

WATER QUALITY ALONG THE MIDDLE STRETCH OF THE RIVER SVRATKA AND ITS TRIBUTARIES

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Abstract

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Water quality in river depends on water quality of its tributaries. During the year 2011 nine selected sites downstream under the Vír dam (from 108 to 79 river km) were monitored. For observation were chosen tributaries Besének, Loučka, Nedvědička, Chlebský creek, Hodonínka, Vrtěžířský creek and Tresný creek. At the same time samples from the places above and under the whole monitored section of the river were taken. Basic physicochemical parameters were monitored monthly during the vegetation period. Flow velocity and discharge were assessed three times. Based on the water quality evaluation of, the river Svratka and its tributaries Hodonínka, Vrtěžířský creek and Tresný creek belong to the second quality class, tributaries Besének, Loučka, Nedvědička and Chlebský belong to the third quality class. In the monitored section the retention of phosphorus in annual amount about 2.2 tons were occurrence. Annual volume of phosphorus at the end of observed section (upstream the Tišnov town) was nearly 17.5 tons. Annual total balance of nitrogen at the end of monitored section was 700 tons per year and 6000 tons of carbon per year. The major source of these nutrients is the river Loučka.

physicochemical parameters, rivers, phosphorus

Streams and rivers are often the first principal recipients of many anthropogenic influences (Petts and Calow, 1996). Organic enrichment and eutrophication of aquatic ecosystems induced by urbanization and agricultural activities are the oldest and the most completely documented forms of pollution. The organic enrichment of rivers is comprised of two aspects: trophy and saprobity. Whereas trophy is the extent of intensity of organic primary production, saprobity is characterized by the communities of organisms reflecting the extent and intensity of organic matter decomposition. In practice, these two factors are difficult to be separated (Brabec *et al.*, 2004). The characterization of river conditions requires the assessment of physical and chemical characteristics.

Water pollution of the river Svratka was already solved in study of professor Roček already in 1931. He emphasized the need of the river protection against overloads of pollution (Roček, 1931). Since 1958, there is the Vír dam in the middle stretch of

the river Svratka. River section under the Vír dam creates suitable conditions for trout, which is very valuable for fresh water fisheries and management. The aim of this study is to evaluate the water quality of Svratka River and its selected tributaries between Vír dam and Tišnov town.

MATERIALS AND METHODS

Characteristics of the observation site

River Svratka is a left-hand tributary of the river Dyje. It springs in Žďárské vrchy and flows across the Nedvědice highland to the Tišnov basin and then flows southward to reach the body of the river Dyje in Dyjsko-svratecký hollow. Confluence is situated near the parish village Mušov, nowadays flooded under the surface of Nové Mlýny reservoir. The average flow rate in the river mouth is $27.24 \text{ m}^3 \cdot \text{s}^{-1}$. Overall length is 173.9 kilometers and river basin has 7118.7 km^2 (Vlček, 1984).



1: Map of the Svatka basin with the study sites indicated. (Explanation of abbreviations is in text).

During the year 2011 were nine selected sites downstream under the Vír dam were monitored. There were chosen tributaries left-hand Besének (BES), right-hand Loučka (LOU) both at 79.4 river kilometer, right-hand Nedvědička (NED) at 95.5 river km, left-hand Chlebský creek (CHLE) at 96.7 river km, left-hand Hodonínka (HOD) and right-hand Vrtěžský creek (VRT) at 102.7 river km and Tresný creek (TRE) at 108.0 river km (Map 1). All of those significant tributaries were selected as probable majority sources of an organic matter inflowing into the monitored section of the river. For a comparison, samples from the river Svatka in two sites were taken. The first was 10 meters above the Tresný creek, generally above the whole monitored section (Sup) and the second is about 100 meters under the Besének, generally under the whole monitored section (Sdown). Sampling was carried out monthly from March to October 2011 ($N = 8$).

Chemical methods

Directly in the terrain basic chemical and physical parameters of water were measured. For this purpose were used portable automatic devices. Temperature, oxygen and pH were measured by Hach HQ40d (Hach-Lange, Colorado, USA) with pH probe Intellical PHC101 and oxygen probe Intellical

LDO. Conductivity was measured by device Hanna Combo HI 98129 (Hanna instruments, USA) with automatic temperature correction on 25 °C. The flow velocities were measured three times a year (March, July, October) using acoustic current digital meter by OTT (Kempten, Germany) and the discharge was calculated according EN ISO 748. In the remaining months (dates) the discharge was estimated by using a reference profile of Czech Hydrometeorology Institute (measured continuously), since a strong correlation between monitored and reference profile was observed. The curve of the each case fitting between monitored and reference profile was performed and the best regression model was chosen according to Akaike information criteria and to mean error of prediction (Meloun and Militký, 2011). Water samples were drawn from the depth about 10cm into the plastic (PE) bottles. Samples from tributaries were taken from their mouths. Samples from river below the whole monitored section were taken from a place where the water from river and tributary were already mixed. All samples were analyzed in the day of sampling. Ammonium ions ($N-NH_4$) were determined using the indophenols method, nitrite nitrogen ($N-NO_2$) by a method using N-(1-naphthyl)-ethylenediamine and nitrate nitrogen ($N-NO_3$) by a method using

sodium salicylate. Total nitrogen (N_T) was measured by dimethylphenol after the transformation of all nitrogen compounds into nitrate by Koroleff's method. Total phosphorus (P_T) and orthophosphate ($P-PO_4$) were measured by using an ascorbic acid and ammonium molybdenate. The acid neutralization capacity (ANC) was measured by a method using hydrochloric acid. Chemical oxygen demand (COD_{Cr}) was measured by a method using potassium dichromate. Total organic carbon (TOC) was determined by digestion with sulphuric acid and peroxodisulphate and transformation into carbon dioxide. All of chemical parameters were assessed by the standards methods (APHA, 1998). Values of total inorganic carbon (TIC) were determined by arithmetic operation at utilization values of water temperature, alkalinity and pH (Žalud, 2008). Total carbon is expressed in Figure 3 as a sum of TOC and TIC values. Annual volume of basic nutrients is given by arithmetic relation of concentration and discharge.

RESULTS

Tab. I and II shows the average and standard deviations of each month measurements of the physical and chemical characteristics at the sites. By the standards for surface water quality (ČSN 757221) tributaries BES, LOU, NED and CHLE match in the

third class and tributaries HOD, VRT and TRE match in the second class of water quality. The Svratka at localities Sup and Sdown meets the second class of water quality.

Fig. 2 shows the cumulative total amount of the basic nutrients in the monitored section of the river Svratka. Retention of phosphorus on this section was about 2.2 tons per year, which means 11% in total content of phosphorus. A annual value of total phosphorus at the end of the monitored section (above the Tišnov city) is nearly 17,5 tons per year. On the other hand the amount of total nitrogen and total carbon increased and the retention was minimal. Total amount at the end of the monitored section was 700 tons of nitrogen per year and 6000 tons of carbon per year. The major source of basic nutrients is river Loučka, which brings 46% of phosphorus, 28% of nitrogen and 32% of carbon of the total volume.

DISCUSSION

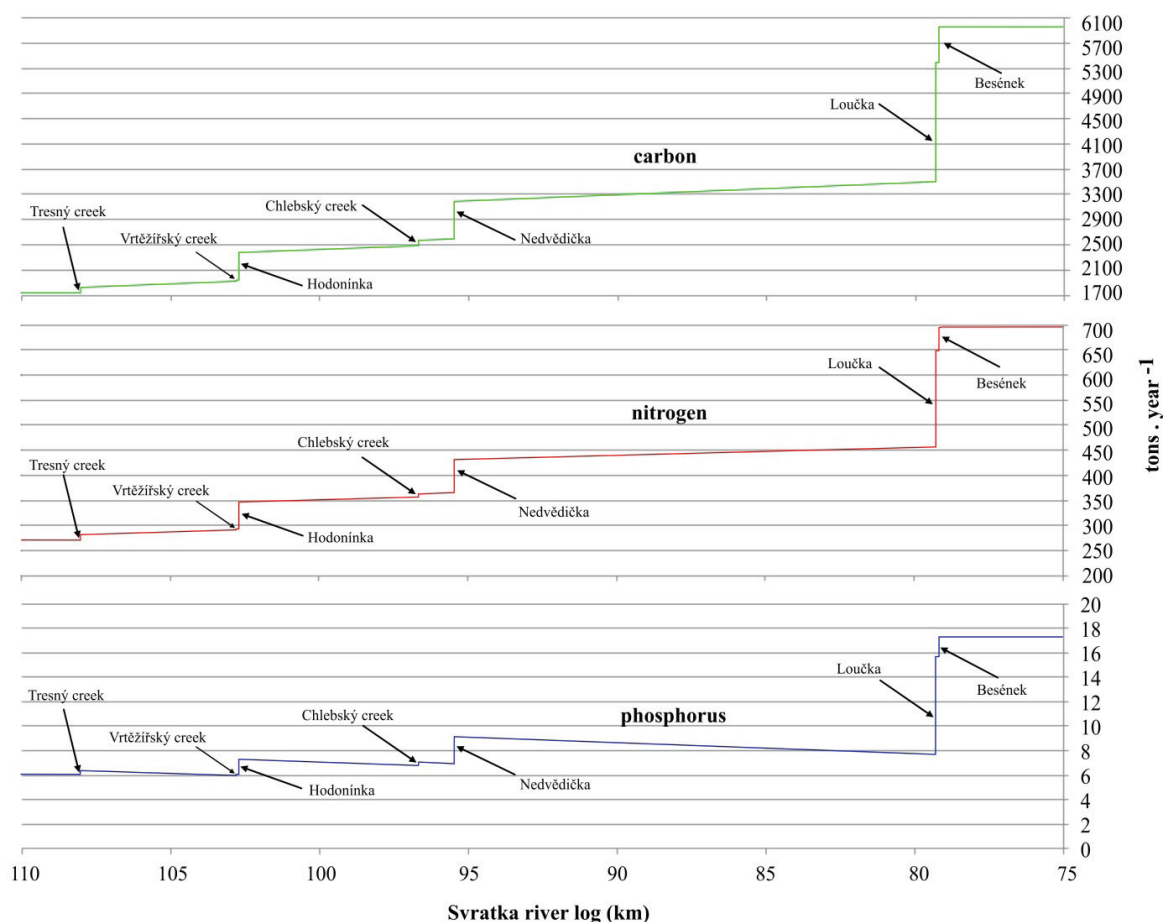
The very first presented data about chemism of the river Svratka comes from years 1929–1931 which is before the water dams on the river were built (Roček, 1931). Besides the chemism of river Svratka, there were observed chemism of its main tributaries (Nedvědička, Loučka, Besének). The most polluted water with higher content of dissolved substances

I: Physical characteristics (mean \pm SD) of the sites in the Svratka River and the tributaries from March to October ($N = 8$)

Locality	Temperature ($^{\circ}\text{C}$)	pH	O_2 saturation (%)	Conductivity ($\text{mS}\cdot\text{m}^{-1}$)	Average discharge ($\text{m}^3\cdot\text{s}^{-1}$)
Sup	7.8 ± 2.9	8.13 ± 0.34	98.5 ± 1.7	17 ± 1	2.40 ± 0.29
TRE	9.2 ± 4.0	8.30 ± 0.18	98.2 ± 5.3	54 ± 8	0.07 ± 0.04
VRT	11.3 ± 5.6	8.90 ± 0.58	102.3 ± 7.7	30 ± 3	0.02 ± 0.01
HOD	11.0 ± 5.2	8.65 ± 0.28	103.8 ± 7.0	48 ± 8	0.36 ± 0.27
CHLE	9.7 ± 4.8	8.24 ± 0.23	95.8 ± 4.5	27 ± 4	0.07 ± 0.06
NED	10.8 ± 5.0	8.45 ± 0.30	105.0 ± 7.3	57 ± 12	0.47 ± 0.21
LOU	10.7 ± 5.4	8.28 ± 0.35	103.7 ± 10.8	36 ± 4	1.58 ± 1.15
BES	9.7 ± 4.7	8.18 ± 0.26	95.3 ± 4.3	50 ± 6	0.32 ± 0.30
Sdown	9.5 ± 4.1	8.11 ± 0.18	95.0 ± 5.7	31 ± 2	5.65 ± 2.56

II: Chemical characteristics (mean \pm SD) of the sites in the Svratka River and the tributaries monthly from March to October. (Explanation of abbreviations is in text), $N = 7$

Locality	N_T ($\text{mg}\cdot\text{l}^{-1}$)	P_T ($\text{mg}\cdot\text{l}^{-1}$)	COD_{Cr} ($\text{mg}\cdot\text{l}^{-1}$)	$N-NH_4$ ($\text{mg}\cdot\text{l}^{-1}$)	$N-NO_2$ ($\text{mg}\cdot\text{l}^{-1}$)	$N-NO_3$ ($\text{mg}\cdot\text{l}^{-1}$)	$P-PO_4$ ($\text{mg}\cdot\text{l}^{-1}$)	ANC ($\text{mmol}\cdot\text{l}^{-1}$)
Sup	3.7 ± 1.0	0.08 ± 0.01	14.6 ± 2.3	0.00 ± 0.00	0.007 ± 0.004	3.04 ± 1.48	0.069 ± 0.054	0.67 ± 0.05
TRE	5.7 ± 1.4	0.08 ± 0.02	7.5 ± 0.8	0.01 ± 0.02	0.036 ± 0.074	4.77 ± 2.20	0.062 ± 0.036	2.50 ± 0.60
VRT	4.7 ± 0.7	0.08 ± 0.03	11.6 ± 2.4	0.04 ± 0.05	0.011 ± 0.010	3.58 ± 1.30	0.062 ± 0.039	1.54 ± 0.57
HOD	6.2 ± 1.4	0.13 ± 0.05	13.5 ± 3.0	0.01 ± 0.03	0.030 ± 0.021	5.42 ± 2.17	0.084 ± 0.048	2.18 ± 0.55
CHLE	3.2 ± 0.8	0.16 ± 0.04	12.6 ± 3.4	0.00 ± 0.01	0.009 ± 0.009	2.62 ± 1.09	0.120 ± 0.053	1.80 ± 0.70
NED	4.7 ± 1.7	0.15 ± 0.06	15.3 ± 2.8	0.01 ± 0.09	0.021 ± 0.020	3.62 ± 2.06	0.119 ± 0.057	1.72 ± 0.10
LOU	4.5 ± 1.9	0.18 ± 0.08	19.2 ± 2.0	0.01 ± 0.01	0.032 ± 0.028	3.69 ± 1.93	0.126 ± 0.066	1.82 ± 0.31
BES	5.7 ± 1.3	0.19 ± 0.05	11.5 ± 1.7	0.02 ± 0.03	0.024 ± 0.016	4.78 ± 2.09	0.154 ± 0.058	3.23 ± 0.63
Sdown	4.5 ± 1.3	0.11 ± 0.03	15.4 ± 3.0	0.03 ± 0.06	0.016 ± 0.009	3.80 ± 1.41	0.076 ± 0.035	1.45 ± 0.11



2: Accumulation of total biogen (C, N, P) in the reference section of the river Svatka in 2011

had in this period Besének stream. The water quality in section between village Vír and Tišnov town had a alfamesosaprobic character and values of basic physicochemical parameters were not significantly different from the current conditions.

Next detailed monitoring of the river was realized in years 1957–1963, when the impact of the dam Vír on chemism and biota in the river below was evaluated (Peňáz *et al.*, 1968). The dam has a particular impact mainly on the decrease of water temperature in the river Svatka and on the lower pH value. In a comparison with our data, the value of pH and nitrate nitrogen at the turn of years 1950's and 1960's was lower and values of ammonia were higher than current values. Range of values of nitrite nitrogen and oxygen saturation of water was in similar range the same as now.

About ten last years the monitoring of water quality in the Svatka river basin has been very intensive especially because of improving the water quality in the Brno water reservoir. South-moravian Region and the City of Brno entered into cooperation with other co-researchers preparatory works for implementation of the project „Čisté povodí Svatky“ [Clean river basin of the river Svatka] in 2003 (www.cistasvatka.cz). The primary aim of the project is reduce of phosphorus supply

from catchment area and thereby the cyanobacteria development limitation in the reservoir. After very active start of the project there has been general focus limited, the deal with an issue of whole catchment area of Svatka river stopped and only Brno dam measures were solved (Duras *et al.*, 2010). In 2012 was prepared a balance model for catchment area of the water dam Brno, but this study was focused only at phosphorus (Gardavská *et al.*, 2012).

In comparison of our data with the balance model, simulated on the conditions in 2011, our measurements in terms of total phosphorus results positively. The amount of total phosphorus at the beginning of monitored section coincides with the balance model, when the annual amount of phosphorus above the Hodonínka is about 6 tons. Our data are different from the balance model in the following river part in the rate of phosphorus retention. The balance model takes into account minimal phosphorus retention in downstream part of the river. Our measurements show that in monitored section, regardless of the other unobserved diffuse sources of pollution, phosphorus retention occurs about 2.2 tons per year. The greatest differences are in the amount of phosphorus inflowing into the river Svatka by tributaries Loučka and Besének. The balance

model assumes the annual phosphorus input by the Loučka about 11 tons and by Besének 0.6 tons. Our measurements shown input of Loučka approximately 8 tons and input of Besének about 1.6 tons. Whereas the results of our measurements constitute real data in comparison with the model, we consider them as more relevant. Results of our physicochemical analysis on each locality are comparable in every parameter with similar data from profiles, where the measurement by the River basin manager was provided. The total amount of phosphorus at the end of our reference point (r.km 79.2) was actually more than five tons per year lower compared to the model (Fig. 1). The relevant data from other authors for comparison with our findings overall balance of nitrogen and carbon are not available.

If compare the data obtained about mass ratio of the basic biogen in the river Svratka (237-604 C: 20-73 N: 1 P) to other research, results correspond to the ratio in natural surface waters 600 C: 20 N: 1 P (Russel-Hunter, 1971; Wetzel, 1983). In comparison with mass ratio of carbon, nitrogen and phosphorus

in plant biomass 40 C: 20 N: 1 P (Kubíček and Lellák, 1991), limiting element of production is apparently just phosphorus. Average concentration of phosphorus in rivers states about 0.07 mg.l^{-1} and due to the pollution its concentration increases to tenths up to units of milligrams (Pitter, 2009). In the case of river Svratka, the key producer of phosphorus in river basin is municipal wastewater which is 75% of all inputs (Gardavská *et al.*, 2012).

Our results of monitoring river Svratka (including tributaries between Vír dam and the town of Tišnov) show slightly polluted water. Due to size of river catchment area and density of population it is possible to consider this condition as satisfying. Further improvement of water quality in the stream will be accompanied by high expenditure for their implementation (waste water plant development in smaller settlements; limit diffuse pollution, nitrogen and phosphorus removal from WWP etc.). Reducing the load of the river Svratka biogen excessive intake is essential to improve water quality in the lower sections of the stream, especially Brno water reservoir.

SUMMARY

The aim of this study is to examine the water quality of the Svratka River and its selected tributaries between Vír dam and Tišnov town. For observation were chosen tributaries Besének, Loučka, Nedvědička, Chlebský creek, Hodonínka, Vrtěžířský creek and Tresný creek. For comparison, also two other localities on the Svratka River – above and under the whole research section were monitored. We observed the content of dissolved oxygen, water temperature, pH, conductivity, concentration of ammonium ions, nitrite, nitrate, total nitrogen, orthophosphate and total phosphorus, total carbon, acidic neutralization capacity, organic matter content and water flow. Sampling was carried out in monthly from March to October 2011 (N = 8). Due to evaluation of water quality the river and tributaries Hodonínka, Vrtěžířský and Tresný correspond to the second class of quality and tributaries Besének, Loučka, Nedvědička corresponds to the third class of water quality. In the reference section phosphorus retention in annual amount about 2.2 tons were occurrence. The annual volume of phosphorus at the end of observed section (upstream the Tišnov town) is nearly 17.5 tons. Total annual balance of nitrogen at the end of reference section is 700 tons per year and 6000 tons of carbon per year. The dominant source of biogen is the river Loučka bringing 46% of phosphorus, 28% of nitrogen and 32% of carbon from the total volume of nutrients. The river Svratka between the Vír dam and Tišnov is slightly polluted. Further improvement of water quality in the river will be accompanied by very high financial costs for its realization, but it is necessary precondition for better water quality in lower parts of the river, especially Brno water reservoir.

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