Heavy Metal Analysis of Three Urban Rivers in Enugu, Nigeria

Abstract

The multiple industrial, domestic, agricultural, medical and technological applications of heavy metals have led to their wide distribution in the environment, raising concerns over their potential effects on human health and the environment. This work focused on the determination of manganese, chromium, zinc, cadmium, arsenic, mercury, iron and lead concentrations in Abakpa, Iva Valley and Transekulu Rivers which are close to residential areas in Enugu, Nigeria. Analysis was carried out using standard methods were carried out using atomic absorption spectrometer (AAS). All the heavy metals tested in the three studied locations exceeded the different drinking water limits except zinc which was below secondary drinking water standard of 5.0mg/l. The levels of mercury and zinc were significantly higher in Abakpa River (0.57±0.112 and 0.881±0.0015 mgl^{-1} respectively). Iva valley showed higher levels of manganese, chromium, iron and arsenic compared to other rivers studied. The presence in these metals in the water sources are a great risk to humans and the environment.

Keywords: Heavy metals, Rivers, Nigeria

Introduction

Water is a necessity and serves many purposes, which include drinking, irrigation, animal farming and recreation. It also serves as habitat to numerous organisms. The availability of good quality water is therefore an indispensable feature for preventing diseases and improving quality of life. A wide range of contaminants are continuously introduced into the aquatic environment mainly due to increased industrialization, technological development, growing human population and exploitation of natural resources, agricultural and domestic wastes run-off. In Nigeria, the situation is no better by the activities of most industries and populace towards waste disposal and management leading to increasing levels of contaminants in the environment (Daniel *et al.*, 2016). Among these contaminants, heavy metals constitute one of the most dangerous groups because of their persistent nature, toxicity, tendency to accumulate in organisms and undergo food chain amplification and more still, they are non-degradable (Sankhla *et al.*, 2016).

Heavy metals are generally defined as metals with relatively high densities, atomic weights, or atomic numbers. The criteria used, and whether metalloids are included, vary depending on the author and context. In metallurgy, for example, a heavy metal may be defined on the basis of density, whereas in physics the distinguishing criterion might be atomic number, while a chemist would likely be more concerned with chemical behavior. Heavy metals are more commonly defined as those having a specific density of more than 5 g/cm3 (Jarup, 2003). The most common heavy metals in Nigeria are zinc, arsenic, cadmium, chromium, lead, mercury, manganese and vanadium.

The contamination of aquatic ecosystem by heavy metals is a serious worldwide ecological problem and has far-reaching implications directly to the biota and indirectly to man. Acute heavy metal intoxications may damage central nervous function, the cardiovascular and gastro intestinal (GI) systems, lungs, kidneys, liver, endocrine glands, and bones (Sankhla *et al.*, 2016). According to Fernandez-Luqueno *et al.* (2013), it may also cause damage to DNA, alterations on gene expression, skin, muscle, blood composition, and other vital organs for humans and other living organisms. There are many industrial activities in Enugu metropolis that are likely to pollute the rivers around. The large population around the metropolis with the associated activities such as washing, bathing and soil excavation could also contribute to the pollution of the rivers. Therefore, to reduce the accumulation of heavy metals, monitoring and assessment of the heavy metal concentration has become a very critical area of study in recent years.

Materials and Methods

The Study Area

Abakpa, Iva valley and Transekulu are towns located in Enugu metropolis. Abakpa is a large town and commercial settlement with increasing number of residents and industrial companies. Iva valley is named after a valley in the area which bears the same name. The locality is also the site of Iva valley coal mine. Transekulu is also a residential area located in Enugu state.

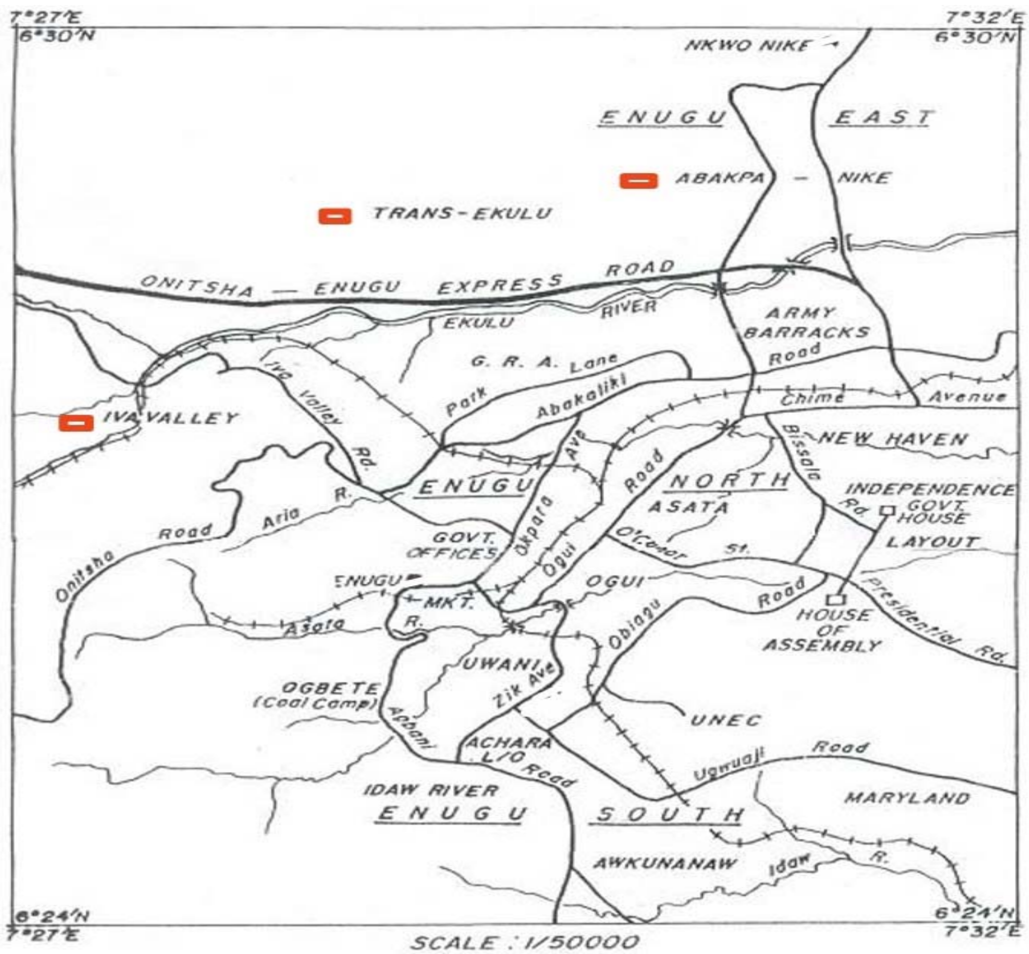

Figure 1: Map of Enugu urban area showing Abakpa, Iva Valley and Transekulu.

Source: Enete and Alabi, 2012.

Sample Collection

Samples were collected from Abakpa, Iva valley and Transekulu Rivers located in Enugu State (Fig 1). They were collected using plastic bottles. Before collection, the plastic bottles were rinsed with 0.02M HNO_3 to maintain the constant pH and minimize loss of sample because of variation in pH, evaporation, precipitation and other relevant physical and chemical properties. The bottles were sealed tightly after collection to avoid loss of samples.

Physico-chemical Analysis of Water

The physico-chemical properties of the water samples such as colour, odour, pH, total dissolved solute, turbidity, temperature, electrical conductivity, biological oxygen demand, were analyzed according to the procedures of APHA, AWWA, WPCF (2005).

Sample Digestion

The digestion procedure was carried out by transferring a measured volume (50 mL) of well mixed acid preserved water sample to a flask. Then 5 mL of conc. HNO_3 and a few boiling chips were added into the flask. The mixture was boiled and evaporated on a hot plate to the lowest volume possible (10 to 20 mL). Heating and addition of conc. HNO_3 as necessary was done until digestion was complete as shown by a light color clear solution. After this, the flasks were washed down with water and filtered. Then the filtrate was transferred into a volumetric flask with two 50 mL portions of water, adding these rinsing to the volumetric flask and cooled and diluted to the mark and mixed thoroughly. A portion of this solution was taken for the required metal determinations.

Metal Analysis of Water

The metals were analyzed with the atomic absorption spectrometer (AAS) using calibration curves after the parameters (lamp alignment, wave length and slit width adjustment and burner alignment) were optimized for maximum signal intensity and sensitivity of the instrument. The wavelength and slit width were selected and adjusted at the beginning of the analysis and was constant up to the end of the analysis. This condition was performed in the same way throughout the study.

Statistical Analysis

Data were analysed using SPSS Version 20.0 (IBM Corp., Amonk, USA. Comparisons of the metals were done using Kruskal−Wallis *H*-test. The values were represented as mean ± standard error (SE). The level of significance was set at $p < 0.05$.

Table 1: Physical Properties of the water Samples from Abakpa, Iva valley and Transekulu

Sample	pH	TDS Mg/l	Temp	EC (Ms/m)	Colour	Turbidity	Odour
Abakpa River	7.2-7.9	5.0-7.5	25℃	10.5-13	Cloudy	Not clear	Odorless
Iva valley	7.3-8.0	4.0-7.0	24℃	10.1-12	Not clear	Not clear	Odorless
Transekulu	8.3-8.9	6.0-7.5	27℃	11.1-13	Cloudy	Not clear	Offensive odor

Table 2: Chemical Parameters of water samples from Abakpa, Iva valley and Transekulu

Sample	Oxygen demand (mg/l)	Chemical oxygen demand(mg/l)	Biochemical Oxygen demand(mg/l)
Abakpa river	10.5-11.5	12.5-13.5	23-25

Iva valley	12.6-13.0	15.0-16.8	27.6-29.8
Transekulu	11.5-14.0	14.0-15.5	25.5-29.5

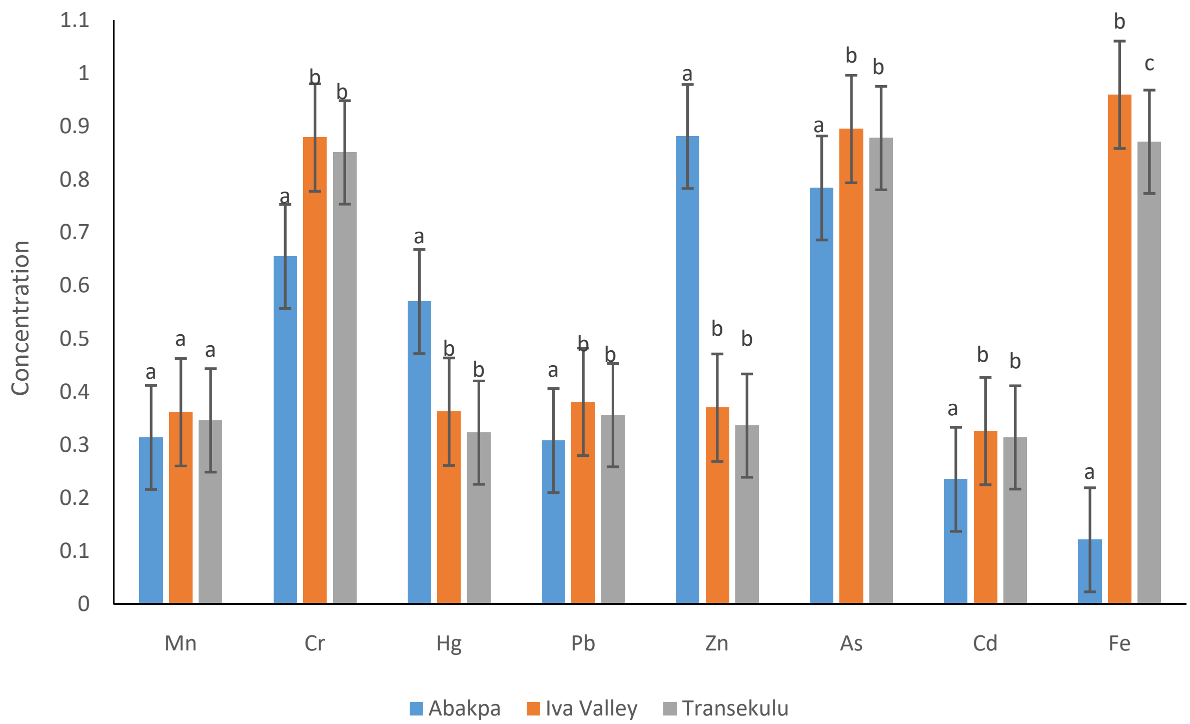

Figure 2: Bar chart showing the concentrations of the detected metals in samples (Mg/l) from Abakpa, Iva valley and Transekulu.

Table 3: Standard Reference for Water According to Environmental Protection Agency / Permissible Limits for Metals.

Metals	Primary Drinking Water Standard (MCL) (Mg/l)	Secondary Drinking Water Standard (Mg/l)	Livestock Water Quality (Mg/l)	Surface Water Quality (Mg/l)
Al		0.05- 0.20	5.0	
As	0.05		0.5	0.04
Sb	0.006			
Ba	2.0			1.0
Be	0.004			
Cd	0.005		0.5	0.02
Cr	0.1		1.0	0.05
Cu	1.3	1.0	0.5	1.0
Fe		0.3		
Pb	0.015		0.05	0.10
Mn		0.05		
Hg	0.002		0.01	0.002
Ni			1.0	
Se	0.05		0.1	0.01
Ag		0.1		0.05
Ti	0.002			
Zn		5.0	25.0	5.0

MCL – maximum contaminant level

Source: https://www.occeweb.com/og/metals-limits.pdf (Accessed, 04/10/2019)

Results and Discussion

The physico-chemical properties of the water samples are presented in Tables 1 and 2. The pH range of 7.2-7.9 for samples from Abakpa, 7.3-8.0 for Iva Valley samples and 8.3-8.9 for Transekulu samples shows that the water samples are alkaline. Higher pH, temperature and electrical conductivity were observed in Transekulu sample (Table 1). The concentrations of heavy metals in water samples from Abakpa, Iva valley and Transekulu was presented in Fig 2. The concentration of manganese was highest in Iva valley with a value of 0.361±0.0235mg/l, followed closely by 0.346±0.015 and 0.314±0.014 in Transekulu and Abakpa respectively. Chromium was found to be highest in Iva valley sample at 0.879±0.116mg/l and lowest in Abakpa at 0.655±0.03. Mercury level in Abakpa sample was highest with a value of 0.57±0.112 mg/l and lowest in Transekulu with a value of 0.323±0.012. Iva valley sample showed highest concentration of lead at 0.381±0,019. Zinc was found to be significantly higher in Abakpa with a value of 0.881±0.0015. Iva valley sample showed high arsenic level at 0.895±0.027 followed by 0.883±mg/l from that of Transekulu and 0.784±0.005 from Abakpa sample. Cadmium was found to be highest in Iva valley sample with a value of 0.326±0.009mg/l and iron also, with 0.959±0.052mg/l concentration. This means that highest levels of manganese, chromium, lead, arsenic, cadmium and iron were detected in Iva valley sample, some of which were followed closely by sample from Transekulu. This may be due to incessant discharge of domestic waste into the water ways by residents. The high values obtained from Iva valley sample may also be linked to the proximity of the abandoned coal mine. Mine waste from mining activities in the times past containing some of these metals may have been discharged and dispersed or washed by water into bodies of water. These metals have remained due to their ability to persist for long periods in the environment and may have bio-accumulated. Zinc and mercury were found to be highest in Abakpa sample. A possible reason for this is industrial effluents such as waste from cement and block industries close to the area, automobile washing and repair, improper refuse disposal which pollute the water. Compared to results obtained by Adaikpoh *et al*. (2005) from river Ekulu sediments, results from this study are much higher than that obtained for the metals; chromium, cadmium, arsenic and lead but correspond with the range of manganese (0.256-0.389mg/kg). The results were reported to be due to the nearness of the coal mine from where the river takes its source and the geological setting of the area which favours intense gullying and fast accumulation of these toxic metals (Adaikpoh *et al*., 2005). Also, Cobbina *et al*. (2015) obtained lower levels of mercury, arsenic and zinc from water samples in Nangodi, northern Ghana but cadmium concentration (0.534) was however higher than that in this study. Our results agree with that of Ayenimo *et al*. (2005) that reported increased accumulation of heavy metals in water samples from Warri River, Nigeria.

In all, the present study indicated that all the heavy metals tested in all three locations exceeded the different drinking water limits except zinc which was below secondary drinking water standard of 5.0mg/l (Table 3). The results of the present study also indicate that Iva valley has higher levels of most of the heavy metals tested. This puts residents of the area more at risk especially since this water is consistently used for domestic purposes. Plants growing within the environment can accumulate the toxic metals. When put to agricultural use, the water containing these toxic elements is absorbed by vegetables which accumulate in the body when ingested. The health implication of the accumulation of these metals in the body may range from damage to the nervous system, lungs, kidneys, liver, endocrine glands, skin and other organs of the body. However, because they mostly present similar symptoms as common illnesses during acute toxicity, some of these heavy metals are usually not easily diagnosed till they get to highly toxic limits in the body. Lead, cadmium and mercury are highly toxic even at low concentration.

Conclusion

This present study focused on the determination of manganese, lead, chromium, mercury, arsenic and cadmium concentrations in water samples from Abakpa, Iva valley and Transekulu Rivers in Enugu State, Nigeria. The results showed that the highest levels of most of the selected heavy metals in the selected areas were detected in the water samples collected from Iva valley. The total concentrations of heavy metals in all three samples were above the standard levels provided by the Environmental Protection Agency except zinc. Failure to control the exposure may result in severe health complications in the future. Also, in this work, the health effects of some heavy metals such as arsenic, lead, mercury, cadmium, chromium, and iron were reviewed.

References

Adaikpoh E. O., Nwajei G. E. and Ogala J. E. (2005). Heavy metal concentrations in coal and sediments from River Ekulu in Enugu, coal city of Nigeria. *Journal of Applied Sciences and Environmental Management*, 9(3): 5-8.

APHA, AWWA, WPCF, 2005. Standard methods for theexamination of water and waste water 21st, 401 Ed. AmericanPublic Health Association, Washington, DC.

Ayenimo J. G., Adeeyinwo C. E. and Amoo I. A. (2005). Heavy metal pollutants in Warri River, Nigeria. *Journal of Sciences*, 27: 43-50.

Brent L. Permissible limits for metals. https://www.occeweb.com/og/metals-limits. (Accessed, 04/10/2019).

Cobbina S. J., Duwiejah A. B., Quansah R. and Obiri S. (2015). Comparative assessment of heavy metals in drinking water sources in two small-scale mining communities in northern Ghana. *International Journal of Environmental Research and Public Health,* 12: 10620-10634.

Daniel E. S., Musa J. J., Akos M. P., Yerima I. Y., Dada P.O., Jibril I. and Manta I. H. (2016). Assessment of Heavy Metal Pollution in Some Nigerian Soils: A Review. 37th Annual Conference and Annual General Meeting; Nigerian Institution of Agricultural Engineers, 456-464.

Enete I. and Alabi M. O. (2012). Observed urban heat characteristics in Enugu urban during the dry season. *Global Journal of Human Social Science Geography and Environmental Geosciences* 12(10): 75-80.

Fernández-Luqueño F., López-Valdez F., Gamero-Melo P., Luna-Suárez S., Aguilera-González E. N., Martínez A. I., García-Guillermo M., Hernández-Martínez G., Herrera-Mendoza R., Álvarez-Garza M. A. and Pérez-Velázquez I. R. (2013). Heavy metal pollution in drinking water - a global risk for human health: A review. *African Journal of Environmental Science and Technology,* 7(7): 567-584

Järup L. (2003). Hazards of heavy metal contamination. *British Medical Bulletin,* 68: 167-182.

Sankhla M. S., Kumari M., Nandan M., Kumar R. and Agrawal P. (2016). Heavy Metals Contamination in Water and their Hazardous Effect on Human Health-A Review. *International Journal of Current Microbiology and Applied Sciences,* 5(10): 759-766.