

RESEARCH ARTICLE

ASSESSING THE LAKE WATER QUALITY AND EUTROPHICATION USING CHEMICAL PARAMETERS – A CASE STUDY

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ABSTRACT

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Water is a valuable natural source and essential for the life in every single cell, organism, or ecosystem. Freshwaters are used as drinking water sources, for domestic and industrial purposes, in energy production, etc. However, a considerable amount of polluted water is discharged into environment, because of inappropriate and intensive use for different purposes. Therefore, an important number of water ecosystems are considered polluted from anthropogenic activities. Agricultural activities, untreated or partly treated wastewater, industrial activities add nutrients and other chemicals to water bodies, influencing the water quality and biological parameters of the ecosystem. Nutrient (nitrogen and phosphorous forms) overloading results in increase of water plants that leads to eutrophication of the water body. Eutrophication is one of the most dangerous types of water pollution with direct effects in fauna due to dissolved oxygen loss that leads to fish death. Enrichment of water systems with nutrients is associated with algal "bloom" and with the degradation of natural water quality. Considering the effects of different pollutants in natural water bodies, the study of water quality in these systems receives a particular importance. The main purpose of this paper is to determine the pollution and the eutrophication level in the lake water, because of the increase of pollutant and nutrient concentration with anthropogenic origin. Belshi Lake, a karstic lake situated in Albania and considered as a case study, takes pollutants mainly from untreated wastewaters and from agricultural practices. The chemical water parameters are measured over a three-year period. Experimental data for the chosen water system are compared with international water quality standards. The chemical measured parameters are used to determine the lake trophic state according to several literature suggestions. Statistical data analysis shows the correlation between chemical parameters measured experimentally.

KEYWORDS

chemical parameters, water pollution, water quality, trophic state, correlation.

1. INTRODUCTION

Water resources are considerable in Albania, both surface and ground waters. The country has several rivers, a number of natural lakes, and a multitude of artificial lakes for energy and irrigation. Lakes cover about 4% of the country's territory. There are also several reservoirs, totalling 5.60 km³ of storage capacity, which have been built for flood protection, irrigation and the production of hydropower. Albania's major environmental problem is water pollution from disposal of trash, discharge of untreated wastewater and soil irrigation (Eftimi and Zojer 2015; Kucaj et al., 2022; Osmani et al., 2023).

Also, eutrophication is one of the most challenging environmental problems that the surface water are facing in present time. The anthropogenic eutrophication, results in some cases in heavy and dense algal blooms and consequently in fish death, causing an anoxic hypolimnion, because of toxins certain algae species produce (Pitois et al., 2001). Low oxygen concentrations accelerate the release of phosphorous, further stimulating the phytoplankton production, and thus affecting the aesthetic values and the use of water (Miho et al., 2005).

Eutrophication of lakes, in particular is considered one of the most dangerous consequences of water quality degradation (Thomas et al.,

1996). It is the biological response toward the nutrient enrichment with nutrients, mainly nitrogen and phosphorous (Hallengraeff, 1995).

Traditionally lakes are underestimated as important water sources for human activities. On the contrary, they provide a wide range of uses and the regions around them are the main human settlements. Water uses include drinking water supplies, industrial, energy, navigation, fishing and other recreational uses. Moreover, the lakes are used for irrigation of agricultural lands, as well as for waste disposal (Thomas et al., 1996). Agricultural practices, urban and industrial waste disposal, as well as untreated wastewaters are the main causes of water quality degradation of a lake.

It is always difficult to establish clear boundaries between different classifications of the trophic status of a water system, due to regional variations of limnological parameters, as well as due to different criteria used to classify lakes into a particular category. Physical components and chemical characteristics that should be considered to determine the lake water quality are transparency, colour, pH, temperature, conductivity, dissolved oxygen, ammonia, nitrites, nitrates, phosphorous, etc.

Temperature affects the physical, chemical and biological processes in aquatic systems. Transparency is determined with Secchi disk and it is a

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measure of the biological activity level (Chapman and Kimstach, 1996). Temperature increase leads to decrease of gas solubility, such as O2, CO2, etc., increase of respiration rate, consequently decrease of oxygen and increase of organic material decomposition. Temperature also affects other water variables (Chapman and Kimstach, 1996).

pH is a very important variable in water quality assessment, because it affects biological and chemical processes in water body. Daily pH variations are due to photosynthesis and respiration cycles of algae in eutrophic waters (Chapman and Kimstach, 1996). Low levels of pH occur in waters with high organic loadings and high levels of pH occur in eutrophic waters (Chapman and Kimstach, 1996).

Oxygen is very important for all forms of life present in water. Literature suggests that dissolved oxygen concentrations lower than 5 mg/l affect the biological community functioning (Nixon et al., 2003). Moreover, values lower than 2 mg/l can lead to fish death (Crouzet et al., 1999). Eutrophic water systems have the same consequence because of the excessive algal growth. The minimum recommended level of dissolved oxygen for freshwater fish is 5 – 6 ppm. Dissolved oxygen concentration in water shows the degree of pollution from organic matter, the degradation of organic substances and the level of self-purification capacity of water system (Chapman and Kimstach, 1996).

Ammonia occurs in water naturally as a result of the degradation organic

and inorganic matter rich in nitrogen content, biota excretion, etc. It is discharged from urban wastewaters and industrial wastes. Total ammonia concentrations in surface waters usually are lower than 0.2 mg/l N, but they can reach values 2 – 3 mg/l N. High ammonia concentrations are an indicator of organic pollution from untreated wastewaters, industrial wastes and leaching from agricultural lands. Unionized ammonia, NH3 is toxic for the fish in level higher than 0.03 mg/l (Chapman and Kimstach, 1996).

Nitrate is most common form of nitrogen in natural waters. Concentrations higher than 5 mg/l N-NO3- usually indicate pollution from human or animal wastes, and fertilizers leaching. Concentrations higher than 0.2 mg/l N-NO3- in a lake stimulate algal growth and indicate possible eutrophication conditions (Chapman and Kimstach, 1996).

Phosphorous is a very important nutrient for the living organisms. It is a limiting element for the algal growth and consequently it controls the primary production in water (Chapman and Kimstach, 1996). Concentrations higher than 50 µg P/l indicate the human impact through wastewater discharges and agricultural leaching (Stanners and Bourdeau, 1995).

EU standards on “Quality of freshwater sustaining fish life” (EC 78/659) set two main criteria; obligatory level and recommended level for Salmonides and Cyprinides water bodies, as showed in table 1 (BMZ, 1995).

Table 1: Obligatory and recommended level for salmonides and cyprinides waters according EU Directive				
Parameter	Salmonides waters		Cyprinides water	
	Obligatory level	Recommended level	Obligatory level	Recommended level
Dissolved oxygen (mg/l)	50%>9	50% >9 100% > 7	50% > 7	50% > 8 100% > 5
pH	6-9		6-9	
Phosphate (PO4 mg/l)	0.2		0.4	
Nitrite (NO2 mg/l)		< 0.01		< 0.03
Total ammonium (NH4 mg/l)	< 1	< 0.04	< 1	< 0.2
NH3 (mg/l)	< 0.025	< 0.005	< 0.025	< 0.005

Norwegian classification is also used to determine the fresh water quality (table 2) (Bratli, 2000).

Table 2: Environmental classes according to norwegian clasification (Bratli, 2000)					
Parameter	Environmental quality class				
	I	II	III	IV	V
	Very good	Good	Medium	Bad	Very bad
Total P (µg/l)	< 7	7-11	11-20	20-50	>50
Chlorophile a (µg/l)	<2	2-4	4-8	8-20	>20
Secchi disk (m)	>6	4-6	2-4	1-2	<1
Total nitrogen (µg/l)	<300	300-400	400-600	600-1200	>1200
Oxygen (mg/l)	>9	6.4-9	4-6.4	2-4	<2
pH	>6.5	6.0-6.5	5.5-6.0	5.0-5.5	<5.0
Colliform bacteria (nr per 100 ml)	>5	5-50	50-200	200-1000	>1000

2. METHODOLOGY

Dumrea carstic lakes in Albania represent the larges group of lakes in the country. Carstic lakes are formed in carbonaceous formations as a consequence of carstic phenomnom (nearly 94 lakes). Belshi lake is situated in Belshi town, the centre of Dumrea region, approximately 148.6 m above the sea level. It has a surface area of 30 ha and a maximum depth of 15 m. Water balance of the lake depends mainly on atmospheric precipitation (Kristo, 2002). The lake is surrounded by inhabited areas, which discharge the untreated wastewated directly to the lake. This lake shows a stratification during the summer months. It is considered as a case study, because its water quality and eutrophication state depend mainly on anthropogenic activities.

Water samples are taken periodically from surface waters every month for a nearly three years period of time (OECD, 1982). Sampling frequency and sampling methodology is conform guidelines. Water samples are analysed for physico – chemical parameters. The parameters measured in situ are

conductivity, temperature, pH and redox potential, using a portable pH meter, pH/Cond 3400i, as well as transparency using a Secchi disk. Chemical parameters determined in laboratory according the literature (Clescerl et al., 1998). Oxygen is determined with the Winkler method, ammonia with Nessler method, nitrates with the Cadmium reduction method, phosphate with the ascorbic acid method (Clescerl et al., 1998). The laboratory results are compared with international water quality standards. Trophic state of the lake is determined based on nutrient content and trophic state index.

3. RESULTS AND DISCUSSIONS

3.1 Water Quality According The Chemical Parameters

Mean, maximum and minimum values of chemical parameters measured in Belshi lake are shown in table 3.

Table 3: Parameter data of Belshi lake

Parameter	1st year			2nd year			3rd year			Mean Value
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	
Dissolved oxygen (mg/l)	9.54 (±1.35)	11	6.7	10.1 (±1.08)	11.4	8.1	10.875 (±0.17)	11.1	10.7	9.9517
Nitrate (N-NO ₃ , mg/l)	1.016 (±0.744)	2.2	0.022	1.6675 (±0.888)	4	0.35	1.7525 (±0.49)	2.15	1.05	1.3871
Ammonia (N-NH ₃ , mg/l)	0.31 (±0.31)	0.99	0.01	0.24 (±0.225)	0.633	0.013	0.2627 (±0.24)	0.583	0.032	0.2772
Ammonia (NH ₃ , mg/l)	0.383 (±0.376)	1.2	0.012	0.29 (±0.274)	0.77	0.016	0.32 (±0.29)	0.71	0.04	0.3374
Fosphate (mg/l)	0.42 (±0.42)	1.65	0.02	0.399 (±0.38)	1.52	0.14	0.20 (±0.038)	0.25	0.16	0.38
Total phosphorous (mg/l)	0.305 (±0.268)	1	0.042	0.223 (±0.166)	0.52	0.058	0.173 (±0.085)	0.26	0.082	0.2528
Transparency (m)	0.31 (±0.29)	1.13	0.048	0.366 (±0.25)	0.82	0.09	0.34 (±0.18)	0.58	0.18	0.1898
Chlorophyll (µg/l)	211.4 (±3.59)	1933.9	19.83	147.90 (±3.12)	749.7	31.705	130.9 (±2.19)	274.6	52.04	263.63

The dissolved oxygen concentrations in Belshi lake vary from 6.7 mg/l to 11.4 mg/l, with the mean value of 9.9517 mg/l. The measured values are generally higher than 2 mg/l, the lowest concentration to sustain fish life in a water system (Crouzet et al., 1999).

Ammonia becomes an important issue if its content in water varies from 0.2 – 2 mg/l (Seager et al., 1988). According EU directive 78/659/EEC “*On the quality of waters that need protection to sustain fish life*”, the limit values for ammonia are respectively 0.005 mg/l for salmonides and 0.025 mg/l for cyprinides (Crouzet et al., 1999). Moreover, according to the Directives 75/440/EEC “*on the quality required for surface waters designed for human consumption*” and 80/778/EEC “*on the quality of water designed for human consumption*”, the maximum allowed concentration (MAC) is 1.5 mg/l for untreated wastewaters and 0.5 mg/l for treated wastewater (Crouzet et al., 1999). According to WQA (Chapman and Kimstach, 1996), ammonia values higher than 3 mg/l indicate organic pollution of water systems. Ammonia (N-NH₃) content in Belshi lake is generally low, but there are seasonal variations. The highest measured value is 0.99 mg/l. The mean value of 0.2772 mg/l is lower than the EU directive, 1 mg/l (Seager et al., 1988), and lower than EU standard for untreated wastewaters, 1.5 mg/l (Crouzet et al., 1999). However, the ammonia content in Belshi lake is higher than the EU limits for salmonids and cyprinids, respectively 0.005 mg/l and 0.025 mg/l (Crouzet et al., 1999), which makes this lake inappropriate for these organisms.

Nitrate content is a very important parameter for the determination of water quality and trophic state of a water system. Nitrate high content in water do not pose any risk to aquatic organisms (UNEP and WHRC, 2007; Nixon, 1995). The use of chemical fertilizers might represent an important source of high nitrate concentrations in water. Higher nitrate concentrations in water than 5 mg/l indicate anthropogenic influence from different sources, such as human or animal direct discharge or agricultural land leachate (Nixon, 1995). Algal growth is stimulated with nitrate concentrations higher than 0.2 mg/l N-NO₃, and shows possible eutrophication conditions (Crouzet et al., 1999). The experimental data show that in all cases nitrate concentrations in Belshi lake are higher than 0.2 mg/l with a maximum and minimum value respectively of 2.2 and 0.022 mg/l N-NO₃ (Crouzet et al., 1999). The mean value of nitrate content in Belshi lake is 1.3871 mg/l N-NO₃ the showing the high tendency of this lake to eutrophy.

Phosphorous is a very important component in water biological cycles. High concentrations of phosphorous are rarely found in freshwater systems, because of its active uptake by the plants. Consequently, there are considerable variations of its concentrations in surface waters. In most cases, phosphorous may vary from 0.005 to 0.02 mg/l P-PO₄₃-. Concentrations lower than 0.001 mg/l P-PO₄ are measured in unpolluted waters, and concentration up to 200 mg/l P-PO₄₃- are found in some salty waters. Since phosphorous is an essential component of biological cycle in water, it is included in water quality monitoring programs (Chapman and Kimstach, 1996). USEPA recommends that total phosphorous content in water systems should be lower than 0.082 mg/l, in order to protect life in water. UE limit for surface waters designed for drinking water consumption is 0.17 mg/l (Crouzet et al., 1999). Moreover, total phosphorous values higher than 0.025 mg/l indicate eutrophic conditions of the water body (Crouzet et al., 1999).

The phosphorous concentrations in Belshi lake vary from 0.042 mg/l to 1 mg/l. The highest values are measured during the summer season, which is related with the quantity of the waters discharged into the lake and the high evaporation rate. The mean phosphorous concentration value is

0.2528 mg/l. In all the measurements, the phosphorous content in Belshi lake is several times than the USEPA limit in 2003 for the life protection in water systems. Moreover, the phosphorous content is several times higher than the EU limit of 0.17 mg/l for the surface water systems and than the EU limit for the eutrophication of water bodies (Crouzet et al., 1999). Even when considering phosphorous as a water quality parameter, the quality of Belshi Lake is very bad, according to NIVA (Bratli 2000). The maximum phosphorous values in Belshi Lake occur during the summer months (1 mg/l) and the minimum (0.04238 mg/l) during the winter months. This coincides with the highest content of chlorophyll in the lake. On the contrary, transparency measured with Secchi disk, reaches the highest values during the winter (1.13 m), when the phosphorous and chlorophyll content is lower. The lowest transparency (0.048 m) is measured during the summer months, when phosphorous and chlorophyll content are higher. Figure 1 represents the correlation between transparency and chlorophyll content in Belshi Lake.

Phosphate content for Belshi lake vary from 0.02 mg/l to 1.65 mg/l, with a mean value of 0.38 mg/l, which in every case are within the limits according to EC 78/659 (BMZ, 1995).

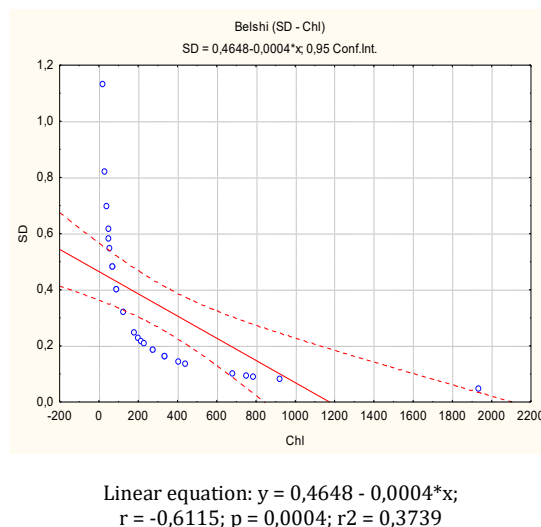


Figure 1: Correlation between transparency (SD) and Chlorophyll in Belshi lake

3.2 Trophic state of Belshi lake

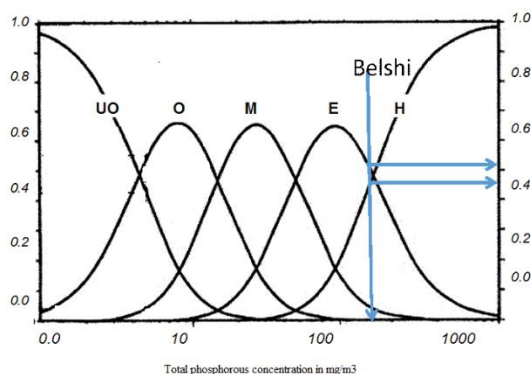
Assessment of trophic state of a lake can be accomplished in various ways. Water Framework recommends that the main indicators that should be measured are biological indicators, descriptive parameters (pH, DO, alkalinity, temperature, etc), nutrient concentration, as well as water flow and level (Heinonen, 2000; Directive, 2000). USEPA recommends the use of combined causative parameters, responsive parameters, oxygen level and trophic state indices that depend on biomass amount in water system (Virginia Tech, 2007). OECD classifies the lakes in five main classes from ultra-oligotroph to hypereutroph, and suggests two classification systems; with fixed boundaries and open boundaries. Table 4 shows the classification of the trophic state of a water system with fixed boundaries (OECD, 1982).

Table 4: Trophic state classification with fixed boundaries according to (OECD, 1982).

Trophic class	Total P, mg/m ³	Chlorophyll a, mg/m ³		Transparency, m	
		Mean	Minimum	Mean	Minimum
Ultra-oligotrophic	≤ 4.0	≤ 1.0	≤ 2.5	≥ 12.0	≥ 6.0
Oligotrophic	≤ 10.0	≤ 2.5	≤ 8.0	≥ 6.0	≥ 3.0
Mesotrophic	10 - 35	2.5 - 8	8 - 25	6 - 3	3 - 1.5
Eutrophic	35 - 100	8 - 25	25 - 75	3 - 1.5	1.5 - 0.7
Hypertrophic	≥ 100	≥ 25	≥ 75	≤ 1.5	≤ 0.7

According to the data on table 4, Belshi lake can be classified as hipereutrophied based on total phosphorous content. The annual mean value of total phosphorous for this lake is nearly 2 times higher than the limit of hipertrophy. Similar situation can be observed when refering to chlorophyll a and transparency for this lake. The minimum chlorophyll value is 19.8 mg/m³ and the minimum value for transparency is 0.04 m. Meanwhile the mean transparency value is 0.19 m. These values classify Belshi Lake in the group of hypereutrophic lakes that takes pollutants and nutrients mainly from untreated wastewaters, and from agriculture.

The open boundaries system designed is easy to use, because there no fixed boundaries between the categories (OECD, 1982). A key element of assessmnet is the propability aspect of water system conditions, taking in consideration the uncertainty of the assessment of the lake's belonging to a certain trophic class. The assessment parameters are the same with the assessment with fixed boundaries, but the propability slopes are used (OECD, 1982).

**Figure 2:** Propability distribution according to Total Phophorous (OECD, 1982)

The OECD propability distribution model (1982) is applied for the Belshi Lake. As it can be seen in figure 2, Belshi lake has 52% chance to be eutrophic and approximately 45% chance to be hypereutrophic. According to OECD system, Belshi lake is in the borderline between eutrophic and hypereutrophic conditions. The OECD propability model has the advantage that it can be used to predict the trophic state of a certain lake in propabilistic terms. However, it is quite impossible to determine strict values between the categories.

Carlson trophic state index (TSI) is one of the most used indicators of trophic state and nutrient conditions assessment in lakes (Carlson, 1977; Carlson and Simpson, 1996). The classification of trophic states according to Carlson is based on algal content in water. The calculation of TSI is based on three parameters that are indicators of biota production: chlorophyll a, total phosphorous and Secchi disc depth. These measurements are converted in a numerical scale from 0 to 100, where high values indicate high production of water biota, which corresponds to poor water quality. TSI is calculated based on Secchi depth, chlorophyll and total phosphorus content, according to the equations (Carlson, 1977; Carlson and Simpson, 1996)

$$TSI (SD) = 60 - 14.41 \ln (SD)$$

$$TSI (CHL) = 9.81 \ln (CHL) + 30.6$$

$$TSI (TP) = 14.42 \ln (TP) + 4.15$$

And $TSI (TN) = 54.45 + 14.43 \ln (TN)$ according to (Kratzer and Brezonik, 1981)

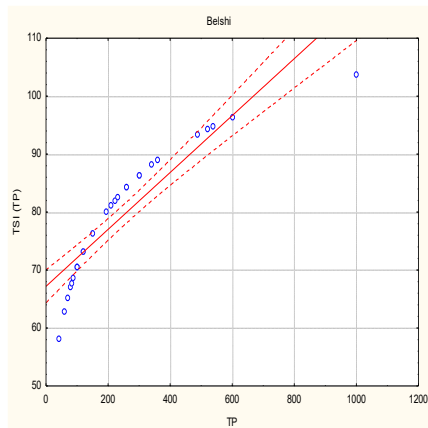
The increase with 10 units of TSI corresponds to the doubling of algal biomass. Usually, total phosphorous is associated with transparency, and oftenly doubling of total phosphorous corresponds to halfening of transparency (Carlson, 1980).

Table 5: Trophic index based on total phosphorous, transparency and chlorophille, and total nitrogen for Belshi lake

TSI (TP)			TSI (SD)			TSI (Chl)			TSI (TN)		
Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
82.3 (±11.42)	103.76	58.18	82.32 (±11.4)	103.77	58.2	83.69 (±11.25)	104.83	59.9	61.29 (±9.2)	74.5	37.55

As it can be observed from the table 5, TSI based total phosphorous, transparency and chlorophyll are close to each other (OECD, 1982). According to the study, classification based on trophic index, Belshi lake is an eutrophied lake, since its trophic state indices are higher than 52. According to the the study classification that describes in detail the state of a water system, Belshi lake can be included in the hypereutrophic class (Carlson and Simpson, 1996). When considering the trophic state based on

nitrogen, it can be noticed that the lake is classified as eutrophied with high tendency to hypereutrophy, and this index is slightly lower than the indices based on total phosphorous, chlorophyll and transparency (Carlson and Simpson, 1996). The indices reach their maximum during the summer, that coincides with the periods with high phosphorous and chlorophyll content and low transparency.

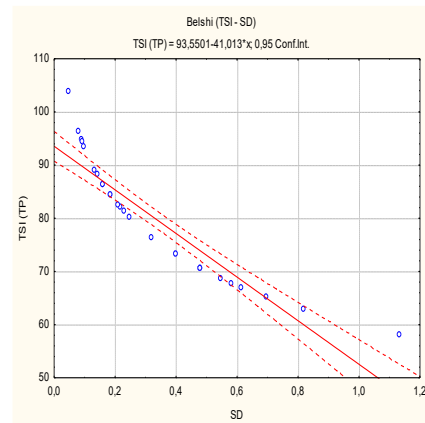


Linear equation: $y = 67,1937 + 0,0491 \cdot x$;
 $r = 0,9124$; $p = 0,0001$; $r^2 = 0,8325$

Figure 3: Correlation between TSI and TP for Belshi lake

Figures 3 and 4 show the correlation between the TSI (TP) and TP and Secchi depth for Belshi lake. There is a positive correlation between TSI and TP, meaning that the increase in phosphorous concentration is associated with an increase of trophic index, and with the increase of eutrophy of the water system. The increase of trophic index leads to the decrease of transparency, which can be observed on the negative correlation between TSI and Secchi depth.

According to the study, N:P ratio as mean value can be interpreted as a lake tendency to switch from phosphorous-dependent to nitrogen-dependent with increasing trophicity (OECD, 1982). However, certain lakes might deviate from this rule, despite the trophic characteristics. Thus, hypereutrophic lakes are not controlled by the nutrient content, but by the



Ekuacioni linear: $y = 93,5501 - 41,013 \cdot x$;
 $r = -0,9261$; $p = 0,0001$; $r^2 = 0,8577$

Figure 4: Correlation between TSI and Secchi Depth for Belshi lake

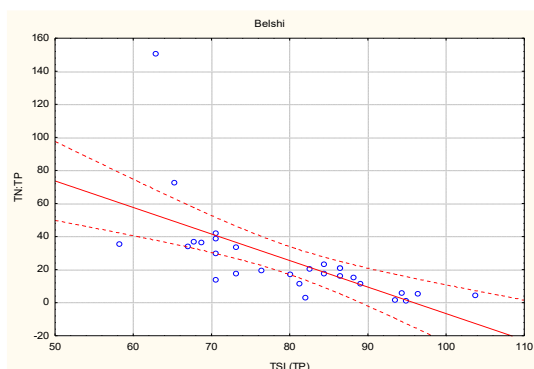
light. Redfield ratio (1934) determines that the stoichiometric ratio between N and P is 16:1. The Si:N:P = 16:16:1 according to and revised is 15:16:1 (Redfield, 1958; Brzezinski, 1985).

Generally, lakes are phosphorous limited when the ratio $TN/TP > 15-16$, and nitrogen limited when the ratio $TN/TP < 7$. Lakes are nitrogen or phosphorous limited or limited by both nutrients, when ratios values of TN/TP are between 15 and 7 (OECD, 1982). Moreover, $TN:TP$ ratio increase from surface to the depth because of the phosphorous consumption in superficial layers during photosynthesis (Quiros, 2002). $TN:TP$ ratio can be used to study the changes in the state of a lake, because there is an oblique proportion between this ratio and the trophic state, and usually this ratio decreases during the eutrophic processes in the lake (Quiros, 2002; Carlson, 1977).

Table 6: Nutrient ratio for Belshi Lake

TN:TP (molar)			Si:TN:TP (molar)		
Mean	Maximum	Minimum	Mean	Maximum	Minimum
14.5:1 (±28.5)	150:1	1.3:1	3.5:14.5:1 (±5.4)	22:150:1	0.004:1.3:1

Table 6 shows the data of nutrient ratio for Belshi lake. Seasonal variation of $TN:TP$ ratio are observed, in accordance with the variation of nitrogen and phosphorous content. The data show variation of N:P ratio for Belshi lake, that correspond to summer months. The minimum value of total phosphorous is measured during august. Meanwhile the minimum value for N:P ratio is measured during june, which corresponds to minimal total phosphorous values (as shown in figure 5). The variation during the study period are related with the discharges composition in the lake. Belshi lake might be limited by nitrogen or phosphorous or both, since $TN:TP$ ratio is between 15 and 7 (OECD, 1982).



Linear equation: $y = 153,9271 - 1,6052 \cdot x$;
 $r = -0,6432$; $p = 0,0002$; $r^2 = 0,4137$

Figure 5: Correlation between N:P ratio and total phosphorous for Belshi lake

limiting factor in Belshi lake is phosphorous, followed by silica. Nitrogen does appear to be a limiting factor for this lake.

Morphoedaphic index (MEI) is mainly used to predict the general productivity of fish and phytoplankton in lake, but it can also be used to determine the total natural phosphorous concentration in lake, and thus becoming an indicator of lowest phosphorous level for which the excessive development of biota in the water body is prevented. It is calculated with the ratio between dissolved solids with mean lake depth. The dissolved solids can be measured directly or determined through alkalinity measurement (MEI_{alk}) or electrical conductivity (MEI_{cond}) (Vighi and Chiaudani, 1985).

The difference between the phosphorous concentration according to OECD limits (that determine the trophic state) and natural concentration (according to MEI index) determines the "excessive" phosphorous concentration as a consequence of human activity. As an indicator of trophic state of a water body, based on total phosphorous is considered 35 µg/l (OECD 1982).

MEI is calculated based on conductivity for Belshi lake. The mean depth of the lake is taken approximately 4 m (Kristo, 2002). The MEI used formula are:

$$MEI_{cond} = \text{Cond} (\mu\text{S}/\text{cm}) : r \text{ (m)}$$

Where conductivity is expressed in µS/cm and r is the lake depth. The natural phosphorous content in lake is calculated according to (Vighi and Chiaudani, 1985):

$$\text{Log}_{10}TP = 1,48 + \text{log}_{10}MEI$$

If Si:N:P ratio is considered, in natural waters it is 16:16:1, and the first

Table 7: Natural phosphorous content and added phosphorous for Belshi lake

	MEI			TP natural, mg/m ³ (based on MEI)			TP added, mg/m ³		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
Belshi Lake	82.5 (±6.6)	90.75	56.75	129.5 (±3.6)	133.6	122.4	94.5 (±3.6)	98.7	87.42

The results on the table 7 show the high quantity of added nutrients in Belshi lake. Thus, the mean values of total phosphorous calculated based on morphoedaphic index are lower than the mean values measured during the study. The mean total phosphorous measured experimentally for Belshi lake is 252.9 mg/m³, which is approximately two times higher than the "natural" phosphorous concentration. Moreover, according to the EEA, the natural phosphorous limits vary from 3-25 mg/m³, and phosphorous content in Belshi lake is far from this limit (Leonard and Crouzet, 1998).

Based on the assessment of the amount of added phosphorous according to the MEI, it is evident that the amount of added phosphorous in Belshi lake is almost twice higher than the natural content. This suggests that

anthropogenic activities such as agriculture, animal farming, and discharge of untreated wastewaters have resulted in increase of total phosphorous in the lake, and consequently increasing the related environmental issues.

3.3 Statistical Discussion On The Experimental Data

Results of the experimental data on chemical parameters are considered statistically in order to evaluate their compatibility. Pearson test, a measure of the correlation between two variables varying from -1 to 1, is used in this study. This test is used to show the strong linear dependency between the variables. The correlation coefficient often is called the Pearson coefficient *r* (Rodgers and Nicewander, 1988; Stigler, 1989).

Table 8: Correlation and Pearson coefficients for the parameters measured in Belshi lake

		N_TOTAL	P_TOTAL	N:P	Si:P	SD	Chl	TSI_TP
N_TOTAL	Pearson Correlation	1	-.038	.585**	.070	.010	-.035	-.024
	Sig. (2-tailed)		.844	.001	.711	.959	.853	.899
	N	29	29	29	29	29	29	29
P_TOTAL	Pearson Correlation	-.038	1	-.514**	-.734**	-.729**	.985**	.918**
	Sig. (2-tailed)	.844		.004	.000	.000	.000	.000
	N	29	29	29	29	29	29	29
N:P	Pearson Correlation	.585**	-.514**	1	.658**	.681**	-.443*	-.649**
	Sig. (2-tailed)	.001	.004		.000	.000	.014	.000
	N	29	29	29	29	29	29	29
Si:P	Pearson Correlation	.070	-.734**	.658**	1	.963**	-.636**	-.914**
	Sig. (2-tailed)	.711	.000	.000		.000	.000	.000
	N	29	29	29	29	29	29	29
SD	Pearson Correlation	.010	-.729**	.681**	.963**	1	-.627**	-.927**
	Sig. (2-tailed)	.959	.000	.000	.000		.000	.000
	N	29	29	29	29	29	29	29
Chl	Pearson Correlation	-.035	.985**	-.443*	-.636**	-.627**	1	.842**
	Sig. (2-tailed)	.853	.000	.014	.000	.000		.000
	N	29	29	29	29	29	29	29
TSI_TP	Pearson Correlation	-.024	.918**	-.649**	-.914**	-.927**	.842**	1
	Sig. (2-tailed)	.899	.000	.000	.000	.000	.000	
	N	29	29	29	29	29	29	29

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

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

The negative correlation between N:P ratio and total phosphorous, $r = -0.514$, as it can be seen in table 8, proves the fact that an increase of total phosphorous in water system results in decrease of N:P ratio for this system. A strong positive relation is observed between the total phosphorous and chlorophyll, $r = 0.985$, and between total phosphorous and trophic index, $r = 0.918$, which is a linear dependency. Thus, as the data show, an increase of total phosphorous content causes an increase of phytoplankton amount and consequently increase of trophic state index of water system toward hypereutrophy. An increase in the concentration of phosphorous is associated with the decrease in transparency and Secchi disk values. This is statistically proven through the strong negative

relation between total phosphorous and Secchi disk, $r = 0.729$.

A negative exponential dependency exists between TN:TP ratio and TP concentration, that can be expressed with the equation ($TN : TP = 95.82 \exp (-0.14 TP)$), with a correlation coefficient $r = -0.514$ ($n = 29$) for Belshi lake. This means that the increase of total phosphorous in water decreases significantly the TN:TP ratio, aiming at achieving a steady state. Literature (Quiros, 2002) suggests that this situation is a characteristics of the lakes with phosphorous as biolimiting element. Moreover, this is observed with the negative correlation between Si:P ratio and total phosphorous, $r = -0.734$ ($n = 29$). A similar situation is evidenced in the dependency between

chlorophyll and TN:TP ratio. This can be explained with the important linear correlation between Chl a and TP concentration in the lake.

4. CONCLUSIONS

Fresh water quality is an important environmental issue nowadays, and thus limiting the water use for different purposes. Water quality and eutrophication are studied in Belshi lake, a karstic lake situated in Albania, that takes pollutants and nutrients from the discharge of untreated wastewaters, agriculture and animal farming. The chemical parameters analysed for this lake show that its water has a very bad environmental quality, according to the Norwegian classification for the fresh waters. When considering the trophic state, this lake belongs to the hypereutrophic class, because the mean total phosphorous content is higher than 100 mg/m³, according to OECD and OECD trophic state index for the lake is higher than 50, which classifies this water body as eutrophic. Moreover, based on Carlson and Simpson this lake is hypereutrophic, because the trophic index calculated on total phosphorous, transparency and chlorophyll is higher than 70 in each case. The trophic state index calculated on nitrogen, includes this lake in the eutrophic class, due to TSI (TN) value between 50 and 70. MEI shows that the added phosphorous in the lake from anthropogenic activities is approximately 2 times higher than the natural phosphorous content. This shows that the anthropogenic activities play an important role in nutrient and pollutant loadings in the lake. Nitrogen – phosphorous ratio for Belshi lake shows that phosphorous is the limiting factor for the lake (OECD 1982). The variation of this ratio is related with the precipitation.

There is a strong positive correlation between total phosphorous and chlorophyll, and between total phosphorous and trophic index. On the contrary, there is a negative correlation between total phosphorous and N:P ratio, and between total phosphorous and transparency. This indicates that the limiting factor, but very important in chlorophyll increase, is phosphorous.

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