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The Lukanga Swamps: A Supposed Sediment Trap for Heavy Metals from Zambia's Copperbelt Mines

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Abstract. Lukanga swamps, the fifth largest wetlands in Zambia were thought of being a sediment trap for the heavy metals from the Copperbelt mines. This study thus set out to ascertain this assertion by looking at various literature, testing water and soil samples collected from carefully selected sites in the study area and analysing them for presence of heavy metals. The water and soil samples were analysed using Atomic Absorption Spectrophotometer method for heavy metals and pH meter for conductivity. The results showed that the heavy metals were below the detection levels signifying the fact that no heavy metals were present in samples. It was also found that the Kafue River did not directly pass through the Lukanga swamps but that the waters of the river and swamps only interacted when there is flooding (the river overflowing). As such the swamps could not be said to trap sediments from water that does not pass through it. In addition other studies had shown that there was attenuation away from the source of the heavy metals.

Keywords: Lukanga swamps, Kafue River, sediment trap, heavy metals

I. INTRODUCTION

Wetlands are some of the most endangered ecosystems on the planet, yet they provide some ecosystem services such as ground water recharge and discharge, flood control, water quality alteration, sediment trapping, waste water treatment, detoxification, nutrient retention, food chain support and water transport (Kachali, 2008; Chabwera, 1998). They act as filters for the contaminated water carried by rivers which pass water through them.

In Zambia, the Kafue river which passes through almost all mining towns on Copperbelt, is said to carry along heavy metals from the tailings dam discharges and rainfall runoff from mining operations. These heavy metals were then said to be trapped by the Lukanga swamps downstream of the Kafue River away from the mines.

This study thus determines whether the Lukanga swamps is a sediment trap for heavy metals carried by the Kafue River from the Copperbelt mines. In so doing water and soil samples from the study area were analyzed. Laboratory tests of the water and soil samples were carried out by the School of Mines Geochemical Analytical Laboratory at the University of Zambia using the Atomic Absorption Spectrophotometer (AAS).

II. SEDIMENT TRAPPING

A sediment trap is generally an impoundment 'basin' or depression on a watercourse which allows sediments to settle out and accumulate permitting their removal (WCD, 2009; USEPA, 1993). Sediment traps detain sediments in storm water runoff, rivers or such other structures to protect other receiving drainage systems. Sediment traps may be constructed but may also be a natural topographic depression where sediments get trapped. Swamps or wetlands are one such natural topographic feature. Wetlands improve downstream water quality by trapping suspended sediments from adjacent water ways or water ways that flow directly into or through them (Kidd et al, 2015, Choongo et al, 2005). Wetlands are function as kidneys of the landscape. The primary characteristic that causes sediment accumulation in wetlands is landscape position.

Thus the Lukanga swamps, located in central Zambia downstream of the Kafue River after it leaves the copper mining areas of the Copperbelt, have been cited by many as a sediment trap for the heavy metals mined on the Copperbelt and transported by the Kafue River (Chabwera et al, 2017; Ikenaka et al, 2010; Nakayama et al, 2010; Choongo et al, 2005). In the Lukanga swamps the swamp vegetation, dominated by reeds (phragmites and Typha) (Chabwera et al, 2017; Ramsar, 2005), act as filters and sinks for suspended particles as they also reduce the flow velocities by their canopy within the swamp (Gacia et al, 1999).

Therefore if there were to be found any trapped heavy metals, they were to be found either in water or soils from the study area. In addition a review of various other researches done by others on heavy metal contamination relating to the Kafue River was carried out.

III. THE KAFUE RIVER AND METAL CONTAMINATION

The Kafue River, the most central of Zambia's rivers, meanders through almost all the mining towns on the Copperbelt where it obviously picks up heavy metal contaminants, either by flowing through mineral rich soils or by picking up discharge and runoff from the mining activities.

Various studies in this regard have been carried out before. Simukanga et al (2002) investigated the impacts of mining effluents on the water quality, sediments, soils and crops in the Mwambashi Catchment area of the Copperbelt. They found that mining activities had negatively affected the water quality along the Mwambashi River and its tributaries in both the dry and wet seasons and argued that the mining effluents influenced the heavy metal concentration in crops in the area. Mwambashi River contributes presumable contaminated water to the Kafue River.

Pettersson (2002) when looking at mining in the Kafue river basin and its effect on water quality stated that at Machiya ferry (upstream of Lukanga swamps) dissolved trace metals had decreased to background levels but reported high copper concentrations of 0.45% in the sediments. After Kafue Hook no mining effects were reported.

In 2004, von der Hyden and New looked at ground water pollution on the Copperbelt which strongly suggested an upslope tailings impoundment as the source of contaminants with the edge of the pollution plume lying 500 - 700m downstream of the impoundment and that the processes of attenuation were removing harmful metals from the aquifer.

In 2005, Choongo et al looked at copper levels in fish and sediments from the Kafue River where they found that copper levels in water were below the detection limit during both dry and rainy seasons for all sites from Chimfunshi in Chililabombwe to Kafue Bridge in Kafue. They however found high concentration of copper in sediments within the copper mining areas and less away from the mining areas. The concentrations in sediments were also higher in dry season than in rainy season. They thus concluded that this was due to increased dilution effect and the high water current which dispersed copper containing particles further downstream beyond the study area. In addition they speculated that the lower copper levels in sediments at sites downstream to the mining area could have been a result of sediment trapping effect by the Lukanga swamps and the Itezh-itezhi.

Similarly, Tembo et al (2006) investigated the distribution of copper, cadmium, lead and zinc concentrations in soils around Kabwe. They found that the dispersal in soils containing lead, cadmium, copper and zinc extended over a 20 km radius from the mine at levels much higher than those recommended by the World Health Organization (WHO) in form of dust and as contamination in soils and sediments. But also found that metal concentrations decreased with distance away from the mines, the source of the contamination.

In 2010 Ikenaka et al studied heavy metal contamination of soils and sediments in Zambia and found that the major sources of heavy metals are the mining areas, Kabwe and the Copperbelt where the heavy metals are then transported within each area by rivers. They also found that even sediments in Kafue National Park were contaminated with high concentrations of copper and moderate levels of lead, though in areas geographically distant from the mines the heavy metal concentrations were moderate or low. They also found that Kabwe was highly polluted by lead, zinc, copper, cadmium and arsenic while the Copperbelt was highly polluted by copper and cobalt. High concentrations of Copper were also found in the aquatic environment in the Copperbelt and as far as Lake Itezh-itezhi 450 km downstream on the Kafue River well past the Lukanga swamps.

In 2013, Kapungwe looked at heavy metal contamination of soils, water and crops from using wastewater for irrigation in Mufulira and Kafue towns. The study revealed heavy metal contamination of wastewater, soils and crops at the two study sites attributed to mining in Mufulira and industrial activities in Kafue. This meant that the contamination at Kafue was not as a result of effluent from the mines at all.

Nachiyunde et al (2013) assessed dissolved heavy metal pollution in water in Zambia and found no apparent serious problems, involving all heavy metals, which could be considered as being beyond remediation. They further found that heavy metal pollution problems were to a large extent confined to the mining towns. They also found that pollution due to dissolved Copper was insignificant even from the effluent water discharged by the mines in Mufulira and Chingola towns.

IV. WATER AND SOIL SAMPLING

In this study, water samples were collected from three sites twice over a period of about a year. The first samples were collected in November 2012 and the second in November 2013 using plastic bottles. Soil samples were collected from five sites in November 2017. Soil samples were collected on at least two locations per site which were at least five metres apart, mostly in water and away from water. The soil samples were delivered to the laboratory after drying and taking away grass and root material (vegetation debri). The areas sampled are depicted in Table 1 and Figure 1 and were as follows:

a) At Munwinu (M1) where the Munwinu channel leaves the Kafue River.
b) At Mukumbang'ombe (M2) where the Munwinu channel enters the Lukanga swamps. No water sample was taken due to logistical problems.

c) At Mukunkwa (M3) where the Lukanga (Mukunkwa) channels leaves the swamp towards the Kafue River.

d) At Mongo (M4) where the Lukanga (Mukunkwa) channel joins the Kafue River.

e) At Nkala (N5) where the crossing of the Lukanga Channel to M1 was done.

Table 1: Water sample points

			Water		Soil Sediments
	Area sampled	Site ID	Nov 2012	Nov 2013	Nov 2017
1	Munwino	M1	✓	✓	✓
2	Mukumbang'ombe	M2	Not sampled		✓
3	Mukunkwa	M3	✓	✓	✓
4	Moongo	M4	✓	✓	✓
5	Nkala	N5	Not sampled		✓

These sampling points were chosen because they are either the entry or exit points of water from the Kafue River to the swamps. Metal presence was therefore expected to show in these areas.

V. LABORATORY TESTING OF THE SAMPLES

The samples were analysed at the Geochemical Analytical Laboratory of the School of Mines at the University of Zambia using the Atomic Absorption Spectrophotometer method and pH meter for conductivity. The samples were analysed for arsenic, cadmium, chromium, copper, iron, mercury, nickel, and conductivity. The results of the laboratory tests are presented in Tables 2 and 3.

It can be seen from the results that arsenic, cadmium, chromium, copper, mercury and nickel could not be detected in the water samples taken from the three sites. This discounts the presence of any of these metals in the water samples and resonates well with the findings of Nachiyunde et al (2013) who found that no apparent serious problems involving all heavy metals and that dissolved copper was insignificant even in effluent water discharged by the mines in Mufulira and Chingola towns.

This finding is also supported by Choongo et al (2005) who found that copper levels in water were below detection levels even within the mining areas (Ikenaka et al, 2010, Mwase et al, 1998).

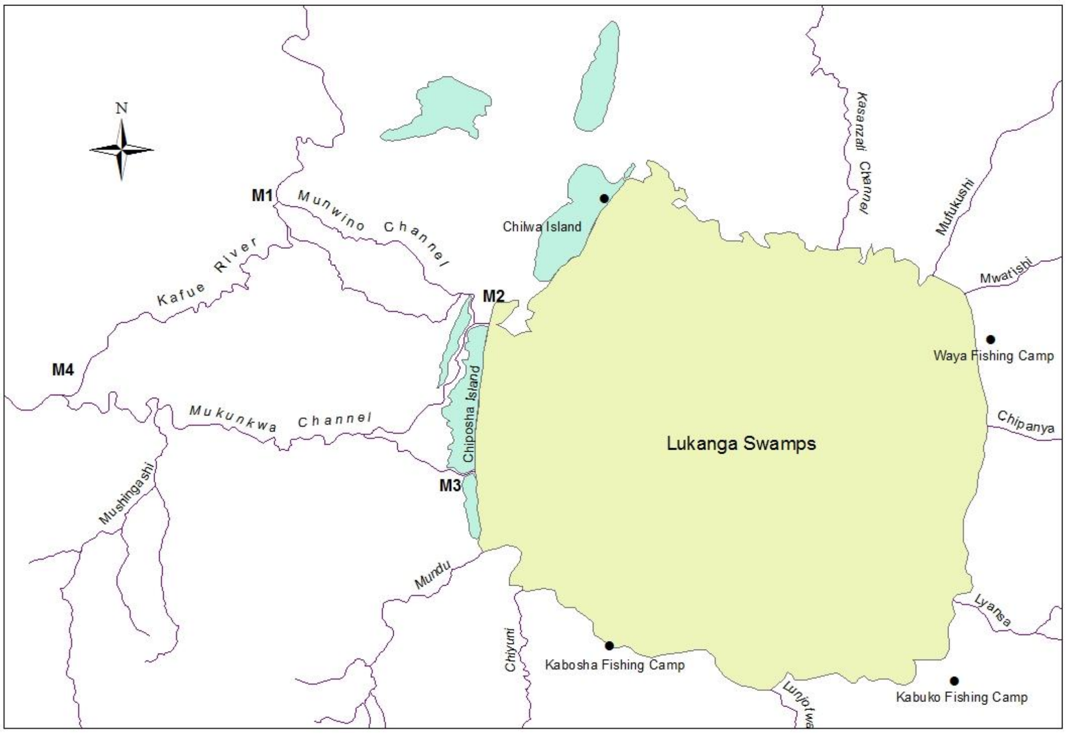

Figure 1: Lukanga Swamps and its water channels showing sample sites

Choongo et al (2005) also found reduced levels of copper in sediments away from the mining areas. Sediments from the Lukanga swamps were not sampled and tested, but from the forgoing it can be said that the Lukanga swamps do not trap heavy metal sediments from the Copperbelt mines. This is because the further away from the heavy metal source, dilution and oxidation of the dissolved heavy metals takes place thereby significantly reducing their amounts as the water reaches the Kafue river - Lukanga swamps area.

Although the Kafue river and its contaminated tributaries in the Copperbelt is highly enriched with copper, cobalt and manganese, these metals normally bind to extractable/ carbonate, reducible and oxidizable fractions other than in the residual fractions to which Iron is bound predominantly (Sracek et al, 2011). Therefore copper and cobalt are normally found in suspensions which settle in both the tributaries and the Kafue River and are attenuated efficiently.

It could therefore be said that the environmental impact of mining and related activities on the Kafue River is relatively limited due to a high neutralizing capacity of the mining wastes which control the rapid precipitation of iron oxides and hydroxides as well as adsorption and/or co-precipitation of copper, and cobalt which settle in the river and could only pose a potential environmental risk when significant fractions of metals in sediments are re-mobilized in case of accidental acid spikes (Sracek et al 2011).

Table 2: Results of the water samples

			November 2012 Samples			November 2013 Samples		
	Tested for	Units	M1	M3	M4	M1	M3	M4
1	Arsenic	mg/l	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
2	Cadmium	mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
3	Chromium	mg/l	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
4	Copper	mg/l	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
5	Iron	mg/l	0.013	0.014	0.035	<0.006	<0.006	<0.006
6	Mercury	mg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
7	Nickel	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
8	Conductivity	µS/cm	460	200	270	90	80	110

Table 3: Results of the soil sediment samples

			M1 (Munwinu)		**M2 (Mukumbang'ombe)**		**M3 (Mukunkwa)**		**M4 (Mongo)**			**N5 (Nkala)**	
	Tested for	**Units**	**M1a**	**M1b**	**M2a**	**M2b**	**M3a**	**M3b**	**M4a**	**M4b**	**M4c**	**N5a**	**N5b**
1	Arsenic	mg/kg	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
2	Cadmium	mg/kg	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
3	Chromium	mg/kg	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
4	Copper	mg/kg	<0.003	<0.003	<0.003	<0.003	742.43	689.11	<0.003	<0.003	<0.003	<0.003	<0.003
5	Iron	mg/kg	4148.78	4587.54	811.81	686.66	6348.47	7090.47	6357.25	3044.14	2737.09	8034.03	7829.00
6	Iron	%	0.42	0.46	0.08	0.07	0.63	0.71	0.64	0 .30	0 .27	0.80	0.78
7	Mercury	mg /kg	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
8	Nickel	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

VI. RESULTS ANALYSIS

The results of November 2012 show some presence of iron in the water samples from all the three sampling sites but in November 2013 the iron was below the detection level and even more Iron was detected in soil samples. Iron is one of the most naturally occurring metals at 5.4% compared to copper at 0.005%. It is only second to Aluminium at 8.1% (Krauskopf, 1979). The human health consideration of 0.3mg/l is based on taste and odour as iron is not considered dangerous to human health (DEQ, 2010, SASKH_2O, 2007). Therefore the highest value of iron of 0.035mg/l sampled at Moongo and less for the other two sites represents some naturally dissolved iron at the site. A little more Iron was detected in soil samples for the same reason that Iron is bound to be naturally occurring in the area and this did not indicate that which should have been transported by the river from the mines.

However, the presence of copper in the soil samples from the Mukunkwa site is significant. This could mean that there is a possible anomaly in the area. Or the area could have had copper related activities in time past that could have left this contamination. This also could not be attributed to that which should have been transported from the mines since its supposed transport route showed no such occurrence at all.

The conductivity of the sampled water was between 80µS/cm and 460µS/cm over the 12 months period but with higher values recorded in November 2012 (200 – 460µS/cm). This conductivity falls within the normal range for most fresh water rivers supporting good mixed fisheries (150 – 500µS/cm) (EPA, 2012). In November 2013 the values were lower (80 – 110µS/cm). These values support the finding that there were no significant Total Dissolved Solids (TDSs) in the water. Hence no heavy metals present in the sampled water.

VII. DISCUSSION

The Lukanga swamps have been cited by many as a sediment trap for the heavy metals mined on the Copperbelt and transported by the Kafue River (Choongo et al, 2005; Ikenaka et al, 2010; Nakayama et al, 2010). Its vegetation, dominated by reeds (phragmites and Typha) (Ramsar, 2005), act as filters and sinks for suspended particles as they also reduce the flow velocities by their canopy within the swamp (Gacia et al, 1999). But for this function of sediment trapping to be performed water from the river must pass through the swamp and exit back into the river presumably cleaner than it was before entering the swamp.

The Kafue River does not pass through the Lukanga swamps per se (see Figure 1) although it may be considered so at maximum flooding when the swamp and the river water become connected (see Figure 2). However, at all other times the river is separated by a land mass of about 22km wide on the Munwinu channel side and about 38km wide on the Lukanga (Mukunkwa) channel side. Water from the river would then seemingly be expected to flow through the Munwinu and Mukunkwa channels into the swamp only during high water levels (floods) and exit through the Mukunkwa channel during low water levels in the river.

The water that flows into the swamp from the river is thus little compared to the total water carried by the river as the overflow only happens when the river bursts its banks which is not always the case. It would therefore support the notion that since the Kafue River does not directly pass through the Lukanga swamp, and that in turn the water from the Kafue River does not always flow through the swamp, the Lukanga swamp would thus not be a sediment trap for the Kafue River.

The results of this study are therefore consistent with the findings of Nachiyunde et al (2013), Choongo et al (2005), Ikenaka et al (2010) and Mwase et al (1998) who found that there was either dilution away from the mining areas or that there was sedimentation of the heavy metals not far away from the mining areas.

VIII. CONCLUSION

In as much as the Lukanga swamp could be seen as being part of the Kafue River, especially when the maximum flood boundary of the swamp is considered, the Kafue River does not directly pass through the swamp. The Lukanga swamp would therefore not perform the sediment trapping task for any sediments that may be carried by the Kafue River, except during maximum flooding.

In addition, water and soil samples from the study area show that there are no heavy metals present in the swamp and the river. The Lukanga swamps are therefore not a sediment trap for the Kafue River for it does not directly pass through the swamp. It is also concluded that the Kafue River does not transport the heavy metal sediments as far as the Lukanga swamps.

The Lukanga swamps are therefore not a sediment trap for the Kafue River because the river does not pass through the swamps proper and that the heavy metals are not carried as far as the Lukanga swamps by the river since attenuation takes place along the way.

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