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PRELIMINARY ASSESSMENT OF SOME HEAVY METALS POLLUTION STATUS OF LISIKILI RIVER WATER IN ZAMBEZI REGION, NAMIBIA

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ABSTRACT: *Good water quality is fundamental to human health and sustenance of aquatic ecosystems. The Lisikili river in Zambezi region, Namibia is a major perennial river which serves diverse economic purposes in the host community. However, it has been receiving pollution threat from effluents discharge and surface run-off from intensive agricultural lands, as well as cottage and hospitality industries and no research has been carried out on the pollution status of the river. Thus, the main aim of this study is to conduct preliminary assessment of some heavy metals pollution status of the river water. Eight (8) water samples were collected at 8 random points within a stretch of approximately 2km on each extremity and median parts of the river. Two major economic fish from the river, tilapia fish (Oreochromis niloticus) and cat fish (Siluriformes) (8 samples of each) were collected using fish net at the points of water sampling. The samples were transported to analytical laboratory in ice boxes for processing and analyses for the levels of Pb, As, Cr, Cd, Cu, Zn, Mn and Fe using Inductively Coupled Plasma-Optical Emission Spectrophotometer (ICP: Perkin Elmer Optima 7000 DV). The results obtained showed wide mean concentrations of the heavy metals in the river water; iron recorded the highest level of 2.375 mg/l and arsenic (0.047 mg/l) recorded the lowest level. Apart from Zn (0.259 mg/l) and Cu (0.073 mg/l) with the present concentrations lower than their guideline permissible limits, the mean concentrations of the other heavy metals exceeded their maximum permissible guideline values for the protection of human and aquatic health. Based on the classification of metal pollution index (PI) for water, apart from Cu (PI = 0.03) and Zn (PI = 0.04); all the other heavy metals recorded pollution indices which suggest moderate to strong effect on the river water quality. In both the catfish and tilapia fish (wet weight whole sample), iron (4.926 mg/kg and 3.323 mg/kg) recorded the highest mean concentration while Cd (0.136 mg/kg and 0.078mg/kg) recorded the lowest level respectively. Generally, the present levels of the heavy metals were below their regulatory limits for the protection of human health. However, the fish's bio-accumulation factors of the metals suggest that they have high potentials to bio-accumulate some of the heavy metals to high levels and this has adverse implication for human consumption. Because heavy metals are non-biodegradable and bio-accumulative in nature which therefore, make their presence in human foods even at very minute levels potential toxins, it is important to monitor their accumulations in the river and fish and advice precautionary measures to limit excessive human exposures to the heavy metals content.*

KEYWORDS: Heavy Metals, River Water, Fish, Human Health, Pollution

INTRODUCTION

Heavy metals are natural components of the environment but they have become a matter of great concern because of the continuous increase in concentration of these metals in our environment (Abah et al, 2013). In particular, studies on heavy metals pollution of rivers, lakes, fish and sediments have become a major environmental focus in the recent decades (Ali and Fishar, 2005). The pollution of aquatic environment by chemical agents such as heavy metals poses adverse threat to aquatic organisms including fish, and this could yield extended effects on the human food chain. Heavy meals concentrations in the aquatic organism depict the past as well as the current pollution load in the environment in which the organism lives (Ravera et al., 2003).. Water pollution occurs when unwanted materials with potentials to threaten human and other natural systems find their ways into rivers, lakes, wells, streams, boreholes or even reserved fresh water in homes and industries (Aboyeji, 2013). According to this author, the effect of water pollution can be catastrophic, depending on the kind of chemical pollutants, concentration of the pollutants and where the pollution occurs. In aquatic ecosystem, the contamination by heavy metals is a serious threat because of their toxicity, and environmental persistence with possibilities for bio-accumulation and bio-magnification in the food chain. Aquatic organisms, including fish, accumulate pollutants directly from contaminated water and indirectly via the food chain (Hammer, 2004; Mohammed, 2009). In the aquatic environment, the trace elements are partitioned among various environmental components (water, suspended solids, sediments and biota) (Shakweer and Abbas, 2005).

Due to increased human population with the attendant anthropogenic activities, both surface and underground water supplies are now affected and deteriorating fast worldwide. Water pollution has been indicated to be the leading cause of death and diseases worldwide (Pink, 2006), and accounting for more than 14,000 deaths of people daily (West, 2006). A report by the Food and Agricultural Organization of the United Nation (FAO) revealed that in African countries, water related diseases had been interfering with basic human development (FAO, 2007). This scenario has raised serious concerns to World Health Organization, in an attempt to improve the cultural and socio-economic standards of people in the tropical region (Umeh et al., 2004). Research report has shown that in addition to the acute problems of water pollution in developing countries, the developed countries also continue to struggle with the same pollution problems (Aboyeji, 2013). For example, in the national report on water quality in the United States, 45 percent of assessed stream miles, 47 percent of assessed lake acres, and 32 percent of assessed bays and estuarine square miles were classified as polluted (EPA, 2007). A report by Hays (2013) indicated that the China government in summer of 2011 reported that 43 percent of state-monitored rivers are so polluted, and are unsuitable for human contact. It was further submitted that by one estimate, one-sixth of China's population is threatened by seriously polluted water. Pyrbot and Laloo, (2015) in a study on the toxic elements of a river noted that water is the most important and precious natural resources that is essential for the survival of living organisms, and which man has exploited more than any other resources for the sustenance of life. River water pollution can be linked to the type of waste water produced by urban, industrial, and agricultural activities that flow into surface and subsurface waters (Vittori et al., 2010).

The increasing quantities and heterogeneity of effluents discharged into water bodies have greatly affected the natural processes of pollutants reduction. Thus, regular monitoring of the qualities of water resources is absolutely necessary to assess the quality of water for ecosystem health and hygiene, industrial use, agricultural use and domestic use (Poonam et al., 2013). It has been submitted that the protection of water and aquatic ecosystem from adverse effects of pollutants such as heavy metals is central to environmental risk management (Bere and Tundisi, 2011). The Lisikili river in Zambezi region of Namibia is a

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high economic resource which serves diverse human needs such as domestic utilization, fishing, and subsistence farm irrigation in the host community. Agricultural contaminations of many resources through fallout, drainage and run-off erosion is highly probable in rivers within the vicinity of intensive agricultural activities (Abah et al., 2013). Where this occurs, it constitutes threat to the sustainable use of the river resources. Even though, the Lisikili river - a major economic river in Zambezi region, is very prone to surface run-off from agricultural lands owing to intensive agricultural activities along the bank of the river, especially its proximity to Kalimbeza National Rice Research field, and effluent discharges from the cottage and hospitality industries within the vicinity of the river, there has not been any documented research on the pollution status of the river. This creates the need to carry out this baseline study with a view to determining the current heavy metals pollution status of the river and provide scientific data for future monitoring of the metals accumulation in the water body. Evaluation and understanding the sources and impact relationship of the effects of heavy metals in water bodies and biological species is important for effective water management, and the preservation of the aquatic ecosystem (Olatunji and Osibanjo, 2012). Thus, it becomes pertinent to carry out preliminary assessment of heavy metals pollution status of the Lisikili river water and its two economic fishes: tilapia fish (*Oreochromis niloticus*) and cat fish (*Siluriformes*) consumed in and around Zambezi region.

MATERIALS AND METHOD

Study area

The Lisikili river in Zambezi region is a major perennial river which forms a tributary of the Zambezi river (the fourth largest river in Africa after rivers Congo, Nile and Niger (Tumbare, 2004). Its basin drains large agricultural fields along the river banks and because of the intensive usage of agrochemicals (chemical fertilizers and pesticides), there are possibilities of residual chemicals being washed in surface run-off into the river. Besides, Lisikili river also receives surface run-off and effluents from Kalimbeza rice research field and the surrounding communities. Agricultural drainage water containing pesticides and fertilizers as well as effluents and run-offs of industrial activities in addition to sewage effluents supply water bodies and sediment with huge quantities of inorganic anions and heavy metals (ECDG, 2002). These have serious implication for the quality status of the Lisikili river resources and hence, the need for this preliminary assessment to provide a baseline data for future monitoring.

Sample collection and pre-treatment

Water sampling: Prior to water samples collection, all the containers (high density polythene bottles) used were washed thoroughly with solution of detergent and deionized water. Then, they were soaked in 10% "Analar" nitric acid overnight followed by rinsing with deionized water to remove trace elements contamination (Wufem, 2009). The samples were randomly collected in March 2015 within a stretch of about 2km over Lisikili river. A total of 8 samples were collected at 8 random points on each extremity and median parts of the river by immersing the pre acid-washed high density polythene bottles to approximately 30cm below the water surface and allowed to overflow. For the purpose of preservation, the water samples were acidified with nitric acid to a pH of 2 (EPA, 2007) and analyzed within two weeks.

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Fish Samples: Eight (8) samples each of tilapia fish and catfish were collected using fish net at the points of water sampling. Great care was taken to select the fishes having approximately the same sizes so as to ensure an approximately the same duration of habitation in the river water. The fish samples were transported to Analytical laboratory in ice boxes and preserved in a mechanical freezer maintained at -20^oC. The samples were rinsed with deionized water prior to laboratory preparation and analyses (Ahmed et al., 2010).

Samples preparation and analysis

Water sample: The raw unfiltered water samples were mixed very thoroughly, and then four subsamples (each 100ml) were taken and subjected to wet digestion. Each 100ml of the unfiltered water was measured into a 250ml beaker followed by addition of 20ml "Analar" nitric acid solution plus 10ml of 50% hydrochloric acid solution. The acidified water was then evaporated on a hot plate to almost dryness and 5ml of 50% hydrochloric acid was again added and heated for 15 minutes. The beaker was removed and cooled to room temperature before transferring the contents into a 100ml volumetric flask and the volume made up to the mark with deionized water (Wufem *et al*., 2009). Then, the digested water was filtered and analyzed for the levels of Pb, As, Cr, Cd, Cu, Zn, Mn and Fe using Inductively Coupled Plasma-Optical Emission Spectrophotometer (ICP: Perkin Elmer Optima 7000 DV).

Fish samples: Eight fishes each of tilapia fish and catfish were prepared for laboratory analysis of their heavy metals levels. The fishes were descaled and transferred whole into an electric oven at 40^oC. They were dried in the oven at this temperature for 24hours and then pulverized in a clean dry porcelain mortar (Ahmed *et al*., 2010). The pulverized samples were dried further for 1hour at a reduced temperature of 20^oC and put into clean dried bottles (Farkas *et al*., 2000; Adeniyi *et al*., 2005). Then, 3.0g each of the pulverized and dried samples was weighed into a silica crucible and ashed in a muffle furnace at a temperature of 600^oC for 5hours (Farkas *et al*., 2000; Adeniyi *et al*., 2005). The ashes were cooled to room temperature and sieved to remove bigger particles and then transferred into a 250ml conical flask. Thereafter, 20ml of concentrated HNO_3 was added and diluted to 50ml with deionised water and swirled gently after which the volume was made up to 100ml with deionised water and analyzed for heavy metals as with the water.

Statistical analysis

The data generated from 8 replicate analyses were computed as mean. T-test analysis was carried out to assess the statistical significance ($p < 0.05$) of the mean metal concentrations between the tilapia and cat fish. Correlation analysis was also carried out to assess the relationship between the fish metals content and those of their water habitat. The river water quality was assessed by calculating the heavy metals pollution load indices and metal indices of the water. Bio-accumulation factors were also calculated to determine the relative accumulations of the heavy metals in the fish.

The river water quality assessment

Metal quality index (MQI):

The following two quality indices were employed to determine the heavy metals' pollution status of the Likisili river water in the Zambezi region, Namibia.

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Pollution index (PI): The pollution index (PI) is based on individual metal calculations according the following equation (Caerio et al., 2005).

$$PI = \frac{\sqrt{\left[\left(\frac{Ci}{Si}\right)^2_{max} + \left(\frac{Ci}{Si}\right)^2_{Min}\right]}}{2}$$

Where Ci = the concentration of each element; Si = metal level according to national water quality criteria. The water quality criteria used in this study were the USEPA's permissible limits of lead, arsenic, chromium, copper, and zinc, and WHO's permissible limits of cadmium, zinc, iron, as reported by Mohod and Dhote (2013). The calculated metals' pollution indices were interpreted based on the standard classification outlined by Goher et al. (2014) as in Table 1

Table 1. Categories of Water pollution index (PI)

Class	Pollution index value	Effect on water quality
1	< 1	No effect
2	1 – 2	Slightly affected
3	2 – 3	Moderately affected
4	3 – 5	Strongly affected
5	> 5	Seriously affected

Source: Goher et al. (2014)

Metal Index (MI): Metal Index (MI) is a method of rating that shows the composite influence of individual parameter on the overall quality of water (Tamasi and Cini, 2004). It is based on a total trend evaluation of the present status. The metal index rated between zero and one, and reflects the relative importance of individual metal quality considerations. Metal index value >1 is a threshold of warning (Bakan et al., 2010). Metal index of pollution has wide application and is used as the indicator of the quality of sea (Filatov, et al., 2005) and river water (Lyulko, et al., 2001; Amadi, 2012), as well as drinking water (Nikoladis, et al., 2008; Amadi et al., 2010). According to (Tamasi and Cini, 2004), the MI is calculated by using the following formula:

$$MI = \sum_{i=1}^{n} \frac{Ci}{(MAC)_i}$$

Where Ci is the concentration of each element, and MAC is the maximum allowable concentration of the element.

RESULTS AND DISCUSSION

Concentrations of the heavy metals in the river water

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Figure 1 presents the mean concentrations (mg/l) of eight replicate analyses of lead (Pb), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), iron (Fe) and zinc (Zn) determined in Lisikili river water in Zambezi region, Namibia. The results showed wide concentrations of the heavy metals with iron recording the highest level of 2.375 mg/l and arsenic (0.047 mg/l) recorded the lowest level. The other results showed that Mn recorded a mean concentration of 1.230 mg/l, Cr recorded 0.299 mg/l, Zn recorded 0.259 mg/l, while Pb, Cd and Cu recorded 0.158 mg/l, 0.151 mg/l and 0.073 mg/l respectively. Apart from Zn and Cu in which the present concentrations are lower than their guideline regulatory limits, the concentrations of the other heavy metals exceeded their WHO and USEPA's maximum guideline values (Table 2). The elevated levels of these heavy metals in the Lisikili river water may be attributed to the effect of surface run-off into the water way during the period of the water sampling (peak of rainy season in the study area). Research reports have indicated that the contamination of water is directly related to the degree of contamination of the environment (Salem et al., 2000; Vaishnavi and Gupta, 2015). Lisikili river is very prone to receiving high volume of surface run-off from agricultural fields and effluents from the adjacent human settlements which discharge varying degrees of wastewater. The discharge from municipal wastewater treatment plant, accelerated industrial activities, atmospheric deposition, as well as rapid agricultural development and/or non-point source run-off containing pesticides and fertilizers were reported to be the main cause of heavy metal pollution in rivers (Khaki et al., 2011; Saeed and Shaker, 2008; Sanayei et al., 2009). In the aquatic environment, heavy metals in dissolved form are easily taken up by aquatic organisms where they are strongly bound with sulfhydryl groups of proteins and accumulate in their tissues (Amirah et al., 2013). In a study on heavy metals in drinking water and their environmental impact on human health, Salem et al. (2000) reported a strong relationship between contaminated drinking water with heavy metals from some of the Great Cairo cities, Egypt and chronic diseases such as renal failure, liver cirrhosis, hair loss, and chronic anaemia. According to the authors, renal failure is related to contaminated drinking water with lead and cadmium, liver cirrhosis to copper and molybdenum, hair loss to nickel and chromium, and chronic anaemia to copper and cadmium. According to Amirah et al. (2013), heavy metal toxicity can result in damaged or reduced mental and central nervous system function, lower energy levels, and damage to blood composition, lungs, kidneys, liver,

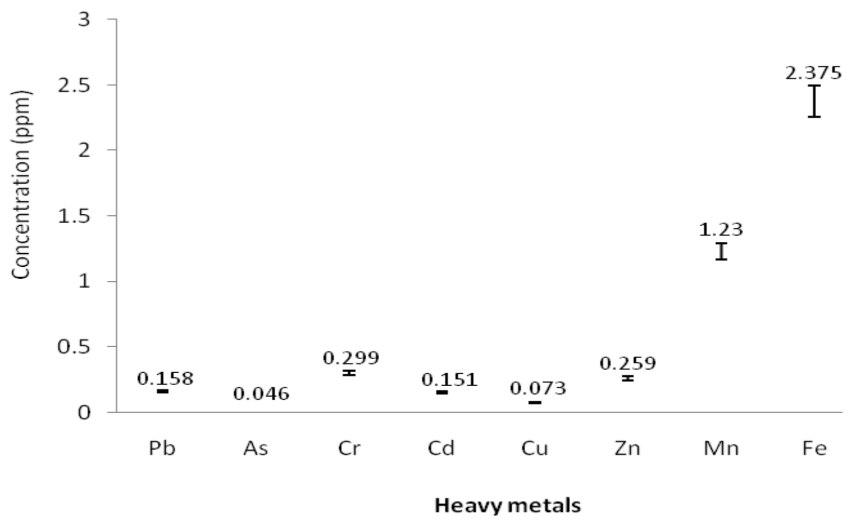

Figure 1. Mean concentrations (ppm) of some heavy metals in Lisikili river water

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Table 2. Heavy metals regulatory permissible limits used in this study

Heavy metal	CAS I.D	Water permissile limits (mg/l)	Source	Reference	Fish permissible limits (mg/kg)	Source	Reference
Pb	7439-92-1	0.015	USEPA	Saha and Zaman (2011)	1.5	FAO/ WHO	Akintujoye et al. (2013)
As	7440-38-2	0.01	USEPA , WHO	Saha and Zaman (2011)	0.5	WHO	Kamaruzzaman et al (2011)
Cr	7440-47-3	0.1	USEPA	Kumar and Puri (2012)	12.0 -13.0	USFDA	Javed and Usmani (2014)
Cd	7440-43-9	0.005	WHO	Mohod and Dhote (2013)	1.0	WHO	El-Moselhy et al. (2014)
Cu	7440-50-8	2.0	WHO	Goher et al. (2014)	30.0	FAO/ WHO	El-Moselhy et al. (2014)
Zn	7440-66-6	5	USEPA	Kumar and Puri (2012)	100.0	WHO	El-Moselhy et al.. (2014)
Mn	7439-96-5	0.4	WHO	Beyene and Berhe (2015	1.0	WHO	El-Moselhy et al. (2014)
Fe	7439-89-6	0.3	WHO	Mohod and Dhote (2013)	100.0	WHO	El-Moselhy et al. (2014)

and other vital organs. The authors also reported that long-term exposure to heavy metals may result in slowly progressing physical, muscular, and Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis. According to Ferner (2001), heavy metals toxicity is a clinically significant condition when it does occur. If unrecognized or inappropriately treated, toxicity can result in significant illness and reduced quality of life (Amirah et al., 2013). Thus, in terms of the heavy metals determined, the present water quality of Lisikili river could be a source of health concern as local inhabitants use the river for many purposes such as bathing, laundry, fishing, crop irrigation, and drinking.

Concentrations of the heavy metals in the Fish (Catfish and Tilapia fish)

The results (Figure 2) show the mean concentrations (mg/kg) of the heavy metals determined in whole catfish (*Siluriformes*) caught from the points of water sampling at the Lisikili river. Iron recorded the highest mean concentration of 4.926 mg/kg while Cd recorded the lowest level (0.136 mg/kg). The other results showed Zn with mean concentration of 3.990 mg/kg, Mn 0.583 mg/kg, Cu 0.428 mg/kg while the concentrations of Pb, As and Cr were 0.169 mg/kg, 0.341 mg/kg and 0.246 mg/kg respectively. The mean concentrations of the same heavy metals in the tilapia fish *Oreochromis niloticus* (Figure 3) showed similar trend. Iron

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(Fe) recorded the highest mean level of 3.323 mg/kg while Cd (0.078mg/kg) was the lowest. The levels of the other heavy metals were: Zn 2.960 mg/kg, Cu 0.341 mg/kg, Mn 0.283 mg/kg, As 0.279 mg/kg, Cr 0.220 mg/kg and Pb 0.104 mg/kg. Generally, the present levels of the heavy metals were below their human health regulatory permissible limits (Table 2). However, fish consumption has been identified as a major route of trace metal exposure for humans (Dougherty et al., 2000), and because of their rapid growth, physiologic and metabolic immaturity, the foetus and children are often at increased risk from toxic substances (Chance and Harmsen, 1998). The rising concern with human exposures to dietary heavy metals generally is due to the high potential of human beings to bio-accumulate metal elements into tissues which after prolong period could reach toxic levels. This is mainly because heavy metals are non-biodegradable in nature which therefore, makes their presence in human foods even at very minute levels potential toxins. In a similar view, Amirah et al. (2013) opined that heavy metals tend to accumulate in advanced organisms through bio-magnification effects in the food chain. Thus they can enter into human body, and accumulate in the human tissues to pose chronic toxicity. Heavy metal-induced toxicity and carcinogenicity involves many mechanistic aspects, some of which are not clearly elucidated or understood, and each metal is known to have unique features and physico-chemical properties that confer to its specific toxicological mechanisms of action (Tchounwou et al., 2012). In biological systems, heavy metals have been reported to affect cellular organelles and components such as cell membrane, mitochondrial, lysosome, endoplasmic reticulum, nuclei, and some enzymes involved in metabolism, detoxification, and damage repair (Wang and Shi, 2001). Metal ions have also been found to interact with cell components such as DNA and nuclear proteins, causing DNA damage and conformational changes that may lead to cell cycle modulation, carcinogenesis or apoptosis (Chang et al., 1996; Wang and Shi, 2001; Beyersmann and Hartwig, 2008). Heavy metals toxicity depends on several factors including exposure dosage, route of exposure, chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals. Thus, in the study area where access to quality food is a major problem confronting majority of the populace, and fish consumption is the most affordable source of meat; prolong exposure to some of the heavy metals detected in the fish may constitute health concern. Notable among the heavy metals are arsenic, cadmium, chromium, and lead which have been ranked among the priority metals that are of public health significance due to their high degree of toxicity (Tchounwou et al., 2012). According to the authors, these metallic elements are considered systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure. Other reports of heavy metals toxicities indicated damage to or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs (Ezejiofor et al., 2013).

The results in Figure 4 show the box plots comparing the paired mean concentrations of the heavy metals in both the tilapia and catfish. The Results of t-test analysis between mean concentrations of the heavy metals in the two fishes were statistically significant ($p < 0.01$) except mean Cr levels. This variation might be due to factors such as differences in the physiological and biochemical functions, including metals storage and elimination from the body by the individual fish which affect the . In separate studies, the ecological needs, size and age of fish, life cycle, feeding habits, and the season of capture have been variously reported to affect experimental results of heavy metals concentrations in fish (Kime et al., 1996; Rurangwa et al., 1998; Onen et al., 2015). Fishes have the ability to take up and concentrate metals directly from the surrounding water or indirectly from other organisms such as small fish, invertebrates, and aquatic vegetation (Polat et al., 2015) they feed on.

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Thus, these are expected to have varying effects on the fishes' levels of the heavy metals recorded in this study. This means that if the ingested foods are reach sources of heavy metals and depending on the rates of uptake and elimination, the fish are expected to bio-concentrate the heavy metals to higher levels.

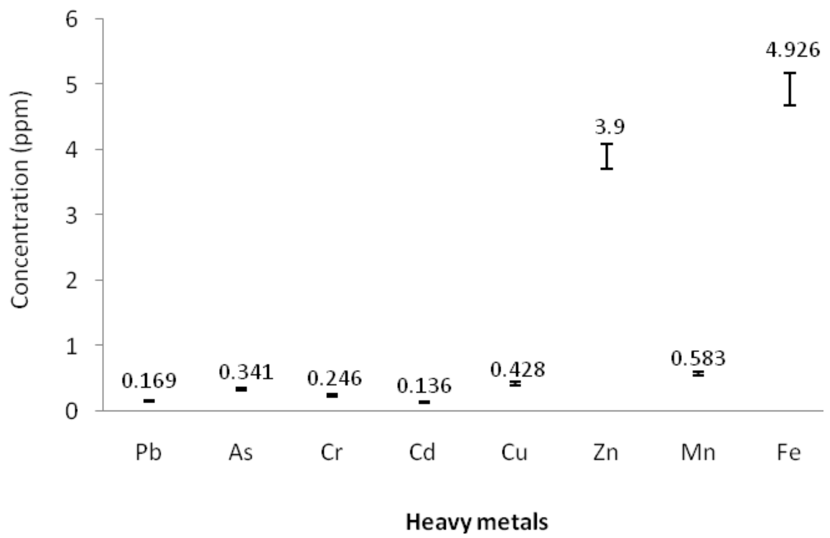

Figure 2. Mean concentrations (ppm) of the heavy metals in Catfish obtained from Lisikili river

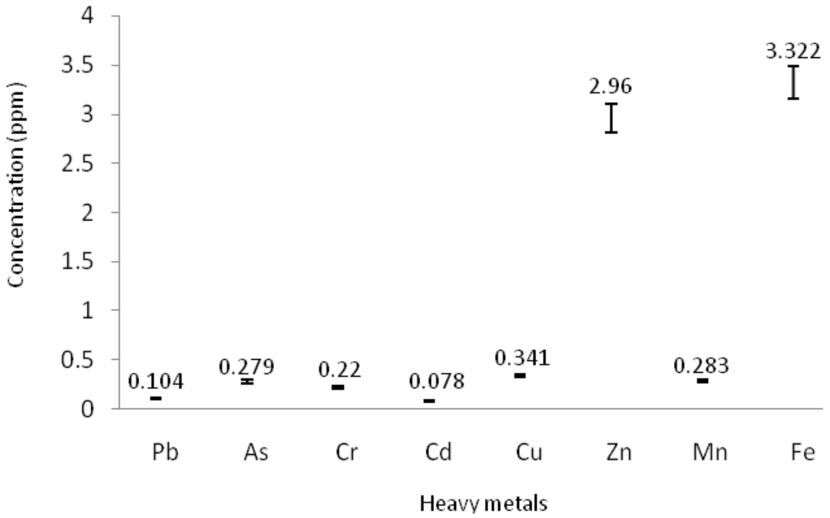

Figure 3. Mean concentrations (ppm) of the heavy metals in Tilapia fish obtained from Lisikili river

Pollution index (PI) and metal index (MI) of the heavy metals in Lisikili river water

Table 3 below presents the pollution and metal indices of the heavy metals determined in this study. Based on the classification of metal pollution index for water (Goher et al., 2014), the results of this study showed that apart from Cu (PI = 0.03) and Zn (PI = 0.04) which have no effect on the water quality, all the other heavy metals have pollution indices which suggest

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moderate to strong effect on the Lisikili river water quality consideration for human and aquatic health. The metal indices also showed that all the heavy metals are at the threshold level (MI > 1) except Cu and Zn. This suggests that the river water quality is threatened by heavy metals pollution and may have adverse implication for drinking and aquatic health. This finding is not surprising as all the heavy metals concentrations except Cu and Zn were found to exceed their guideline regulatory limits. Considering the complexity of factors associated with surface run-off which could elevate heavy metals levels in surface water during rainy season, this finding indicates the need to carry out a more detail study spanning at least, two years to determine the levels of the heavy metals during the dry seasons where surface run-off of effluents are very minimal in the study area. According to Ibrahim and Omar (2013), the amount of fluctuations of agricultural drainage water, sewage effluents and industrial wastes discharged into water ways are the main reasons for temporal difference of heavy metals content of water. Water quality can also be affected when the rate of atmospheric deposition, storm water run offs, domestic or industrial waste water discharges, surpasses the carriage capacity of water (USEPA, 1998).

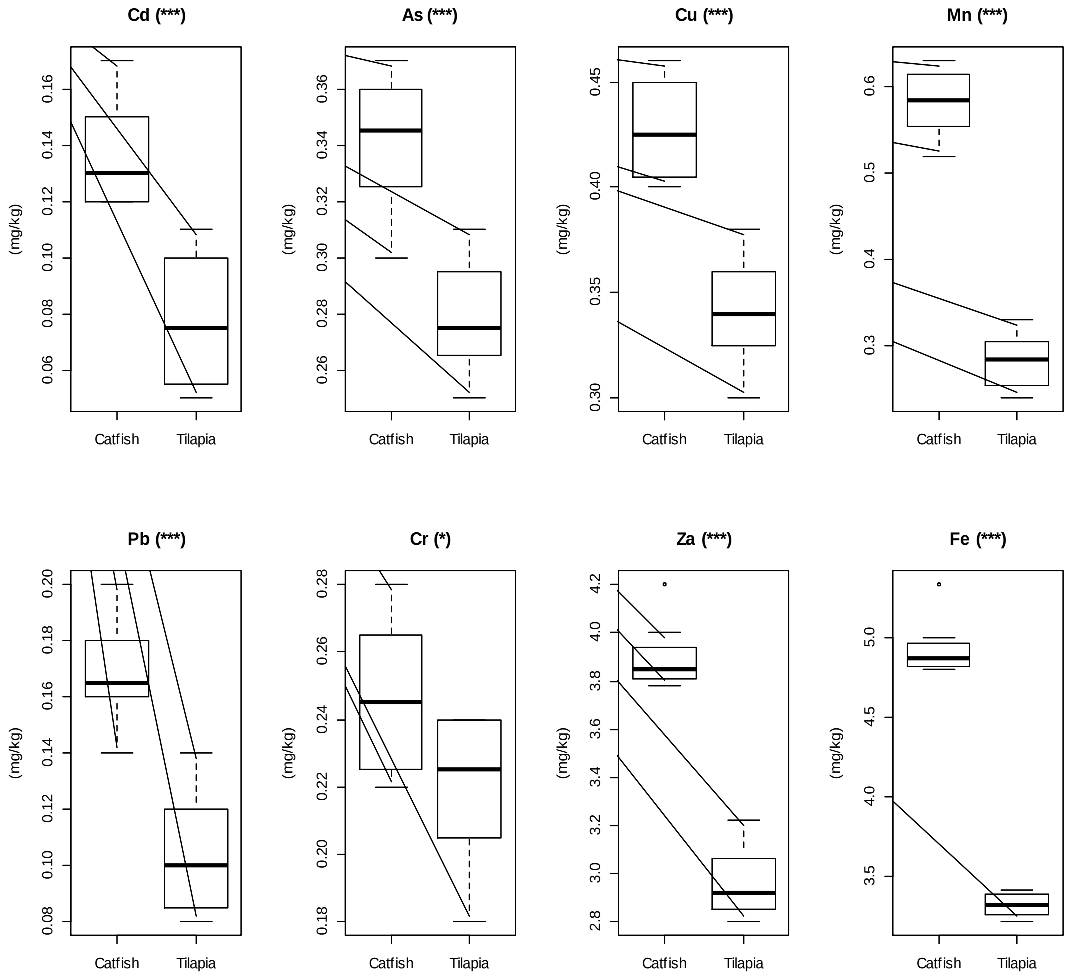

Figure 4. **Box plots comparing the paired mean concentrations of the heavy metals determined in the tilapia and catfish (*** indicates t-test analysis was statistically significant (p < 0.01) and * indicates t-test analysis was not statistically significant**

Table 3. Pollution index (PI) and metal index (MI) of the heavy metals in Lisikili river water

Heavy metal	Pollution Index	Effect of the PI for Human and aquatic health	Metal Index	Effect of the MI for Human and aquatic health
Pb	7.95	Seriously affected	10.53	Threshold level
As	3.35	Strongly affected	4.63	Threshold level
Cr	2.24	Moderately affected	2.99	Threshold level
Cd	3.81	Strongly affected	30.20	Threshold level
Cu	0.03	No effect	0.04	No threat
Mn	2.17	Moderately affected	3.08	Threshold level
Fe	5.55	Seriously affected	7.92	Threshold level
Zn	0.04	No effect	0.05	No threat

Inter-elemental correlation between paired mean concentrations of the heavy metals

The results (Table 4) below show the inter-elemental correlation analysis between the mean heavy metals concentrations of the tilapia fish and its water habitat, the catfish and its water habitat as well as between the tilapia fish and catfish. Between the catfish and its water habitat, the results of Mn and Zn (0.0288) showed extremely weak positive correlation, Mn and Cu (0.1283) showed very weak positive correlation while Cr and

Table 4. Inter-elemental correlation analysis between the paired mean concentrations of the heavy metals

		Pb	As	Cr	Cd	Cu	Zn	Mn	Fe
Catfish and water	Pb	1.0000							
	As	0.6506	1.0000						
	Cr	0.9748	0.4649	1.0000					
	Cd	0 .9888	0.5301	0.9972	1.0000				
	Cu	0.6760	0.9994	0.4946	0.5585	1.0000			
	Zn	0.5993	0.9978	0.4056	0.4732	0.9950	1.0000		
	Mn	0.8175	0.0946	0.9254	0.8943	0.1283	0.0288	1.0000	
	Fe	0.8849	0.9295	0.7586	0.8054	0.9415	0.9032	0.4551	1.0000
Tilapia and water	Pb	1.0000							
	As	0.3304	1.0000						
	Cr	0.9964	0.4095	1.0000					
	Cd	0.9861	0.1689	0.9683	1.0000				
	Cu	0.3749	0.9989	0.4524	0.2156	1.0000			
	Zn	0.2573	0.9971	0.3386	0.0932	0.9923	1.0000		
	Mn	0.8852	-0.1466	0.8424	0.9502	-0.0994	-0.2217	1.0000	
	Fe	0.8122	0.8189	0.8590	0.7040	0.8453	0.7727	0.4477	1.0000

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Tilapia and catfish	Pb	1.0000							
	As	0.9761	1.0000						
	Cr	0.9569	0.9971	1.0000					
	Cd	0.9986	0.9634	0.9404	1.0000				
	Cu	0.9801	0.9998	0.9955	0.9683	1.0000			
	Zn	0.9873	0.9982	0.9909	0.9777	0.9992	1.0000		
	Mn	0.9889	0.9330	0.9031	0.9953	0.9397	0.9528	1.0000	
	Fe	0.9978	0.9885	0.9742	0.9929	0.9912	0.9957	0.9767	1.0000

Pb (0.9748), Cd and Pb (0.9888), Cu and As (0.9994), Zn and As (0.9978), Zn and Cu (0.9950), Fe and As (0.9295) and Mn and Cr (0.9254) showing extremely strong positive correlations respectively. Between the tilapia fish and its water habitat, Mn and Cu (-0.0994) showed extremely weak negative correlation, Mn and As (-0.1466) and Mn and Zn (-0.2217) showed very strong negative correlation while Cr and Pb (0.9964), Cd and Pb (0.9861), Cu and As (0.9989) as well as Zn and As (0.9971) recorded extremely strong positive correlation. Between catfish and tilapia, all the heavy metals recorded extremely strong positive correlations. The positive correlations between the heavy metals suggest that they may have common source of anthropogenic inputs intothe river water, and therefore their accumulation proceeds simultaneously while the negatively correlated metals suggest different sources of anthropogenic inputs and their accumulation depends on each metal's source of input.

Bio-accumulation factor

The results of the bio-accumulation factors of the heavy metals in the catfish(Fig. 5), revealed that Zn > As > Cu > Fe > Pb > Cd > Cr > Mn. Similar results in the tilapia fish (Fig. 6), showed an almost similar trend (Zn > As > Cu > Fe > Cr > Pb > Cd > Mn) except that Cr was higher than Pb, Cd and Mn. The bio-accumulation of heavy metals refers to an increase in the metals' concentration in an organism over time, compared to the concentration in the environment. This often occurs whenever heavy metals are taken up and stored faster than are broken down (metabolized) or excreted from the body of the organism. Fish are relatively situated at the top of the aquatic food chain and therefore, can accumulate heavy metals from food, water and sediments (Yilmaz et al., 2007; Zhao et al., 2012). However, the tendency of heavy metals to bio-accumulate in fish can be influenced by several factors such as the fish species, fish age and size, feeding behaviour, metabolic roles of metals and the ease of their excretion, as well as quality of the water ecosystem. In a similar study, Eneji et al. (2011), noted that the rate of bioaccumulation of heavy metals in organisms depends on the ability of organisms to digest the metals and the concentration of such metals in the river. According to these authors, bio-accumulation also has to do with the concentration of the heavy metals in the surrounding soil as well as the feeding habits of the fish species. These submissions are likely factors in the study area as the river is very prone to receiving residual heavy metals from agricultural lands along its bank.

Due to their non-degradability and environmental persistence, heavy metals are conservative pollutants and their bioaccumulations through the food chain imply that human beings are potentially affected. According to Shah and Altinda (2003), heavy metals may affect organisms directly or indirectly by transferring to the next tropic level of the food chain. Exposure to heavy metals is normally chronic (exposure over a longer period of time) due to

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food chain transfer (Moldoveanu, 2014). It was further submitted that acute (immediate) poisoning from heavy metals is through ingestion or dermal contact. The association of symptoms indicative of acute toxicity is not difficult to recognize because the symptoms are usually severe, rapid in onset, and associated with a known exposure or ingestion (Ferner, 2001). The International Occupational Safety and Health Information Centre reported that long-term exposure to heavy metals may result in slowly progressing physical, muscular, and neurological degenerative processes that mimic Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis. It was further indicated that allergies are not uncommon and repeated long-term contact with some metals or their compounds may even cause cancer.

A report by Singh et al. (2011), indicated that heavy metals disrupt metabolic functions in two ways: (1) They accumulate and thereby disrupt function in vital organs and glands such as the heart, brain, kidneys, bone, liver, etc. and (2) They displace the vital nutritional minerals from their original place, thereby, hindering their biological function. Because some of these heavy metals (Pb, As, Cd, Cr, Zn, Cu) have been associated with various human health effects, it becomes important to monitor their accumulations in human diets and take precautionary measures to limit excessive exposure to them.

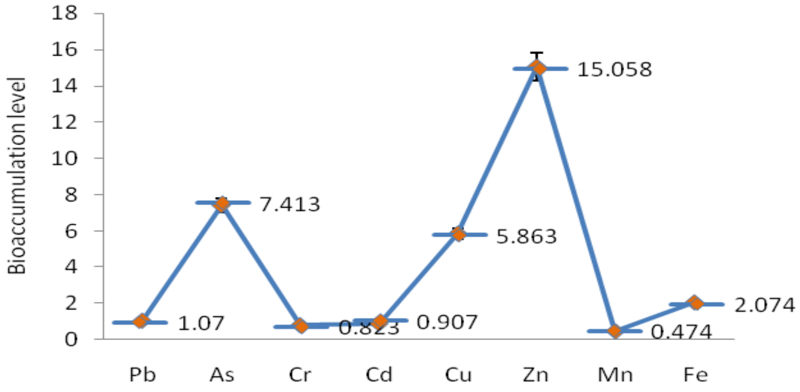

Figure 5. Bioaccumulator factors of the heavy metals in the catfish

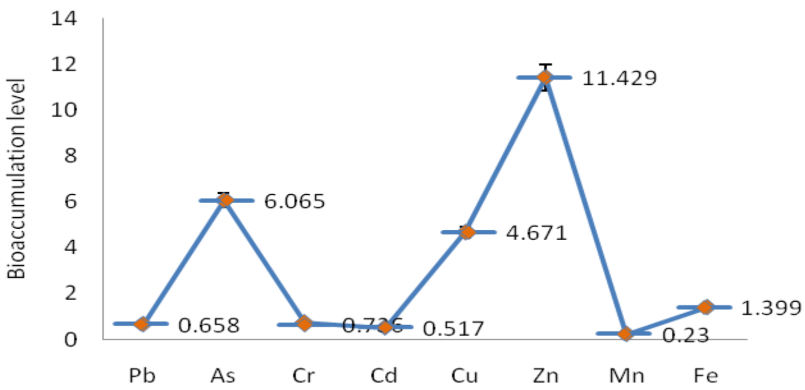

Figure 6. Bioaccumulator factors of the heavy metals in the tilapia

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IMPLICATION TO RESEARCH AND PRACTICE

There is currently high expansion of anthropogenic activities in the vicinity of Lisikili river in the Zambezi region, Namibia. Notable among them are the proliferation of wet season and dry season irrigation agriculture as well as rapid development of cottage and hospitality industries along the river. Thus, the river will continue to receive contaminants-laden surface run-off from the agricultural lands and complex effluent discharges from the cottage and hospitality industries. These may post significant pollution threat to the river in the short to long term run. Because the Lisikili river serves diverse economic purposes in the host region, the afore-mentioned scenario create the need for periodic research in order to monitor the impact of the various anthropogenic activities on the quality of Lisikili river and limit unintended human exposure to anthropogenic pollutants.

CONCLUSION

The results obtained in this study showed wide mean concentrations of the heavy metals in the Lisikili river water with iron (Fe) and arsenic (As) recording the highest and lowest levels respectively. Apart from zinc (Zn) and copper (Cu) with the present concentrations lower than their guideline permissible limits, the mean concentrations of the other heavy metals exceeded their maximum permissible guideline values for the protection of human and aquatic health. Based on the classification of metal pollution index for water, it was found that apart from Cu and Zn, all the other heavy metals recorded pollution indices which suggest moderate to strong effect on the river water quality. In both the catfish and tilapia fish (whole sample wet weight basis), Fe recorded the highest mean concentration while Cd recorded the lowest level. The Results of t-test analysis between mean concentrations of the heavy metals in the two fish were statistically significant ($p < 0.01$) except Cr levels. This may be due to differences in the physiological and biochemical functions, including metals storage and elimination from the body by the individual fish. Generally, the present levels of the fish's heavy metals were below their regulatory limits for the protection of human health. However, the results of bio-accumulation factors of the metals by the fish suggest that they have high potentials to bio-accumulate some of the heavy metals to high levels and this has adverse implication for human consumption. Because heavy metals are non-biodegradable and are bio-accumulative in nature which therefore, make their presence in human foods even at very minute levels potential toxins, it is important to monitor their accumulations in the Lisikili river water and fish and advice precautionary measures to limit excessive human exposures to the heavy metals content.

FUTURE RESEARCH

Future research on Lisikili river should identify the respective impact of the increasing anthropogenic activities on the overall quality of the river water for human consumption, aquatic health and irrigation agriculture and advice precautionary measures to enhance healthy and sustainable use of the water resources.

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