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Full Length Research Article

HEAVY METALS POLLUTION ON SURFACE WATER SOURCES IN KADUNA METROPOLIS, NIGERIA

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ABSTRACT
This study examine the effects of heavy metal pollutants to aquatic ecosystems and the environment by considering the role of urban, municipal, agricultural, industrial and other anthropogenic processes as sources of heavy metal pollution in surface water sources of Kaduna metropolis. Samples of the polluted water were collected from River Kaduna and along the Kakuri – Makera drains. The X – Ray florescence (XRF) was used as an analytical technique for the detection of heavy metals (Lead {Pb}, Arsenic {As}, Iron {Fe}, Chromium {Cr}, Copper {Cu} and Zinc {Zn}). The results shows the concentration of most of the heavy metals were higher than WHO (1997) acceptable limits. It is concluded that the water from the river is polluted and may cause serious ecological and health hazards. It is recommended among other things that there should be proper monitoring of effluents into receiving water as an integral part of water management in the river to enable verification of whether or not imposed standards and regulations are met.

Keywords: Heavy Metal, Pollutant, World Health Organization (W.H.O) Standards, X – Ray florescence (XRF), Surface Water and Kaduna

INTRODUCTION

In Natural aquatic ecosystems, heavy metals occur in low concentrations, normally at the nanogram to microgram per liter level. In recent times, however, the occurrence of contaminants, especially heavy metals in excess of natural loads has become a problem of increasing concern. This situation has arisen as a result of; the rapid growth of population, increased urbanization, expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern agricultural practices, as well as non-enforcement of environmental regulations (Biney *et. al*. 1991).

The major routes of heavy metal uptake by man are food, drinking water and air. For instance, aquatic fauna especially fish are the most important source of mercury (Hg). As trace elements some heavy metals (example of copper and zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. The heavy metals linked most often to human poisoning are lead (Pb), mercury (Hg), arsenic (As) and Cadmium (Cd). Others including copper (Cu), Zinc (Zn) and Chromium (Cr) are actually required by the body in small amounts, but can also be toxic in higher amount (Biney *et. al*. 1991).

Unlike other pollutants like petroleum hydrocarbons and litter which may visibly build up in the environment, trace metals may accumulate unnoticed to toxic level. The presence of heavy metals in water can be detrimental to human health and the aquatic ecosystem, a clear instance is seen in the "Mina Mata Disease" which occurred in Japan, caused by mercury poisoning of consumers of fish, from the industrially polluted Mina Mata Bay (Tanko, 1989 and FEPA, 1991).

For effective water pollution control and management, there is the need for a clear understanding of the inputs (loads) distribution and fate of contaminants, especially heavy metals from industrial discharge and other land-based sources into aquatic ecosystems. This should be considered together with the possible effects it can cause on humans when such pollutants enter the food chain. The central focus of this paper is thus to analyze the concentration of heavy metal pollutants in River Kaduna and their possible ecological and environmental consequences.
Kaduna State has one of the largest concentrations of industries in Nigeria, which discharge waste water, it is also a rapidly expanding city through urbanization (KEPA, 1998).This means several activities in addition to industrial discharge of waste water and municipal sludge which may probably contain heavy metal pollutants all of which pass through industrial drains, tributary streams and finally into River Kaduna (KEPA, 1998).

River Kaduna may suffer enormous pollution and may contain high concentration of heavy metals as a result of industrial activities and other anthropogenic sources of contamination, it is thus important to test and analyze the concentration of these heavy metals in the River; this is important, in view of the fact that the River basin serves as a major source of irrigation water for most of the farming activities practiced along the flood plain of the River and aquatic foods such as fish for most of the inhabitants of Kaduna metropolis and beyond. This means there is every possibility of these heavy metals to Bio-accumulate in fishes or plants which eventually can be consumed by humans leading to severe diseases.

Many villages and communities downstream also source their domestic water from the River and the Kaduna south water works source its raw water from the River at the southern axis where industries discharge their waste into the river. This would mean a high cost of purification in terms of treating the water.

This study therefore intends to find answers to the following research questions (i) what are the specific concentration of the metal pollutants in the River? (ii) What are the major sources of these metal pollutants? (iii) What are the deviations of the concentration of the metals from the W.H.O. standard for drinking water (v) What are the likely ecological and health hazards that may be attributable to these heavy metal concentration to the inhabitants of the area and the environment in general.

The major aim of this research is to identify and examine the level of the following heavy metals: Lead {Pb}, Arsenic {As}, Iron {Fe}, Chromium {Cr}, Copper {Cu} and Zinc {Zn} in River Kaduna.

The objectives are:-

a. To determine the concentration levels of the above named six heavy metal pollutants in the surface waters of River Kaduna and the Kakuri-Makera drains.

b. To compare the level of concentration of the heavy metal with W.H.O recommended permissible limits for portable water.

c. To establish the extent to which the level of concentration of the heavy metal pollutants can influence water pollution.

THE STUDY AREA

Kaduna metropolis has a total land area of about 3,080km^2 (1,190 sq mi)and is located on latitude 10^{0}52' north of the equator and longitude 7^0 44' east of Greenwich meridian.

The river Kaduna (Figure 1) divides the metropolis into two major areas, namely; Kaduna north and Kaduna south. The north houses mostly the commercial centers and residences areas while the south is the industrial area (Amin, 2006).

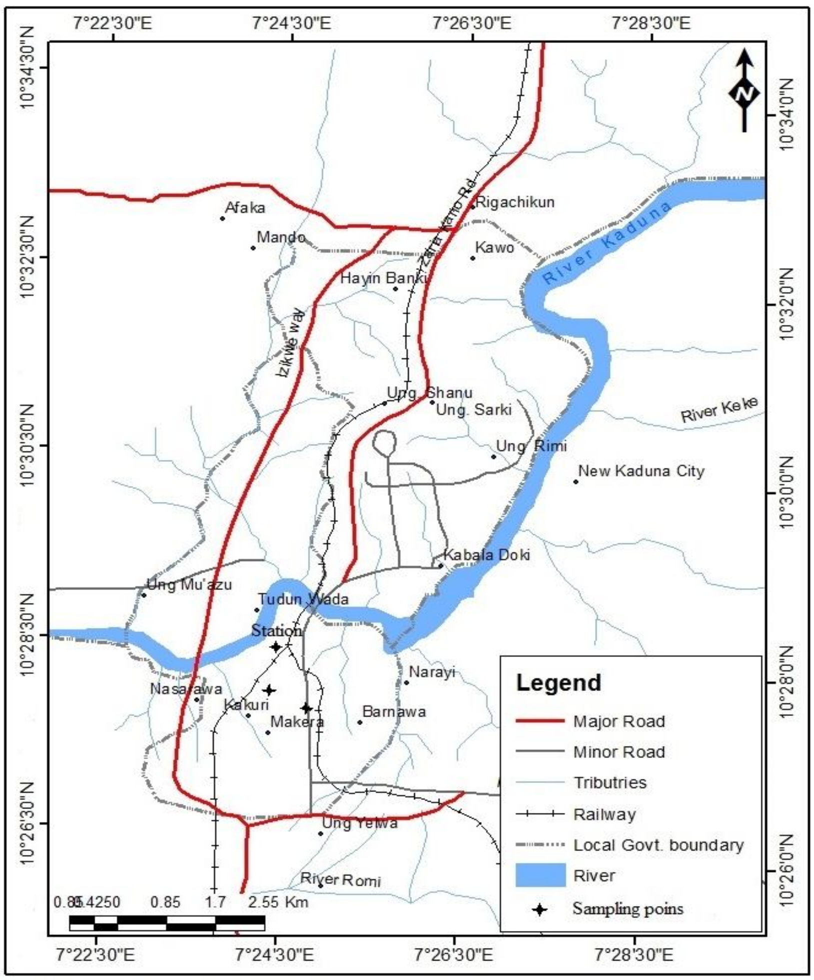

Fig. 1: Drainage System of Kaduna Metropolis Showing Sample Locations

METHODOLOGY

This involves a reconnaissance survey, collection of samples and laboratory analysis. A reconnaissance survey was conducted in order to know the sources of pollution and contamination along the southern part of River Kaduna and its tributaries. The spearman's correlation technique was used in comparing the results obtained from the XRF analysis with W.H.O 1997 standards.

A total of five (5) composite samples were obtained from selected points along the Kakuri – Makera drains and along river Kaduna. The samples were marked A, B, C, D and E.

The samples were first collected on the 25th of February, 2009. Sample A was obtained along Kakuri – Makera drain, a 125ml container was used to collect water samples at three (3) different points along point A (at intervals of 50 meters each). The same process of collection was applied at point B where the drains empty into River Kaduna. Three other samples C, D and E were also sourced along River Kaduna from point B downstream at approximately 100 meters interval each.

The same procedure of collection of samples was repeated 3 days later on 28th February and also on the 3rd of March 2009. The overall samples were at each instance compounded and shaken thoroughly in a 75cl container to form composite samples A, B, C, D, and E.
The composite samples were preserved by adding 5ml of concentrated Nitric acid (HNO_3) and preserved in a refrigerator before taken to the laboratory for analysis.

The XRF – X – ray florescence was used for lead (Pb) chromium (Cr) Arsenic (As) Iron (Fe), copper (Cu), and zinc (Zn) determination. The XRF is widely used for qualitative and quantitative, elemental analysis of environmental, geological, biological industrial and other samples analysis compared to the use of other techniques, such as Atomic Absorption Spectroscopy (AAS), Inductive Coupled Plasma Spectroscopy (ICPS) and Neutron Activation Analysis (NAA).XRF has the advantage of being non-destructive, multi–elemental, fast and cost effective. Its main disadvantage is that analysis is generally restricted to elements heavier than fluorine (Center for Energy Research &Training -CERT, 2009).

PREPARATION OF WATER SAMPLES FOR XRF ANALYSIS
In order to prepare the samples, 100ml of each of the composite samples was measured using a measuring cylinder and poured into 5 – separate beakers. 3 drops of Nitric acid (HNO_3) is then added in each beaker, the essence is to cause reaction in the water samples so that each element present can manifest itself. The solution was then filtered using a mill pore filter paper (0.22 μm). The precipitate was collected on the filter and measured using the X-Ray Florescence

Measurements were performed using an annular 25mci cd^{109} (cadmium source) as the excitation source that emits Ag-K X – Rays energy of 22.1 Kev (Kilo election volts) in which case all elements with lower characteristic excitation energies were accessible for detection in the samples. The system consist furthermore of a silicon Lithium Si (Li) detector, with a resolution of 170 eV for the 5.90kev line coupled to a computer controlled ADC (Analog-to-Digital-Converter) card (CERT, 2009).

RESULTS
The result of the XRF analysis shows the presence and concentration of Cr, Fe, Cu, Zn, As, and Pb as shown in Table 1. The concentration of the elements was obtained in parts per million (PPM), all the values are detected at LOD – Limit of Detection which is the minimum amount of an element that can be detected using a particular technique (in this case the XRF). The values are thus converted to mg/l.

Table 1: Concentrations of Heavy Metals in Water Sample Collected

	METALS	CONCENTRATION IN SAMPLES (mg/l or (PPM x 10^{-6})					MEAN
		A	B	C	D	E	
1.	Chromium (Cr)	3.72	3.69	1.65	1.55	1.44	2.41
2.	Iron (Fe)	5.20	2.57	0.986	0.976	0.976	2.14
3.	Copper (Cu)	3.16	1.22	0.502	0.614	0.502	1.19
4.	Zinc (Zn)	2.32	1.19	0.427	0.408	0.434	0.95
5.	Arsenic (Ar)	2.59	1.01	0.467	0.448	0.539	1.01
6.	Lead (Pb)	3.67	1.45	0.648	0.627	0.765	1.30

The result of the analysis shows that in sample 'A' the concentration of Chromium is about 3.72mg/l, As = 2.59 mg/l, Fe = 5.20mg/l, Cu = 3.16mg/l, Zn =2.32 mg/l, Ar = 2.59mg/l and lead= 3.67mg/l (see Table 1).Sample A was sourced from the Kakuri – Makera drain and as such the approximately high concentrations of the elements may not be unconnected to the fact that industrial, municipal and urban waste water are discharged into the drain.

DISCUSSION
Amadi, *et al.,* (2014) and Tanko,(1989) have reported that heavy metal concentrations in surface water and sediments is influenced by input from source, character of sediments, organic materials, temperature and sometimes the mineral composition of the underlying rock in the area where the surface water is situated. Thus, spatial and temporal variations in heavy metal concentrations in sediments and especially in water should be naturally expected.

In the present study significant variations were indicated by the concentrations of the metals with higher concentrations shown by the samples from the earth drain and lower values from samples along the river.

Table 1 contains the results of the laboratory analysis conducted on the water samples from River Kaduna and the Kakuri – Makera drain. From the Table, it may be observed that the values for chromium are far above the WHO maximum allowable concentration of 0.05mg/l(Appendix A), the mean value of 2.41 mg/l for all the samples indicated that the water is polluted. Iron level of samples as shown in the table are also above the maximum acceptable limit of 0.3mg/l, however the samples from the main river(C,D and E) were all below the maximum allowable concentration of 1.0mg/l. The mean value of2.14mg/l for iron is higher than the maximum allowable and acceptable concentration recommended by WHO (Appendix A) for portable water. It should be noted that concentration of iron above 1.0mg/l can cause ill health such as gastro intestinal irritation (Oni, 1997).

Except for the First sample A, along the Kakuri- Makera drain (Table1) all the values for Copper (Cu) are below the maximum allowable concentration of 1.5mg/l recommended by WHO. The mean value of 1.19mg/l is clearly below the maximum allowable limit and slightly above the acceptable limit of 1.0mg/ (Appendix A).

Zink (Zn) concentration in all the samples is clearly below the maximum acceptable limit of 5.0mg/l and allowable limit of 15.0mg/l recommended by WHO (Appendix A) the mean value of 0.95 for all the samples is also below these limits.

The concentration of Arsenic in all the samples is very high especially in the first 2 samples (A and B) meaning the water in the drains is highly polluted. The other samples along the river are slightly below the maximum allowable limit of 0.5mg/l recommended by W.H.O the mean values of <1.01mg/l for all the samples is also above W.H.O standard limits. Even though some of these metals were recorded at below allowable limits, the fact that they are present in the water is a cause for concern since they can bio-accumulate in organisms' overtime causing health hazards.

Lead (Pb) concentration in all the sample were clearly above the maximum allowable limit of 0.05mg/l recommended by W.H.O, the mean concentration of 1.01mg/l for all the samples were above these allowable limit. These trace elements are known to bio-accumulate sometimes and even undergo bio-magnification in organisms such as fishes and even plants with serious health implications to the aquatic ecosystem. The case of Mina Mata (organic mercury poisoning) and Ita-Ita (cadmium poisoning) in human beings is enough to drive home the serious health hazards due to these metals (Tanko, 1989).

Finally, the result indicates pollution due to high concentration of heavy metals along the earth drain. The values of heavy metals obtained along the main river though lower in most cases show higher difference than the W.H.O recommended standards.

Moreover considering the fact that irrigated agriculture and fishing were practiced along the downstream of the river these heavy metals bio-accumulate in fishes and irrigated plants especially vegetables, tomatoes, lettuce and cabbage which when consumed by humans cause serious health implications.

CONCLUSION

It is concluded that the water in River Kaduna, and especially along Kakuri – Makera drain is polluted with heavy metals. The pollution is most severe at the drains than along the main river as indicated by the high concentration of the heavy metals in the samples. These pollutants were likely due to urban, municipal, industrial effluents and other anthropogenic sources all of which are discharged into the drains and subsequently into the River. Other sources may be due to heavy fertilizer application which might have added to the pollution especially along the river.

It should be pointed out that the water from these sources may likely pose health hazard through bio - accumulation in fishes and other agricultural produce which are consumed by most of the inhabitants of the metropolis.

The following recommendations are hereby suggested:

Generally, it is more economical in many cases to maintain the quality of waters through source protection. Villages downstream of river Kaduna should abstain from direct consumption of such waters. There should be proper monitoring of effluents into receiving water portable water as an integral part of water management of the river to enable verification of whether or not imposed standards and regulations are met. A regular schedule for sampling tributary streams and the main river should be established on the basis of the potential pollution effect of stream water, frequency of the sampling should take into consideration the types of hazards, seasonal flows, storms and other factors which may change during the year and after the data might have been collected.

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APPENDIX A: World Health Organization Recommended Standard for Portable (Drinking) Water (WHO 1997)

SN	Substances or Parameters	Maximum Acceptable Concentration	Maximum Allowable Concentration
1.	Total Solids	580mg/l	1,500 mg/l
2.	Colour	5 units	50units
3.	P. H. Range	7.0 – 8.5	6.5 – 9.2
4.	Temperature	29°C	-
5.	Turbidity	5 units	25units
6.	Taste	Unobjectionable	-
7.	Odour	"	-
8.	Iron (Fe)	0.3 mg/l	1.0mg/l
9.	Manganese (Mn)	0.1 mg/l	0.5 mg/l
10.	Copper (Cu)	5.0 mg/l	1.5 mg/l
11.	Zinc (Zn)	75 mg/l	15.0 mg/l
12.	Calcium (Ca)	50 mg/l	200 mg/l
13.	Magnesium (mg)	200 mg/l	150 mg/l
14.	Sulphate (So4)	0.5 mg/l	400 mg/l
15.	Chloride (Cl)	50 mg/l	600 mg/l
16.	Fluoride (F)	-	1.5 mg/l
17.	Nitrate (No_3)	500 mg/l	10 mg/l
18.	Hardness ($CaCo_3$)	0.001 mg/l	120 mg/l
19.	Magnesium + Sodium Sulphate	0.2 mg/l	100 mg/l
20.	Phenolic substances	0.5 mg/l	0.002 mg/l
21.	Carbon chloroform extract	-	0.5 mg/l
22.	Alkly-benzysulfonates	-	1.0 mg/l
23.	Electrical conductivity	-	-
24.	Lead	-	0.05 mg/l
25.	Arsenic	-	0.5 mg/l
26.	Selenium	-	0.01 mg/l
27.	Chromium	-	0.05 mg/l
28.	Cyanide	-	0.2 mg/l
29.	Cadmium	-	0.01 mg/l
30.	Barium	-	0.1 mg/l

Source: World Health Organization (1997)