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# Assessing the Borta Reservoir using physicochemical parameters, Oromia Regional State, Ethiopia

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## ABSTRACT

This study was conducted in the Borta Reservoir (Ethiopia) to portray physicochemical parameters between September 2018 and July 2019 for three data collection sessions. Accordingly, the sampling site was purposely selected perimeter-wise from the Borta Reservoir based on the distance from human settlements; anthropogenic effect and accessibility for the study three stations (sampling sites) were purposely selected perimeter-wise and the sites were coded as Site one (S1), site two (S2), and site three (S3). Water samples were collected monthly for three sample collection sessions. Samples were collected from each site and transported to the Limnology Laboratory and other parameters were measured on-site using a pre-calibrated portable instrument. SPSS version 20 was used for the statistical analysis. The recorded physicochemical parameters were in the range of freshwaters. It was evident that the Borta Reservoir had been showing signs of water quality loss over time. This could have resulted from stressors linked to anthropogenic sources from domestic wastes and pollutants from agricultural lands. This study suggested a restoration action be undertaken.

**Key words:** anthropogenic factors, domestic wastes, nutrients, pollution, water quality

## HIGHLIGHTS

- The appropriate study design and method of sample collection is applied.
- The characteristics of water quality parameters are controlled.
- More detailed settling information about water quality parameters can improve and estimate water treatment performance.
- It was demonstrated that the dynamics of the wastewater characteristics under dry and wet seasons influence concentration water quality parameters.

## GRAPHICAL ABSTRACT

## LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| $<$ | less than |
| $\pm$ | plus or minus |
| $\leq$ | less than or equal to |
| °C | degree Celsius |
| µg/l | micrograms per liter |
| ANOVA | analysis of variance |
| APHA | American Public Health Associations |
| BOD | biological oxygen demands |
| COD | carbon oxygen demands |
| Conc. | concentration |
| EC | electrical conductivity |

| | |
|---|---|
| mg/l | milligrams per liter |
| $NH_3$ | ammonia |
| $NO_3^-$ | nitrate ion |
| $SiO_2^-$ | silicon dioxide |
| $SO_4^{2-}$ | sulfate ion |
| Std. | standard |
| T° | temperature |
| TDS | total dissolved substance |
| TP | total phosphorus |
| UEPA | United States Environmental Program Agency |
| WHO | World Health Organization |

## 1. INTRODUCTION

Water is vital to the existence of all living organisms, but this valued resource is increasingly being threatened as human populations grow and demand more water of high quality for domestic purposes and economic activities (Elham *et al.* 2014). The freshwater body has an individual pattern of physical and chemical characteristics (WHO 1996). The need for water quality could be for drinking, other domestic uses, industrial, agricultural, irrigation, or fish farming (Ani *et al.* 2016). The level of physicochemical parameters of water will determine the purpose with which the water could be best used for little or no treatments. Variability in physicochemical parameters is responsible for the distribution of organisms in different freshwater habitats according to their adaptation, which allows them to survive in a specific habitat (Jeffries & Mills 1990). The water quality problems affect some beneficial use of lake water to an extent (WHO 1996). Water gathers impurities from both natural and anthropogenic sources (WHO and UNICEF 2010).

Many chemicals found in drinking water sources could have adverse human health effects (WHO 2004). Dissolved oxygen is an important indicator of water quality, ecological status, productivity, and health of a reservoir (Mustapha 2008). The electrical conductivity of water is affected by factors such as the amount, type, and charge of dissolved solids joining water (Meride & Ayenew 2016). Nitrogen concentrations can be an important indicator of stream health. High levels of nitrogen can lead to an overproduction of organic matter (Hardison *et al.* 2006). Decomposition of this organic matter quickly consumes available oxygen. Nitrogen concentrations can be a good indicator of livestock's effects on the watershed (Belsky *et al.* 1999). Nitrogen should be measured in three general forms, ammonium, nitrate, and total dissolved nitrogen. The majority of phosphorous in aquatic ecosystems is derived from the dissolution of minerals in soil and organic matter such as leaf litter. Phosphorous can often be a limiting nutrient in plant and algae growth, but too much phosphorous can lead to excessive plant growth and algal blooms (Kentucky Water Watch 2006).

The impairment of water quality due to the introduction of pollutants is a problem faced by most towns around the world (Abida *et al.* 2008). Predominantly, this could be due to urbanization and agricultural activities, and the extent of impervious or disturbed land increases (Frondorf 2001). Consequently, land-use changes increase impervious surfaces resulting in storm runoff that negatively affects aquatic ecosystems and water quality (Paul & Meyer 2001). Lentic systems with substantial agricultural and urban land use in their watersheds experience increased inputs and varying compositions of organic matter and nutrients mainly phosphates and nitrates from fertilizer application (Sickman *et al.* 2007), and major non-point sources are from pesticide spraying or fertilizer application (UNEP 1996).

The problem of drinking water contamination and its management has become a need of our nation because of its far-reaching impact on human health (Bharathi *et al.* 2014) due to its vulnerability to anthropogenic perturbation (Kaufmann *et al.* 2014); WHO (2011) also described that water quality may rely on the protection of the source water and the distribution system as the principal control measures for provision of safe water. More typically, water treatment is required to remove it.

Otherwise, poor water quality can result in low profit, low product quality, and potential human health risks (Ahmed *et al.* 2015). The Borta Reservoir is one of the Ethiopian artificial reservoirs that have huge ecological, socio-economic, and aesthetic values. The anthropogenic effects in and around the reservoir have been degrading its quality and quantity progressively, but monitoring studies and management action were not fairly practiced. Consequently, the overall objective of this study is to assess the Borta Reservoir using physicochemical parameters.

## 2. MATERIALS AND METHODS

### 2.1. Site description

This study was conducted in the artificial Borta Reservoir between September 2018 and July 2019. The Borta Reservoir is found in the Oromia region, Kellem Wolega Zone, and it is bordered by Dambi Dollo Town in the Northwestern direction. Dambi Dollo Town is located 653 km west of Addis Ababa, the capital city of Ethiopia, within altitude ranges of 1,701–1,827 m above sea level. Dambi Dollo Town has four Kebeles, namely Biftu, Dollo, Lafto, and Yabalo. The town has a total population of 48,344, of which 24,336 are males and 24,008 are females (Eticha & Adisu 2022). Emergent macrophytes are the dominant aquatic vegetation in this reservoir. S1 is at the mid-section of the reservoir which represented the area of lentic water where pollution joins the reservoir. S2 is at the dam axis where a lot of human activities such as washing, bathing, and fish landing take place. S3 is at the headwater of the reservoir which represented the lotic section at which the reservoir is bordered by grazing land (Figure 1).

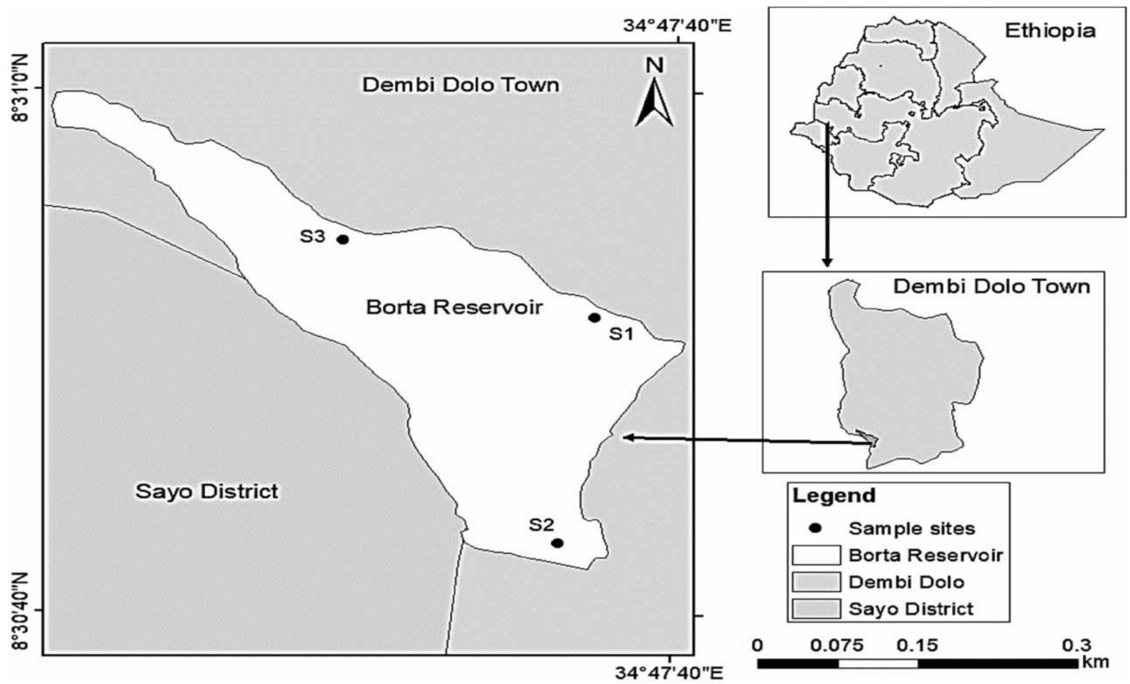


**Figure 1** | Map of the study area (researchers' map, 2019).

### 2.2. Sample site selection

Three stations (sampling sites) (see Figure 1) were purposely selected perimeter-wise from the Borta Reservoir based on the distance from human settlements, anthropogenic effect, and accessibility for study following the criteria in Barbour *et al.* (1999), and the sample sites were coded as S1, S2, and S3.

### 2.3. Study design and sampling procedure

The method of sample collection was done as outlined in the WHO (2006) and the American Public Health Association Guidelines (APHA 1999). The samples were collected from three stations (sampling sites) for three sessions between February and July 2019 and duplicated samples as taken at each site. The sampling process was done starting from 9.00 a.m. and lasted for approximately 2–3 h at the three sites covering the study segment. Samples were collected with a 1 L plastic bottle (a nonmetallic water sampler) from each site and labeled with a collection point, stored in an icebox before analysis, and transported to Addis Ababa Limnology.

Water samples were filtered through 0.45 μm glass fiber filters (GF/F) except for total phosphorous (TP). Then, parameters were measured and put in appropriate units, soluble reactive phosphorous (SRP) and total phosphorous (TP) in μg/l, silicon (in mg/l), carbon oxygen demand (COD) in mg/l, biochemical oxygen demand (BOD) in mg/l, and sulfate (in mg/l) as in APHA (1999). Nitrate (mg/l) was measured using cadmium reduction and ascorbic acid methods, respectively, according to the spectrophotometer (HACH, DR/2010, USA) procedures outlined in APHA (1999). Dissolved oxygen, electrical conductivity, and water temperature were measured on-site using a pre-calibrated HACH multimeter hand-held probe, model HQ40D, and readings were taken in μS/cm for conductivity, in °C for temperature, and mg/l for total dissolved solids (TDS). The pH of the water was also measured on-site using a pre-calibrated portable pH meter (Model: HI96107 HANNA Instrument).

### 2.4. Data analysis

Descriptive statistics such as range and mean were used to analyze physicochemical data. The statistical software (SPSS version 20) was used for the statistical analysis.

## 3. RESULTS

### 3.1. Physicochemical characteristics

The value ranged between 0.87 and 0.91 mg/l for silicon dioxide ($SiO_2$), 0.07 and 0.12 mg/l for ammonia ($NH_3^-$), 0.06 ± (0.02) mg/l for nitrate ($NO_3^-$), 0.34 and 0.37 μg/l for phosphorous ($PO_4^{3-}$), 35.7 and 127.4 mg/l for COD, 6.84 and 24.43 mg/l for biochemical oxygen demand (BOD), and 1.18 and 7.00 mg/l for sulfate ($SO_4^{2-}$) (Table 1).

**Table 1** | Laboratory analysis of physicochemical parameters in the Borta Reservoir

| Parameters | Statistic | Sample sites | | |
|---|---|---|---|---|
| | | Site 1 | Site 2 | Site 3 |
| Silicon dioxide ion ($SiO_2^-$ concentration in mg/l) | Mean ± Std. Error | 0.87 ± 0.07 | 0.903 ± 0.6 | 0.91 ± 0.09 |
| | Std. Deviation | 0.2 | 0.18 | 0.28 |
| Ammonia ($NH_3^-$ concentration in mg/l) | Mean ± Std. Error | 0.07 ± 0.01 | 0.09 ± 0.03 | 0.12 ± 0.03 |
| | Std. Deviation | 0.03 | 0.09 | 0.09 |
| Nitrate ($NO_3^-$ concentration in mg/l) | Mean ± Std. Error | 0.06 ± 0.02 | 0.06 ± 0.02 | 0.06 ± 0.02 |
| | Std. Deviation | 0.07 | 0.09 | 0.06 |
| Phosphorous ($PO_4^{3-}$ concentration in μg/l) | Mean ± Std. Error | 0.35 ± 0.14 | 0.34 ± 0.13 | 0.37 ± 0.14 |
| | Std. Deviation | 0.42 | 0.39 | 0.43 |
| Carbon oxygen demand (COD concentration in mg/l) | Mean ± Std. Error | 127.4 ± 2.6 | 35.7 ± 1.32 | 60.82 ± 1.7 |
| | Std. Deviation | 6.78 | 3.96 | 5.92 |
| Biochemical oxygen demand (BOD concentration. in mg/l) | Mean ± Std. Error | 24.43 ± 0.9 | 6.84 ± 0.55 | 12.16 ± 0.5 |
| | Std. Deviation | 2.1 | 1.64 | 1.35 |
| Sulfate ion ($SO_4^{2-}$ concentration in mg/l) | Mean ± Std. Error | 1.18 ± 0.12 | 4.85 ± 0.33 | 7.00 ± 0.55 |
| | Std. Deviation | 0.35 | 0.99 | 1.65 |

In the present study, laboratory analysis revealed that ammonia ($NH_3^-$), nitrate (as $NO_3^-$), and sulfate ion ($SO_4^{2-}$) were below the recommended standard range set by WHO (2011, 2017) and BIS (2012) (see Table 2).

**Table 2** | Standard value versus measured value of physicochemical parameters in the Borta Reservoir ($n = 2$)

| Physicochemical parameters | Ranges of measured values | Standard values |
|---|---|---|
| Silicon dioxide ion ($SiO_2^-$) | 0.87 ± (0.07) – 0.903 ± (0.06) mg/l | – |
| Ammonia ($NH_3^-$) | 0.07 ± (0.01) – 0.12 ± (0.03) mg/l | 0.5 mg/l |
| Nitrate ($NO_3^-$) | 0.06 ± (0.02) mg/l | 50 mg/l |
| Phosphorous ($PO_4^{3-}$) | 0.34 ± (0.13) – 0.37 ± (0.14) μg/l | – |
| Carbon oxygen demand (COD) | 35.7 ± (1.32) – 127.4 ± (2.26) mg/l | – |
| Biochemical oxygen demand (BOD) | 6.84 ± (0.55) – 24.43 ± (0.69) mg/l | – |
| Sulfate ion ($SO_4^{2-}$) | 1.18 ± (0.12) – 7.00 ± (0.55) mg/l | 250 mg/l |

In the present study, some physicochemical parameters such as $SiO_2^-$, $NH_3$, and analysis of variance (ANOVA) had portrayed significant variation among sites ($p < 0.05$). However, in cases of COD, BOD, $NO_3^-$, and TP, there was no variation (Table 3). Although ANOVA had not shown a significant difference among sites ($p > 0.05$), the mean value varied among sites for some parameters including COD, BOD, $NO_3^-$, and TP in this study (Table 3).

**Table 3** | Mean variations of physicochemical parameters among sample sites in the Borta Reservoir (degree of freedom; DF = 5, $n = 6$)

| | **ANOVA** | | |
|---|---|---|---|
| | **Significant variations test ($P < 0.05$)** | | |
| | **Comparison between groups** | | |
| | **Sites** | | |
| **Parameters** | **S1** | **S2** | **S3** |
| Silicon dioxide ion ($SiO_2^-$) | 0 | 0.005 | 0 |
| Ammonia ($NH_3^-$) | 0.035 | 0 | 0.377 |
| Nitrate ($NO_3^-$) | 0 | 0 | 0 |
| Phosphorous ($PO_4^{3-}$) | 0 | 0 | 0 |
| Carbon oxygen demand (COD) | 0.602 | 0.049 | 0.002 |
| Biochemical oxygen demand (BOD) | 0.069 | 0.054 | 0.4 |
| Sulfate ion ($SO_4^{2-}$) | 0.4 | 0 | 0.011 |

### 3.2. Seasonal variation of physicochemical parameters

In the present study, measured values of some parameters displayed seasonal variation (see further Figure 2).

The results in Figure 2 showed that there was an increment within seasonal variation and parameters like pH, TDS, and EC were higher in the wet season than the dry season apart from T°. This might be due to pollutant inlets via erosion and runoff during the rainy season. The increment of concentration of the recorded parameters (Figure 2 and Table 4) among sites was shown seasonal variation. This might be a good indicator of the existence of prospective sources of water contaminant at the sampling sites seasonally. For some parameters measured *in situ*, the Borta Reservoir had shown mean variation between seasons in the present study. Likewise, the recorded mean value ranged from 6.88 to 7.08 for pH, 82.43 to 114.70 mg/l for TDS, 126.65 to 132.28 μS/cm for EC, and 20.75 to 23.76 °C for T° between wet and dry seasons, respectively (Table 4).

## 4. DISCUSSIONS

### 4.1. Physicochemical characteristics

From the laboratory analysis, the present study found the values within the ranges of African lentic waters. Likewise, many parameters of the reservoir were within the standard range recommended by WHO (2011), BIS (2012), and (WHO 2017). Average values of the physicochemical parameters measured in the Borta Reservoir were in the range of physicochemical parameter values reported in freshwaters of the African tropic (Mugo 2010; Katsallah 2012).

### 4.2. pH

In the present study, all sites of water met national and WHO guidelines that state drinking water pH between 6.5 and 8.5 are satisfactory. In this study, a high pH value was recorded in the dry season. This could be due to high decomposition activities in this season. A similar result was observed in Sagar Lake (Choudhary & Ahi 2015). The minimum recorded pH was 6.88. This could be due to the work of microbiological activities, which was alleviated by the solution formed through leaching into the reservoir. The finding of this study was in agreement with the result reported by Awol (2018), which states a slightly lower pH was recorded for water samples from Hora springs. This is due to the marshy area surrounding springs that enhance microbiological activities. Factors such as photosynthesis, respiratory activity, temperature exposure to air, and disposal of waste bring out changes in the pH (Swaranlatha & Narsingrao 1998).

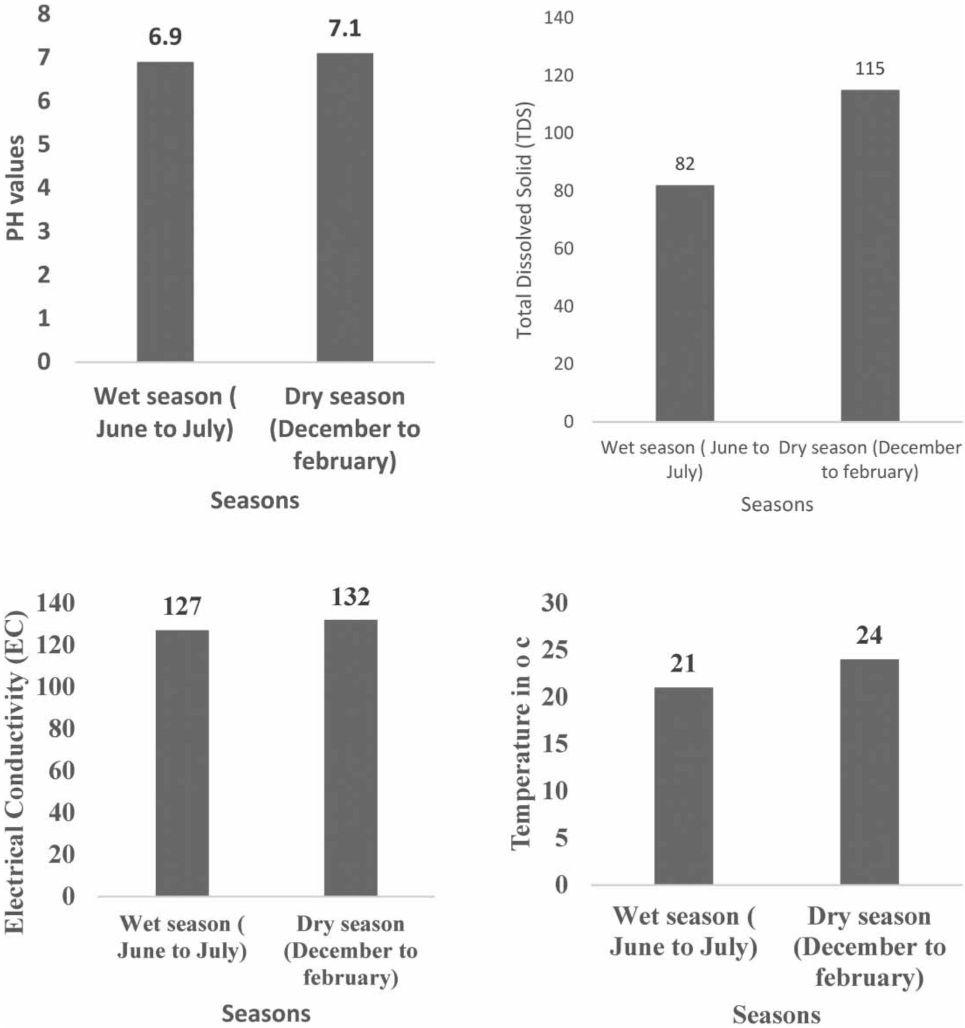


**Figure 2** | On-site measurements of the physical and chemical parameters in the dry and wet seasons.

**Table 4** | The measured value of the Borta Reservoir versus the standard value

| Physicochemical parameters | Measured value | Standard value |
|---|---|---|
| pH | 6.88–7.08 | 6.5–8.5 |
| TDS | 82.43–114.70 mg/l | 500 mg/L |
| EC | 126.65–132.28 μS/cm | 500 μS/cm |
| T° | 20.75–23.76 °C | ≤15 °C |

### 4.3. Temperature (°C)

All water sources met the internationally standardized guidelines of the World Health Organization (WHO) except for temperature. According to the report of WHO (2018), the standard set was ≤15 °C. The present showed a higher measurement (20.75–23.76 °C) compared to the standard of ≤15 °C. However, it had met other standards of African freshwater. Sikder (2018) reported that surface water temperature ranging from 23.1 ± 0.5 to 29.6 ± 0.1 °C was obtained in 2003. The present study found that surface water temperature ranged from 20.75 to 23.76 °C, which was similar to or below in comparison with the ranges reported for other African freshwater (Mugo 2010; Katsallah 2012; Sikder 2018), although standards set by the WHO (≤15 °C) were surpassed in the mean record of the present study.

### 4.4. Carbon oxygen demand

The maximum (127.4 mg/l) COD was recorded at Borta Reservoir Site 1. This could be due to high pollutants of oxidizable organic matter of different natures entering into the Reservoir from Dambi Dollo town through runoff. A similar finding was reported by Boyd (1981) that COD increases with the increasing concentration of organic matter.

### 4.5. Ammonia, nitrate, sulfate, and phosphate

The mean variations of physicochemical parameters such as phosphate (0.34–0.37 μg/l), nitrate (0.06 mg/l), ammonia (0.07–0.12 mg/l), and sulfate ($1.18 \pm 0.12$–$7.00 \pm 0.55$ mg/l) concentrations were observed in this study. This could be due to the presence of ecologically adverse human activities surrounding the reservoir, particularly in the riparian zone and its watershed regions. Anthropogenic sources including washing with soap and domestic wastes joining the reservoir via flood or through direct contact with pollutants by livestock might be the driving factors. The finding of this study was in line with the report of Sikder (2018) that stated washing livestock wastes and bathing with phosphate-based detergents and soaps in the reservoir could have been causing the high concentration of the ions in the Oyun Reservoir. According to a report by EPA (1995), no amount of phosphate in water is believed to have effects on human health. Phosphate has no significant adverse effect on man's health. The mean concentration of nitrate was not consistent with that of phosphate, ammonia, and sulfate. This could be due to pollutant inlets into the reservoir from agricultural lands and domestic wastes. Zhao (2015) highlighted that diffused sources of pollution are mainly caused by the extensive use of synthetic and organic nitrogen fertilizers. This researcher also reported that plants do not necessarily use all the nitrate in (chemical) fertilizers or all the nitrate produced when organic matter decomposes. Therefore, nitrate can accumulate in the soil when the nitrate supply is more than the amount plants use. With high nitrogen inputs to increase crop yields, the efficiency of nitrogen use may reduce and increase the potential for nitrate leaching into the water bodies.

The level of phosphate in all the water samples is below the permissible limit (0.34–0.37 μg/l). Therefore, they are good both for drinking and domestic uses. However, too much phosphate in water could lead to eutrophication in water bodies. In the Encyclopedia of Life Sciences, it was described that the important role played by phosphorus in lake algal production is generally accepted today and successful management of many lake ecosystems depends upon controlling phosphorus inputs (Hairston & Fussmann 2002).

The maximum recorded mean values were 0.37 μg/l, 0.06 mg/l, 0.12 mg/l and $7.00 \pm 0.55$ mg/l concentrations for phosphorous, nitrate, ammonia, and sulfate ions, respectively, and these findings were relatively low recorded values. Therefore, the observation made by the present study went along with the finding of Hairston & Fussmann (2002) that states nitrogen and phosphorus are much less available and suggest that phosphorus, followed by nitrogen, is most likely to limit algal production in lakes.

## 5. CONCLUSIONS

The present study generally found mean variations for parameters including $SiO_2^-$ and $NH_3$, whereas COD, BOD, $NO_3^-$, and TP have no variation. Due to ongoing human activities such domestic waste joining the reservoir, the water and ecological quality of the reservoir gets worse and worse. This study concluded that there was the manifestation of poor riparian and water shade that threatened the sustainability of the reservoir. The stressors in and around the Borta Reservoir were linked to anthropogenic sources with the intensity of human pressure associated with domestic wastes joining the reservoir via flood or through direct contact of pollutants by livestock consumption for drinking and the wastes joining from agricultural lands. The assessment of the physicochemical parameters and the ecological status of the Borta Reservoir endow with evidence of what is happening in a reservoir. Therefore, seasonally fluctuating physicochemical parameters and the progressively degrading ecological status suggest that the Borta Reservoir is severely modified by human influences, and it needs immediate restoration and rehabilitation tasks. This study also provided pertinent information on assessing the physicochemical parameters and the ecological status of the Borta Reservoir, which can inform managers and other decision-makers to give serious attention at all levels to taking participatory and integrated measures so that ecological viability and sustainable utilization of the reservoir are guaranteed. Further study should be conducted on aquatic fauna and macrophytes surrounding the Borta Reservoir since these biotic factors are the best tools for indicating the status of ecological robustness.

## CONSENT TO PUBLICATION

It is verified that I abide by your publication policy.

## AUTHORS' CONTRIBUTIONS

All of these authors were working in collaboration during data collection, analysis, and manuscript writing.

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## DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

## CONFLICT OF INTEREST

The authors declare there is no conflict.

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