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Research Article

Effect of Season on the Concentration of Nutrients in the Three Highland Lakes of Ethiopia

Takele Shitaw*, **Lammessa Berisa**, **Berhan Asmamaw**

Department Animal Biodiversity, Ethiopian Biodiversity Institute, Addis Ababa, Ethiopia

ABSTRACT

Water resource contamination is still a major concern in several regions of developing countries especially in sub-Saharan countries in which polluted waters pose serious risks to human health and the environment. The research was aimed to evaluate the current water quality status of highland Lakes (Ardibo, Logo and Tana) of Ethiopia in different season and to identify potential pollution sources sites. Physico-chemical water quality parameters have been determined by taking duplicate samples from three sampling sites of each lake and the results were compared with WHO and FAO standards. The result of the study indicates nutrients concentration to be Alkalinity (428, 269.945, 109.935 mg/L), calcium (31.542, 46.873, 77.12 mg/L), chloride (89.165, 77.5, 40.125 mg/L), magnesium (94. 755, 93.165, 39.396 mg/L), NH_3 (0.418, 0.184, 0.6493 mg/L), NH_4 (0.433,0.145, 0.753 mg/L), potassium (1.299,19.325, 6.547 mg/L), sodium (22.489,39.5, 10.671 mg/L) and sulphate (2, 2.075, 1.479 mg/L) in Lake Logo, Ardibo and Tana, respectively. The concentration of Calcium and NH_4 were significantly more abundant in rainy season than dry season ($p<0.01$) and the concentration of Chloride, magnesium, Potassium, Sodium and Sulphate were significantly more abundant in dry season than rainy season in lake Ardibo ($p<0.01$). The concentration of NH_4 were significantly more abundant in rainy season than dry season and the concentration of magnesium were significantly more abundant in dry season than rainy season in lake Tana ($p<0.01$) and also the concentration of alkalinity, magnesium, and sulphate were significantly more abundant in dry season than rainy season in Lake Logo and the concentration of NH_3 and Potassium were significantly more abundant in rainy season than dry season ($p<0.01$). The concentration of NH_3 and NH_4 were 0.6088 mg/l, 0.679 mg/l in rainy season and 0.6897 mg/l, 0.8083 mg/l in dry season respectively in Lake Tana. As the result shown that the concentration is higher in rainy season and the main reason for these results were the storm water and sediment load from different catchment of the lake released in the form of run off and soil erosion. The farmers use fertilizer to increase their crop production since NH_4 and NH_3 are directly released in to the lake in the form of runoff hence the concentration of these nutrients increase in rainy season.

Keywords: Highland lakes; Potassium; Eutrophication management

INTRODUCTION

Water is essential to human being, animals, and plants and without water life on earth would not exist. Humans need water not only for drinking but also for various other purposes like bathing, washing, cooking, industrial, agricultural, and recreational activities. Therefore, adequate supply of potable water is necessary for proper health care and significant socio-economic development. However, water resources all around the world are under pressure and especially eutrophication is a major environmental problem. This raises the need to address the problem of water pollution with the view of monitoring the situation and formulating possible mitigating measures. Monitoring the water quality is used to assess the usability of that water for a particular purpose, whether for human consumption, agricultural production, industry or the needs of the environment. During the last decades, there has been an increasing demand for monitoring water quality of many rivers by regular measurements of various water quality variables [1,2].

Specifically, the identification of the interactions governing water quality in the three highland Lakes of Ethiopia at the watershed scale is required to precisely characterize water quality degradation processes and to construct an integrated water quality management

Correspondence to: Dr Takele Shitaw, Department Animal Biodiversity, Ethiopian Biodiversity Institute, Addis Ababa, Ethiopia, E-mail: takeleshitaw30@gmail.com/bichiruet@yahoo.co.uk

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plan at the watershed scale. Sources of pollutants are derived from diverse sources in watershed systems, mostly originated from non-point sources (NPS) compared to point sources (PS). Nutrients and eroded sediment from agricultural fields cause deterioration of water quality in agricultural watersheds. The increasing fertilizer overuse beyond crop uptake influences water quality by transporting nutrients from the croplands to water bodies. The major challenges of Most Ethiopian highland lakes are sedimentation in the form of runoff from the upper catchment and pollution by transporting nutrients from the croplands to water bodies. Eroded sediments are transported from agricultural areas into streams through frequent soil disturbances and land-use changes. The transported sediments to inland waters have Been considered a major problem for the management of water quality, causing severe economic implications. Even if the two Lakes (Logo and Ardibo) are far from the point source pollution like industry, domestic sewage, hospitals, hotels, and others which release the waste directly in to lake Tana, high amount of nitrite and nitrate is released from the upper agricultural lands. So, the municipal administration and other service rendering sectors should provide a wastewater treatment plant in Lake Tana and buffer zone enclosure in lake Logo and Aridibo to reduce the pollutants entering the lakes [3-6].

MATERIALS AND METHODS

Description of the study areas

Lake Tana is the largest lake in Ethiopia with an area of about 3200 km2 and located in the northwestern highlands of Ethiopia at an altitude of about 1800 m with an average depth of 8 m and maximum depth of 14 m. It is the only source of the Blue Nile River and constitutes almost half of the freshwater bodies of the country. Lake Tana, the third largest lake in Africa next to Victoria and Tanganyika, originated by the blocking of Blue Nile River with volcanic basalt two million years ago. It is characterized by low nutrient concentrations, relatively high silt concentrations with a loading rate of 8.96-14.84 million tons of soil per year and the trophic status is oligotrophic to mesotrophic. The Lake Tana area has a warm climate with four years mean annual rainfall of about 1564 mm, of which 59 percent falls in the months of July and August, when the mean rainfall can be 444-483 mm per month. The seasonal rains cause the lake level to fluctuate regularly with an average difference between the minimum, in May-June, and maximum in September-October of about 1.5 m. Lake Tana and its adjacent wetlands both directly and indirectly provide a livelihood for more than 500 000 people and about three million people live in the catchment. This Ethiopia's largest lake is source of Blue Nile. The only out flowing river is Blue Nile [7-14].

Lake Ardibo is located between 1114'°N latitude and 3946' °E longitude at an elevation of 2120 meters above sea level (m a.s.l) in northern Ethiopia. The surface area of the lake and its catchment is 15.8 $km^2$and 52.6 km^2, respectively. The Lake Ardibo catchment is closed drainage within the northwestern watershed of the Awash River basin, near the headwaters of the Mille River. The area is dominantly hilly and intensively cultivated. High altitude areas are characterized by scattered bushes and grazing fields. The climate is sub-humid with an average annual temperature and rainfall of 18°C and 1158 millimeters (mm), respectively [15].

Lake Logo is one of the highland lakes of Ethiopia located in the Northern part of Ethiopia, Amhara Regional State, South Wollo Administrative Zone, at 11°15' N latitude, 39°57' E longitude, and at an altitude of 2,030 m above sea level. It is a crater lake with surface area, maximum depth, and means depth of 23.2 km2, 88 m, and 37.4 m, respectively. The only stream of any size entering the lake is the Ankarka River, which flows to its southeast corner. The lake has no visible outlet. A small town called Haiq is located at the southern shore of the lake. The water level of the lake fluctuates with the variability of rainfall, its maximum volume being during the rainy season. The area is characterized by a sub-humid tropical climate with an average annual rainfall of 1211.4 mm and a mean annual temperature of 25.9°C (Figure 1) [16].

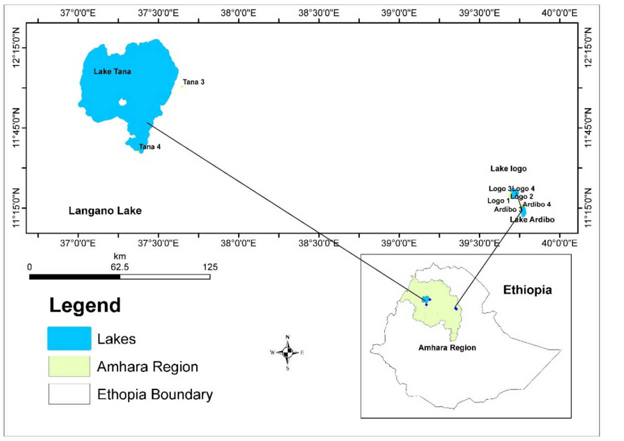

Figure 1: Marked shoulder subluxation.

Sampling and data collection

Water samples were collected from the three highland lakes of Ethiopia (Tana, Logo, and Ardibo) during the peak of dry and wet seasons of 2018-2019. The samples were collected from three different sites (at the reference, moderate, and more suspected of pollution from each of the three lakes. Water samples from all of the three lakes were taken from three different sampling sites by observing the surrounding ecosystem of the lakes and after the sites were selected as the more pollution suspected, less pollution suspected and the reference. The water samples of each lake were taken by using dry 300 ml bottles. Then those samples were transferred to Addis environmental service laboratory. In this laboratory different water quality parameters like alkalinity, calcium, chloride, magnesium NH_3 and NH_3 were analyzed from those samples which were collected from the three lakes. Nitrate and nitrite (NH_3 and NH_4) were measured as nitrite cadmium reduction methods and also Calcium, magnesium, potassium, and sodium were determined by the atomic absorption spectrometric method. Chloride was determined by mercuric nitrate-nitrogen titrimetric method and sulfate was determined by turbid metric method or gravimetric method. DO, temperature, and pH were measured at the field by multiprobe pH meter [17].

Data analysis

For data analyses, the SPSS version was used to analyze the collected data. Descriptive statistics were used to determine the Mean ± Std. Deviation of physicochemical water quality parameters and the nutrient concentration of the three Lakes. The spatial and temporal variations of each nutrient were analyzed by Chi-Square Tests.

RESULTS

As in Table 1 the results shown above the conductivity Lake Ardibo is low and similar at the three sampling sites (255, 268,255) in the pollution suspected, moderate and reference sites respectively. The conductivity of Lake Logo and Lake Tana is high and the value is different in each three different sites (367, 437,380), (460, 456, 441) pollution suspected, moderate and reference site respectively.

The conductivity is increases as the concentration of TDS increases. TDS and conductivity affect the water sample and the solubility of slightly soluble compounds and gases in water. The corrosiveness of the water increases as TDS and EC increase. As the result shown above Total dissolved solids (TDS) of Lake Tana was (0.334 mg/l, 0.103 mg/l, 0.095 mg/l) at the pollution suspected, moderate and reference site respectively. Is a measure of salt dissolved in a water sample after removal of suspended solids? The TDS load carried in streams throughout the world has been estimated by Livingston to 120 mg/L (Tables 2 and 3).

The result indicated that the concentration of NH_3 and NH_4 exceeded the WHO standard due to point sources pollution from factory, ceramics, Hotels, Hospital, domestic swage in Lake Tana and the increasing fertilizer overuse beyond crop uptake influences water quality by transporting nutrients from the croplands to the three lakes (Tana, Logo and Ardibo). Moreover, the study indicated that the three Lakes have also been polluted by non-point source pollution caused by, agricultural runoff, overgrazing, deforestation, soil erosion, and land development. Therefore, intervention measures should be put in place to prevent pollution of the lake. The nutrient concentration value in dry and rainy seasons gives different superscript letter were significantly different in chloride, magnesium, and NH_4. The concentration of NH_4 was significantly more abundant in the rainy season than in a dry season and the concentration of magnesium was significantly more abundant in the dry season than in the rainy season in Lake Tana (Table 4).

Table 1: The physicochemical water quality parameter of the three highland lakes of Ethiopia at each three sampling sites.

Lake	Sampling site	Parameter	Mean value
Ardibo	Polluted	Temperature	22.2°C
		Conductivity	255 ppm
		Seci -disk	1.64 m
	moderate	Temperature	22.1°C
		Conductivity	268 ppm
		Seci disc	1.8 m
	reference	Temperature	21.1°C
		Conductivity	255 ppm
		Seci-disck	2.10 m
Logo	polluted	Temperature	23.9°C
		Conductivity	367 ppm
		Seci-disk	4.165 m
	moderate	Temperature	23.1°C
		Conductivity	437 ppm
		Seci-disck	3.945 m
	reference	Temperature	24.3°C
		Conductivity	380 ppm
		Seci-disck	3.967 m

Tana	Polluted	Temperature	21.50°C
		Conductivity	460 ppm
		TDS	0.334 mg/l
		DO	7.78 mg/l
		PH	6.75
	moderate	Temperature	21.98 0C
		Conductivity	456 ppm
		TDS	0.103 mg/l
		DO	7.84 mg/l
		pH	6.67
	Reference	Temperature	21.3°C
		Conductivity	441 ppm
		TDS	0.095 mg/l
		DO	7 mg/l
		pH	6.8

Table 2: A mean value ± SD and WHO maximum allowable concentration for drinking of the nutrients.

Season	Site	Alkalinity	Calcium	Chloride	Magnesium	NH3	NH4	Potassium	Sodium	Sulfate
Dry	Ardibo polluted	237.500 9.257	33.5	108.50023.274	108.500 ± 50.763	0.1825	0.1975	5.225	52	2.7500 ±
	Ardibo moderate	287.500 ±11.506	49	89.5000 ± 22.274	150 ± 15.345	0.165	0	50.5	50.5	1
	Ardibo reference	282.5	46.5	85.5000± 21.273	125 ± 50.763	0.14	0	49.5	49.5	2
wet	Ardibo polluted	430.0000 ± 7.07107	29.0000 ± 12.02082	91.0000 ± 22.274	260.0000 ± 97.22	4920 ± .144	.5330 ± .15698	.0100 ± 6.71	8.8000 ± 64.488	4.0000 ±1.76777
	Ardibo moderate	430.0000 ± 10.606	31.5000 ± 7.601	87.0000 ± 25.1023	250.0000 ± 90.156	3600 ± .0778	3315 ± .1298	1.4500 ± 6.046	.1350 ± 70.438	.5000 ±.7071
	Ardibo reference	420.0000 ± 14.142	33.2500 ± 2.475	87.0000 ± 25.1023	250.0000 ± 90.156	.3600 ± .078	.3315 ± .1298	1.4500 ± 6.046	.1350 ± 70.438	.5000 ±.70711
Dry	Logo polluted	430.000 ±7.345	35.0000 ± 3.475	81.0000± 20.173	250.000 ± 56.765	3960	0.429	0	0.9854	2.000 ±
	Logo moderate	440.000 ±.9.856	46.000 ± 10.543	122.500± 19.374	122.500 ± 25.356	0.695	0.755	9.5	100	1.5
	Logo reference	282.500 ± 12.432	46.500 ± 14.000	85.500 ± 23.274	1250 ± 11.253	0.14	.0000±	49.5	49.5	2
Wet	Logo polluted	193.7500 ± 8.839	123.7500 ± 35.002	59.0000 ± 19.799	55.2500 ± 10.253	100.845 ± 140.226	107.80± 130.390	17.5500 ± 23.052	17.4875 ± 12.039	3.000 ± .70711
	Logo moderate	420.00 ± 14.142	33.250 ± 2.475	98.000± 24.042	168.750±14.949	.4080 ± 017	4420 ± .01838	4.875± 6.894	54.00±63.649	1.000 ± 1.4421
	Logo reference	193.7500±8.839	123.7500 ± 35.002	59.000 ± 19.799	55.2500 ± 10.253	100.845 ± 140.226	107.80 ± 130.390	17.550± 23.052	17.488± 12.039	3.000 ± .707
Dry	Tana polluted	281.2500 ± 8.839	49.000 ± .000	59.250±42.781	39.2500 ± 18.890	0.0675	0.0725	1.5	1.5	8.25
	Tana moderate	193.7500 ± 9.124	123.7500 ± 2.456	59.0000±17.025	55.2500 ± 33.456	0.845	0.8	17.55	17.488	3
	Tana reference		54.5000 ± 44.000	66.5000 ± 59.397	83.000 ± 36.062	.1410±.013	1540±.016	2.3600 ± 3.24	27.750 ± 32.173	5000 ±.70711
Wet	Tana polluted	66.25	51.0000 ± 14.000	37	48	1.69	15.6	1.5	8.25	0.75
	Tana moderate	200.000 ± .684	99.000 ± 15.000	73	62.5	0.0675	0.075	1.5	8.25	0.75
	Tana reference	66.8750 ± .884	51.2500 ± .354	25.5000 ± 16.263	27.6250 ± 16.440	.3098 ± .343	3353 ± .372	7825 ± 1.015	5.3500 ± 4.101	6250 ± .177
WHO maximum allowable concentration for drinking		200	200	250	150	1.5	1.5		250	250

Table 3: Chi-square tests to compare the nutrient concentration variation between seasons in Lake Tana.

Season	Alkalinity	Calcium	Chloride	Magnesium	NH3	NH4	Potassium	Sodium	Sulfate
Dry	108.83	77.08	42.0	41.416	0.6088	.697	6.666	11.135	1.5
Wet	111.04	77.16	38.25	37.375	0.6897	.8083	6.4275	10.206	1.458

Table 4: Chi-square tests to compare the nutrient concentration variation between seasons in Lake Logo.

				Nutrient					
Season	Alkalinity	Calcium	Chloride	Magnesium	NH3	NH4	Potassium	Sodium	Sulfate
Dry	430	31.833	86.33	253.3	0.416	0.431	0.487	24	2.167
Wet	426	31.25	92	226.25	0.42	0.4355	2.112	20.978	1.833

The nutrient concentration value in dry and rainy season gives different superscript letter was significantly different in magnesium, alkalinity, Potassium, and sulfate. The concentration of alkalinity, magnesium, and sulfate was more abundant in the dry season than in the rainy season in Lake Logo and the concentration of NH_3, and Potassium was significantly more abundant in the rainy season than the dry season (Table 5).

The nutrient concentration value in dry and rainy season gives different superscript later were significantly different in Calcium, Chloride, and magnesium, NH_3, NH_4, Potassium, Sodium and Sulphate. The concentration of Calcium, NH_3 and NH_4 were significantly more abundant in rainy season than dry season and the concentration of Chloride, magnesium, Potassium, Sodium, and Sulphate were significantly more abundant in the dry season than in the rainy season in Lake Ardibo (Table 6).

The nutrient concentration value in the three sampling sites gives different superscript letter other than NH3 was significantly different. The concentration of Alkalinity, Calcium, Magnesium, Potassium, and Sodium, and chloride was more significantly abundant in Tana polluted sites than Tana moderate and Tana reference (Table 7).

The nutrient concentration value in the three sampling sites gives different superscript letter in; Magnesium, Potassium, Sodium, NH_4, and Sulphate were significantly different in Lake Logo. The concentrations of Alkalinity, Calcium, Chloride, and NH_3 were not significantly different in the three sampling sites of Lake Logo (Table 8).

Table 5: Chi-square tests to compare the nutrient concentration variation between seasons in lake Ardibo.

				Nutrient					
Season	Alkalinity	Calcium	Chloride	Magnesium	NH3	NH4	Potassium	Sodium	Sulfate
Dry	268.66	42.83	94.5	109.5	.1625	.06583	35.075	52	2.375
Wet	271.23	50.916	60.5	76.835	0.205	0.224	3.574	27.05	1.775

Table 6: Chi-square tests to compare the nutrient concentration spatial variation between three sites in lake Tana.

				Nutrient's concentration					
Site	Alkalinity	Calcium	Chloride	Magnesium	NH3	NH4	Potassium	Sodium	Sulfate
Pollution suspected	193.75	123.5	59	55.25	0.8795	1.00925	17.55	17.487	3
moderate	72.5	56.5	30.25	42.5	0.8795	1.2185	0.95	7.6	5.875
reference	66.563	51.125	31.25	33.438	0.233a	.521	1.141	6.8	.875

Table 7: Chi-square tests to compare the nutrient concentration spatial variation between three sites in lake Logo.

				Nutrient's concentration					
Site	Alkalinity	Calcium	Chloride	Magnesium	NH3	NH4	Potassium	Sodium	Sulfate
Logo polluted	430	31.5	87	250	.36	0.533	1.145	0.135	0.5
Logo moderate	430	29	91	260	0.492	0.332	0.01	8.8	4.00
Logo reference	425	34.125	89.5	209.375	0.402	0.2145	2.4375	27	1.5

Table 8: Chi-square tests to compare the nutrient concentration spatial variation between three sites in lake Ardibo.

	Nutrient's concentration								
Site	Alkalinity	Calcium	Chloride	Magnesium	NH3	NH4	Potassium	Sodium	Sulfate
Ardibo polluted	271.875	51.75	78	83	0.1537	0.077	28.32	26.1	3.825
Ardibo moderate	284.375	41.25	83.875	90.375	0.153	0.077	26.43	39.13	0.75
Ardibo reference	274.375	47.875	70.625	75.25	0.2363	0.181	26.05	38.4	1.5

DISCUSSION

Total Hardness (TH), calcium and magnesium

The nutrient concentration value in the three sampling sites gives different superscript letter in, Alkalinity, Chloride, Magnesium, Sodium, and Sulphate were significantly different in lake Ardibo. But the concentration of Calcium, NH_3, NH_4 and Potassium were not significantly different in the three-sampling site of Lake Ardibo.

The total hardness values or the concentration of calcium and magnesium variation shows with an average value of 65.59 mg/l, 135.67 mg/l and 64.92 mg/l in lake Tana, Logo, and Ardibo, respectively. All values of total hardness are within the limits prescribed by WHO for drinking water purposes, (<500 mg/l). In this study, the observed values for Ca were 56-123 mg/l, 29-34 mg/l, 41.25-5175 mg/l with an average of 89.5 mg/l, 31.54 mg/l, 46.958 mg/l and those for Mg ranges from 33-56 mg/l, 209.375-260 mg/l, 75.25-90.375 mg/l with an average value of 44.5 mg/l, 239.79 mg/l and 82.875 mg/ lake Tana, Logo and Lake Ardibo, respectively. The concentration of calcium and magnesium in the three lakes is not beyond desirable limits. Great amount of magnesium imparts a repulsive taste to the potable water but in the current study the concentration was below the value recommended by WHO [18,19].

Sodium and potassium

The concentration of sodium ranged 6.8 to 17.487 mg /l, 0.135 to 27 mg/l, 26.1 to 39.13 mg/l with an average value of 10.629 mg/l, 11.978 mg/l and 34.53 mg/l in Lakes Tana, Logo and Ardibo, respectively. In all the sampled sites the concentration of sodium is lower than the permissible limit of WHO 200 mg/l. More consumption of sodium may cause hypertension, congenital heart diseases, and kidney problems. According to Chin, elevated concentrations of Na in surface waters may arise from sewage and industrial effluents that directly join lake water. In the present study both K+ and Na+ were not beyond the prescribed permissible allowable limits of WHO, which is 10.629 mg/l, 11.978 mg/l, 34.53 mg/l for Na and 6.5 mg/l, 27.1 mg/l, 1.198 mg/l for K [18-20].

Chloride

The existence of chloride in water in excess amounts is not desirable. In the present investigation, the concentration of Cl^- ranges between 30.25 mg/l to 59 mg/l, 87 mg/l to 91 mg/l, 70 to 83.875 mg/l with an average value to the lakes 40.125 mg/L, 89.17 mg/l and 77.5 mg/l in lakes Tana, Logo and Ardibo, respectively which is in far below the prescribed limits of WHO, 250 mg/l for drinking water. Its concentration above that imparts water taste and may harm metallic pipes [18,20].

pH

The pH of the Lake Tana water ranged from 6.8 to 7.675 with an average value of 6.74. The high value of pH (7.675) in the wet season is due to the rainfall, which may dilute the alkaline substances or the dissolution of the atmospheric carbon dioxide. The pH of Lake Tana is low when compared with the previous researches done by Goraw Goshu (pH=7.7- 8.7). These may reveal the increment of organic matter load from different point source pollution like Hotels, Hospitals, universities, and storm water to the Lake Tana lake ecosystem. The pH of Lake Tana is within the permissible limits of for drinking, recreation, agricultural and aquatic life water use (6.5-8.59) [21-24].

Dissolved oxygen: The result of this study indicated that the amount of dissolved oxygen of Lake Tana is found in the range of 7 mg/l to 7.84 mg/l and the average of the three-sampling site were 7.54 mg/l. The amount of dissolved oxygen in lakes is dependent on the water temperature, the quantity of sediment in the lakes, the amount of oxygen taken out of the lakes by respiring and decaying organisms, and the amount of oxygen put back into the lakes by photosynthesizing plants, stream flow, and aeration. The temperature of lake water influences the amount of dissolved oxygen present; less oxygen dissolves in warm water than cold water. For this reason, there is cause for concern for streams with warm water. Trout need DO levels above 8 mg/liter, striped bass prefer DO levels above 5 mg/l, and most warm-water fish need DO more than 2 mg/l [25,26].

Nitrate

In all observed sampling sites, the amounts of nitrate concentration of the lakes were below the permissible limit of WHO for drinking uses which is 10 mg/l. According to Murdoch High nitrate content (>1 mg/l) is not conducive for aquatic life. Nonetheless, in unpolluted waters, the level of nitrate is usually less than 0.1 mg/l. The highest mean value of nitrate at the pollution suspected site in Tana, Logo and Ardibo, respectively were 0.8795 mg/l, 0.492 mg/l, 0.235 mg/l and the concentration of nitrite at the pollution suspected site in lakes Tana, Logo and Ardibo, respectively were 1.22 mg/l, 0.533 mg/l, 0.343 mg/l. The average value of nitrate in lakes Tana, Logo and Ardibo, respectively were 0.664 mg/l, 0.0418 mg/l, 0.1947 mg/l and nitrite were 0.917 mg/l, 0.533 mg/l,0.181 mg/l. The concentration of NH_3 and NH_4 in the water collected from lake Tana were 0.6088 mg/l, 0.679 mg/l in rainy season and 0.6897 mg/l, 0.8083 mg/l in dry season, respectively [20,27,28].

As the result indicated, the concentration is higher in the rainy season and the main reason for these results were the storm water and sediment load from the different catchment of the lake released in the form of runoff and soil erosion. These may be due to organic wastes from Hotels, Hospitals University, etc.., agricultural fertilizers, intensive livestock operations, surface runoff, sewage discharge, and atmospheric deposition into the Lake Tana through the different catchments in the rainy season. In the normal status, a lake nitrite level is never greater than 0.001 mg/l, however, in Lake Tana it reaches 0.917 mg/l. Chi-square tests indicated that the concentration of NH_4 in the polluted, moderate sampling site, and reference sampling site in lake Tana were significantly different ($p<0.01$). Author's observation of direct waste water disposal without treatment in more pollution suspected site (Bilu Nile Hotel, Felegehiwot Hospital, and Tayitu Resort), was supported by the laboratory result. In the moderate site, untreated waste water was also disposed from ADA building and Bahir Dar university to the Lake, but because there is a natural wetland in between these point sources and the lake that purifies the waste water, the concentration of NH_4 was relatively low. Moreover, the head of Blue Nile River is facing serious problem of waste effluents (discharges) from Bahir Dar City, Agricultural activities in the surrounding wetlands, solid and liquid waste disposal at the shoreline of Lake Tana. NH4 level indirectly affecting the spawning site of Laboebarbus fish species that are endemic to Ethiopia [29-34].

The concentration of NH_3 and NH_4 was higher in the rainy season than dry season in Lake Ardibo. Sediment loads from different catchment of the lake released ammonia and nitrate in the form of run of and soil erosion. The surrounding catchment of Lake Ardibo is agricultural field where farmers use ammonia and nitrate to increase their crop production. In the rainy season, these nutrients are directly released into the lake in the form of runoff and soil erosion. Even if the concentration of NH_3 and NH_4 has not shown a significant difference in the rainy and dry season in Lake Logo the average concentration is beyond the desired limits (nitrate is usually less than 0.1 mg/l). Aquatic life is dependent upon these photosynthesizes, which usually occur in low levels in surface water. Excessive concentrations of nutrients, however, can overstimulate aquatic plant and algae growth. Bacterial respiration and organic decomposition can use up dissolved oxygen, depriving fish and invertebrates of available oxygen in the water (eutrophication). The study has shown that the concentration of metals such as manganese, calcium, sodium, potassium and nutrients like, Nitrate and Nitrite were found above the recommended WHO standard for drinking purpose and this could have an adverse impact on aquatic life and humans and animals that uses the lake water for various purposes [26].

CONCLUSION

Elevated levels of these metals and nutrients could be due to point source pollution from ceramics, Hotels, hospital, University and other small loges located near streams that end up into the lake. Thus, Bahir Dar City Administration should take measures to check the effluents of those point source pollutants in order to meet the requirements of effluent discharge limits and prohibitions in lake Tana. Furthermore, the three lakes also faces non-point source pollution caused by urban storm water, agricultural runoff, over grazing, deforestation, soil erosion and land development as it was indicated by elevated levels of TDS, EC, turbidity, calcium, magnesium and potassium. As a result, the federal government, Amhara Regional Stat and Bahir Dar City Administration along with other NGOs, physical soil and water conservation measures with ultimate intention of reducing sever soil erosion and its associated impact in communal and private lands of the upper catchments of Lake Tana, Logo and Ardibo watershed should be put in place in order to rehabilitate the condition of the of the three lakes. Nonetheless, the condition of the lakes will continue to deteriorate unless intervention measures are put in place.

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There are many different point and non-point source pollutants threatening aquatic life in the studied lakes. These water bodies and the life they sustain would be safe and sound if corrective measures are taken by all the concerned stakeholders at different levels. As any scholars know in flowing rivers carry heavy loads of soil and suspended sediment into the lake, which affects the water quality and creates favorable conditions for the spread of water hyacinth. The release of untreated waste water from point source pollutant around the lake adds to the deterioration of the lake ecosystem. So those stakeholders who are responsible for waste disposal of Lake Tana should give a grate attention for the sustainability of the lake ecosystem by constructing water treatment plant before the release the waste in to the lake. The land management and planting should be improving at the upper catchment of Lake Logo and Ardibo to reduce the nutrient loads from the agricultural land sites.

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