Use of algal indices for determining of water quality in the Sirvan River tributaries (Kurdistan-Iran)

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Abstract

Zhaveh Dam was built on the Sirvan River (Sanandaj-Iran), after the cross of the two main branches namely Gaveh-rood and Gheshlagh, with the aim of being used in agriculture and industry. Due to the importance and mutual relation between algae and water quality, this paper is going to study water quality based on algal indicators (phytoplankton and algal periphyton) in this basin for the first time. Seasonal sampling was conducted in 5 stations, from the upstream to the reservoir of the dam from the fall of 2020 to the summer of 2021. The saprobic index value classified the water in the "medium organic polution" group in all samples. Most of the of Palmer's index values (especially in algal periphyton) indicated to" moderate to heavy" pollution of organic matter. Also, based on the "diatom species resistant to organic pollution" about 68% (phytoplankton) and 83% (algal periphyton) samples clssified in "organic pollution likely to contribute significantly to eutrophication" and "heavily contamination with organic pollution" groups. Most of the Diatom Trophic Index (TDI) values in water and periphyton were mor than 3.5 and in they were in" hypertrophic condition, with very high nutrient load". As a conclusion, the high nutrients load and organic pollution in the river show the need to optimize wastewater treatment plants, control the entries of wastewaters into the river, and improve and rehabilitation the river, as prerequisites for any planning and water use.

Keywords: Algal indicators, Water quality, Pollution, Trophic level, Sirvan River, Kurdistan

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Introduction

In recent decades, quantitative and qualitative results of biological monitoring are used in water quality evaluation. By studying these changes and related indices (biological, pollution, trophic,…) during different seasons and years, it is possible to identify sensitive areas, especially in rivers that receive water from sewage treatment stations (Zutinic *et al*., 2020). Microalgae are autotrophic organisms and have the ability to absorb nutrients during photosynthesis. Microalgae are observed as floating (phytoplankton) or attached to surfaces such as floor and stone (periphyton) in aquatic ecosystems. Algal periphytons living under certain physical and chemical characteristics for a long time in each place and are suitable for determining long-term pollution in the river. In the short-term changes of environment conditions, the species structure of periphyton may not have enough time to change. These changes can be recorded by studying phytoplankton. By knowing the diversity of microorganisms and comparing different environments, it is possible to determine the functional capabilities and stability of an ecosystem (Behzadi *et al*., 2021). For example, the study of the Bijar River (Gilan) showed that the increase in nitrate (caused by agricultural activities) along with the increase in temperature in the summer season was one of the factors affecting the abundance of phytoplankton (Ebrahimi Sabet *et al*., 2020). Also, the evaluation of the ecological status of the Krka River (Croatia) based on the periphytic-diatoms index showed that the upstream water had an "excellent" ecological status. While in the middle station, due to anthropogenic effects, its ecological status was degraded to "good" class. But in the downstream station again, the ecological situation became "excellent" due to receiving water from small lakes and proper self-purification of water. These results showed that Krka River is very sensitive and is affected by human activities. Therefore, it needs continuous monitoring and implementation of strict protection laws (Zutinic *et al*., 2020).

Zhaveh Dam was built on the Sirvan River, after the cross of the two main branches of the Gaveh-rood and the Gheshlagh Riveres, with the aim of being used in the agricultural and industrial sectors. There are gardens and agricultural lands on the bank of the Gaveh-rood branch. The Gheshlagh branch enters to the dam after passing the urban of Sanandaj city and industrial areas and receiving several kinds of sewage. The branch will supply about 43% of the dam's water. The physico-chemical factors of the Sirvan River and modeling of the trophic level in the dam area investigated by Mashanir (2017). Due to the importance and mutual relation between algae and water quality, this paper is going to study water quality based on algal indicators (phytoplankton and algal periphyton) in this basin for the first time. The results of this study will be useful in determining the efficiency of the wastewater treatment sites in the region, the type and level of uses of the water body, and the risk of dewatering of dam in terms of water quality and trophic level.

Materials and methods

This study was carried out in the Gheshlagh and Gaveh-rood tributeries of Sirvan River (Sanandaj-Kurdistan province). A total 5 stations selected in this study. 3 stations were located in Qashlaq branch. Stations 1: in upstream before Sanandaj wastewater treatment plant, station 2: near the Sanandaj wastewater treatment plant and station 3: after the treatment plant and before the crosing with Gaveh-rood. Then, station (4) determined in the branch of Gaveh-rood River and station (5) at the reservoir of Zhaveh Dam (Fig. 1). These stations were located between longitudes E 47.011.2.1 - E 46.8310111 and latitudes N 35.22.35.8 - N 35.0647637.

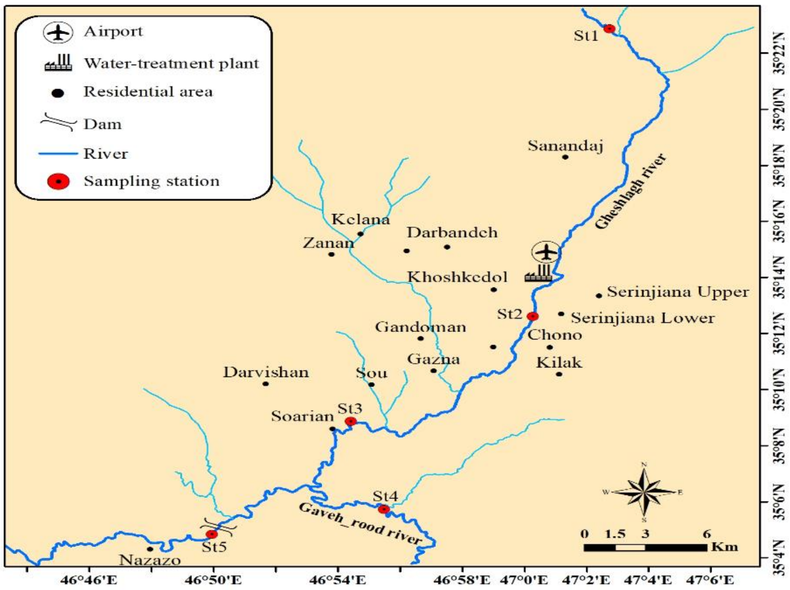


Figure 1: Map of sampling stations in the Sirvan River from fall of 2020 to summer 2021.

The air and water temperature were determined by a thermometer. The value of rainfall was extracted from the official portal of the Regional Water Company of Kurdistan (Kdrw.ir/cs/RainStatistic).

To study of phytoplankton, water samples were directly collected in the selected stations. In each station, 500 cc of integrated water sample in a glass bottle was fixed with formalin to the final volume of 0.5-2%. In the laboratory, the samples were subjected to microscopic analysis after the preparation steps (siphon and centrifuge). Algal periphyton samples were prepared by scraping of 1×1 cm square of submerged stone in each station. The algal periphyton samples fixed by formalin for microscopic analysis (APHA, 2017). Valid refrences and identification keys (Tiffany and

Britton, 1971; Hartley *et al.*, 1996; Wehr *et al.*, 2003) were used to identification of algae taxon. Phytoplankton and algae periphyton abundance were reported as numbers/m^3 and numbers/cm^2 respectively (APHA, 2017).

Indices

Shannon's index of species diversity: The index was calculated according to Washington (1984). Then, based on Shannon's index values, water quality was classified into three groups: clean (>3), moderatly polluted (1-3) and heavily polluted (<1) (Mason, 1991).

Saprobic Index: This index (the organic matter pollution) was calculated based on the formula provided by Pantle and Buck (1955) and then the results were classified in 4 groups. So that the saprobic indices (1.10-1.50), (1.51-2.50), (2.51-3.50) (3.51-4.00) respectively indicating to (very slightly), (moderatly) (heavily) and (very heavily) polluted (Pantle and Buck, 1955).

Index of diatom taxa tolerant to organic pollution (% tolerant), The count of diatom taxa tolerant to organic pollution (key species) was divided to the total diatoms and the result were expressed as a percentage. Then the percentages (>20), (40-21), (60-41) and (<61) respectively interpretated to (free of significant organic pollution), (some evidence of organic pollution), (likely to contribute significantly to eutrophication of site) and (Site is heavily contaminated with organic pollution) (Kelly and Whitton, 1995).

Palmer index (organic pollution), The sum of organic pollution index related to each of the key taxa of algae was calculated in each sample. The results: ≥15, 19-15 and ≤20, respectively defined to (low), (medium) and (high) organic pollution (Palmer, 1980).

Diatom trophic index TDI (Ttrophic diatom index), It is an index based on the sensitivity of diatoms to organic matter pollution, which was calculated according to the formula of Kelly and Whitton (1995). The results were set in numerical groups (1.0-1.4), (1.5-1.8), (1.9-2.2), (2.3-2.7), (2.8-3.1), (3.2-3.5), (3.6-4.0). These groups express (the trophic condition and nutrient load) of environment in classes of (oligotrophic, natural), (oligo-mesotrophic, low), (mesotrophic, moderate), (meso-eutrophic, critical), (eutrophic, significant), (eu-hypertrophic, high) and (hypertrophic, very high) respectively (Kelly and Whitton, 1995).

Statistical data analysis was done using SPSS18. Station and season were considered as independent variables, phytoplankton abundance as dependent variable. Parametric tests (T-test and ANOVA), Post Hoc tests (Tukey and Duncan) and Pearson's correlation test were performed at the 5% level of Standard Error (Nasiri, 2019). The cluster analtsis of percentage similarity of temporal and spatial of parameters was performed with MVSPW software.

Results

The values of air and water temperature, on the sampling day, the value of rainfall in the month of sampling, as well as the two weeks leading up to the sampling day are shown in Figure 2.

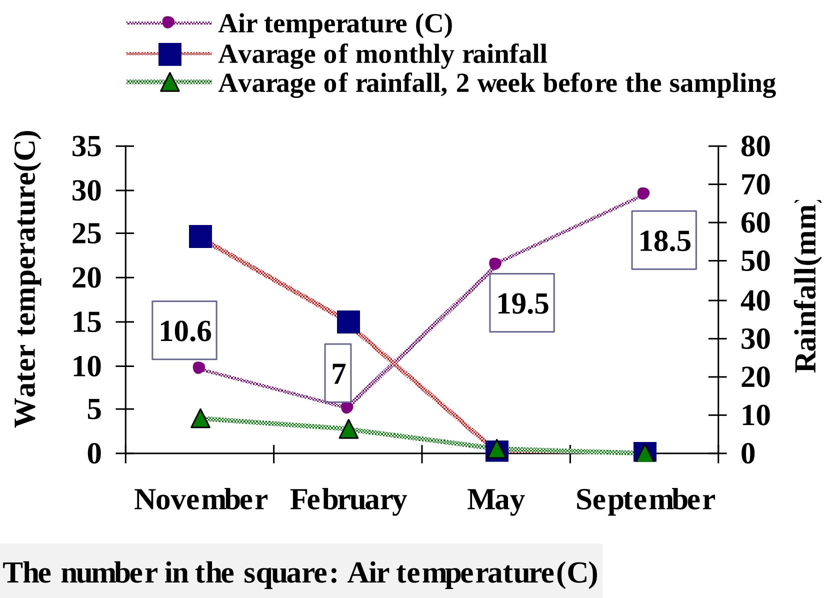
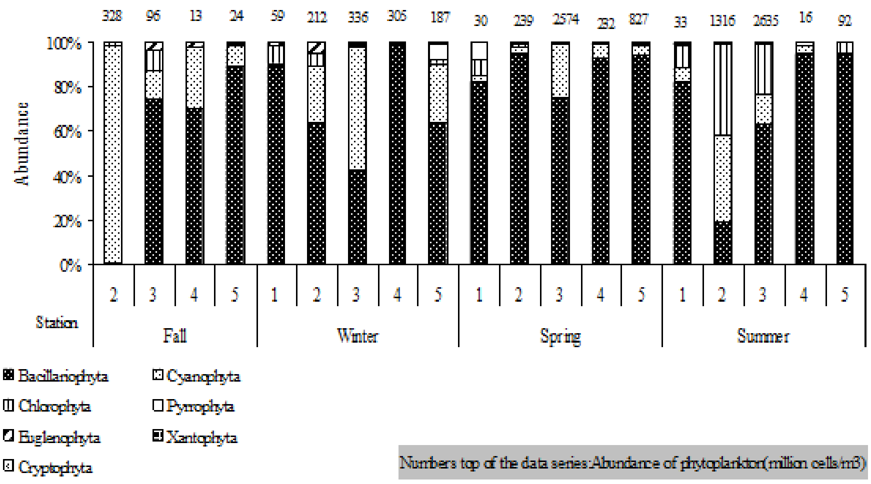


Figure 2: The air and water temperature on the sampling day and the value of rainfall in the Sirvan River from fall 2020 to summer 2021.

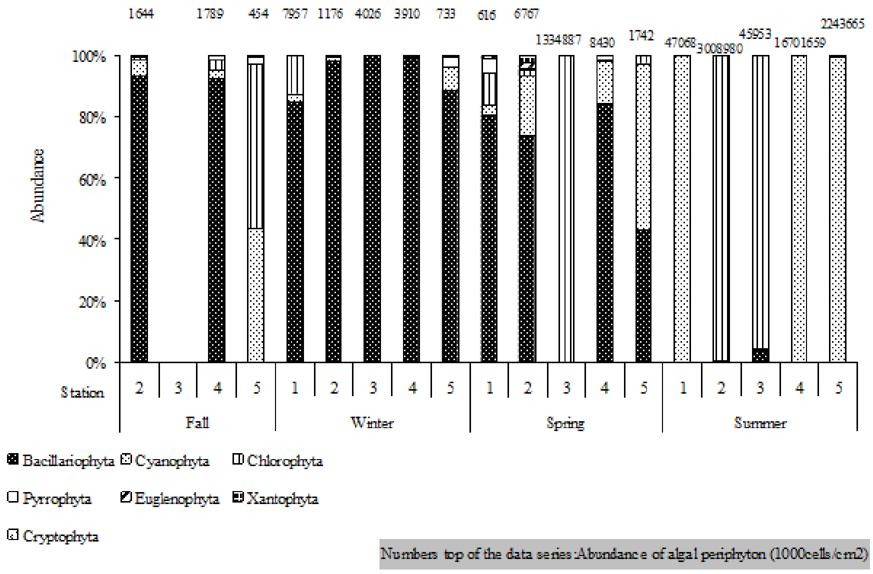
Phytoplankton and algal Periphyton

A total of 157 species of microalgae were identified by microscopic observation in water and periphyton samples. The species were classified into 7 phyla namly: Bacillariophyta, Pyrrophyta, Cyanophyta, Chlorophyta, Euglenophyta, Xantophyta and Cryptophyta. The highest number of species was found in the Bacillariophyta (42% of the total number of species), followed by Cyanophyta and Chlorophyta (about 22% in each phylum). The other three phyla included about 10% of all species. Most of the identified algae species were similar among the samples taken from water and periphyton.

Phytoplankton abundance in water showed changes from 13 (autumn, station 4) to 2635 (summer, station 3) million cells/m^3. The phytoplankton abundance in station (3) in spring (2574 million cells/m^3) almost was similar to the abundance in summer. The maximum abundance in stations 1, 4 and 5 were mainly recorded in winter and then in spring, but in stations 2 and 3 the maximum abundance was recorded in summer. Algal periphyton abundance was recorded from a maximum of 17,000 million cells/cm^2 (summer, station 4) to a minimum of 454,000 cells/cm^2 (autumn, station 5). The maximum abundance of algal peiphyton was in summer in all stations (except in station 3). In station 3, an increase in filamented chlorophyta caused a sharp increase in the abundance of algae in the spring (Fig. 3). According to the Pearson test, the correlation coefficient (r) between the abundance of phytoplankton and the abundance of bacillariophyta, cyanophyta, and chlorophyta were 0.94, 0.83 and 0.66, respectively. These values refer to the Bacillariophyta as dominant phylum in phytoplankton abundance. In the periphyton samples, Bacillariophyta was the first dominant phylum.in stations 1 to 4 in all seasons except in summer. In the summer, Cyanophyta and Chlorophyta were the first dominant phylum in stations 1 and 4 and in stations 2 and 3, respectively. The Pearson correlation coefficient (r) of algal periphyton abundance with cyanophyta was 0.98 During the study period.



Water



Periphyton

Figure 3: The participation percentage abundance of phytoplankton and algal periphyton phyla in the Sirvan River from fall 2020 to summer 2021.

Indices

Palmer index (organic pollution), The valus of Palmer's index in phytoplankton indicated to different ranges of organic pollution (from low to haigh organic pollution). In periphyton, the Palmer index showed high and sometimes moderate organic pollution except at station (4) in the summer season (Table 1).

Table 1: The class of organic pollution (by palmer index definition) in the Sirvan River from fall 2020 to summer 2021.

Periphyton	water	Station	Season	Periphyton	water	Station	Season
High	Low	1	Spring	-	-	1	Fall
High	Low	2		Medium	Low	2	
High	High	3		-	Medium	3	
High	High	4		High	Low	4	
High	High	5		Medium	Low	5	
High	Low	1	Summer	High	Low	1	Winter
High	Low	2		High	High	2	
High	Medium	3		High	High	3	
Low	Low	4		High	High	4	
High	Low	5		High	High	5	

Shannon index: The maximum (3.12) and minimum (0.34) Shannon index of phytoplankton were in winter and fall seasons, respectively, in station 2. In algal periphyton, the maximum Shannon's index was obtained in the winter at station (5) and the minimum Shannon index (0.01 - 0.05) was reported in summer at all stations except station (3). The minimum value of station (3) was recorded in spring. The water quality was generally placed in the "relatively polluted" group, based on the Shannon index values of phytoplankton (Fig. 4). In autumn, the water quality decreased and it was classified in the “heavily polluted". The values of Shannon index in algal periphyton, was generally classified in the "relatively polluted" group (except in summer). In summer, the quality decreased to “heavily polluted" in all stations.

Saproby index: The changes of saproby index was from 1.5 to 2.5 during the study period. This range of saprobic index indicates to "moderatly polluted" of organic matter (Fig. 5)

The mean saproby of dominant algal species in periphyton was mainly classified in the "moderatly polluted" group. Only in the winter at stations 2 and 3, the mean of saproby was placed in the “heavily polluted" group.

The dominant and similar algal species in water and periphyton in different classes of organic pollution (based on the saproby index species) are shown in Table 2.

According to Table 2, there were 5 species (*Cyclotella meneghinian, Navicula cryptocephala, Nitzschia palea*, *Lyngbya* sp. and *Stigeoclonium* *amoenum*) in the "heavily polluted" group. The abundance of *Nitzschia palea* and *Stigeoclonium amoenum* species were higher in rainy season (autumn and winter). However, abundance of *Lyngbya* sp., *Navicula cryptocephala* and *Cyclotella meneghiniana* were higher in spring and summer seasons.

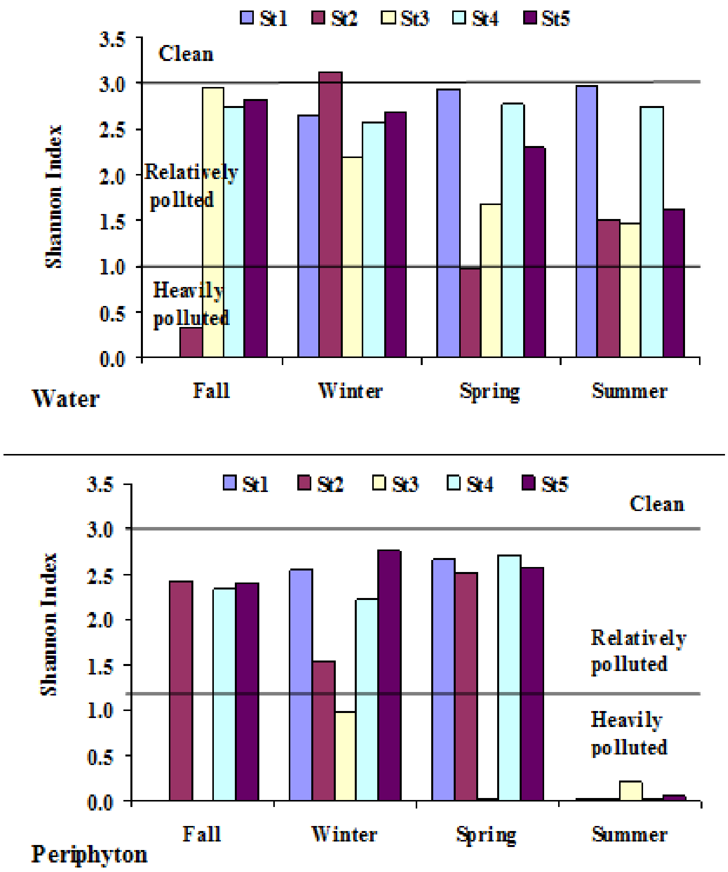


Figure 4: Seasonal Changes of Shannon index of phytoplankton and algal periphyton in different stations in the Sirvan River from fall 2020 to summer 2021.

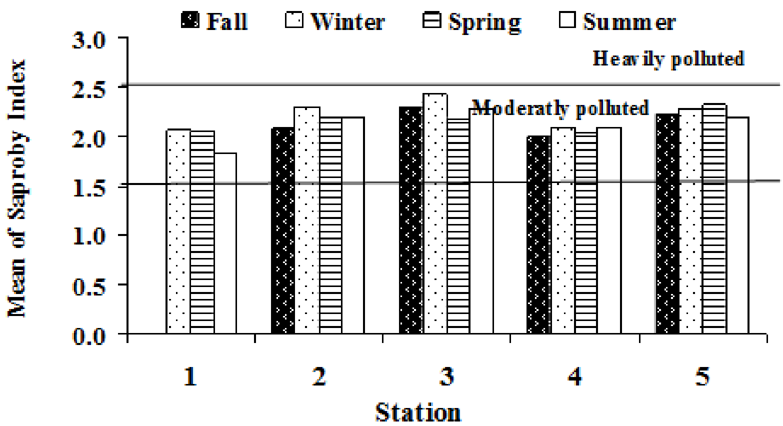


Figure 5: Seasonal Changes of Saproby index of phytoplanktoo in different station in the Sirvan River from fall 2020 to summer 2021.

Table 2: The dominant and similar of algal species in water and periphyton in different classes of organic pollution (based on the saproby index of species) in the Sirvan River from fall 2020 to summer 2021.

Very slightly polluted	**Moderatly polluted**				**Haively polluted**
Cocconeis placentula	*Cladotrix* sp.	*Nitzschia* sp.3	*Gomphonema curtum*	*Cymbella cymbiformis*	*Cyclotella meneghiniana*
	Botryococcus sp.	*Rhoicosphenia curvata*	*Melosira varians*	*Cymbella ventricosa*	*Navicula cryptocephala*
	Cladophora	*Synedra ulna*	*Navicula* sp.	*Diatoma vulgaris*	*Nitzschia palea*
	Oocystis parva	*Oscillatoria limosa*	*Nitzschia* sp.	*Fragilaria* sp.	*Lyngbya* sp.
		Oscillatoria sp.	*Nitzschia* sp.2	*Gomphonema acuminatum*	*Stigeoclonium amoenum*

Index of diatom taxa tolerant to organic pollution (% tolerant), The percentage of diatoms in (free of significant organic pollution), (some evidence of organic pollution), (likely to contribute significantly to eutrophication of site) and (site is heavily contaminated with organic pollution) classes were obtained (11), (32), (32) and (26) respectively in water samples. These parameters had values of (11), (22), (33) and (33) respectively in periphyton samples.

The seasonal similarity cluster analysis was done based on the results of the structural pattern (total, phyla and dominant species abundance) and biological indices (saprobe, Shannon, and Index of diatom taxa tolerant to organic pollution) of phytoplankton and algal periphyton (Fig. 6). The seasons were divided into two main groups (spring and summer) and (autumn and winter). The percent similarity of seasons in each of the groups in water samples was more than periphyton. The sampling stations were divided into 3 groups:(1), (2, 3) and (4, 5), based on the water samples. The test divided the stations, into 4 groups: (1), (2, 3), (5) and (4), based on the periphyton samples.

Trophic state: Calculation of diatom trophic index (TDI) based on diatom abundance in water and periphyton samples showed that the values were more than 3.5 in all cases (except station 2 in springs). This amount of TDI, classifies the samples in the (hypertrophic) group by loading of (very high) organic matter. In spring season, TDI of water sample was (2.3) at the station (2), which is groped in (meso-eutrophic condition) by critical loading of organic matter. The coefficent of the Pearson correlation was positive and direct (r=0.57) between Saproby and TDI indices.

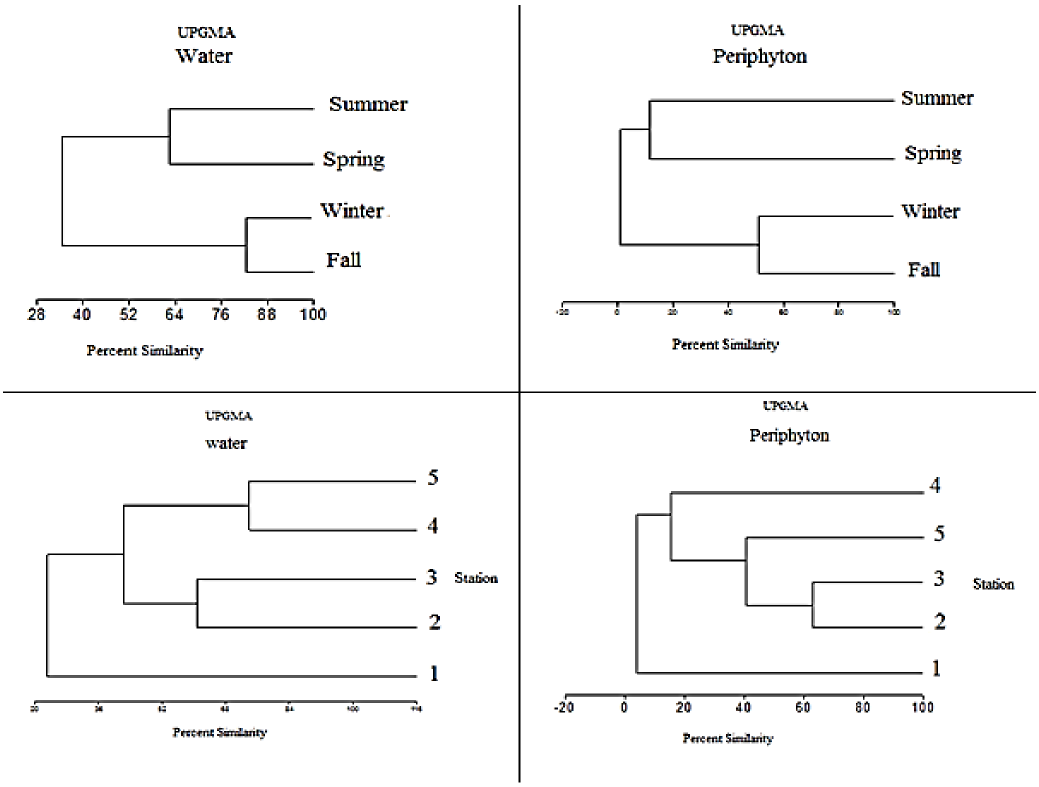


Figure 6: The cluster analysis based on percent similarity of abundance (total, phyla and dominant species abundance), and biological indices (Shannon % diatoms tolerant and saprobe) of phytoplankton and algal periphyton in the Sirvan River from fall 2020 to summer 2021.

Discussion

The values of rainfall decreased from autumn (November) to winter (March) and continued this decrease in the following seasons during the study period. By the dcreasing trend of rainfall, the mean of monthly rainfall was zero (mm) in sampling month (September) of summer. ANOVA test on the abundance of dominant species did not show any significant (except in a few cases) difference between the 4 seasons ($p>0.05$), while through grouping of parameters into two groups: (fall, winter) and (spring, summer), most of them were significantly different ($p<0.05$) in T-test. The dividing of seasons into two groups (rainfall and dry seasons) during the study period was determined by cluster analysis of biological parameters as well. Therefore, in this study, in several cases, expressing of the changes was more logic by grouping the seasons into two groups of rainy and dry seasons. The spatial clustering tanalysis based on the same parameters of phytoplankton and algal periphyton showed that stations 1 to 3 were divided into two groups (1), (2 and 3). In the cluster analysis, the situation of station (5) was different in phytoplankton and algal Periphyton samples. According to the clustering of the phytoplankton results, stations (5) and (4) were placed in one group, while in the algal periphyton cluster, station 5 and 4 were in separated groups. Therefore, based on the clustering test in algal periphyton, there is a long-term difference between stations 5 and 4, but based on the clustering test in water, there is a temporal and transitory influence of station 4 on the station 5. So, stations were mainly different from each other and stations did not have the same conditions except stations 2 and 3.

During the rainy seasons (autumn and winter), turbulence and soil washing caused by natural factor (rainfall) were increased the saprobic index values in downstream (stations 2, 3, and 5). The monthly rainfall in spring showed a 90-fold decrease compared to the previous 2 seasons (autumn and winter) and reached to 0.2 mm. Therefore, the rainfall and soil washing factors for transfer of polluted matter were not existingin in dry seasons (spring and summer). However, the highest phytoplankton saproby index obtained again in at stations 2, 3, 5. These increases were due to the increase in local pollution resulting from anthropogenic activities (sewage treatment palnt, poultry and livestock slaughterhouses and landfills) in dry seasons especially in summer season. It seems that, during the period study, the effects of antropogenic activities were more effective than than natural factors in water quality changes of the area. The simulated models study in the rivers of Qezl-Ozen (Shahroud) and Sefidroud (Gilan) showed that the phosphorus entering these rivers due to human activities is the most important cause of excessive growth of algae. If unnatural inputs of nutrients are controlled, natural factors (such as flow and air temperature) are only able to produce normal and general changes (Faqihi Rad *et al*., 2021).

Based on the phytoplankton saprobic index, the river was generally classified in "moderately polluted" during the study period. The negative effects of the discharge of several types of sewage into the tributaries of this river were reflected in the high saprobe index. The average saprobic index of dominant species in algal periphyton showed changes from 1.5 to 2.8 (moderately to heavily polluted). In algal periphyton, the average saprobic index of the dominant species in stations 2 and 3 was higher than stations 1 and 4 in the rainy season. It seems that the rainfall and soil washing showed more obvious role in the changes of organic pollution indicator algal species in periphyton compare to water. The high abundance of indicator species resistant to organic matter pollution in the wastewater discharge site indicates that these species are resistant to inorganic nutrients as well (Bellinger and Sigee, 2010). The increase in organic matter pollution in stations 2 and 3 can lead to an increase in the trophic state. In this study (especially based on the results of the saprobic index of dominant algal species in periphyton) it showed that not only stations 2 and 3 but also the other stations have constant pollution during the year and there is a suitable situation for the formation of eutrification.

The results obtained of the Palmer index showed that there was high organic pollution in most of the samples (especially based on the algal periphyton). The high distribution and abundance of indcators species of Palmer Index such as *Cyclotella meneghiniana*, *Navicula cryptocephala*, *Gomphonema olivaceum*, *Nitzschia tryblionella*, *Oscillatori*a, were recorded in the Sirvan River. These recording, indicate the diffusion of domestic and agricultural wastewater as well as from the wastewater treatment site to the river (Palmer, 1980; Ghernaout and Elboughdiri, 2020). Also Maleki *et al*. (2020) reported an increase in the Palmer index due to the continuous and abundant presence of *Oscillatoria*, *Navicula*, *Cyclotella*, *Ankistrodesmus*, *Euglena*, *Synedra* and *Nitzschia* in Gorgan Bay. They considered the increase in the abundance of algae with high Palmer index and critical condition of the water quality of the bay due to the mixing of water and nutrients loading after the rain and surface runoff towards the bay.

More than 60% of the obtained index of diatom taxa tolerant to organic pollution indicated to increase of organic matter, so that they could able to to contribute significantly to eutrophication of site. The Trophic Diatom Index (TDI) based on the abundance of diatoms in water and periphyton in the headwaters to reservoir of the dam were often more than 3.5. This amount of TDI indicates to the (hypertrophy) condition with a (very high) amount of nutrient load. If only the TDI from the upstream to the downstream stations is high, it can be relating to the entry of smaller wastewaters along the river. However, the increase of percent of tolerant diatom taxa (more than 60%) shows that the sewage treatment system and the self-purification of the river are insufficient to improve water quality and percent tolerant diatom taxa, from the sewage treatment stations (stations 2 and 3) into the station 5 in resevior (Kelly and Whitton, 1995).

The cluster analysis of station similarity based on the biological indices showed that station 5 in the dam area was more similar to station 4 in Gaveh- rood branch compared to other stations in Gheshlagh branch. Based on this, even if the efficiency of wastewater discharge stations in Gheshlagh branch is increased, it is also necessary to manage the discharge of wastewaters such as agricultural, in Gaveh-rood branch.

The results of Iran Water quality Index (IRWQI) and NSF, also showed that the water quality of Sirvan River were in the range of (relatively bad) to (very bad) in more than 80% of the samples collected (Nasrallehzadeh Saravi, 2022, unpublished). It means that the water quality in the lowest level of pollution and in the best condition was suitable for use in transportation (non-recreational) boats, but for use in public and drinking water, it was required to advanced treatment. In term of fisheries and aquaculture the water was suitable only for breeding tolorent species (critical for salmon and doubtful for sensitive fish) and even for use in industry and agriculture it was needed to pre-treatment (Shukohi *et al*., 2012). Therefore, with considering the results of IRWQI (Nasrallehzadeh Saravi, 2022, unpublished) and the biological results of the present study it is concluded that the water was mainly in moderate to severe organic pollution and probably leading to eutrification. To design and definition of using a water source is generally not done periodically and in short-term and basically it is necessary that the quality should be in standard range in all seasons (especially for drinking purposes and aquaculture). Therefore, it is emphasized again on the optimization of wastewater treatment plant, control of wastewaters inputs to the river and the modification and rehabilitation of the river, as prerequisites for any planning and defining type of water useage.

Conclusion

The increase in the pollution of organic and inorganic matter in water has provided suitable conditions for eutrophication in this basin. These conditions have significantly affected the abundance, presence and diversity of tolerantt species and increasing the probability of algal blooms. The occurrence of pollution and its increasing trend due to any reason in the ecosystem is requires to activities for improve and rehabilitation the river. Also, increasing the efficiency of the wastewater treatment plant and applying strict regulatory rules in the discharge of various wastewaters will reduce the critical conditions in water quality of the river.

Acknowledgments

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