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Assessment of heavy metals contamination of groundwater in Ila Orangun community, Osun State, Nigeria

Saanu Emmanuel Kosemani, Tosin Oyelami
Institute of Ecology and Environmental Studies, Faculty of Science, Obafemi Awolowo University, Ile-Ife, Nigeria

Abstract
The present study was aimed to access heavy metals contamination of groundwater in Ila Orangun community, Osun State, Nigeria. Six (6) functional hands dug wells and four (4) boreholes within three streets area were randomly selected in the study. Water samples were collected during dry season (December, 2015 and February, 2016) and rainy season (June and September, 2016). The result of physical parameters revealed that there was significant difference ($p < 0.05$) between the value obtained for temperature during dry and rainy season whereas pH value showed no significant difference ($p > 0.05$) between dry and rainy season, almost all the heavy metal determined were found above the permissible limit of WHO 2008 except As and Zn that were within the permissible limits. The study concluded that metals determined in this study suggested that pollution of the well water and boreholes in the area as being attributed to anthropogenic activities.

Keywords: heavy metal, contamination, physiochemical parameter, water quality, groundwater

1. Introduction

The quality of water available and accessible to a community has tremendous impact on their living standard and wellbeing; thus global and local efforts are widespread at ensuring adequate provision of clean and safe water to the world's growing population [1]. Population growth coupled with other factors such as urbanization, agricultural activities, industrial and commercial processes have resulted in the accumulation of wastes and pollutants which ends up in water bodies, thereby altering the water quality, species composition and biodiversity in many aquatic systems [2]. Water is absolutely essential for life; it is undoubtedly the most precious natural resource that exists on our planet [3]. Water has unique chemical properties due to its polarity and hydrogen bond which means it is able to dissolve, absorb, adsorb or suspend many different compounds [4]. In nature, water is not pure as it acquires contaminants from its surrounding and those arising from humans and animals as well as other biological activities [5]. Groundwater is considered among the healthiest source of drinking water, but domestic, agricultural and industrial activities have led to the degradation of groundwater quality in different parts of the world [6]. Groundwater pollution which is man-made is worse than natural pollution as it eventually renders water unsuitable for use than its original state [4]. The provision of good quality water is needed as an urgent step that will ensure groundwater quality, protection and conservation. Groundwater is an important source of drinking water for humankind, it contains over 90% of the fresh water resources and it is an important reserve of good quality water. In Nigeria, drinking water comes from groundwater and surface water including rivers, lakes and reservoirs. Their water qualities may be impaired as a result of low water flow, municipal effluents and industrial discharges [7]. Metal concentrations in waterbodies can increase as result of the input by runoff and the proximity of industrial or urban zones and these metals from incoming tidal water and fresh water sources are rapidly removed from the water body and are deposited into the sediment [8, 9]. Increased urbanization and industrialization are to be blamed for an increased level of trace metals, especially heavy metals, in our waterways [10]. Many dangerous chemical elements if released into the environment accumulate in the soil and sediments of water bodies [10]. Since heavy metals cannot be degraded biologically, they are transferred and concentrated into plants and animal's tissues, posing long term damaging effects on the affected species and man [11]. The heavy metals in drinking water linked most often to human poisoning are lead, iron cadmium copper, zinc and chromium [12]. They are required by the body in small amounts, but can also be toxic in large doses. They constitute one important group of environmentally hazardous substances if present [12]. Heavy metals have the ability to enter the human body through inhalation, ingestion and dermal contact absorption [13, 14, 15]. Therefore, this study aimed at determining the presence of heavy metals such as lead, cadmium, copper, arsenic and zinc in groundwater as well as the quality of domestic water Ila Orangun community, Osun State so as to look into the rate at which drinking water has been impaired due to human activities generally in the study area.

2. Materials and Method

2.1 Study Area

The study was conducted in Ila Orangun community of Osun State, Nigeria between December, 2015 and September, 2016. Ila Orangun is an ancient city in Osun State, Nigeria, that was capital of an ancient city-state of the same name in the Igbomina area of Yorubaland in south-western Nigeria. Ila Orangun is located on the Latitude 8˚1''0'' north of the equator and Longitude 4˚54' 0'' east of the Greenwich Meridian with about 7.5 miles (12 km) to the north-east. The vegetation of Ila Orangun community is characterized by rainforest ecosystems which form part of the rich fauna and flora of the state. The major economic activities in the area are farming and the public sector which are basically government owned schools. The major sources of water for drinking in the area are water from wells and borehole. Fig. 1 showed the map of sampled wells and boreholes in the study area.

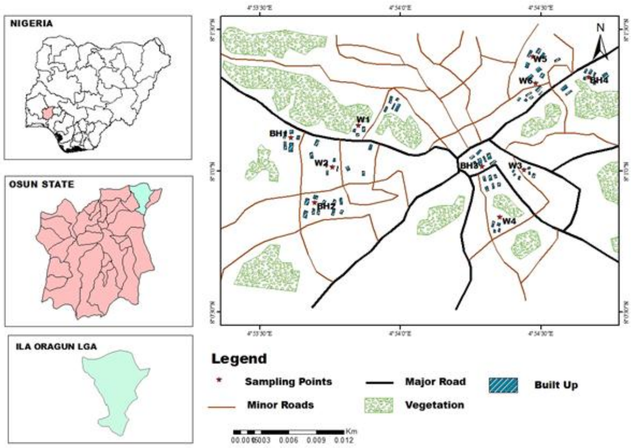

Fig 1: The map of sampled wells and boreholes in the study area.

2.2 Sampling Programme, Field Determinations and Laboratory Analysis

The procedure for data collection started with a reconnaissance survey to Ila Orangun for identification of functional wells and boreholes as one that are used frequently with level of patronage, three streets were randomly selected in Ila Orangun community for the study. Water samples were collected during dry season (December, 2015 and February, 2016) and rainy season (June and September, 2016) from both well and boreholes at the selected street in Ila Orangun. Six (6) functional wells and four (4) boreholes were randomly selected, with their coordinates recorded in the streets selected, forty (40) water samples were collected from all the ten sampling stations throughout the period of study. An improvised water sampler of 1 litre capacity was used for the collection of water samples from all the selected sampling stations. During sampling, air temperature and water temperature (using mercury in glass thermometer), pH (using and pH meter) were determined on the field in situ. Water samples were collected at the borehole heads whereas water sampled from the well were collected using an improvised drawer and transferred into the sample container. The water samples collected from boreholes and wells from the study area was anlayesd at Center for Energy and Research Development, Obafemi Awolowo University, Ile Ife. The samples were digested with concentrated Nitric acid. 10 ml of Nitric acid was added to 50 ml of water in a 250 ml conical flask. The mixture was evaporated to half its volume on a hot plate after which it was allowed to cool and then filtered. Trace metal concentrations in the drinking water samples were determined using a Buck Model 205 Flame Atomic Absorption Spectrophotometer (AAS) from East Norwalk, United States of America. The data collected for each location in the study were subjected to appropriate descriptive and inferential statistic using SPSS version 20. Results were considered significant with $p < 0.05$.

3. Result and Discussion

3.1 Physical and Chemical Parameters

The results the physical and chemical parameters of water collected from the boreholes and wells is shown in Table 1-3, the mean air and water temperature was shown to vary between 24.3±1.04 C^o and 26.1±0.55 C^o (BH3 and Well 3) and 23.3±1.17 C^o and 26.6±0.94 C^o (BH 2 and Well 4), there was no significant difference (p<0.05) in the mean temperature of boreholes and wells water during the period of study (Table 1), the result of physical parameters further revealed that there was significant difference (p<0.05) between the value obtained for temperature during dry and rainy season, the values recorded were within the range of 8ºC and 30ºC to which fish in the tropics is adapted [16]. pH of some of the water sampled were acidic in all stations except in borehole 4 and well 6 which became significantly (p< 0.05) alkaline, the rate at which the water samples collected in these study were acidic could be attributed to agricultural activities that is paramount in all this community [17,18]. Result of the seasonal variation in the values of pH revealed that there was no significant difference (p > 0.05) between dry and rainy season, this could be attributed to almost same anthropogenic activities going on in the study area.

3.2 Heavy Metal

For the protection of human health, guidelines for the presence of heavy metals in water have been set by International Organisations such as World Health Organisation (WHO), thus, heavy metals have maximum permissible level in water as specified by this organisation. Maximum contaminant level (MCL) is an enforceable standard set at a numerical value with an adequate margin of safety to ensure no adverse effect on human health, the highest level of a contaminant that is allowed in a water system. The five elements studied in this research includes: Lead (Pb), Copper (Cu), Arsenic (As), Cadmium (Cd) and Zinc (Zn) have Maximum Contaminant Levels of 10.0 µg/L, 20.0 µg/L, 10.0 µg/L, 3.00 µg/L and 3000 µg/L respectively [18]. The results of the heavy metals composition analysis of boreholes, wells and rivers water samples collected from the sampling stations in Ila Orangun, Osun State are presented in Table 1 to 3. The concentration of lead (Pb) in water samples collected from all the sampling station during the study period ranged from 98.7±26.25 µg/L (well 2) and 379.0±28.34 µg/L (well 1) along sampling stations Pb varied greatly but there was no significant difference (p>0.05) among the stations (Table 1), these results are of concern as lead has been recognised for centuries as a cumulative general metabolic poison [19]. It is a neurotoxin and is responsible for the most common type of human metal toxicosis [20]. Values of lead obtained were elevated in most of the boreholes and wells in all the three studied streets in the community. [18], suggest the permissible range of Pb for drinking and domestic water to be 10.0 µg/L. Cu is an essential trace metal to human life at moderate levels, functioning as part of several enzymes such as tyrosinase, cytochrome oxidase, super oxide dismutase, amine oxidases and uricase[21], the highest mean value of copper (Cu) concentration was recorded Street A (560.6±138.9 µg/L) while the lowest mean value was observed other sampling stations (465.3±125.0 µg/L) (Table 2), however the result in Table three showed values recorded for dry season was not significantly difference ($p<0.05$) from value recoded in the raining, the source of copper may be due to the intrusion of agricultural and domestic wastes [22]. This may be so as agriculture discharge waste runoff that percolates through soil reaching the underground water [23]. Concentration of copper in the groundwater samples were significantly higher than 20.0 µg/L standard level for drinking water of [18]. According to [24], elevated levels of arsenic in drinking water may cause thickening and discolouration of skin, nausea, vomiting, diarrhoea, numbness in the hand and feet. Values obtained for Arsenic in Table 1 was quite low in all stations when compared with values of other heavy metal determined, from the table well 5 was found with lowest (2.75±0.08 µg/L) concentration of arsenic, the result of this metal further revealed that there was significant difference ($p<0.05$) between the value obtained for arsenic during dry and rainy season (Table 3), the values recorded during the study period were found within the permissible limit stipulated by [18] which makes the water safe from arsenic pollution. All the water sources had values higher than the recommended level of 3.00 µg/L suggest by [18] as the permissible range of cadmium for drinking and domestic. The cadmium (Cd) concentrations along sampling stations varied greatly with no significant difference ($p<0.05$) among the stations (Table 1). Comparative analysis of the seasonal variation revealed that the mean value (84.05±14.5 µg/L) of cadmium concentration recorded during dry season was statistically lower than the value (26.1±3.33 µg/L) recorded in the rainy season (Table 3), result further narrates that value obtain rainy season was significantly different ($p<0.05$) from dry season, the variations could be as well attributed to agricultural activities that is utmost in the community with high cadmium [17].

Table 1: Mean Variation in Physicochemical and Heavy Metal Parameters of Water Quality of Boreholes, Wells in the Study Area

Stations		Air temperature (°C)	Water temperature (°C)	pH	Pb (µg/L)	Cu (µg/L)	As (µg/L)	Cd (µg/L)	Zn (µg/L)
BH1		25.0±0.61	24.5±0.67	6.1±0.74	109.7±83.8	548.7±46.0	5.25±0.75	56.0±13.8	159.3±55.9
BH2		24.9±0.8	23.3±1.17	6.47±0.81	157.0±35.3	448.5±64.3	9.50±2.50	37.25±9.9	167.32±19.1
BH3		24.3±1.04	24.3±0.87	6.67±0.86	179.7±39.4	358.7±69.6	9.5±2.30	40.5±14.0	162.3±26.1
BH4		25.0±0.73	25.2±0.77	7.47±0.51	240.5±48.2	524.0±34.2	6.5±2.3	96.7±23.4	180.9±22.6
Well1		24.8±0.77	26.0±0.64	6.77±0.74	379.0±28.34	847.2±54.03	8.0±2.46	58.5±12.65	201.62±62.5
well2		25.0±0.40	25.1±0.42	6.12±0.55	98.7±26.25	398.0±62.7	17.5±5.87	52.5±16.3	204.5±55±3
well3		26.1±0.55	25.7±0.92	6.17±0.5	244.2±89.7	312.5±72.3	17.7±8.77	46.7±13.3	213.0±45±9
well4		25.7±0.82	26.6±0.94	6.42±0.31	205.759.93	794.2±105.1	9.75±4.20	56.0±19.5	197.0±61.5
well5		25.0±0.52	25.7±1.08	6.05±0.15	228.2±66.9	288.5±50.23	2.75±0.08	59.2±14.63	208.0±51.59
well6		25.5±0.50	25.5±0.64	7.70.35	331.7±96.1	583.4±97.62	14.2±3.80	47.2±15.5	225.5±44.2
ANOVA	F	0.549	0.651	0.211	0.565	0.361	0.300	0.115	0.651
	P	0.827	0.745	0.991	0.814	0.945	0.969	0.999	0.745

The concentration of zinc (Zn) in water samples collected from all the sampling station during the study period ranged from 159.3±55.9 µg/L (BH 1) and 225.5±44.2 µg/L (well 6), along sampling stations zinc varied greatly but there was no significant difference ($p>0.05$) among the stations (Table 1). However, the results obtained were significant during the dry and rainy season, also from the Figure 2, it revealed that zinc concentration in the sample were significantly ($p<$ 0.05) low when compared with [18]. This indicates that water from the sampled groundwater contain the right proportion of Zn which is an essential plant and human nutrient element. The low concentration further implies that the water does not have caustic taste, hence good for consumption and other domestic uses. Figure 2 showed the comparison of heavy metals determined with World Health Organisation permissible limits of heavy metals in drinking and domestic water. From the figure, almost all the heavy metal determined were observed above the permissible limit of [18] except arsenic and zinc that were found within the permissible limits. The dominant heavy metals recorded in the study period were copper (Cu) and lead (Pb) respectively. The mean concentration of all heavy metals showed the order of dominance of Cu > Pb > Zn > Cd > As in most of the stations (BH 3, BH 4, well 1, well 3, well 4, well 5 and well 6) and Cu > Zn > Pb > Cd > As in borehole

1, 2 and well 2. The relationship among the physical, chemical and heavy metal were established using cluster analysis for the whole sampling period are shown in Figure 3. For the whole sampling period, the cluster diagram showed single clustered groups where the it subdivided into two subgroups, parameters observed in subgroup 1 includes air and water temperature, Cu, Zn, Cd, and. Group 2 had just lead (Pb), the analysis showed that all the heavy metals determined had a close relationship (Figure 4.7).

The results of this study showed high concentration some theof heavy metals determined and in some cases the levels were above WHO. Some of the metals analyzed in this study suggested that pollution of the well water and boreholes in the study areas as being attributed to anthropogenic activities (such as agricultural activities). It is therefore recommended that government and private individuals should ensure that groundwater are properly constructed, located in areas where there is minimum potential for contamination and have appropriate well head protection measures in place.

Table 2: ANOVA Statistic of Variation in Heavy Metal of Water Samples Collected in the Selected Street of Ila Orangun

Parameters	Street A	Street B	Street C	ANOVA	
				F	P
Air temperature (°C)	24.94±0.26	25.41±0.49	25.19±0.31	0.463	0.633
Water temperature (°C)	24.75±0.42	25.58±0.55	25.5±0.45	1.035	0.365
pH	6.36±0.33	6.42±0.32	6.43±0.29	0.013	0.987
Pb (µg/L)	186.12±87.6	209.9±86.2	266.8±121.0	0.174	0.838
Cu (µg/L)	560.6±138.9	488.5±132.2	465.3±125.0	0.145	0.866
As (µg/L)	10.06±4.13	12.33±5.13	7.83±3.42	0.246	0.783
Cd (µg/L)	51.06±9.38	47.75±12.8	67.75±23.3	0.455	0.638
Zn (µg/L)	183.19±28.89	190.7±36.3	204.8±38.7	0.105	0.901

Table 3: ANOVA Statistic of Seasonal Variation in Heavy Metals of Water in the Study Area

	Season		ANOVA	
Parameters	**Dry**	**Rain**	**F**	**P**
Air temperature (°C)	24.5±0.20	25.7±0.29	11.393	0.002*
Water temperature (°C)	24.3±0.35	26.0±0.29	16.203	0.00*
pH	6.27±0.23	6.54±0.27	0.544	0.465
Pb (µg/L)	385.3±58.2	49.7±4.26	11.639	0.002*
Cu (µg/L)	432.0±84.1	588.7±72.4	1.057	0.31
As (µg/L)	17.35±2.32	2.80±0.33	11.255	0.002*
Cd (µg/L)	84.05±14.5	26.1±3.33	15.151	0.00*
Zn (µg/L)	101.04±22.3	282.9±12.1	51.245	0.00*

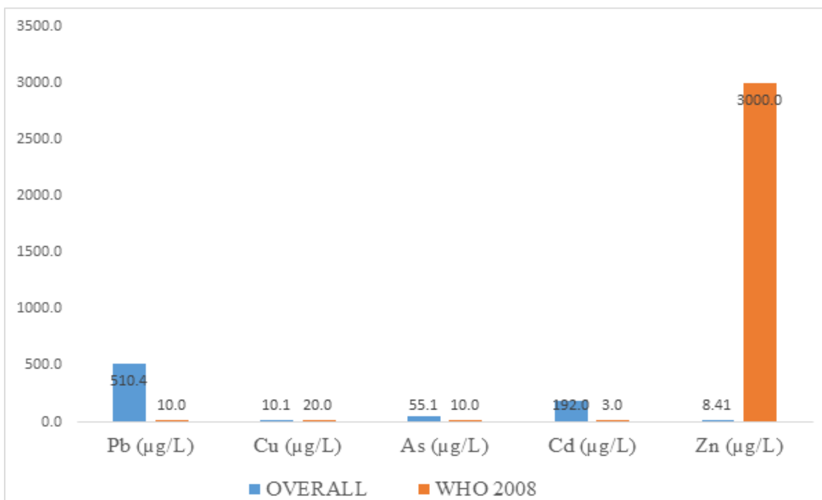

Fig 2: Comparison of Concentration of Heavy Metal Determined in the groundwater with World Health Organization Standard

Table 4: Order of Dominance of Heavy Metal (µg/L) in different Stations and Seasons of the Study.

	SECTION	CATIONIC ORDER
STATIONS	BH 1	Cu > Zn > Pb > Cd > As
	BH 2	Cu > Zn > Pb > Cd > As
	BH 3	Cu > Pb > Zn > Cd > As
	BH 4	Cu > Pb > Zn > Cd > As
	WELL 1	Cu > Pb > Zn > Cd > As
	WELL 2	Cu > Zn > Pb > Cd > As
	WELL 3	Cu > Pb > Zn > Cd > As
	WELL 4	Cu > Pb > Zn > Cd > As
	WELL 5	Cu > Pb > Zn > Cd > As
	WELL 6	Cu > Pb > Zn > Cd > As
SEASON	DRY	Cu > Pb > Zn > Cd > As
	RAINY	Cu > Zn > Pb > Cd > As

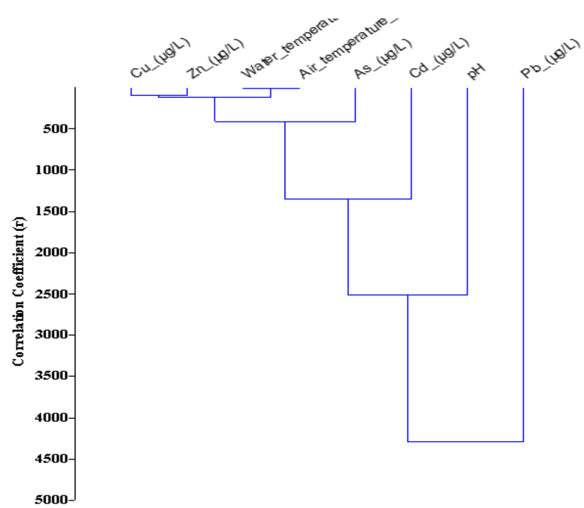

Fig 3: Cluster Analysis Showing Relationship between Physico-Chemical Parameters and Heavy Metals of Boreholes and Wells in the Study Area.

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