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Daily Dynamics of Water Chemistry in a Lowland Polyhumic Dam Reservoir

E. Jekatierynczuk-Rudczyk, A. Górniak, P. Zieliński, J. Dziemian

Department of Hydrobiology, Institute of Biology, University of Białystok, ul. Świerkowa 20 B, 15-950 Białystok, Poland

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Abstract

The daily dynamics of water chemistry were investigated in the polymictic and polyhumic Siemianowka Dam Reservoir (SDR), in NE Poland. The highest concentration of ammonia, nitrate and orthophosphate ions during the day and the highest values of conductivity at night were recorded. A maximum of dissolved organic carbon was noted during afternoon hours while the content of aromatic DOM compounds was smaller during the day than at night. Significant differences in water chemistry were noted between the morning, afternoon and night hours, especially in the spring season, this being affected by the activity of phytoplankton in the water of the eutrophic reservoir.

Keywords: water quality, daily dynamics, dam reservoir

Introduction

The Siemianowka Reservoir is a strongly eutrophicated water body as shown by high concentrations of chlorophyll (100-200 μg/dm^3) and total phosphorus (max. 470 μg P/dm^3) during the summer season. High concentration of dissolved organic carbon (max. 62 mg/dm^3) and the resuspension of sediment, chiefly in the central part of the reservoir contribute to the high level of trophy in the reservoir. The high trophy favours the occurrence of water blooms, chiefly of blue-green algae of the genera *Aphanizomenon, Anabaena,* and *Microcystis* [1]. The aim of the investigation is to show the effect of the excessive development of algae on the daily dynamics in the quality of the surface water layer. In the methodical aspect of the investigation the discussion concerned the effect of the date of sampling on the concentration of selected parameters of waters in eutrophic water bodies.

Material and Methods

The Siemianowka reservoir lies in northeastern Poland in the Vistula River catchment, in the upper course of the Narew River, which supplies over 70% of water to the reservoir [2]. The catchment of the reservoir covers 1050 km^2 and is characterized by a large participation of marshy and forest areas, so that the feeding waters and the reservoir itself contain large quantities of organic and mineral products of organic matter decomposition [3, 4]. The reservoir is shallow, of a fairly large area as for the conditions of Poland, and accumulates almost 80 million m^3 water [2]. In the region of the reservoir the average annual discharge of the Narew River is almost 6 m^{3}s^{-1}, varying from 3 to 10 m^{3}s^{-1}.

Owing to the railway embankment crossing the reservoir, its upper part plays the function of an initial water body. The most variable area depending on the height of damming (Fig. 1) characterizes this part of the reservoir.

Correspondence to: Dr. E. Jekatierynczuk-Rudczyk; e-mail: rudczyk@uwb.edu.pl

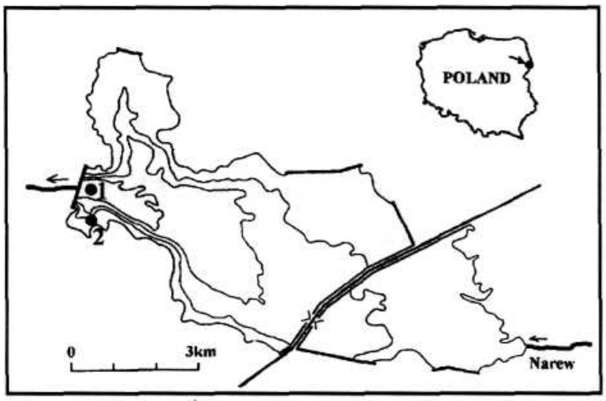

Fig. 1. The Siemianowka Dam Reservoir (SDR) and sampling site locations.

The average retention time of waters is fairly long, varying from four to six months, depending on the season of the year [2].

The Siemianowka dam reservoir has been functioning for 10 years, maintaining its eutrophic character, high colour of water, and the content of DOC and some nutrients since 1996. The chemical composition of water in the reservoir changes throughout the year on account of the thawing character of feeding rivers and the intensive biogeochemical transformations occurring in the vegetation season [3].

The selected physico-chemical parameters of the water were measured 5-times in the daily cycle (at 3-hour intervals, beginning at 12 noon). The investigation was conducted in July, August, September, and October 1997 and in May 1998. Water samples were taken from the

Table 1. Physico-chemical parameters in water of the SDR in 1997-1998.

Parametrs	Season	Average	Minimum	Maximum	Coefficient of variation [%]
Temperature °C	Spring	15.8	14.0	17.6	7.1
	Summer	24.3	21.6	28.2	8.4
	Autumn	12.4	8.3	16.8	**29.2**
TDS mg/dm3	Spring	289	274	303	2.4
	Summer	267	225	287	6.4
	Autumn	330	315	345	2.6
HCO_3 mg/dm^3	Spring	136	133	139	1.3
	Summer	157	148	183	4.9
	Autumn	180	171	185	1.6
Na mg/dm^3	Spring	3.97	3.06	4.52	8.6
	Summer	7.44	4.00	20.15	**55.9**
	Autumn	3.93	2.80	5.50	18.7
K mg/dm^3	Spring	1.13	1.03	1.43	9.9
	Summer	1.48	1.24	1.69	8.3
	Autumn	1.21	0.81	2.36	**23.3**
$N\text{-}NH_4$ µg/dm3	Spring	433	343	567	13.7
	Summer	116	77	179	20.8
	Autumn	225	52	501	**73.0**
$N\text{-}NO_3$ µg/dm	Spring	58	25	104	33.1
	Summer	127	85	207	25.2
	Autumn	301	154	545	**39.7**
$P\text{-}PO_4$ $\mu g/dm_3$	Spring	37	30	49	12.2
	Summer	59	7	170	**90.7**
	Autumn	45	29	71	26.8
TP $\mu g/dm^3$	Spring	152	81	236	29.1
	Summer	172	17	705	**74.0**
	Autumn	213	47	951	**81.6**
DOC mg/dm^3	Spring	19.1	15.2	24.0	10.0
	Summer	16.2	9.9	23.9	**32.7**
	Autumn	23.0	19.4	27.4	10.6
SUVA Abs_{260}/mgC	Spring	23.6	18.5	30.7	10.8
	Summer	30.4	19.5	42.8	28.5
	Autumn	24.7	20.9	29.6	11.1

Table 2. Correlation coefficient of physico-chemical parameters observed in daily cycle in Siemianowka Dam Reservoir water (samples size = 80; 0.87 - correlation coefficient; *0.05* - probability level).

	T	TDS	HCO_3	Na	K	N-NH_4	N-NO_3	P-PO_4	DOC	SUVA
T	1.00 *0.00*									
TDS	**– 0.87** *0.00*	1.00 *0.00*								
HCO_3	– 0.39 *0.00*	**0.61** *0.00*	1.00 *0.00*							
Na	0.41 *0.00*	– 0.22 *0.05*	– 0.21 *0.05*	1.00 *0.00*						
K	**0.57** *0.00*	– 0.38 *0.00*	– 0.01 *0.96*	**0.53** *0.00*	1.00 *0.00*					
N-NH_4	**– 0.61** *0.00*	0.25 *0.03*	– 0.31 *0.01*	– 0.32 *0.00*	**– 0.55** *0.00*	1.00 *0.00*				
N-NO_3	– 0.66 *0.00*	**0.66** *0.00*	**0.74** *0.00*	– 0.25 *0.03*	– 0.31 *0.01*	0.19 *0.09*	1.00 *0.00*			
P-PO_4	0.12 *0.28*	0.11 *0.34*	– 0.09 *0.43*	**0.57** *0.00*	0.20 *0.08*	– 0.19 *0.09*	– 0.03 *0.78*	1.00 *0.00*		
DOC	**– 0.58** *0.00*	**0.76** *0.00*	0.31 *0.01*	0.13 *0.26*	– 0.19 *0.09*	0.11 *0.33*	0.35 *0.00*	0.44 *0.00*	1.00 *0.00*	
SUVA	**0.49** *0.00*	**– 0.56** *0.00*	0.06 *0.57*	– 0.27 *0.02*	0.19 *0.10*	– 0.33 *0.00*	– 0.13 *0.25*	**– 0.54** *0.00*	**– 0.89** *0.00*	1.00 *0.00*

surface layer (0.5 m) at two stations: a pelagial and a littoral one (Fig. 1). In the outdoor study the temperature and electrolytic conductivity of the water were measured using a Checkmate apparatus, and calculated per total amount of dissolved mineral compounds (TDS). In the sampled water the concentration of HCO_3 was measured using the titration method; the content of ammonia and nitrate nitrogen using the spectrophotometric method; orthophosphates and total phosphorus using the molibdate method (TP after UV mineralization); dissolved organic carbon (DOC) using a TOC 5050A Shimadzu analyser; and sodium and potassium using flame photometry. The absorbency in 1-cm water layer of natural reaction was determined at 260 and 330 nm wavelength. On the basis of the obtained results the SUVA index determining the quality of dissolved organic matter was calculated (Specific UV Absorbency) as SUVA = A_{260} x 1000 / DOC [5].

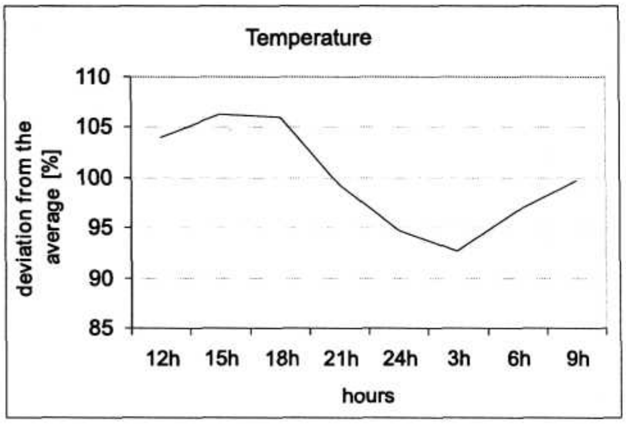

Fig. 2a. Daily dynamic of water temperature in the Siemianowka Dam Reservoir.

Results and Discussion

In the investigated physico-chemical traits of the water no statistically significant differences (the rank test) were determined in the concentrations and in daily changes between the pelagial and littoral stations. Significant differences in the daily cycle, however, were found between the investigated parameters throughout the seasons of the year. The greatest variation was characteristic of nitrogen and phosphorus compounds, a slightly smaller one for water temperature and DOC, and the smallest of TDS and bicarbonates (Table 1). In spring the investigated parameters change to a fairly small degree. In summer TDS, bicarbonate, sodium, orthophosphate ions, DOC, and the SUVA parameter manifested the greatest daily dynamics. In autumn the temperature of water, mineral nitrogen compounds, potassium ions, and the concentration of total phosphorus distinctly changed in the daily cycle (Table 1).

In the investigated parameters of the water the direction of changes and their intensity were varied. The daily changes in water temperature were associated with the

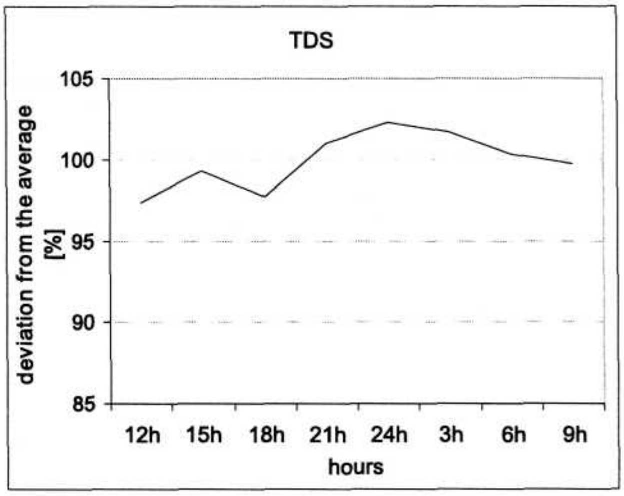

Fig. 2b. Daily dynamic of total dissolved substances ions in SDR water.

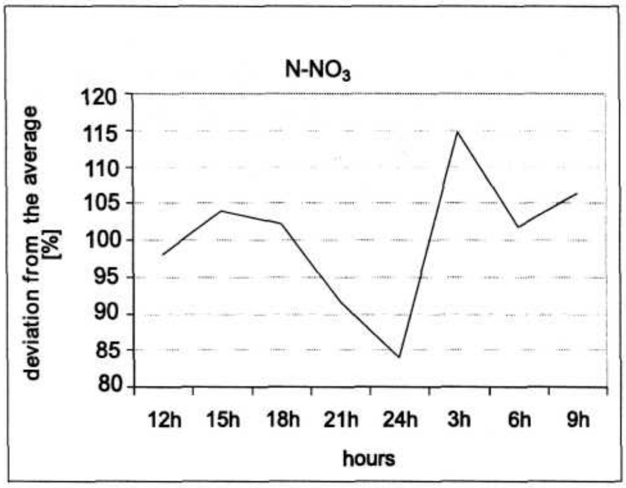

Fig. 2e. Daily dynamic of nitrate ions in SDR water.

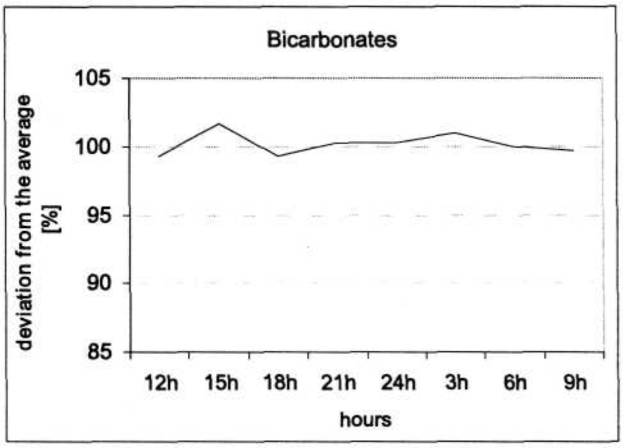

Fig. 2c. Daily dynamic of bicarbonate ions in SDR water.

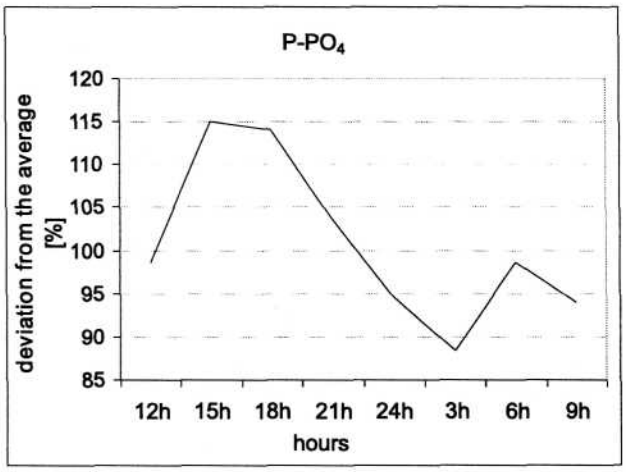

Fig. 2f. Daily dynamic of othophosphate ions in SDR water.

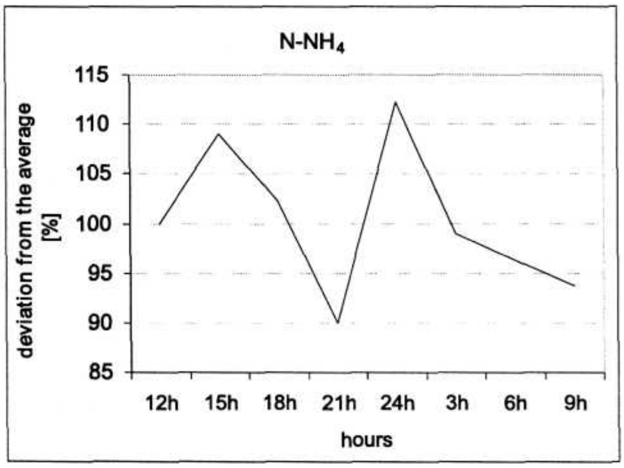

Fig. 2d. Daily dynamic of the ammonia ions in SDR water.

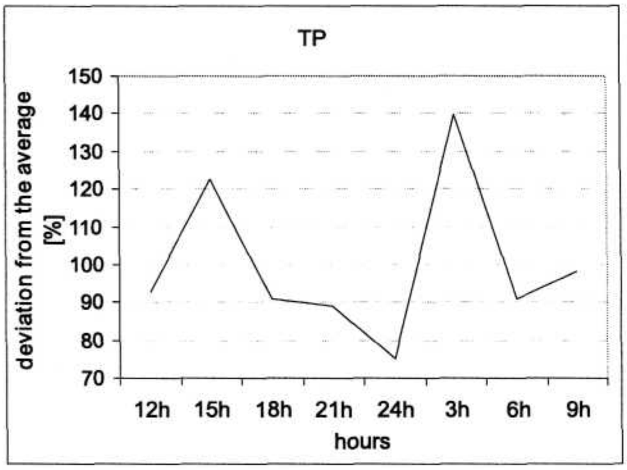

Fig. 2g. Daily dynamic of total phosphorus in SDR water.

temperature of air (Fig. 2a) and the range of variation chiefly depended upon the length of day. Changes in water temperature in the 24-hour cycle were closely connected with the concentration of most investigated parameters in the surface water layer (Table 2). With the decreasing water temperature the concentration of TDS, mineral forms of nitrogen and DOC decreased while the concentration of potassium and the SUVA parameter significantly increased.

TDS concentration at night exceeded those during the day (Fig. 2b), this being associated with the uptake of mineral substances by autotrophic organisms during the day. The greatest daily changes in TDS occurred in summer accompanied by the highest concentration of chlorophyll (Table 1). The highest concentration of bicarbonates in water is usually recorded at night [6]. This dependence was also observed in the present study (Fig. 2c) due to the intensive respiration processes of autotrophic organisms at night, particularly in the summer season (Table 1).

Sodium and potassium are indispensable for the functioning of organisms; however, their quantities in water usually exceed the requirements of these organisms. The above elements are taken up and excreted in almost equal quantities at the same time, e.g. instead of the hydrogen ion [7]. Therefore sodium almost always shows significant positive correlation coefficients in relation to potassium (Table 2). The significant positive relation of potassium and water temperature shows that in the daytime autotrophs assimilate protons necessary for the photosynthetic process from the water and release (among other forms) potassium cations to the water to maintain the ionic balance. A similar tendency was also observed with respect to sodium concentrations (Table 1). In summer 1997 massive kills of perch fry occurred, most probably affecting the daily dynamics in sodium and potassium content in the water to a great degree (Table 1).

The water temperature decisively affects the intensity of changes of nitrogen compounds in the water of the reservoir, particularly the nitrification process involving ammonia ions. The effect was very distinct in summer (Table 1) when the greatest concentrations of NH_4 were noted at midnight. NO_3 ions produced in the nitrification process can be liable to denitrification or can be utilized by phytoplankton. In the present study no distinct changes in mineral nitrogen were observed in the daily cycle, probably owing to the occurrence of intensive chemical processes and the biological utilization of nitrogen at the same time (Fig. 2d,e).

In general, phosphorus compounds are regarded as the most important parameter affecting the trophic condition of water bodies [8]. Orthophosphates and total phosphorus were among the most variable water parameters in the investigated dam reservoir, particularly in summer and autumn (Table 1). In all the investigated

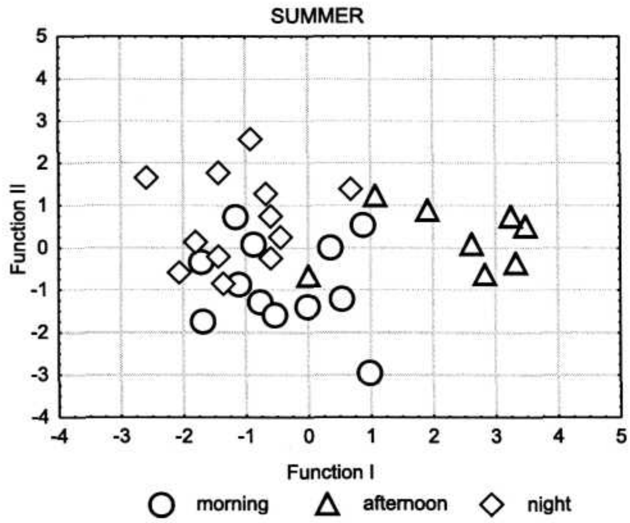

Fig. 3b Discriminant analysis of physico-chemical parameters in water Siemianowka dam reservoir - summer.

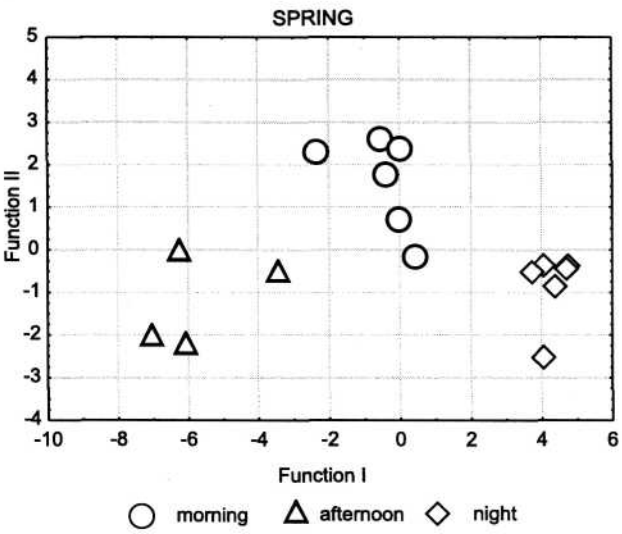

Fig. 3a Discriminant analysis of physico-chemical parametrs in water Siemianowka dam reservoir - spring.

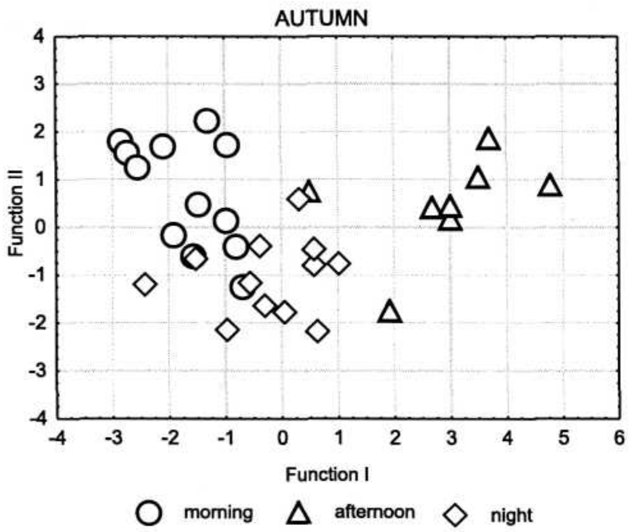

Fig. 3c Discriminant analysis of the physico-chemical parameters in water Siemianowka dam reservoir - autumn.

seasons greater PO4 concentrations were recorded in water at daytime than at night (Fig. 2f), which contradicts generally accepted opinions [9]. In the investigated eutrophic reservoir characterized by high DOC concentrations the release of phosphorus compounds from mineral-organic complexes is easily effected by UV irradiation during the day [10, 11]. This is the main factor of the constant humoeutrophication of waters. A reverse direction of changes, though less distinct than that concerning PO_4 ions, was observed in the case of total phosphorus (Fig. 2g). This should be associated with the varied position of blue-green alga cells throughout the 24-hour cycle [12].

In summer the intensified UV irradiation and the highest activity of micro-organisms in the annual cycle reduce the concentrations and bring about qualitative changes in DOC. Hence in temperate climatic zones the greatest variability of DOC in water is found in summer (Table 1). A reverse tendency of changes characterized the SUVA parameter whose values were lower during the day than at night. The utilization of aliphatic DOC chains effected by UV irradiation was fairly rapid while that of the aromatic ones was slower, hence the aromaticity of DOC at the daytime exceeded that at night as shown by the significant negative correlation coefficient for DOC and SUVA (Table 2).

The results of discriminant analysis show that in the hydrochemical aspect a distinct tripartite division of the 24-hour cycle occurs in the investigated reservoir in spring (Fig. 3a). In this season of the year the forenoon (6-12), afternoon (15-18) and night (21-3) time significantly differ with respect to the chemical composition of the water. In summer the differences were less distinct (Fig. 3b) and it was only the afternoon that differed from the remaining parts of the day. In autumn the hydrochemical differentiation of the parts of the day was slightly more distinct, although it was less pronounced than in spring (Fig. 3c).

Conclusions

1. Daily dynamics of most physico - chemical parameters of waters in the eutrophic reservoir was similar in pelagial and littoral stations.

2. The concentrations of orthophosphates, ammonia and nitrate nitrogen were higher during the day than at night.

3. Blue-green algae dominated phytoplankton activity and the effect of UV radiation on the concentration and quality of DOC.

4. Statistically significant differences were determined between the morning, afternoon and night concentrations of nutrients, especially in spring.

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