HEAVY METALS PRESENCE IN MUFULIRA RIVER ON THE COPPER BELT PROVINCE OF ZAMBIA, A CASE STUDY

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ABSTRACT

Heavy metals are elements that can be toxic to human health when consumed in large quantities, some even in trace elements such as Cadmium and Arsenic, and these can be introduced into the water through the spilling of mining effluents or damping garbage and other metal-containing materials into natural water bodies (anthropogenic source) or by leachates (natural source) and thereby causing pollution. The Mufulira River receives mining effluents on a daily basis which are carried over along the river to places where people do agriculture, fishing, and domestic activities. This study was carried out in order to investigate the possible presence and concentrations of the elements Cu, Cd, As, Fe, Mn, and Pb in the water that may have been introduced into the river by AAS. The elements Cu, Cd, As, and Pb were undetected (Below detection limit BDL) during the analysis while Mn (**0.069-0.186 ppm)** and Fe **(0.087-0.193 ppm)** were detected.

Keywords: Mining effluents, heavy metals, toxic, human health, pollution, poisoning, Mufulira River.

INTRODUCTION

The term pollution in its broad sense refers to any undesirable change in the natural quality of the environment brought about by physical, chemical, or biological factors [1]. Armal and Ramteke, 2015, defined it as a man-made alteration to the quality of life which developing countries where the capacity and resources to treat polluted water are almost zero [2]. Hence, the minimization of pollution may be considered the most viable solution. In Zambia, pollution has in recent years become one of the major challenges affecting the quality of water due to the loading of wastes from agriculture, industries, and domestic activities into the water systems. Yet there has been limited analysis of the quality of water especially in high mining townships. With the increasing population resulting in increased agricultural, mining activities, and urbanization, pollution is likely to emerge as the major drawback of sustainable production in natural water bodies [3,4].
To better manage water pollution, it is important to employ accurate monitoring and assessment procedures. Heavy metals are among the major environmental pollutants resulting from both natural and anthropogenic activities. However, the increased accumulation of heavy metals in the environment is often caused by anthropogenic activities, such as mining and smelting, industrial activities, agrochemicals, atmospheric deposition, and natural denudation of bedrock and ore deposits [6-11]. This has not only raised environmental issues but also public health concerns. In aquatic ecosystems, rapid urbanization coupled with heavy industrialization has been recognized as the major driver of heavy metal accumulation [9, 10, 12-14]. This is worsened when industries release effluents that could contain heavy metals above permissive levels into rivers, streams, or lakes [7, 10-11, 16-17]. Rivers and lakes are the most important capture fishery areas as well as an important source of water for aquaculture activities in Zambia. Despite not being classified as a fishery, the Mufulira river is an important source of livelihood, particularly through fishing for the local community in the district. It is also a source of water used in agriculture and drinking. The river is located in the Mufulira district of Copperbelt Province of Zambia which is a major mining area in the country. Close to this river is a major copper and gold mining company whose effluents directly or indirectly enter this river. This presents a potential health risk to the communities that consume the water and fish from this river. These toxicants if they go beyond the threshold, they can affect the health of humans [19-24]. Despite Mufulira River supporting a good number of people with drinking water, fish, and water for irrigation and the presence of mining companies nearby, the levels of heavy metals contamination in the surface water are not well known. Therefore, the present study is aimed at

assessing the levels of heavy metal (Cu, Fe, Mn, Pb, Cd, and Zn) contamination in surface water and of Mufulira River in Copperbelt province in the Mufulira district. Studies have been done in various parts of Zambia and heavy metals found in soil, fish or water bodies, but none has been done yet in Mufulira river on water and fish caught in the river [21-24]. Mufulira district is located in the copper province of Zambia as shown in the diagram below.

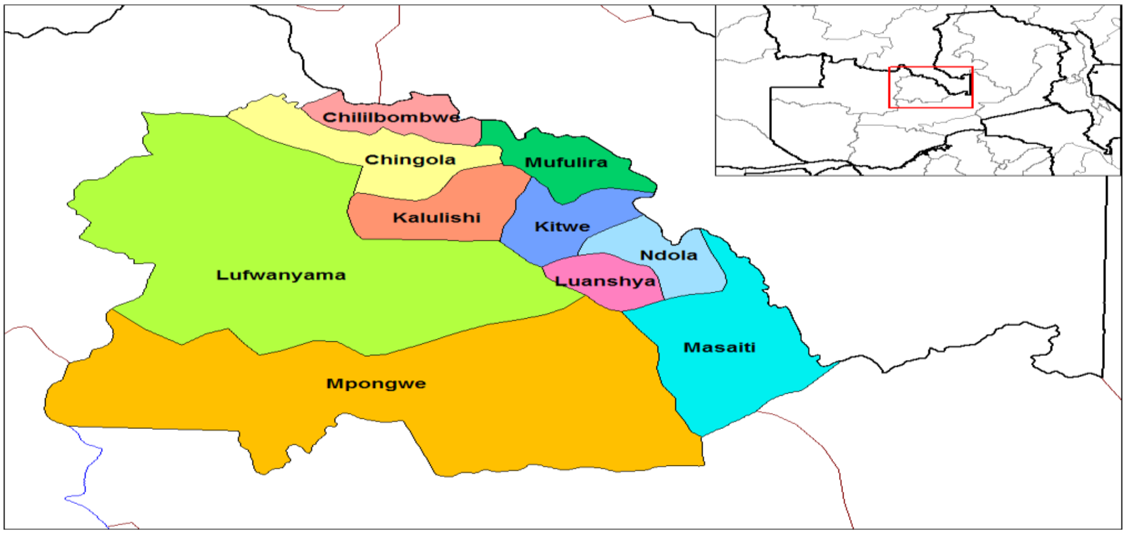

Fig 1: Map showing the location of the study area on the Copperbelt Province

(12°33'27.1" **S,** 28°16'12.7" **E**)

MATERIALS AND METHODS

Nitric acid from Merck

Deionized water from Perkin Elmer

Water sampling and analysis

Good quality Surface water samples were collected randomly in triplicates from three different and sufficiently distant points identified as BMTD (**Before Mufulira Tailings Dam**) Sampling Point 1 **(**12°33'12.5" **S**, 28°11'7.4" **E**), AMTD (**After Mufulira Tailings Dam**) Sampling Point 2 **(**12°33'33.1" **S,** 28°11'14.6" **E)** and CF (**Concrete Farrow**) Sampling Point 3 **(**12°33'33.5" **S,** 28°11'35.1" **E)** from upstream to downstream respectively as shown in **Fig 2**. The samples were collected at a depth of 0.5 – 1 m by scoop method into 100mL polyethylene bottles which were thoroughly washed and rinsed with deionized water and labeled appropriately.
The water samples were preserved by adding 1mL of 65% HNO_3 to each 100 mL sample (1% v/v) and the presence and concentrations of heavy metals, Copper (Cu), Iron (Fe), Manganese (Mn), Lead (Pb), Cadmium (Cd) and Arsenic (As) were quantitatively analyzed at the University of Zambia, School of Mines laboratory using Atomic Absorption Spectrophotometer (AAS: model PinAAcle 500, PerkinElmer Inc., Shelton, USA).

Key : **BMTD** – Sampling Point 1 (12°33'12.5" **S**, 28°11'7.4" **E**)
AMTD – Sampling Point 2 (12°33'33.1" **S,** 28°11'14.6" **E)**
CF – Sampling Point 3 (12°33'33.5" **S,** 28°11'35.1" **E)**

Fig 2. Showing the three sampling points along the river

RESULTS & DISCUSSION

Table 1 shows results for the presence and concentrations of heavy metals under investigation per sample. The concentration values having the sign (<) represent metals whose concentrations were below detection limit (BTL). **Table 2** shows cleaned results after statistical analysis and they give the actual picture of the findings. Finally, **Table 3** shows the World Health Organization (WHO) international standards for drinking water.

Table 1. Showing generic results of heavy metal concentrations

Sample	Heavy Metal concentrations (mg/L)					
	Cu	**Pb**	**Mn**	**Cd**	**Fe**	**As**
BMTD 1	<0.003	<0.01	0.068	<0.002	0.087	<0.01
BMTD 2	<0.003	<0.01	0.07	<0.002	0.088	<0.01
BMTD 3	<0.003	<0.01	0.069	<0.002	0.086	<0.01
AMTD 1	<0.003	<0.01	0.135	<0.002	0.121	<0.01
AMTD 2	<0.003	<0.01	0.134	<0.002	0.123	<0.01
AMTD 3	<0.003	<0.01	0.135	<0.002	0.122	<0.01
CF 1	<0.003	<0.01	0.186	<0.002	0.193	<0.01
CF 2	<0.003	<0.01	0.185	<0.002	0.192	<0.01
CF 3	<0.003	<0.01	0.187	<0.002	0.193	<0.01

Table 2. Showing statistical results of heavy metal concentrations

Sample	Heavy Metal concentration (mg/L) Mean ± SD					
	Cu	**Pb**	**Mn**	**Cd**	**Fe**	**As**
BMTD	Below detection limit	Below detection limit	0.069 ± 0.001	Below detection limit	0.087 ± 0.001	Below detection limit
AMTD			0.135 ± 0.0006		0.122 ± 0.001	
CF			0.186 ± 0.001		0.193 ± 0.0006	

Table 3. Showing the WHO international standards for drinking water [30]

Limits	Elements/ concentrations (mg/L)					
	Cu	**Pb**	**Mn**	**Cd**	**Fe**	**As**
Lower Limit	1.00	-	0.10	-	0.30	-
Upper Limit	1.50	0.05	0.50	0.01	1.00	0.05

The data shows that the water from the river had some presence of heavy metals even before the mining damp site. Manganese was at 0.069 mg/L and iron 0.087 mg/L. This could be attributed to natural sources from the river course. This increased substantially as the river course ran along side the Mufulira tailing dam. This too suggests that the mine wastes could have been introducing some metals ions. This could be confirmed even by a higher concentration of the same metals at site after the damp but just where the mine farrow drains into the river (CF). The general trend for metal ions could be seen as in fig 3.0 below.

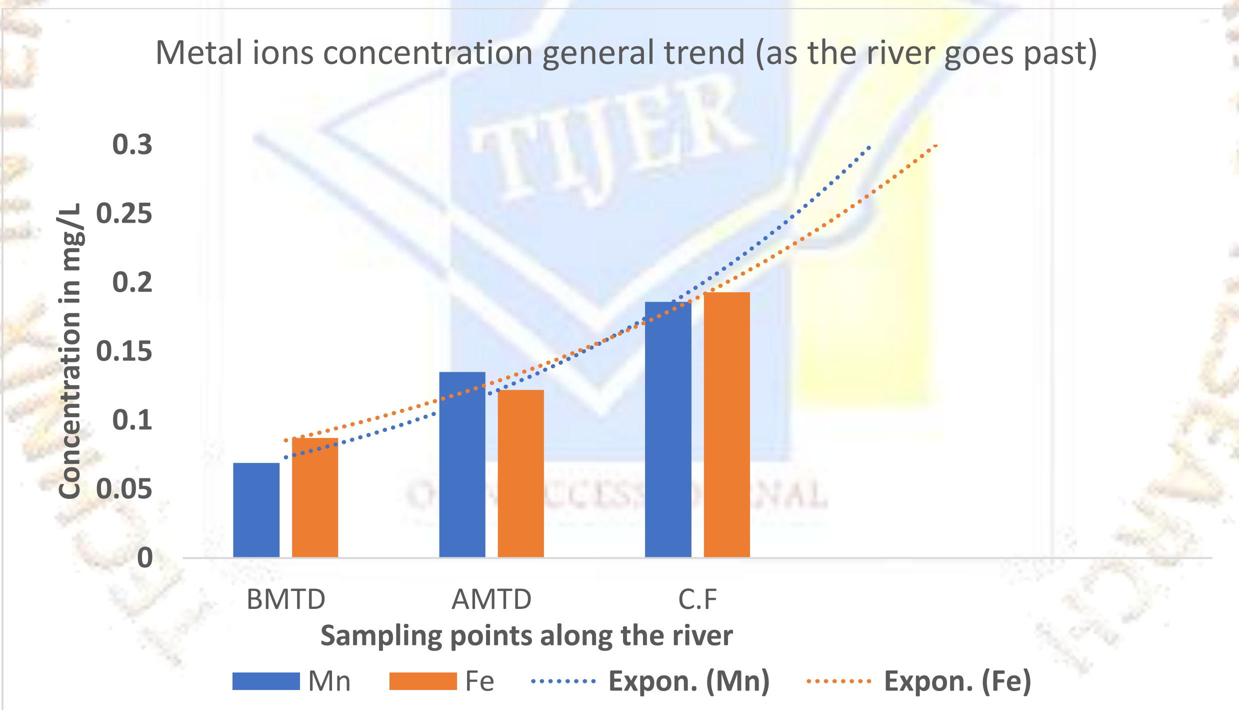

Fig 3.0 Showing the trend of metal ions as the river passes along the tailing plant of the mine.

This clearly indicates that the effluents from the mines do indeed affect the overall metal ions' load.

When the metal ion presence is evaluated against the World Health Organization bench marks the trend stands as shown in fig 3.1 a and b below.

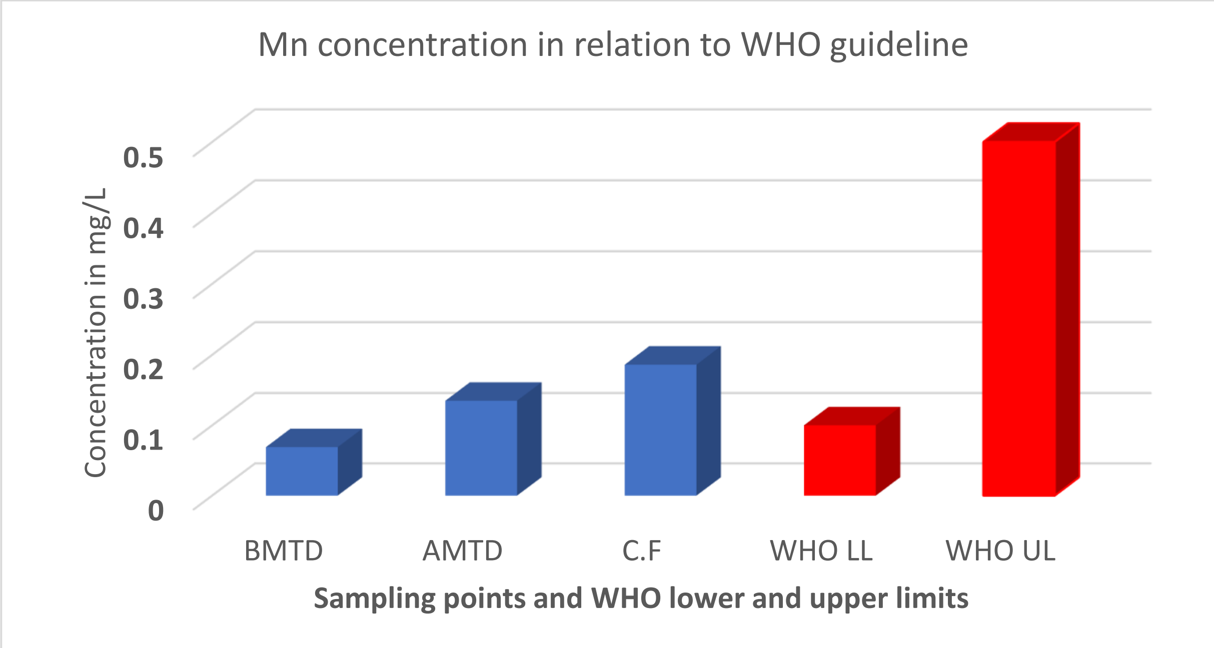

Fig 3.1 a Showing the concentration Manganese in relation to the guideline by WHO.

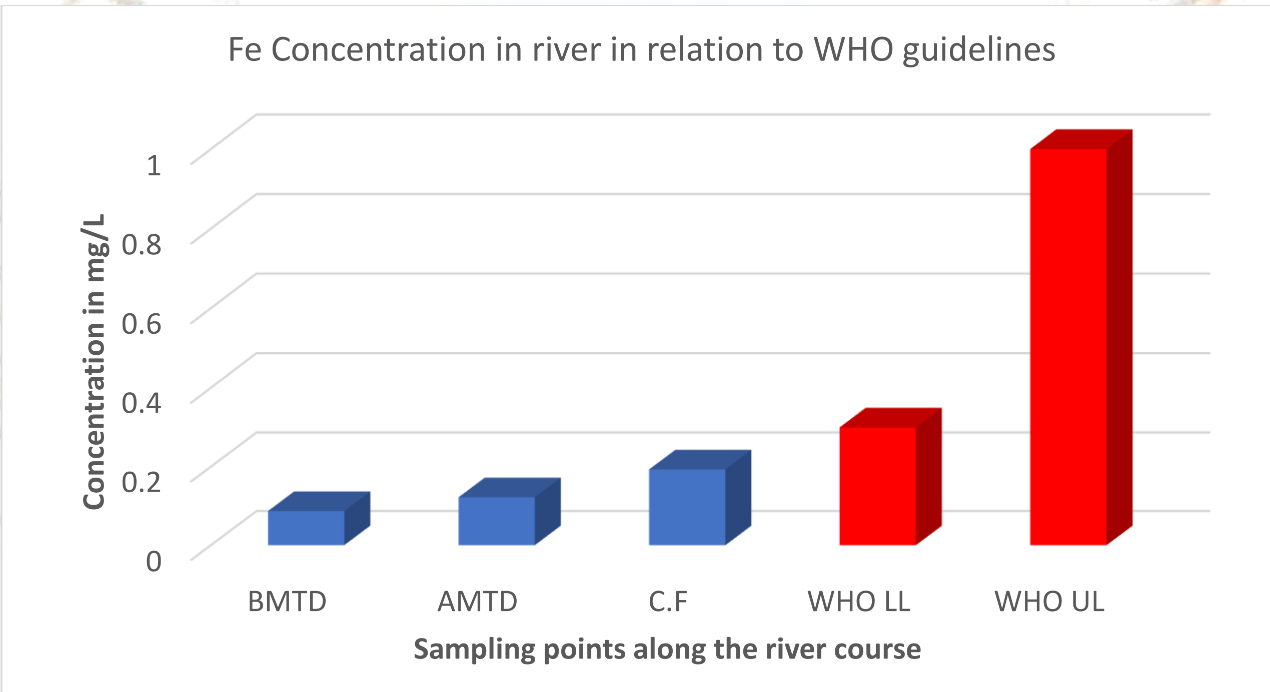

Fig 3.1 b Showing the concentration of Iron in relation to WHO limits

The lower limit (WHO LL) for most metals all the sampling point were higher, this seems to show naturally the river course may have some of its ions of manganese even before mining tailing plant. However, the increase in the increase in Mn along the plant and at the point where mines allow their effluents to join the stream there is a steady rise. The trend for iron is that even though it increased in concentration as the river went along and past the sites, still the overall concentrations was below the WHO LL. This in itself suggests possible permeates from the site. This is agreement with the study conducted by Yacoub *et el* (2014), which indicated that mining activities tend to impact the surrounding eco systems with heavy metals [25]. It is not strange therefore that most studies subsequently found presence of heavy metals in various living organisms. [18, 20-22, 26-33]. In some cases, they were even higher than the upper limits of the country's regulatory organisations and that of WHO. [23, 34-38].

CONCLUSION

It has been established that the Mufulira tailing dam could be leaching some of its metal ions into the river that's runs along dam. The concentration of Manganese was found to **0.069 to 0.183 mg/L**. The concentration of iron was from **0.08 to 0.193 mg/L**. They were all with the limits of WHO guidelines for these metals. It was also noted that Arsenic, Lead and Cadmium where below the detection limit. This may suggest two things. (i) The water may be safe for use (ii) The metal ions could be present if other much more sensitive equipment were use. **ACKNOWLEDGEMENTS**

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