Assessment of Heavy Metal In Urbanised River in Ibadan, Nigeria

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Abstract

Contamination by heavy metals in river water is a global problem especially in developing countries like Nigeria. Ten heavy metals were investigated in River Ona located in Ibadan, a state capital in Nigeria. The river which stretches over more than 30km length drains through different land uses in the city. Laboratory analysis conducted on ten water samples collected at 1km equidistance position reveals that concentration levels of six (Lead, Cobalt, Copper, Zinc, Manganese and Iron) out of the ten heavy metal investigated in the study conform to the World Health Organisation (2011) recommendation for human consumption while the remaining four elements (Cadmium, Chromium, Nickel and Arsenic) were above the WHO (2011) recommended levels. The mere presence of heavy metals in concentration near those limits considered safe for human consumption should be a matter of concern especially for residents who use the river water for domestic activities and those who consume fish from the river. A number of recommendations were subsequently put forward as a way of quality management of the river water.

Keywords: Heavy Metals, Contamination, Pollution, Urbanisation, Environment.

Introduction

Water is one of the most important resources without which no existence is possible. Though the hydrosphere is estimated to contain about 1.36 billion Km^3 of fresh water, 99.9 percent of this is locked up in seas and oceans with only 0.3 percent available for the use of man through sources such as rivers, streams, springs, groundwater and aquifers (Wilson, 1978). Apart from water being required by man, the resource is also of great demand in the maintenance of ecological balance. However, the world is currently experiencing scarcity of fresh water supply, most especially in the developing countries. According to UNICEF (2016) women across the world spend 200 million hours a day to search and collect water. Because scarcity of water is increasing, there is thus the need to plan, monitor and manage the resources especially for the purpose of sustainable development (Iroye, 2017).

Among the oldest water sources in the world are rivers (Higler, 2012). Rivers and their catchments constitute an important part of the natural environment and play an integral part in the sustainability and livelihood of communities; and due to the universal usefulness of water, most communities are often found along riverbanks. Their status therefore affects the health and well-being of humans, animals and plants that depend on them. However, a number of factors determine both the quantity and quality of river water. Among such factors include natural processes of precipitation, weathering and erosion and anthropogenic activities such as urban development, industrialisation, transportation and agricultural activities.

One of the factors of quality impairment of surface water is pollution by heavy metals. Heavy metal refers to any metallic chemical element that has a relatively high density and is toxic and poisonous even at low concentrations. According to Tam and Wong (2000), heavy metals are one of the most serious pollutants in man's natural environment due to their toxicity, persistence and bioaccumulation problems. As a result of human activities, the rate and degree of heavy metal pollution in natural water bodies have been on the increase. According to Wangboje and Ekundayo (2013), presence of heavy metals in water bodies is leading to a variety of negative impacts with consequent effect on ecosystem.

In surface water such as rivers and other natural aquatic ecosystems, heavy metals occur naturally in low concentrations, normally at the nanogram to microgram per litre level. In recent times, however, its occurrence has become a problem of increasing concern (Islam *et al.*, 2015). This situation according to Biney *et. al.* (1991) and Martin *et al.*, (2015) has arisen as a result of rapid growth of population, increased urbanisation, 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. The major routes of heavy metal uptake by man are through food, drinking water and air. For example, aquatic animals, most especially fish which are consumed by man, are a source of mercury (Hg) contamination.

As trace elements, some heavy metals such as copper and zinc are essential to maintain the metabolism of the human body. However, at higher concentrations, they can lead to poisoning. Heavy metals linked most often to human poisoning are lead (Pb), mercury (Hg), arsenic (As) and cadmium (Cd). Others, such as 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).

Ayoade (1988) and Adebola (2001) observed that water resource problems worldwide are generally of three main types; these are problems of too little water, too much water and polluted water. In the case of River Ona, the main focus in this investigation, the problem is polluted water which comes in form of heavy metals and other impurities in the river water. This pollution problem may not be unconnected with the numerous socio-economic activities taking place within the riparian environment of the river. Much of the wastes generated within the drainage basin are usually discharged into the river untreated. These wastes apart from adversely affecting the normal hydrochemistry of the river, also result in debris pileup on the river bed and decrease channel capacity at various points, thus inducing flood.

While the resultant effects of polluted water on public health and environment are enormous, pollution of rivers by heavy metals are especially dangerous on aquatic organisms and man. Their presence in water causes imbalance in ecological distribution of both fauna and flora organisms. Dadzie (2012) observed that the consumption of arsenic leads to skin cancer and cardiovascular diseases while consumption of lead and mercury leads to breakdown of the central nervous system as well as neurological disorder. Efficient and effective water quality management is a prerequisite for reducing pollution in water. It is germane for the protection of the integrity of ecosystem. Such a task, however, begins with monitoring of water bodies as currently being done in this investigation. According to Milicevic (2013), monitoring as defined by the International Organisation for Standardisation (ISO) is the programme process of sampling, measurement and subsequent recording or signaling or both, of various water quality characteristics, often with the aim of assessing conformity. This task is being carried out in this study through the assessment of concentration levels of heavy metals, examination of the spatial variability in concentration levels of the heavy metals and investigation of the nature of inter-relationships among the heavy metals.

The Study Area

Ibadan, Oyo State capital located, in the south-western part of Nigeria (Fig 1) is the study area in this investigation. Ibadan is located between longitudes 3º55 E and 3º91 E and between latitudes 7º23 N and 7º39 N. The city is located approximately 145 km north of Lagos. It lies completely within the tropical forest zone. Ibadan is regarded as the largest indigenous city in tropical Africa with a population of about 2,550,593 (NPC, 2006). In terms of physical expansion and land coverage, this pre-colonial urban centre has expanded very fast sprawling daily into the hinterland. Fabiyi (2006) noted that developed land in Ibadan increased from only 100 ha in 1830 to 214 km^2 in 1988. Ibadan currently covers a land mass of 400km^2 (Egbinola, *et al.*, 2013).

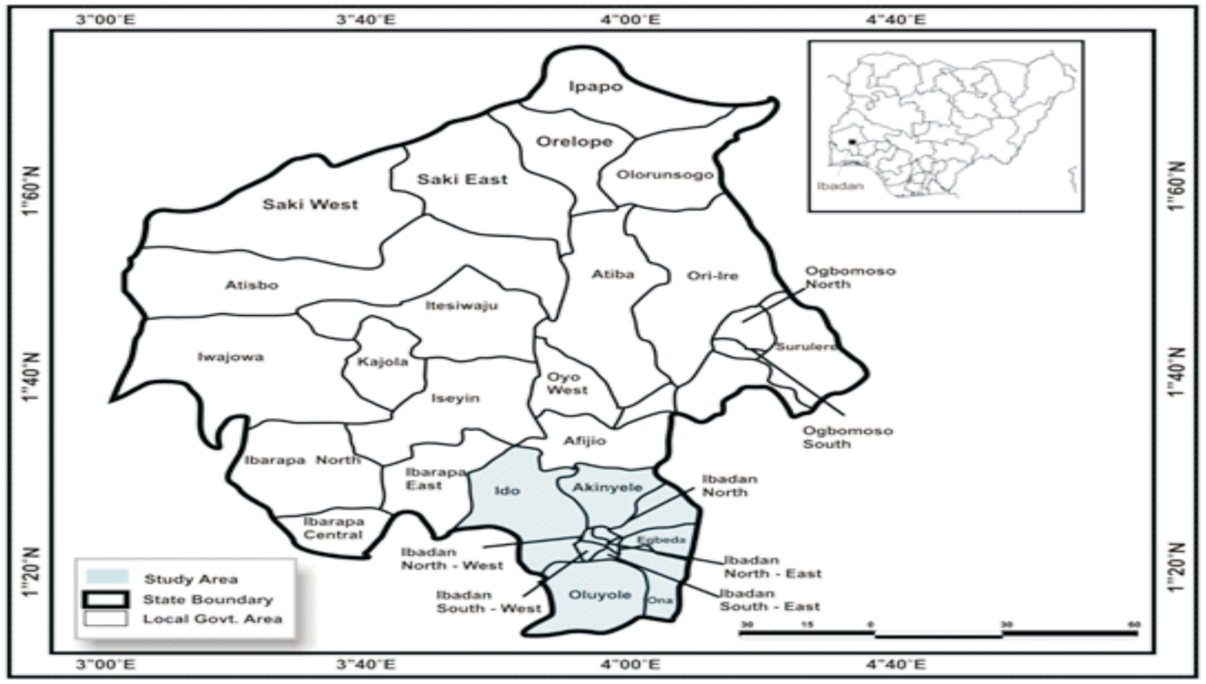

Figure 1 Map of Oyo State Showing Ibadan with Nigeria as Inset.
Source: Ministry of Lands and Housing, Ibadan, 2011.

The climate of Ibadan is influenced by the movement of the inter-tropical convergence zone (the ITCZ), a quasi-stationary boundary zone which separates the sub-tropical continental air mass over the Sahara and the equatorial maritime air mass over the Atlantic Ocean. The former air mass is characterised by the dry northeasterly winds known as Harmattan, the latter by the rain-bearing southwesterly winds from the Gulf of Guinea. Ibadan has an annual rainfall of about 1,306mm (Oke, *et al.*, 2013). Rainy season in the region begins in early March and ends around the month of November while dry season is experienced between the months of November and February. The change of the rainy season to the dry season in the area is rather abrupt while the onset of rains after the dry season is gradual. The month of February is the hottest when temperature can reach as high as 34.6^{0}c. Vegetation around Ibadan comprises trees, herbs, shrubs, grasses and palms, most of which are evergreen. However, the impact of man has greatly been felt negatively on the vegetation. This is through various activities such as lumbering, construction and agricultural activities. Examples of tree species in the region include *Bamboosa Aridinarifolia*, *Azadhirachta Indica*, *Mangifera Indica*, *Citrus Spp*, *Musa Paradisicum*, while *Axonopus Fissifolius*, *Heteropogon Canorous*, and *Pennistrum Purpureum* are few examples of grass species.

Geologically, Ibadan is underlain by basement complex rocks which are mainly metamorphic rocks of Precambrian age with granite, quartzite and migmatite as the major types. The minor rock types include pegmatite, aplite and diorite. The city is dominated by three main landform units of plains, hills and rivers. The hills are the most striking features though they constitute less than 10 percent of the total surface area. This relief can generally be described as undulating with height ranging between 185 and 230 meters above sea level. Ibadan is drained by a network of rivers which exhibits a dendritic drainage pattern. Four important rivers in the city are Rivers Ogunpa, Ona, Kudeti and Ogbere.

River Ona which is the case study in this investigation flows in a north-south direction of the city from its source at the International Institute of Tropical Agriculture (IITA) through Eleyele where it is dammed. It thereafter flows through Oluyole Estate to Odo Ona Elewe and eventually empties its water into the Lagos Lagoon. The river covers a length of over 30km and it has a catchment area of 81km^2. River Ona, from its source to its mouth is crossed by three (3) dams. The first dam is located at IITA, the second is located in University of Ibadan while the third is the Eleyele dam found in the north where the Alapata stream joins the river (Alayande, *et. al.,* 2012). River Ona thus serves as a dependable source of water for agricultural, industrial and domestic uses in the city.

Methodology

Water samples were collected from ten sampling points located at 100m equidistance positions along the study river in the downstream segment beginning at a kilometer distance away from Eleyele Dam (Fig 2). The water samples were collected using sterilized 75cl plastic bottles. At the point of collection, the plastic bottles were rinsed twice with the same water to be collected. After the collection, each water sample was labeled with date and collection station. The collected water samples were later transported to the laboratory under preserved storage using cooler filled with ice cubes. This was to ensure that the characteristics to be analysed are not changed between the time of collection and analysis.

The concentration levels of these heavy metals were analysed at the University of Ibadan Agronomy Laboratory using Atomic Absorption Spectrophotometer (AAS) method. This technique, which is generally used in analysing metals in water, involves atomisation of samples by thermal sources and the absorption of a specific wavelength by the atomic source as it is excited. The radiation used is a hollow cathode lamp containing, as its cathode, the same element under analysis. Greaney (2005) has earlier used the method to a great level of success. The instrument for the measurement was set up at wavelengths specific to each element to be analysed based on APHA (2005).

Before determining the concentration of heavy metals through Atomic Absorption Spectrometer (AAS) method, the water samples were digested by measuring 20ml of each water sample into 50ml of an acid mixture of Nitric and Per chloric acid. The beaker content was placed on a heating mantle at 105°C for thirty minutes under a fume cupboard. The digest was allowed to cool, and thereafter, read on an Atomic Absorption Spectrometer. The results of the laboratory were subsequently subjected to descriptive statistical analysis. In all, concentration levels of ten heavy metals were examined; these heavy metals include zinc, lead, copper, cadmium, chromium, arsenic, nickel, cobalt, manganese and Iron.

Figure 3.1: Street Map of Ibadan Showing the Sampling Locations
Source: Fourchard (2003)

Table1: Heavy Metal Concentration in the Study Area

Parameter / Sampling Points		Pb (mg/l)	Cd (mg/l)	Cr (mg/l)	Co (mg/l)	Cu (mg/l)	Ni (mg/l)	Zn (mg/l)	Mn (mg/l)	Fe (mg/l)	As (mg/l)
Eleyele (1)		0.04	0.00	0.02	0.02	0.001	0.040	0.037	1.33	3.22	0.08
Nihort (2)		0.05	0.01	0.02	0.01	0.001	0.030	0.000	1.95	2.46	0.08
Idi Ishin (3)		0.03	0.01	0.03	0.03	0.000	0.020	0.000	0.38	2.43	0.04
Moor Plantation (4)	Upstream	0.04	0.02	0.04	0.02	0.001	0.650	0.045	0.09	2.61	0.01
Moor Plantation 2 (5)		0.03	0.01	0.02	0.03	0.950	0.060	0.048	0.14	2.87	0.04
Ago tailor (6)		0.10	0.03	0.06	0.04	0.001	0.020	0.018	0.15	2.56	0.05
Oluyole Estate 1 (7)	Midstream	0.08	0.02	0.05	0.05	0.016	0.100	0.031	0.43	5.18	0.04
Oluyole Estate 2 (8)		0.08	0.03	0.04	0.04	0.039	0.080	0.048	0.28	3.42	0.06
Adeoyo Hospital (9)		0.08	0.03	0.05	0.04	0.001	0.080	0.192	0.07	1.82	0.04
Odo Ona Elewe (10)	Downstream	0.10	0.03	0.04	0.05	0.001	0.100	0.000	0.11	0.95	0.08
Total		**0.62**	**0.19**	**0.37**	**0.33**	**1.011**	**1.18**	**0.419**	**4.93**	**27.52**	**0.52**

Source: Author's Fieldwork, 2017

RESULTS AND DISCUSSION

Concentration of Heavy Metal in the Studied River

Table 1 presents the result of the laboratory analysis on heavy metals in water samples collected from River Ona

Table1: Heavy Metal Concentration in the Study Area

The table shows that values of Lead, Cadmium and Nickel were highest at the downstream segment of the river while values of Copper and Iron were highest at the midstream segment. Manganese was, however, highest at the upstream segment. Out of the ten elements investigated in the study, values of Copper, Nickel, Manganese and Zinc exhibit high variability while iron exhibits relatively low variability. Values of Manganese, Nickel and Iron deviate much from mean with Nickel recording the highest standard deviation of 3.10. Accumulative Factor (AF) which gives the degree of contamination of river water at the downstream segment when compared with upstream segment revealed high values for Copper and Cobalt while the same was low for elements such as Manganese, Nickel and Iron.

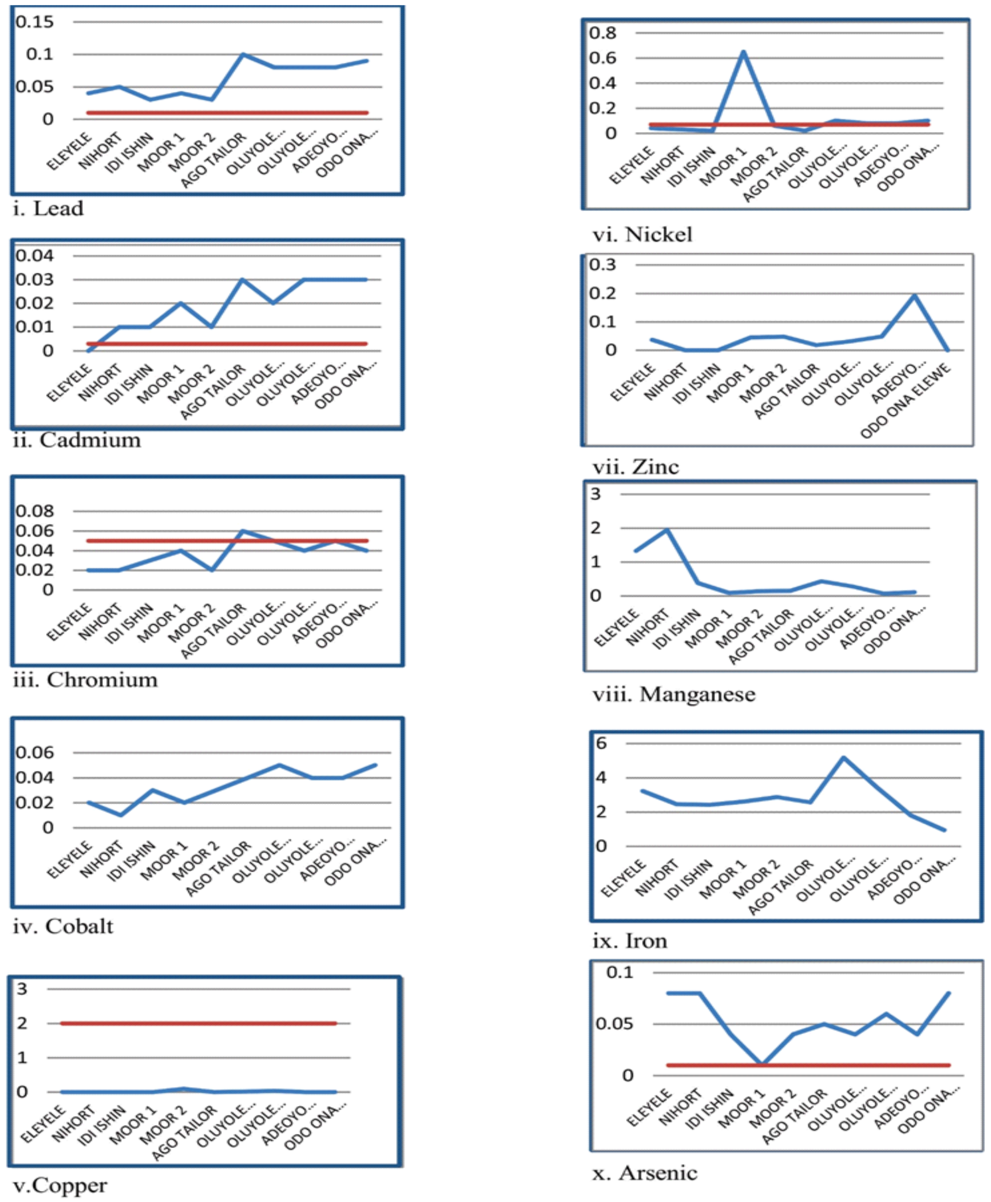

Fig 3: Spatial Variations in Concentration of Heavy Metals in River Ona
Source: Author's Fieldwork 2017

Spatial Variation in Concentration Level of Heavy Metals in the Study River

Figure 3 (i-x) shows the variability in concentration levels of the ten heavy metals investigated in this study.

Lead concentration (Fig 3i) generally undulates around 0.4mg/l between Eleyele and Moor Plantation II before rising to its peak value of 0.1mg/l at Ago Tailor. The high value at Ago Tailor, however, dropped to 0.08mg/l between Oluyole Estate and Adeoyo Hospital before slightly rising again to 0.09mg/l at Odo ona Elewe. The significant increase in Lead value at Ago Tailor could be as a result of the presence of a mechanic workshop very close to the river. Studies such as Getachew (2015) and Ololade (2014) have indicated that the presence of mechanic workshop in an area increases heavy metal concentration such as Lead, both in the soil and surrounding water bodies. Ololade (2014) reported that the increase in concentration of Lead within the visibility of mechanic workshop may be linked to the presence of addictive in lubricants used by auto-mechanics.

The high concentration of Lead in Oluyole Estate 1 and Oluyole Estate 2 could be attributed to the presence of industries in the area. This finding is in agreement with earlier observation made by Ayenimo, *et. al* (2005) which reported that different industries contribute significantly to heavy metal load of a river. The concentration of Lead is also very high at Adeoyo Hospital. This could be as a result of effluent discharged into the river both from the hospital and from the surrounding residential areas. This factor can also be held accountable for the high concentration of Lead at Odo Ona Elewe.

Figure 3ii shows that cadmium which was absent in the study river at Eleyele gently rose from 0.01mg/l observed at National Horticulture Research institute (NIHORT) to 0.03mg/l at Ago Tailor. Cadmium value in the study river however dropped to 0.02mg/l at Oluyole Estate I before rising back to stabilize at 0.03mg/l in Oluyole Estate II, Adeoyo Hospital and Odo Ona Elewe. The significant increase in Cadmium value at Ago Tailor could be as a result of the presence of a mechanic workshop located very close to the river. While the high concentration at Oluyole Estate II could be as a result of the discharge of industrial waste into the water bodies. The high concentration in Odo Ona Elewe could be as a result of the effluents discharged into the water from anthropogenic sources. The increase in concentration of cadmium at the downstream segment level of the river can be accounted for by accumulation factor of this element in the river. Concentration of Cadmium in all the sampling points exceeded the WHO (2011) maximum permissible level for drinking water with the exception of Eleyele.

Chromium (Fig. 3iii) which was 0.02mg/l at Eleyele rose to 0.04mg/l at Moor Plantation I. The value of this parameter, however, dropped to 0.02mg/l in Moor Plantation II before rising back to 0.06mg/l at Ago Tailor and falling again to 0.04mg/l at Oluyole Estate II. The increase in Chromium value at Ago Tailor could be as a result of discharge from the nearby mechanic workshop. This was observed by Ololade (2014) where Chromium was named as one of the most concentrated heavy metals in mechanic workshops. According to WHO (2011), Chromium content of surface water reflects the extent of industrial activities. This observation is particularly for Oluyole Estate I where high concentration of Chromium was observed. Concentration of Chromium in the study river is, however, below the WHO (2011) maximum permissible level for drinking water with the exception of that of Ago Tailor.

The value of Cobalt (Fig. 3iv) in the study river also exhibits undulating characteristics around 0.02mg/l between Eleyele and Moor Plantation I before rising gently to its peak value of 0.05mg/l at Oluyole Estate I. The high value at Oluyole Estate I, however, dropped to 0.04mg/l at Oluyole Estate II and Adeoyo Hospital before slightly rising again to 0.05mg/l at Odo Ona Elewe. The high concentration of Cobalt in Oluyole Estate could be associated with discharge of industrial effluents that are generated as a result of industrial activities in the area. The high concentration in Odo Ona Elewe could also be linked to the effluents discharged into the water that comes from anthropogenic sources. There is no World Health Organisation (WHO) recommendation for Cobalt in drinking water.

The concentration of copper in the sampled water (Fig 3v) is very low. In fact, this parameter is almost absent in all the sampling points with the exception of Moor Plantation II where its value rose to 0.095mg/l. The relatively high concentration of copper in Moor Plantation II could be linked to the use of fertilisers and other agricultural activities that take place in the area. Earlier research conducted by Mortvedt (1996) indicated that fertilizers contain small amounts of heavy metal contaminants. According to the research, animal manures and sewage sludge are the main organic fertilisers and the latter may contain heavy metal contaminants.

The concentration level of Nickel in the study river can generally be considered very low (Fig 3vi). The values of this parameter in the first six sampling points with theexception of Moor Plantation I do not exceed the WHO (2011) recommended limit. However, this parameter undulates around the WHO (2011) recommended limit in the last four sampling points; the development may not be unconnected with poor waste disposal methods as these areas are highly built-up with residential houses. The significant increase in Nickel value at Moor Plantation I could also be linked to the use of fertilisers and other agricultural activities that takes place in the area. Mortvedt (1995) indicated that fertilisers contain small amounts of heavy metals. According to the research, animal manures and sewage sludge are the main organic fertilisers and the latter may contain heavy metal contaminants.

Zinc, which generally, fluctuates around 0.018mg/l in the study river was completely absent in NIHORT, Idi Isin and Odo-Ona (Fig 3vii). Zinc concentration, however, rises to its peak value of 0.192mg/l at Adeoyo Hospital. The increase in concentration level of this parameter at Adeoyo hospital could be as a result of anthropogenic waste deposited in the river. The increased concentration could also be as a result of natural occurrence of Cadmium and Lead as these three elements are associated metals (Philips, 1976).

Though, the concentration of Manganese in drinking water is not of health concern, the value of this parameter was very high within the vicinity of NIHORT where it records a value of 1.95mg/l (Fig 3 viii). However, the value of Manganese in the study river downstream of NIHORT did not exceed 0.043 mg/l recorded at Oluyole Estate I. The high concentration of Manganese in NIHORT could be as a result of the application of Manganese sulphate in horticultural plants at NIHORT. This chemical which is applied to the horticultural plants could be washed down to the river by rainfall. According to WHO (2011), increase in concentration of Manganese could be as a result of erosion of agricultural soils in the upstream segment into water bodies and as a result of anthropogenic activities in the riparian area of the river.

Iron concentration in the study river fluctuates between 3.22mg/l at Eleyele and 2.42mg/l at Ago Tailor before rising to its peak value of 5.18mg/l at Oluyole Estate I (Fig 3 ix). This high value, however, drops sharply to 0.95mg/l in Odo Ona Elewe. The high concentration at Oluyole Estate I and II may have been influenced by changes in redox condition as earlier observed by Kritzberg and Ekstrom (2011). This means that, more anoxic water with high concentration of soluble iron II may be feeding into the river at this point.

Arsenic concentration in the study river exhibits high variability (Fig 3 x). This parameter exceeds the WHO (2011) recommended limit in drinking water in all the sampling points with the exception of Moor Plantation I. Arsenic concentration was exceptionally high (0.08mg/l) in the study river at Eleyele, NIHORT and Odo-Ona. Its high concentration in these places may be due to the nature of underlying geology and industrial processing of paper, wood preservatives and textiles in those places.

Inter-relationships of Heavy Metal in the Study River

A multiple correlation was generated among the parameters investigated to enable an understanding of the relationships that exists between them and the type and the extent of their relationships. The varieties of these relationships are as seen in the correlation matrix (Table 2).

Table 2: Inter-relationships of Heavy Metal in the Study River

	Pb	Cd	Cr	Co	Cu	Ni	Zn	Mn	Fe	As
Lead	1.00									
Cadmium	0.84	1.00								
Chromium	0.81	0.83	1.00							
Cobalt	0.73	0.70	0.70	1.00						
Copper	-0.28	-0.13	-0.33	0.07	1.00					
Nickel	-0.22	0.11	0.12	-0.23	-0.14	1.00				
Zinc	0.16	0.32	0.30	0.17	0.04	0.07	1.00			
Manganese	-0.32	-0.64	-0.61	-0.68	-0.24	-0.29	-0.32	1.00		
Iron	-0.06	-0.25	0.06	0.08	0.24	-0.02	-0.10	0.14	1.00	
Arsenic	0.21	-0.17	-0.35	-0.06	-0.16	-0.64	-0.32	0.62	-0.22	1.00

Source: Author's Fieldwork, 2017.

The matrix revealed high correlation between lead and cadmium (r=0.84), chromium (r = 0.81), and Cobalt (r=0.73) and between cadmium and chromium (r=0.83) and Cobalt (r = 0.70). This result suggests similar sources of input (anthropogenic and natural) for these heavy metals at River Ona. This type of relationships was earlier observed by Ali, *et al.*, (2016). According to Jiang *et al* (2014) and Manoj *et al* (2012), high concentrations between specific heavy metals in water may reflect similar levels of contamination and/or release from the same sources of pollution, mutual dependence and identical behaviour during their transport in the river system.

Recommendations

Based on the findings from this investigation, the study thus put forward the following recommendations towards reducing the rate of heavy metal pollution in rivers. High level of heavy metal pollution, to a large extent, affects the quality of the river as well as the biota present in and around the water body.

i. Public Awareness Fora should be created by the Federal Environmental Protection Agency (FEPA) and Ministry of Water Resources to educate the populace about the increased degradation of River systems especially amongst people who live in the riparian environment of the river and the effects it could have on their health,

ii. People should be discouraged from using water collected directly from the river for domestic activities. This is important in order to prevent incidents of diseases known to be caused by ingestion of contaminated water,

iii. There should be proper monitoring of effluents into river bodies as an integral part of water management in early river system. This will enable the verification of whether or not imposed standards and regulations are met. A regular schedule for sampling the 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, and

iv. Subsidies can be given to industries to enable them treat their effluents before discharging them into the water courses. The subsidies may come in form of tax credits, loan with low interest or outright grant.

Conclusion

The presence of heavy metals in an environment is one of the major concerns of pollution control and environmental agencies in most parts of the world. This is mainly due to the health implications of these metals in water as they are non-essential metals and of no benefit to humans. Although, the levels of six (Lead, Cobalt, Copper, Zinc, Manganese and Iron) out of the ten heavy metals examined in this investigation do not exceed the safe levels for human consumption as recommended by WHO (2011), the exceedance of four of the heavy metals (Cadmium, Chromium, Nickel and Asenic) above the WHO (2011) recommended levels and constant presence of heavy metals in concentration near those limits considered safe for human consumption, is a reason for concern, and residents who constantly consume fish from river Ona should be warned.

Heavy metal pollution can be controlled by practising low-impact development activities, improved chemical handling (e.g. management of motor fuels and oil and lubricants, fertiliser and pesticides). Industries operating within the drainage basin should be mandated to treat their effluents before discharging them into rivers. System of sewage disposal which has its terminal at a waste treatment plants should also be encouraged by government agencies responsible.

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