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PRINCIPAL COMPONENT ANALYSIS: AN APPROPRIATE TOOL FOR TROPHIC PARAMETERS INTERACTION - APPLICATION IN LARGEST LAKE IN BALKAN

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Abstract

The Lake of Shkodra is the largest lake in the Balkans with Ramsar status, which offers a variety of important ecosystem services such as water sources for agriculture, rich biodiversity and providing habitat and nesting grounds for wildlife, and tourism development for Albania and Montenegro. During the last decade, different studies reported an increase in macronutrient content, reporting the increase in the eutrophication in this lake which may reduce the biodiversity of the species. The aim of this study is to use the Principal Component Analysis (PCA) as a tool to define the relation of water quality parameters with the TN: TP ratio. According to PCA, the TN: TP molar observed ratio can be related to the anthropogenic activities and agricultural land use patterns around the catchment area indicating a high possibility of untreated waste entering the lake through the active inlets.

Key words: *PCA, Shkodra Lake, TN: TP ratio, TSI.*

INTRODUCTION

Monitoring of water quality is of high importance as water pollution and its irrational use represent two risk factors for the sustainable development of human society. The chemical composition of surface waters is related to natural and anthropogenic processes (Bojarczuk et al., 2018). Natural sources can be found in microbial activity, geological structures, and naturally existing pollutants found in water supplies. On the other side, anthropogenic causes are caused by human activities such as industrial operations, agricultural practices, inappropriate waste disposal, and insufficient sewage systems (Babuji et al., 2023). The preservation of water quality can be attained through the establishment of indicators that are systematically monitored and tailored specifically to freshwater ecosystems. The Agriculture, Forestry, and Other Land Uses (AFOLU) sector contributes about 13-21% of global total anthropogenic GHG emissions (IPCC, 2022), meanwhile the agriculture sector contributes to nitrate pollution (inland and coastal waters e.g. eutrophication) which represent the main chemical contaminant in the world's groundwater aquifers (WWAP, 2013). In the European Union, 38 % of water bodies are significantly under pressure from agricultural pollution (WWAP, 2015). Diffuse pollution from agriculture is the most common pressure causing less-than-good groundwater chemical status and affects 19% of the total groundwater body area in the EU-27 (EEA, 2021).

Albania's average quantity of fresh water is estimated at about 8,700 cubic meters per capita per year, which is one of the highest in Europe (MPWT, 2011). In this regard, one of the largest water catchments is the Drini River where an important water body in this basin is Shkodra Lake, the largest in the Balkan Peninsula (Kashta et al., 2001). The Shkodra lake has also been part of the Ramsar Wetlands Convention since 2005 (Demiraj et al., 2018). These areas are threatened by urban, industrial, and agricultural activities from water courses that discharge into them by contributing to trophic status, water quality deterioration, and diminishing the biodiversity index (Demiraj et al., 2018; Rakočević, 2018; Pešić et al., 2018; Bacu et al., 2011; Sulçe et al., 2018). Several indicators represent different aspects of water quality that vary in their significance in different geographical regions (Walsh & Wheeler, 2012). Furthermore, in some cases it can be difficult to convey relevant water quality information to policymakers and the public regions (Walsh & Wheeler, 2012).

The aim of current study was:

(i) to have full data of water quality parameters for the highest pollution pressure spring-summer-autumn;

(ii) to evaluate the importance of water parameters in water quality evaluation by using statistical modelling such as Principal Component Analysis (PCA) after data collection.

MATERIALS AND METHODS

The Shkodra lake is laid in the northern part of Albania with a surface of approximately 360-540 km² part of Drin - Buna River basin, the largest one with typical karstic origin. The main tributary is Moraça River in the northern part of the Lake and the total water flow is about 210 m³/sec. The watershed of Shkodra lake is characterised by concave topography, steep slopes, high annual rainfall (IGEWE, 2016) and high erosion processes. This lake is a host ecosystem for a diverse number of species: 52 species of fish, 240 species of aquatic plants and 283 bird species. The physio-geography classifies the watershed as mainly composed of geologically limestone with 330.000 inhabitants where about 85% of their activity is related to the lake such as intensive agricultural and tourism activities.

Figure 1. A map from Shkodra Lake and sampling stations

Due to this a program of monitoring was established with a total of 13 sampling expeditions, from May - October 2022. During this expedition some water quality parameters were evaluated in situ: Temperature (T, ºC), pH (pH unit), dissolved oxygen (DO, mgL^{-1}), electrical conductivity (EC, μScm^{-1}) by using a Parametric multi-probe WTW 340 instrument. Meanwhile, sampling was transported at Agriculture University of Tirana to perform the: Total suspended solids (TSS, mg/L), Total dissolved solids (TDS, mg/L), nitrate nitrogen ($N\text{-}NO_3^-$, $mgNL^{-1}$), phosphate-phosphorus ($P\text{-}PO_4^{3-}$, $mgPL^{-1}$), p-alkalinity and *Chlorophyll* a in mgL^{-1}. The sampling process was performed before 12:00 PM since ISO 10260:1992 was followed.

Nutrient phosphorus and nitrogen species were assessed by spectrophotometric means as follows: phosphate-phosphorus ($P\text{-}PO_4^{3-}$) when using the molybdenum blue method (DIN EN 16169, 2012; Murphy & Riley, 1962); nitrate nitrogen ($N\text{-}NO_3^-$) when using 2,4-phenoldisulphonic acid in a basic medium (Sandu et al., 2023a; 2023b). Appropriate calibrations of the devices employed in analyses were performed before determinations to ensure the quality of the analytical procedures and correctness of the obtained data. The sampling process was performed before 12:00 PM since

ISO 10260:1992 was followed. Total P was analyzed using the ascorbic acid molybdenum blue method (DIN EN 16169, 2012; Murphy & Riley, 1962). N-NO_3^- was determined within 24 h, by using a spectrophotometer. The data collected was statistically elaborated by using JMP 11 software. Principal Component Analysis (PCA) is a robust technique utilised for identifying patterns that elucidate the variance within extensive datasets comprising interrelated variables, subsequently facilitating their transformation into smaller sets of independent variables, known as principal components (Zela et al., 2020).

RESULTS AND DISCUSSIONS

Studies show that the premises for eutrophication are not the specific amounts of each element soluble in water but the molar ratios between TN:TP. The first result was elaborated for nutrient parameters to estimate the TN:TP ratio. This ratio was used by Downing, J.A. & E. McCauley in 1992 to examine the form of the relationship of total N (TN) to total P (TP) in some world's lakes. The lakes with a high concentration of TP are usually often rich in TN (Sakamoto, 1966), therefore there is a positive correlation between the TN and TP concentrations of lakes. Furthermore, it is observed that if the slope of this relationship is constant, then TN:TP might not be related to lake trophic status, whereas if the reverse occurs, then nutrient sources of oligotrophic and eutrophic lakes have differing TN:TP ratios (Ahl, 1979).

In ratios > 16:1, TP is the limiting factor for algae growth, in lower ratios the limiting factor is TN. In this regard in our study, the results show that during the late spring (May) with the high number of freshwater flows, the TN:TP ratio is between 1.40-3.63, respectively higher in the stations of Vrake and Shtojt, indicating a presence of nitrogen in the discharges that come mainly from agricultural lands and which dictates that the limiting element for the development of the eutrophication process is phosphorus (Figure 2). The same results were obtained in all the stations during August and September where the amount of freshwater decreased. The increase in rainfall during the October season returns the decreased amount of phosphate due to the low amount of fertiliser used in agriculture areas and the low solubility of phosphorus from sediment of the lake.

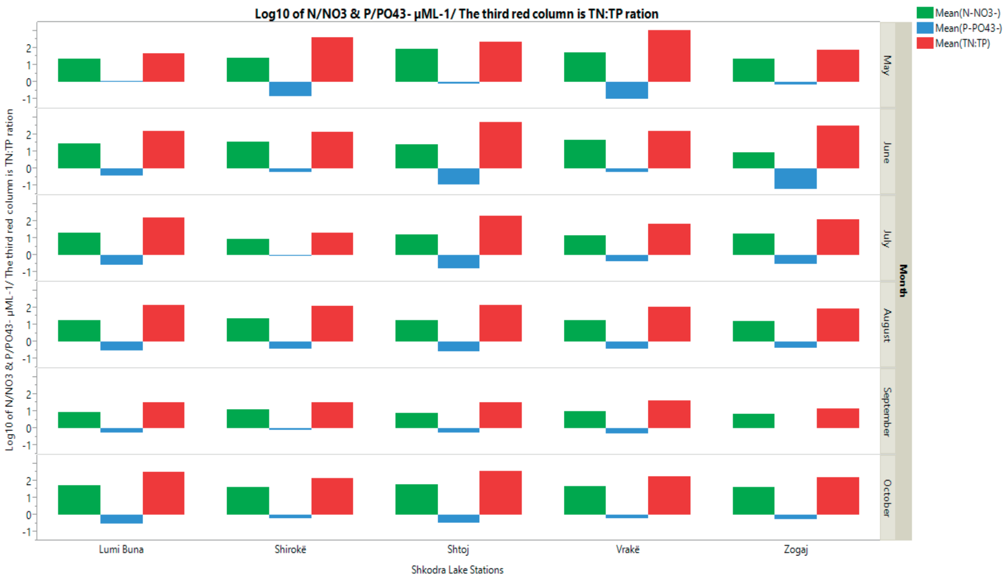

Figure 2. The value is calculated in molar concentration of N/NO_3^- and P/PO_4^{3-}, while their report is represented as TN:TP

Principal Component Analysis (PCA) is a methodology to elucidate alterations within datasets and explain the interrelationships among variables, thereby discerning their significance across distinct groups by down weighting the least influential variables. In PCA, the comprehensive index of transformation analysis is usually called the principal component. The principal component is a linear combination of the original variables and is not correlated with each other (Zhang et al., 2019).

In this study, PCA was applied to process data for each season across multiple years. The PCA approach hinges upon scrutinizing correlation structures utilizing Pearson distribution, thereby establishing links and directing factors towards the original variables to facilitate comprehensible interpretation.

Figure 3 shows the obtained results from the PCA analysis of the measurements performed during the May were the component 1 describe the 43% of total variation and was comprised by Temperature, N/NO_3^-, $CaCO_3$, DO, pH, TDS and TN:TP while the component 2 explained the 24 % of the variance and significantly consisted of P/PO_4^{3-}, TSS and *Chlorophyl* a. Another situation was observed during June (Figure 4) where component 1 describes the 40% of total variation Temperature, N/NO_3^-, $CaCO_3$, DO, pH, and TN:TP. Component 2 estimated by 20% of total variation between TDS, TSS, $CaCO_3$, P/PO_4^{3-}, TSS and *Chlorophyl* a.

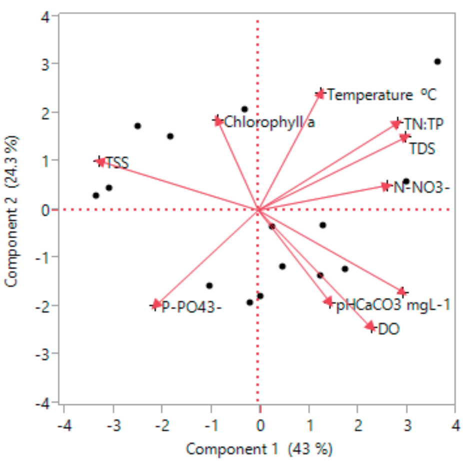

Figure 3. PCA of TN:TP and of the physicochemical parameters as 10 variables and their influence during May

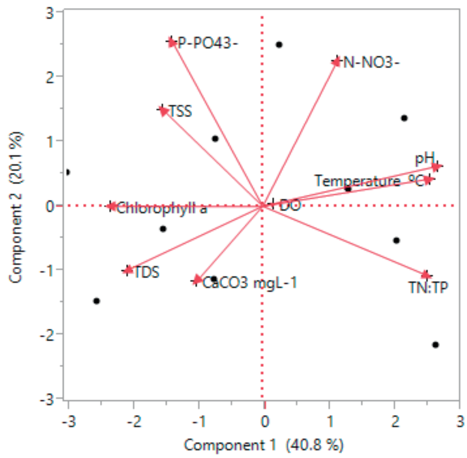

Figure 4. PCA of TN:TP and of the physicochemical parameters as 10 variables and their influence during June

As we expected in July (Figure 5) the reduction of rainfall helps that physical and chemical processes develop more intensively in water. In this regard the Component 1 represented by P/PO_4^{3-}, TSS, TDS, pH, DO, Temperature, N/NO_3^-, $CaCO_3$ cover 52% of total variation and strongly correlated with TN:TP and *Chlorophyl* a in component 2 with 21% of total variation.

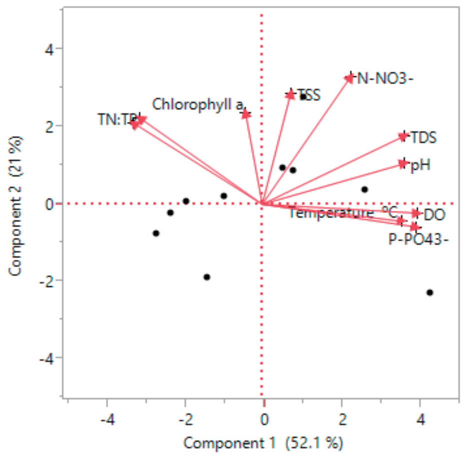

Figure 5. PCA of TN:TP and of the physicochemical parameters as 10 variables and their influence during July

After the consumption of DO during the August (Figure 6) the water system has decrease the pH which is in correlation with DO, Temperature, TN:TP, TSS, TDS and *Chlorophyl* a in component 1 with 42% but the component 2 about 33% represented by N/NO_3^- and P/PO_4^{3-}, $CaCO_3$.

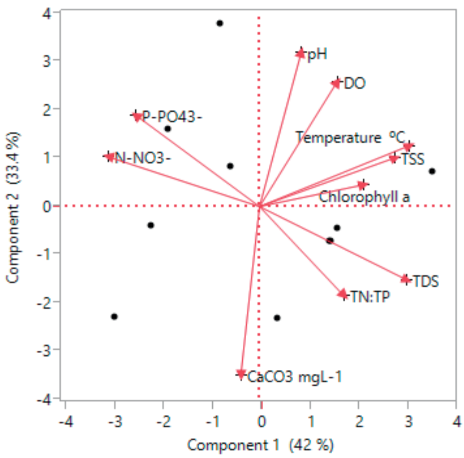

Figure 6. PCA of TN:TP and of the physicochemical parameters as 10 variables and their influence during August

During the September (Figure 7) the component 1 describes the 48% of total variation represented by TSS, DO, pH, Temperature, P/PO_4^{3-}, *Chlorophyl* a. In the other hand the component 2 describe the 23% of total variation by considering the TDS, TN:TP, N/NO_3^- and $CaCO_3$.

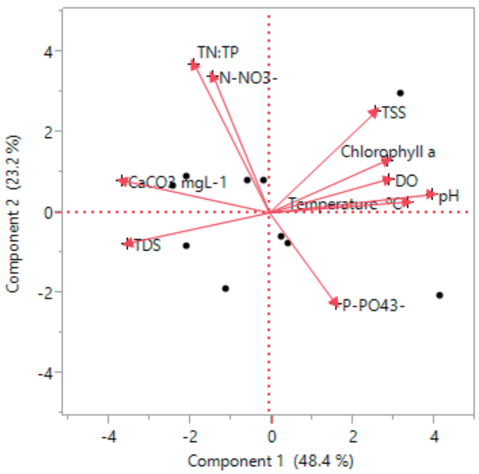

Figure 7. PCA of TN:TP and of the physicochemical parameters as 10 variables and their influence during September

The last period of data collation has increased the interaction between factors so the component 1 in October (Figure 8) represents 46% of total variation by involving the TN:TP, N/NO_3^- and $CaCO_3$, TDS, TSS. Component 2 represents 26 % of the variation with a correlation between pH, DO, Temperature, P/PO_4^{3-} and *Chlorophyl* a.

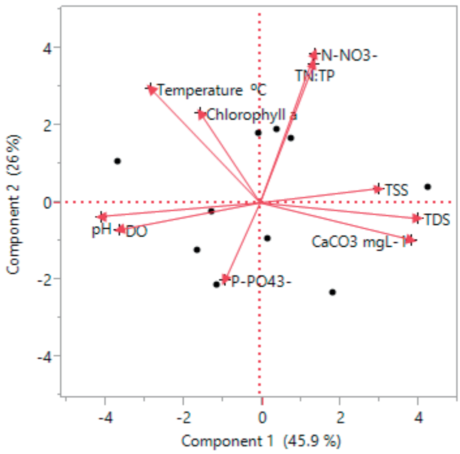

Figure 8. PCA of TN:TP and of the physicochemical parameters as 10 variables and their influence during October

CONCLUSIONS

The eutrophication of the Shkodra lake represented by the PCA helps in the determination of the factors that interact between each other that implicate the status. The decrease of freshwater quantity as well as the consequent decrease of dissolved oxygen implies the physico-chemical reactions that lead to the eutrophication of the lake, which is also assessed by the TN:TP ratio in this study. Our results underline the fact that extending these assessments over a longer period would help to determine more precisely the sources of eutrophication of this lake.

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