**EREM 72/1**

Journal of Environmental Research, Engineering and Management
Vol. 72 / No. 1 / 2016
pp. 45-53
DOI 10.5755/j01.erem.72.1.14972


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Received 2016/01 | Accepted after revision 2016/04

http://dx.doi.org/10.5755/j01.erem.72.1.14972

# Temporal Variation of Eutrophication Assessment of Lake Bosomtwe, Ghana

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Bosomtwe Lake is a freshwater lake in the Ashanti Region of Ghana, and is the habitat for many native plant and animal species. It is also a place for tourism and, therefore, the water quality and health status of the lake are vital for conservation of species and tourism. The main objective of this study was to examine the water quality of the lake in relation to nutrient load and possible eutrophication of the lake. It also explored the correlation between some physico-chemical parameters of the lake to inform policy direction on a watershed management strategy of the lake. A total of 40 samples were taken from different parts on the lake for analysis. This was done during the wet and dry seasons in 2012 and 2013. The results showed a general lower concentration of these parameters in the wet season and a higher concentration in the dry season. The statistical results also indicated a negative correlation between Total Nitrogen and Total Phosphorus ($r = -0.839$, $p = 0.075$), Total Nitrogen and Total Dissolved Solid ($r = -0.771$, $p = 0.125$), Total Nitrogen and Dissolved Oxygen ($r = -0.749$, $p = 0.145$) and Total Nitrogen and pH ($r = -0.754$, $p = 0.141$). However, Total Phosphorus showed a positive correlation with Total Dissolved Solid ($r = 0.670$, $p = 0.216$), Dissolved Oxygen ($r = 0.830$, $p = 0.085$), pH ($r = 0.546$, $p = 0.314$) and Temperature ($r = 0.427$, $p = 474$). The nutrient load on the lake water though low, it has the potential to increase the eutrophication of the lake if not controlled and this will be dangerous for ecological entities within the catchment. The association between TP and TDS should be closely monitored since there was a strong positive correlation between them. The major setback of this study was unavailability of the facilities to analyse colour, turbidity, faecal coliform, Escherichia coli count, chlorophyll-a, and algal growth in the lake.

**Keywords:** *water quality, Lake Bosomtwe, eutrophication, wetlands.*

## Introduction

According to Bureau, 2005, wetlands include a wide variety of habitats such as marshes, peatlands, floodplains, rivers and lakes, and coastal areas such as salt marshes, mangroves and seagrass bed but also coral reef and other marine areas no deeper than 6 metres at low tide, as well as human-made wetlands such as waste-water treatment ponds and reservoirs. Wetlands perform a host of ecological and hydrological functions that benefit human kind. It plays an important role in the area of water supply, water purification, flood control and socio-economic functions such as provision of habitat for fisheries and forestry resources, which are critical for the conservation of biological diversity (Bureau, 2004).

Eutrophication is the process of nutrient enrichment of waters, which results in the stimulation of an array of symptomatic changes, including increased production of algae and aquatic macrophytes (Chapman, 1996). Though eutrophication is seen as a natural process in many surface waters, which results in the beneficial naturally high biomass productivity with high fish yields, it is the external inputs from watershed and other anthropogenic sources that are of primary concern (Chapman, 1996). Even though there are natural sources of nutrients which contribute to eutrophication, the common sources are traced to human activities, and this type is called cultural eutrophication, which is a process where water body changes due to increased reception of nutrients, such as nitrogen and phosphate from anthropogenic activities (Davis and Masten, 2004; Elizarova, 2004). The received nutrients contribute to the productivity of the lake. Based on the productivity of lakes, it can be classified as oligotrophic, eutrophic, mesotrophic, dystrophic and hypereutrophic (Davis and Masten, 2004).

The process of eutrophication is one of the most critical causes of degradation of aquatic ecosystems. The eutrophication process is known to pose a major threat to the water quality of lakes, rivers and other fresh water reservoirs (Andersen *et al*., 2004). Sperling (2002) indicates that shallow tropical lakes are of high importance to consider for protection due to accelerated assimilation of nutrients and enhanced decomposition of organic matter. According to Davis and Masten (2004), a high rate of eutrophication of lakes may cause a lake to become a senescent lake (an old lake which is very shallow and in an advanced stage of eutrophication due to high organic sediment from accumulated dead vegetation). The sources of nutrients to feed lakes and wetlands for the eutrophic process to occur have been identified by many authors to be from domestic and industrial waste disposals, agricultural fields through runoffs and deliberate application of fertilisers to raise plankton for aquacultural purposes (Mainstone and Parr, 2002). Lenhart (2008) indicates that lakes and wetlands act as sinks and processors of sediments and nutrients from the watershed, transforming nutrients into large quantities of algae and aquatic vegetation.

Limited studies have been done on Lake Bosomtwe nutrient loading and the spatial-temporal variations of the water quality. More so, studies on the association between nutrient load on lake water and other polluting physico-chemical indicators are limited. Therefore, this study examined the quality of Bosomtwe Lake in relation to pollution load, nutrient load and possible eutrophication of the lake. It also explores the association between some physico-chemical parameters of the lake to inform policy direction on a watershed management strategy for the lake.

## Materials and methods

### Study area description

Lake Bosomtwe is located 35 km southeast of Kumasi, the capital of the Ashanti region in central Ghana. Kumasi is at about 6S"N, 150 km from the coast and has an elevation of 310 m (Gardner *et al*., 1995). The lake lies in an isolated closed basin entirely surrounded by the Pra River basin, which has an area of 22,500 km$^2$ and has climate, vegetation and bedrock similar to the lake basin (Figure 1).

Lake Bosomtwe itself lies in a roughly circular closed basin, which was formed by a large meteor impact (Maclaren, 1931). The crater, which occurs in Precambrian bedrock of schist and intruding granites (Junner, 1937; Watkins *et al*., 1993), is about 11 km in diameter and


**Fig. 1**
Map of Ghana showing the location of Lake Bosomtwe and Pra River basin (Gardner et al., 1995)

has an area of 106 km$^2$, of which 52 km$^2$ are covered by the lake. The basin is bounded by steep slopes, which rise from the lake edge at 99 m, to 460 m over a distance of about 1.5 km (Gardner *et al*., 1995). Just to the south of the basin lies the Obosum Range, which has a peak of 710 m. The plain lying to the west, north and east of the basin has a typical elevation of 240 m. The lake's watershed is covered by forest, cultivated land, and some 21 small villages with an aggregate population of about 1,000 people. During the fieldwork, it was revealed that the lake water was not suitable for drinking according to indigenes. Instead, villagers make use of boreholes for domestic activity. It was also revealed that there was no consumption of stream water or lake water for irrigation or industrial use (Figure 1). The explanation given by villagers was that of high concentration of sodium ions present in the water. The lake is the habitat for mainly tilapia fish and a few cat and mud fish.

The climate is characterised by a dry season between December and February, highest rainfall in June, and a cooler and drier period in August with smaller rainfall in October.

Because the area of the watershed is small compared with that of the lake, 80% of the water that enters the lake annually is from rainfall on its surface, which makes the water balance of the basin extremely sensitive to small changes in annual rainfall (Turner *et al*., 1994). The average monthly temperature ranges from 23.2°C in August to 26.8°C in February, and aver-

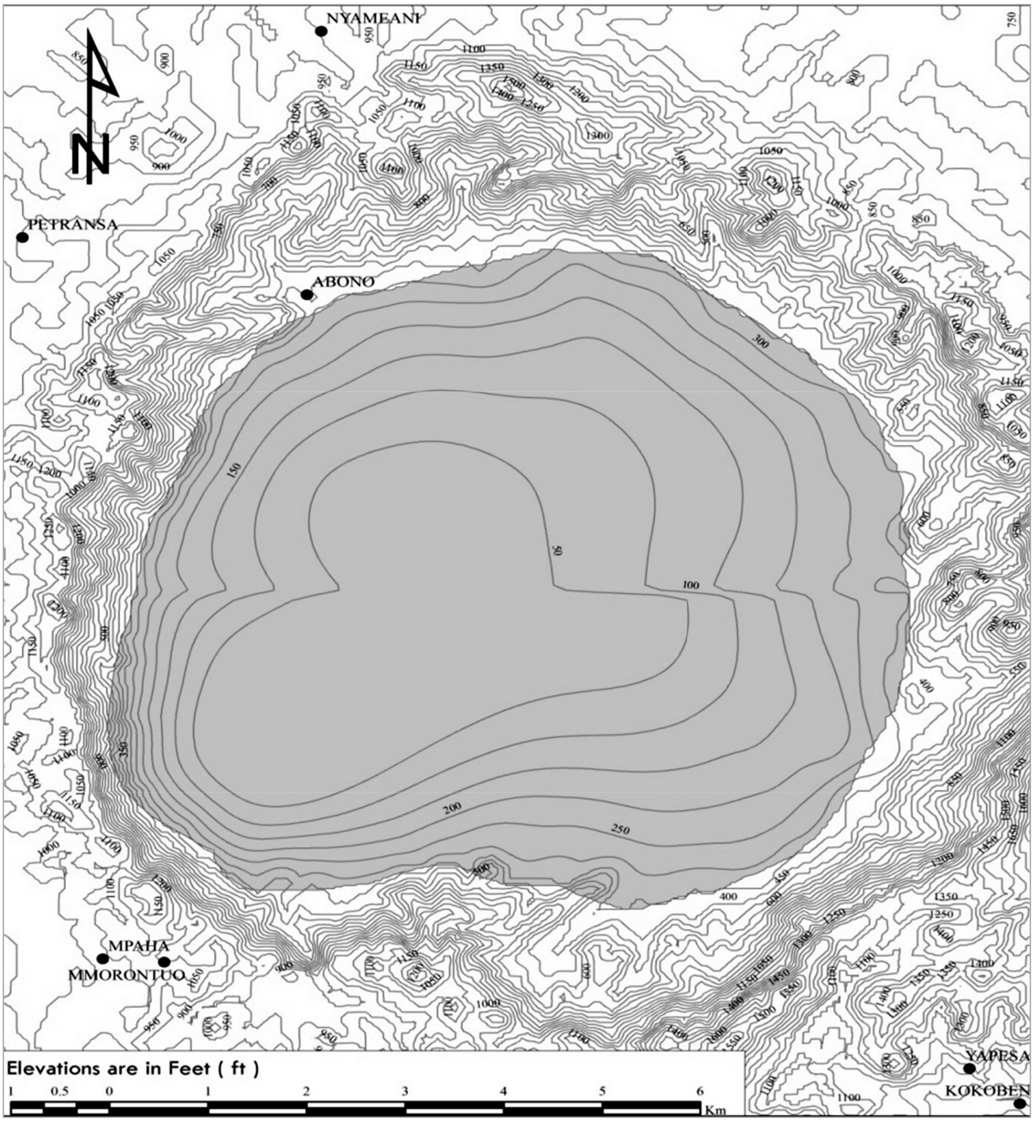


**Fig. 2**

Map of Lake Bosomtwe showing watershed and surrounding villages

age monthly humidity ranges from 84.7% in August to 75.3% in January (Gardner *et al*., 1995).

## Water sampling and analysis

Twenty locations were selected in different parts of the lake for sampling and each sample was a composite of 2 sub-samples making a total of 40 water samples. The water samples were collected in the middle of the lake during 2 consecutive seasons (wet and dry seasons) in 2012 and 2013. The samples were taken from 10 to 15 cm below the water surface using acid-washed, wide-mouth polyethylene plastic bottles. The samples were kept in a cool place over ice and transported to laboratories for analysis. Total organic carbon (TOC) was determined by the Walkley and Black method as described by Nelson and Sommers (1982). Total nitrogen (TN) was determined by the kyeldahl digestion and distillation procedure as described in Soil Laboratory staff (1984). The Nitrate-Nitrogen ($NO_3$-N) and Ammonium-Nitrogen ($NH_4$-N) were determined by the titration method (Jackson, 1967). Total phosphorus (TP) was determined by the molybdenum blue method after digestion with peroxodisulfade (ALPHA, 1992). Total dissolved solid (TDS) was measured by gravimetric analysis. The Winkler method was used for the analysis of dissolved oxygen (DO) and biological oxygen demand (BOD), while for chemical oxygen demand (COD) the dichromate reflux method was utilised (ALPHA, 1992). The in-situ measurements of pH and temperature were taken with potable pH-meter and digital thermometer, respectively. The detection limits for TP, BOD, COD, DO, TOC, TN, $NO_3^-$ and $NH_4^+$ were 0.01 mg/L. The results from the analysis were compared with US-EPA water quality criteria (1986).

### Statistical Analysis (Pearson Correlation)

The data collected in the rainy season of 2012 were subjected to proper statistical analysis. Two-way analysis of variance (ANOVA) was used to test for variations of various water quality parameters. Pearson correlation coefficient was calculated to test the degree of the relationship between irrigation water quality parameters. This was computed using the relation:

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2] * [n\sum y^2 - (\sum y)^2]}}$$

For Pearson correlation, a correlation coefficient can be described as: small correlation $-0.10 \le r \le 0.29$, medium correlation - $0.30 \le r \le 0.49$, and large correlation - $0.50 \le r \le 1.0$. The positive and the negative point to the direction of the relationship, where the positive indicates an increase in one variable associated with an increase in the other, whilst the negative correlation means an increase in one variable related to a decrease in the other.

## Results and discussion

The results generally showed lower concentration of these parameters during the wet season, which is due to the dilution factor as a result of heavy rainfall. The higher concentration was recorded during the dry period and this might be attributed to evaporation of the water leaving dissolved ions in the remaining water.

Average water temperature varied from 29.00°C to 32.00°C, which was within the potable water quality temperature range of 40°C, as set by the US-EPA. The pH values were not within the permissible level of 6.5 to 8.5 varying between 8.82 in the wet season and 8.90 in the dry season. The higher pH revealed the existence of aerobic conditions that might stem from the fact that there are no anthropogenic sources of pollution in the lake, as indicated by Charkhabi *et al*. (2006).

Total dissolved solids of the water samples varied from 671 mg/L to 833 mg/L during the sampling periods. In the wet season, the TDS values tend to be diluted by surface runoff and direct precipitation since it is a measure of dissolved salts in the water. This could be the reason for the levels of TDS values in the wet season lesser than the values in the dry seasons (Table 1). The mean TDS value (671 mg/L) for the lake water in the year was higher than the standard level of 500 mg/L set by the EPA (US-EPA, 1986). This means that there may be possible salt intrusion into the lake from the natural geology. Total dissolved solids cause toxicity in the aquatic medium through increased salinity, changes in the ionic composition of the water and toxicity of individual ions (Weber-Scannell & Duffy, 2007).

The average dissolved oxygen concentrations (DO) during the sampling periods ranged from 7.04 mg/L to 7.93 mg/L. These were above the permissible level of 6 mg/L set by the US-EPA (1986) as shown in Table 1. This is a good sign that at least there is enough oxygen for supporting aquatic life in the lake. It was, therefore, no surprise that the lake had an abundance of fish varieties. The average BOD ranged from 1.93 mg/L to 2.86 mg/L. The mean BOD for the study period was below the standard value for US-EPA (1986) for lake waters. This parameter (BOD) is a good indicator of healthy aquatic life. The DO and BOD are an indication of the level of biodegradable contaminants or pollutants in the water. A high level of DO means a low BOD and indicates a low level of organic contaminants or pollutants in the water, which enhances the aesthetic aspect of the water (Stumm & Morgan, 1995). Therefore, in this study the indication is that there is low level of organic biodegradable pollutant in the lake water and sufficient oxygen for supporting aquatic life. The COD values for the wet seasons of 2012 and 2013 were lower than for the dry seasons of the same years (19.46 and 19.34 mg/L for 2012 and 2013, respectively), indicating temporal seasonal variation. The average COD, however, was within the standard of US-EPA for lake water quality (1986).

The average concentration of $NO_3$-N ranged from 0.44 mg/L to 0.71 mg/L. These temporal changes might be due to the fact that the nitrate loading is usually highest in the wet season due to intensive agricultural activities within the watershed or from the natural geology and decomposed organic matter through surface runoff discharge into the lake. This implies that some agricultural activities within the catchment involve fertiliser application, which might contaminate the lake. In addition, the risk of $NO_3$-N leaching is particularly high after the harvest, when plant uptake is low, but N-release as mineralisation continues. This may explain the seasonal variation in the amount of nitrate measured from the lake water (Charkhabi *et al*., 2006).

Moreover, denitrification and leaching cause most N loss from a catchment. For example, aerobic conditions created by ploughing enable ammonification and subsequent nitrification, which results in $NO_3$-N release from organic compounds in soils. However, in forest soils inorganic nitrogen concentrations are generally low and mostly N is in organic complexes associated with biological materials (Charkhabi *et al*., 2006).

The mean total nitrogen (TN) concentration found for the lake was 14.16 mg/L for the 2 years of the study. The annual seasonal average values were 16.75 mg/L and 14.16 mg/L in 2012, whilst 2013 recorded 15.03 mg/L and 14.85 mg/L, respectively, for the wet and dry seasons (Table 1). Total nitrogen of the lake during the wet seasons probably owing to land use change in the catchment, application of chemical fertilisers and dead organic matter added to the lake water through runoff from the agricultural land. Total nitrogen, which is from all the inorganic sources, is very high to supply enough nutrients for algal and aquatic growth in the lake. This is likely to affect water quality and for that matter lake water uses. This may speed up the process of eutrophication of the lake.

The total phosphorus concentration in the lake for 2012 dry and wet seasons were 0.62 mg/L and 0.84 mg/L, respectively, and 2013 recorded 0.69 mg/L and 1.02 mg/L, respectively. This implies that the dry seasons showed high levels of phosphorus for the 2 years and, hence, more availability for aquatic weeds growth. Statistically, there was no significant difference in the TP loading of the lake for the seasons studied for the 2 years. It is important to indicate that if this pattern continues, the lake productivity will be high and rapid eutrophication will be inevitable. The level of phosphorus in the lake also varied for the 2 seasons for the 2 years with a mean of 0.62 mg/L, which was below the standard set by US-EPA for lake water quality (1986).

### Correlational analysis of TN and TP with other physico-chemical parameters

The Pearson correlation results for the tested parameters showed some interesting correlations between some parameters. There was a strong negative correlation between TN and TP ($r = -0.839$, $p = 0.075$), TN and TDS ($r = -0.771$, $p = 0.125$), TN and DO ($r = -0.749$, $p = 0.145$) and TN and pH ($r = -0.754$, $p = 0.141$). However, TP showed a positive correlation with TDS ($r = 0.670$, $p = 0.216$), DO ($r = 0.830$, $p = 0.085$), pH ($r = 0.546$, $p = 0.314$) and T ($r = 0.427$, $p = 474$). A strong negative correlation between TN and TP, TDS, DO, and pH implies that an increase in TN in the lake water is correlated with a decrease in TP, TDS and DO at the suitable pH and vice versa. This is not surprising because phosphorus is said to be a limiting factor in the eutrophication process than nitrogen (Davis and Masten, 2004). This means that nitrogen provides the nutrient for aquatic plants to build tissue through consumption of phosphorus in the water via photosynthesis. The Minnesota Pollution Control Agency (2008) indicates that nitrogen is essential to the production of plant and animal tissue and phosphorus is a vital nutrient for converting sunlight into usable energy, and essential to cellular growth and reproduction. Dissolved oxygen will normally be required to degrade biodegradable organics and chemicals and, therefore, the association is normal. This means that if aquatic plants are going to utilise TN for tissue building, more dissolved oxygen will be released and more TP will be consumed.

The strong positive association between TP, TDS, DO, T and pH implies that an increase in TP is associated with an increase in TDS and DO at the appropriate pH and temperature. This was expected because TDS is a measure of inorganic salts, organic matter and other dissolved materials in water (US-EPA 1986).

## Conclusions

The study showed that there were low organic contaminants in the lake. Also, there were lower and higher concentrations of these parameters during the wet and dry seasons; this could be due to the dilution of the parameters from rain and evaporation of the lake water in the dry season leaving high concentration of dissolved ions. The results also indicated a temporal variation in the lake water quality of the wet season from the dry season. The nutrient load on the lake water though low, it has the potential to increase the eutrophication of the lake if not controlled and this will be dangerous for ecological entities within the catchment. The association between TP and TDS should be closely monitored since there was a strong positive correlation between them. The major setback of this study was unavailability of the facilities to analyse colour, turbidity, faecal coliform, Escherichia coli count, chlorophyll-a, and algal growth in the lake. Furthermore, limiting the sampling for the studies to only the upper part of the lake does not bring to bear the full quality and classification of the water quality variation and the mixing nature of lake waters. It is recommended that future studies should consider the classification of the lake and quality changes at different depth of the lake. More so, bacteriological as well as aesthetic quality should not be neglected by future researchers.

**Table 1**
Average and standard deviation of water quality parameters in Lake Bosomtwe during wet and dry seasons in 2012 and 2013.

| Season | Value | TN | TP | TOC | $NH_4^+$ | $NO_3^-$ | TDS | DO | BOD | COD | Temp °C | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg/l | | | | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Wet (2012) season | Av. | 16.75 | 0.62 | 2.82 | 16.66 | 0.65 | 671.00 | 7.93 | 2.52 | 17.45 | 29.00 | 8.90 |
| | STD | 0.99 | 0.25 | 2.25 | 0.56 | 0.44 | 42.76 | 0.42 | 0.52 | 7.99 | 1.58 | 0.10 |
| Dry (2012) season | Av. | 14.16 | 0.84 | 4.38 | 12.66 | 0.48 | 833.00 | 7.19 | 2.86 | 19.46 | 32.00 | 8.86 |
| | STD | 2.05 | 0.61 | 3.15 | 0.80 | 0.55 | 2.68 | 0.93 | 0.44 | 9.24 | 0.84 | 0.09 |
| Wet (2013) season | Av. | 15.03 | 0.69 | 1.63 | 15.96 | 0.71 | 700.00 | 7.04 | 1.93 | 18.08 | 31.40 | 8.82 |
| | STD | 1.49 | 0.38 | 1.15 | 0.10 | 0.30 | 9.41 | 0.96 | 0.33 | 8.67 | 0.89 | 0.05 |
| Dry (2013) season | Av. | 14.85 | 1.02 | 4.16 | 11.84 | 0.44 | 816.40 | 7.48 | 2.57 | 19.73 | 31.40 | 8.82 |
| | STD | 1.06 | 0.50 | 1.98 | 0.55 | 0.23 | 33.09 | 0.95 | 0.44 | 9.39 | 1.34 | 0.05 |

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Gauta:
2016 m. sausis
Priimta spaudai:
2016 m. balandis

# Bosumtvio (Gana) ežero eutrofikacijos kitimo vertinimas laiko bėgyje

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Bosumtvio ežeras yra gėlo vandens ežeras Ašanti regione, Ganoje. Jis yra gausybės vietinių augalų ir gyvūnų rūšių buveinė. Jis taip pat yra mėgiama turistų vieta, todėl vandens kokybė ir ežero sveikatos būklė yra labai svarbūs saugant augalų bei gyvų organizmų rūšis bei plėtojant turizmą. Pagrindinis šio tyrimo tikslas buvo ištirti ežero vandens kokybę, priklausančią nuo maistinių medžiagų koncentracijos ir galimo eutrofikacijos poveikio. Taip pat , tyrimo metu, buvo nustatyta kai kurių fizikocheminių parametrų koreliacija, kas gali suteikti naudingos informacijos kuriant baseino valdymo strategijos kryptį. Tyrimams buvo paimta iš viso 40 mėginių iš skirtingų ežero vietų. Mėginiai buvo imami drėgnuoju ir sausuoju sezonais 2012 ir 2013 m. Rezultatai parodė, kad tiriamų parametrų bendrosios koncentracijos yra aukštesnės sausuoju sezono metu, lyginant su drėgnuoju. Statistiniai rezultatai parodė neigiamą koreliaciją tarp bendrojo azoto ir bendrojo fosforo ($r = -0{,}839$, $p = 0{,}075$), bendrojo fosforo ir bendrųjų ištirpusių dalelių ($r = -0{,}771$, $p = 0{,}125$), bendrojo azoto ir ištirpusio deguonies ($r = -0{,}749$, $p = 0{,}145$) ir bendrojo azoto ir pH ($R = -0{,}754$, $p = 0{,}141$). Tačiau bendrojo azoto koncentracija parodė teigiamą koreliaciją su bendrųjų ištirpusių dalelių koncentracija ($r = 0{,}670$, $p = 0{,}216$), Ištirpusio deguonies koncentracija ($r = 0{,}830$, $p = 0{,}085$), pH, ($R = 0{,}546$, $p = 0{,}314$) ir temperatūros ($r = 0{,}427$, $p = 474$ ). Nors ir buvo nustatyta nedidelė biogeninių medžiagų apkrova ežero vandeniui, tačiau ir nustatytas biogeninių medžiagų kiekis nekontroliuojant turės įtakos eutrofikacijos didėjimo procesui, kuris galikelti grėsmę ežero ekosistemai. Kadangi buvo nustatytas stiprus teigiamas ryšys tarp bendrojo azoto ir bendrųjų ištirpusių dalelių koncentracijų, jų koncentracijų santykis turi būti atidžiai stebimas. Šio darbo pagrindinis trūkumas yra tai, kad dėl reikiamos įrangos nebuvimo šiame tyrime nebuvo analizuoti tokie parametrai kaip spalva, drumstumas, koliforminių bakterijų skaičius, Escherichia coli bakterijų skačius, chlorofilas-a, ir dumblių augimo intensyvumas ežero vandenyje.

**Raktiniai žodžiai:** *vandens kokybė, Bosumtvio ežeras, eutrofikacija, pelkės.*