World Journal of Chemical Education, 2014, Vol. 2, No. 3, 42-47
Available online at http://pubs.sciepub.com/wjce/2/3/3
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DOI:10.12691/wjce-2-3-3

Detection of Copper and Zinc (Heavy Metals) in Water of Lake Chamo, Arbaminch Ethiopia

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Received October 17, 2014; Revised October 23, 2014; Accepted November 02, 2014

Abstract This study, detection of copper and Zinc (heavy metals) in water of Lake Chamo, was done from July, 2011 to April, 2012. The water was taken from three different sites of the lake in July, October, January and April (in four different seasons) and analysis of phsico-chemical parameters and copper and zinc ions content of the lake water were done. When physical and chemical parameters compared with the previous studies, it is found that most of these parameters were higher than the recommended standards and this affect the biota in the studied area and form a public health problem.

Keywords: *heavy metals, Lake Chemo*

Cite This Article: Belay Tafa, and Eshete Assefa, "Detection of Copper and Zinc (Heavy Metals) in Water of Lake Chamo, Arbaminch Ethiopia." *World Journal of Chemical Education*, vol. 2, no. 3 (2014): 42-47. doi: 10.12691/wjce-2-3-3.

1. Introduction

1.1. Background and Justification

In natural aquatic ecosystems, metals occur in low concentrations, normally at the nanogram to microgram per liter level. In recent times, however, the occurrence of metal contaminants especially the heavy metals in excess of natural loads has become a problem of increasing concern. This situation has arisen as a result of the rapid growth of population, increased urbanization, and expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern agricultural practices as well as the lack of environmental regulations [12].

Lakes are more sensitive to pollution inputs because lakes flush out their contents relatively slowly. Even under natural conditions, lakes undergo eutrophication, an aging process that slowly fills in the lake with sediment and organic matter. The eutrophication process alters basic lake characteristics such as depth, biological productivity, oxygen levels, and water clarity [20].

Lake Chamo is under the Abaya Chamo drainage basin is a sub basin of the rift valley that crosses through Ethiopia midway in the north south direction. The basin comprises mainly the two lower lying lakes. The rivers kulfo and Sile enter in to Lake Chamo and the overflow from Lake Chamo drains in to the Sagan River, which in turn drains finally to the Chew Bahir. The rivers draining in to Lake Chamo are listed as: Sile, Argoba, Wezeka, Sego, in addition to the over flow from Lake Abaya which confluences with river kulfo and eventually drains to Lake Chamo. The Abaya and Chamo Lakes are hydrologically interconnected. An overflow from Lake Abaya flows in to Kulfo River that in turn ends up in to the Chamo Lake. The level difference between the two lakes is 62 meters, Abaya Lake being higher than Chamo Lake. The two lakes have been used for transport (Lake Abaya), fishery (Lake Chamo) and tourism. The lakes have not been used for irrigation. However, the tributaries (rivers Bilate, Kulfo, etc) have been used intensively for irrigation [1].

There have been some studies done in the past about the limnology of the two lakes and the influence of increased upper catchment activities and increased utilization of the tributaries to the two lakes. There had been isolated cases of observation in which wild lives were seen to have died, may be due to the consumption of toxic substances produce by the blue green algae [1]. Lake Chamo, the field of the present investigation, one of the three large lakes in Ethiopia next to Lake Tana and Abaya. It is an inland closed basin with one apparent natural outlet (Segan river), of about 118 Km shoreline length, and has a maximum depth of 10 m. It lies in a semi-arid region, occupying the southwest part of Arba Minch town.

The lake climate is further characterized by high rate of evaporation (about 2300 mm per year on average) and the precipitation average of about 600 mm. The area in the past has been affected by global climatic change with a shift to a decrease in precipitation peaks and with consequent impact on the lakes. In addition to this the lake suffered drastic chemical changes during the last years where it is used as a general reservoir for agricultural wastewaters drainage, as well as for the drainage of Arba Minch town through Kulfo River. Therefore, its salinity increases progressively which affects greatly the lake biota. These conditions led to change in the biodiversity of the different biota (especially fish species that the lake is known). In previous times, this Lake was known by its fish potential as a freshwater lake, contained freshwater fish species, and now its fish potential is decreasing time to time and at the same time studies showed the water salinity increased progressively from past to present [1]. The freshwater fish species that were abundant from Lake Chamo are catfish, tilapia and Nile perch, which are less salt tolerate species.

Copper is essential as micronutrient for fish and aquatic life, widely used as a very effective algaecide and molluscicide [18]. The permissible levels of copper in water are 1.0 ppm, while, in fish tissues, they are 20 ppm [23]. Since copper from anthropogenic sources eventually contaminates water bodies, toxicity of this metal to aquatic organisms has been intensely studied over the past two decades [13,23].

Zinc is an essential trace element in living organisms, being involved in nucleic acid synthesis and occurs in many enzymes. Background values of zinc in natural inland surface waters may vary from 0.001 to 0.2 mg/l or even higher. Zinc and its compounds are extensively used in commerce and in medicine. The common sources of it are galvanized iron work, zinc chloride used in plumbing and paints containing zinc. It is soluble in water and illness may be caused by drinking water containing zinc. Zinc wastes can have a direct toxicity to aquatic life, and fisheries can be affected by either zinc alone or more often together with copper and other metals [7].

Taking into consideration that the lake is a closed ecosystem, and as a result of extensive evaporation of water, the accumulation of chemical pollutants (salts, heavy metals, pesticides and other pollutants) is expected to increase annually in all its components (e.g. water, sediment and fish) and to change their quality and affect their aquatic life.

This paper focuses on the studying of the water quality criteria, distribution of copper and zinc in the water of Lake Chamo.

1.2. Objectives

1.2.1. General Objective

- To study the water quality and the accumulation of copper and zinc (heavy metals) in the water of Lake Chamo

1.2.2. Specific Objectives

The specific objectives includes

- To study accumulation of copper and zinc in water of Lake Chemo
- To study the physico-chemical parameters of Lake Chemo
- To draw appropriate recommendation and conclusion about Lake Chamo after analysis of the result.

2. Materials and Methods

2.1. Study Area

Lake Chamo is a lake in the Southern Nations, Nationalities, and Peoples Region of southern Ethiopia. It is located in the Great Rift Valley at an elevation of 1,235 meters. It is just to the south of Lake Abaya and the city of Arba Minch, and east of the Guge Mountains. The lake's northern end lies in the Nechisar National Park. According to figures published by the Central Statistical Agency, Lake Chamo is 26 kilometers long and 22 Km wide, with a surface area of 551 square kilometers and a maximum depth of 10 meters.

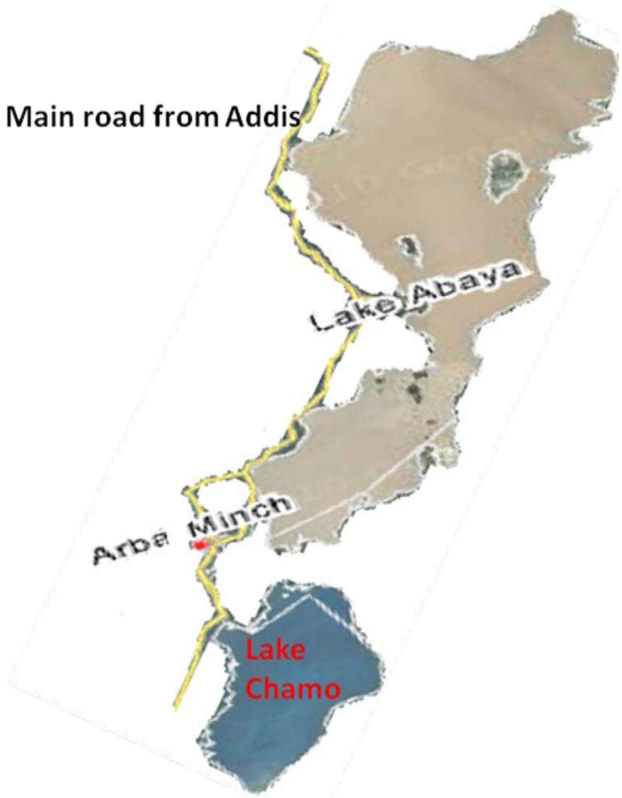

Figure 1. Lake Abaya and Chamo with the main road from Addis Ababa to Arba Minch

2.2. Sampling and Procedure

The study was carried out for one year from July 2011 to May 2012 during four subsequent seasons (two rainy (October and April) and two dry seasons (July and January)). Samples of water was seasonally taken from three different localities (Kulfo, Centere and Sile sites) covering the whole lake area. The first site (Kulfo) is near the mouth of Kulfo river (~ 50m), the second site is near the center of the lake and the third site is near the mouth of Sile river (~ 50m).

On site sampling, the temperature (°C) of the surface water, salinity (g/l), conductivity (mmhos/cm), dissolved oxygen (mg/l) and pH were measured using electronic portable meters and digital pH meter.

A water sampler (polyvinyl chloride Van Dorn bottle) of 2L capacity was used to collect surface water (e.g. 15 cm depth) from the three different localities. The chemical parameters were measured using methods adopted by standard methods described in APHA (4).

2.3. Determination of Physicochemical Parameters

On site sampling, the temperature (°C) of the surface water, salinity (g/l), conductivity (mmhos/cm), dissolved oxygen (mg/l) and pH were measured using electronic portable meters and digital pH meter.

2.4. Analysis of Heavy Metals

Concentrations of the heavy metals (Copper and Zinc) in the lake water were determined using flame atomic absorption spectrophotometer (expressed in mg/l).

3. Result

3.1. Physicochemical Parameters

The results of these parameters of Lake Chamo are shown in Table 1. The minimum water temperature was recorded during in October in all sampling sites (27.8°C), while the maximum one was observed during January (29.90°C) at Kulfo site and April (29.50°C,) at Sile site and the total mean of lake chamo was 28.58 during the study time. The higher values of electrical conductivity (EC) were recorded during April in all sites (1.38 mmhos/cm in Kulfo site, 1.27 mmhos/cm in Sile site and 1.26 mmhos/cm in the center site), while the lower (0.99 mmhos/cm) were recorded during October at Sile site and the mean total of electrical conductivity was 1.12 mmhos/cm during the study period. The higher value of total dissolved solids (TDS) was recorded during April (1100.00 gm/l) at Sile site and the lower value was recorded during July (608.00 gm/l) at the center of Lake Chamo and the average TDS in all sites was 725.58 gm/l. The minimum value of salinity was recorded at Sile site during July, Juanuary and April (614.00 ppm) and the maximum value was recorded during October (647.00 ppm) at Kulfo site and 646.00 ppm at the center of the lake and the average salinity of Lake Chamo during this study was 629.50 ppm.

Table 1. Monthly variation of physico-chemical parameters in Lake Chamo during the study period

Seasons	Temp (°C)	EC (ms)	TDS (Mg/L)	Salinity (ppm)	Ph	DO (ppm)	TALK (Mg/L)	TH (Mg/L)	Chloride (Mg/L)	NO_2^- (Mg/L)	NO_3^- (Mg/L)	PO_4^{-3} (Mg/L)	SO_4^{-2} (Mg/L)	Cu (Mg/L)	Zn (Mg/L)
Sille Site															
July	29.10	1.07	618.00	614.00	8.47	8.86	1080.00	80.00	129.14	43.00	0.90	1.39	82.30	0.06	0.14
Oct	28.90	0.99	612.00	646.00	8.40	8.40	1120.00	72.00	123.78	49.00	2.50	2.09	73.45	<0.0001	<0.0001
Juan	29.50	1.07	621.00	614.00	9.00	7.46	1080.00	80.00	130.14	42.50	0.80	1.49	84.20	0.03	0.05
April	29.30	1.27	1100.00	614.00	8.92	7.54	1084.00	86.00	131.14	52.00	2.60	2.46	94.60	0.07	0.04
Mean	29.30	1.10	737.75	622.00	8.70	7.82	1091.00	79.50	128.55	46.63	1.70	1.86	83.64	0.05	0.08
Centere Site:															
July	27.90	1.07	608.00	624.00	8.50	8.72	1260.00	72.00	151.64	42.00	1.10	1.53	56.30	0.02	0.30
Oct	26.90	1.08	651.00	646.00	8.20	8.70	1074.00	68.00	149.74	51.00	0.60	1.39	42.76	<0.0001	<0.0001
Juan	27.60	1.06	645.00	624.00	8.90	8.43	1260.00	71.00	150.64	48.30	1.40	1.51	64.30	0.03	0.32
April	28.20	1.26	900.00	624.00	8.92	8.23	1262.00	74.00	152.67	37.00	1.20	1.91	59.30	0.09	0.05
Mean	27.65	1.12	701.00	629.50	8.63	8.52	1214.00	71.25	151.17	44.58	1.08	1.59	53.17	0.05	0.22
Kulfo Site:															
July	29.20	1.08	630.00	633.00	8.10	7.86	1122.00	74.00	151.34	46.00	1.30	1.77	75.30	0.04	0.30
Oct	27.30	1.05	659.00	647.00	8.70	7.98	1124.00	68.00	129.77	50.00	3.20	1.85	52.26	<0.0001	<0.0001
Juan	29.90	1.08	663.00	634.00	8.90	7.74	1120.00	76.00	151.34	47.40	1.70	1.67	74.30	0.03	0.62
April	29.10	1.38	1000.00	634.00	8.92	7.70	1121.00	81.00	153.61	45.00	2.10	2.01	84.30	0.09	0.05
Mean	28.88	1.15	738.00	637.00	8.66	7.82	1121.75	74.75	146.52	47.10	2.08	1.83	71.54	0.05	0.32
Mean Total	28.58	1.12	725.58	629.50	8.66	8.05	1142.25	75.17	142.08	46.10	1.62	1.76	69.45	0.05	0.21

The pH values of the lake water were alkaline, with average pH of 8.66 and the lowest reading was recorded during July (8.10) at Kulfo site, while the maximum record was recorded during January (9.00) at Sile site. For dissolved oxygen, the maximum value was measured during October (8.70 mg/L) at the center site, while the lowest reading was recorded in April (7.54 mg/L) at Sile site and the average dissolved oxygen during the study period was 7.82 mg/l. For total alkalinity, the lower values recorded during October (1074.00 mg/l) while the higher values were recorded during April (1262.00 mg/l) at the center of the lake and the average total alkalinity was 1142.25 mg/l. The average chloride values were recorded as 142.08 mg/l with maximum value was measured during April (153.61 mg/l) at Kulfo site and the lowest value was recorded during October (123.78 gm/l) at Sile site. For total hardness (TH), the lower value recorded during October (68.00 mg/l) at Kulfo and center of the lake while the higher value was recorded during April (81.00 mg/l) at Kulfo site and the mean total hardness of the lake was 75.17 mg/l.

The seasonal variations of nitrite show that the lower values recorded during April (37.00 mg/l) at the center of the lake while the higher values were recorded during April (52.00 mg/l) and the average nitrite value was 46.10 mg/l. The results of the nitrate revealed that the higher values recorded during April (2.60 mg/l) and October (2.50 mg/l) at Sile site and the lower values were recorded during October (0.60 mg/l) at the center of the lake and the mean nitrate value during the study period was 1.62 mg/l. The highest value of phosphate (PO_4^{-3}) was recorded in October (2.09 mg/l) at Sile site while the lower value was recorded in July and October (1.39 gm/l) at Sile and center of the lake and the mean value of phosphate was 1.76 mg/l. The mean value of sulphate ion (SO_4^{-2}) during the study period was 69.45 mg/l while the highest and the lowest value were recorded during April (94.60 mg/l) at Sile site and October (42.76 mg/l) at the center of the lake respectively.

3.2. Copper and Zinc in Water

The mean value of copper and Zinc ions during the study period were 0.5 mg/l and 0.21 mg/l while concentrations of copper and Zinc in water showed a regular distribution pattern, where there were an obvious gradual decrease from October (<0.0001 mg/l) at the three sites to January (0.03 mg/l of Cu and 0.05 of Zn) and return to increase of Copper during April (0.09 mg/l) in the three site and Zinc during January (0.62 mg/l). The values of all the studied parameters in spring, summer and autumn with the exception of salinity, the dissolved oxygen, total alkalinity and total hardness were significantly increased when compared with the values of winter

4. Discussion

Assessment and control of aquatic pollution depended upon physico-chemical monitoring to identify and quantify toxicants and to provide data that, for regulatory purposes, could be compared to allowable concentrations for particular recipient water [15,16]. The concept that water quality criteria are the basis for any kind of water pollution control policy is certainly valid [11].

4.1. Physico-chemical Characteristics

Temperature: The water temperature increased in the January season due to the increasing in air temperature. There is no clear thermal stratified recorded in the lake due to shallowness of the lake (10m depth in max). The minimum and maximum lake temperature was coincided with the minimum and maximum atmospheric temperature in the region. The surface water temperatures of Lake Chamo are a little higher to those of other Ethiopian Rift Valley Lakes including Lakes Ziway 18.5-27.5°C; [14], Abijata and Langano 18-27°C; [9] and Awassa 23.8-28.4°C [8] and other lakes, like Lakes Kilole 18.5-24°C; [9], Babogaya 20.5-28.4°C; [26] and the Legedadi Reservoir 22.2-23.9°C; [2].

Electrical conductivity: The increasing of the values during April may be attributed to the decreasing on the water level as a result of high rate of evaporation and lowering the amount of drainage water pour in the lake during this season. During October (rainy season), the lower values were due to direct effect of dilution by drainage water especially areas facing the drains. It was found that, the values of EC are tremendous than, and more thousands folds of, the 200 μmhos/cm value marking eutrophication in aquatic habitats [19].

Total dissolved solids (TDS): The total dissolved solids increased during April that mainly attributed to high rate of evaporation and lowering the water level in the Lake due to the flow of the drainage water from the main drains was lowered. While the TDS decreased during July (608 mg/l) which may be attributed to the raising of the water level in the lake because of increasing of the amount of drainage water during May to June. TDS reflect the increasing extent of industrial and domestic discharge in aquatic habitats [21].

Salinity: As a whole, the salinity considered being the main factor responsible for the deterioration of the environmental conditions of the Lake Chamo and the drop in its fish production. The highest value of 647 mg/l recorded during October may be attributed to the high rate of evaporation in the region, while the lowest value of 614 mg/l recorded during July, may be due to the effect of dilution arises from drainage water from Kulfo and other rivers.

pH: The pH of Lake Chamo ranged from a minimum of 8.10 in July, 2008 to a maximum of 9.00 in January, 2008. The pH values recorded for this lake in the present study are closer to the result obtained by Eyasu; 8.53-9.44; [10] in the same lake. On the other hand the pH values of Lake Chamo, were generally lower than those recorded in the nearby crater lakes, Lake Bishoftu; 9.2; [19] and Babogaya; 8.84-9.09; (26 The pH values are low during July than other seasons, which may be attributed to the decomposition of organic matter. Furthermore, the pH values increased relatively during January. This relative increase mainly attributed to the increasing of photosynthetic activity, which reduces the CO_2 amount in water. In addition, this may be attributed to the low levels of dissolved oxygen where there is a negative correlation between pH and dissolved oxygen.

Dissolved oxygen: The highest value of dissolved oxygen of 8.7 mg/1 recorded during October, which mainly attributed to decreasing of temperature, prevailing winds action that permits to increase the solubility of atmospheric oxygen gas [17]. The dissolved oxygen values showed relative decrease during April (7.54 mg/l) which is mainly attributed to elevation of water temperature that leading to decrease the solubility of oxygen gas (Rai, 2000), in addition to the oxidation of organic matter by the microbial activity of microorganisms, which consumes a part of dissolved oxygen. On the other hand the oxygen concentration in the surface water of Lake Chamo was generally closer to those recorded for other Ethiopian lakes, Lake Kilole;3.4 to 10.6 mg O_2 l^{-1}; (10), and Babogaya; 2.75-15.8 mg O_2 l^{-1}; [26].

Alkalinity: For total alkalinity, the obtained results increased during April whereas decreased during October. The increasing of bicarbonate during April attributed to decrease in water and air temperatures led to the precipitation of calcium bicarbonate. The use of lake water for irrigation and evaporation may be the reason for fluctuation of alkalinity of the current lake. Irrigation affects the water input-output relationship thereby determining the extent of evaporative concentration of ions [25]. It is also considered that the diversion inflows are one of the main reasons for the increases in the salinity of many lakes of the world’s largest and permanent lakes during the last several decades [24].

Chloride: The highest value of chloride was recorded during April and the lowest value was recorded in October. The high rate of evaporation during April and low water level of the lake; as well as, the decrease in the discharged runoff during April; regard the main reason for increase the chloride content. The lowest values in October attributed mainly to the dilution effect of the introduced agricultural runoff from surroundings, especially, during October where the amount of discharged runoff increased.

Total Hardness: In the present study, the general seasonally average trend was characterized by a progressive increase during April and decrease during October reported that the increase in hardness concentration in April may be due to the increase in dissolved oxygen with temperature decrease, but the decrease in levels in October were due to the carbonic acid decrease leading to the precipitation of $CaCO_3$.

Nitrite: It is quite clear from the above mentioned results that, nitrite contents in Lake Chamo showed relative narrow monthly fluctuations. The results declared that the nitrite concentration increases during April and October, which mainly attributed to oxidation of exist ammonia yielding nitrite as reaction intermediate [22]. European Economic Community standards [3] has set 100 μg/l as a maximum admissible limit for nitrite in natural water and here in all cases, Lake Chamo exceed the admissible levels by several times and this may due to increase of organic pollutants or domestic wastes. Nitrite poisoning causes fish mortality resulting in converting hemoglobin to form methemoglobin [5,6].

Nitrate: Nitrate is a prime plant nutrient and rising in its concentrations might be expected to increase the eutrophication of waters [12]. In Lake Chamo, the nitrate values in water varied, in the same trend of nitrite, in the range from 1.39 mg/l (July) to 2.46 mg/l (April). From the mentioned results, it is obviously that, nitrate contents in Lake Chamo showed also a relative narrow monthly fluctuation. Nitrate concentrations are dependent on the type of agricultural runoff. In the areas where nitrate is derived from organic pollution, the high nitrate may be accompanied by high chloride concentration.

4.2. Concentrations of Copper and Zinc in the Water of Lake Chamo

It appears that seasonal variations in the concentrations of trace elements in the lake are strongly dependent on both the drainage water discharged from the various drains in the lake as well as the velocity and direction of winds. The presence of trace metals in Lake Chamo is mainly of allochthonous origin due to either agricultural influx, wastes of farms or sewage via surrounding cultivated lands.

The distribution patterns of Cu and Zn in the Lake water increased in January and April which may be attributed to concentration of different ions in the lake due to excessive evaporation in January. January is characterized by dry season in the area and evaporation of water in aquatic environments are high during in this period and another reason why this two heavy metals increase in April may be the release of heavy metals from the surroundings due to runoff and also sediments to the overlying water under the effect of both high temperature and fermentation process resulted from decomposition of organic matter [4]. April is characterized by the second rainy season in the area and it is the time of farmers cultivation their crops. The increase of these heavy metals in this month might be due to runoff chemicals from fertilizers and pesticides from the surrounding. In addition, the values of Cu and Zn showed an obvious decrease in the water during October (cold period) due to precipitation of heavy metals from water column to the sediments under slightly high pH values and the adsorption of heavy metals onto organic matter and their settlement downward [10]. October is characterized by short heavy rainy season of the area.

5. Conclusion

This study revealed that the physicochemical variables such as temperature, DO, Alkalinity, TDS and Salinity of Lake Chamo were higher than the recommended standards and this affect the biota in the studied area and forms a public health problem.

The pH of this study showed that the lake water was slightly alkaline which might have an effect on the availability of dissolved metals.

The concentrations of dissolved Cu and Zn in the lake water were undetectable during the rainy season. However, these metals were detected in the samples of the water in the other three seasons.

Acknowledgement

We would like to express our heartfelt gratitude to Arbaminch university research coordinator office for the financial aid and Arbamiich city Fisheries Corporation for their unreserved and committed consistent support and guidance of our research.

Statement of Competing Interests

The authors have no competing interests.

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