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CHANGES IN BIOLOGICAL AND PHYSICOCHEMICAL PARAMETERS OF RIVER WATER IN A SMALL HYDROPOWER RESERVOIR CASCADE

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Abstract

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The impact of single small hydropower plants on the environment is thought to be negligible. Their effect progressively increases with the cascade development of the river basins, thus the cumulative environmental effects of small hydropower reservoirs can have a significant impact on the ecological state of the rivers. We have studied the effect of two small hydropower reservoirs on some parameters of river water quality. The Lakatnik Reservoir and the Svrazhen Reservoir are situated in the middle reaches of the Iskar River, directly one after another. The river water is rich in nutrients and organic substances and carries high amounts of suspended sediments. As it flows through the cascade, the river temperature increases, while oxygen concentration, electrical conductivity and suspended sediments decrease, mostly due to the enhanced degradation and transformation of the organic substances in the water. The amount of the phytoplankton depends on the residence time and the amount of the abioseston in the river water. Despite their recent construction, the reservoirs support rich assembly of macrophytes, mostly indicators of eutrophic conditions. The observed changes in biological and physicochemical parameters of the river water are a direct result of increased retention of water in the reservoirs. The study shows the potential of small hydropower cascades to influence the river water quality.

Key words: chlorophyll-a, SHPP, macrophytes, reservoir cascade, water quality, run-of-the-river reservoirs
Abbreviations: Chl-a – chlorophyll-a; SD – Secchi disc depth; TP – total phosphorus; TSI(Chl) – trophic state index derived according to the Chl-a values; TSI(SD) – trophic state index derived according to the SD values; TSI(TP) – trophic state index derived according to the TP values; AvrgTSI – average value of the individual trophic state indices; Q – river discharge

Introduction

At present, the major modifications of the rivers are through the construction of artificial aquatic systems and the development of water storage and flow regulation structures (Schulze, 2003). Thus, in many rivers, the system components are now more controlled by anthropogenic forcing than by natural drivers (Turner et al., 1990; Messerli et al., 2000).

Most human activities result in a modification of riverine concentrations of organic and inorganic material loads from the watershed. One of the most common and earliest uses of waters is still the dilution and downstream transfer of wastes. Although riverine loads of nutrients and pollutants are generally increasing along its course, they can also decrease if the retention and the transformation processes exceed the additional sources of material (Meybeck, 2002; Meybeck, 2003). Even the construction of small hydropower reservoirs creates an efficient cascade of sediment traps (Meade and Parker, 1985) and fragments the river courses, thus modifying the aquatic ecosystem. The accumulated sediments are returned back into the river only oc-

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casionally at peak water discharges by sluicing of the reservoirs for downstream sediment transport.

The aim of the study is to assess the cumulative impact of two small hydropower reservoirs in the middle reaches of Iskar River. The reservoirs are the first in operation from a cascade of nine small hydropower plant (SHPP) reservoirs along a 33-km course of the river. The river stretch is intensively studied and data about microbiological aspects of self-purification and dynamics of the physicochemical parameters can be found in Lincheva et al. (2010) and Todorova and Topalova (2010).

Materials and Methods

The data is collected from the deepest point (at ≈ 25 m from the dam) in each reservoir. A total of 10 sampling events were conducted in Lakatnik reservoir (run-of-the-river, mean depth 2.7 m, area 11.1 ha), and 9 in Svrazhen reservoir (run-of-the-river, mean depth 3.1 m, area 22.57 ha). The samples were collected two to three times per year, between June and September. On site measurements of water transparency (Secchi disc visability), dissolved oxygen (WTW 3310), electrical conductivity and pH (HI 98129) were conducted. Chemical analysis of water samples included total phosphorus and total nitrogen concentrations (colorimetrically after CracTest digestion in autoclave, MERCK – PMB methods 14848 and 14773, correspondingly), chlorophyll-a (acid corrected, ISO 10260) and total alkalinity (ISO 9963-1. 2000). The concentrations of ammonium, nitrate and nitrite nitrogen are determined according to MERCK – PMB methods 14752, 14773 and 14776, correspondingly. The Carlson's trophic state indices were used to assess the trophic conditions in the reservoir (Carlson, 1977; Carlson and Simpson, 1996). Descriptive statistics were conducted for the studied environmental variables. The relationships between the variables were assessed by means of Spearman rank correlation. All analyses were performed using Statistica 6.0 software.

Results and Discussion

We present data on selected physical and chemical variables in the reservoirs from their construction up to the present moment (Table 1). The retention time strongly influences the values of the electrical conductivity, nutrient concentrations and alkalinity due to the increased share of effluents, both treated and untreated, in the period of low water discharge.

The Lakatnik reservoir acts as sediment trap, reducing the amount of TP in Svrazhen reservoir on average by ≈ 32% and the concentration of PO_4-P by ≈ 20%. This also determines the observed increase of the water transparency on average by 17%. Respectively, this leads to improved light conditions, and together with the increased RT in Svazhen reservoir, determine the increased amount of Chl-a (by ≈ 24%), correspondingly the amount of the phytoplankton.

The differences of the main physicochemical parameters between the two reservoirs are small resulting in relatively

Table 1

Mean values, standard deviation (St.Dev.), coefficient of variation (CV%) and corresponding number of observations (n) of the physicochemical parameters in the reservoirs

	Lakatnik reservoir				Svrazhen reservoir			
	Mean	St. Dev.	CV%	n	Mean	St. Dev.	CV%	n
Q m^3/s	15.5	5.0	32.3	10	15.87	5.2	32.8	9
RT d	0.24	0.07	28.5	10	0.56	0.17	30.3	9
T^{o}C	19.9	1.9	9.6	10	21.0	2.4	11.7	9
DO %	86.9	6.6	7.6	10	83.4	12.5	15.0	9
DO mg/l	7.6	0.6	7.4	10	7.2	1.3	17.6	9
SD m^{-1}	0.82	0.30	37.17	10	0.96	0.29	30.3	9
pH	7.75	0.29	3.7	10	7.73	0.43	5.5	9
EC µS/cm	435.3	49.5	11.4	9	424.1	47.9	11.3	9
Chl-a µg/l	8.78	3.53	40.1	10	10.88	5.85	53.8	8
TPmg/l	0.79	0.64	80.78	8	0.53	0.24	44.2	6
PO_4-P mg/l	0.61	0.34	55.8	9	0.50	0.29	57.2	7
NO_3-N mg/l	3.48	1.1	31.2	9	3.5	1.0	29.0	7
NH_4-N mg/l	0.5	0.5	95.9	8	0.56	0.29	52.0	6
TNmg/l	5.14	1.71	33.3	5	5.06	1.68	33.2	5

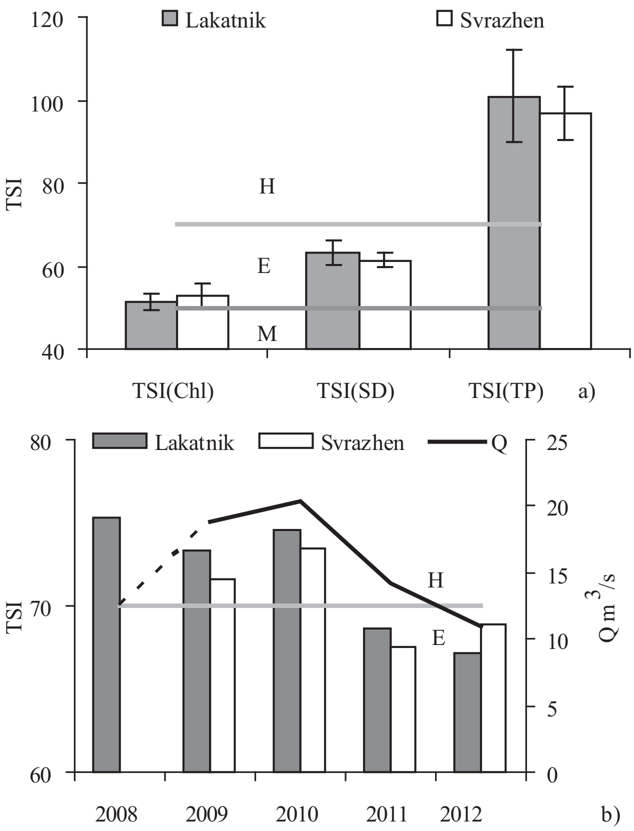

Fig. 1. Mean values of: a) – Chlorophyll-a, Secchi disc depth and Total phosphorus trophic state indices (TSI(Chl); TSI(SD) and TSI(TP), correspondingly); b) – AvrgTSI values from 2008 to 2012 in Lakatnik and Svrazhen reservoirs and river discharge (Q). Vertical bars represent ± one standard deviation. Horizontal lines denote the boundaries between the major trophic classes: H – hypereutrophic; E – Eutrophic and M – Mesotrophic

equal annual mean values of the trophic state indices (TSI). The overall trophic state of the reservoirs is eutrophic, with stronger fluctuations of TSI(SD) and TSI(TP) values in Lakatnik reservoir and of TSI(Chl-a) in Svrazhen reservoir (Figure 1a). Since 2008/ 2009, the reservoirs have shown slight tendency toward reduction of the averaged TSI values (AvrgTSI), mostly due to the reduced amount of TP. Although, the differences are not significant, they indicate a shift from hypereutrophic toward eutrophic conditions in the reservoirs. The observed shift in the trophic state is due to the reduced river outflow, as a very good correlation exists between the AvrgTSI and Q. The relation is broken in 2008 as only a single observation is available.

Table 2

Composition of the aquatic macrophytes in Lakatnik and Svrazhen reserevoirs and the years of first observation

Aquatic macrophytes	Lakatnik	Svrazhen
Ceratophyllum demersum L.	2009	2010
Elodea canadensis Michx.	2009	2010
Elodea nuttallii (Planch.) H.St.John	2009	2010
Lemna gibba L.	2011	2011
Potamogeton crispus L.	2009	2010
Potamogeton nodosus Poir.	2010	2010
Potamogeton pusillus L.	2009	
Potamogeton pectinatus L.	2009	2011
Typha latifolia L.	2010	2011
Myriophilum spicatum L.	2011	2011
Myriophilum verticilatum L.	2011	2011
Sagittaria sagittifolia L.	2010	

The results show the potential of a cascade of small hydropower reservoirs to influence the water quality. The increased water retention time in the future cascade will have the same effect as the observed reduction in AvrgTSI values under low river discharge in recent years. Thus, the construction of the remaining 7 reservoirs from the cascade has the potential to further modify the longitudinal gradients of the physicochemical parameters along the river, especially, during the summer periods.

The first observation of the aquatic plants composition in the reservoirs was done in 2010. We found eight species (Table 2), three of which (*Ceratophyllum demersum; Elodea canadensis* and *Potamogeton pusillus* were described as new species for the floristic region of Western Stara Planina Mts (Tosheva and Traykov, 2010). In the following years the list of the macrophytes in the reservoirs was expanded by another four species and *Lemna gibba, Myriophilum spicatum* and *Myriophilum verticillatum* were also added to the list of the new species for the region (Tosheva and Traykov, 2012).

Most of the species (*Ceratophyllum demersum, Elodea canadensis, E. nuttallii, Lemna gibba, Potamogeton crispus, Potamogeton pusillus, Sagittaria sagittifolia*) are typical indicators of eutrophic conditions, while the others are indifferent to the trophic state of the water bodies (Schaumburg et al. 2007).

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