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ASSESSMENT OF PHYSICOCHEMICAL PROPERTIES OF WATER FROM LAKE CHAMO

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ABSTRACT

Water collected from Lake Chamo was examined and its physicochemical properties were studied. This study was conducted between July 2014 and April 2015. This period covered four succeeding seasons. October and April were considered as the rainy season, whereas July and January were considered as the dry season. Water samples were collected from the lake from three random sites for every season. Totally, collections were made four times, one for every season. The collected water samples were subjected to physicochemical analyses to check its properties such as pH, electrical conductivity (EC), total dissolved solids (TDS), total alkalinity (TA), and total hardness (TH). In addition, levels of certain ions such as chloride (Cl^-), nitrite (NO_2^-), nitrate (NO_3^-), phosphate (PO_4^{3-}) and sulphate (SO_4^{2-}) were also quantified. Physicochemical properties varied with every season. High salinity was reported from the waters of the lake. This could be the cause for the deteriorating environmental conditions in the lake, as well as the reduction in fish production. The quantity of nitrite ions was also several-fold higher than the admissible limits. To conclude, the waters of Lake Chamo did not show much variation in its physicochemical properties for different seasons, except in its salinity and nitrite levels.

KEYWORDS: Lake Chamo, Water Quality, Physicochemical Properties

INTRODUCTION

Background and Basis for the Study

In comparison to other water bodies, lakes are polluted easily as a result of misuse, because lakes are capable of eliminating the pollutants relatively slowly. Even in the absence of pollution, eutrophication occurs. This is an aging process that gradually leads to the piling up of sediment and organic matter, which modify the basic features of the lake such as depth, biological productivity, oxygen levels, and water clarity (20).

Lake Chamo is beneath the Abaya–Chamo drainage basin, which is a sub-basin of the rift valley that crosses across Ethiopia midway in the north–south direction. Two lower lying lakes are the prominent features of the basin. Waters from two rivers, Kulfo and Sile, drain in to Lake Chamo. In turn, the overflow from Lake Chamo drains in to the Sagan River, which finally drains in to the Chew Bahir. Therefore, Sile, Argoba, Wezeka, and Segoare considered as the rivers that drain in to Lake Chamo. Apart from these rivers, the overflow from Lake Abaya confluences with river Kulfo, which ultimately drains in to Lake Chamo. Geographic data show the existence of a hydrological interconnection between the Abaya and Chamo lakes. This has been proved by the overflow from Lake Abaya, which flows in to Kulfo River, eventually ending up in Lake Chamo. Both lakes are located in different levels, and the difference between the two levels is 62 meters. Abaya lakeis located at a higher altitude than Chamo Lake. These lakes serve as a means for transport (Lake Abaya), fishery (Lake Chamo) and tourism. In addition, these lakes, alongwith its tributaries (rivers Bilate, Kulfo, etc.), help to irrigate the agricultural lands in the neighborhood. (1)

Literature reports a few studies on these two lakes. These studies dealt with the impact of enhanced upper catchment area activities and increased consumption of water from the tributaries of the two lakes. In some instances, death of wild animals has been reported. These deaths might have been because of the ingestion of toxins produced by the blue green algae (1).

Lake Chamo is one of the three large lakes in Ethiopia, only next to Lake Tana and Lake Abaya. It is located in a semi-arid region of the southwest part of Arba Minch town. It is an inland, closed basin, with only one evident natural outlet (Seganriver). The outlet stretches to about 118 Km shoreline length, with a maximum depth of 10 m.

Because of its geographic location, the waters of the lake are subjected to a high rate of evaporation (an average of about 2300 mm per year). The precipitation average is about 600 mm. Global climatic changes influence the climate of the region. In the past, climatic changes have lowered the precipitation peaks, thereby leading to shrinkage of the lakes. In addition, agricultural wastewaters drain into the lake, which enhances the chemical content considerably. The drainage of Arba Minch town flows into the Kulforiver, some of which enters into Lake Chamo. This bio augmentation gradually increases the salinity of the lake, significantly affecting the lake’s biota. Several flora and fauna are depleted from the lakes, resulting in sudden variation in the biodiversity of the lake (particularly fish species that the lake is known for). From time immemorial, this lake was recognized as a freshwater lake, with potential freshwater fish species. However, nowadays, with the increase in salinity, a steady decrease in fish population is being observed (1).

On the basis of these underlying observations, the characteristics of water from Lake Chamo were checked and its physicochemical properties were researched. In conclusion, appropriate inferences could be drawn and justified recommendations could be made to improve the environmental conditions of the lake.

MATERIALS AND METHODS

Study Area

Lake Chamois one of the largest lakes in the Southern Nations, Nationalities, and Peoples Region of southern Ethiopia. It is positioned in the Great Rift Valley at an altitude of 1,235 meters. Geographically, it is to the south of Lake Abaya and the city of Arba Minch, and east of the Guge Mountains. The northern end of the lake is part of the Nechisar National Park. As per the data published by the Central Statistical Agency, Lake Chamo is 26 kilometers in length and 22 Km in width. Its total surface area is 551 square kilometers, with a maximum depth of 10 meters. In the borders of the lake, abundant beds of Typha were noticed. Numerous wetlands were seen on the fringes. The catchment area was about 2220 square kilometers. Water from Kulfo River and numerous smaller streams, as well as overflow from Lake Abaya through the Kulfo River reached the lake. When Oscar Neumann explored this expanse in 1901, he discovered a dry channel that linked Lake Chamo to the Sagan River. On the basis of his discovery, he concluded that the lake feeds water to the Sagan during the heavy rainfall seasons. The fauna in the region comprises fish such as the Nile tilapia, catfish (Bagrusdocmac) and Nile perch. In addition, the lake is also home to the hippopotamus and Nile crocodiles.

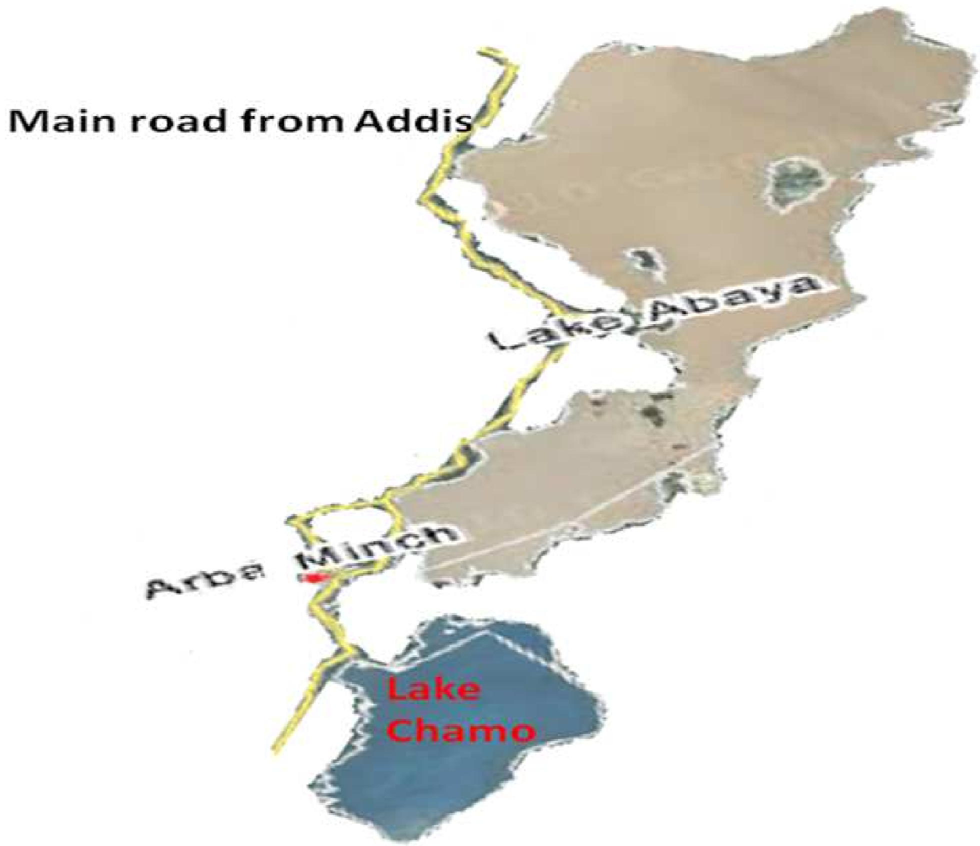

Figure 1: Lake Abaya and Lake Chamo Interlinked with the Main Road Connected Addis Ababa Andarba Minch

Protocol for Sampling and Experimentation

This study was conducted over four subsequent seasons in one year from July 2014 to May 2015.The seasons included two rainy (October and April) and two dry seasons (July and January). Sampling was done every season from three different localities (Kulfo, Centere, and Sile sites), which were located far apart and there by accounted for varying zones in the lake. The first site (Kulfo) is located close to the mouth of Kulforiver (~ 50m), the second site is more or less at the center of the lake and the third site is located close to the mouth of Sile river (~ 50m).

Polyvinyl chloride Van Dorn bottles of 2L capacity were used to collect the surface water (i.e. 15 cm depth). The chemical properties were analyzed using methods adopted by standard methods described in APHA (4).

Sample Preparation

The water samples were transferred to the laboratory. Straightaway, the samples were filtered, followed with acidification with HNO_3.The samples were then stored at 4^oCuntilfurther analysis.

Assessment of Physicochemical Properties

The physical properties of the water samples were also checked. These included temperature (°C) of the surface water, salinity (g/l), conductivity (mmhos/cm), dissolved oxygen (mg/l), and pH, which was measured using electronic portable meters and digital pH meter.

RESULT

Physicochemical Properties

Table (1) illustrates the physicochemical properties of Lake Chamo. In all sampling sites, water temperature was minimum (27.8°C) during the rainy season in October, whereasit was maximum during January (29.90°C) at the Kulfo site and in April (29.50°C) at Sile site. The average temperature of the lake was estimated as 28.58°C. Electrical conductivity (EC) was elevated 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 central site), whereas the least value (0.99 mmhos/cm) was documented during October at Sile site. The average total electrical conductivity was estimated to be 1.12 mmhos/cm. Total dissolved solids (TDS) wereat elevated levels during April (1100.00 gm/l) at Sile site, with the samples from the center of Lake Chamo showing the lowest readings in July (608.00 gm/l). The average TDS in all sites was 725.58 gm/l. Salinity levels in the lake were reduced at Sile site during July, January, and April (614.00 ppm),with the maximum value being documented in October (647.00 ppm) at Kulfo site, followed by the sample site at the center of the lake (646.00 ppm).The average salinity of Lake Chamo was estimated as 629.50 ppm.

The waters of Lake Chamo were alkaline in nature. The average pH was 8.66, with the lowest pH valuein July (8.10) at Kulfo site, and the maximum in January (9.00) at Sile site. Dissolved oxygen was recorded to be maximum during October (8.70 mg/L) at the center site, whereas the lowest reading was in April (7.54 mg/L) at Sile site. The average dissolved oxygen was estimated as 7.82 mg/l. Total alkalinity was least during October (1074.00 mg/l), with the highest values in April (1262.00 mg/l) from the site at the center of the lake. The average total alkalinity was 1142.25 mg/l. The average chloride levels were estimated as 142.08 mg/l, with the maximum value in April (153.61 mg/l) at Kulfo site and the minimum value in October (123.78 gm/l) at Sile site. On measuring the total hardness (TH) of water, least values were recorded during October (68.00 mg/l) at Kulfo site and at the center of the lake, whereas the highest value was documented in April (81.00 mg/l) at Kulfo site. The average total hardness of the lake was 75.17 mg/l. Nitrite levels varied with every season, with the lowest values in April (37.00 mg/l) at the center of the lake and the highest values also in April (52.00 mg/l).The average nitrite content was assessed to be 46.10 mg/l. Nitrate levels too varied with every season, with the highest readings in April (2.60 mg/l) and October (2.50 mg/l) at Sile site and the lowest reading sin October (0.60 mg/l) from the site at the center of the lake. The mean nitrate value was estimated as 1.62 mg/l. Phosphate (PO_4^{-3}) levels were highest in October (2.09 mg/l) at Sile site. The lowest levels (1.39 gm/l) of phosphate were also recorded from Sile site in July, and from the center of the lake in October. The average value of phosphate was estimated to be 1.76 mg/l. Sulphate ions (SO_4^{-2}) were estimated to be present at an average value of 69.45 mg/l. Sulphate ions had the maximum concentration at Sile site in the month of April (94.60 mg/l),and the least concentration was at the center of the lake in the month of October (42.76 mg/l).

Table 1: Monthly Variation of Physicochemical Parameters in Lake Chamo during the Study Period

Seasons	Temp Oc	Ec ms	TDS Mg/L	Salinity ppm	pH	DO ppm	TA Mg/L	TH Mg/L	Cl^- Mg/L	NO_2^- Mg/L	NO_3^- Mg/L	PO_4^{3-} Mg/L	SO_4^{2-} Mg/L
Sile Site													
July	29.10	1.07	618.00	614.00	8.47	7.86	1080.00	80.00	129.14	43.00	0.90	1.39	82.30
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
Jan	29.50	1.07	621.00	614.00	7.46	7.46	1080.00	80.00	130.14	42.50	0.80	1.49	84.20
April	29.30	1.27	1100.00	614.00	7.54	7.54	1084.00	86.00	131.14	52.00	2.60	2.46	94.60
Mean	29.20	1.10	737.75	622.00	8.70	7.82	1091.00	79.50	128.55	46.63	1.70	1.86	83.64
Center 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
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
Jan	27.60	1.06	645.00	624.00	8.90	8.43	1260.00	71.00	150.64	48.30	1.40	1.51	54.30
April	28.2	1.26	900.00	624.00	8.92	8.23	1262.00	74.00	152.67	37.00	1.20	1.91	59.30
Mean	27.65	1.12	701.00	629.5	8.63	8.52	1214.00	71.25	151.17	44.58	1.08	1.59	53.17
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
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
Jan	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
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
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
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

DISCUSSION

Aquatic pollution needs to be controlled. For this purpose, the waters of the aquatic bodies should be evaluated to obtain data regarding the physicochemical properties. These data help in the monitoring of aquatic pollution, and assist in the identification and quantification of toxicants present in aquatic bodies. In addition, for regulatory reasons, these data could be compared to estimate the permitted concentrations of toxicants for particular inflow water **(**14, 13). The perception that that water quality criteria determine any kind of water pollution control policy is definitely valid (12).

Physicochemical Attributes

Temperature: With the increase in the temperature in the month of January, the water of the lake too showed an increase in temperature. However, no thermal stratification was noticed, as the lake was shallow during this season (maximum depth of 10m). The minimum and maximum lake temperature was concurred 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^{0}c; (8)), Abijata and Langano (18-27^{0}c ; (10)) and A was sa (23.8-28.4^{0}c) (8) and other lakes, such as Lakes Kilole (18.5-24^{0}c; (5)), Babogaya (20.5-28.4^{0}c; (23)) and the Legedadi Reservoir (22.2-23.9^{0}c; (2)).

Electrical Conductivity: Electrical conductivity reading values increased during April. This is because of concentration of salts in the lake with the reduction in water level. This is a consequence of the rapid evaporation during the summer months. In addition, the drainage from other water bodies is also very low. During October (rainy season), the opposite effect occurs. The values are low in this season with the dilution of the salts by the drainage water, especially in areas with large inflow. The rains are the major contributory factor. Overall, EC had values higher than the threshold value of 200 μmhos/cm. This indicates severe eutrophication in these aquatic habitats (17).

Total dissolved solids (TDS): Total dissolved solids also increased in concentration during April. This is a consequence of the high rate of evaporation during the summer months, which reduce the water level in the lake. In addition, drainage water from the main drains was low. A reverse effect was noticed in the month of July with the TDS decreasing (608 mg/l). This is because of increase in water level in the lake with extensive drainage water, which is influenced by the heavy input of industrial and domestic is charge into the aquatic habitats between May and June (18). Increasing TDS has a severe impact on the survival and growth of fish (9).

Salinity: Increasing salinity, attributed to various other factors, was the main cause for the deterioration of environmental conditions of Lake Chamo and lowering of fish production. The highest value of salinity was recorded in October (647 mg/l). High rates in this month are a consequence of the high rate of evaporation in the region because of the summer season. The lowest value was recorded in July (614 mg/l).This month reported heavy inflow of water from Kulfo and other rivers.

pH: The pH of Lake Chamo was predominantly alkaline. Previous studies report that its pH range from a minimum of 8.10 (July 2008) to a maximum of 9.00 (January 2008). This study also reported similar pH values (11). However, the pH values of Lake Chamo are lower than the nearby crater lakes, such as Lake Bishoftu with pH 9.2 (24) and Babogaya with pH in the range of 8.84-9.09 (23). July month recorded the lowest pH. This could be ascribed to the disintegration of organic matter. Furthermore, with increasing photosynthesis with increasing biota, the pH values increased comparatively during January. Photosynthesis reduces the CO_2levels in water, and simultaneously increases the oxygen content. Increased pH in the lake is because of the low levels of dissolved oxygen. There is a negative correlation between pH and dissolved oxygen.

Dissolved oxygen: Dissolved oxygen had its highest value of 8.7 mg/1 in October. This is mainly a consequence of the decrease in temperature and prevailing winds action that increase the solubility of atmospheric oxygen (16). The values relatively dropped during April (7.54 mg/l) with the onset of summer. This is because of increase in water temperature that leads to decrease in the solubility of oxygen gas (15). The oxidation of organic matter by the microbial activity of microorganisms also consumes a part of the dissolved oxygen. However, the oxygen concentration of the surface water of Lake Chamois generally similar to thatof other Ethiopian lakes, such as Lake Kilole (3.4 to 10.6 mg O2 l-1) (5), and Lake Babogaya (2.75-15.8 mg O2 l-1) (23).

Alkalinity: Total alkalinity content increased in April, the summer season, and decreased in October, the rainy season. Bicarbonate content increased significantly during April because of the decrease in water and air temperatures, which caused precipitation of calcium bicarbonate. Reduction of lake water by its usage in irrigation and evaporation may increase the alkalinity. Irrigation is one the major reasons for water output. The input–output relationship determines the extent of evaporative concentration of ions (22). Reduction in inflows, mainly because of diversion for other purposes, has been considered to be the main cause for the increase in salinity of this lake as well as several other large and permanent lakes in the world during the last several decades (21).

Chloride: Individual salt concentration was also high in April and low in October. This trend was observed for chloride concentration as well. This is attributed to the high rate of evaporation and low water levels during April. In addition, there is reduced is charge run off during April. Agricultural runoff was one of the major contributory factors for the low value of chloride in October. This month reported a total increase in discharged runoff.

Total Hardness: The general seasonal trend with progressive increase during April and decrease during October was noticed with regard to the total hardness also. The increase April is attributed to the increase in dissolved oxygen with temperature decrease, and the decrease in October is attributed to the carbonic acid decrease, which causes precipitation of $CaCO_3$.

Nitrite: Nitrite contents in Lake Chamo reported relatively limited monthly fluctuations, even though a slight increase was noticed during April and October. This increase could be because of the oxidation of existing ammonia, which generates nitrite as an intermediate in the reaction (19). European Economic Community standards (3) have set 100 μg/l as the maximum admissible limit for nitrite in natural water. Lake Chamo surpasses this admissible level by several folds. Increasing organic pollutants or domestic wastes is the major triggering factor. Nitrite poisoning causes fish mortality by converting hemoglobin to form methemoglobin (6, 7).

Nitrate: Nitrate is a fundamental plant nutrient. Its increase in one of the major contributors for eutrophication (9). In Lake Chamo, the nitrate values also reported limited variation, with insignificant monthly fluctuation. This is a similar trend as nitrite. Nitrate level sranged between 1.39 mg/l (July) and 2.46 mg/l (April). Agricultural runoff was the major contributory factor for nitrate concentration. In the areas where nitrate originated from organic pollution, high nitrate content was accompanied by high chloride concentration.

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