Assessment of Heavy Metals in Water from Lake Kivu, Rwanda

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Abstract Heavy metals are among the pollutants that threaten living organisms including human beings. Heavy metals in water are of great concern due to their toxicity and ability to bio-accumulate in aquatic organisms. There is a need to regularly monitor their concentration in an aquatic medium. The present study was conducted to evaluate the level of heavy metals in lake Kivu. Water samples from lake Kivu were taken from three sites, namely: Rusizi, Karongi, and Rubavu. Heavy metals were analyzed using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Copper, lead, cadmium, chromium, manganese, mercury, and arsenic were analyzed in the water samples. The concentration of copper ranged from 3.240 to 10.011 μg/L, the concentration of lead varied from 8.81 to 37.44 μg/L, cadmium ranged from 5.014 to 14.012 μg/L. Chromium concentration was between 139.5 and 226.6 μg/L, and that of manganese was between 598.3 and 795.7 μg/L, mercury concentration ranged from 0 to 0.047 μg/L while Arsenic was not detected. Thus, except for arsenic, the concentrations of heavy metals in Kivu lake waters were above the Environmental Protection Agency (EPA) maximum permissible limit for class III surface water intended for fish consumption, recreation, propagation, and maintenance of a healthy population of fish and wildlife. There is a need to further establish the sources of lake water pollution and limit the amounts of heavy metals entering lake Kivu to avoid the excess heavy metals beyond the maximum tolerable limit.

Keywords Heavy metals · Lake kivu · Water samples

1 Introduction

Lake Kivu is situated at 1,463 m altitude and maximum depth of 485 m in the Western part of the East African Lift zone between Rwanda and Democratic Republic

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of Congo. The lake is surrounded by highly active volcanoes (Nyamuragira and Nyiragongo) and is known to contain a huge amount of methane gas and carbon dioxide [1]. It is possible that lake Kivu might be vulnerable to human activities, which could contribute to heavy metals pollution. Among the sources of the heavy metals present in the lake, there could be the discharge of untreated effluents from various sources into the lake [2] and soil erosion. Erosion, landslides, and seismicity result in the transport of the neighboring soil which may contain heavy metals [3] into the lake. Lake Kivu is also located in a volcanic region and surrounded by active volcanoes (Nyamuragira and Nyiragongo). The active volcanoes may contaminate the lake with mercury and other heavy metals. Heavy metals are metallic chemical elements with a density greater than 5 g/cm^3, and they are also called trace elements as they are found in small concentrations in biological systems [4]. Heavy metals can be found naturally as small concentrations in aquatic environment [5]; however, anthropogenic activities marking the modern development such as modern agriculture, industrialization, construction, and mining have contributed to the increase of heavy metals and other pollutants in different environmental compartments [6].

Heavy metals are persistent in the environment as they are not eliminated by biodegradation or by chemical means [7]. Some heavy metals are toxic, others are not. Toxic heavy metals include arsenic, cadmium, lead, mercury, and nickel [8]. Lead, cadmium, arsenic, and mercury have no biological role in the metabolism of human and other aquatic organisms and are very toxic to both human and aquatic organisms [9]. Apart from the toxic heavy metals, other metals can be classified as probably essential. Copper, manganese, and chromium are essential for the metabolism of living organisms including human beings; they are, however, toxic at high levels [10]. Considering the toxicity of some heavy metals to human beings and aquatic organisms, the present study investigated the level of heavy metals in lake Kivu. Assessing the level of heavy metals in lake could be an important aspect of environmental protection and a tool that influences the policy-makers in decision-making on environmental issues. While most studies concentrated mainly on methane gas to attract investors for its use [11–15], very few studies have investigated the issue of pollution in lake Kivu.

2 Materials and Methods

Water samples were taken in Northern, Eastern, and Southern parts of lake Kivu—At Rusizi, Karongi, and Rubavu locations. A GPS Garmin 60 data were collected at Rusizi (28.89341, −2.48202); Rubavu (29.25512, −1.73278); and Karongi (29.31138, −2.06042) locations. The water samples were taken at 0 and 40 m depth using a NISKIN bottle, on which an RBR 620 CTD (Conductivity, Temperature, and Depth) probe was attached to record the depth and physical properties of the water. The samples were transported in a cooling box to the laboratory and stored at 4 °C. A Method 3005, which is an acid digestion procedure, was used to prepare

the water samples for analysis by Inductively Coupled Plasma Optic Emission Spectroscopy (ICP-OES). These samples were acidified at the time of collection with HNO_3 (5 mL/L).

At the time of analysis, the water samples were heated with acid and substantially reduced in volume. The obtained volume was filtered and diluted. 100-mL aliquot of well-mixed sample was transferred to a beaker and 2 mL of concentrated HNO_3 and 5 mL of concentrated HCl were added. The sample was covered with a ribbed watch glass and heated on a hot plate at 90 °C until the volume was reduced to 15 mL. The beaker was then removed from the hot plate and allowed to cool. The beaker was washed down the walls with water and sample filtered to remove silicates and other insoluble materials that could clog the nebulizer. The volume was then adjusted to the final volume of 100 mL with reagent water.

3 Results

The concentration of lead exceeded the maximum permissible level (MPL) by 3 times or higher in both, surface water and at 40 m depth (Table 1) varying from 8.81 to 37.44 μg/L. The Chromium concentration exceeded the MPL by 3 or 4 times (ranging from 139.5 to 226.6 μg/L), at both surface water and 40 m depth samples. Cadmium concentration ranged from 5.014 to 14.012 μg/L, which slightly exceeded the MPL in Rubavu (both at surface as at 40 m depth) and surface samples in Rusizi (Table 1). Mercury concentration was below the MPL in Rusizi and Karongi samples, but exceeded MPL in Rubavu samples, both in surface water and at 40 m depth, ranging from 0 to 0.047 μg/L (Table 1). The concentration of copper exceeded the MPL in all sites and both, surface water and at 40 m depth and it ranged from 3.240 to 10.011 μg/L (Table 1). For manganese concentration, there was no established MPL and its concentration varied from 598.3 to 795.7 μg/L (Table 1). Clearly, the samples taken at 40 m depth had slightly lower concentrations of all heavy metals.

4 Discussion

Recent studies on contamination of African great lakes reported heavy metal contamination in lake Victoria [16], where the concentration of lead and cadmium were higher (1.4 mg/L and 0.02 mg/L) than those of our study [16]. The concentration of copper and manganese in lake Kivu were higher than those reported in lake Tanganyika of less than 6 μg/L for copper and 10 μg/L for manganese, while lead concentration in lake Kivu (our study) was lower than that reported in lake Tanganyika (120 μg/L) [17]. The findings of our study on heavy metal contamination raise a particular concern because an estimated 2 million people use lake Kivu water as their source for drinking water without any treatment [18]. The concentration of heavy metals in lake Kivu could be attributed to the anthropogenic activities around the lake [19],

Table 1 Heavy metal concentrations (μg/L) in lake Kivu water samples at surface and 40 m depth

	Locations						
	Rusizi		Karongi		Rubavu		
Parameters	0 m	40 m	0 m	40 m	0 m	40 m	MPL
Pb	28.27 ± 6.06	23.13 ± 11.17	28.47 ± 2.67	29.993 ± 0.894	27.15 ± 3.65	21.64 ± 1.93	8.5
Cd	8.84 ± 3.33	7.68 ± 1.76	7.53 ± 0.81	7.323 ± 0.834	9.72 ± 1.56	9.30 ± 1.83	8.8
Cu	6.98 ± 1.84	7.87 ± 1.47	4.44 ± 1.24	4.88 ± 0.161	6.77 ± 0.72	7.58 ± 1.63	3.7
Cr	200.53 ± 8.13	205.73 ± 19.27	160.51 ± 14.26	153.32 ± 12.87	176.49 ± 23.91	165.57 ± 5.77	50
Mn	740 ± 48.20	673.47 ± 17.57	680.74 ± 55.24	683.56 ± 67.91	611.63 ± 10.28	623.08 ± 14.74	NR
As	ND	ND	ND	ND	ND	ND	50
Hg	0.016 ± 0.010	0.013 ± 0.005	0.0012 ± 0.0014	0.0007 ± 0.0012	0.028 ± 0.006	0.029 ± 0.017	0.025

ND: Not detected; NR: Not Regulated, MPL: Maximum Permissible Limit set by the United States Environmental Protection Agency for Class II surface water intended for fish consumption, recreation, propagation, and maintenance of a healthy population of fish and wildlife

like mining, industrial wastewater, municipal wastewater, and agricultural activities [20]. However, in surface water it may be influenced not only by the wastewater discharged but also by the mineral composition of underlying rock and soil composition around [10]. The excessive content of heavy metals in surface water has an effect on both, water organisms and human beings [21] and on primary productivity in aquatic ecosystem [22] as well. There is a need to limit the amount of heavy metals entering lake Kivu to avoid the excess of heavy metals beyond the maximum tolerable limit. This can be achieved by preventing untreated wastewater from entering lake Kivu through various sources and controlling erosion around the lake.

5 Conclusion

The results from the performed assessment of heavy metals in lake Kivu revealed that the concentrations of lead, chromium, copper, cadmium, and mercury exceeded the maximum permissible limit in all or part of the investigated water samples. There is a need to further establish the sources of lake water pollution and limit the amounts of heavy metals entering lake Kivu.

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