Heavy Metal Concentration in Groundwater around Obajana and Its Environs, Kogi State, North Central Nigeria

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Abstract

There has been a consistent demand for groundwater through the construction of borehole and hand dug wells to meet the growing population of Obajana where Dangote cement factory is situated. However, there has been an increased concern as to the safety of groundwater for human consumption, following reported cases of the occurrence of heavy metals in groundwater within the area which by nature are injurious to human health. This paper in response to this, examined the occurrence of heavy metals in few streams and groundwater sources especially after the commencement of operations by Dangote cement factory within Obajana and its environs. The study was carried out in twenty-four locations in Obajana area of Kogi State. Three samples were obtained from surrounding streams, six samples from bore-holes and fifteen hand-dug wells. Thus, a total of twenty-four samples were obtained and analysed in all. Heavy metals such as copper, copper, zinc, cadmium, lead, and iron were analyzed using Atomic Absorption Spectrometer. Result showed that there were no heavy occurrences of copper, zinc, cadmium, lead and iron in the entire sample taken from water sources within the study area. At-least, their concentration values fall well below the limits specified by World Health Organization (WHO). The implications of the result on the management and use of groundwater in the study area were identified and discussed. It was recommended that a periodic and systematic study of the heavy metals concentrations in groundwater sources in the area should be carried out regularly.

Keywords: Groundwater, Heavy Metals, Bore-holes, Hand-dug Wells, Concentration.

1. Introduction

Water is precious and necessary for a sustainable economic development of an area as it is the next major support to life after air. In the urban areas where pipe-borne water, bore-hole water and hand-dug wells are available is an indication that water is a vital component of human existence. Groundwater is of major importance and is intensively exploited for private, domestic and industrial uses. According to Ajibade et al., (2011) 90% of the population depend largely on hand-dug wells. Rapid growth in urban populations, industrial activities, commercial and agricultural developments result in increase in the search and uses of potable water. Heavy metals are elements having some atomic weight between 63.54 and 200.59, and a specific gravity greater than 4, Kennish(1992). Although trace amount of some heavy metals are required by living organisms, any excess amount of these metals can be detrimental to life (Berti and Jacobs, 1996; Akhilesh*et al.*, 2009). The solubility of these metals in soils and groundwater is largely controlled by pH [6-8]; amount of metal and cation exchange capacity (Martinez and Motto, 2000), organic carbon content (Elliot *et al.*, 1986) and the oxidation state of mineral components as well as the redox potential of the system (Connell and Miller, 1984).

Pollution of groundwater is an impairment of water quality by chemicals, heat or bacteria to a degree that does not necessarily create public health hazards, but does adversely affect such water for domestic, farm, municipal or industrial use (Akhilesh*et al.*, 2009; Weiss, 1974 and Ogbonna*et al.*, 2006). Trace elements are generally present in small concentration in natural water system. Their occurrence in groundwater and surface water can be due to natural sources such as dissolution of naturally occurring minerals containing trace elements in the soil zone or the aquifer material or to human activities such as mining, fuels, smelting of ores and improper disposal of industrial wastes.

Investigation of heavy metals is very essential since slight changes in their concentration above the acceptable levels, whether due to natural or anthropogenic factors, can result in serious environmental and subsequent health problems (Yahaya*et al.*, 2009).Data available reveals that the geology of Obajana and its environs contains significant amount of marble deposits within the Basement Complex geology of the area (Hockey, *et al.*, 1986 and Etu-efeotor et al., 1989). With the construction of Obajana cement factory which is exploiting the Obajana marble deposit through mining, there is every need to assess from time to time environmental impact of mining on the environment. This includes the careful study of the heavy metal concentration in the groundwater of Obajana area after the commencement of the cement production and the extent to which it has affected the quality of groundwater for domestic use. Generally, groundwater accounts for about 98% of the world's fresh water resources and it is well distributed throughout the world (Buchanan, 1983; Bouwer, 2002). Over the years, groundwater has served as a potential source of water supply especially through springs, hand dug wells and boreholes. Due to their increasing popularity as a veritable source of water supply, it becomes necessary to access critically their quality and portability for human consumption. It is view of this that the present study was carried out in other to examine to what extent heavy metals in these deposits have polluted groundwater within and around the study area.

2. Location And Geology of Study Area

Obajana lies within longitude 6°24'E to 6°27'E and latitude 7°54'N to 7°56'N (Figure1). It is has an undulating surface which gently slopes downward southwest–northeast trend. The study area lies within the Benin-Nigeria shield, situated in the Pan-African mobile zone extending between the ancient Basements of West African and Congo Cratons in the region of Late Precambrian to Early Palaeozoic orogenies (Rahaman, 1976; Odigi, 2002andEkwueme, 2003). The Basement Complex rocks of Nigeria are composed predominantly of migmatite gneiss complex; slightly migmatised to unmigmatisedparaschists and metaigneous rocks; charnockitic, older granite suites and unmetamorphosed dolerite dykes. (Rahaman, 1976). The Precambrian Basement rocks of Obajana area, South-western Nigeria comprise of schists and gneisses which have been subjected to major supracrustal tectonic events such as the Dahomeyan (3000± 200Ma), Eburnean (1850 ± 250Ma), Kibaran (1000± 100Ma), and Pan-African (550± 100Ma). (Ezepue and Odigi, 1993). The Obajana gneisses (Figure 2) comprise of three types of rocks designated as quartz-biotite gneiss; quartz-biotite-hornblende-pyroxene gneiss and quartz-biotite-garnet gneiss (Odigi and Ezepue, 1993; Ezepue and Odigi, 1994; Odigi, 2002). According to these authors, igneous rocks of this area occur as small, circular to oval outcrops and include members of the older granite suite mainly granites, granodiorites and syenites while associated schists in the area are: quartz-biotite schist, amphibolite schist, muscovite schist and quartzitic schist.

3. Materials and Methods

Groundwater samples were randomly collected from thirty locations within the study area. The samples were collected from twenty-one hand dug wells and three stream channels spread all over the community surrounding Obajana area. Total samples taken from the location were twenty- four in all. Water samples were thencollected in clean plain polyethylene containers. Prior to that, the polyethylene containers had been sterilized. The containers were thoroughly cleaned with 1:1 HNO3 and rinsed several times with distilled water, then dried in electric oven. After this, the containers were completely filled with water before they were corked to avoid trapping of air bubbles. The samples were stored in a cool dry place before the commencement of laboratory analysis. The samples were tested for the occurrence of heavy metals such as Copper, Zinc, Cadmium, lead, and Manganese.
The metals investigated included zinc, nickel, lead, iron, copper and arsenic. The laboratory analysis involved the use of instruments such as, water spectrophotometer, pH meter and also the addition of some test reagents to the collected water samples in order to obtain desired reaction which will indicate the amount of specific constituents that are present in the sample.

Specially, heavy metals were analysed by determining the trace of metal concentration in each water sample using the Atomic Absorption Spectrometer.

4. Result and Discussion

Results of the analysis of the heavy metals in the water samples is presented in Table 1, wherein, six metals were investigated in the laboratory and the result for all the sampled boreholes and hand-dug wells are presented. The metals analysed include copper, zinc, cadmium, lead and manganese, viewed against the standards as prescribed by the World Health Organisation (WHO) presented in table 2. Values obtained for copper ranges from 0.001mg/L to 0.085mg/L, which falls below the maximum permissible limit of 2.0mg/L. Although, it is slightly above the highest desirable limit of 0.5mg/L of World Health Organization standard.

The result for zinc shows that the values obtained for the wells ranges from 0.004mg/L to 0.066mg/L which is far below the desirable limits set by world health organisation (WHO).Cadmium (Cd) concentration ranges from 0.001to 0.017 mgL-1. This is below the desirable limit for World Health Organisation. Results reveal the concentration of lead in all the study area ranges from 0.001 mgL-1to 0.012 mgL-1 which is below the WHO limit of 0.4mg/l. Lead is a very toxic element, which accumulates in the skeletal structure of man and animal. Manganese (Mn) concentration levels ranges between 0.001 mgL-1 to 0.0105 mgL-1. The concentration is below the desirable far above limit of 0.4mg/L and maximum permissible limit of 0.4mg/L. Manganese impacts a bitter taste to water, stains cloths and metal parts and precipitate in foods when used for cooking and it also promotes the growth of algae in reservoirs.

Data from the analysis in table 1 shown above are presented alongside with the WHO standards in table 2. Graphical plots represented in figure 3 and 4(a-c) were obtained. Figure 3 generally shows the concentration of constituent element of the water in relation to the World Health Organization (WHO) standards. Separate plot (figures 4a, 4b, and 4c) were obtained for water samples from different location of stream channels (L10 – L12), hand-dug wells (L1 – L3, L5, L6, L15 – L24) and bore-holes (L4, L7 - L9, L13, L14). A general trend in the elemental concentration exists in the graph plotted for all water sources. The plots reveal that concentrations of heavy metals in the ground water resources of Obajana and its environs are generally less than the WHO desirable standard.

However in the order of concentration is Fe >Mn>Zn >Cu>Pb>Cd. No abnormal heavy metal concentration was noticed in all the analysed water samples. Concentrations of Cu, Zn, Cd, Pb,andMn were all below the desirable limits of world health organisation. Iron concentration are in the ranges of 0.007mg/L – 0.627mg/L. Excess concentration of iron has a negative effect as it can cause gastrointestinal irritation and enhance the growth of iron bacteria that affects the water taste. The high concentration values of iron has the potential of staining laundry, metal pipes for reticulation and scaling in pipes. It may also give undesirable taste [21,28,30-32]. This explains the reddish brown colour stain commonly seenon most metal tanks and fence within the study area. Iron can be treated by encouraging the iron to precipitate when the water is exposed to the air. The study reveals that heavy metal concentration in the groundwater sources in the area is below the desirable limit of WHO standards in most of the locations sampled and were considered fit for human consumption, although there were traces of high iron in all the hand dug wells and some of the boreholes. This discovery is in consonance with Danbatta (2006). However, heavy metal concentrations were still within the maximum permissible limits set by the WHO standards.

5. Conclusion

Over the years, groundwater has served as a potential source of water supply especially through streams, hand dug wells and boreholes. With the establishment of the Obajana cement factory which is one of the largest in Africa, it becomes necessary to access critically their quality and portability for human consumption. The water samples from hand-dug wells, bore-holes and streams were chemically analysed in order to determine whether there were high concentration of heavy metals such as copper, Zinc, Cadmium, lead, Manganese and iron present. The analysis shows that both the surface and groundwater within the study area is not polluted in any way. This is because the result showed that the quality of the properties or parameters tested for were within the acceptable and desirable limits set by the WHO and were considered fit for human consumption and other domestic purposes.

To prevent the effects of the polluted water on the health of the inhabitants in the nearest future, the authorities concerned should designate a properly engineered landfill in the area, putting into consideration the groundwater and its flow directions.

There is also need to also establish functional waste disposal mechanisms in the area with sanitation inspectors recruited with enactment of sanitary bye-laws. More importantly, systematic study of the heavy metals concentrations in groundwater sources in the area should be carried out regularly. This is important, since the inhabitants in the area depend on groundwater for drinking purposes. Industries in the area should set up effluents treatment plants and should remain effectively operational in order to safe guard.

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Table 1: Analysis of heavy metals in water samples

Sample Locations	Co-ordinates	Sample source	Heavy metal ion concentration in mg/l					
			Cu	Zn	Cd	Pb	Mn	Fe
L1	N07°55'0.7" E06°26'13.6"	Hand dug well	0.002	ND	0.001	ND	ND	0.055
L2	N07°55'06.8" E06°26'15.8"	Hand dug well	0.020	0.035	0.017	ND	0.010	0.123
L3	N07°55'04.0" E06°26'29.3"	Hand dug well	0.010	0.030	0.001	0.004	0.021	0.049
L4	N07°55'14.0" E06°26'29.0"	Bore-hole	0.001	0.052	ND	0.003	0.011	0.014
L5	N07°55'10.5" E06°26'11.4"	Hand dug well	0.002	0.040	ND	0.012	ND	0.034
L6	N07°55'11.0" E06°26'05.7"	Hand dug well	0.005	0.030	ND	0.002	0.003	0.007
L7	N07°55'15.1" E06°25'58.3"	Bore-hole	0.010	0.066	ND	0.002	0.051	0.012
L8	N07°55'27.1" E06°25'56.9"	Bore-hole	0.006	0.043	ND	ND	0.027	0.028
L9	N07°55'40.7" E06°25'57.1"	Bore-hole	0.002	0.047	ND	0.001	0.016	0.013
L10	N07°55'54.7" E06°25'53.3"	stream	0.006	0.011	ND	0.004	0.105	0.101
L11	N07°55'58.2" E06°25'44.5"	stream	0.008	0.020	0.002	0.003	0.055	0.078
L12	N07°55'05.2" E06°25'44.7"	stream	0.007	ND	ND	0.002	0.002	0.036
L13	N07°55'59.6" E06°25'54.1"	Bore-hole	0.020	0.040	0.004	0.001	ND	0.044
L14	N07°55'13.6" E06°26'12.6"	Bore-hole	0.001	0.032	ND	0.001	0.034	0.021
L15	N07°55'43.9" E06°26'17.0"	Hand dug well	ND	0.004	ND	ND	0.002	0.031
L16	N07°55'05.0" E06°26'29.5"	Hand dug well	0.003	0.010	0.003	ND	0.031	0.075
L17	N07°55'12.4" E06°26'20.9"	Hand dug well	0.012	0.062	ND	0.001	0.001	0.032
L18	N07°55'15.0" E06°25'40.7"	Hand dug well	0.085	0.048	ND	0.004	0.003	0.281
L19	N07°55'09.1" E06°26'00.7"	Hand dug well	ND	0.044	ND	0.003	ND	0.156
L20	N07°55'05.0" E06°26'04.0"	Hand dug well	0.085	0.041	ND	0.003	ND	0.041
L21	N07°55'59.8" E06°25'57.5"	Hand dug well	0.001	0.039	0.003	ND	0.003	0.023
L22	N07°55'05.1" E06°25'55.0"	Hand dug well	0.011	0.007	0.002	0.004	0.001	0.627
L23	N07°55'10.9" E06°25'54.3"	Hand dug well	ND	0.004	0.002	0.003	ND	0.072
L24	N07°55'08.1" E06°25'05.1"	Hand dug well	0.052	0.032	0.002	0.001	ND	0.057

Table 2: World Health Organization (WHO) standard for Heavy metals

S/N	Metal	Highest Desirable mg/l	Max. Desirable mg/l
1	Fe	1.0	3.0
2	Cu	0.5	2.0
3	Zn	1.0	3.0
4	Pb	0.4	0.4
5	Ni	0.01	0.02
6	Cr	0.05	0.05
7	Cd	0.003	0.03
8	As	0.01	0.01
9	Ba	0.05	0.05
10	Hg	0.001	0.001
11	Sb	0.01	0.02
12	Sn	0.01	1.0
13	Se	0.01	0.01
14	Mn	0.4	0.4

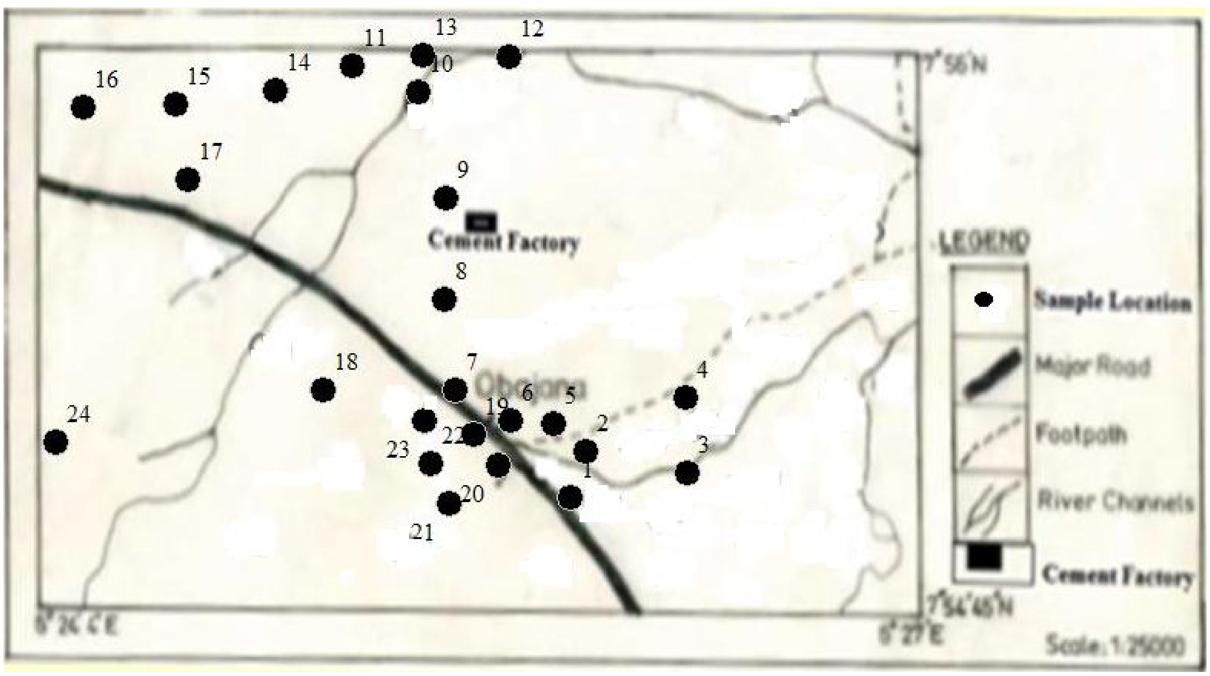

Figure 1: Location of Sampled Points on the Map of the Study Area.

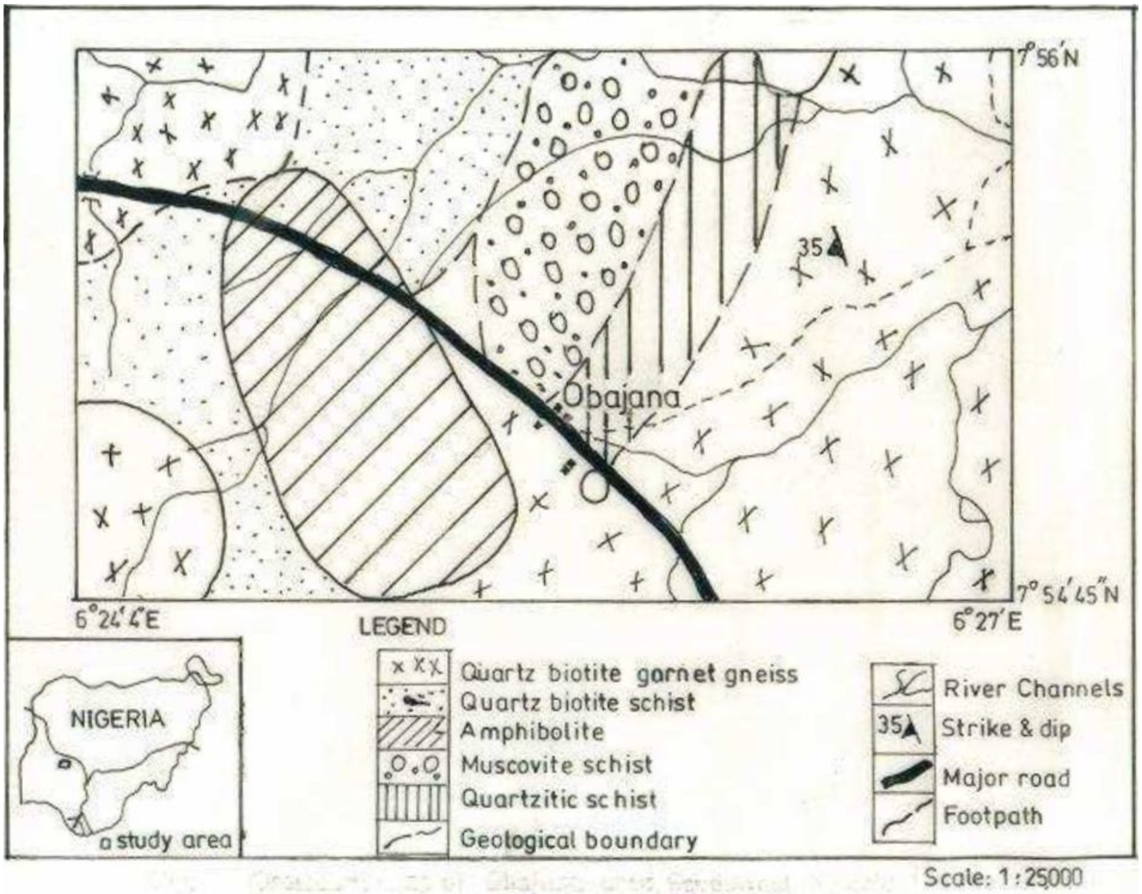

Figure 2: Geological map of the study area.

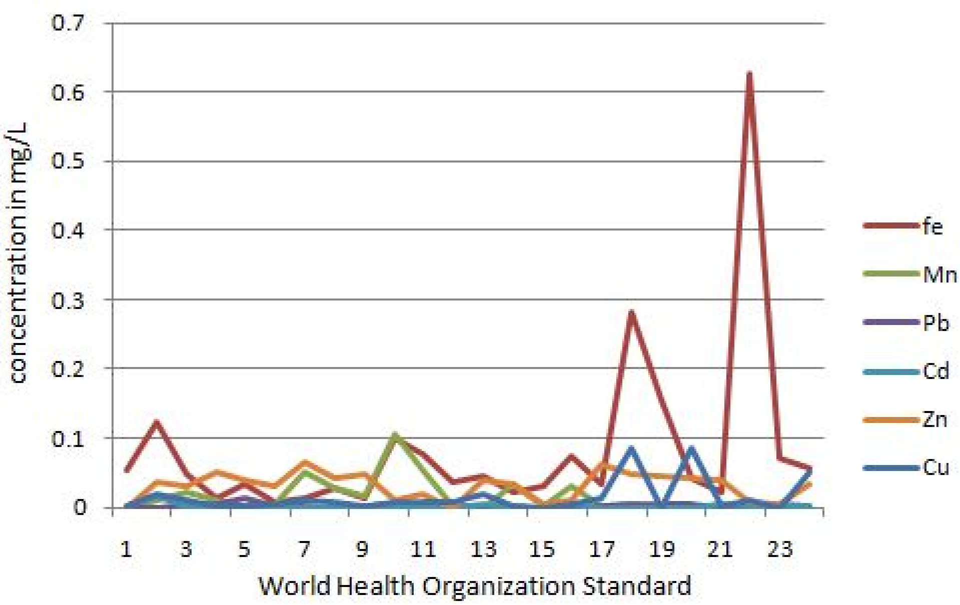

Figure 3: A generalized plot of heavy metal concentration with World health organization (WHO) standard in the study area.

Figure 4a: Heavy metals concentrations with World Health Organization standard for streams located within the study area.

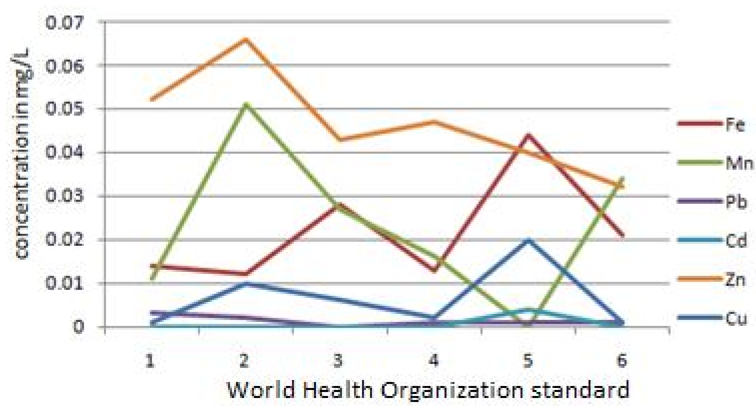

Figure 4b: Heavy metals concentrations with World Health Organization standard for bore-holes located within the study area.

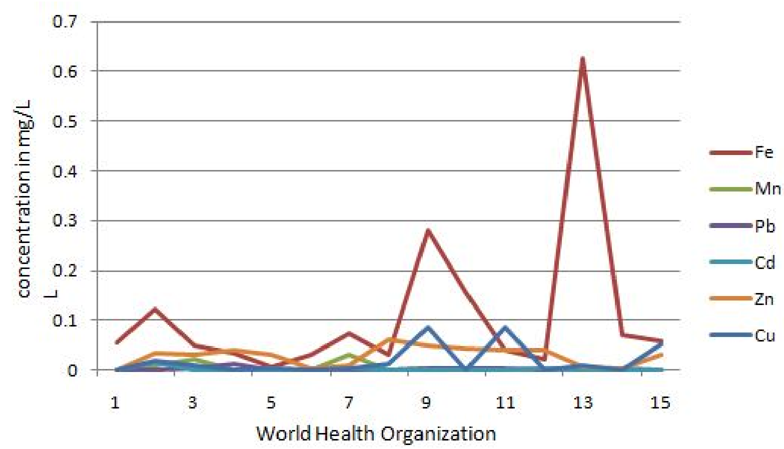

Figure 4c: Heavy metals concentrations with World Health Organization standard for hand dug wells located within the study area.

References

Ajibade, O. M., Omisanya, K. O. And Odunsi, G. O., (2011): Groundwater potability and flow directionof urban aquifer, Ibadan, SouthwesternNigeria;*Journal of the Nigerian Association ofHydrogeologists*, Volume 21, ISSN 0795-6495. Pp38-55

Akhilesh, J., Savita, D., and Suman, M., (2009): Some trace elements investigation in groundwater ofBhopal and Sehore District in Madhya Predesh, India. *Journal of Appl. Sci. Environ. Manage*, 13(4): 47-50.

Baker, A.J.M and Walker, P.L., (1990). Heavy metal tolerance in plants; In: Shaw, A.J Evolution aspects (ed). Boca Raton: CRC Press, p 155 – 177.

Berti, W.R and Jacobs, L.W.P.,(1996): Chemistry and Phytotoxicity of soil trace elements fromrepeated sewage sludge application. J. Environ Qual. (25) 1025 – 1032.

Bower, H.,(2002): Artificial recharge of groundwater; Hydrology and Engineering;*Hydro-geologistJournal* 10(1). pp121-142

Buchanan, T. J.,(1983): International Water Technology Conference and Exposition (AUGA EXPO'83)Acapulco, Mexico.

Connell, D.W and Miller, G.J.,(1984). Chemistry and Ecotoxicology of pollution, John Wiley & Sons, N.Y 444p.

Danbatta, U. A.,(2006). A baseline study of hydrochemistry of River Adankole around Obajana, Kogi State.*Chemclass Journal*, vol. 3, pp10-17.

Ekwueme, B. N.,(2003). The Precambrian geology and evolution of the southwestern Nigerian Basesment Complex; University of Calabar press

Elliot, H.A., Liberali, M.R., and Huang, C.P.,(1986). Competitive Adsorption of Heavy Metals by soil.*J. Environ. Qual*. (15):15 – 214.

Etu-efeotor, J. O., Akpokodje, E. G., Ike, E. C. and Njoku, C. O.,(1989): Report of the multi- disciplinaryTask Force on non-metallic mineral Raw material for Nigerian industries,pp290.

Ezepue, M. C. and Odigi, M. I.,(1993):*Journal of mining and geology*, vol. 29, No. 1

Ezepue, M. C. and Odigi, M. I.,(1994):*Journal of mining and geology*, vol. 30, No.1, pp1-9

Henry, J.R., 2000. An overview of photoremediation of lead and mercury, NNEMS Report, Washington, D.C. p3 – 9.

Hockey, R. D., Sacchi, R., de Graaf, W. P. F. H. and Muotoh, E. O. G.,(1986). The geology of Lokoja–Auchi area. Published by Geological Survey of Nigeria, Bulletin No. 39, pp124.

Kennish, M.J.,(1992): Ecology of Estuaries: Anthropogenic effects. CRC Press, Inc., Boca Raton, FL.494pp.

Martinez, C.E and Motto, H.L.(2000): Solubility of lead, zinc and copper added to mineral soils. Environmental Pollution, (107):153 – 158.

McNeil, K.R and Warring, S.,(1992)contaminated lead treatment technologies. In: Rees, J.F (ed)Society of Chemical Industry, *Elsevier Applied Sciences*, London, pp143 -159

Nwankwoala, H.O.,Uudom, G.J. and Ugwu, S.A.,(2011).Some heavy metal investigations ingroundwater sources in Yenagoa, Bayelsa state, Nigeria.*Journal of Applied Technology inEnvironmental Sanitation*, 1 (2): 163-170. ISSN 2088-3218.

Odigi, M. I. and Ezepue, M. C.,(19930:*Journal of mining and geology*, vol. 29 (1), pp41-50

Odigi, M. I.,(2002). *Journal of mining and geology*, vol. 38 (2), pp81-89

Ogbonna, D.N., Igbenijie, M. and Isirima, N.O.,(2006): Microbiological and Physico-chemical characteristics of the soils of waste collection sites in Port Harcourt City, Nigeria. Nigeria *Journal of Soil Science, (*16):162 -167.

Omada, J. I., Omatola, D. O. And Omali, A., (2011). Physico-Chemical Characteristics of Surface andGroundwater in Anyigba and lts Environs, Kogi State, *Nigeria Journal of the Nigerian Association of Hydrogeologists*, Vol 21, November,2011, pp 18 – 25.

Rahaman, M. A., (1976) Review of basement geology of southwestern Nigeria: In geology of Nigeria (C. A. Kogbe, Ed.). Elizabethan publishing Co., Lagos.

Weiss, A.,(19740):Sanitary Landfill Technology; Noyes Data Corporation, England 204p.

Yahaya, M.I., Mohammad, S. and Abdullahi, B.K.,(2009). Seasonal variations of heavy metals concentratrion in Abbatoir dumping site in Nigeria. *J. Appl. Sci. Environ.Manage.* (13) (4): 9 – 13.