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Analysis of Physicochemical Properties of Lake Beseka; "The Ever Growing Lake of Ethiopia's Great Rift Valley"

Fuad Abduro[1,2,*] and Gelaneh W.Michael[2]

[1]Department of Chemistry, College of Natural Science, Jimma University, P.O. box 378, Jimma, Ethiopia.

[2]Department of Chemistry, School of Applied Science, Adama Science and Technology University, P.O. box 1888, Adama, Ethiopia.

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ABSTRACT

In this work we reported the status of one of Ethiopia's Great Rift Valley Lakes; "The ever expanding Lake known as Beseka" in respect to water quality parameters. A composite sample was prepared by combining equal volumes of water samples taken from five Sampling sites. Five physical parameters (pH, DO, EC, T° and Turbidity) were determined for all samples at the spot of sampling while other physical parameters such as TSS and TDS were determined in the laboratory. AAS was used for the determination of heavy metals Pb, As, Cd, Cr, Fe, and Pb while spectrophotometer was used to determine water hardness, total chlorine, NO3-, PO43-, NH3, SO42 Alkali metals Na and K are determined by Flame Photometer. The findings indicated that the lake was found to be alkaline with pH above nine and brakish with TDS value of 2569.70 mg/L. The measured higher values of EC and turbidity resulted from higher values of TDS and TSS. Also these values are much higher than the acceptable values for surface water such as lakes. Similarly Pb, Cd, As, F- and total Cl are above the permissible values while other Physical and chemical parameter are within the acceptable limit of both WHO and FAO Guidelines for drinking and irrigation water.

1. Introduction

Ethiopia is naturally endowed with abundant water resources that help to fulfill domestic requirements, irrigation and hydropower (Ministry of Water Resources, 2000). With its current per-capita fresh water resources estimated at 1924m^3, the country is one sub-Saharan African countries endowed with the largest surface fresh water resource. However, only 2% of potential is annually utilized (MoWR, 1999).

The main Ethiopian rift (MER) valley is a part of east African rift system, which extends from the Kenya border up to Red sea. The seismically and volcanically active northern main Ethiopian rift (MER) and Afar rifts are virtually the only places worldwide where the transition between continental and oceanic rifting is exposed on the land (Keir D, 2006). The complex geological processes associated with the rift valley are responsible for creation of east African's largest lakes as well as much of its topography (UNEP, 2008). The main Ethiopian (Woldemichael, 2014) rift valley system occupies very wide plain areas and is constituted by number of surface water bodies mainly lakes of different hydrological and morphometric characteristics (Turdua, 2006).The lakes in the Ethiopian rift valley are situated within three basins: Awash basin (lake Koka, Beseka, Abe), which is located in the northern main Ethiopian rift, the lakes region (HaroDambal, Langano, Abijata, and Shalla), occupying central part of the MER and southern basin (lakes Awassa, Abaya, Chemo and Chew bahir) in the southern section of the main Ethiopian rift (Wikipedia) https://en.wikipedia.org/wiki/Great_Rift_Valley,_Ethiopia Being one of the Rift valley lakes, Lake Beseka is subjected mostly to the impact of natural geologic activities related to the rift valley formation and also to anthropogenic activities that could affect the water quality of the lake and enhance its pollution (Tamiru, 2005). Lake Beseka is one of the highly mineralized lake waters (Bedilu Demissie, 2014). The beds of the lake are volcanic rock and sediments of volcanic ash. Hence the Lake is volcanically dammed, endothermic and saturated with dissolved solids. Lake Beseka has been expanding at an astounding rate since the late 1960's and early 1970's. According to the study carried out by Sir William Hal crow and partners in 1978, in 1962 the lake covered only 3 km^2 and by the year of 1972, the area coverage had reached to 11km^2 (Ministry of Water Resource, 1990). In 1998 its coverage was about 40 km2 with maximum depth of 11m (MoWR, 1999). In 2005 the lake coverage was about 41.8km2 corresponding to depth of 15.2m (Tenalem, 2005). Tenalem has evidently showed that change in volume has been found to be related to shift of water balance caused by ground water inflow through open rift faults from the surrounding over irrigated fields and regulated Awash River. Moreover, it has been ever expanding in volume as a result of which serious social, economic environmental factors have been under threat (Tenalem, 2005), (Amare, 2005) (Tamiru, 2005); (MoWR, 1999). The expansion of Lake Beseka is alarming and has detrimental effect on the surrounding biological, physical, hydrological and infra-structural environment. However, trace metal hydrochemistry of the lake which can potentially be affected by presence of hot springs and the on-going physical dynamism of the lake that involves interaction of the water of the lake with its surrounding geology needs to be studied

Tele: +2519-13569913
E-mail address: fuadabduro8@gmail.com

since the lake is allowed to flow to Awash River, on which thousands of lives are dependent (Ministry of Water Resource, 1990) (Ministry of Water Resources, 2000). Lake Beseka is by the surrounding population for sanitation, drinking water for cattle, home for different aquatic, animals, birds and a number of wild animals. In addition to natural geological factors Lake Beseka is vulnerable to huge anthropogenic activities by the nearby Metehara municipal; Metehara Sugar Estate and Abadir Farm. The color of the lake Beseka is yellowish-brown (Amare, 2005) and this also visually observable. There are different factors such as presence of natural metallic ion (Fe and Mn), humus and peat materials, plankton, weeds and industrial wastes which can impart color to natural water (APHA, 2005); the reason why the color of water of the Beseka is yellowish-brown has not been analyzed. Since, change in color can affect water quality in terms of changing transparency of the water of the lake and hence its biological productivity potential (Wetzel, 1999). MoWR is trying to control the expansion of the lake by discharging about 10m3/s of water to Awash River. However, the adverse effect of the above fact has not studied yet .To these end, the result of the investigation will play a crucial role for further understanding of the chemistry of the lake water and thus contribution to the future water resources management, utilization and environmental protection. So the study involves investigations of the effects of geological and anthropogenic activities on the physical and chemical water quality parameters as well as the impact of the lake on the surrounding ecosystem especially on the downstream of Awash River.

2. Materials and Methods

2.1. Study Area

Lake Beseka (latitude 39°51'- 31°53'N and longitude 8°52'- 8°54'E) is located in the northern half of the Ethiopian Rift Valley close to Metehara Town at the junction of the Main Ethiopian Rift (MER) and the Afar Triangle about 190 km to East of Addis Ababa. Fringed either side of the main highway and railway line, the lake has been threatening Ethiopia's only access to the Port of Djibouti. It covers an area of more than 40 km^2 with a mean depth of 6 m and maximum depth of 11 m. Moreover, the surface area of the lake has been increasing continuously and its size has changed from 3 km2 in 1964 to more than 42 km^2(Tenalem, 2005).

Figure 2.1. Boundaries of Lake Beseka in 2015 and its watershed and sampling sites (Source: Google Earth open source).

Table 1. Surface sampling points and the corresponding locations.

Surface Sampling sites	Altitude (m)	GPS Coordinates	
		Northing	Easting
Lake BesekaPoint1 (LBP1)	3179	8°54'22.10"	39°53'01.25"
Lake BesekaPoint2 (LBP2)	3158	8°53'31.62"	39°51'27.98"
Lake BesekaPoint3 (LBP3)	3139	8°52'21.14"	39°52'25.05"
Lake BesekaPoint4 (LBP4)	3554	8°53'24.62"	39°54'30.70"
Lake BesekaPoint5 (LBP5)	3139	8°49'46.15"	39°50'35.66"

2.2. Instrumentation

A number of instruments and apparatus are used in sampling, sample holding, transportation, preparation, preservation and testing. PET bottles were used as sample holder and ice box for preservation of water sample during transportation. Turbid metric 2100A, EC meter (JENWAY, 4200), pH meter (JENWAY, 430), to measure turbidity, electrical conductivity and pH at the spot of sampling. For this study, a number of instruments were used to determine the concentration of selected Chemical parameters. The Determination of Pb, Cd, Cr, Mn, As, and Fe done out by FAAS whereas the determination of, NO3-, SO42-, NH3, F-, PO43-, total hardness and Total Cl was done with Spectrophotometer. The calibration of the instruments was carried out based on (APHA, 2005) protocol.

2.3. Water sampling, transportation, preparation and preservation

Sample collection protocol is the most important step to be followed in any analysis of environmental samples such as water, air or soil. In this experiment we followed (UNEPA, 2010), Guidelines for regulatory monitoring and testing water and waste water protocol. Accordingly, new plastic bottles were labeled and transported to the sampling site. The bottles were rinsed twice with sample water before they are filled with water sample. All the samples were grab samples taken from the surface at one point in the cross-section of the flow. Following the protocol, the samples are then acidified with ultrapure HNO3, to pH of 2±0.2 (1mL of 65% HNO_3 per liter of the sample), packed and transported to the laboratory for further preparation. The water samples were filtered with a 0.45 μm pore size cellulose acetate membrane filter inserted in a Millipore filtration glass assembly. Samples for metal analysis are transferred to UV-transparent new polyethene bags and, then, 100 μmol/L of ultrapure H_2O_2 was added to initiate radical generation during Solar-UV irradiation. This sample was irradiated with solar-UV of intensity 560 mW/cm^2 for 24 hours (Gelaneh W.M, 2011).

2.4. Method Validation, quality assurance and Sample Analysis

Method Validation quality assurance and Sample Analysis was done according to (UNEPA, 2010) guidelines for regulatory monitoring and testing water and waste water 2003. Accordingly MDL, percentage recovery were determined for method validation while mean, standard deviation and One way ANOVA are used for quality assurance.

3. Results and Discussion

3.1. Recovery Test Results

The percentage recovery lied in between 98.32 to 100.12% for AAS as described in table 3.1 and 99.55 to 100.1% for spectrophotometer (Table 3.1). These imply that, the measured results are within the acceptable range of 75-

110%. Thus the digestion of water samples procedure for chemical analysis in the water sample was validated.

Table 3.1. Recovery test results for metals analyzed by FAAS and spectrophotometer.

Parameters	Pb	Cd	Cr	As	Fe	Mn
% recovery	98.32	99.60	100.12	99.90	100.01	101.01

3.2. The results of physicochemical parameters

According to (Chapman, 1996), (WHO, 2004) the pH of most natural waters are within the ranges of 6.5-8.5 implying that lake Beseka is considered as alkaline(table 3.2). The alkaline nature of Lake Beseka arises from the presence of bicarbonate ions (Bedilu Demissie, 2014); (MoWR, 1999) and other alkali and alkaline metals present in the bed rock and volcanic ash. (MoWR, 1999) classified the lake as a sodium bicarbonate type and evidently showed the correlation of its higher pH value with its dominating bicarbonate ions.

The mean temperature of the lake water is 26.6 °C. This phenomenon of temperature has an effect on the physicochemical parameters such as total dissolved solids (TDS), electrical conductivity (EC), pH, dissolved oxygen (DO), and other aquatic life and limnological factors of natural waters. This increased temperature is partially responsible to low amount of DO in in the lake water.

The electrical conductivity of Lake Beseka is measured to be 2709.98µs/cm (table 3.2) which was above the allowable standard for drinking (WHO, 2004). The reason for the observed value of EC arises from the presence of high amounts of dissolved inorganic substances.

The turbidity value of the lake Beseka was 6.34 NTU (table 3.2) and this is slightly higher than the limits allowed for drinking water quality, according to the WHO (2008) standard which is 5 NTU. The presence of high TSS (630 mg/L) is responsible for this value. This increase in turbidity decreases the light attenuation by the lower portion of the water and this in turn can affects aquaculture.

The total dissolved chemical species (TDS) is 2569.7 mg/L (table 3.2). This implies that Lake Beseka can be classified as a brackish water type since natural waters with TDS values between 1500 mg/L and 5000 mg/L are classified as brackish. In other words, the lake water is between the classes of natural waters known as fresh-waters and saline-waters. The research finding clearly shows that the observed total dissolved solids and suspended solids are above the agreements of (WHO, 2004).

FAO classified water resources with TDS values greater than 2000 mg/Lunder 'severe' degree of restriction for the use of irrigation based agriculture. Lake Beseka's mean TDS value was about 2569.7mg/L which is well above the FAO guideline limit and thus cannot be recommended for irrigation purpose. Since the lake water has been reported to be sodium-bicarbonate type (Bedilu, 2005), (MoWR, 1999) the application of the water for irrigation purpose may cause sodicity problem to agricultural soils. On the other hand, releasing the lake water into Awash River to regulate the ever expanding volume of the lake as it has being practiced by the Ministry of Water Resources may also have possible negative implications on one of the most vital rivers of the country.

BOD indicates the amount of biodegradable organics that can deplete DO and it is the measure of the amount of waste or the presence of nutrients which helps the growth of green plants such as algae because the decomposition of these plants increases the concentration of biodegradable organic matter or BOD. In this analysis the amount of BOD and COD is found to be 0.50 and 23.40 mg/L (table 3.3) the lake water is in the acceptable range (WHO, 2004)

Ammonia is extremely toxic to fish and should be present below 0.2 mg/L. Values above 2 m/L are usually an indication of serious organic pollution (Chapman, 1996). Accordingly, the measured value (0.22 mg/L) is in the acceptable range. This implies that, the lake is safe for aquatic life in respect to ammonia.

In fresh waters, the concentration of nitrate does not exceed 0.001 mg/L and are rarely higher than 1mg/L (Chapman, 1996). Under the influence of human activities, natural waters may contain up to 5 mg/L and this indicates pollution by human or animal waste or fertilizer-run off. The Measured value of nitrate ions was found to be 4.42 mg/L (table 3.3) indicates that the lake is getting polluted by anthropogenic activities.

Arsenic was measure to be 0.059 mg/L (table 3.3) confirming that it is in the range to be present in natural waters (1–2 mg/Land0.01 mg/L) in drinking water (WHO, 2003)(WHO, 2011). The research finding indicated that, the mean values of arsenic is within the above acceptable limit for the lake (WHO, 2003) as surface water but it is above the Permissible limit to be used for drinking purpose.

The observed concentration of cadmium is 0.054 mg/L (table 3.3). The maximum allowed concentration for drinking water is0.003 mg/L (WHO, 2004). This indicated that the lake water is not recommended for drinking. Therefore, releasing the lake water to Awash River might pollute the river itself and can increase health risk of the people living downstream and drinking Awash River water. High concentration of cadmium is also toxic to beans, beets, and turnips at concentrations of 0.1 mg/Lin nutrient solution.

The fluoride content is 2.404 mg/L (table 3.3) which is above WHO's standard (1.5 mg/L) in drinking water (WHO, 2011). The observed high value of fluoride ion confirmed a typical characteristic of ground water of the rift system it is the main cause for the observed tooth decay in the area.

The total amount of iron species over the surface of lake water averaged 0.19 mg/L (table 3.3). This is far less than the concentration of iron expected in natural waters which is 0.50 - 50 mg/L (WHO, 2003). However, the research findings indicated that, iron concentration of the lake increased from previous studies (MoWR, 1990) which were reported to be in the range of 0.01- 0.16 mg/L.

The high temperature of the Ethiopian Grate Rift system is believed to increase the rock-water interaction which could be the main driving force for increasing iron concentration of the lake (Tamiru, 2005).

Lead concentration is 0.631 mg/L (table 3.3) and this revealed that lead concentration is above the maximum allowable international standards. According to WHO, concentration of lead greater than 0.01 mg/L is toxic for humans especially for infants and pregnant. Lead is toxic to both central and peripheral nervous systems including subencephalopatic neurological and behavioral effects (WHO, Guidelines for Drinking-water Quality, 2004).

Table 3.2. Mean results of Physical parameters for composite water samples.

Parameters	pH	EC(µs/cm)	DO (mg/L)	Turb.(NTU)	Temp.(oC)	TSS(mg/L)	TDS(mg/L)
Values	9.42±0.02	2709.9± 0.01	6.01 ± 0.03	6.342± 0.01	26.6± 0.50	630 ± 32.01	2569.7±35.43

Table 3.3. Mean results of Chemical parameters for composite water samples.

Parameters	Conc. (mg/L)	WHO limit (mg/L)	Pollution status
BOD	0.50± 0.21	*	Acceptable for the lake
COD	23.40 ±1.21	*	Acceptable for the lake
Total Hardness	80.70±3.60	*	Can cause scaling pipe lines/boilers
Ca-Hardness	58.00±2.10	*	Can enhance scaling
Total Alkalinity	8.60±0.31	*	Induce scaling of pipe lines/boilers
Pb	0.63± 0.01	0.01	High; can induce subencephalopathic neurological and behavioral effects.
Cd	0.05 ± 0.004	0.003	Can affect kidney
Cr	ND	0.05	Safe
As	0.06 ± 0.07	0.01	Polluted
Fe	0.19± 0.01	*	Safe
Mn	0.08 ± 0.06	0.4	Safe
NH3	0.215 ± 0.02	*	Can cause taste and odor problems
Na	1415.10± 8.02	*	May give rise to unacceptable taste
K	45.80 + 1.00	*	Safe
F-	2.40 ± 0.12	1.50	Higher, may cause Skeletal/tooth fluorosis
NO3-	4.42± 0.01	50	safe
Tot. Cl	339.8± 0.02	5	Very high, cause sterilization of the lake
PO43-	21.68 ± 0.08	*	Safe
SO42-	187.22 ± 0.06	*	Safe; but may cause noticeable taste

*No health-based guideline value is proposed.

Blood lead level of 30 µg/L causes intelligent quotient deficit of about four points in children. Thus the amount observed in analysis revealed that, the water from the lake is unsafe for both humans and animals.

Manganese concentration was found to be 0.075 mg/L (table 3.3). This concentration is much less than WHO guideline value (0.4 mg/L) for manganese implying the lake water is safe in respect to manganese.

The concentration of sodium in the lake water was found to be 1415.1 mg/L (table 3.2 and 3.3). The highest concentration of sodium is one of the reasons for the highest TDS of the lake. According to WHO, no firm conclusion can be drawn concerning the possible association between sodium in natural waters and the occurrence of hypertension (WHO, Guidelines for drinking water quality, 2011). Therefore no health based guideline is proposed.

The average concentration of potassium value of the lake water was 45.8 mg/L (table 3.3). Although potassium may cause some health effects in susceptible individuals, potassium intake from drinking-water is well below the level at which adverse health effects may occur (WHO, Guidelines for Drinking-water Quality, 2004).

The measured concentration of sulfate (SO_4^{2-}) is 187.22 mg/L (table 3.3). No health-based guideline is proposed for sulfate. However, because of the gastrointestinal effects resulting from ingestion of drinking-water containing high sulfate levels, it is recommended that health authorities be notified of sources of drinking water that contain sulfate concentrations in excess of 500 mg/l. The presence of sulfate in drinking-water may also cause noticeable taste and may contribute to the corrosion of distribution systems.

The concentration of phosphate obtained from the laboratory analysis is 21.68 mg/L (table 3.3). Thus the lake water has less contribution to the plant nutrient and hence to the increase concentration of BOD. In other words effect of Phosphate to the depletion of DO is insignificant.

Results obtained for $CaCO_3$ was 80.7 mg/L (table 3.3). Thus the analyzed sample meets WHO and Ethiopian drinking water quality guideline standards of 500 mg/L $CaCO_3$ respectively (WHO, 2004). This also indicates that, the concentration of divalent ions Ca^{2+} and Mg^{2+} ions at Lake Beseka was very low and the water is soft water.

4. Conclusion

Lake Beseka is expanding from time to time as indicated in part one of this article and the base rock is basically of volcanic ash and is contributing to the alkaline nature of the lake water. Thus the release of the lake water to the river Awash needs careful attention since it can corrupt the river itself by increasing the pH of the water, salinity and less suitable for river biota by reducing DO and increasing chlorine toxicity. The high concentration of some toxic heavy metals such as lead can also contaminate the river and can endanger human health downstream.

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