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Full Length Research Paper

Occurrence and health implications of high concentrations of Cadmium and Arsenic in drinking water sources in selected towns of Ogun State, South West, Nigeria

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In this study, we report the quantification of the concentrations of Cd, Pb and As in borehole, well, stream and rain water sources in Ota and some major towns in Ogun State, Nigeria. The pH ranges from 4.8 to 6.98, 5.40 to 7.86 and 6.99 to 8.20 in boreholes, well and rain respectively. Lead was not detected at all in the drinking water sources in all the locations investigated. However, the concentrations of Cadmium and Arsenic were observed to be higher than the maximum allowable limits (MAL) in drinking water by the WHO and the Nigerian Standard for drinking water quality in some of the drinking water sources. The Cadmium levels in boreholes for Ota, Agbara, Ifo, Abeokuta and the Male hostel of BellsTech are greater than the maximum allowable limits while the metal was not detected in the boreholes of CU student hostel and the Female hostel of BellsTech. Similarly, the Arsenic levels in boreholes for Ota, Abeokuta, Agbara and Ifo are greater than the maximum allowable limits whereas the metal was not detected in the boreholes of Male and Female hostels of BellsTech and Covenant University (CU) student hostel. The health implication is that if nothing is done to remove these metals before drinking from these water sources in which the concentrations are significantly higher than the MAL, the consumers of such drinking water are at risk of the health hazards that could be caused by these metals.

Key words: Health, Cadmium, Arsenic, drinking water, Ota, maximum allowable limits.

INTRODUCTION

Water is a basic and indeed an absolute requirement for the survival of human race. The quality of drinking-water is a powerful environmental determinant of health (WHO, 2010) and an adequate supply of good quality safe water is essential for the promotion of public health. Generally, in less developed parts of the world and particularly in the tropic areas, the health hazards caused by polluted water supplies are more numerous than those in the temperate and more developed areas of the world. Water for domestic use should be clear, colorless, odorless, pleasant to drink and reasonably cool and free from impurities harmful to health. It is very well known that human health and survival depend on uncontaminated and clean water for drinking and other domestic uses (Memon, 2002). There is no substitute for water in many of its uses unlike many other raw materials (Sylvester, 2003).

Ground water is the most important source of the domestic, industrial and agricultural water supply in the world (Adeyeye and Abulude, 2004). Although, it is easily accessible from lakes, rivers, streams and springs,

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Abbreviations: Pb, Lead; **Cd,** Cadmium; **As,** arsenic; **MAL,** maximum allowable limit; **BellsTech,** Bells University of Technology; **CU,** Covenant University.

borehole water is of better quality. Rock weathering, atmospheric precipitation, evaporation and crystallization control the chemistry of water. The influence of geology on chemical water quality is widely recognized (Gibbs, 1970, Lester and Birkett, 1999). Developing countries are witnessing changes in ground water which constitute another source of portable water.

The influence of soils in water quality is very complex and can be ascribed to the processes controlling the exchange of chemicals between the soil and water (Hesterberg, 1998). The water chemistry of the ground water will mainly consist of inorganic chemicals and suspended solids as a result of urban run-off (McGregor et al., 2000).

The concern for water resources containing contaminants, such as heavy metals and toxic metalloids, that pose a threat to health, has increased worldwide (Anazawa, 2004). The presence of metals in water results from two independent factors. The first involving the weathering of soils and rocks (Bozkurtoglu et al. 2006; White et al., 2005; Donahue et al., 1983) with its products being transported by air (Moreno et al., 2006; Rubio et al., 2006) and water (Das and Krishnaswami, 2007), and the second involving a variety of anthropogenic activities that have created a societal health risk in rivers that receive a substantial amount of waste from such activities (Espino et al., 2007; Rubio et al., 2004; Rubio et al., 2005).

Arsenic is found widely in the earth's crust in oxidation states of -3, 0, +3 and +5, often as sulfides or metal arsenides or arsenates. In water, it is mostly present as arsenate (+5), but in anaerobic conditions, it is likely to be present as arsenite (+3). It is usually present in natural waters at concentrations of less than 1 to 2 mg/L. However, in waters, particularly ground waters, where there are sulfide mineral deposits and sedimentary deposits deriving from volcanic rocks, the concentrations can be significantly elevated. Apart from occupational exposure, the most important routes of exposure are through food and drinking-water, including beverages that are made from drinking-water. Where the concentration of arsenic in drinking-water is 10 mg/L or greater, this will be the dominant source of intake. In circumstances where soups or similar dishes are a staple part of the diet, the drinking-water contribution through preparation of food will be even greater. Levels in natural waters generally range between 1 and 2 mg/L, although concentrations may be elevated (up to 12 mg/L) in areas containing natural sources (WHO, 2010).

Cadmium is released to the environment in wastewater, and diffuse pollution is caused by contamination from fertilizers and local air pollution. Contamination in drinking-water may also be caused by impurities in the zinc of galvanized pipes and solders and some metal fittings. Food is the main source of daily exposure to cadmium. The daily oral intake is 10 to 35 mg. Smoking is a significant additional source of cadmium exposure (WHO, 2010).

Owing to the decreasing use of lead containing additives in petrol and of lead-containing solder in the food processing industry, concentrations in air and food are declining, and intake from drinking-water constitutes a greater proportion of total intake. Lead is rarely present in tap water as a result of its dissolution from natural sources; rather, its presence is primarily from household plumbing systems containing lead in pipes, solder, fittings or the service connections to homes. The amount of lead dissolved from the plumbing system depends on several factors, including pH, temperature, water hardness and standing time of the water, with soft, acidic water being the most plumbosolvent. Concentrations in drinking-water are generally below 5 mg/L, although much higher concentrations (above 100 mg/L) have been measured where lead fittings are present (WHO, 2010).

Atomic Absorption Spectrophotometry (AAS) is an analytical technique in which the absorption of light of free atoms is measured. In AAS, light of a wavelength characteristic of the element of interest is shone through the atomic vapor. Some of this light is then absorbed by the atoms of that element. The amount of light that is absorbed by these atoms is then measured and used to determine the concentration of that element in the sample (Boss and Fredeen, 1997).

MATERIALS AND METHODS

Sample collection and location

Water samples were randomly collected in Six different areas in Ogun State. These areas include; Abeokuta, Ewekoro, Ifo, Sango-Ota, Ota and Agbara. The samples were collected between the month of July and September, 2010. The drinking water samples were collected in prewashed polyethylene bottles. The samples were obtained directly from the sources and each sample bottle and its cap rinsed three or four times before collection. The composition of the water collected were representative of the water sources. The samples were labeled immediately and transported to the Laboratory (Central Research Laboratory, Bells University of Technology, Ota, Ogun State, Nigeria) where the pH was measured. The electrode of the pH meter with a temperature sensor was rinsed with distilled water and lowered into the beaker containing the water sample. The pH meter was allowed to stabilize and the pH of the sample read. The analysis was carried out at a temperature of 25°C

Sample analysis

The water samples were analyzed for the presence of Cadmium, Arsenic and Lead with wavelengths 228.8, 193.7 and 217.0 nm respectively. AAS (S Series 712354 v1.27) with a deuterium background collector was used in the determination of the trace metals. This analysis was carried out at the Central Laboratory of the University of Agriculture, Abeokuta, Ogun State, Nigeria.

RESULTS

Table 1 shows the pH and concentrations obtained for Pb

Table 1. The pH and concentrations of Lead (Pb) and Arsenic (As) in drinking water samples from boreholes.

Locations	pH	Pb (mgL^{-1})	As (mgL^{-1})
Abeokuta	7.0	ND	0.305
Agbara	4.8	ND	0.478
Ota	5.5	ND	0.237
Ifo	5.7	ND	0.595
FH BellsTech	6.4	ND	ND
MH BellsTech	6.2	ND	ND
CU Hostel	5.9	ND	ND

*ND = Not Detected.

Table 2. The pH and concentrations of heavy metals in drinking water samples from well sources.

Locations	pH	Pb (mgL^{-1})	As (mgL^{-1})
Abeokuta	7.9	ND	0.264
Agbara	5.4	ND	0.638
Ota	7.1	ND	ND
Ifo	5.8	ND	0.350
Ewekoro	7.8	ND	0.560
Brewery Area	5.9	ND	0.290

*ND = Not Detected.

Table 3. The pH and concentrations of heavy metals in drinking water samples from Rain.

Locations	pH	Pb (mgL^{-1})	As (mgL^{-1})
Ota	7.0	ND	ND
Ifo	8.2	ND	0.055

*ND = Not Detected.

and As in drinking water from boreholes in the various locations sampled. The pH values range from 4.80 to 6.98 which suggest that the water from the boreholes in this locations are slightly acidic. Lead was not detected at all in the locations sampled. Similarly, arsenic was not detected in the Male and Female Hostels of BellsTech and CU Student Hostel. We observed that the concentrations of Arsenic are all excessively greater than the WHO standard for MAL in Abeokuta, Agbara, Ota and Ifo. The trend of accumulations of this metal in these locations is as follows: Ifo > Agbara > Abeokuta > Ota. The results for the concentrations of Pb and As in drinking water from wells are depicted in Table 2. The pH values of these sources show that they are mostly slightly acidic. Again Pb was not detected while the As values are higher than the MAL in the locations sampled except Ota where the metal was not detected. The trend of accumulations of As in these locations is as follows: Agbara > Ewekoro > Ifo > A Brewery area (Sango-Ota) > Abeokuta.

Rainwater was only collected from two locations namely, Ota and Ifo. As was not detected in the rainwater in Ota whereas the concentration observed from rainwater in Ifo is 5.5 times greater than the MAL. Pb was not detected at all in the rainwater of both locations. The results are shown in Table 3. A stream used as a source of drinking water in an area in Abeokuta was analyzed and the pH was found to be weakly alkaline. The As value (0.275 mg/L), is higher than the MAL value but Pb was not detected. Table 4 illustrates this result.

The acceptable limits or MAL for consumption for the metals are as follows: Lead – 0.01 mg/L, Cadmium – 0.003 mg/L, Arsenic 0.01 mg/L. The levels of cadmium in drinking water from boreholes in the sampled locations

Table 4. The pH and concentrations of heavy metals in drinking water samples from stream.

Locations	pH	Pb (mgL^{-1})	As (mgL^{-1})
Abeokuta	7.9	ND	0.275

*ND = Not Detected.

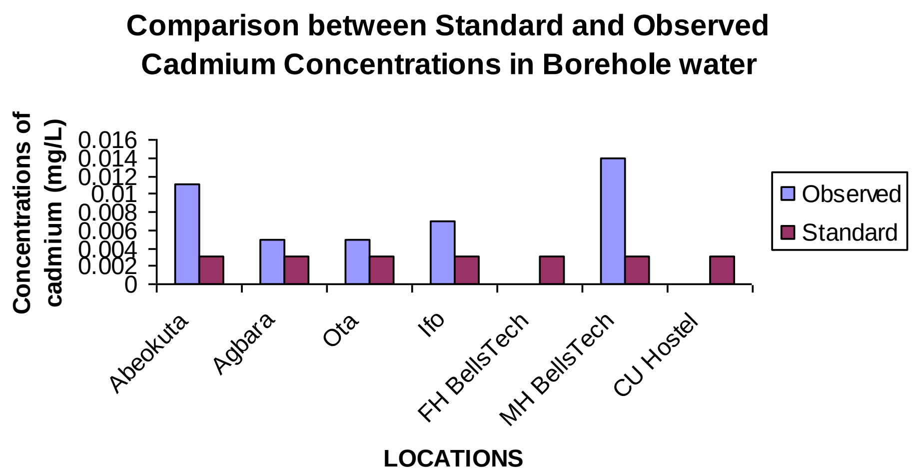

Figure 1. The concentrations of Cadmium compared to the MAL standard in drinking water samples from boreholes and their locations.

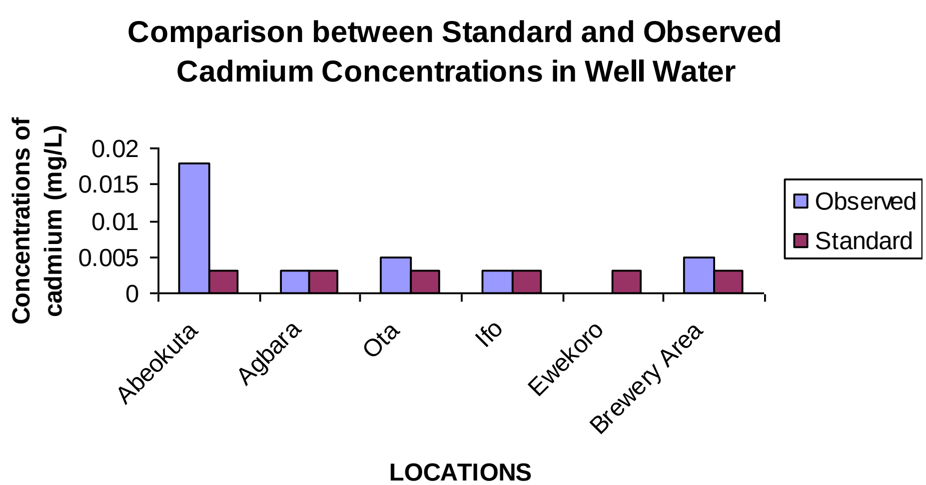

Figure 2. The concentrations of Cadmium compared to the MAL standard in drinking water samples from wells and their locations.

are illustrated in Figure 1. This metal was not detected in the boreholes used by the Female Hostel of BellsTech and the CU Student Hostel. The concentrations of Cadmium are 0.005, 0.007, 0.011 and 0.014 mg/L for Agbara and Ota, Ifo, Abeokuta and the Male Hostel BellsTech respectively and are observed to be greater than the MAL value. Cadmium levels are also observed to be higher in drinking water from Well in Abeokuta, Ota and in a brewery area in Sango-Ota. Cadmium was not detected in the well sampled from Ewekoro. The Cadmium levels from Well in Agbara and Ifo are exactly the same as the MAL value (Figure 2).

The Cadmium levels in the rainwater collected from Ota and Ifo shows a two-fold and three-fold increase

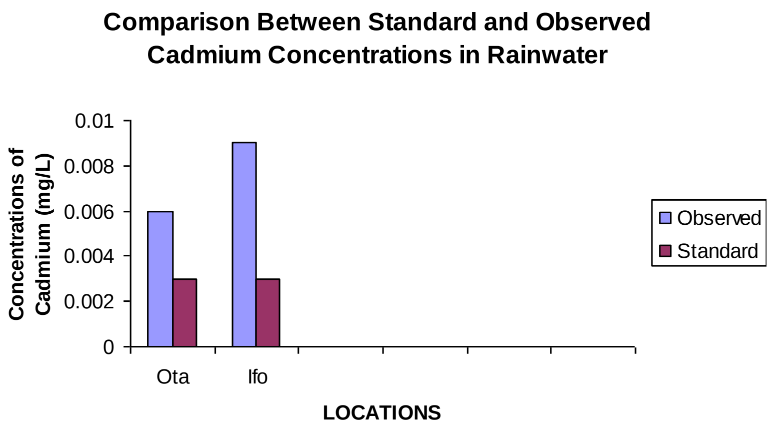

Figure 3. The concentrations of Cadmium compared to the MAL standard in drinking water samples from rainwater and their locations.

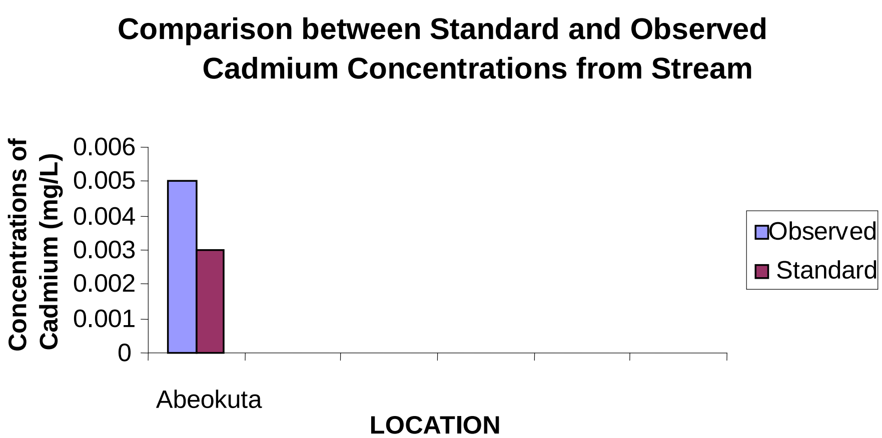

Figure 4. The concentration of Cadmium compared to the MAL standard in drinking water sample from a stream in Abeokuta.

respectively from the MAL value (Figure 3). The Cadmium concentration in the stream used as a source of drinking water in an area in Abeokuta is about twice the MAL value (Figure 4).

DISCUSSION

Borehole, well, stream and rain are common sources of drinking water in Ogun State. Some are treated, while others are consumed untreated. Due to high level of urbanization and industrialization around Ota, Agbara, Abeokuta and some other towns in Ogun State, and indiscriminate waste disposal practices, it is not unlikely that all or some of the drinking water sources are contaminated with some highly dreaded heavy metals in drinking water sources. Domestic sewage, combustion emission, mining operations, metallurgical activities and industrial effluents are among the sources of anthropogenic metal inputs and heavy metals such as Pb, Cd, Cu, and Zn are released as a result of these processes (Chinni and Yallapragda, 2000). The results of several current analyses of sachet water have implied some levels of microbiological and organic contamination (personal communication); natural sources are now being preferred as safer sources. Hence, these sources have to be assessed for the level of their actual safety. Unfortunately, the results observed from our assessment show that majority of these drinking water sources contain heavy metals such as Arsenic and Cadmium in amounts greater than the maximum allowable limit of the WHO and Nigeria standard for drinking water quality which implies that they may not be safe for drinking. Consequently, there may be accumulation of these metals in the consumers of this drinking water from those sources which may results in cancer (Nigerian Industrial Standard, 2007) and other related diseases.

Lead was not detected in any of the sources in all the locations sampled which suggests that the metal level if present at all is very low and there had not been an accumulation of it in ground water in those areas. It also means that there have been little or no anthropogenic activities resulting in lead accumulation in those areas.

Only the drinking water from boreholes of the CU Student Hostel, and the Female Hostel, BellsTech could be considered to be safe for drinking in our own opinion because the results reveal that the drinking water from these boreholes are free of Lead, Arsenic and Cadmium contamination. However, there is need for monitoring and further assessment of other trace metals that could affect human health in order to fully establish the quality of drinking water from these sources. The drinking water from the borehole of the Male Hostel end of BellsTech contains Cadmium concentration greater than the MAL and should therefore be subjected to further treatment so as to remove or at least reduce the Cadmium level below the MAL value. Also the drinking water from well in a residential building from Ewekoro does not contain detectable levels of Cadmium and Arsenic which suggests that the water is relatively safe for drinking. The lack of detectable levels of these metals is probably due to the location of the well which is about 1.5 km from the famous Ewekoro Cement Factory, Ogun State, Nigeria. However, report has shown that water sources very close to the factory contain high levels of heavy metals (personal communication).

Generally, the drinking water sources from the city of Abeokuta would require adequate water treatment and removal of heavy metals such as Arsenic and Cadmium to improve the quality and make it safe for drinking and other domestic uses. This is very necessary in our own opinion because the results of assessment of the drinking water sampled from borehole, well and stream in Abeokuta gave high concentrations of arsenic and cadmium. Similarly, the drinking water sources from Ota and Agbara would also require treatment and proper monitoring in order to reduce or remove toxic metals. However, the water from wells in Ota and Agbara appears to be safer than the water from boreholes according to the results of these findings.

The quality of water may be described according to their physico-chemical and microbiological characteristics. The quality of ground water is never constant; it is constantly changing in response to daily, seasonal and climatic rhythms. For effective maintenance of water quality through appropriate control measures, continuous monitoring of large number of quality parameters is crucial because the changes in properties of water have far-reaching implications directly to the biota and indirectly to man. Water quality data are thus, essential from the implementation of responsible water quality regulations for characterizing and remediating contaminants and for the protection of the health of humans and ecosystem.

The effect of Cadmium poisoning in humans are very serious. Among them are high blood pressure, kidney damage, destruction of testicular tissue, and destruction of red blood cells. It is believed that much of the physiological action of Cadmium arises from its chemical similarity to Zinc. Specifically, Cadmium may replace Zinc in some enzymes, thereby altering the stereo-structure of the enzymes and impairing its catalytic activity. Diseases symptoms ultimately result (Bhata, 2008). It may be speculated that the high values of Arsenic detected in Ota and the other locations is because the largest number of industries in Ogun State are located in Ota and its environs. Ota is also in the vicinity of the flow of the country's water course into Lagos lagoon hence, the possibility of contamination through surface or aquifer water flow. Moreover, there is a major cement factory located nearby Ota in Ogun State and the direction of water flow is from the cement factory down to Ota town. The findings on high levels of As in drinking water sources reported here, must be an alert to health agencies in the locations concerned because this element has been associated to development of Leukemia (Robinson et al., 2001), abnormalities in children (Steinmaus et al., 2004) cancer (Chen et al., 1988; IARC, 2004) and with various other diseases (Hopenhayn-Rich et al., 1998; NRC, 2001).

Arsenic toxicity strongly depends on the form in which arsenic is present. Inorganic arsenic forms, typical in drinking water, are much more toxic than organic ones that are present in Sea food (Branislav, 2007). The first visible symptoms caused by exposure to low Arsenic concentrations in drinking water are abnormal black-brown skin pigmentation known as *melanosis* and hardening of palms and soles known as *keratosis*, further thickening (*hyperkeratosis)* and can lead on to skin cancer (WHO, 2001). Arsenic may attack internal organs including lungs, kidney, liver and bladder without causing any visible external symptoms, making Arsenic poisoning difficult to recognize. Elevated concentrations in hair, nails, urine and blood can be an indicator of human exposure to Arsenic before visible external symptoms (Rasmussen and Anders, 2002). The disease symptoms caused by chronic Arsenic ingestion are called *arsenicosis* and develop when Arsenic contaminated water is consumed for several years. However, there is no universal definition of the disease caused by Arsenic, and no way of knowing which cases of cancer were caused by drinking Arsenic affected water. A correlation between hypertension and Arsenic in drinking water has also been established in a number of studies. The International Agency for Research on Cancer has concluded that: “There is sufficient evidence in humans that Arsenic in drinking-water causes cancers of the urinary bladder, lung and skin” (IARC 2004).

Conclusion

In the light of the parameters assessed, it can be concluded that the drinking water sources in the selected towns of Ogun State in this study may not have any adverse effect as far as Lead is concerned. On the other hand, the high Arsenic and Cadmium concentrations measured in this study raises a red flag to the health of communities settled in the affected towns. Although, further studies on the assessment of these metals and other heavy metals are ongoing in our research laboratory, we will like to advocate for regular proper treatment and monitoring of these drinking water sources.

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