# SEASONAL VARIATION IN PHYSICO-CHEMICAL PARAMETERS OF TEKEZE RESERVOIR, NORTHERN ETHIOPIA

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**ABSTRACT**

***Tekeze reservoir is situated in the northern part of Ethiopia. Physico-chemical parameters of reservoir water such as temperature, dissolved oxygen (DO), pH, transparency, electric conductivity, total dissolved solids (TDS), alkalinity, total hardness, phosphate and sulphate levels was carried out from August 2013 to July 2014 from three sampling stations to access the water quality. The water temperature ranged between 24.19 – 27.30$^0$C, dissolved oxygen ranged between 4.51 – 6.76 mg/l. The pH, transparency, conductivity and TDS were 7.14 – 8.64, 46.67 – 305.33 cm, 233.30 – 452.00 µs/cm and 0.91 – 1.77 g/L, respectively. There was significant difference ($p<0.05$) between all the parameters measured, except for water temperature among the seasons, but there was no significant different ($p>0.05$) in all the parameters between the stations and all the recorded values were within the recommended limit for fish production.***

**Keywords:** Conductivity, Physico–chemical, Tekeze reservoir, Seasonal variation

## INTRODUCTION

The presence of water on the earth is the vital force for the presence of life on earth. All the living organisms including human being depend on water. Due to its unique properties water is of multiple uses for living organisms. The increasing of the importance of fish to human being led to deal the quality of the water required for the fish in terms of their physico-chemical parameters such pH, temperature, dissolve oxygen, transparency, total alkalinity, total hardness, electrical conductivity, phosphate and sulphate. According to Unanam and Akpan (2006), the physico-chemical properties of water are vital for the distribution and richness of the aquatic organisms.

Wetzel (2001) defined that reservoirs are large, man-made impoundments of water, usually constructed in the area where there is shortage of natural freshwater or where the water available is unsuitable for human use. Reservoirs are built throughout the world for different uses, like for domestic drinking, watering of livestock, irrigation, flood control and hydropower generation.

The study of physico-chemical parameters of water is important to observe the functional relationship and productivity of freshwater or marine ecosystems as they are regulated by the dynamics of their chemical, physical and biotic environment (Boyd, 1981). The quality of a given water body where, fish lives is controlled by its physical, chemical and biological factors, all of which the interaction of the parameters with one another influences the productivity of the water body. In order to evaluate the productivity of such aquatic ecosystem for their essential management and effective utilization, there is the need to study these parameters with a view to controlling and maintaining them within optimum range

(USEPA, 1989). Because the quality of the water is directly or indirectly affects species abundance, composition and diversity of the aquatic life (Balarabe, 1998). Ethiopia is blessed with over 15 million hectares of inland freshwater bodies hence; this led to study the limnology of the water bodies (FISON, 2001).

Tekeze Reservoir was created with major objective of providing hydropower generation to the country; however, fishing has become other established uses of the reservoir. This study was carried out to determine some physico-chemical parameters of Tekeze reservoir in relation to water quality requirement for fish production.

## MATERIALS AND METHODS

**Description of Study Area:** Tekeze reservoir is a hydropower reservoir constructed in 2009 over the Tekeze River (Figure 1), the major river in Ethiopia and is a tributary of Nile River.

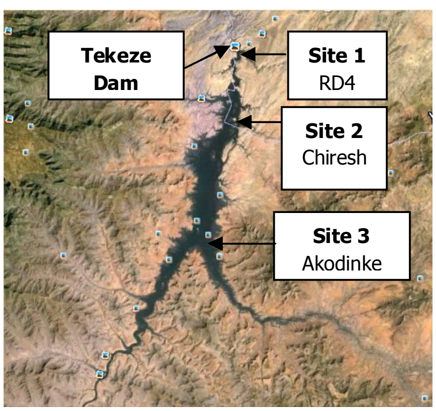


**Figure 1: Map of the study areas showing the sampled stations on Tekeze River, Ethiopia (**Virtual Globe Trotting, 2016)

Tekeze reservoir has maximum length of 75 km and maximum width of 6 km, and covering an area of about 160.4 km$^2$. According to National Statistics of Agency (NSA) (2008) Tekeze River is 608 kilometers long. Mana, Tsilare, Seletsa, Avera and Ariqua rivers are the main tributaries of the Tekeze River joined in to the reservoir. The canyon which it has created is the deepest in Africa and one of the deepest in the world, at some points having a depth of over 2000 m. Tekeze River originates in the central Ethiopian Highlands near Mount Qachen within Lasta, at 14°11N 37°31.7 E and 14.18.3°N 37.52 83° E. The reservoir is located at an elevation of 1107 m above sea level. The capacity of the reservoir is about 9.293 billion m$^3$ (9.293 km$^2$) of water. The main aim of constructing of the reservoir was to produce electricity, but the reservoir fisheries were later recognized as a significant socio-economic importance to Tigray and Amhara people.

**Sample Collection and Analysis Methods:** Surface water parameters were measured monthly from three stations for twelve months between August 2013 and July 2014. Site 1 (RD 4) was near the dam there was no fishing in this area. Site 2 (Chiresh) was fish landing site with a lot of human activities such as washing and bathing take place site 3 (Akodinke) has also a lot of fishing activities. Surface water temperature, pH, Dissolved oxygen, Electric conductivity and transparency were measured *in situ.* Temperature, DO, Electric conductivity (EC) and total dissolved solids (TDS) were measured using portable digital water quality multi meter model CO 411, and pH was measured with portable pH meter model CP 401. Transparency was measured with 20 cm diameter white and black secchi disk. The samples were drawn with a plastic bucket. Prior to sampling, all glassware and sample bottles were washed with liquid detergents, rinsed with tap water and soaked in 10% $HNO_3$ for 48 hour. They were there after rinsed with distilled water to preclude trace metal contaminations. The plastic bottles meant for sampling were further rinsed thrice on site with well waters being sampled. About 2 liter well water sample for physical and chemical parameters determination were collected monthly from each sampling location. Physico-chemical parameters of the water like temperature, pH, conductivity, TDS, dissolved oxygen and transparency were monitored monthly in the field using the methods as described in APHA (1998). Parameters like phosphate were calculated by colorimetric technique (APHA, 1998); Sulphate, total alkalinity and total hardness, were also determined by methods described by Ademoroti (1996) in the laboratory.

**Statistical Analysis:** Data collected were subjected to statistical analysis. One-way analysis of variance (ANOVA) was used to test differences; while the means were compared using Duncan's Multiple Range Test (DMRT) and SPSS software was used for the analysis.

## RESULTS AND DISCUSSION

**Physical Parameters:** Seasonal variations showed that all the examined parameters were significant ($p<0.05$) at wet and dry seasons as shown in Table 1. The physical water parameters of the reservoir were not significant ($p>0.05$) between the sampling stations (Table 2).

The lowest pH mean value of 8.03 ± 0.44 was recorded at Chiresh site and highest pH value of 8.20 ± 0.62 at Akodinke site (Table 2). Seasonal variations showed that pH values in dry season (7.80 ± 0.58) were significantly lower ($P<0.05$) than wet season (8.30 ± 0.34) as shown in Table 1. The pH of the reservoir recorded during the period of the study falls within the recommended limits of 6.5 – 8.5 (Kemdirim, 1993) suitable for productive waters and falls within range of WHO standards of 6.5 to 8.5 for drinking water indicating that the reservoir in all indication is good for drinking and fish production. pH is one of the most important operational water quality parameters, supposing, pH is above 7, this will indicate that water is probably hard and contains calcium and magnesium (David, 2004).

The value of surface water temperature of the reservoir ranges between 24.19 and 27.30 $^0$C. The record of water temperature showed that there was significant difference ($p<0.05$) among the seasons. According to Jayalakshmi *et al.* (2011) report water temperature is a vital factor effect in the chemistry and biochemical reactions in the organism. Temperature at which samples are analyzed and at which physico-chemical measurement are made is important for data correlation and interpretation purposes (Ogunfowokan *et al.,* 2007). High temperature may increase the toxicity of many substances such as heavy metals in water for domestic use (Fatoki and Awofolu, 2003). Based on the results it was noted that temperature fluctuated in between 24.19 – 27.30º C and 24.80 – 27.04º C during dry and wet season respectively (Table 2). The lower value 24.98ºC was found in Akodinke site and the highest water temperature value (25.92º C) at Chiresh site. The values obtained in this study were slightly above the recommended WHO (2006) standard of 25 ºC. High water temperature enhances the growth of micro-organisms and may increase problems related to taste, odor, color and corrosion (WHO, 2011). In wet temperature, the viscosity increases. This in turn, diminishes the efficiency of settling of the solids that the water quality may contain because of the resistance that the high viscosity offers to the downward motion of the particles as they settle (Jayalakshmi *et al.,* 2011). The electrical conductivity (EC) of a water body is a very useful parameter for determining the water quality. Jayalakshmi *et al.* (2011) reported that electric conductivity is a measurement of water's current and is directly related to the concentrations of ionized substance in the water and the levels affected by the EC of water are a direct function of its total dissolved solids, organic compounds and temperature (Jayalakshmi *et al.,* 2011). From the results it was evident that the highest value of 363.32 µS/cm was obtained at Chiresh whereas the lowest value (355.13 µS/cm) at RD4 (Table 2). There was no significant difference ($p>0.05$) of electric conductivity between the sampling sites. Seasonal variation (Table 1) showed that the range of EC during dry season (233.30 – 367.67 µS/cm) was lower than that the range of wet season (390.33 – 452.00 µS/cm). These values were below the recommended limits of 1000 µS/cm for drinking water and fish production.

**Chemical Parameters:** Total alkalinity of water denotes the capacity to neutralize strong acid. The solubility of various substances directly depends on the levels of alkalinity in the water. In Table 2, the highest alkalinity mean value of 145.67 ± 9.11 mg/l was seen at RD4 and the lowest alkalinity value of 132.67 ± 12.90 mg/l at Chiresh sampling site. Table 4 showed that dry season range values (109 –

**Table 1: Seasonal mean and range values of physico-chemical parameters in Tekeze Reservoir**

| Season | Temp. ($^oC$) | pH | EC (uS/cm) |
|---|---|---|---|
| **Dry** | 25.90 ± 1.12 | 7.80 ± 0.58 | 290.90 ± 24.32 |
| **Range** | 24.19 – 27.30 | 7.14 – 8.16 | 233.30 – 367.67 |
| **Wet** | 25.70 ± 1.54 | 8.30 ± 0.34 | 428.50 ± 45.90 |
| **Range** | 24.80 – 27.04 | 7.69 – 8.64 | 390.33 – 452.00 |
| **Sig. (0.05)** | 0.042 | 0.004 | 0.000 |
| | **DO (mg/l)** | **Transp. (cm)** | **TDS (g/l)** |
| **Dry** | 5.90 ± 0.66 | 265.20 ± 32.62 | 1.01 ± 0.29 |
| **Range** | 5.07 – 6.76 | 190.33 – 305.33 | 0.91 – 1.13 |
| **Wet** | 5.30 ± 0.42 | 89.20 ± 12.40 | 1.54 ± 0.43 |
| **Range** | 4.51 – 6.20 | 46.67 – 145.67 | 1.37 – 1.77 |
| **Sig. (0.05)** | 0.001 | 0.000 | 0.000 |

**Table 2: Mean values of physico-chemical data in Tekeze reservoir by sampling stations**

| Sampling site | Temperature ($^oC$) | pH | EC (uS/cm) |
|---|---|---|---|
| **RD4** | 25.85 ± 0.83 | 8.04 ± 0.28 | 355.13 ± 23.02 |
| **Chiresh** | 25.92 ± 1.20 | 8.03 ± 0.44 | 363.32 ± 30.64 |
| **Akodinke** | 24.98 ± 0.98 | 8.20 ± 0.62 | 360.75 ± 26.49 |
| **Sig. (0.05)** | 0.757 | 0.885 | 0.996 |
| | **DO (mg/l)** | **Transp. (cm)** | **TDS (g/l)** |
| **RD4** | 5.63 ± 0.65 | 178.50 ± 12.00 | 1.32 ± 0.16 |
| **Chiresh** | 5.51 ± 0.37 | 177.13 ± 9.10 | 1.26 ± 0.30 |
| **Akodinke** | 5.55 ± 0.50 | 175.94 ± 14.68 | 1.26 ± 0.21 |
| **Sig. (0.05)** | 0.963 | 0.980 | 0.985 |

**Table 3: Variation of some physico-chemical parameters in Tekeze Reservoir by sampling sites**

| Sampling site | Alkalinity | Total hardness | Phosphate | Sulphate |
|---|---|---|---|---|
| **RD4** | 145.67 ± 9.11 | 248.33 ± 21.07 | 0.03 ± 0.00 | 4.83 ± 0.50 |
| **Chiresh** | 132.67 ± 12.90 | 248.67 ± 15.98 | 0.05 ± 0.00 | 5.67 ± 0.43 |
| **Akodinke** | 141.00 ± 7.66 | 270.50 ± 25.10 | 0.06 ± 0.02 | 5.83 ± 0.68 |
| **Sig. (0.05)** | 0.439 | 0.26 | 0.70 | 0.64 |

**Table 4: Seasonal variation of some physico-chemical parameters of Tekeze Reservoir**

| Season and range | Alkalinity | Total hardness | Phosphate | Sulphate |
|---|---|---|---|---|
| **Dry** | 127.78 ± 5.88 | 238.11 ± 13.55 | 0.03 ± 0.00 | 4.11 ± 0.34 |
| **Range** | 109 – 148 | 205 – 259 | 0.01 – 0.07 | 3 – 6 |
| **Wet** | 151.78 ± 10.23 | 273.56 ± 18.43 | 0.06 ± 0.02 | 6.78 ± 1.19 |
| **Range** | 128 – 162 | 240 – 292 | 0.03 – 0.08 | 4 – 9 |
| **Sig. (0.05)** | 0.01 | 0.31 | 0.01 | 0.01 |

148 mg/l) was lower than wet season range values (128 – 162 mg/l) and showed significant difference ($p<0.05$) among the seasons. These values were below WHO recommended limit of 200 to 600 mg/l for drinking water.

Alkalinity and total hardness were significant ($p<0.05$) between the sampling sites. Phosphate and sulphate were not significant different ($p>0.05$) between the three sampled sites. Total hardness is a measure of capacity of water and precipitates the soap. In most fresh water, total hardness is imparted mainly by calcium and magnesium ions, which apart from sulphate, chloride and nitrate are found in combination with carbonates and bicarbonates (Sangpal *et al.,* 2011). The lowest value of total hardness (248.33 mg/l) was seen at RD4, while the highest value 270.50 mg/l) at Akodinke site (Table 3). In Table 4, the mean value total hardness for dry season (238.11 ± 13.55 mg/l) was lower than the mean value for wet season (273.56 ± 18.43 mg/l). These values were found to be lower than the recommended value of WHO (2006) which is 500 mg/l. These findings implied that the reservoir environment was not hard. Although hard water has no known effects on health but it is unsuitable for domestic use (Sangpal *et al.,* 2011). Phosphate comes from fertilizers, pesticides, industry and cleaning compounds and natural sources include phosphate containing rocks and solid or liquid wastes. The lowest phosphate mean value of 0.03 ± 0.00 mg/l was observed at RD4 and highest phosphate value of 0.06 ± 0.02 mg/l at Akodinke fishing area (Table 3). In wet season, the phosphate value ranges from 0.03 – 0.08 mg/l was higher than dry season range value of 0.01 – 0.07 mg/l (Table 4). The values obtained for phosphate were lower than WHO (2006) recommended limit of 2.2 mg/l. The lowest sulphate value was recorded at RD4 (4.83 ± 0.50mg/l) and highest sulphate values of 5.83 mg/l at Akodinke sampling (Table 3). In dry season, sulphate mean value of 4.11 ± 0.34 mg/l was lower than wet season value of 6.78 ± 1.19 mg/l (Table 4). The mean values obtained in this study were lower when compared with WHO limit of 250 mg/l for drinking water (WHO, 2006). Based on the results, the sulphate are not likely to cause health hazard and can be said to be potable. The presence of sulphate in drinking water can cause noticeable taste and very high levels might cause a laxative effecting unaccustomed consumers (WHO, 2011).

There are some marked variations in the physico-chemical parameters observed for the sampling sites and seasons. Water temperature range for the entire reservoir, compares well with the ranges recorded for other tropical Lakes (Ovie and Adeniji, 1993). Aquatic organisms (from microorganisms to fish) depend on certain temperature range for optimal growth (APHA, 1992). The normal range to which fish is adapted in the tropics is between $8^0$C and 30°C (Alabaster and Lloyd, 1980). The slight lower water temperature of Tekeze reservoir during the wet season could be as a result of seasonal changes in air temperatures associated with the rain fall during the season. Balarabe (1989) was observed lower water temperature in Makwaye Lake, near Zaria, during wet period. Kolo and Oladimeji (2004) made similar findings in Shiroro dam. The water temperature range for Kontagora reservoir is within the range of $10^0$ C – $50^0$ C for river and dam water meant for domestic purposes, and for fish culture in tropical waters (WHO, 1984). The higher dry season secchi-disc transparency mean value compared to that of the rainy season could be due to absence of floodwater, surface run-offs and settling effect of suspended materials that followed the cessation of rainfall. Kemdirim (1990) reported similar observations. Low secchi-disc transparency recorded during rainy season, agrees with the findings of Wade (1985), who observed that onset of rain decreased the secchi-disc visibility in two main lakes around Jos, Nigeria. Lower transparency recorded during rainy season when there was turbulence and high turbidity, has a corresponding low primary productivity, because turbidity reduces the amount of light penetration, which in turn reduces photosynthesis and hence primary productivity (APHA, 1992). The hydrogen ion concentration (pH) was near neutral throughout both season, and it was within the range for inland waters (pH 6.5 – 8.5), as reported by Antoine and AI-Saadi (1982). Boyd and Lichtkoppler (1979) reported that pH range of 6.09 - 8.45 as being ideal for supporting aquatic life including fish. Thus, the pH range obtained in this study is within the acceptable level of 6.0 to 8.5 for culturing tropical fish species (Huett, 1977) and, for the recommended levels for drinking water (WHO, 1984). Federal Environmental Protection Agency (FEPA) recommended pH 6.5 – 8.0 for drinking and 6.0 – 9.0 for aquatic life. Higher dry season conductivity value obtained could be attributed to concentration effect as a result of reduced water volume from their main tributary channels. Ovie and Adeniji (1993) as well as, Kolo and Oladimeji (2004), observed a similar trend for Shiroro Lake. The dissolved oxygen in the reservoir was higher during the dry season than the rainy season. The high oxygen value for the dry season coincides with periods of lowest turbidity and temperature. The amount of dissolved oxygen in water has been reported not constant but fluctuates, depending on temperature, depth, wind and amount of biological activities such as degradation (Ibe, 1993). In this study, wind which increases wave action, and decrease surface water temperature might have contributed to the increased oxygen concentration during the dry season, while the rains, created increased turbidity and decreased oxygen concentration during the rainy season. Oniye *et al.* (2002), made similar observation for Zaria dam. Water hardness was higher during the dry season than the rainy season. This could be as a result of low water levels and the concentration of ions, and the lower rainy season value could be due to dilution. This agrees with the result of Kolo and Oladimeji (2004) for Shiroro Lake and Ufodike *et al.* (2001) for Dokowa mine lake. The mean alkalinity agreed with the range value documented by Moyle (1946) and Boyd (1981) for natural water. The alkalinity is higher in the dry season and lower in the rainy season, when the reservoir had high water level. This could be due to low water levels with its attendant concentration of salts and the lower value in the rainy season could be due to dilution. Ufodike *et al.* (2001), recorded similar result for Dokowa Mine Lake. The high level of alkalinity in the dry season agrees with the findings of Adebisi (1981), on the correlation of the seasonal fluctuation of water level and alkalinity. The negative correlation values obtained indicate that alkalinity of water increase with decreasing water level. Similar observations have been made by Holden and Green (1960) and Tailing and Rzoska (1967) on Rivers Sokoto and Nile in Egypt respectively. The high dry season mean value of phosphate (phosphorus, $PO_4$-P) could be due to concentration effect because of reduced water volume. It could also be due to lower water hardness, thus less co-precipitation of phosphate with calcium carbonate, a phenomenon that has often been reported to occur in many fresh water lakes (Heleen *et al.,* 1995). Akpan and John (1993), made similar findings in Cross River state in Eastern Nigeria. The higher nitrate-nitrogen ($N0_3$-N) concentration during the rainy season could be due to surface run-offs as well as the decomposition of organic matter. Ufodike *et al.* (2001), made similar observations for Dokowa Mine Lake. Kennedy and Hain (2002) also reported that nitrate-nitrogen increase with surface run-off and at deeper depths. Comin *et al.* (1983), stated that a high nitrate concentration in lake is related to inputs from agricultural lands.

**Conclusion:** Assessment of water quality is an important factor for assessing pollution levels and the productivity of the water body. This study revealed that the water in the reservoir is suitable for fish production and other domestic purposes. The periodical assessment of physico-chemical analysis of the water body should be carried out, as this would be helpful in early detection of any future water quality. In all, the ranges of physico-chemical properties of Tekeze Reservoir are comparable to those found in non-polluted African reservoirs, and are within the allowable limits recognized by WHO for drinking water supply as well as fish production.

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