



Vertical Changeability of Physico-Chemical Characteristics on Bottom Sediments in Lakes Chamosouthern Ethiopia

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Abstract

Vertical variation of the physico-chemical characteristics of bottom sediments per two centimeter intervals was the main objective of this research. The samples were collected from three different lake stations (inflow, deep and outflow) in Feb. 2015. Different parameters pH, electrical conductivity, salinity, major ions (Mg^{++} , K^+ , Ca^{++} , Fe^{++} and Na^+), total organic matter and total organic carbon were analyzed. The average concentration of pH 7.31, conductivity 378.61 $\mu S/cm$, salinity and 0.337% were recorded. Maximum total organic matter 74.33g/kg and maximum total organic carbon 24.31g/kg was recorded at the upper part of sediment mainly at the inflow station. Some of the concentration increased at the inflow sampling station, like organic matter and organic carbon. Vertically only organic matter and organic carbon decreased down the depth, but others are varied within the depth. Likewise some concentration increased at the outflow station. In a deep lake to decrease the human impact, suspended particles, the tendency to change the chemical composition along the sediment profile but other stations affected. Similarly at the inflow station indicates significant increase in water contribution it has a power to change sediment chemistry. The changes in chemical composition of bottom sediments beside with depth point to periodical increases in fertility as a result of waste suspended particles from inflow. In an outflow lake, the related variation has indicated disturbances in the mechanism of sedimentation rate. All data analyzed using SPSS, excel and one-way ANOVA. Statistically strongly positive correlations between the content of organic matter and total organic carbon were found.

Keyword: lake, sediment, physico-chemical parameters

Introduction

Bottom sediments of lakes are built by the reach of minerals composition and organic substances removed from the water during the processes of precipitation, sorption and sedimentation by the tributaries, winds, decomposition of aquatic plants and animals, etc. The deposition of these minerals they play a significant role in the functioning of the ecosystem system of aquatic plants and animals; related to the possibility of secondary release of these substances [1-2]. The quality of lake is easily determined by the existence of watershed, topography, soil, geology and vegetation. In all the productivities and pollution of lake directly related with the materials that entering to the lake [3]. The impact of the biogenic substances accumulated in sediments on water quality depends on the lake basin morphology and on the morphology of the surroundings, determining such factors as the friction of the inflowing air masses causing water movements.

The depositions of the minerals compositions directly affect the physico-chemistry of sediment [4, 5]. As well as the formation of bottom sediments is also influenced by physical-chemical processes such as precipitation of insoluble calcium and magnesium carbonate, iron(II) hydroxide, sodium and potassium chloride and organic metals [6, 7]. The autochthonous matter in the suspended particles (remains of hydrobionts and macrophytes) dissolved in water (metabolites, enzymes) were characterized by high content of nitrogen and phosphorus compounds. Lakes basin with the high share of forest, important sources of macro and microelements are plant remains and mineral-organic compounds of humus origin [8].

Lake Bottom sediments are a mixture of material like, both organic and inorganic compositions, derived chiefly from the lake and its catchment, but material in trace quantities are also derived from the atmosphere [9]. Being a result of lake life, bottom sediments are extremely important for its nutrient economy, acting as sink or source of nutrients depending upon the redox conditions [9, 10].

The gradual decline in the production and productivity of these water bodies in terms of fishery has been a concern for the regional administration and the surrounding community. Hence studying the physico-chemical aspects of various sections of the lakes found to be crucial by our college. The aim of our study was to determine the differentiation of the physical and chemical parameters of bottom sediments in the vertical profile of Chamo lakes which are found in Gamogofa zone near Arbaminch city.

Description of Study Area

Location of Lake Chamo

Lake Chamo is found in the SNNPR of southern Ethiopia, and it is located in the Great Rift Valley at an elevation of 1,235 meters south of Lake Abaya and the city of Arba Minch, and east of the Guge Mountains. The northern end of the lake lies in the Nechisar National Park, measuring 26 km long and 22 km wide, with a surface area of 551 square kilometers and a maximum depth of 10 meters. Lake Chamo does not always have an outflow, but in some years, it overflows into the Sagan River, and in some years, it is fed by overflow from lake Abaya.

Table 1: The global position system (GPS) reading during sampling

Sample stations	Latitude	Longitude	Elevation in (m)
Inflow	5.908663 ⁰	37.559233 ⁰	1110
Deep	5.804475 ⁰	37.563065 ⁰	1110
Outflow	5.717841 ⁰	37.491771 ⁰	1110

Methods

The assessment of the physical-chemical vertical depth of bottom sediment was carried out in Feb. 2014 at Chamo lake. The samples of sediments from three different stations (inflow, deep and outflow) were collected by direct core cutting into per 2cm length. The cores sediment collected from inflow Lake station were 24cm long, at deep station 36cm long, while the outflow lakes station were 20cm long. Each sample of sediment per two centimeter collects in plastic bugs and immediately brought in to laboratory then saved the sample at 4°c in the refrigerator [11].

Chemicals and apparatus used

Analytical grade chemicals were used for the investigation. H₃PO₄ (AVONCHEM A6168-M), FAS (ES eagle scientific NG9 6DZ), hydrogen peroxide H₂O₂ (UNI-CHEM H47055-4J), Concentrated acids such as hydrochloric acid (density. 1.184; 37% HCl; 12M), nitric acid (density.1.41, 65% HNO₃) and sulfuric acid (density 1.83, 94% H₂SO₄), JENWAY Na, K, Ca, Fe and Mg standards were used.

Apparatus and Instruments

Glassware, plastic bag, pipette, beaker, test tube, ice bathe and GPS were used. Sensitive Electronic balance (OHASUS E11140), HQ40D 24 (HQ40D53000000 HACH), Magnetic bided hot plate (CB162 R000100037, UK), oven (British B35), Furnace (FUSEF1AH, R000047 UK), flame spectrophotometer (JENWAY) and Atomic Absorption spectroscopy (AAS- 210VGP) were used throughout the experimentation.

Analysis of Sediment Samples

Measurement of pH, Salinity and Electrical Conductivity of Sediment Samples

For this purpose, saturated sediments water extract was prepared. 10:20 sediments and distilled water respectively was added to the 250ml beakers for each samples. The dry sediment and distilled water are mixed thoroughly for 30minutes on automatic shaker machine, then pH, conductivity and salinity of this clear filtrate was measured by using HQ40D [12].

Digestion for major ion

Sediment samples were air dried in the laboratory; any unrecompensed matter found in the sediment were removed and mixed uniformly. Sediments were sieved through a 2mm sieve to remove coarse particles. 1g of the sediment samples were weighed out into acid washed glass round bottom flask. Sediment samples were digested by the addition of 20ml of aquaregia (mixture of HCl and HNO₃, ratio 3:1). Fit the condenser to the round bottom flask that reflex for two hours at 95°C. After reflex 10 ml of 30 % H₂O₂ was added slowly drop by drop. The round bottom flask wall was washed with distilled water and the sample was filtered out to separate the insoluble solid from the supernatant liquid. The volume was adjusted to 100 ml with distilled water. All samples and blanks were stored in conical flask [13, 14]. Standard solution of each sample Mg, Ca, K, Fe and Na was prepared according to Sc 2000 manufacturer procedure for Atomic absorption spectroscopy and flame spectrophotometer respectively.

Method validation

The digestion method and AAS analysis were validated by measuring the recovery of Na, K, Ca, Mg and Fe spiked to sediment samples. The known volume and concentration of standard solutions were employed on the samples in order to determine recovery test. The volume of 5mL and known concentrations of Na, K, Ca, Mg and Fe was added to 1g of sediment sample. The spiked samples were then digested in the same way as sediment sample. The final volume of the digest was diluted to 100mL in conical flask. The concentration of analyte was determining by each hallo cathode lamp of each metal on AAS and flam photometry. Metal concentration determined by the calibration curve [15].

Recovery tests

The performance of the optimized methods was evaluated by employing spiking experiments in which the concentration of the analyte is already known. The amount of spiked metals recovered after the digestion of spiked samples was used to calculate percentage recovery [16].

$$\text{Recovery test} = \frac{\text{con of spiked sample} - \text{con of unspiked}}{\text{con of analyte added (spiked)} \times \text{DF}} \times 100 \dots \dots \dots 1$$

Where the DF = sample volume / (total volume of sample plus spike)

Determination of Organic matter

A representative portion of sediment sample was transferred into a pre-weighed aluminum foil dish and sample weight (A) was determined using an analytical balance. Samples were transferred into a drying oven at 110°C for 24 hours. After cooling, samples were weighed (B) then combusted at 550°C for 2 hours to remove organic matter [17]. The samples were reweighed (C) and percentages of organic matters were determined as:

$$\% \text{OM} = \frac{(B - C) \times 100}{(B - A)} \dots \dots \dots 2$$

Determination of Total Organic Carbon

0.2g dried sediment of each samples was weighed and transferred into 500ml conical flasks, 10ml of 0.5M $K_2Cr_2O_7$ was added and stir gently. 18M of Concentrated H_2SO_4 (20 ml) was added with care directly into the flasks containing the analyte. The analyte was mix gently and allowed to stand for about 40minutes. 200ml of distilled water was added, followed by careful addition of 10ml concentrated H_3PO_4 . The analyte was allowed to cool and three drops of ferroin indicator was added. The analyte were then titrated with 0.25M FAS to wine-red end point the titration. A blank titration was carried out using the same procedure as above this procedure [18]. The % TOC of the sediments was calculated using:

$$\%TOC = \frac{(V_b - V_s) \times M \times 1.38}{W} \dots\dots\dots 3$$

Where V_b = Volume of FAS for Blank

V_s = Volume of FAS for sample

M = Morality of FAS

W = Weight of the sample in gram.

Data Analysis

The comparison between means and standard errors were tested for significance using ANOVA analysis and Duncan's multiple range tests. In addition, the correlation of physic-chemical parameters and the levels of metals in sediment were assessed using Pearson's correlation analysis. All statistical analyses were calculated, using the computer program of SPSS, Origin Lab 8.1 and excel at the 0.05 level of significance.

Result and Discussion

The results of Physico-chemical analysis of sediment samples listed in table 1. The major ions, organic matter and organic carbon described graphically.

Table 2 The mean value of pH, conductivity and salinity of sediment.

Sample stations	Unit of measurement	inflow	deep	outflow
pH		6.35±1.05	7.77±1.02	7.81±0.83
conductivity	μS/cm	247.33±1.33	365.82±2.11	522.67±2.52
salinity	‰	0.25±.01	0.32±.04	0.44±.03

Test of sediment pH is one of the most useful tests that can be carried out in studies attempting to relate the occurrence of native plant species and aquatic animals to environmental conditions. The sediment pH value can provide information about the presence or absence of carbonates and about the availabilities of a range of essential and non-essential or toxic elements [1, 12]. The mean value of pH in this study ranged from 6.35 to 7.81. As the results implies at the inflow station it is in the acidic range, but from inflow to outflow the acidity decreased and silently basic but is not significantly change in the vertical depth. Different factors control the deposition and preservation of carbonates in the sediments. Important is the flux of organic matter to the lake floor (related to primary production) mostly at the inflow station and its respiration/remineralization in the sediments, transport of carbonate material by currents and calcium carbonate saturation states of the water mass above the sediment. The carbonate maximum at the outflow station, it may be due to the decrement of level of water from the tributaries. The study conducted by Pravin [19] proved that many biological processes, such as reproduction could not function in strongly acidic or alkaline sediment environment. Effect of toxic substances aggravation is higher in acidic environment due to the release in toxicant from sediment material that present in aquatic system but chamo lake somewhat is in good range of pH. The result of this study also agreed with the report of Adeniyi [20].

It is well known that electrical conductance is a good measure of dissolved solids ions. Conductivity is a measurement used to determine mineralization contain of sediment. Certain physiological effects on plants and animals are often affected the increment and decrement by the number of available ions in the sediment [3, 12]. In the present investigation, the average conductivity values of the sediment samples varies from minimum of 247.33μS/cm to maximum of 522.67μS/cm at the inflow and outflow sampling stations respectively (Table 1). From the results of present investigation it was observed that electrical conductivity is lower at the inflow this may be due to the level of water increased, this implies the ions diluted by the amount of water inflow. Maximum at the outflow station this also may be due to the decrement of the level of water. The availability of ions concentrated from inflow to outflow and concentrated down the depth. Furthermore sediment's electrical conductivity is primarily a function of soil type moisture content and degree of saturation, concentration of dissolved solutes, and temperature and phase state of the sediment moisture. The results of the present investigation are in good agreement with the work reported by Farha and Pattusamy [21, 22].

Salinity is an important ecological parameter in its own right; and it is important in some chemical processes. Most aquatic organisms function optimally within a narrow range of salinity [5]. Salinity is also an important control on the types of pathogenic organisms and invasive species that can occur in a coastal waterway, on the types of species that can occur in algal blooms [21], and on the activity of nitrifying and denitrifying bacteria [22]. The results of this study were ranged in between 0.25 to 0.44‰. The maximum salinity recorded at the outflow station this may be due to the deposition of salt contains compounds at this station but somewhat the decrement at the inflow station. It also increased through the vertical depth and similarly this implies ret of deposition of ions increase within the depth.

The Recovery of Metals in Sediment

The performance of the optimized method was evaluated by using spiked samples against blank sample. According to the spiking experiment, the percentage recoveries of metals in the spiked samples ranged from 82.9% to 104.8% for sediment. The result purely comply with literature result and therefore acceptable. This indicates that, the developed digestion method can be considered reliable and was applied for the determination of major ions in digests of sediment.

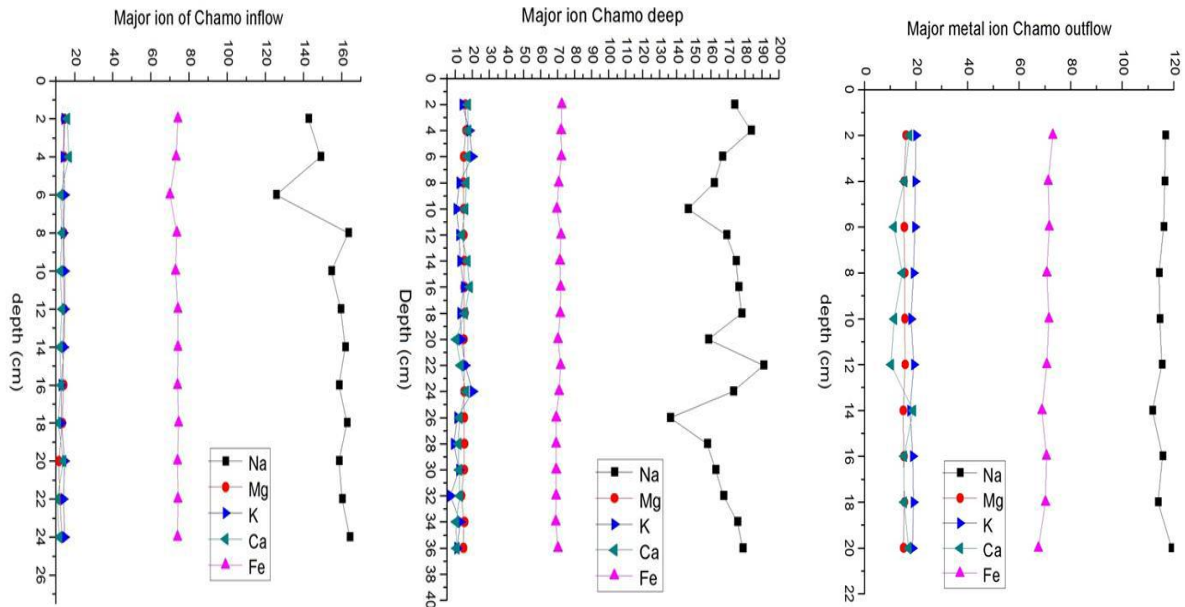


Fig 1: The major ions mean value per each two centimeter length interval.

Magnesium, calcium and potassium concentrations showed not significant verse correlation with vertical depth of sedimentation of Chamo lake, indicating that these elements are probably associated with crudely-grained sediments. Presumably, this fraction may include classic feldspars, clays, and alumina-silicate minerals and also other [20]. However, iron and sodium did a significant correlation with sedimentation vertical depth per 2cm of each sample. The calcium, magnesium and potassium content showed a fairly uniform distribution over the lake bottom sediment.

Manganese: Manganese has not been careful to be too much harmful and poisonous but the concentration of it in a particular spot may vary the taste and yet causes turbidity [23]. The value of magnesium in this study ranged 9 to 19.6g/kg. The maximum mean value was recorded at the outflow station at twelve (12cm) 19.6g/kg but the minimum value recorded at the inflow station at twenty (20) centimeter 9.22g/kg in fig 1. This confirms the deposition of mineral which contain magnesium increases or decreases depend on the depositions and precipitations at outflow station of minerals and dilution by amount of water at inflow station. The result of the study is less than the reported by Pradeep [24].

Calcium: The total Ca^{++} concentration reported here represents Ca^{++} both as CaCO_3 and as other calcium-bearing minerals. The concentration of calcium in this study varied in between 10 to 21g/kg. The maximum 21g/kg concentration was recorded at the outflow station at 14cm depth. The minimum 10.12g/kg of concentration was recorded at inflow sampling station at 6cm. the depositions of calcium minerals increased from inflow to outflow and increased the minerals deposition varied in the vertical depth. However, Pradeep, U.; et al [24] found that the sludge in the deeper area of the lake generally showed higher CaCO_3 content than sludge in shallow areas. The results of this reports is found lower than the reported by Pradeep [24].

Potassium: Potassium concentration in sediments ranges from 10.34 to 22.1g/kg. The maximum concentration was recorded at the outflow station mostly at the upper part of sediment. Generally the element K occurs as K^+ ions in water, but in sediment it exist in deferent form of minerals. The deposition of potassium mineral compounds was lower down the depth. This rivaled that potassium minerals is exist in the dissolved form in water. It is a lithophile and biophile metallic element, and is a major constituent of many rock-forming minerals, including important silicate minerals such as alkali feldspar, leucite, biotite, muscovite, phlogopite and some amphiboles. It is also a component of many phosphate, halide and sulphate minerals. It forms several minerals in its own right, including sylvite KCl and carnallite $\text{KMgCl}_3 \cdot 6\text{H}_2\text{O}$, which occur in evaporate deposits [25]. The results are lower than the reported by Upadhyay [23].

Iron: Iron is an important nutrient for aquatic plants and animals. The shortage of iron is a major problem for living beings and about 10-18 mg of iron content is required for adults per day 23 [26]. Iron, steel industry and sewage form the main cause for anthropogenic activities. The concentration of iron lies in between 52.13 g/kg to 79.45 g/kg. The concentration of iron in the samples is shown in the fig 1. The maximum concentration was recorded mostly at the outflow station, but the minimum mean value recorded at the inflow sampling station. The result of this study is in good agreement with reported value by Dhanakumar [26], whose study also showed that iron could be present in water in two forms; the soluble ferrous iron or the insoluble ferric iron.

Sodium: sodium exists in deferent form of minerals compounds. One and the most minerals is Halite commonly known as rock salt is the minerals form of sodium chloride (NaCl). Halite forms isometric crystals. This mineral is typically colorless or white, but May also be blue, dark blue, red, orange or yellow depending on the amount and type of impurities [8, 26]. It commonly occurs with other evaporate deposit minerals such as several of the sulfates, halides, and borates. In this study the concentration of sodium more abundant than other major ions. The concentration in this study ranged in between 112.67 to 194.24 g/kg. It is mostly maximum concentration recorded at the deep sampling station at the 22cm depth and minimum mean value at outflow at the depth of 2cm. This result implies the concentration and mineral deposition increases down the depth and it precipitate at the lake water becoming deeper. This may be due to existence of sodium in insoluble form which settled down to the bottom of the water. This study in good agreement with reported value by Upadhyay [23].

Organic matter (OM) is matter composed of organic compounds that has come from the byproducts of agricultural destroyed such as plants and animals. Organic molecules can also be made by chemical reactions that don't involve life.

It is very important in the movement of nutrients in the environment and plays a role in water retention on the surface of the planet [8, 23].

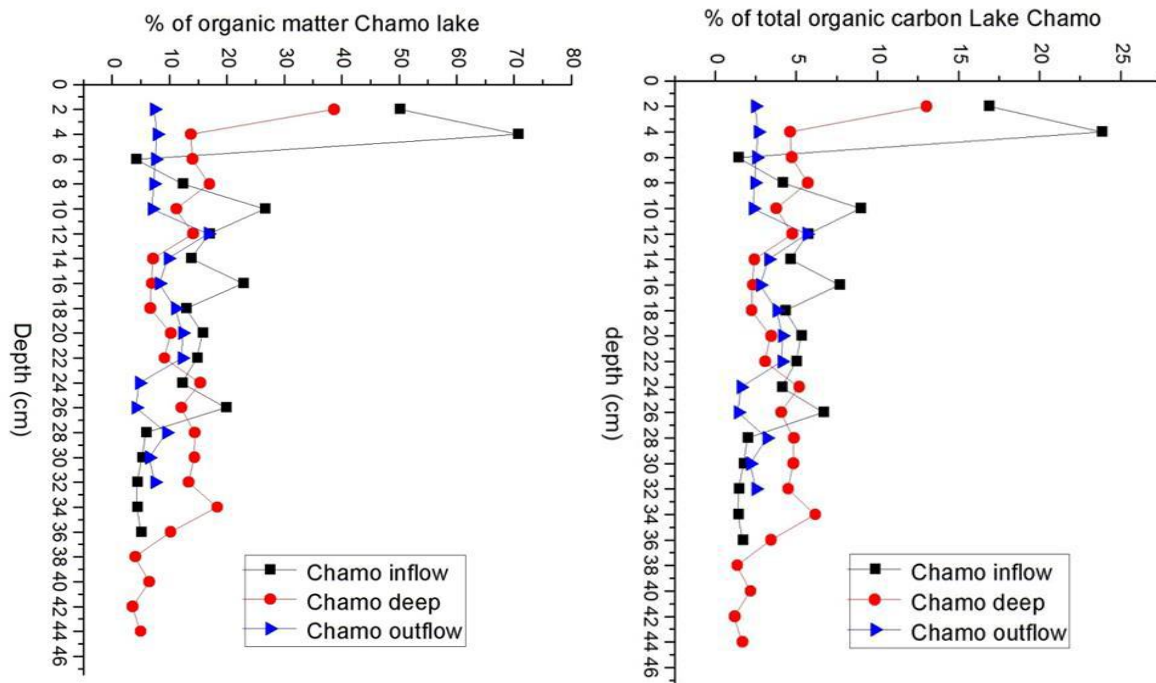


Fig 2: the concentration of total organic matter and total organic carbon per two centimeter interval.

Organic matter is present throughout the biological ecosystem [28]. After degrading and reacting, it can move into sediment and mainstream water via water flow. Organic matter provides nutrition to plant and living organisms. Organic matter acts as a buffer in aqueous solution to maintain a neutral pH in the environment. The buffer acting component has been proposed to be relevant for neutralizing acid rain [8]. In this study the concentration of organic matter in Chamo lake ranged between 3.21 to 74.33 g/kg. Maximum concentration was recorded at the inflow sampling station; this may be due to most of the suspended particle sinks at this station. The sinking suspended particle decreased from inflow to the outflow station. It is consecutively decreased from inflow to the outflow sampling stations. It decreased continuously down the depth. This implies the rate of deposition decomposition simultaneously takes place. The increment of this organic matter is polluting the lake by deputations of aquatic plants, consecutively the aquatic animals deteriorating. Upadhyay [23] also proved decomposition rates of organic matter increase as nitrogen and phosphorus contents increase. The result of this study is in good agreement with the study of Upadhyay [23].

Total organic carbon (TOC) is the amount of carbon found in an organic compound and is often used as a non-specific indicator of water quality or cleanliness of pharmaceutical manufacturing equipment. TOC may also refer to amount of organic carbon in a geological formation, particularly the source rock for a petroleum play [28]. The determination of total organic carbon is an essential part of any site characterization or ecological assessment since its presence or absence can markedly influence how chemicals reaction will react in the sediment [8, 27]. Carbon is usually derived from weathering of the parent material/geology, the decomposition of plant and animal matter, or by addition through anthropogenic activities. As the result of this study implies it was ranged in between 1.21 to 24.31 g/kg. Total organic carbon and total organic matter have a positive correlation among them. In vertical depth the concentration decreased but rate of decomposition increased. The concentration of TOC and TOM decreased vertically down the depth. This decrement may be due to the suspended particles decomposed in the depth increased and it converts to smaller particle matter. The concentrations of organic matter and organic carbon of Chamo lakes are higher than the findings by Aabid [29].

Table: The sediment Pearson correlations matrix of Chamo Lake

Correlations										
	pH	Conductivity	Salinity	TOM	TOC	Mg ⁺⁺	K ⁺	Ca ⁺⁺	Fe ⁺⁺	Na ⁺
pH	1									
Conductivity	.837	1								
Salinity	.796	.998	1							
TOM	-.724	-.983	-.994	1						
TOC	-.724	-.983	-.994	1.000	1					
Mg ⁺⁺	.993	.896	.863	-.801	-.801	1				
K ⁺	.496	.890	.920	-.958	-.958	.596	1			
Ca ⁺⁺	.999	.857	.818	-.749	-.749	.997	.528	1		
Fe ⁺⁺	-.950	-.624	-.568	.473	.473	-.906	-.200	-.938	1	
Na ⁺	.034	-.519	-.578	.665	.665	-.086	-.851	-.003	-.344	1

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).

As the Pearson correlations matrix of Chamo Lake impaled pH is strongly positive correlation between calcium and magnesium and strongly negative correlation between iron; conductivity of sediment chamo strongly positive correlation with salinity and strongly negative correlation with total organic matter and total organic carbon. Salinity is strongly

positive correlation with potassium and strongly negative correlation with total organic matter and total organic carbon. Total organic matter is strongly positive correlation with total organic carbon and strongly negative correlation with potassium. Total organic carbon is strongly negative correlation with potassium.

Conclusion

The high input of forests and agricultural byproduct in the lake catchment area create environment favoring isolation of the bottom sediments from outside interactions, capable of causing their motorized disturbance. The pH of Chamo lake sediment relatively slightly alkaline but at the inflow it is slightly acidic. Electrical conductivity and salinity is higher at the outflow sampling stations. The pH, conductivity and salinity somewhat increased down the depth. Major ions (Mg^{++} , K^+ , Ca^{++} , Fe^{++} and Na^+) mostly is not constantly increased or constantly decreased through across the vertical depth. Sodium is the most abundant ions in Chamo lake sediment. Relatively $Na^+ > Fe^{++} > K^+ > Mg^{++} > Ca^{++}$ is arranged when comparing the mean to each other and sodium containing minerals most predominant. Total organic matter and total organic carbon is higher at the inflow station. As well as it is decrees from inflow to outflow. Vertically both organic matter and organic carbon decreased. Chamo lake is reach of total organic matter and total organic carbon. This can cease high nutrient deposition, the result to increase deputations of aquatic plants to cover lake water.

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