium (Cr) is very toxic, mutagenic and known to be possible human carcinogen, where long term exposure can cause damage to liver, kidney circulatory and nerve tissues, as well as skin irritation (California Environmental Protection

Agency Fact Sheet, 2009). The high level of Chromium (Cr) recorded in this current study has equally been reported by Akan (2007). However, as submitted by this author that the effluent released from industries in the vicinity of the study area had a whole lot to do with the increased level of Chromium (Cr) obtained during his research study, the same reason can be attributed to this current study.

The mean concentration level of lead (Pb) in hand-dug wells (SP 1, 2 and 3) were found to be 0.0870, 0.0650 and 0.1305 mg/L (Table 2). The mean concentration values of lead (Pb) in boreholes (SP 1, 2 and 3) were found to be 0.0430, 0.0870 and 0.1085 mg/L, respectively. These results have shown that both hand-dug wells and boreholes wells have got lead (Pb) above the recommended limits set by WHO, NSDWQ and NAFDAC. These results suggest that consumption of water in the study without proper treatment is not advisable. In a similar study conducted by Ravi and Prasada (2014) obtained minimum and maximum concentration of lead (Pb) which varied between 0.012 – 0.153 mg/L and Edo (2014) also reported the mean value of 0.038 mg/L which exceeded the allowable limits of drinking water quality standards.

The hand-dug wells mean concentration levels of Zinc (Zn) in SP 1, 2 and 3 were found to be 0.0975, 0.0280 and 0.0420 mg/L. In the boreholes, the mean concentration values of Zn in SP 1, 2 and 3 recorded 0.0695, 0.0560 and 0.0830 mg/L, respectively. This implies that the concentrations of Zinc (Zn) in both hand dug wells and boreholes were below the maximum permissible limits set by potable water quality. These results are in line with a similar study conducted by Casimir *et al.* (2015), which reported Zn concentration range of 0.073 - 1.670 mg/L.

Conclusion

The results of the physicochemical properties and heavy metals in the sampled water in this study showed that hand dug wells or poorly covered wells pose the commonest risk to water quality. The mean concentrations of heavy metals such as cadmium (Cd), chromium (Cr) and lead (Pb) in the groundwater were far above the allowable potable water standards set by WHO, NSDWQ and NAFDAC, while zinc (Zn) is within the permissible limits. The results of this study have clearly shown that the quality of boreholes and hand dug wells in Sharada Industrial area is unfit for human consumption considering the fact that heavy metals detected are toxic even at low level as it can lead to kidney damage and cardiovascular problems. The physicochemical parameters which include potassium (K) and chloride (Cl) were above acceptable limits with the exception of Sharada Phase three (3) which was within permissible limits. The pH of water samples was not within acceptable limits with exception of Sharada Phase three (3) which was within acceptable limits. However, nitrate (NO_3), electrical conductivity (EC), sodium (Na), calcium (Ca) and magnesium (Mg) were all within recommended limits. It is therefore recommended that proper drainage and sewer systems should be constructed in the study area in order to ensure proper disposal of hazardous liquid waste, thereby preventing their seepage into the groundwater. Government and relevant regulated authorities should ensure and enforce stringent standard practices with a view to preventing indiscriminate disposal of untreated effluent into the environment and ultimately saving the groundwater from further pollution.

Conflict of Interest

The authors declare that there is no conflict of interest.

References

Adefemi AO 2012. Physicochemical and microbiological assessments of groundwater from Ijan-Ekiti South Western Nigeria. *Environmental Res. J.*, 6(5): 316-320.

Akan JC, Moses EA, Ogugbuaja VO & Abah J 2007. Assessment of tannery industrial effluents from Kano metropolis, Kano State, Nigeria. *J. Appl. Sci.*, 7: 2788-2793.

Amoo AO, Zakari AW, Ijanu EM, Adeleye AO & Amoo NB 2017. Physicochemical and bacteriological assessment of surface water quality: A case study of Jakara River, North-western Nigeria. *Int. J. Appl. Res. & Techn.*, 6(9): 65 – 74.

APHA 1998. Standard Methods for the Examination of Water and Wastewater, 20th edition. American Water Works Association, Environment Federation, Washington.

Ayedun H, Oyede RT, Osinfade BG, Oguntade BK, Umar BF & Abiaziem CV 2012. Groundwater quality around new cement factory, Ibase Ogun state, South West Nigeria. *Int. J. Physical Sci.*, 10(9): 306-310.

Bichi MH & Bello UF 2013. Heavy metals pollution in surface water and groundwater used for irrigation along River Tatsawarki in Kano state, Nigeria. *IOSR Journal of Engineering*, 3(7): 2278-8719.

California Environmental Protection Agency 2009. Office of Environmental Health Hazard Assessment: Draft Public Health Goal for Hexavalent Chromium Fact Sheet. Available at https://oehha.ca.gov/media/downloads/water/document/hexchromfacts082009.pdf. Accessed on January 22nd, 2018.

Casimir EG, George IN, Elayi DP, James DH & Lamis AM 2015. Heavy metals Assessments of groundwater in Kaltuga LGA, Gombe State, Nigeria. *J. Sci. & Techn.*, 4(2): 49-56.

Dan Azumi S & Bichi MH 2010. Industrial pollution and heavy metals profile of Challawa River in Kano, Nig. *J. Appl. Sci. Envt. Sanitation*, 5(1): 23-29.

Fasunwon OO, Ayeni AO & Lawal AO 2010. A comparative study of borehole water quality for sedimentary terrain and basement complex in Southern Nigeria. *Res. J. Envtal. Sci.*, 4(3): 327-335.

Fetter CW 1994. Applied Hydrogeology, Third Edition. Prentice Hall, New Jersey.

Hodgson E & Levi PE 2001. *In Handbook of Pesticide Toxicology, 2nd ed*., Krieger, R. I., Ed.; Academic Press: San Diego, CA; Vol. 1, pp. 531–562.

Hoko Z 2005. An assessment of the water quality of drinking water in rural areas districts in Zimabwe. The case of Gokwe South, Nkayi, Lupane and Mwenezi distrcts. *J. Phy. & Chem. Earth*, 30: 859-866.

Jones JAA 1997. Global Hydrology: Processes, Resources and Environmental Management. Pearson Education Limited. Edinburgh. England.

Karpagam V & Ramesh K 2015. Assessments of groundwater quality of Chrompet industrial area. *Int. J. Engr. Techn., Mgt. & Appl. Sci.*, 3(7): 2349-4476.

Kwari WJ 2015. Groundwater quality assessments: A case study of groundwater from hand-dug wells in Hawul LGA of Borno State, Nigeria. *Int. J. Advanced Res.*, 3(2): 537-546.

McMurry J & Fay RC 2004. Hydrogen, Oxygen and Water. In: McMurry Fay Chemistry. K.P. Hamann, (Ed.). 4th Edition. New Jersey: Pearson Education, pp. 575-599.

Mendie U 2005. The Nature of Water. In: The Theory and Practice of Clean Water Production for Domestic and Industrial Use. Lagos: Lacto-Medals Publishers, pp. 1-21.

Mohammad SD, Fikri NA, Irda K, Dwiluci A, Emma TS & Tantowi EP 2015. Ground water quality assessments for suitable drinking and agricultural irrigation using physicochemical water analysis in the Rancaekek-Jatinangor District, West Java, Indonesia. *Int. Conference on Envtal. Sci. & Techn*., 84: 56-62.

Onwughara NI, Ajiwe VIE & Nria B 2013. Physicochemical Studies of water from selected boreholes in Umahia North, LGA of Abia State, Nigeria. *Int. J. Pure & App. Biosci*. 1(3): 34-44.

Pritchard M, Mkandawire T & O'Neil JG 2007. Biological, Chemical and Physical drinking water quality from shallow wells in Malawi: Case study of blantyre, Chiradzulu and Mulanje. *Physics and Chemistry of the Earth*, 27: 845-850.

Ravi T & Prasada R 2014. Heavy metals assessments in industrial area groundwater in and around Vijaya Wada and Andhra Pradesh, India. *Academic J. Sci*., 4(6): 45-50.

SOPAC/WHO 2005. Drinking Water Quality in the Pacific Island Countries: Situation Analysis and Needs Assessment. World Health Organisation, Geneva, Switzerland.

Vanloon GW & Duffy SJ 2005. The Hydrosphere. In: Environmental Chemistry: A Global Perspective. 2nd Edition. New York: Oxford University Press, pp. 197-211.

WHO 2008. World Health Organization. *Guidelines for Drinking-Water Quality, Geneva*, 1(3): 306-492.

WHO/UNICEF 2012. Joint Monitoring Programme for Water Supply and Sanitation: Meeting the MDG drinking water and sanitation target: a mid-term assessment of progress. Geneva, Switzerland.