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RESEARCH ARTICLE

Assessment of Heavy Metal Pollution in the White Nile River in the Sudan

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Abstract

This study was carried out to investigate the level of heavy metal pollution of the White Nile River in Sudan. Three locations were selected to represent high, medium and low pollution-risk areas. Location 1, in the river port town of Kosti, represented a high pollution locality. Location 2 at Elfeteihap, near an industrial area in the capital city, Khartoum, was a medium pollution-risk area. Location 3, at the Elshagara research station south of Khartoum, represented areas considered to be at lowest risk of heavy metal pollution. At each location, concentrations of the heavy metals copper (Cu), cobalt (Co), lead (Pb), cadmium (Cd) and nickel (Ni) were measured in water and sediment samples as well as in the flesh of a bioindicator fish, the Nile Tilapia (*Oreochromis niloticus*), using atomic absorption spectroscopy.
Fish sediment and water samples collected from Location 1 showed the highest level of contamination with heavy metals. Accumulation of heavy metal contaminants in fish samples from this area was clearly associated with their concentration in sediment and water. The high levels contamination was attributable to oil spills and other activities at the river port. Because the concentrations of heavy metal contaminants were found to be less than the permissible values recommended by the FAO/WHO reports, it is concluded that water and fish from the sampled areas of the White Nile are safe for human consumption. However, due to the accumulative nature of these contaminants and the likely future increase in contaminant discharge into the river, continued monitoring is highly recommended.

INTRODUCTION

Freshwater ecosystems support human life in numerous ways; on top of being a source of drinking water, rivers provide water for irrigation, industry, transport and many other aspects of food production and processing. Pollution of the aquatic environment by inorganic chemicals and heavy metals is a major threat to human health and to aquatic organisms (Samir and Ibrahim 2008). Heavy metals pollution in aquatic ecosystem is growing at an alarming rate and has become an important worldwide problem (Malik *et al*., 2010). According to the World Health Organization reports, about 5 million people die every year from drinking polluted water (WHO, 2009). Anthropogenic activities represent the major contributor to the contamination of aquatic environments. Drainage water containing pesticides and fertilizers, effluents of industrial activities, and sewage effluents contaminate water bodies and sediments with huge quantities of heavy metals. Heavy metal contamination is particularly significant in ecotoxicology since these metals are highly persistent and can bioaccumulate and biomagnify in the food chain, thus becoming toxic to living organisms at higher trophic levels (Storelli *et al.* 2005).

On the other hand, heavy metals are natural elements that occur in the earth crust. Some of these metals are necessary for human health and metabolic activities in trace amounts (Abdulla, 1990, Haward, 2002 and Smith, 2007).While, others, such as mercury, cadmium, lead and chromium, are toxic even in low concentrations. Trace metals derived from natural inputs and anthropogenic emissions are ubiquitous in the global environment (Milenkovic *et al*., 2005). Since heavy metals cannot be degraded, they are deposited, assimilated or incorporated in water, sediment and aquatic animals (Linnik and Zubenko 2000) and thus, causing heavy metal pollution in water bodies (Malik *et al*., 2010). Therefore, metals that are deposited in aquatic environment accumulate in the food chain and pose a threat to human health due to biomagnifications over time (Yilmaz and Yllmaz 2007; Agah *et al*., 2009).

Aquatic organisms have been widely used in biological monitoring and assessment of safety levels of heavy metals in the environment (Tiina *et al*., 2006). They have been reported to accumulate heavy metals in their tissues several times above ambient levels (Canli and Atli, 2003). Fish are often used as indicators of heavy metals contamination in the aquatic ecosystem because they occupy high trophic levels and are an important food source (Blasco *et al*., 1998 and Agah *et al*., 2009).

The aim of this study is to investigate heavy metal (Cd, Pb, Cu, Ni and Co) pollution at different localities along the White Nile River (Sudan), and their adverse effects on Nile tilapia *(Oreochromis niloticus*) as indicators of heavy metals contamination in aquatic ecosystem

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Materials and Methods:

Study Area: This study was conducted in three locations (1, 2 and 3) along the White Nile River. Location (1), the city of Kosti, serves as a river port, where oil spills and other waste materials reach the water. Location (2) is to the North of Khartoum industrial area, where it receives waste materials of iron and steel from the Khartoum Central Foundry and other factories as well. The 3^{rd} location was chosen to represent a remote contaminant free area and therefore was considered a control sampling site.

Sample Collection: Five water samples of 5ml each were collected from each location. Five sediment samples of 10g were collected from each location. Together with 30 Tilapia specimens (*Orechromis niloticus*) were collected from each location. Collections were carried out by fishermen using a net that ensures comparability of fish size (weight), during the period from July to October 2010.

Muscle samples for mineral analysis: Muscle samples weighting 5g approximately were cut from each fish specimen. The samples were taken from two sites under and above the lateral line of one side of the body. Each muscle sample was weighed and placed in Petri dish, covered in plastic wrap and stored at 0˚C until used for analysis.

To perform mineral analysis, muscle samples were dried in an electric oven at 105˚C for at least 9 hours or until a constant weight was reached. The dry samples were grounded manually using a porcelain mortar. All the tools used for skinning, sampling and drying were made of stainless steel and were thoroughly cleaned to avoid contamination with metal residues as well as cross-contamination between samples. Powder samples were then kept in air tight plastic bags until they were used for mineral analysis.

Heavy Metals Determination: Flesh samples were prepared as described in AOAC(2000) and used for the determination of Cu, Pb, Ni, and Cd. Atomic Absorption Spectrometer (A.A.S Varian 220) was used to detect heavy metals. The detection limit of A.A.S. was 228.8 nm for Cd, 324.7 nm for Cu, 231.0 nm for Ni and 217.0nm for Pb.

Statistical Analysis: Results were presented as means ± the standard deviation. Analysis of variance (ANOVA) was conducted using the Statistical Packages of Social Science (SPSS). Significance was determined at $p < 0.05$.

Results:

The results of the heavy metals in water, sediment and fish flesh samples from the study sites are shown in figure (1) and table (1) respectively. Cadmium and lead were not detected in water sample from location 3. In sediment samples, cadmium and lead were not detected in location (3). Sediment samples collected from location (1) showed the highest concentration of heavy metals compared to location (2) and (3). Significantly high concentration of cobalt was reported in location (1) as shown in table (1).

Flesh samples of tilapia collected from the different sites showed significant variation in heavy metals concentration as shown in figure (1). Concentrations of Pb (0.083ppm) and Cu (0.045ppm) were found to be significantly high in flesh samples collected from locations 1. Concentration of Pb (0.064ppm) was found to be non-significantly high in flesh sample collected from locations 3. The concentration of Cd (0.057-0.067ppm), Ni (0.031-0.055ppm) and Co (0.021-0.031ppm) did not show significant variation in the flesh samples collected from the three locations.

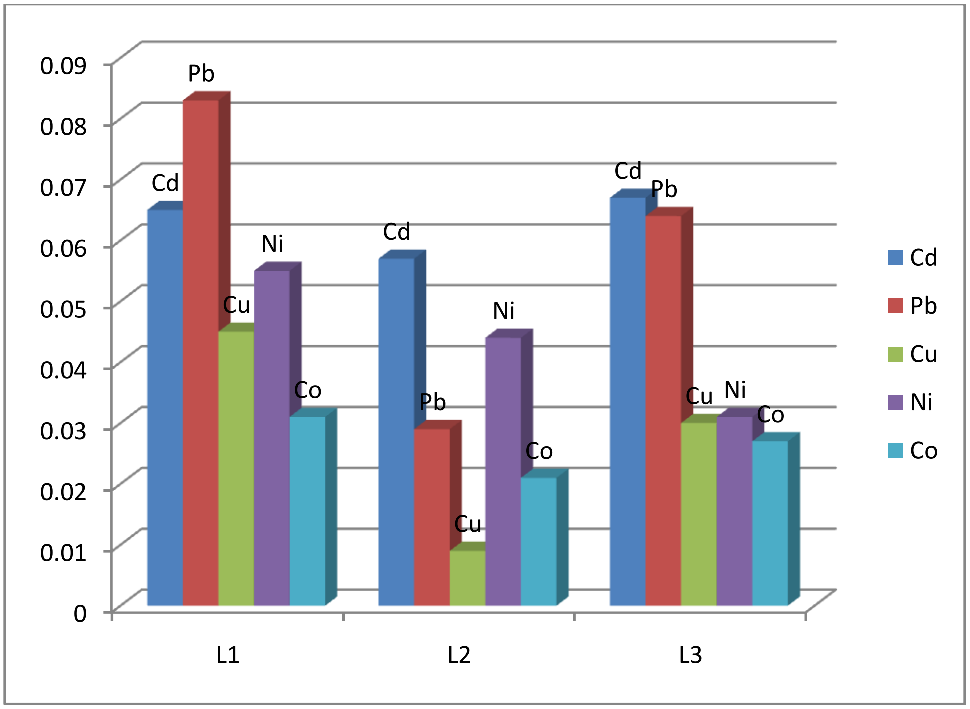

Fig 1: Heavy metals concentration of muscle samples collected from the three locations (1, 2 and 3)

	Water Samples			Sediment Samples			Flesh Samples		
Heavy metals	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3
Cadmium	0.003 ± 0.0001	0.003 ±0.0022	Not detected	0.005 ± 0.000	Not detected	Not detected	0.065 ± 0.031	0.057 ± 0.010	0.067 ± 0.036
Lead	0.409 ± 0.2836*	0.160 ±0.0421	Not detected	0.005 ± 0.230*	0.003 ± 0.321	Not detected	0.083 ± 0.035*	0.029 ± 0.005	0.064 ± 0.042
Copper	11.826 ± 2.836*	0.006 ± 0.0083	0.001 ± 0.0001	0.003 ± 0.002	0.001 ± 0.004	0.0001 ± 0.000	0.045 ± 0.033*	0.009 ± 0.003	0.030 ± 0.016
Nickel	3.035 ± 0.631*	0.002 ± 0.0006	0.001 ± 0.0003	0.030 ± 0.002	0.002 ± 0.005	0.0021 ± 0.000	0.055 ± 0.029	0.044 ± 0.022	0.031 ± 0.024
Cobalt	0.0103 ± 0.004	0.133 ± 0.0049	0.002 ± 0.0001	0.116 ± 0.003*	0.008 ± 0.001	0.001 ± 0.000	0.031 ± 0.018	0.021 ± 0.014	0.027 ± 0.014

(*) = significant values ($P < 0.05$)

Table 1: Concentration (mean± standard deviation) in ppm of heavy metals in water, sediment and flesh samples collected from the three locations (1, 2, and 3)

Discussion:

The present study revealed that copper, nickel and lead concentrations in water samples collected from location 1 were significantly higher, while location 2 reported high levels of cobalt in water samples. Higher concentrations of lead and cadmium were reported in water collected from the Blue Nile and the White Nile in the study carried out in Sudan by Ahmed *et al.* (2010). Lower concentrations of lead and copper were reported in water of Lake Manzala, Egypt (Bahnasawy *et al.*, 2011). These variations in heavy metals may be attributed to the different anthropogenic activities that supply the water bodies. The higher concentration of lead may be due to the use of leaded gasoline (Yacoub and Gad 2012).). However, despite the various anthropogenic activities the values reported for heavy metals concentrations in water did not exceed the guideline limits of FAO/WHO (2011).

On the other hand, the concentration of heavy metals in sediment samples collected from the study areas showed significant variation. Values reported for heavy metals concentrations in sediment samples were the least compared to those of water and flesh samples. The highest concentration of heavy metals was also reported in sediment samples collected from location (1). This finfing is compatible with the result obtained for water samples concentration of heavy metals of the same location in the present study. Sediment polluted with heavy metals can be considered as a potential source of pollutants in the long run, which afflict water and aquatic organisms. Similar findings were reported by Fernandes *et al*., (2007) who stated that heavy metal contamination in sediment can affect the water quality and bioaccumulation of metals in aquatic organisms, resulting in potential long-term implication on human health and ecosystem.

The concentration of heavy metals in flesh samples collected from location (1) is closely associated with the heavy metals concentration in water samples collected from the same location. Concentration of heavy metals in flesh samples collected from location (1) and (3) did not show significant variations. The least values of heavy metal concentrations were reported in flesh samples collected from location (2). Heavy metal accumulation in flesh samples was highest compared to water and sediment samples of the present study. These findings were in accordance with the results obtained by Yacoub and Gad (2012). Higher concentration of copper and lead were reported in flesh samples of Nile tilapia collected from River Nile, Egypt (Yacoub and Gad 2012). Copper and lead were found to be high in flesh samples of some fish species obtained from Northern Jordan Valley, Jordan (Al-Weher 2008). The concentration of heavy metals in fish muscle reflected their availability in the surrounding environment. Biomarkers for water pollution are early diagnostic tools for biological effect measurement and environmental quality assessment (Cajaraville *et al*., 2000). Heavy metals access fish organs through respiration and dietary routes, while dermal route contributes the minimum due to its role as effective barrier (Fernandes et al., 2007).Fortunately, muscles the most edible part of the fish accumulates the least amount of heavy metals compared to other organs (Yacoub and Gad 2012). In this study heavy metals concentration in flesh samples were below the limits of FAO/WHO (2011). Similar results were reported by Akan *et al*., (2012) in flesh samples collected from River Benue, Nigeria.

Conculotion:

Heavy metals concentration in water samples, sediment and tilapia flesh was estimated in samples collected from three locations along the White Nile River. All samples showed concentrations within the acceptable limit stated by FAO/WHO (2011). Therefore, human consumption of fish and water collected from the White Nile is considered to be safe. However, regular monitoring of water, sediments and fish flesh contamination with heavy metals is highly recommended.

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