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Assessment of Water Quality and Identification of Pollution Sources of Lake Hawassa, Ethiopia

Melaku Zigde[1], Endale Tsegaye[1] and Fiseha Tadele[2]

[1]Chemistry Department, College of Natural and Computational Science, Hawassa University, Hawassa, Ethiopia.

[2] Bore, Guji Zone, Oromia, Ethiopia.

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ABSTRACT

This research aimed to evaluate the current water quality status of Lake Hawassa in order to identify potential pollution sources, and put in place monitoring programs. Eleven potential sampling sites were included in the study. Selected water quality parameters were considered and the results were compared with WHO and FAO standards. And the values of TDS (381.7 to 1286.0 mg/L), SC (733.7 to 2151.3 µS/cm), turbidity (8.20 to 87.3 NTUs), BOD_5 (4.02 to 76.2 mg/L) , phosphate (0.348 to 1.90 mg/L), fluoride (11.6 to 17.5 mg/L), chromium (0.173 to 0.665 mg/L), manganese(0.133 to 1.83 mg/L), and copper (1.40 L to 18.2 mg/L) were found above the prescribed limit of WHO guidelines for drinking purposes, while all the analyzed water quality parameters fall within the FAO standard limit for irrigation purposes. These suggested that both point and non-point pollution sources such as human sewage, industrial waste from ceramics, dyes, plastics and food processing industries, urban stormwater, agricultural runoff and land development were impacting the lake. Thus, mitigation measures should be put in place to prevent the Lake from further deterioration.

Introduction

Water is an indispensable and basic element which supports life and the natural environment, a prime component for industry, a consumer item for human beings and animals and a vector for domestic and industrial pollution. Access to adequate water for domestic purposes, irrigation, and sanitation are the three basic needs which impact significantly on socio-economic development and the standard of life. In general, urbanization, industrialization, agricultural activities, and tourism as well as population growth, changes in climate and lifestyle put increasing constraints on water resources and ecosystems [1].

Ethiopia is endowed with a number of lakes and large rivers which gives immense value to overall economic development. For instance, the country has twelve river basins, eleven fresh lakes, nine saline lakes, four crater lakes and over twelve major swamps/wetlands. The Rift Valley Lakes Basin (RVLB) is a hydrologically closed basin, characterised by terminal lakes; those with no surface water outlet. Four of the seven main lakes of the RVLB are terminal in themselves, and those which are not (Ziway, Langano and Abaya) flow into terminal lakes and are thus part of a terminal lake system. Ethiopian Rift Valley Lakes have significant environmental, economic and cultural importance to the region [2].

Among freshwater resources, Lake Hawassa is one of the major Rift valley lakes in Ethiopia and used for various purposes by semi-urban and urban dwellers [3,4]. It is considered to be the livelihood of all business created along the shore and plays a great role in tourism, investment, and biodiversity conservation. However, the lake faces high risk of pollution as a result of natural activities such as erosion and heavy rainfall and anthropogenic activities such as urbanization, intense agriculture, rapid industrialization, growth of population, urban runoff and municipal waste, overfishing, grass cutting along the shores, car washing on the lakeshore, and horticultural farming on the lakeshore [4-10]. Thus, the aim of this study was to assess the current pollution status of the Lake and identify major types of pollution in order to carry out appropriate measure.

Materials and Methods

Description of the Study area

This study was carried out in Lake Hawassa, one of the major Rift valley lakes with closed basin feature and receives only one perennial river from eastern escarpment, TikurWuha River. It is located between 06°58′ to 07° 14′ North latitudes and 38° 22′ to 38° 28′ East longitudes with an elevation of 1680 meter above sea level. It has a total surface area of 90 km^2 and a drainage area of 1250 km^2 [11]. The sampling sites were selected based on information available about the sampling sites. Information about sampling sites is given in Table 1 and the location map of the selected sampling sites is shown in Figure 1.

Table 1. Sampling sites information of the study area.

Sampling code	Portable Geographic Coordinate System (GPS)		
	Sampling sites name	Latitude	Longitude
SLW1	Tikurwuha River	07o08.4'8.8"	038 o 28.9'3.1"
SLW2	Tikurwuha Lake	07o05.3'3.6"	038 o 28.8'6.1"
SLW3	Near Haile Resort	07o04.7'7.1"	038 o 28.6'8.3"
SLW4	Fikir Hayik	07o03'4.91"	038 o 28'.060"
SLW5	Fikir Hayik Marsh	07o03'.21.9"	038 o 28'.006"
SLW6	Near Lewi Resort	07o03'011"	038 o 27'.7.93"
SLW7	Amora Gedel	07o02'15.3"	038 o 27'058"
SLW8	Back of Referal Hospital	07o01'46.2"	038 o 27'858"
SLW9	Around Loke	07o00'34.6"	038 o 27'52.1"
SLW10	Near new Air port(Buko)	07o07'48.0"	038 o 25'55.1"
SLW11	Near Algi Rima village	07o07'31.3"	038 o 27'93.7"

Tele: +251912371675
E-mail address: melerevised@gmail.com

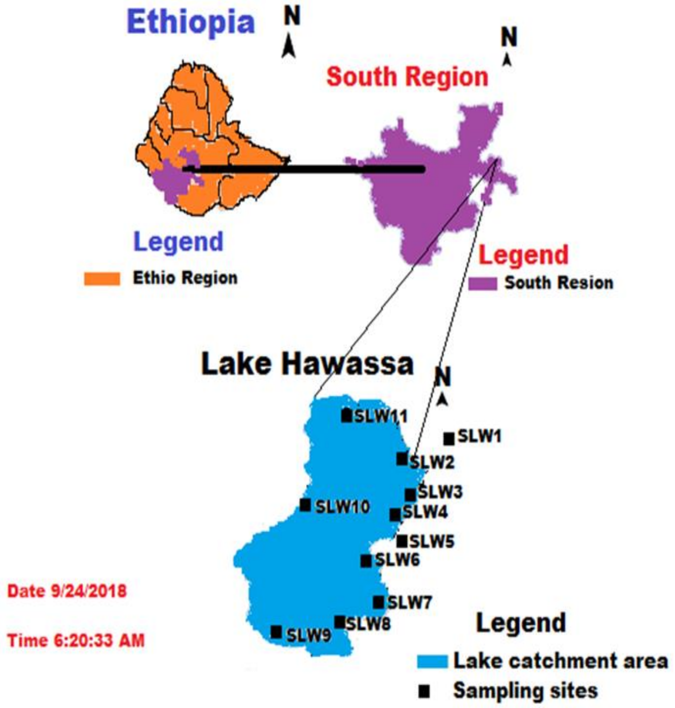

Figure 1. Location map of sampling sites at Lake Hawassa.

Sampling, Sample preparation and Analysis

A total of twenty two water samples were collected from the selected sampling sites during the wet season (July and August) in 2018. The samples were collected in one liter capacity plastic bottles after they have been thoroughly rinsed with the sample and preserved airtight in order to avoid evaporation. Physical parameters such as TDS, SC, and temperature were determined in situ using Wagtech Conductivity/TDS Meter. Dissolved oxygen was also determined in situ using HANA Model HI 9143 Dissolved Oxygen meter. Turbidity and pH were determined onsite using Wagtech turbidimeter, and pH meter respectively. These samples were kept refrigerated prior to analysis of nutrients, and major and trace metals. Major ions such as K^+ and Mg^{2+} and trace metals such as iron were determined using Photometer 7100 integrated with the Palintest system of water analysis.

Nutrients such as NO_3^-, SO_4^{2-}, PO_4^{3-} and F^- were determined using Photometer 7100 integrated with the Palintest system of water analysis. Total alkalinity and total hardness measurements were carried out by acid titration with 0.02 N H_2SO_4 and ethylenediamine tetra acetic acid (EDTA) titration respectively.

For the analyses of trace metals such as Mn, Cu, Zn, Cr, and Pb 100.0 mL of unfiltered water sample were taken in a beaker and heated until the volume of the sample solution reached 20.0 mL. Then the sample solution was cooled and acidified with 2.0 mL of concentrated nitric acid and made up to the mark with deionized water. And then the analyses were completed using Atomic absorption spectrophotometer (Buck Scientific, Model 210 VGP Atomic absorption spectrophotometer, USA).

Statistical Analysis

Descriptive statistics for the selected physic-chemical water quality parameters were carried out. A one-way ANOVA analysis with a post hoc multiple comparisons (Tukey's test) were used to compare the mean values of results obtained for each sampling sites. The results were compared with WHO and FAO standards.

Results and Discussion

Correlation analysis

Pearson's correlation coefficients between physico-chemical water quality parameters are summarized in Table 2.

Table 2. Pearson correlation coefficient matrix of the physico-chemical water quality parameters.

Pearson Correlations

	TDS	pH	Temp	SC	Turbidity	DO	BOD5	Total Hardness	Total Alkalinity	Nitrate	Sulfate	Phosphate	Fluoride	Potassium	Magnesium	Iron	Lead	Chromium	Manganese	Copper	Zinc
TDS	1																				
pH	-.204	1																			
Temp	.623**	.127	1																		
SC	.134	.913**	.463**	1																	
Turbidity	-.020	-.736**	-.047	-.672**	1																
DO	.578**	.298*	.710**	.562**	.040	1															
BOD5	-.569**	-.016	-.884**	-.329**	-.117	-.734**	1														
Total Hardness	.104	-.398**	.400**	-.269*	.438**	.237	-.532**	1													
Total Alkalinity	-.205	-.188	.020	-.228	.103	-.354**	.112	.321**	1												
Nitrate	-.180	.356**	.065	.225	-.170	.134	.089	-.055	-.135	1											
Sulfate	-.457**	-.581**	-.501**	-.708**	.677**	-.379**	.382**	.379**	.132	-.019	1										
Phosphate	.449**	-.196	.084	-.057	.386**	.544**	-.194	-.083	-.459**	.065	.073	1									
Fluoride	-.029	.373**	.397**	.488**	-.054	.472**	-.422**	.106	-.163	.147	-.082	.303*	1								
Potassium	-.571**	.186	-.218	.019	.175	.029	.097	.325**	.286*	-.007	.335**	-.034	.165	1							
Magnesium	.247*	-.101	.351**	-.007	.066	.219	-.430**	.024	.004	.131	-.336**	.298*	.237	-.095	1						
Iron	.650**	-.362**	.342**	-.133	.144	.313*	-.535**	.490**	.018	-.335**	-.040	.169	.041	-.253*	.088	1					
Lead	.435**	-.294*	.090	-.148	.339**	.300*	-.200	.098	-.183	.230	.197	.593**	.319**	-.372**	.102	.510**	1				
Chromium	.437**	.085	.523**	.266*	-.254*	.164	-.424**	.055	.085	-.468**	-.595**	-.394**	-.314*	-.273*	.019	.251*	-.444**	1			
Manganese	.365**	-.851**	-.111	-.723**	.726**	-.049	-.082	.157	-.113	-.347**	.415**	.536**	-.137	-.319**	.173	.445**	.580**	-.177	1		
Copper	-.257*	-.188	-.439**	-.433**	-.114	-.442**	.343**	.111	.131	.156	.159	-.172	-.506**	.304*	.133	-.098	-.348**	-.125	-.069	1	
Zinc	-.479**	.070	-.286*	-.094	-.103	-.376**	.519**	.010	.586**	.102	.273*	-.217	-.089	.527**	-.119	-.529**	-.419**	-.289*	-.336**	.330**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

It can be seen that TDS had a significant positive correlation with temperature, and DO. In addition, the three parameters exhibited negative correlations with BOD_5, which in turn negatively correlated with total hardness. However, DO value showed a positive correlation with phosphate. pH had a significant positive correlation with specific conductance, whereas it showed a negative correlation with manganese, sulfate , and turbidity. Specific conductance exhibited positive correlations with DO, but negative correlations with manganese and sulfate.

Physical parameters of Lake Hawassa

Twenty two physicochemical parameters were determined during this study and the mean concentrations of the selected physical parameters were shown in Table 3 along with their stacked graphs shown in Figure 2 respectively.

Table 3. Mean concentration (mean ± SD in mg/L, n=6) of selected physical parameters at the sampling sites in Lake Hawassa.

Sample code	pH	Temp	DO	BOD5	TDS	SC	Turbidity	Total hardness	Total alkalinity
SLW1	7.27±0.05	21.1±0.186	2.39±0.031	76.2±1.60	428.7±8.78	843.0±2.68	32.3±0.860	67.2±0.753	80.2±1.17
SLW2	9.14±0.04	24.9±0.098	5.74±0.041	27.1±0.352	518.3±1.37	1956.0±2.00	22.6±0.841	60.2±1.60	14.5±0.837
SLW3	9.40±0.05	24.5±0.089	7.04±0.098	31.5±0.302	1135.0±5.48	2151.3±1.63	10.4±0.327	62.8±2.48	36.7±1.03
SLW4	6.68±0.271	21.03±0.150	3.03±0.095	64.2±1.18	1155.0±5.48	850.5±1.52	24.4±0.487	52.8±0.983	14.5±0.837
SLW5	9.22±0.04	20.4±0.308	3.91±0.170	62.2±0.719	381.7±8.89	1663.2±4.45	20.5±0.414	55.7±0.816	11.3±1.211
SLW6	8.55±0.06	25.1±0.767	6.40±0.748	16.0±0.861	1146.7±5.16	1626.8±7.22	9.52±0.476	63.8±0.753	11.5±0.548
SLW7	5.86±0.04	25.2±0.756	6.82±0.285	11.2±0.736	1165.0±5.48	733.7±3.01	87.3±4.26	72.5±1.049	19.2±0.753
SLW8	8.16±0.07	28.4±0.133	6.04±0.772	4.02±0.209	1284.7±1.37	1831.0±2.37	8.20±0.108	69.7±2.42	14.4±0.543
SLW9	8.14±0.06	28.3±0.266	5.73±0.703	6.76±0.345	1183.7±1.50	1748.3±4.88	28.2±1.13	62.7±2.06	74.5±0.548
SLW10	8.72±0.04	25.0±0.041	6.57±0.132	46.6±0.551	1286.0±2.83	1963.8±1.60	13.3±0.242	54.3±0.816	12.0±0.894
SLW11	8.90±0.06	25.6±0.155	6.57±0.123	40.9±0.593	1035.0±5.48	1844.2±2.04	28.2±1.13	56.8±1.17	10.5±0.837
Total	**8.17±1.09**	**24.5±2.59**	**5.48±1.59**	**35.2±24.0**	**[illegible]74.5±335.[illegible]**	**[illegible]564.7±487.[illegible]**	**25.9±21.2**	**61.7±6.32**	**27.2±24.9**
WHO	6.5 to 8.5	<40.0	5.0 to 7.0	2.0 to 5.0	500	750	5	300	120
FAO	6.0 to 8.5		>4	8	2000	3000	----	----	----

All units except temperature (°C), Turbidity (NUTs) and SC (µS/cm) are in mg/L.

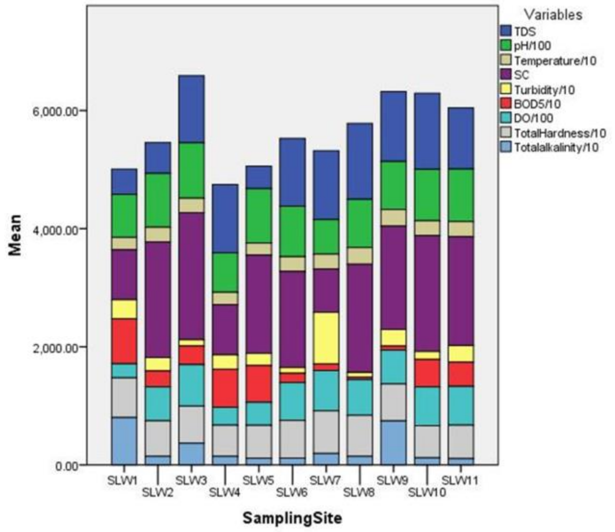

Figure 2. Mean concentration (mean ± SD in mg/L, n=6) of selected physical parameters in the sampling sites.

pH

pH values vary from a minimum of 5.86 ± 0.04 and a maximum of 9.40 ± 0.05. The average values for pH was within the permissible limit of WHO and FAO standards set for drinking and irrigation purposes. However, highest values of pH were recorded in SLW2, SLW3, and SLW5 and lowest value in SLW7. These might be due to point source pollution. Statistical analysis showed that the mean values of pH was significantly different 95 % confidence level among SLW1, SLW3, SLW4, SLW7 and the other sampling sites which might indicate point source pollution caused by chemicals that might come from agricultural runoff, wastewater discharge or industrial run off in these sampling sites of the Lake.

Temperature

Water temperature obtained during the sampling period for all sites did not differ significantly at 95% confidence level and water temperature varies from 20.4 ± 0.31 °C to 28.4 ± 0.13 °C, with an overall mean value of 24.5 ± 2.59 °C and it was considered lower as compared to WHO maximum permissible limit (WHO, 2008). However, relatively high temperature values were recorded at SLW8 (28.4 ± 0.133 °C) and SLW9 (28.3 ± 0.266 °C).These might be due to agricultural runoff and deforestation along the lake and municipal effluents. Nonetheless, temperature of Hawassa Lake water is likely suitable for aquatic lives.

Dissolved oxygen (DO)

DO values in the present study ranges from 2.39 ± 0.03 to 7.04 ± 0.1 mg/L, with an overall mean concentration of 5.48 mg/L. The findings also indicated that at 95 % confidence level, there were a significant difference among SLW1, SLW5 and the other sampling sites. The lowest DO values were recorded at SLW1 (2.39 ± 0.031 mg/L), SLW4 (3.03 ± 0.095 mg/L), and SLW5 (3.91 ± 0.170 mg/L). These might be due to decomposing organic matter, dissolved gases, industrial waste, mineral waste and agricultural runoff and this might adversely affect aquatic life [12]. However, the overall mean concentration of DO value was within the permissible limits set by WHO and FAO standards.

Biological oxygen demand (BOD_5)

Biological oxygen demand (BOD_5) value in the present study ranges from 4.02 ± 0.21 mg/L to 76.2 ± 1.6 mg/L. The values of BOD_5 excep$_t$ for SLW8 and SLW9 were higher than the recommended values of FAO. At 95% confidence level, there is a significant difference within the sampling sites, highest being at SLW1 (76.2 ± 1.60), SLW4 (64.2 ± 1.18), and SLW5 (62.2 ± 0.719) and the mean values of BOD_5 was 35.2 mg/L. This indicates high levels of organic pollution due to discharge of domestic waste from the city and other human activities and agricultural fertilizers brought by the runoff. Increased levels of BOD decrease the dissolved oxygen content of Lake water [13].

Total dissolved solids (TDS)

The total dissolved solids of Lake Hawassa at the sampling sites range from 381.7 ± 8.9 mg/L to 1286.0 ± 2.83 mg/L and the overall mean value was 974.5 mg/L and this was higher than the standards given by both WHO and FAO. For all the other sampling sites, except for SLW1 and SLW5, the average value of TDS exceed the maximum permissible limits of WHO for the drinking purpose but within the limit given by FAO for irrigation water. Excessive total dissolved solids can be toxic to aquatic life through increases in salinity or changes in the composition of the water. Primary sources for higher TDS in the Lake water might be due to agricultural runoff, discharge of domestic waste from the town and other human activities like washing of clothes or different vehicle at and around the lake.

Specific conductivity (SC)

The specific conductivity of Hawassa Lake range from 733.7 ± 3.01 µS/cm to 2151.3 ± 1.63 µS/cm and the overall mean value was 1564.7 µS/cm and this was higher than WHO standards for drinking purposes and lower than FAO standard for irrigation. The sampling sites were significantly different at 95% confidence level. The lowest SC value was recorded at SLW7 (733.7 ± 3.01 µS/cm) and the highest were recorded at SLW3 (2151.3 ± 1.63 µS/cm), SLW10 (1963.8 ± 1.60 µS/cm) and SLW2 (1956.0 ± 2.000 µS/cm). The increased conductivity at SLW2, SLW3, and SLW10 sampling sites might be due to agricultural runoff or a sewage discharge, and the decrease in conductivity at SLW7 might be due to an oil spill or addition of other organic compounds from the fish market near the sampling site. In both cases, the values of conductivity indicated pollution of Lake water.

Turbidity

The turbidity value of the sampling sites range from values from 8.20 ± 0.12 NTUs to 87.3 ± 4.26 NTUs and the overall mean value was 25.9 NTUs. These indicated high turbidity of the lake and higher than WHO standard for drinking purposes. These might be due to the development of an algal bloom on a lake, or a steady increase in suspended sediment due to a polluted tributary and surface runoff.

Total Hardness

Total Hardness values range from 52.8 ± 0.98 mg/L $CaCO_3$ to 72.5 ± 1.05 mg/L $CaCO_3$ and the overall mean was 61.7 mg/L $CaCO_3$. Thus, the recorded values of total hardness for all sampling sites were within the permissible limit of WHO standard. This is related to the absence of limestone rock in the study area.

Total Alkalinity

Total alkalinity values range from 10.5 ± 0.837 mg/L $CaCO_3$ to 80.2 ± 1.17 mg/L $CaCO_3$ and the overall mean was 27.2 mg/L $CaCO_3$. Thus, the recorded values of total alkalinity for all sampling sites were within the permissible limit of WHO standards. However, highest value of total alkalinity were recorded at SLW1 (80.2 ± 1.1717 mg/L $CaCO_3$) and SLW9 (74.5 ± 0.548 mg/L $CaCO_3$). And these might be due to waste discharge and microbial decomposition of organic matter in the sampling sites.

Nutrients and major metal concentrations of Lake Hawassa

The mean concentrations of the selected nutrient and major and essential metals concentration were shown in Table

4 along with their corresponding stacked graphs shown in Figure 3 respectively.

Table 4. Mean concentration (mean ± SD in mg/L, n=6) of selected nutrients and major metal concentrations at the sampling sites in Lake Hawassa.

Sample code	Nitrate	Sulfate	Phosphate	Fluoride	K	Mg
SLW1	4.20 ± 0.341	178.0± 4.47	0.348 ± 0.04	11.6 ± 0.42	89.1 ± 2.54	23.0 ± 1.30
SLW2	4.26 ± 0.42	125.8 ± 5.34	1.25 ± 0.08	17.5 ± 0.71	83.6 ± 1.75	28.9 ± 0.86
SLW3	4.30 ± 0.419	114.0 ± 5.76	1.38 ± 0.039	15.8 ± 0.52	79.6 ± 0.89	22.7 ± 1.10
SLW4	3.21 ± 0.166	126.3 ± 5.72	1.30 ± 0.037	12.2 ± 0.5	53.2 ± 1.56	26.6 ± 1.55
SLW5	3.40 ± 0.290	127.3 ± 4.18	0.358 ± 0.05	12.2 ± 1.3	82.0 ±2.06	20.5± 1.09
SLW6	4.60 ± 0.316	82.80 ± 2.07	1.33 ± 0.06	12.9 ± 0.57	81.4 ± 2.61	31.0 ± 1.52
SLW7	2.84 ± .050	183.0 ± 5.06	1.90 ± 0.02	13.7 ± 0.54	80.7 ± 2.95	25.9 ± 2.80
SLW8	3.54± 0.350	106.2 ± 5.04	0.350 ± 0.05	13.5 ± 0.64	61.9 ± 3.08	23.4 ± 3.69
SLW9	2.81 ± 0.261	70.33 ± 10.4	0.588 ± 0.07	13.4 ± 0.6	70.8 ± 2.09	29.5 ± 2.61
SLW10	2.37 ± 0.087	91.00 ± 2.90	1.53 ± 0.05	12.7 ± 0.6	75.6 ± 3.23	23.7 ± 1.01
SLW11	6.93 ± 0.419	111.5 ± 7.61	1.36 ± 0.046	13.3 ±0.7	65.2 ± 3.04	26.2 ± 0.89
Total	**3.86 ± 1.23**	**119.7 ± 34.3**	**1.06 ± 0.53**	**13.5 ± 1.76**	**74.8 ± 10.6**	**25.6 ± 3.59**
WHO	45	250	0.1	1.5	20	30
FAO	50	400	2	-----	-	120

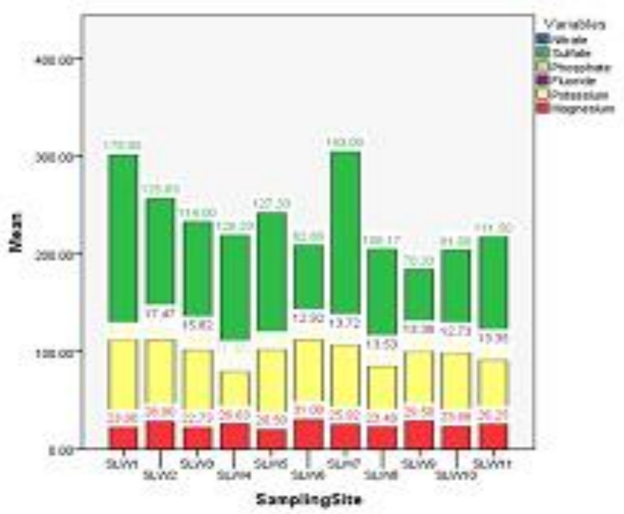

Figure 3. Mean concentration (mean ± SD in mg/L, n=6) of selected nutrients and major metal concentrations in the sampling sites.

Nitrate

The concentration of nitrate range from 2.37 ± 0.087 mg/L to 6.93 ± 0.419 mg/L and the overall mean was 3.86 mg/L. These values were within the limit of WHO and FAO standards showing that the lake was less polluted by nitrogenous materials. However, highest concentration of Nitrate-nitrogen was recorded at SLW11 (6.93 mg/L) and this could be due to agricultural runoff and and certain industrial wastes.

Sulphate

The concentration of suphate range from 70.33 ± 10.4 mg/L to 183.0 ± 5.06 mg/L and the overall mean was 119.7 mg/L. The obtained values were within the limit of WHO (2008) and FAO standards. However, highest concentration of sulfate was recorded at SLW7 (183.0 ± 5.06 mg/L) and SLW1 (178.0 ± 4.47 mg/L). And these could be related to the discharge of sulphate containing municipal sewages and surface runoff that contain organic fertilizers from agricultural activities.

Orthophosphate

The concentration of orthophosphate range from 0.348 ± 0.04 mg/L to 1.90 ± 0.02 mg/L and the overall mean was 1.06 mg/L. Highest concentration of orthophosphate was recorded at SLW7. And these values were higher than the limit of WHO (2008) and lower than FAO standards. These could be due to pollution from domestic sewages, surface runoff from phosphate containing fertilizers and certain industrial wastes that led to eutrophication.

Fluoride

The concentration of fluoride range from 11.6 ± 0.42 mg/L to 17.5 ± 0.71 mg/L and the overall mean was 13.5 mg/L. And these values were exceeded WHO limit for drinking purpose. The high levels of fluoride content recorded in the Lake waters could indicate pollution by sewage, industrial waste or seepage of ground water into the Lake.

Potassium and Magnesium

In the present study, concentration of potassium range from 53.2 ± 1.56 mg/L to 89.1 ± 2.54 mg/L with an overall mean concentration of 74.8 mg/L. This value is higher than WHO (2008) standard. Magnesium contents range from 20.5 ± 1.09 mg /L to 31.0 ± 1.52 mg/L. And the recorded value for magnesium concentrations lies within the prescribed limit of WHO and FAO. However, higher concentration was recorded in SLW6 (31.0 mg/L) which might be due to discharge of effluent into the Lake.

Selected essential and toxic trace metal concentrations of Lake Hawassa

The mean concentrations of the selected essential and toxic metal concentration were shown in Table 5 along with their corresponding stacked graph shown in Figure 4.

Table 5. Mean concentration (mean ± SD in mg/L, n=6) of trace metals at the sampling sites in Lake Hawassa.

Sample code	Fe	Mn	Zn	Cu	Pb	Cr
SLW1	0.24 ± 0.072	0.147 ±0.008	17.4 ± 0.175	15.16 ± 0.78	0.04 ± 0.006	0.240 ± 0.015
SLW2	0.13 ± 0.023	0.133 ± 0.052	7.50 ± 0.126	1.76 ± 0.15	0.07 ± 0.009	0.173 ± 0.014
SLW3	0.79 ± 0.049	0.200 ± 0.089	4.52 ±0.248	1.65 ± 0.14	0.153 ± 0.012	0.243 ± 0.032
SLW4	0.57 ± 0.069	1.55 ± 0.055	1.17 ± 0.05	7.48 ± 0.44	0.135 ± 0.010	0.280 ± 0.028
SLW5	0.25 ± 0.043	ND	1.48 ± 0.117	6.86 ± 0.51	0.025 ± 0.006	0.443 ± 0.036
SLW6	0.57 ± 0.068	0.267 ± 0.103	3.03 ± 0.082	18.2 ± 0.82	0.06 ± 0.01	0.427 ± 0.014
SLW7	0.76 ± 0.068	1.83 ± 0.052	0.433 ± 0.052	3.73 ± 0.21	0.14 ± 0.02	0.302 ± 0.029
SLW8	0.75 ± 0.06	0.133 ± 0.052	0.250 ± 0.055	3.28 ± 0.23	0.07 ± 0.009	0.610 ± 0.039
SLW9	0.54 ± 0.058	0.450 ± 0.055	3.90 ± 0.063	1.40 ± 0.11	0.062 ± 0.012	0.665 ± 0.067
SLW10	0.29 ± 0.033	0.250 ± 0.055	8.77 ± 0.103	3.45 ± 0.25	0.04 ± 0.005	0.537 ± 0.054
SLW11	0.16 ± 0.034	0.200 ± 0.089	4.05 ± 0.152	3.45 ± 0.06	0.120 ± 0.013	0.263 ± 0.019
Total	**0.459 ± 0.247**	**0.469 ± 0.596**	**4.77 ± 4.8**	**6.04 ± 5.44**	**0.082 ± 0.045**	**0.380 ± 0.163**
WHO	0.3	0.1	5	2	0.01	0.05
FAO	-	-	-----	-----	-----	-----

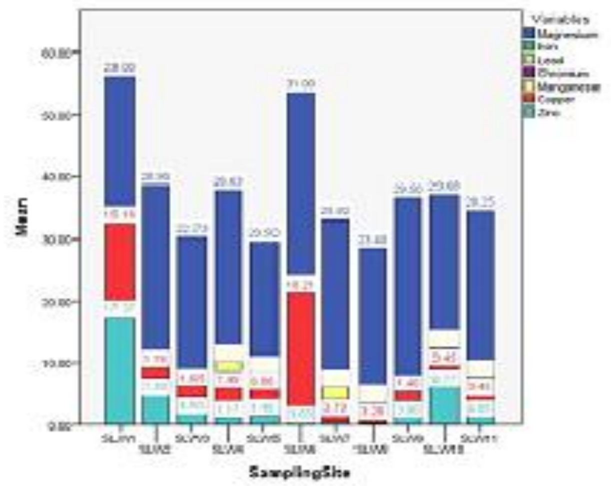

Figure 4. Mean concentration (mean ± SD in mg/L, n=6) of selected trace metals in the sampling sites.

Iron and Manganese

Iron concentration range from 0.13 ± 0.023 to 0.79 ± 0.049 mg/L with an overall mean concentration of 0.46 mg/L. And this value exceeded WHO limit for drinking purpose. Manganese concentration range from 0.133 ± 0.052 to 1.83 ± 0.052 mg/L with an overall mean concentration of 0.47 mg/L. Manganese was not detected in SLW5. However, the concentration of Mn recorded for the rest of the sampling sites exceeded WHO standard.

Zinc

Zinc concentration range from 0.250 ± 0.055 mg/L to 17.4 ± 0.175 mg/L with an overall mean concentration of 4.77 mg/L. And this value lies within the prescribed limit of WHO limit for drinking purpose. However, a higher levels of Zn were recorded in SLW1 (17.4 mg/L), SLW10 (8.77 mg/L) and SLW2 (7.50 mg/L), which might be due to stormwater draining from vehicle oil, grease and lubricants spill on roads, vehicle repairing and washing areas and from other consumer products into the Lake during rainfall.

Copper

Copper concentration ranges from 1.40 ± 0.11 mg/L to 18.2 ± 0.82 mg/L with an overall mean concentration of 6.04 mg/L. And this value exceeded WHO limit for drinking purpose. Moreover, high levels of copper were recorded at SLW6 (18.2 ± 0.82 mg/L) and SLW1 (15.16 ± 0.78 mg/L). And these might be due to incineration of waste, industrial discharge, sewage disposal and antifouling paints [14].

Lead

Lead concentration ranges from 0.025 ± 0.006 mg/L to 0.153 ± 0.012 mg/L with an overall mean concentration of 0.082 mg/L. And this value exceeded WHO limit for drinking purpose. And these might be due to stormwater draining from vehicle oil, grease and lubricants spill on roads, vehicle repairing and washing areas and from other consumer products into the Lake during rainfall.

Chromium

Chromium concentration ranges from 0.173 ± 0.01 mg/L to 0.665 ± 0.07 mg/L with an overall mean concentration of 0.380 mg/L. And this value exceeded WHO limit for drinking purpose. These might be due to industrial discharge from pigments, paints, ceramic, glass and leather tanning industries. Cadmium was not detected or below the detection limit in all the sampling sites.

Conclusion

This study have shown that the Lake encounters many threats from point and non-point pollution sources such as industrial waste from ceramics, dyes, plastics and food processing industries, urban stormwater, agricultural runoff and land development. And these continue to deteriorate the condition of the lake unless mitigation measures are put in place.

Copyright Forms

You must submit the Elixir Copyright Form (ECF) as described.

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