Mj. Int. J. Sci. Tech. **2008** , *02* (02), 361 - 373

Maejo International
Journal of Science and Technology
ISSN 1905-7873
Available online at www.mijst.mju.ac.th

Full Paper

Water quality of Wenchi Crater Lake in Ethiopia

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Received: 5 February 2008 / Accepted: 4 June 2008 / Published: 13 June 2008

Abstract: Determination of physico-chemical properties of water samples from Wenchi Crater Lake in Ethiopia was carried out. Selected heavy metals in water, sediment, and plant samples from the lake were also comparatively determined. The results indicated that most general physico-chemical properties of the lake water fell within those recommended for drinking water. However, the lake water was found to be high in some heavy metals, which also accumulated in the sediment. Bioconcentration of these metals was also observed in the plant samples.

Key words: Wenchi Crater Lake, water quality, heavy metals, sediment, *Typha latifolia*

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Introduction

Wenchi Crater Lake is one of the important lakes in Ethiopia. The lake is located in Western Shoa region, which extends between latitude 15^0 N -3^0 S and longitudes 48^0 E-33^0 W. It is situated at the major topographic feature in the country, being 130 km south-west of the capital city, Addis Ababa. It is surrounded by Kelela region in the north, Dera region in the east, Goro Wenchi region in the south and Haro Gebeya region in the west. This lake, 1,600 square metres in total area, is ecocologically, recreationally, and aesthetically important as well as a popular place for tourists. The topographical location of the lake is presented in Figures 1 and 2.

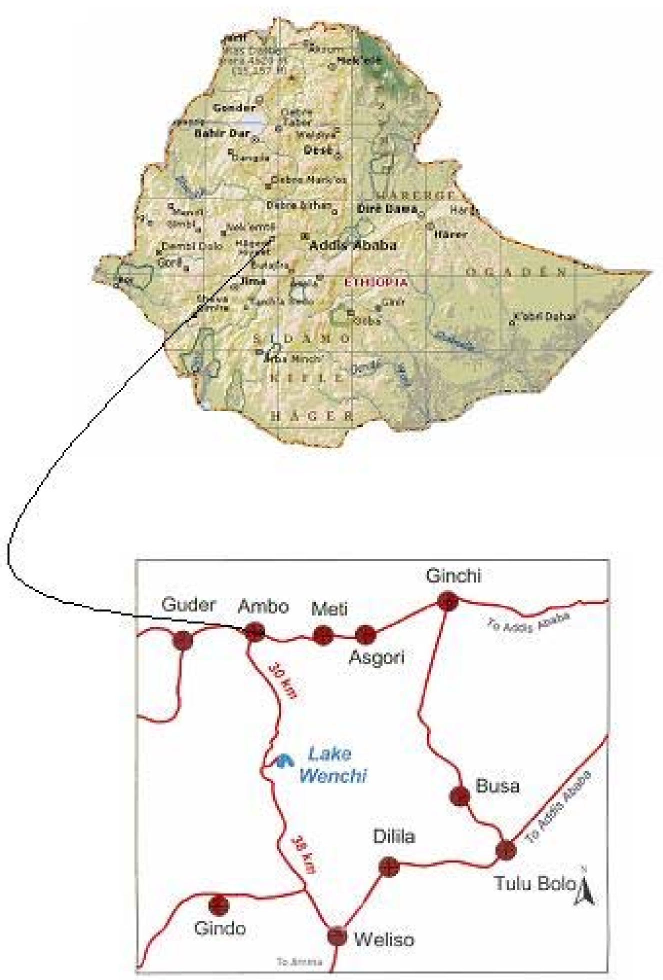

Figure 1. Location of Wenchi Crater lake in Ethiopia

Figure 2. Topography of Wenchi Crater Lake

The health of a lake is governed by the quantity of nutrients it receives from various streams. Nutrient recycling and proper productivity are necessary for sustenance and balance of the system. Due to nutrient enrichment, the system may lose its balance and may turn eutrophic. Thus, water quality studies are necessary to ascertain the suitability of water for various beneficial uses and to assess the trophic level of the lake.

In aquatic systems, the natural concentrations of metal ions are principally dependent on the ambient distribution, weathering and leaching of the elements from the soil in the catchment area, while heavy metals are carried to the lakes through atmospheric deposition and other man made activities. The characteristics of the water, such as acidity and the amount of organic matter, are known to be important factors in determining the fate of heavy metals in lakes [1-3].

The sediment of the aquatic environment acts as a major reservoir of metals [4] and also as a source of contaminants. Enrichment of heavy metals due to industrialisation and urbanisation was recorded in the sediment of coastal areas all over the world [5-9]. The monitoring of the heavy metal resulting from anthropogenic activities are particularly important for the assessment of environmental quality and protection. Heavy metal distribution in lagoonal and intertidal sediment has frequently been used to investigate chronological inputs [10-12].

Increased loading of heavy metals into lakes may have several ecological consequences. Elevated trace metal concentrations may lead, for example, to toxic effects or biomagnification in the aquatic environment. Accumulation of heavy metals in the food web can occur either by bioconcentration from the surrounding medium such as water or sediment, or by bioaccumulation from the food source.

In the following study, no attempts were made to investigate the environmental health of Wenchi Crater Lake. The main objective of this study, the first performed for this lake, is to monitor the water quality of the lake with reference to standard water quality parameters and heavy metals in its water and sediment, and in *Typha latifolia*, a major aquatic plant present in the lake.

Materials and Methods

The water, sediment and *Typha latifolia* samples were collected bimonthly between January-December 2007 from eight sampling points (Figure 2) in the lake in cleaned polythene containers. The water quality parameters, viz. pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), total alkalinity (ALK), common metal ions (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}), anions chloride (Cl^{-} and SO_4^{2-}), and dissolved oxygen (DO) were analysed employing standard experimental protocols outlined in the literature [13-14]. In case of heavy metals, Cd, Cu, Ni, Cr, Pb, Mn, and Zn were selected and analysed as per the standard experimental protocols outlined in the literature [13] using a Shimadzu AA 6200 atomic absorption spectrophotometer. All the chemicals and reagents used in the experiments were of analytical grade. All the results were statically significant at $p < 0.05$.

Results and Discussion

The results of the physico-chemical analysis of the water samples collected from all the sampling points were presented in Table 1.

pH and dissolved oxygen (DO)

The pH of Wenchi Crater Lake water (7.4-7.6) fell within the desirable range (6.5-8.5) for drinking water as per the WHO guideline [16]. This result indicated that there were no human influences in the lake area and the responsible factor for the slightly alkaline value of the pH was only through the chemical composition of the bed rock sediment.

Dissolved oxygen is very essential for all living organisms in any water bodies. The recorded level of dissolved oxygen in the water of Wenchi Crater Lake ranged between 7.4- to 7.6 mg/L (WHO range: 4.5-7.5 mg/L). A similar result was also reported for Lake Naivasha, Kenya [15]. In the lake, the population of phytoplankton was relatively more than that of the zooplankton. The overgrowth of the plankton species and other aquatic plants might cause eutrophication in the lake in due course of time.

Table 1. Physico-chemical characteristics of the lake water

Water quality parameter	Sample collection point in the Crater Lake								WHO guideline value for drinking water [16]
	S1	S2	S3	S4	S5	S6	S7	S8	
	Mean value								
pH	7.5	7.6	7.6	7.4	7.5	7.5	7.6	7.6	6.5 – 8.5
EC (μmhos/cm)	1180	1182	1179	1180	1183	1182	1181	1183	1500
TDS (mg/L)	767	768.30	766.35	767	768.95	768.30	767.65	768.95	1000
TH (mg/L)	282	283	280	282	285	284	282	284	400
Ca (mg/L)	135	137	135	136	134	135	136	135	200
Mg (mg/L)	105	102	105	104	106	105	103	105	100
Na (mg/L)	48	52	50	49	48	50	48	47	200
K (mg/L)	26	28	27	28	26	28	29	27	20
Cl^- (mg/L)	458	460	458	462	460	457	459	460	400
$SO4^2$ (mg/L)	390	394	392	390	392	394	392	390	400
DO (mg/L)	7.4	7.6	7.5	7.5	7.6	7.5	7.6	7.5	4.5 – 7.5

Note: The analytical results were statistically significant at $p < 0.05$.

Electrical conductivity (EC) and total dissolved solids (TDS)

The conductivity of the water samples registered 1179-1183 μmhos/cm. This is well below the WHO guideline value prescribed for drinking purpose (1500 μmhos/cm). The TDS present in the water affects its aesthetic value as well as its physico-chemical and biological properties. The TDS values found (766.35-768.95 mg/L) were also below the drinking water standard (1,000 mg/L).

Total hardness (TH), calcium and magnesium

The lake water samples recorded a low level of total hardness (280-285 mg/L). The total hardness has no known adverse effects on human health, and the recorded values were well below the guideline value for drinking purpose (400 mg/L).

Primarily, the calcium and magnesium present are responsible for the hardness of the water. The desirable limit for calcium in water is (75 mg/L) and the maximum permissible limit is (200 mg/L), and for magnesium these values are 30 and 100 mg/L respectively. In the present investigation, we have observed that the values for calcium were 134-137 mg/L and those for magnesium, 102-106 mg/L.

Sodium and potassium

Sodium and potassium are the monovalent cations commonly present in water. These ions do not produce hardness to water. However, significantly high amounts of these ions in water create problem in its taste as well as make the water unsuitable for irrigation purpose. In the present study, the concentration of sodium (47-52 mg/L) was well below the listed value in Table 1, while that of potassium (26-29 mg/L) exceeded the allowed value (20 mg/L). This might be due to the presence of potash minerals in the area. A further geological investigation of the studied area is necessary.

Chloride and sulphate

The presence of chloride and sulphate in water in excess amounts is not desirable. Its origin is mainly from mineral weathering of bed rocks as well as from anthropogenic source. In the present investigation, the concentrations of chloride and sulphate ranged 457-462 mg/L and 390-394 mg/L respectively. The desirable limit of chloride is 250mg/L and the maximum permissible limit is 400 mg/L and for sulphate, it is 200 and 400 mg/L respectively. The concentration of chloride was thus somewhat higher than the permissible limit for drinking purpose.

Heavy metals in water

The concentrations of Cd, Cu, Ni, Cr, Pb, Mn, and Zn were determined in water samples from eight sampling points in the lake. The analytical results are presented in Figure 3. The drinking water standards (WHO guidelines) for the trace inorganic contaminants such as Cd, Cu, Ni, Cr, Pb, Mn and Zn are 0.003, 2.0, 0.02, 0.05, 0.01, 0.5 and 5.0 mg/L respectively [16]. The results indicate that only the levels of Cu, Mn and Zn in the lake water were well within the allowable concentrations. The concentrations of all other metals were significantly increased in the lake water.

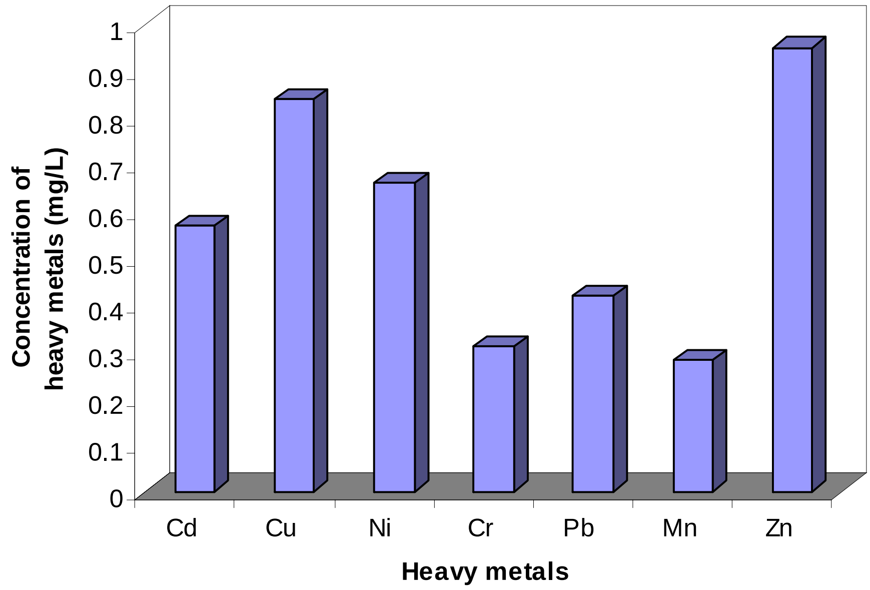

Figure 3. Levels of heavy metals in the lake water

Heavy metals in sediment

Sediment samples were collected in the same eight locations in the lake and were analysed for the concentration of Cd, Cu, Ni, Cr, Pb, Mn and Zn. Two sediment samples were fine-grained and others were coarse-grained. The sediment samples registered significantly higher amounts of heavy metals than the water samples (Figure 4).

Heavy metals in plant samples (Typha latifolia)

Typha latifolia was the major aquatic plants in the lake. Their roots were collected near the water sampling points and analysed for heavy metal concentrations, the average values of which are presented in Figure 5. The result shows that the plants accumulated significantly higher amounts of heavy metals compared to the sediment. Since heavy metals present in water and sediment are slowly absorbed by the aquatic plants and thereby concentrated in the root metabolism, the plants can be used as a bioindicator of heavy metal pollution in the lake.

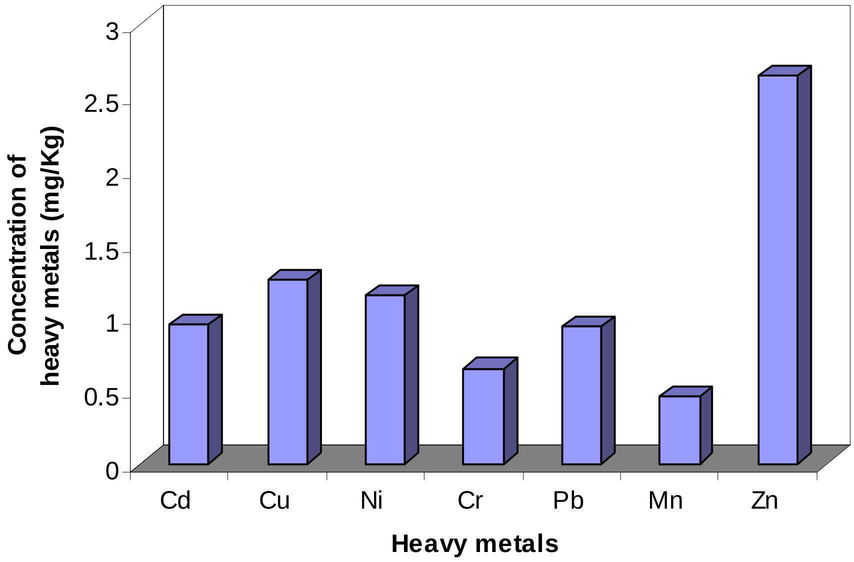

Figure 4. Levels of heavy metals in lake sediment

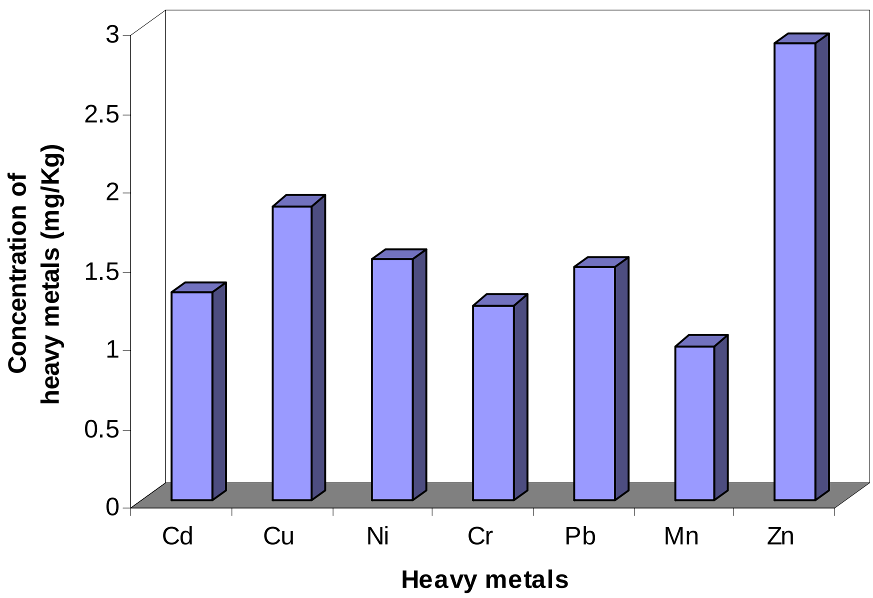

Figure 5. Levels of heavy metals in roots of *Typha latifolia*

Notably the three sampled items show distinct variation in metal contents. The concentration gradients (plant root > sediment > water) exist for all the heavy metals in the lake and it might be possible that the sedimental particles were transported towards the lower reach of the lake. Parallel gradients of organic matter contents and grain size distribution of the sediment are also likely to influence the heavy metal concentration in the lake [17-18]. The fine-grained sediment is reported to have a greater influence on the adsorption of heavy metals from the water [19].

It is also observed in many estuaries across the world that the concentration of heavy metals from known anthropogenic input generally increases [10,20]. In Wenchi Crater Lake area there are three inlets and two outlets. However, the outlet points are present only in the upper part of the lake and the volume of water discharge is comparatively small while the bulk of the lake water is lost through evaporation and absorption. Therefore the lake area becomes a large sink for heavy metals. The concentration factor is the main cause of sediment toxicity while this factor through bioaccumulation by plants (*Typha latifolia* in this case) is apparently more pronounced. Land erosion and natural weathering of bedrocks of the lake are probably the main factors responsible for the accumulation of heavy metals in the lake ecosystem.

Conclusions

Most physico-physcical properties of Wenchi Crate Lake conformed to the standards set out by WHO for drinking water, except for the level of magnesium, chloride, and sulphate ions, which just overstepped the borderlines. As for heavy metals, it was observed that only Cu, Mn, and Zn were well within the allowable concentrations while Cd, Ni, Cr, and Pb were significanly higher than the set limits allowable for potable water. Moreover, the lake sediment was found to be enriched with these heavy metals compared to the lake water. However, heavy metal enrichment through bioconcentration by plants in the lake was even more conspicuous.

The presence of increased amounts of heavy metals may have a direct impact on the health of humans as well as aquatic animals. Visibly the water looks very clean with no contamination. The volume of water in the lake is very high and can potentially be used for various purposes by employing artificial recharging technologies and special purification methods. However, there is a dense population of macrophytes in the lake. Further research work is necessary to study them and their impact on the water quality of the lake.

Acknowledgement

The authors wish to acknowledge the research and publication coordination office of the Ambo University College, Ambo Town, Ethiopia for the financial support.

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