Assessment and Analysis of the Presence of Heavy Metals in Water in Ara and Laminga of Nasarawa State, Nigeria: Health Implication on the Populace

Rilwan Usman[1*]; Aliyu Muhammad Kamal[2]; Emmanuel I. Ugwu[1]; Idris M. Mustapha[2]; Adamu Mamman[3]; and Abdulrahman Hudu[3]

[1]Department of Physics, Nigerian Army University, PMB 1500 Biu, Borno State, Nigeria.
[2]Department of Physics, Nasarawa State University, PMB 1022 Keffi, Nasarawa State, Nigeria.
[3]Department of Chemistry, Nigérian Army University, PMB 1500 Biu, Borno State, Nigeria.

E-mail: rilwan.usman@naub.edu.ng*
emmanuel.ifeanyi@naub.edu.ng

ABSTRACT

We present the analysis and assessment of heavy metal concentrations in water sources across Ara and Laminga Local Government Area (LGA) of Nasarawa State using Micro Plasma Atomic Emission Spectroscopy (MP-AES). The results revealed that heavy metals were present in water to the level of (Zn (0.35 and 0.2), Cd (0.00 and 0.00), Fe (0.05 and 0.05), Cu (0.02 and 0.01), Pd (0.04 and 0.02), Ni (0.012 and 0.012) and Mn (0.04) mg/L, respectively. The conclusion here was that the mean concentrations are insignificant for all metals except lead, and as such the water in the area may be considered mostly free of heavy metals and good for human consumption. However, long term accumulations of these metals may result in the gross toxicological implications or carcinogenic risk on the body systems/organs of the inhabitants from the study areas due to long-term continuous consumption of the water containing some of these metals.

(Keyword: water assessment, heavy metals, accumulation, public health, concentration, gastropods, Micro Plasma Atomic Emission Spectroscopy, MP-AES. potable water)

INTRODUCTION

Water is an essential component of life and fresh water constitutes about 3% of the total water on the Earth's surface. Only 0.01% of this fresh water is available (1). With two thirds of the Earth's surface covered by water and the human body consisting of 75% water, it is evident that water is one of the prime compounds responsible for life on Earth.

Regrettably, even this small portion of fresh water is under pressure due to anthropogenic pollution sources that results from rapid growth in population and industrial activities (2). Heavy metals are the main pollutants and elements of risk in drinking water (3). Investigations on water contamination by the presence of heavy metals have become the prime focus of environmental scientists in recent years (4). More attention should be given to toxic heavy elements because of their bio accumulation and bio magnification potential, and their persistence in the environment.

Heavy metal concentrations in water are a serious global issue that calls for great attention and concern. Their presence in water (e.g., Lead (Pb), Cadmium (Cd), Zinc (Zn), Iron (Fe), Copper (Cu), Nickel (Ni), Manganese (Mn), etc.), could emanate from fertilizer application, animal manures, atmospheric disposition, and a variety of other sources. These contaminants can pose health challenges as a result of their buildup in different parts of the body including the blood, kidney, liver, heart, etc.

The consumption of water worldwide increases yearly while most of the world's water resources continue to dwindle due to improper environmental management practices (5). Globally, more than twenty-five thousand people die daily as a result of water related diseases (6).

Heavy metals differ widely in their chemical properties, and are used extensively in electronics, machines, and the artifacts of everyday life, as well as in high-tech applications. As a result, they are able to enter into the aquatic environment and food chains of humans and animals from a variety of anthropogenic sources as well as from the natural geochemical weathering of soil and rocks.

The main sources of contamination include mining wastes, landfill leachates, municipal wastewater, urban runoff, and industrial wastewaters, particularly from the electroplating, electronic, and metal-finishing industries. With increasing generation of metals from technological activities, the problem of waste disposal has become one of paramount importance.

Many aquatic environments face metal concentrations that exceed water quality criteria designed to protect the environment, animals, and humans. The problems are exacerbated because metals have a tendency to be transported with sediments, are persistent in the environment, and can bioaccumulate in the food chain. Some of the oldest cases of environmental pollution in the world are due to heavy metal use, for example, Cu, Hg and Pb mining, smelting, and utilization by ancient civilizations, such as the Romans and the Phoenicians.

These heavy metals are among the most common pollutants found in wastewater. These metals pose a toxicity threat to human beings and animals even at low concentration. Lead is extremely toxic and shows toxicity to the nervous system, kidneys, and reproductive system. Exposure to lead causes irreversible brain damage and encephalopathic symptoms (7).

Cadmium is used widely in electroplating industries, solders, batteries, television sets, ceramics, photography, insecticides, electronics, metal-finishing industries, and metallurgical activities. It can be introduced into the environment by metal-ore refining, cadmium containing pigments, alloys, electronic compounds, cadmium containing phosphate fertilizers, detergents, and refined petroleum products. Rechargeable batteries with nickel–cadmium compounds are also sources of cadmium and excess in of cadmium causes renal dysfunction, bone degeneration, liver, and blood damage. It has been reported that there has been indicated evidence of the carcinogenicity resulting from cadmium intake (8, 9).

Copper, as an essential trace element, is required by biological systems for the activation of some enzymes during photosynthesis, but at higher concentrations it has harmful effects on the human body. High-level exposure of copper dust causes nose, eyes and mouth irritation and may cause nausea and diarrhea. Continuous exposure may lead to kidney damage and even death. Copper is also toxic to a variety of aquatic organisms even at very low concentrations. Mining, metallurgy, and industrial applications are the major sources of copper exposure in the environment (10).

Zinc is also an essential element in our diet. Too much zinc, however, can also be damaging to health. Zinc toxicity in large amounts causes nausea and vomiting in children. A higher concentration of zinc may cause anemia and cholesterol problems in human beings. Mining and metallurgical processing of zinc ores and its industrial application are the major sources of zinc in the air, soil, and water. It also comes from the burning of coal (11).

Nickel occurs naturally in soils and volcanic rock. Nickel and its salts are used in several industrial applications such as in electroplating, automobile and aircraft parts, batteries, coins, spark plugs, cosmetics, and stainless steel, and it is used extensively in the production of nickel–cadmium batteries on an industrial scale. It enters water bodies naturally by weathering of rocks and soils and through the leaching of the minerals. The water-soluble salts of nickel are the major problems of contamination in aquatic systems (10). Paint formulations and the enamel industry discharges harmful nickel containing contents to the nearby bodies of water. Nickel is also found in cigarettes, as a volatile compound commonly known as nickel carbonyl (11;12). Nickel plays an essential role in the synthesis of red blood cells; however, it becomes toxic when taken in higher doses. Trace amounts of nickel do not damage biological cells, but exposure to a high dose for a longer time may damage cells, decrease body weight, and damage the liver and heart. Nickel poisoning may cause reduction in cell growth, cancer and nervous system damage (13).

The undesirable presence of some of these mentioned metals must be curtailed in drinking water as they present a toxicity threat to human health. Though some like iron and manganese are required by the biological system as they play major roles in the hemoglobin synthesis and functioning of cells, monitoring must be implemented to ensure safe levels are not exceeded (14,15).

Table 1: The Standard Metal Concentration in Drinking Water and the Health Effects.

Metals	Effect	Drinking Water Standard
Lead	- Toxic to humans, aquatic fauna and livestock. - High doses cause metabolic poison - Tiredness, irritability anemia and behavioral changes of children - Hypertension and brain damage - Phytotoxic.	- By the Environmental Protection Agency maximum concentration: 0.1 mg/L - By European Community: 0.5 mg/L - Regulation of water quality (India) 0.1 mg/L
Nickel	- High conc. can cause DNA damage - Eczema of hands - High phytotoxicity - Damaging fauna	- By the Environmental Protection Agency maximum concentration: 0.1 mg/L - By European Community: 0.1 mg/L - Regulation of water quality (India) 0.1 mg/L
Copper	- Causes damage in a variety of aquatic fauna - Phytotoxic - Mucosal irritation and corrosion - Central nervous system irritation followed by depression	- By the Environmental Protection Agency maximum concentration: 1.0 mg/L - By European Community: 3 mg/L - Regulation of water quality (India) 0.01 mg/L
Zinc	- Phytotoxic - Anemia - Lack of muscular coordination - Abdominal pain etc.	- By the Environmental Protection Agency maximum concentration: 5 mg/L - By European Community: 5 mg/L - Regulation of water quality (India) 0.1 mg/L
Cadmium	- Cause serious damage to kidneys and bones in humans - Bronchitis, emphysema, anemia - Acute effects in children	- By the Environmental Protection Agency maximum concentration: 0.005 mg/L - By European Community: 0.2 mg/L - Regulation of water quality (India) 0.001 mg/L

The increasing dependence on ground water as a source of potable water supply has spurred efforts to protect the quality of this limited resource. Heavy metals are priority toxic pollutants that severely limit the beneficial use of water for domestic or industrial application (13).

Pollution due to artisanal activities, threatened to increase the heavy metal concentration in water sources of Ara and Laminga areas in Nasarawa Local Government. Whilst different studies in auto repair workshops have been carried out by different authors on soil contamination, little is known on the effect of artisanal activities on water sources, especially in the study area. Therefore, this research work will be of benefit to the people living in the various communities around the study location because the study will unveil the existence of heavy metals as well as their respective concentrations in various sources of their portable drinking water using Micro Plasma Atomic Emission Spectrometer (MP-AES) and compare the results with the recommended basic safety standard.

This research is also important in the sense that it is concerns the health of the populace. Other bodies or organizations wishing to carry out research similar to this study in a broader scope can use this work as reference point for the detailed survey. Hence the research will contribute immensely to literature.

MATERIALS AND METHOD

Materials

The instruments/materials that were used for the assessment of heavy metals concentration in portable drinking water across Ara and Laminga in Nasarawa Local Government Area of Nasarawa State are shown in Table 2.

Method

On the basis of geologic and tectonic setting, two towns having 3 water sources each were selected for water sampling in the areas respectively. Water samples were collected from Borehole (1 sample), well (1 sample) and stream (1 sample) and their pH values were measured on the spot, using a pH meter (Hanna instrument). At each sampling point, the water samples were collected in cleaned plastic bottles pre-washed with 20% dilute nitric acid (HNO_3) and double distilled water.

Table 2: Materials, Specifications, and Uses.

Materials	Quantity	Specifications	Uses
500ml bottles	1	Plastic Type	Used for collection of water samples.
Funnel	1	Plastic Type	Used for easy passage of water samples into the sample bottles.
Cup	1	Plastic Type	Used for easy transfer of water sample through the funnel to bottles.
Hand Glove	5 sets	Polythene	Used to protect the hand from direct contact to the chemicals.
pH Meter	1	Hanna Plastic type, Range 0-14, Resolution 0.1, Accuracy ±0.1, Consort C937.	Used for measuring the acidity and basicity of the water samples.
Concentrated Nitric Acid	500 ml	Liquid Type	Used for rinsing the sample bottles before (HNO_3) sample collection.
Drawer	1	Rubber Type	Used for drawing water from the well.
Masking Adhesive Tapes	1	Paper Type	Used for labeling the water samples as well as sealing the mouth of the bottles.
Global Positioning System	1	URIC Type	Used for taking the coordinates of each sample points.
Sack	1	Leather Type	Used for packaging of collected water samples for easy transportation.
Macro Plasma Atomic Emission Spectrometer.		MP-AES-MY17380004	Used for analyzing the water samples in the laboratory.

The water samples were filtered and a few drops of $HNO_3$was then added before transporting the sample to the laboratory for analysis.

Study Areas

This research centered on Ara and Laminga of Nasarawa Local Government Area, in Nasarawa State. The sample points are abbreviated as A1, A2 and A3, for Ara Borehole, Ara Well and Ara Stream, respectively, while L1, L2, and L3 for Laminga Borehole, Laminga Well, and Laminga Stream, respectively. These points are located at $8^0$36'22.97"N and $7^0$35'02.01"E, $8^0$36'28.63"N and $7^0$34'47.50"E and $8^0$36'19.03"N and $7^0$34'32.01"E for Ara, while $8^0$40'29.99"N and $7^0$49'49.27"E, $8^0$40'59.09"N and $7^0$48'39.93"E and $8^0$40'48.59"N and $7^0$48'32.07"E for Laminga.

Sample Collection

Six (6) water samples were randomly collected from different points in Ara and Laminga. The sampling was carried out in a season. Two (2) drops of nitric acid (HNO_3) were added to each water sample before analyzed to maintain the constant pH and minimize loss of sample because of variation in pH, evaporation, precipitation, and other relevant physical and chemical properties. Samples were collected from different water sources such as streams, wells, and boreholes located in Ara and Laminga. The samples were collected randomly using acidified plastic bottles and mixed. The bottles were filled and then sealed tightly to avoid head space that might cause loss of samples because of oxidation.

Sample Preparation

The samples for analysis were digested by measuring 250 ml of the water sample in a conical flask and 5 ml of concentrated nitric acid was added to the measured sample and then heated on microwave machine until the total volume was reduced to about one third of the initial volume to break the complex bond and release the sample into solution. The solution was then filtered using a filter paper into another beaker, made up of 50 ml with distilled water and mixed thoroughly. The sample was packaged into samples bottles before taking to MP AES machine for analysis.

Sample Analysis

All filtered and acidified water samples were analyzed for all the heavy metals by using Micro Plasma Atomic Emission Spectrometer under standard operating conditions. In view of data quality assurance, each sample is analyzed in triplicate and after every sample, two standards (one blank and another of 2.5 mg/L) of respective metal were analyzed on atomic emission. The reproducibility was found to be at 95% confidence level. Therefore, the average value of each water sample was used for further interpretation.

Standard solutions of all elements were prepared by dilution of 1000 mg/L certified standard solutions of corresponding metal ions with double distilled water. All the acids and reagents used were of analytical grade. All these analyses were performed in the Micro Plasma Atomic Emission Spectrometer (MP AES), at Bayaro University Kano, Kano State, Nigeria.

RESULTS AND DISCUSSION

The data collected from Ara and Laminga of Nasarawa LGA was analyzed using Micro Plasma Atomic Emission Spectrometer (MP-AES) in Table 3, showcasing the concentration level of heavy metals in the areas of study. These metals are as follows; Manganese (Mn), Nickel (Ni), Copper (Cu), Zinc (Zn), Cadmium (Cd), and Lead (Pb) (15).

Table 3: Heavy Metals Concentration (mg/L).

Villages	Sample Points	pH	Zn	Cd	Fe	Cu	Pb	Ni	Mn
LAMINGA	L1	2.7	0.26	0.000	0.07	0.010	0.02	0.002	0.011
	L2	1.7	0.17	0.000	0.01	0.010	0.01	0.022	0.108
	L3	2.0	0.16	0.000	0.07	0.010	0.02	0.011	0.001
MEAN			**0.20**	**0.000**	**0.05**	**0.010**	**0.02**	**0.012**	**0.040**
WHO (2005)			**3.00**	**0.003**	**0.30**	**2.000**	**0.01**	**0.100**	**0.500**
ARA	A1	0.8	0.35	0.000	0.05	0.030	0.03	0.005	0.087
	A2	0.9	0.50	0.000	0.03	0.020	0.06	0.000	0.308
	A3	0.4	0.19	0.000	0.07	0.010	0.03	0.002	0.010
MEAN			**0.35**	**0.000**	**0.05**	**0.020**	**0.04**	**0.002**	**0.135**
EPA (2005)			**5.000**	**0.005**	**0.300**	**1.00**	**0.10**	**0.100**	**0.500**
Mean (Ara & Laminga)			**0.275**	**0.000**	**0.05**	**0.015**	**0.03**	**0.012**	**0.040**

1 = Borehole, 2 = Well, 2 = Stream, L = Laminga, A = Ara

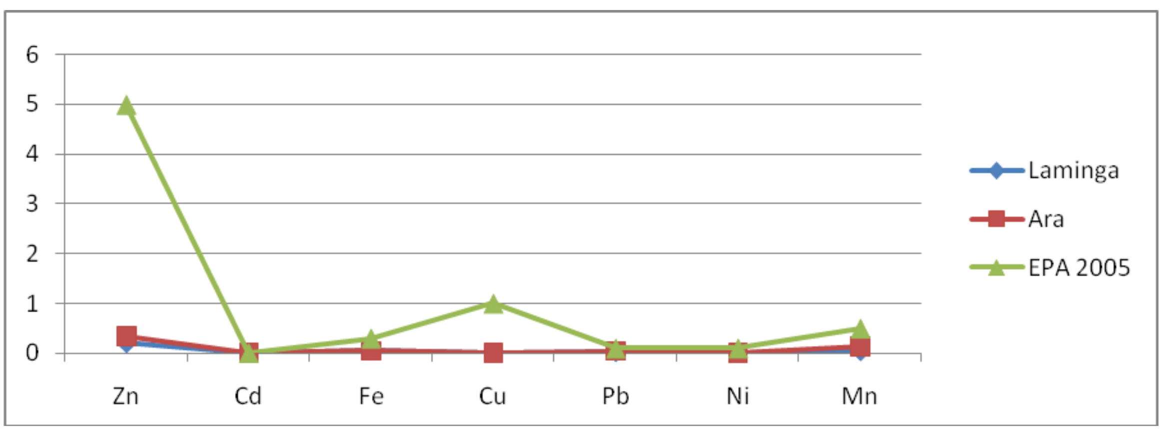

Figure 1: Comparison of Mean Concentration with World Health Organization Guidelines.

It was used to plot in conjunction with the data in Table1. The chart as presented in Figure 1, was used in order to compare the results obtained in this work with the World Health Organization's guideline on the issue of minimum threshold concentrations of each element that is tolerable in water to be considered reasonable for human consumption.

DISCUSSION

The level of presence of heavy metals in these two areas, as presented, indicates that the mean values of concentration of various heavy metals found in the water sample. Table 3 showcased seven heavy metals along with their respective concentrations in mg/L observed from the analysis of the water samples from the areas. From this analysis it has been revealed that the mean concentration of the analyzed heavy metals in all water samples for all the sampled water is arranged in decreasing order represented by Zn> Fe >Pb; Mn> Cu > Ni > Cd in Ara, while Zn > Fe >Mn>Pb> Ni > Cu > Cd in Laminga as in (15,16).

In the case of mean concentration level of zinc, it is found from this study that the zinc mean concentration level for water samples is on the average 0.275 mg/L. This implies that the mean concentration level of zinc in those areas is not significant compared to WHO (2005) standards for which the average mean concentration level for zinc is 3.0 (mg/L). Thus, it is clear that it may not impose a reasonable toxic hazard to the populace unless when accumulated over a long period of time.

In the case of Cadmium, this study has revealed that the mean concentration level in the water samples is 0.00 mg/L, meaning that the mean concentration level of cadmium in those areas is not significant compared to WHO standards (2005). WHO's mean concentration level for cadmium was 0.003 mg/L just like zinc and the measured values may not cause significant toxicity problems to the populace unless accumulated over a long period of time.

For Iron the mean concentration level was observed as 0.05 mg/L for water samples in this study. This implies that the mean concentration level of iron in those areas is not significant compared to WHO standards (2005) who's mean concentration level for iron was 0.3 mg/L. Thus, Fe may not cause toxicological hazard to the populace, but rather its toxic implications may create some health problems to the people of the area when accumulated over a long period of time.

While for copper, the mean concentration level was seen to be 0.015 mg/L and comparing this with WHO (2005) mean concentration level for copper which is 2.0 mg/L, it implies that the mean concentration level of copper in water in those areas is not significant as to pose any toxicological problem to the populace unless accumulated over a long period of time.

As for Lead, Nickel, and Manganese, their concentrations level in the water samples were shown to be 0.03mg/L, 0.012mg/L, and 0.04mg/L, respectively while WHO recommended concentration levels for each of the metal were, 0.01mg/L, 0.01mg/L, and 0.5mg/L for Lead, Nickel and Manganese, respectively. Based on this analysis it is obvious that the presence of lead in water may pose a health hazard to the populace because its concentration level is very much higher than WHO'S recommended concentration level in those study areas. For other metals whose concentration were lower, their presence in the water may only pose problem to the people over a long period of consumption due to their toxic nature.

CONCLUSION

This work is to create the awareness on the likely toxicological implications associated with heavy metal intake that are imminent to the populace of the study areas if there is continuous intake of untreated water without control and based on the analysis it had been verified that seven heavy metals along with their respective concentrations for both Ara and Laminga in mg/L were identified, From the findings as presented here, it is clearly revealed that the mean concentration level of heavy metals in those areas with the exception of Lead (Pb) in all locations is however not significant and may not be considered toxicological hazardous on the populace unless when the accumulated continuous over a long period of time.

There is therefore an indication that the water in the area may be considered as good water with the exception of the lead concentration. Caution is warranted based on the possibility of long-term accumulation, as it may appear to have chronic exposure implications on the populace. It is therefore recommended that proper monitoring exercise should be conducted on the water in these studied area from time to time in order to create the awareness for the people of the area the implication of high concentration of these heavy metals on their water sources as it can cause various forms of cancer to the populace as time goes on due to their toxic nature.

REFERENCES

1. Hinrichsen. D. and H. Tacio. 2002. "The Coming Fresh Water Crisis is Already Here". *Finding the Source: The Linkages between Population and Water*. Woodrow Wilson International Center for Scholars: Washington, DC, ESCP Publication. Spring. 123.

2. Li, S., W. Liu, S. Gu., X. Cheng, Z. Xu, and Q. Zhang. 2009. "Spatio-Temporal Dynamics of Nutrients in the Upper Han River Basin". *China. J. Hazard. Mater*. 162(2): 1340.

3. Enaam, J.A. 2013. "Evaluation of Surface Water Quality Indices for Heavy Metals of Diyala River Iraq". *J. Nat. Sci. Res*. 3(8): 63-64.

4. Fenglian. F.U. and W. Qi. 2011. "Removal of Heavy Metal Ions from Waste Waters: A Review". *Journal Environmental Management*. 92(3): 407-418.

5. Vanloon, G.W. and S.J. Duffy. 2005. "The Hydrosphere". In: *Environmental Chemistry: A Global Perspective, (2nd Edn).* Oxford University Press: New York, NY. 197-211.

6. Jain, C.K., K.K.S. Bhatia, and T. Vijay. 1995. "Ground Water Quality Monitoring and Evaluation in and Around Kakinada, Andra Pradesh," Technical Report, CS (AR) 172, National Institute of Hydrogeology, Roorkee, India. 1994-1995.

7. ATSDR. 2007. *Toxicological Profile for Lead*. U.S. Department of Health and Human Services, Atlanta, Agency for Toxic Substances and Disease Registry Report: Washington, D.C.

8. Dojlido, J. and G.A. Best. 1993. *Chemistry of Water and Water Pollution*. Ellis Horwood Ltd.: Chichester, UK.

9. Volesky, B. 1990. *Biosorption of Heavy Metals*. CRC Press: Boca Raton, FL.

10. Wong, J.P.K., Y.S. Wong, and N.F.Y. Tam. 2000. "Bio Resource". *Journal of Technology*. 7(3): 133.

11. World Health Organization (WHO). 1984. *Water Quality. World Health Organization, Guidelines for Drinking*. WHO: Geneva, Switzerland.

12. WHO. 2005. *Trace Elements in Human Nutrition: Manganese. Report of a WHO Expert Committee*. WHO: Geneva, Switzerland. 34–36. Technical Report Series No. 532.

13. Wase, J. and C. Forster. 1997. *Biosorbents for Metal Ions*. Taylor & Francis Ltd.: London, UK.

14. Nagendrappa, G., C.V. Bhaskar, and K. Kumar. 2010. "Assessment of Heavy Metals in Water Samples of Certain Locations Situated around Tumkur, Karnataka, India". *E-Journal of Chemistry*. 7(2): 349-352.

15. Rilwan U., A. Abbas, and S. Muhammad. 2020. "Assessment and Analysis of the Presence of Heavy Metals in Water in Ara and Laminga of Nasarawa State, Nigeria: Health Implication on the Populace". *Asian J. App. Chem. Res.* 5(2):1-11.

16. Rilwan U, A. Abbas, S. Abdulrahman. 2020. "Heavy Metal Contamination in Swampy Agricultural Soil of Kokona, Nasarawa, Nigeria". *Asian J. App. Chem. Res.*, 5(2): 28-33.

SUGGESTED CITATION

Usman, R., A.M. Kamal, E.I. Ugwu, I.M. Mustapha, A. Mamman, and A. Hudu. 2020. "Assessment and Analysis of the Presence of Heavy Metals in Water in Ara and Laminga of Nasarawa State, Nigeria: Health Implication on the Populace". *Pacific Journal of Science and Technology*. 21(2):240-246.

Pacific Journal of Science and Technology