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# Evaluation of ecological status of the Shkumbini river based on Bio-chemical indicators

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**ABSTRACT**

Aims of this paper is the water quality assessment using bio-chemicals monitoring techniques, during July and September 2015, for the Shkumbini River, located in central Albania. Purpose is to provide more information about the ecological status and protection of these ecosystems. In this study from algae community, we used diatoms for Biomonitoring because they have a siliceous frustule. Three different indices (SI, $TI_{DIA}$ and H') were used for biological evaluation. Based on diatom community structure, Shkumbini water quality was classified from mesotrophic to polytrophic, which shows a high status of eutrophication. Concentration of total phosphorus and nitrogen were used for the evaluation of trophic status for all sampling stations. This situation is due to the presence of inorganic and organic matter, originated from agricultural activity, restaurants, urban waste discharge and erosion by inhabitant centres.

***Key words*** *: Biomonitoring, Diatom, Nutrients, Freshwater,*

## Introduction

In the last decade high variation in the structure and function of river environment have been observed due to human activity and have also profound impacts upon the fluxes of nitrogen (*N*) and phosphorus (*P*) (Weigelhofer *et al*., 2018). Variation of *N* and *P* caused by anthropogenic changes have strongly impacted the aquatic ecosystem too. Phosphorus and nitrogen are the primary drivers in eutrophication of aquatic ecosystems, where increased nutrient concentrations lead to increased primary productivity (Guignard *et al*., 2017). *N* and *P* exported from different sources can have severe effects into the quality of fresh waters (Carpenter *et al*., 1998; Correll, 1998). Water resources degradation due to the eutrophication can lead to depletion of their species component, as well as reduction of the facilities or services provided by this watershed (Correll, 1998). Disposal of solid and domestic waste along the Shkumbini valley, especially in nearby urban areas, has an effect not only on the quality reduction but also to the aesthetic appearance (Paparisto *et al*., 2010). Furthermore, the uncontrolled urban development and the lack of regulations on housing construction has led to improper disposal of construction waste, which is also a source of contamination for the rivers. The eutrophication phenomena along Shkumbini River are due to the high concentrations of nutrients (especially nitrogen and phosphorus), produced by human activities like, urban wastewater, industries, mining activities, gravel extraction, agriculture, and animal farming.

Water quality monitoring based on physic-chemical data usually do not offer a time integrated representation of the ecosystem's response to external stresses, neither do they furnish valuable information about the impact of these variation on biological communities (Arle *et al*., 2016). On the other hand, use of bio indicators can ensure an integrated data of measurement for the water quality as experienced by the aquatic biota and contribute with a helpful addition to chemical assessment based of water quality (Lavoie *et al*., 2011; Jakovljeviæ *et al*. 2016). The diatoms community is widely considered the first biological community to respond to eutrophication pressures and is the most direct of all the Biological Quality Elements of nutrient concentration in the water (John, 2002). Their use for biomonitoring has been developed to help determining quality of the aquatic environment trends and how that quality is influenced by waste treatment plant, or other anthropogenic activities (Chapman, 1996).

Diatoms respond to both water column nutrient concentration and habitat quality, and this has led to increasing interest in its use as a monitoring tool for running water like rivers. According to EN 13946 (2003) standard, samples of diatoms can also be collected from submerged hard surfaces, or submerged macrophytes. This Standard establishes also a method for the sampling and laboratory preparation of benthic diatoms for water quality assessments (STANDARD EN 14407 2004). Data produced by this method are suitable for production of water quality indices based on the relative dominance of taxa. With appropriate modifications, this method can also be utilized for the study of benthic diatoms in lakes. The Standard EN 14407 (2004) is applied for the identification and enumeration of the relative abundance of diatom taxa on preparation of permanent slides and interpretation of relevant data for the water qualiy assessment. Following European sectorial directives in the aquatic environmental field (Water Framework Directive and Environmental Quality Standards Directive) over recent decades, it pursues an integral approach for a uniform European water policy for the first time. Bio-monitoring methods are getting more and more intention in the last 100 years and are used in fresh waters to get information on the biota due to the impact from waste waters or fertilized agricultural lands (Whitton, 1995; Kupe *et al*., 2006). Phytobenthic (diatoms) needs to be assessed in freshwater, with the assumption that these are particularly sensitive to nutrient and acidification also diatom community's changes are correlated with concentrations of both organic and inorganic materials (Sládeèek, 1986; Kelly and Whitton, 1995; Whitton, 1995; John, 2002; Prygiel *et al*., 2002). Diatoms follow quickly environmental changes because they have a short lifecycle. They are easily sampled and preserved due to their siliceous cell wall, also allows water quality assessment onshort or long-term changes. This has made them one of the preferred communities for biomonitoring all around the world (Cox, 1991; Kovacs *et al*., 2006).

Based in the Water Framework Directive our aim was to evaluate diversity of phytobenthic, saprobe and the trophy level in Shkumbini River. The trophy level is based in three indices: Saprobic Index – SI (Rott *et al*., 1999) which is correlated with organic matter; Trophic Diatom Index - $TI_{DIA}$ (Rott *et al*., 1997) is correlated with inorganic matter and Shannon Index (H') which show the diversity of species (Zelinka and Marvan, 1991). In the last decades, quality of waters has got larger attention in Albania, as well as their suitable management (Miho *et al*., 2005; Kupe, 2006; Kupe *et al*., 2008). At once is increasing the role of environmental monitoring, as a source of information for addressing environmental issues. The aim of this study was (i) to verify the degrees of organic pollution, (ii) usefulness of diatom indices in water quality assessments for Shkumbini River and (iii) to determine the dominant diatom taxa characteristic of the Shkumbini River.

## Materials and Methods

### Sampling sites

Shkumbini River is one of the most important rivers of Albania. It flows for 181 km in the center of Albania, with a drainage basin of 2444 $km^2$**.** It flows through the districts of Librazhd, Elbasan, Cerrik, Peqin, Kavaja and Lushnja, which are regions with high population density (Kabo, 1990-1991). Evaluation of water quality for the Shkumbini River, based on bio-chemical indicators was carried out in July and in September 2015. In this region, many effluents from local agriculture land, restaurant or other services are discharged directly to the river and furthermore untreated sewage from villages of Librazhd, Prrenjas and Elbasan increase level of pollution. We have collected 10 samples in five stations (Karkavec - Prrenjas, Dardhe - Librazhd, Labinot-Fushe, Paper and Peqin), (Fig. 1, Tab. 1), collected during July and September. The site stations were situated at different locations from human impact; the numbering is downstream the river, from the

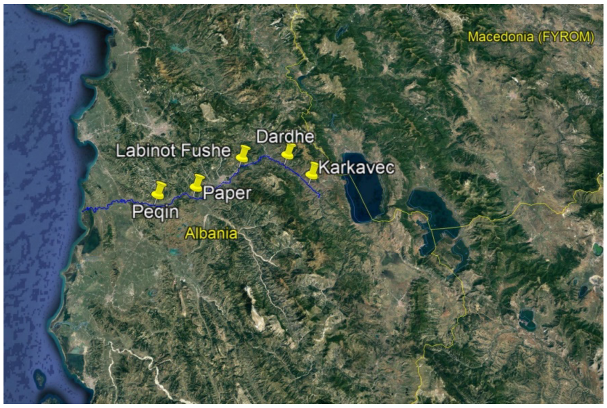



**Fig. 1.** Represents location of sampling sites.

least to the most polluted parts.

The sampling sites are listed in table below (Table 1).

**Sample collection, preparation, and data analyses**

**Biological data collection**

Diatoms were collected as periphyton in the upper surface of selected rocks from the river with a toothbrush. Suspension materials were collected and conserved in 4% formaldehyde (Kolkwitz, 1950; Lund *et al*., 1958; Kelly and Whitton, 1995). Samples rich in organic and inorganic matterin addition to diatoms need stronger oxidation than clean ones and the optimum ratio of sample to oxidants may need to be tested first.

Diatoms frustules were cleaned from both organic and inorganic materials by boiling in concentrated HCl (20 ml), followed by boiling in concentrated $H_2SO_4$ (20 ml) containing a few crystals of $KNO_3$, washing with distilled water following the books of Krammer and Lange-Bertalot (1986-2001). To getcredible results (95%), about 500 valves were counted per each slide using 100x oil immersion, (Lund *et al*., 1958; Pascher, 1976; Kelly and Whitton 1995; Lavoie *et al*. 2011). Diatoms were identified using the following literature: Cleve-Euler (1951–1955); Pascher (1976); Krammer and Lange-Bertalot (1986-2001); Kupe *et al*., (2013). The trophic diatom index ($TI_{DIA}$) and saprobic index (SI) for the diatoms were calculated using the formula of Shannon and Weaver (1949); Rott *et al*. (1997, 1999) as below:

$$H' = -\sum_{i=1}^{n} p_i \log_2(p_i) \quad .. (1)$$

$$TI_{DIA} = \frac{\sum_{i=1}^{n} TW_i G_i p_i}{\sum_{i=1}^{n} G_i p_i} \quad .. (2)$$

$$SI = \frac{\sum_{i=1}^{n} S_i G_i H_i}{\sum_{i=1}^{n} G_i H_i} \quad .. (3)$$

Where:

- $H'$ is diversity index, with $p_i$ denoting the proportion in group $n$.
- $TI_{DIA}$, trophic index for diatoms; $TW_i$, trophic value of $i$ species (1-3); $G_i$, indicative weight of $i$ species (1-3); $H_i$, relative frequency of $i$ species (%); $n$, total number of species. Respective values of $TW_i$ and $G_i$, as well as trophic classes were taken after Rott *et al*. (1999).
- *SI*, saprobic index for diatoms; $S_i$, saprobic value of $i$ species (1-5); $G_i$, indicative weight of $i$ species (1-3); $H_i$, relative frequency of $i$ species (%); $n$, total number of species. Respective values of $S_i$ and $G_i$, as well as saprobic classes were taken after Rott *et al*. (1997).

Cleaned of cell contents and mounted in a medium with a high refractive index, diatoms were identified and counted using a high power light microscope (Motic BA310, with 100X) until an appropriate sample size has been obtained. These data are then interpreted using indices or other assessment methods, according to STANDARD EN 14407 (2004). In order to rate the level of a particular stress, a biological index or score specifically designed to evaluate that stress should be used. Most of the indices were developed for use in a single geographical area but subsequent testing has shown to have broader validity. It is important that the dominant and sub-dominant taxa present in the region are represented in the index. Trophic (Rott *et al*., 1999) and Saprobic (Rott *et al*., 1997) indices may be used to make a rought estimate of rivers condition and to

**Table 1.** General sampling data from Shkumbini River (June ÷ September 2015)

| Nr. | Site name | River | Code | Month | Year | Longitude | Latitude |
|---|---|---|---|---|---|---|---|
| 1 | Peqin | Shkumbin | $AL_{SH}0001$ | July/September | 2015 | 19.76966 | 41.03672 |
| 2 | Paper | Shkumbin | $AL_{SH}0002$ | July/September | 2015 | 19.94164 | 41.05157 |
| 3 | Labinot-Fushe | Shkumbin | $AL_{SH}0003$ | July/September | 2015 | 20.1668 | 41.14826 |
| 4 | Dardhe | Shkumbin | $AL_{SH}0004$ | July/September | 2015 | 20.37328 | 41.1498 |
| 5 | Karkavec | Shkumbin | $AL_{SH}0005$ | July/September | 2015 | 20.4742 | 41.05906 |

determinate a water quality. These values are correlated to the known trophic and saprobic classes, respectively (Table 2).

### Chemical data collection

For the determination of total nitrogen (TN) and total phosphorus (TP), the method of UNEP/MAP/MED POL (2005) was used. For a 50 ml of sample, 5 ml of the oxidizing agent is added. The flask and autoclave were closed for at least half an hour. Then, the autoclave was opened to allow cooling the flask nearly the room temperature. With a bulb pipette was taken from the flask 5 ml of the digested sample, on which TN as nitrate can be determined separately. The remaining 50 ml of sample was transferred to a phosphate reaction flask and added 1 ml of ascorbic acid and mixed with reagent solutions. The absorbance was measured at 880 nm after 10-30 minutes using 10 cm cell (or the longest available cell).

## Results

### Biological data

115 species of diatoms were found in ten sampling sites and two periods for Shkumbini River (both in July and September), (Fig. 2). Only eight of them were centric diatom, the rest were Pennate. The number of species oscillated from 28 (in Peqin, July) to 66 (in Prrenjas-Karkavec, July). Other stations like: Paper and Labinot-Fushe were rich in species. Most common and widespread species of pennate diatoms were: *Cocconeis pediculus*, *Cymbella microcephala*, *Fragilaria capucina*, *Fragilaria ulna*, *Gomphonema minutum*, *Navicula cryptotenella*,

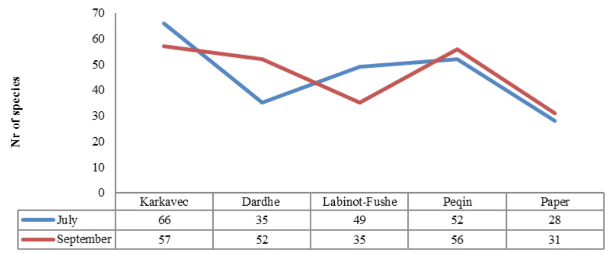



**Fig. 2.** Number of species at the 10 sampling sites, during sampling months (July and September 2015).

*Nitzschia incospicua*, *Nitzschia palea*, *Nitzschia umbonata* etc.

Diversity index (see Fig. 3) in Shkumbini river in July oscillated from 1.57 (Peqin) to 3.56 (Prrenjas and Karkavec), but in September, the minimum value was found in Labinot-Fushe (1.32) and the maximum value in Dardha and Librazhd (3.74).

Regarding trophic index ($TI_{DIA}$) the average lowest values were observed in Paper (approximately 1.8); Dardha and Librazhd (1.9); the water quality in Dardha belongs to meso-eutrophic classes (Rott *et al*., 1999). Two other sampling places belong to

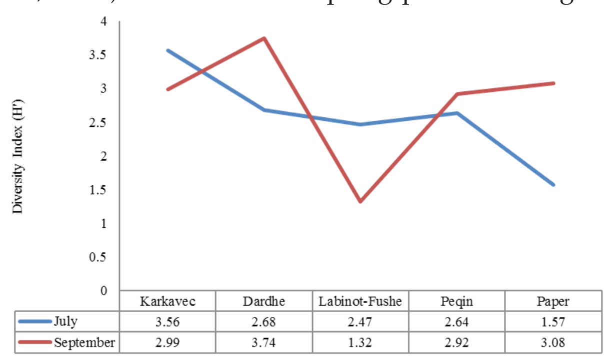



**Fig. 3.** Variation of Shannon Diversity Index (H'), during sampling period July-September 2015.

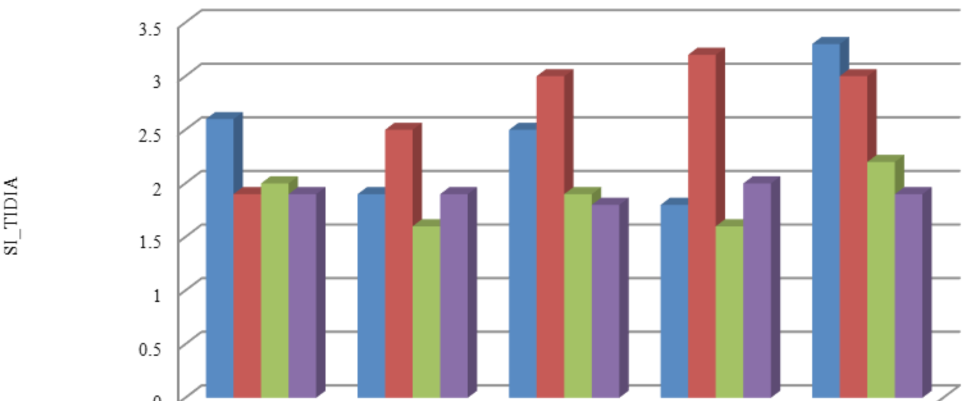
**Table 2.** Correlation between trophic and saprobic value with trophic and saprobic classes by Rott *et al*. (1997, 1999).

| Value of TIDIA | Trophic classess | Description of the pollution | Value of SI | Saprobic classess | Description |
|---|---|---|---|---|---|
| £1.0 | Ultraoligotroph | No polluted | 1.0-<1.5 | Oligosaprob | None |
| 1.1-1.3 | Oligotroph | Slighty polluted | 1.5-<1.8 | Oligosaprobb-mesosaprob | Little |
| 1.4-1.5 | Oligo-mesotroph | Slighty polluted | 1.8-<2.3 | β-mesosaprob | Moderate |
| 1.6-1.8 | mesotroph | Moderately polluted | 2.3-2.7 | β-α mesosaprob | Fair |
| 1.9-2.2 | meso-eutroph | Obvious | 2.7-<3.2 | α-mesosaprob | Obvious |
| 2.3-2.6 | eutroph | Heavely polluted | 3.2-<3.5 | a-meso-polysprob | Heavy |
| 2.7-3.1 | eu-polytroph | Heavily to masive polluted | 3.5-<4 | polisaprob | Strong to |
| 3.2-3.4 | polytroph | Massive polluted | | | |
| >3.4 | poly-hypertroph | Very masive polluted | | | |

eutrophic classes (Rott *et al*., 1999; Kupe *et al*., 2010; Kupe *et al*., 2013) approximately 2.6 (Karkavec and Prrenjas) and 2.5 (Labinot- Fushe). Polytrophic classes were observed for Peqini station, showing a strongly polluted part. But in September the trophic diatom index oscillated from 1.9 in Prrenjas and Karkavec to 3.2 in Peqin. The same values approximately 3.0 were found in Labinot-Fushe and in Paper. Considering the saprobic value oscillated from 1.6 (oligo β-mesosaprob) in Paper and Dardha (Librazhd) to 2.2 (β-mesosaprob to a-mesosaprob) in Peqin (Fig. 4), which show the low and the high value of saprobic index (Sládeèek, 1986; Rott *et al.,* 1997). Higher densities were observed especially in Peqin and Prrenjas (Karkavec). In September, the saprobic value oscillated from 1.8 (Labinot-Fushe) to 2.0 in Peqin. In other sampling places were found 1.9 (meso-eutroph). All samples belong to the same interval in saprobic classes (β-mesosaprob) with moderate organic matter. Composition of diatom community in Shkumbini river were also classified from mesotroph (Paper) to polytroph (Peqin), by Rott *et al*. (1999) and especially Peqini site show a high level of inorganic and organic matter. Based on the trophic index in July, the water quality in Shkumbini river were classified from mesotrophic (Paper) to polytrophic (Peqin) by Rott *et al*. (1999) showing a high status of pollution.

### Chemical data

The parameters which affect the water quality, nitrogen, phosphorus, and dissolved oxygen, are differ-




| | Karkavec | Dardhe | Labinot-Fushe | Peqin | Paper |
|---|---|---|---|---|---|
| TIDIA July | 2.6 | 1.9 | 2.5 | 1.8 | 3.3 |
| TIDIA September | 1.9 | 2.5 | 3 | 3.2 | 3 |
| SI July | 2 | 1.6 | 1.9 | 1.6 | 2.2 |
| SI September | 1.9 | 1.9 | 1.8 | 2 | 1.9 |

**Fig. 4.** Variation of Trophic diatom index ($TI_{DIA}$) and Saprobic index (SI) during the sampling period July-September 2015.

**Table 3.** The physic-chemical parameters of water and nutrients (as an average value n=3) in sampling stations at Shkumbini River (July-September 2015)

| Sampling stations | Sampling time | DO (ppm) | ToC | pH (mS/cm) | Conductivity (mg/l) | Plot | Ntot |
|---|---|---|---|---|---|---|---|
| Karkavec | July | 7.9 | 17.9 | 6.9 | 414 | 0.01c | 0.19c |
| | September | 8.8 | 19 | 7.1 | 423 | 0.012c | 0.24c |
| Dardhe | July | 7.9 | 21 | 7 | 398 | 0.016c | 0.22c |
| | September | 8.8 | 26.3 | 7.2 | 395 | 0.014c | 0.34c |
| Labinot fushe | July | 7.88 | 20.2 | 7.1 | 270 | 0.033b | 0.29b |
| | September | 9.2 | 27.5 | 6.05 | 262 | 0.05b | 0.38b |
| Paper | July | 7 | 18.5 | 6.85 | 340 | 0.044a | 0.42a |
| | September | 8.1 | 26.2 | 7 | 330 | 0.08a | 0.47a |
| Peqin | July | 7.1 | 18.7 | 6.8 | 475 | 0.055a | 0.479a |
| | September | 8 | 25.9 | 6.9 | 450 | 0.089a | 0.5a |

ent at stations, (Table 3). Water temperature varies according to the seasons and the sampling site from 17.9º to 21 ºC in July and 19º to 27.5 ºC in September. Regarding dissolved oxygen, which is an essential parameter for life of water species and organic substance presence, the conditions for living species in the stations are better in Prrenjas, Dardhe and Labinot Fushe than in more agricultural regions like Paper and Peqin. According to the trophic situation classification of fresh water by OECD, (Table 4), it results as follows: considering the content level of two main nutrients, nitrogen and phosphorous, stations Prrenjas, Dardhe, Labinot Fushe present an almost oligotrophic situation, whereas Paper and Peqin station present mesotrophic situation. *P* total, (OECD 1982; Correll 1998) for stations Peqin, Paper, Labinot field and *N* total for Prrenjas were the highest in September (the early rainy season), and lowest in July (the dry season) (Table 2).

**Table 4.** Classification of natural water quality (classification of fresh water by OECD)

| | Oligotrophic | Mesotrophic | Eutrophic | Hypertrophic |
|---|---|---|---|---|
| *P* total (mg/l) | <0.013 | <0.040 | <0.100 | >0.100 |
| *N* total (mg/l) | <0.300 | <0.400 | <1.00 | >1.00 |

Alabaster *et al*. (1980) and Abulude *et al*. (2002) considered pH range of 6.50 ÷ 9.00 as an indicator of a good fish population. In Shkumbini River pH varies from 6.05 to 7.2. The data of nutrient (*N*; *P*) concentrations in water of Shkumbini River were subjected to *t*-tests for equality of means to check the differences across the stations and seasons. Values with the different letter indicate significant differences for nutrient concentration between stations and inverse for values with the same letter, according to *t*-test for equality of means (Table 5).

## Discussion

### Biological interpretation

Many diatoms species in Shkumbini river were common and with not a taxonomic interest. We will be mentioning the low presence of *Caloneis* sp. that often is found in rivers in the less polluted parts as epiphyte over *Chladophora*, which were found only in Dardha (Librazhd) and Paper (in September); in other sampling places were found but not more widespread. Evaluation of the relative abundance of *Achnanthidium minutissimum* is well known (Stevenson and Bahls, 1999) and their expanses show the level of disturbance. *A. minutissima* is considered as a tolerant species (Hofmann, 1994; Miho *et al*., 2005; Kupe, 2006) and was found almost in all sampling stations, it was often accompanied with *Cocconeis pediculus*. A special structure of diatom community was observed in the most polluted parts, like Peqini, Prrenjasi and Labinot-Fushe. *N. palea*var. *palea*, as a saprotroph species (Hofmann, 1994; MIHO *et al*., 2005), which grow up until polysaprobic habitats, was very frequent in Peqin (July) and the same species were more dominant in Dardha and Librazhd (September). The high dominance of *Nitzschia palea* together with the rare number of taxa was the causes of the low values of diversity index calculated in those stations (Fig. 3). *N. palea* was mostly associated with other saprotroph or tolerant species, like *Navicula accomoda, Gomphonema parvulum, Navicula cryptotenella, Fragilaria ulna*, etc. (Table 6/a and 6/b). Usually, diversity index is highly correlated with the number of species. The low value of diversity index shows the low number of common species. The most polluted part of river has indication from restaurants, agriculture land, discharge of waste and erosion by inhabitant centre of Librazhd, Prrenjas and Elbasan cities and their villages. These values show a highest pollution with organic maters. The Shannon Diversity Index was found a good and widely used tool in comparing diatoms communities' independently from pollution effects. The Saprobic Index (Rott *et al*., 1997; Miho *et al*., 2005; Kupe *et al*., 2013) and Trophic Indices (Lund *et al*., 1958; Kupe *et al*., 2008) are correlated respectively with organic and inorganic matter in the water (Lavoie *et al*., 2011). Furthermore, Saprobic

**Table 5.** Significant differences for nutrient concentration in water of Shkumbini river between seasons according to t-test for equality of means.

| Sampling stations | Peqin | | | Paper | | | Labinot-Fushe | | | Dardhe | | | Karkavec | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Micronutrient | t | df | sig | t | df | sig | t | df | sig | t | df | sig | t | df | sig |
| Ptot (mg/l) | -5.4 | 4 | .006* | -12.4 | 4 | 0.0001* | -4.45 | 4 | .011* | -1.05 | 4 | 0.35 | -1.93 | 4 | 0.12 |
| Ntot (mg/l) | -0.99 | 4 | 0.37 | -1.4 | 4 | 0.21 | -2.36 | 4 | 0.077 | -0.61 | 4 | 0.57 | -3.55 | 4 | 0.02* |

**Table 6a.** Diatom list of sampling stations in Shkumbini River (July 2015)

| Sampling stations | Paper | Dardhe | Karkavec | Labinot-Fushe | Peqin | |
|---|---|---|---|---|---|---|
| ***Centric*** | *p%* | *p%* | *p%* | *p%* | *p%* | % |
| *Cyclotella meneghiniana* Kützing | | | 0.6 | 0.3 | | 40 |
| *Cyclotella ocellata* Pantocsek | + | | | | | 20 |
| *Melosira varians* Agardh | + | | 0.1 | 0.6 | | 60 |
| *Pantocsekielladelicatula* (Hustedt) K.T.Kiss & E.Ács | + | | | + | | 40 |
| *Thalassiossira weissflogii* (Grunow) Fryxell et Hasle | | | + | + | | 40 |
| Pennate | | | | | | |
| *Achnanthes minutissima* Kützing agg. | 14.2 | 33.8 | 24.4 | 8.9 | 1.8 | 100 |
| *Amphipleura pellucida* Kützing | | 0.2 | | | | 20 |
| *Amphora montana* Krasske | | | + | | | 20 |
| *Amphora ovalis* (Kützing) Kützing | | | + | | | 20 |
| *Amphora pediculus* (Kützing) Grunow | 0.3 | 0.7 | + | | | 60 |
| *Aneumastus stroesei* Oestrup | + | | | | | 20 |
| *Brachysira neoexilis* Lange-Bertalot | + | | | + | | 40 |
| *Caloneis hendey* Lange-Bertalot | | | + | | | 20 |
| *Caloneis silicula* (Ehrenberg) Cleve | | | + | | | 20 |
| *Caloneis* sp2. (like in Brari) | + | | + | + | + | 80 |
| *Cocconeis pediculus* Ehrenberg | 14.7 | 22.2 | 15.4 | 0.3 | + | 100 |
| *Cocconeis placentula* Ehrenberg agg. | 1.5 | | 3.1 | 1.6 | + | 80 |
| *Cocconeis placentula* var. *lineata* (Ehrenberg) Van Heurck | | 2.7 | | | | 20 |
| *Cymatopleura solea* (Brebisson) W. Smith | + | | 0.3 | | | 40 |
| *Cymbella affinis* Kützing agg. | 5.6 | 2.4 | 2.3 | 1.3 | | 80 |
| *Cymbella amphicephala* Naegeli | + | + | + | | + | 80 |
| *Cymbella caespitosa* (Kützing ) Brun | 1.0 | | + | | | 40 |
| *Cymbella cf. cistula (Ehrenberg) Kirchner* | + | + | | + | | 60 |
| *Cymbella cistula* (Ehrenberg) Kirchner agg. | + | + | | | | 40 |
| *Cymbella descripta* (Hustedt) Krammer & Lange-Bertalot | + | | | | | 20 |
| *Cymbella helvetica* Kützing | | 0.2 | | + | + | 60 |
| *Cymbella lanceolata* (Ehrenberg) Van Heurck | + | | | | | 20 |
| *Cymbella microcephala* Grunow gr. | 13.5 | 22.3 | 0.3 | 0.6 | + | 100 |
| *Cymbella minuta* Hilse | | + | | | | 20 |
| *Cymbella silesiaca* Bleisch | + | | 0.6 | 1.3 | | 60 |
| *Cymbella sinuata* Gregory | | 0.3 | + | + | | 60 |
| *Cymbella subhelvetica Krammer* | + | | | | | 20 |
| *Cymbella tumida* (Brebissoni) Van Heurck | + | | + | 0.6 | | 60 |
| *Cymbella ventricosa* Agardh | + | | | | | 20 |
| *Diatoma ehrenbergii* Kützing | 1.7 | | + | | | 40 |
| *Diatoma mesodon* (Ehrenberg) Kützing | + | | | | | 20 |
| *Diatoma moniliformis* Kützing | 2.6 | | + | 0.3 | 2.7 | 80 |
| *Eunotia sp.* | | | + | | | 20 |
| *Fragilaria capucina* Desmazières agg. | 40.1 | | 1.5 | 2.5 | | 60 |
| *Fragilaria capucina* var. *perminuta* (Grunow) Lange-Bertalot | | 4.4 | | | | 20 |
| *Fragilaria ulna* (Nitzsch) Lange-Bertalot agg. | 2.0 | 2.2 | 2.8 | 40.1 | 0.7 | 100 |
| *Frustulia vulgaris* (Thwaites) De Toni | | | + | | | 20 |
| *Gomphonema angustum* (Kützing) Rabenhorst | | | | + | | 20 |
| *Gomphonema clavatum* Ehrenberg | + | | + | | | 40 |
| *Gomphonema exilissimum* (Grunow) Lange-Bertalot | + | | | | | 20 |
| *Gomphonema gracile* Ehrenberg | | | | + | | 20 |
| *Gomphonema minutum* (Agardh) Agardh agg. | 0.3 | 3.6 | 15.1 | 9.6 | | 80 |
| *Gomphonema olivaceum* (Hornemann) Brebisson gr. | 0.7 | | | | 0.4 | 40 |

**Table 6a.** *Continued ...*

| Sampling stations<br>***Centric*** | Paper<br>*p%* | Dardhe<br>*p%* | Karkavec<br>*p%* | Labinot-Fushe<br>*p%* | Peqin<br>*p%* | <br>% |
|---|---|---|---|---|---|---|
| *Gomphonema parvulum* Kützing agg. | | | 3.3 | 7.3 | 0.4 | 60 |
| *Gomphonema pumilum* (Grunow) Reichardt & Lange-Bertalot | | | 1.2 | + | | 40 |
| *Gomphonema tergestinum* Fricke | 0.7 | 1.7 | + | 1.0 | | 80 |
| *Gyrosigma acuminatum* (Kützing) Rabenhorst | | | + | + | | 40 |
| *Gyrosigma scalproides* (Rabenhorst) Cleve | + | + | + | + | | 80 |
| *Hantzschia amphioxys* (Ehrenberg) Grunow | | | + | | | 20 |
| *Craticula accomoda* Hustedt | | | | | 0.4 | 20 |
| *Craticula ambigua* Ehrenberg | | | + | + | | 40 |
| *Craticula cuspidata* Kützing | | | + | | | 20 |
| *Fallacia pygmaea* Kützing | | | + | + | 0.4 | 60 |
| *Luticula kotschyi* Grunow | | | + | | | 20 |
| *Sellaphora bacillum* Ehrenberg | + | | | | | 20 |
| *Navicula atomus* (Kützing) Grunow | | | 2.3 | | 0.4 | 40 |
| *Navicula capitatoradiata* Germain | + | 0.3 | 7.7 | 1.0 | 0.4 | 100 |
| *Navicula caterva* Hohn & Hellerman | | + | + | | | 40 |
| *Navicula cryptotenella* Lange-Bertalot | 0.3 | 2.0 | 4.4 | 9.9 | | 80 |
| *Navicula cryptotenelloides* Lange-Bertalot | | + | + | + | + | 80 |
| *Navicula decussis* Oestrup | + | | | | | 20 |
| *Navicula gregaria* Donkin | 0.3 | | | | | 20 |
| *Navicula oligotraphenta* Lange-Bertalot & Hofmann | + | + | 0.3 | + | | 80 |
| *Navicula recens* (Lange-Bertalot) Lange-Bertalot | + | | | | | 20 |
| *Navicula reichardtiana* Lange-Bertalot | | 0.3 | 0.6 | 0.3 | | 60 |
| *Navicula schroeteri* Meister | | | 0.3 | | | 20 |
| *Navicula schroeterii* Meister var. simetrica | + | | | 0.6 | | 40 |
| *Navicula tripunctata* (O. F. Müller) Bory | | + | | | | 20 |
| *Navicula veneta* Kützing | | | | | 0.4 | 20 |
| *Navicula viridula* var. *rostellata* (Kützing) Cleve | + | + | 0.3 | + | | 80 |
| *Neidium dubium* (Ehrenberg) Cleve | + | | + | | | 40 |
| *Nitzschia acicularioides* | | | | 0.3 | | 20 |
| *Nitzschia amphibia* Grunow | | | 0.9 | | | 20 |
| *Nitzschia constricta* (Kützing) Ralfs | | | | | + | 20 |
| *Nitzschia denticula* Grunow | | + | + | | | 40 |
| *Nitzschia dissipata* (Kützing) Grunow | + | + | 1.2 | 1.3 | 1.8 | 100 |
| *Nitzschia fonticola* Grunow | | | 1.2 | | | 20 |
| *Nitzschia incospicua* Grunow | | | 6.1 | 5.7 | 0.7 | 60 |
| *Nitzschia lacuum* Lange-Bertalot | | | + | | | 20 |
| *Nitzschia linearis* (Agarth) W. Smith var. *linearis* | + | | 1.2 | + | | 60 |
| *Nitzschia palea* (Kützing) W. Smith var. *palea* | 0.5 | 0.7 | 2.6 | 4.1 | 59.8 | 100 |
| *Nitzschia sigmoidea* (Nitzsch) W. Smith | | + | + | | | 40 |
| *Nitzschia umbonata (*Ehrenberg) Lnage-Bertalot | | | | | 29.9 | 20 |
| *Nitzschia valdestriata* Aleem et Hustedt | | | + | | + | 40 |
| *Rhoicosphaenia abbreviata* (Agardh) Lange-Bertalot | | | + | + | | 40 |
| *Rhopaloida gibba* (Ehrenberg) O. Müller | | | | | + | 20 |
| *Surirella angusta* Kützing | + | + | + | | | 60 |
| *Surirella bifrons* Ehrenberg | | | | + | | 20 |
| *Surirella brebissoni* Krammer & Lange-Bertalot | | | 0.1 | 0.3 | | 40 |
| *Surirella splendida* | | | + | + | | 40 |
| ***Number of species, N:*** | **48** | **31** | **62** | **45** | **24** | |
| Diversity Index (Shannon Index), H': | 2.64 | 2.68 | 3.56 | 2.47 | 1.57 | |

**Table 6a.** *Continued ...*

| Sampling stations | Paper | Dardhe | Karkavec | Labinot-Fushe | Peqin | |
|---|---|---|---|---|---|---|
| ***Centric*** | *p%* | *p%* | *p%* | *p%* | *p%* | % |
| Trophic Diatom Index, $TI_{DIA}$: | 1.8 | 1.9 | 2.6 | 2.5 | 3.3 | |
| Trophic Classes | Mesotroph | Meso-Eutroph | Eutroph | Eutroph | Polytroph | |
| Saprobic Index, SI | 1.6 | 1.6 | 2.0 | 1.9 | 2.2 | |
| Saprobic Classes | Oligo to β-mesosaprob | Oligo to β-mesosaprob | β-mesosaprob | β-mesosaprob | β-α-mesosaprob | |

Index SI classifies water quality in rivers based on the load of dissolved organic matters originating from wastewater. The water quality assessment based on chemical-physical parameters and nutrients content are in good accordance with those obtained from biological parameters. Also, according NIVA classification and the European Directive on "Quality of fresh waters", we can conclude that water quality of station Prrenjas > Qukes > Labinot-Fushe results better than Paper and Peqin stations. Is well known that diatoms are very sensible to environmental changes like environmental conditions and pollution (Rott *et al.*, 1997, 1999).

### Chemical interpretation

The recorded values are within the acceptable limits for the survival, metabolism, and physiology of aquatic organisms (Alabaster and Lloyd, 1980). This is as well reflected in nitrogen and phosphorous nutrients content that is related to the presence of organic substances which at stations Prrenjas > Dardhe > Labinot-Fushe with a higher amount of dissolved oxygen results at lower level compared to Paper and Peqin stations. The *t*-tests for mean values showed significant variation between seasons for *P* in all stations except Prrenjas and inverse for Nitrogen. *T*-tests showed that in general there was significant statistical difference between industrial and ultramafic area for the concentration of *N* and *P* in water of Shkumbini River (Table 5). It is well known that phosphorous is a necessary element for organisms' growth and usually it is the main nutrient that restricts primary productivity (phytoplankton) at a water setting. This results from the relation of this element with carbon at living organisms, through photosynthesis process. Regarding the above-mentioned factors and the presence of dissolved oxygen in water setting of stations, it is likely suggested that the species present in stations Prrenjas > Dardhe > Labinot-Fushe, are larger in number compared to those in station Paper and Peqin. So, from biotic index parameter used for water quality, bio classification result of stations Prrenjas > Dardhe > Labinot-Fushe are better than Paper and Peqin one.

## Conclusion

Depending on the total phosphorus and nitrogen in the Shkumbini River it can be classified as oligotrophic in Prrenjas, Dardhe, Labinot Fushe stations and mesotrophic in Paper and Peqin stations. The water quality of Shkumbini river in Paper and Peqin stationsare suggested to affect the health and the different components of the aquatic ecosystem. The most common and widespread species of pennate diatoms were: *Achnanthes minutissima*, *Cocconeis pediculus*, *Cymbella microcephala*, *Fragilaria capucina*, *Fragilaria ulna*, *Gomphonema minutum*, *Navicula cryptotenella*, *Nitzschia incospicua*, *Nitzschia palea*, *Nitzschia umbonata* etc. *A. minutissima*, considered as a tolerant species (Cleve-Euler, 1951-1955) and was found almost in all sampling stations, it was often accompanied with *Cocconeis pediculus*. Based on diatom community structure, Shkumbini river were classified from mesotrophic (Paper) to polytrophic (in Peqin) in July, by Rott *et al.* (1999), show the high status of pollution, which indicated from medium inorganic and organic matter, originated from agricultural activity and restaurants. Especially, Peqini site show the highest level of inorganic and organic

**Table 6b.** Diatom list of sampling stations in Shkumbini River (September 2015)

| Sampling stations | Karkavec | Labinot-Fushe | Dardhe | Peqin | Paper | % |
|---|---|---|---|---|---|---|
| Centric | p% | p% | p% | p% | p% | % |
| *Cyclotella cyclopuncta* Hackansson | | + | | | | *20* |
| *Cyclotella meneghiniana* Kützing | | 0.5 | | + | | *40* |
| *Cyclotella ocellata* Pantocsek | 3.2 | + | | | + | *60* |
| *Melosira varians* Agardh | 0.1 | 0.9 | + | 8.1 | 1.4 | *100* |
| *Pantocsekielladelicatula* (Hustedt) K.T.Kiss & E.Ács | + | + | | + | | *60* |
| Pennate | | | | | | |
| *Achnanthes exilis* | + | | + | | | *40* |
| *Achnanthes minutissima* Kützing agg. | 11.1 | 51.9 | 7.7 | + | + | *100* |
| *Amphipleura pellucida* Kützing | 0.4 | | | | | *20* |
| *Amphora montana* Krasske | | | 0.4 | | | *20* |
| *Amphora ovalis* (Kützing) Kützing | + | | | | | *20* |
| *Amphora pediculus* (Kützing) Grunow | 0.3 | | + | + | | *60* |
| *Aneumastus stroesei* Oestrup | + | | | | | *20* |
| *Brachysira procera* Lange-Bertalot | 5.8 | | | | | *20* |
| *Caloneis cf. lancetula* | | | + | | | *20* |
| *Caloneis bacillum (Grunow) Cleve* | + | | | | | *20* |
| *Caloneis* sp. | | + | 0.7 | + | 3.2 | *80* |
| *Cocconeis pediculus* Ehrenberg | 2.3 | + | + | + | + | *100* |
| *Cocconeis placentula* Ehrenberg agg. | + | 2.4 | + | 13.5 | 11.8 | *100* |
| *Cymatopleura solea* (Brebisson) W. Smith | | | + | + | | *40* |
| *Cymbella affinis* Kützing agg. | 0.5 | | 7.4 | + | | *60* |
| *Cymbella amphicephala* Naegeli | + | | + | + | | *60* |
| *Cymbella caespitosa* (Kützing ) Brun | 1.1 | | + | 0.9 | | *60* |
| *Cymbella cistula* (Ehrenberg) Kirchner agg. | + | | + | 0.4 | 0.4 | *80* |
| *Cymbella descripta* (Hustedt) Krammer & Lange-Bertalot | 0.3 | | | | | *20* |
| *Cymbella helvetica* Kützing | 0.3 | | | | | *20* |
| *Cymbella lanceolata* (Ehrenberg) Van Heurck | | | + | + | | *40* |
| *Cymbella microcephala* Grunow gr. | 8.5 | + | 3.2 | + | + | *100* |
| *Cymbella minuta* Hilse | | | | | + | *20* |
| *Cymbella silesiaca* Bleisch | + | | 1.1 | + | 0.7 | *80* |
| *Cymbella sinuata* Gregory | | | + | + | | *40* |
| *Cymbella subhelvetica Krammer* | + | | + | | | *40* |
| *Cymbella tumida* (Brebissoni) Van Heurck | | + | | 1.1 | 1.8 | *60* |
| *Cymbella turgidula* (cf. var. *venezuelana* Krammer) | | | 1.4 | | | *20* |
| *Denticula tenuis* Kützing | 0.5 | | | | | *20* |
| *Diatoma ehrenbergii* Kützing | 3.7 | | + | | | *40* |
| *Diatoma mesodon* (Ehrenberg) Kützing | | | + | | | *20* |
| *Diatoma moniliformis* Kützing | 36.7 | + | 3.2 | 0.7 | 0.7 | *100* |
| *Diatoma vulgaris* Bory gr. | | | + | 0.4 | | *40* |
| *Fragilaria acus* Kützing | | + | | | | *20* |
| *Fragilaria arcus* (Ehrenberg) Cleve | + | | | | | *20* |
| *Fragilaria biceps* (Kützing) Hustedt | 1.1 | | | | | *20* |
| *Fragilaria capucina* Desmazières agg. | 17.9 | 2.8 | | + | | *60* |
| *Fragilaria capucina* var. *rumpens* (Kützing) Lange-Bertalot | | | 6.0 | | | *20* |
| *Fragilaria parasitica* (W. Smith) Grunow var. *parasitica* | + | | | | | *20* |
| *Fragilaria ulna* (Nitzsch) Lange-Bertalot agg. | + | 0.5 | 8.1 | 36.5 | 17.5 | *100* |
| *Frustulia vulgaris* (Thwaites) De Toni | | | + | | | *20* |
| *Gomphonema angustum* (Kützing) Rabenhorst | 0.3 | | | | + | *40* |
| *Gomphonema gracile* Ehrenberg | 0.3 | + | | | | *40* |

**Table 6b.** *Continued ...*

| Sampling stations | Karkavec | Labinot-Fushe | Dardhe | Peqin | Paper | |
|---|---|---|---|---|---|---|
| Centric | p% | p% | p% | p% | p% | % |
| *Gomphonema minutum* (Agardh) Agardh agg. | 1.1 | 6.1 | | 2.2 | | *60* |
| *Gomphonema olivaceum* (Hornemann) Brebisson gr. | 0.3 | | 2.5 | + | 0.4 | *80* |
| *Gomphonema parvulum* Kützing agg. | | 3.8 | 1.1 | 2.8 | 0.9 | *80* |
| *Gomphonema pumilum* (Grunow) Reichardt & Lange-Bertalot | | + | 0.4 | + | | *60* |
| *Gomphonema tergestinum* Fricke | 0.3 | | 1.4 | | + | *60* |
| *Gomphonema truncatum* Ehrenberg | + | | | + | | *40* |
| *Gyrosigma acuminatum* (Kützing) Rabenhorst | + | + | | + | | *60* |
| *Gyrosigma scalproides* (Rabenhorst) Cleve | | | 0.4 | 1.1 | 1.8 | *60* |
| *Craticula accomoda* Hustedt | | 2.8 | | | + | *40* |
| *Craticula ambigua* Ehrenberg | | | + | | | *20* |
| *Craticula cuspidata* Kützing | | | | + | 0.4 | *40* |
| *Sellaphora bacillum* Ehrenberg | + | | | | | *20* |
| *Navicula atomus* (Kützing) Grunow | | 2.4 | 0.4 | | 1.8 | *60* |
| *Navicula capitatoradiata* Germain | + | | 0.7 | 13.0 | 7.9 | *80* |
| *Navicula caterva* Hohn & Hellerman | + | + | + | | | *60* |
| *Navicula cryptocephala* Kützing | | + | | | | *20* |
| *Navicula cryptotenella* Lange-Bertalot | 0.3 | 18.9 | 1.1 | 9.1 | 20.2 | *100* |
| *Navicula cryptotenelloides* Lange-Bertalot | | | + | + | + | *60* |
| *Navicula oligotraphenta* Lange-Bertalot & Hofmann | + | | + | + | | *60* |
| *Navicula radiosa* Kützing | + | | | | | *20* |
| *Navicula reichardtiana* Lange-Bertalot | 0.5 | | 8.1 | + | + | *80* |
| *Navicula saprophila* Lange-Bertalot | | | 5.6 | | | *20* |
| *Navicula schroeteri* Meister | | | 0.7 | + | | *40* |
| *Navicula schroeterii* Meister var. simetrica | | + | | + | | *40* |
| *Navicula tripunctata* (O. F. Müller) Bory | + | | + | + | | *60* |
| *Navicula veneta* Kützing | | 0.9 | | + | | *40* |
| *Navicula viridula var. grunowii* | | | + | | | *20* |
| *Nitzschia acicularis* W. Smith | | | | + | | *20* |
| *Nitzschia amphibia* Grunow | + | | | + | | *40* |
| *Nitzschia angustata* (W. Smith.) Grunow | 0.3 | | | | | *20* |
| *Nitzschia constricta* (Kützing) Ralfs | | | | + | | *20* |
| *Nitzschia denticula* Grunow | 0.4 | | | | + | *40* |
| *Nitzschia dissipata* (Kützing) Grunow | + | + | 17.3 | 6.7 | 24.6 | *100* |
| *Nitzschia fonticola* Grunow | + | | | | | *20* |
| *Nitzschia hungarica* Grunow | | | | + | | *20* |
| *Nitzschia incospicua* Grunow | | + | | + | | *40* |
| *Nitzschia lacuum* Lange-Bertalot | 1.6 | | | | | *20* |
| *Nitzschia linearis* (Agarth) W. Smith var. *linearis* | 1.1 | | | + | | *40* |
| *Nitzschia palea* (Kützing) W. Smith var. *palea* | | 6.1 | 19.7 | 2.4 | 4.6 | *80* |
| *Nitzschia sinuata* var. *tabellaria* (Grunow) Grunow | + | | | | | *20* |
| *Nitzschia umbonata (*Ehrenberg) Lnage-Bertalot | | + | | | | *20* |
| *Nitzschia vermicularis* (Kützing) Hantzsch | | | | + | | *20* |
| *Rhoicosphaenia abbreviata* (Agardh) Lange-Bertalot | | | | + | | *20* |
| *Surirella angusta* Kützing | | | 1.1 | 0.7 | | *40* |
| *Surirella bifrons* Ehrenberg | | | | + | | *20* |
| *Surirella brebissoni* Krammer & Lange-Bertalot | | | 0.7 | 0.4 | 0.4 | *60* |
| Number of species, N | 53 | 32 | 48 | 53 | 29 | 99 |
| Diversity Index, H' | 2.99 | 1.32 | 3.74 | 2.92 | 3.08 | |
| Trophic Diatom Index, $TI_{DIA}$ | 1.9 | 3.0 | 2.5 | 3.2 | 3.0 | |

**Table 6b.** *Continued ...*

| Sampling stations | Karkavec | Labinot-Fushe | Dardhe | Peqin | Paper | |
|---|---|---|---|---|---|---|
| Centric | p% | p% | p% | p% | p% | % |
| Trophic Classes: | Meso-euttroph | Eu-Polytroph | Eutroph | Polytroph | Eu-polytroph | |
| Saprobic Index, SI | 1.9 | 1.8 | 1.9 | 2.0 | 1.9 | |
| Saprobic Classes | β-mesosaprob | β-mesosaprob | β-mesosaprob | β-mesosaprob | β-mesosaprob | |

matter. In September is oscillated from meso-eutroph (Prrenjas-Karkavec) to polytrophic in Peqin. In this period the water of Shkumbini river was charged with moderately to heavily polluted inorganic matter and moderate polluted with organic matter. We observed, by the levels of nitrogen and phosphorus in the water, increased turbidity due to the large content of solids, in some cases, large and organic pollution,e.g., stations: the saprobic index belong to â-á meso-saprob (2.2) Peqin; â-meso-saprob (2.0) Prrenjas and â-mesosaprob (1.9) Labinot-Fushe. Presence of macroscopic algae like as *Chladophora glomerata*was not widespread (only in July). This situation comes as a result of the influence of cities: Prrenjas, Librazhd, Elbasan, Peqin and Rrogozhinë; that are the main reason of high values for trophic and saprobic index in Shkumbini river.Most of farmlands in the watershed are irrigated, which increases the load to the river. Most of the drained water discharged directly or indirectly into the river. Industry, restaurants, or other discharge also contributes pollution to the river in many forms. In Shkumbini River, the metal parts factories discharge wastes to the river without treatment. Shkumbini River is fertilized by nutrients in detergents and human and animal waste and by nutrients in runoff from the land. As a result, the river is becoming more eutrophic and polytrophic. Evidence of the ecological impacts of human activities is apparent in both the aquatic plant community and the benthic diatoms in the water.

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