Assessment of trace metals in drinking water and groundwater sources in Ota, Nigeria

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Abstract- The levels of six trace metals namely iron, lead, manganese, copper, zinc and nickel were investigated in drinking water and groundwater sources in Ota, Nigeria. Detected concentrations of Mn, Cu and Zn were below the World Health organization and Standard Organization of Nigeria maximum permissible limits. Fe (92%) and Ni (53%) in some drinking water and groundwater sources were found in concentrations that exceeded the maximum permissible limits for these metals. Notably, the levels of Pb were below detection limit in all the bottled, well and borehole water, with exception of the hospital borehole, while the swimming pool had high concentrations of Fe (0.88 mg/L), Pb (0.21 mg/L) and Ni (0.19mg/L) compared to SON (0.30 mg/L), WHO (0.01 mg/L) and WHO (0.07 mg/L) respectively. Pollution indices indicated significant pollution of Pb, Fe and Ni. Overall, the mean metal levels in the sampled water sources followed a descending order, Fe>Cu>Zn>Ni>Pb>Mn. Some of the drinking water and groundwater sources could be considered safe for drinking, but proactive measures should be taken to check the levels of Fe, Pb and Ni in the swimming pool.

Index Terms- Water quality, Drinking water, Groundwater, Trace metals, Water pollution

I. Introduction

In recent times, there has been an increasing health related concern associated with the quality of drinking water in developing countries. According to a recent report by WHO/UNICEF, about 780 million people in the developing world lack access to potable water due largely to microbiological and chemical contaminations **(1)**. Drinking water sources in these so-called developing countries are under increasing threat from contaminations by chemical, physical and microbial pollutants. Known sources (both naturally occurring and anthropogenic) of chemical contamination of water supplies include organic and inorganic substances from industrial effluents, municipal wastes, petroleum derived hydrocarbons, detergents, mining, agricultural pesticides and fertilizers **(2, 3)**. Limnic and lacustrine aquatic ecosystems (fresh water lakes, rivers, streams, etc.) and groundwater (well, borehole, or spring water) are increasingly used for refreshment, domestic, industrial, agricultural, and recreational purposes. Surface water systems are particularly vulnerable to pollution than groundwater. However, it has been reported that groundwater contains enhanced concentrations of arsenic, iron, fluoride, radioactive elements and nitrates attributed to natural processes as well as human –mediated activities such as seepages from underground storage facilities and faulty septic systems **(4)**.

Trace metals, among a wide range of contaminants, are consistently of health concern due to their toxicity potentials at very low concentrations, and tendency to bioaccumlate in tissues of living organisms over time **(5)**. They gain entrance into human systems via contaminated drinking water, food and air. Once in the body, the bioavailable form of these metals can compete with, and displace essential minerals such as zinc, copper, magnesium and calcium; and interfere with organ system function **(6)**.

Toxic metals such as mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl) and lead (Pb) have no beneficial effects in humans, as such long-term exposure may cause more severe disruptions in the normal functioning of the organ systems where the metals are accumulated. Pb, for example, is associated with a wide range of negative pregnancy outcomes, including early membrane rupture and spontaneous abortion, erectile dysfunction, and contributes to **c**ardiovascular diseases **(7)**. Metals such as As, Mn, Ti, Cd, Cr, V, Co, Cu, Fe, Pb, Ni, Zn and their compounds have been shown to be initiators or promoters of carcinogenic activity in animals. Also, Be, Sb, Al, Hg, Ni, Cd and Co can cause adverse reproductive/fertility problems **(8)**.

However, as micronutrients, some trace metals such as zinc, copper, iron and manganese are required by the body in small amounts for metabolic activities. These same elements, at higher concentrations can cause adverse health effects or illness **(9)**. Zinc toxicity leads to diarrhea **(10)**, manganese may hamper the intellectual development of the child **(11)**. Iron has been associated with genetic and metabolic diseases and, repeated blood transfusions **(12)** and copper toxicity is related to several health concerns, including stomach cramps, nausea, vomiting, diarrhea,cancer, liver damage and kidney disease **(13)**.

In Nigeria, public and private water supplies are not sufficiently monitored by regulatory agencies such as National Environmental Standards and Regulations Enforcement Agency (NESREA) and National Agency for Food and Drugs Administration and Control (NAFDAC) respectively, resulting in proliferation and distribution of unsafe and substandard drinking water. However, taking cognizance of the far-reaching health consequences of deteriorating drinking water quality in the country, it has become imperative to comprehensively investigate the amounts of chemical constituents of these water sources. Therefore, this research work was aimed at assessing the concentrations of Fe, Pb, Mn, Cu, Zn and Ni in several water sources from a typical urban settlement in Nigeria. It also attempted to determine the trace metal pollution indices as well as compare the observed concentrations with the water quality permissible limits specified by the World Health Organization and Standard Organization of Nigeria.

II. MATERIALS AND METHODS

A. Description of study area

Ota is a town in Ogun state, and the capital of Ado-Odo/Ota local government area. It has a geographical coordinates of 6°41′00″N 3°41′00″E to the north of the Area. It is home to a number of manufacturing industries in Nigeria. Their major sources of water are underground and rivers.

B. Sample collection, pre-treatment and chemical analysis

Twelve water samples were randomly collected within Ota in Ogun state. The water sources include: borehole, well, bottled, sachet and swimming pool. Samples were collected in 1L polyethylene container. The sample containers were washed with 20 % analytical grade nitric acid and rigorously rinsed with distilled deionized water. Prior to sampling, it was further rinsed with the actual sample. Collected samples were preserved by chemical adjustment of the pH < 2, by acidifying with 5 milliliters of analytical grade nitric acid. This reduces precipitation and sorption losses to the container walls. After which the samples were stored under ice on transit and then refrigerated after arriving at the laboratory at a temperature of (4°C) prior to analysis. The water samples and reagent blank were digested using concentrated nitric acid (HNO_3) for the determination of metal ions concentration and was further analysed using S series atomic absorption spectrophotometer (AAS). This was critical in order to destroy the organic matrix capable of trapping the trace metals, and thus making them unavailable for the instrumental analysis. Also, prior to metal ion analyses, calibration solutions of the target metal ions were prepared from standard stock by serial dilution. Quality assurance and control was performed according to the specified method of **(14).**

III. RESULTS AND DISCUSSIONS

The swimming pool is expected to comply with the standard for drinking water **(17)**. The suitability of swimming pool for intended purpose is dependent on the sanitation culture of the managers of the pool. Hence, to evaluate the safety of water for drinking and recreational purposes, concentrations of trace elements in water in the present study were compared with the guidelines for drinking-water quality established by WHO (15) and SON (16). The results shown in Table 1 for the levels of trace metals in drinking and swimming pool are the means of triplicate measurements. Table 1 shows the concentrations of trace metals namely- Fe, Pb, Mn, Cu, Zn, and Ni analyzed in borehole, well, bottled sachet and swimming pool samples in Ota and its environs.

A. Trace metals below permissible limit (Mn, Cu and Zn)

Mn, Cu and Zn, which are considered as essential elements to the human body, were found in relatively low concentrations in all the samples. The concentration of Mn and Cu in the water sources were in the range of 0.02 to 0.08 mg/L and 0.04 to 0.75 mg/L, respectively, while that of Zn ranged from 0.04 to 0.65 mg/L (Table 1).

Table 1.0: Observed concentrations (mg/L) of trace metals in drinking water and groundwater sources

Sample location	Sample ID	Fe	Pb	Mn	Cu	Zn	Ni
Borehole							
Iyana borehole	BI	0.46	<LD	0.04	0.07	0.09	0.11
Hospital borehole	BH	0.73	0.03	0.02	0.06	0.14	0.08
NNPC borehole	BN	1.41	<LD	0.08	0.07	0.09	0.09
Covenant borehole	BC	0.77	<LD	0.04	0.17	0. 65	0.02
Well							
C_4 well	WC	1.24	<LD	0.07	0.08	0.15	0.03
Iyana well	WI	0.11	<LD	0.03	0.06	0.04	0.08
Bottled							
Kesh Bottled	KB	0.42	<LD	0.05	0.15	0.11	0.07
Hebron Bottled	HB	0.43	<LD	0.04	0.07	0.05	0.1
Sachet							
Bakers Sachet	BS	0.41	<LD	0.05	0.07	0.08	0.18
Hebron Sachet	HS	0. 58	0.01	0.02	0.04	0.05	0.07
Swimming Pool							
Bells Pool	BP	0.49	0.21	0.04	0.44	0.09	0.13
Covenant Pool	CP	0.88	0.05	0.03	0.75	0.12	0.19
Standards							
WHO (mg/L)		-	0.01	-	2.00	-	0.07
SON (mg/L)		0.30	0.01	0.20	1.00	3.00	0.02
Remark		**APL**	**APL**	**BPL**	**BPL**	**BPL**	**APL**

<LD = below detection limit, APL = above permissible limit; BPL = below permissible limit,
SON = Standard Organization of Nigeria, WHO = World Health Organization

Table 2.0: Pollution Index for the metal ions

Parameter	Pollution Index
Iron	2.20
Lead	7. 50
Manganese	0.22
Copper	0.08
Zinc	0.05
Nickel	1.37

These values are far below the maximum permissible limit of 0.20 mg/L (SON), 2.00 mg/L (WHO) and 3.00 mg/L (SON) respectively as shown in Table 1.

A previous work done in the same study area revealed that the range of concentration of Zn varied between 0.030 mg/L to no Zn detected in samples **(18)**. When compared with the result for Zn (0.04 to 0.65 mg/L) in this work, an increasing trend of Zn present in water is seen.

Also, on comparing with similar study, investigating the chemical characteristics of these metals in Osun state, it was also seen that the concentrations of Mn, Cu and Zn in all the samples were below the regulatory desirable level for the metals in the various water sources **(19)**. Based on the result from the various water sources in this study area, it can be implied that these trace metals do not impart undesirable taste and colour to the water, nor pose possible health threat to consumers.

B. Trace metals above permissible limit (Fe, Pb and Ni)

The concentration of Fe in the different water sources shown in Table 1 ranged between 0.11 and 1.41 mg/L. Interestingly, It was observed that about 92% of Iron in all the water samples were all excessively greater than the SON standard for maximum permissible limit of 0.30 in drinking and swimming pool with exception of Iyana well water (WI = 0.11mg/L). The highest concentration of iron was recorded in borehole water collected at NNPC. The trend of accumulations of this metal in these water sources are as follows: borehole > well > swimming pool > sachet >bottled. Result agrees to previous works of (**18, 20**) where iron was reported to occur in high concentrations in ground and drinking water. This excess concentration of iron may be attributed to rocks and soil containing iron, which can dissolve into the water source. Even though iron poses no danger to health at levels found in drinking water, it may affect acceptability of drinking water by altering its appearance, taste, odour, stain clothing and appliances and promote the growth of iron bacteria in the water system (**15**). Hence, operator(s) may be advised to treat the water using a water softener or iron filter.

Lead concentrations above WHO and SON guideline (0.01 mg/L) were present in 25% of the samples, swimming pool (C.P = 0.21 and B.P 0.05) and bore hole (B.H = 0.03) (Table 1). Notably, the levels of lead were below detection limit in all the bottled, well and borehole water, with exception of the hospital borehole. The possible sources of lead in these samples could be associated with the corrosive water effects on household plumbing systems containing lead in pipes, solder, fittings or the service connections to homes. The swimming pools are located along busy roads as such Pb contaminated street dust and lead-based paint from the buildings in the vicinity could have contributed to the elevated value. Hence, the hospital borehole water is not fit for domestic purposes, and the swimming pool water may not also support recreational purposes until the Pb level is reduced since exposure to lead level above 0.01 mg/L is associated with a wide range of effects, including renal failure, impaired fertility and adverse pregnancy outcomes, hematological and neurological problems, permanent damage to the central nervous system, the brain, and kidneys (**11, 15**).

The results when compared with similar studies investigating the chemical characteristics of potable and surface water sources in Ota and environs showed that while Pb ranged from not detected to 0.086 mg/L in tap, sachet and swimming pool (**18**), it was not detected in other borehole and well water sources investigated (**21**). This implies that Pb contamination in some of the water sources could be attributed more to anthropogenic activities than accumulation in ground water from the study locations.

The concentration of Ni as shown in (Table 1 ranged between 0.02 mg/L and 0.19 mg/L obtained for water samples from BC and BP locations respectively. Nickel was present in all samples. Only 40% of the potable water samples were within the WHO set standard of 0.07mg/L for nickel, while others were above by 60%. Also, both swimming pool samples exceeded the WHO guideline values for nickel. Even though nickel is regarded as an essential trace metal, it is equally toxic at elevated concentration. Hair loss, lung fibrosis, skin allergies, outbreak of eczema, and variable degrees of kidney and cardiovascular system poisoning have been associated with humans exposed to high level of nickel (***22***). In addition, it has the tendency of substituting for iron and zinc in the body, thus interfering in the normal biochemistry (**23**).

C. Pollution Index (Pi)

Pollution index (Pi) is defined as the ratios of the concentration of individual parameter against the baseline standard. It provides information on the relative pollution contributed by individual samples. The critical value is 1.0, values greater than 1.0 indicates significant degree of pollution while values less than 1.0 shows no pollution (**24, 25)**. Pi is computed as:

$$\text{Pollution index}\,(Pi) = \frac{\text{Concentration}}{\text{Standard}}$$

The pollution Index value is presented in Table 2. The values obtained for iron, lead, manganese, copper, zinc and nickel in all the samples investigated revealed that some of the waters sources were polluted. Amongst the six metals, significant degree of pollution was seen in lead, iron and nickel. This confirms the results on trace metals above permissible limit (Fe, Pb and Ni), for the different water sources in section B above.

IV. CONCLUSIONS AND RECOMMENDATIONS

Overall, the mean metal levels in the sampled water sources followed a descending order: Fe>Cu>Zn>Ni>Pb>Mn. Fe (92%), Ni (53%) and Pb (25%) in the observed water sources (Table 1) exceeded the maximum permissible limits in drinking water and swimming pool as specified by WHO and SON standards. Also, the pollution index result obtained confirmed significant pollution in lead, iron and nickel. It is therefore suggested and advised that the concern contaminated sources be subjected to further treatments that will reduce drastically, the concentration of these identified trace metals which are capable of posing adverse threat to health of consumers and the society. Individuals are advised to take responsibility of their well-being by testing their drinking water sources periodically.

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