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EUTROPHICATION POTENTIAL OF WASTEWATER TREATMENT PLANTS IN THE UPPER REACHES OF SVRATKA RIVER

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Abstract

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During the year 2012 thirteen selected sites were monitored in the stretch between Brno reservoir and Nedvědice village. Based on the former monitoring, samples from the major tributaries (Besenek, Loucka, Nedvedicka, Lube, Bily brook) and Svratka River above and below monitored area were taken. Besides the water from tributaries and the river also samples of water discharged from sewage treatment plants in villages Nedvědice, Doubravník, Březina and Veverská Bítýška were taken. Basic chemical and physical parameters of water were measured. Major impact of monitoring was to target the amount of nutrients, especially phosphorus. Requirements for salmonid (Svratka upper, Nedvedicka, Loucka, Besenek, Bily brook) or cyprinid (Lube, Kurimka, Svratka lower) waters quality meet at all localities. Wastewater treatment plants (WWTP) meet the emission standards in all cases. Monitoring of the amount of nutrients out-flowing from WWTP at extreme flows is not usually carried out at all. Based on our results, the phosphorus inflow into Brno reservoir would be up to 50 t per year in the case of average flow 7.96 $m^3.s^{-1}$ of Svratka River in Veverská Bítýška.

Keywords: wastewater treatment plant, river, phosphorus, eutrophication

INTRODUCTION

The water quality in rivers and water reservoirs is influenced by human activity in its surroundings. Besides the direct negative activity with toxic materials, man burdens the water environment by large amount of nutrients. The excessive nutrients amount produced by human and discharged into water influences the rapid increase of trophy (Kočí *et al.*, 2000). Among the main sources of eutrophic nutrients belong the intensive agricultural production, some kinds of industrial waste waters, using of polyphosphates in detergents and increasing production of municipal waste waters and wastes of faecal character (Smith *et al.*, 1999). Anthropogenic activity is frequently a cause of annual changes in the chemical composition of stream waters. Man affects river quality by changing the amount and quality of household sewage discharged to the river. A reduction of sewage and an improvement of its quality have an effect on the water chemical compounds and instantly lead to a decrease of ammonia ions concentration and, to a lower extent, to decrease of orthophosphates (Muscutt & Whithers, 1996; Lehmann & Rode, 2001).

There are increased phosphorus concentrations at the most of the natural bodies of water and the attendant of different degree of eutrophication of these waters in Czech Republic. The main sources of nutrients, primarily the phosphorus, are point sources, especially discharging of municipal waste waters (Hejzlar & Borovec, 2004). Balance study of phosphorus and nitrogen sources in the basins of Orlík and Mostiště water reservoirs enumerates the participation of point sources in total phosphorus input to reservoir at 51–55% (Hejzlar *et al.*, 2007; Hejzlar *et al.*, 2010). Waste waters from point sources are getting into recipients usually via wastewater treatment plants (WWTP). Under the Government Regulation Act No. 61/2003 as amended, keeper of WWTP do not monitor the nutrients emissions during the unusual situations (intensive rain falls, floods) which are the major states posing the significant nutrients sources for recipient from the pollution of surface water point of view. There is occurring the substantial undervaluation of importance of point sources of pollution from cities and villages when evaluated only on the basics of data declared by WWTP keepers (Potužák *et al.*, 2013).

The aim of this project was to ascertain the delivery of basic nutrients from main sewage treatment plants into the Svratka River above the Brno reservoir by the own monitoring and to compare the results with accessible data from WWTP keepers.

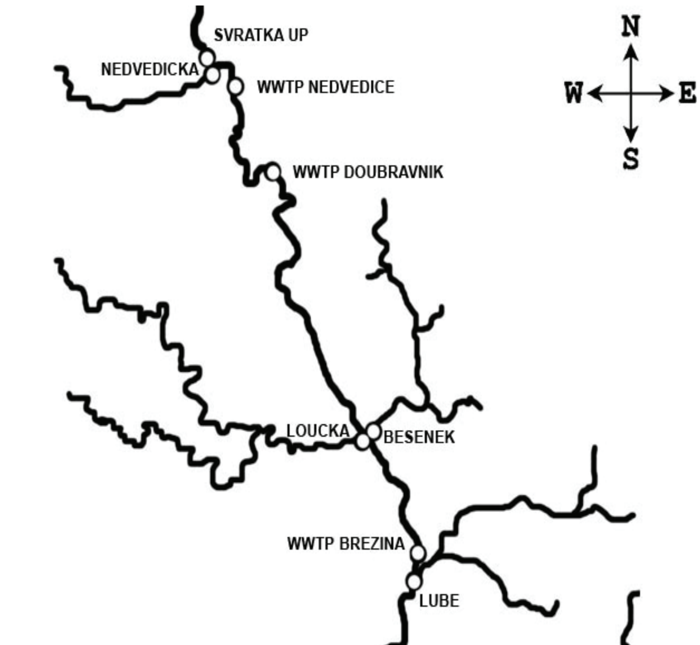
MATERIALS AND METHODS

Characteristics of the Observation Site

The Svratka River is a left-hand tributary of the Thaya River. It springs in Žďárské vrchy, flows through the Nedvědice highland to the Tišnov basin and then goes southward across the part of Bobrava highlands to the Thaya River in Dyjsko-svratecký úval. The confluence is situated near the parished village Mušov, nowadays under the surface of Nové Mlýny reservoir. The average flow rate in the river mouth is 27.24 $m^3.s^{-1}$. Overall length is 173.9 km and river basin has 7 118.7 km^2 (Vlček, 1984).

Monitoring was carried out from April to October 2012 (12^{th} April, 18^{th} May, 30^{th} June, 8^{th} July, and 11^{th} October). Thirteen localities were chosen in the stretch between Brno reservoir and Nedvědice village. Based on the former monitoring, samples from tributaries Besenek, Loucka both at marker 79.4 km and Nedvedicka at marker 95.5 km were taken. Further, there were tributaries Bily brook, Lube and last tributary Kurimka with sampling place at the mouth chosen for monitoring. Another two localities are placed directly on the Svratka river where the samples were taken on the beginning of the whole stretch in Nedvědice village above the mouth of Nedvedicka tributary (Svratka upper) and on the end of the whole monitored stretch Svratka lower, (see Fig. 1). Except the water from tributaries and the river also, samples of water discharged from sewage treatment plants in villages Nedvědice, Doubravník, Březina and Veverská Bítýška were taken.

Samples from Svratka upper locality were taken about 1 m from the right river bank 3 m above the mouth of Nedvedicka. Samples from Svratka lower locality were taken from jetty on the beginning of backwater of Brno reservoir under the bridge of the road Veverská Bítýška – Chudčice. Water samples from WWTPs Nedvědice,



1: *Map of the Svratka basin with the studied sites indicated.*

Doubravník and Březina were taken directly from the pipe outlet; samples from WWTP Veverská Bítýška were taken from trench below the outlet. All of the taken samples were analysed at the day of sampling.

WWTP Nedvědice is situated at marker 93.8 km. 795 inhabitants are connected to sewage works. Adequate burden of sewage works is 676 PE (population equivalent). WWTP capacity is 2257 PE. WWTP works at the basics of mechanic or primary treatment and biological treatment using the activated sludge. Tertiary level is missing (PRVKJM, 2009; EAGRI, 2003).

WWTP Doubravník is situated at marker 86.5 km on the right river bank. This facility processes in the order of 95 m^3 of waste waters per day. 529 inhabitants are connected to it. Burden of sewage works correspond 770 PE. Its capacity is 1200 PE. There is multilevel treatment technology and biological treatment using the activated sludge and settlement tank used in WWTP. Tertiary treatment is missing (PRVKJM, 2009; EAGRI, 2003).

WWTP Březina is situated at marker 74 km on the left river bank. 9771 inhabitants of villages Březina, Předklášteří, Štěpánovice and Tišnov city are connected to it. Burden of sewage works corresponds to 18500 PE. WWTP capacity is 18000 PE. There is mechanic-biological technology without tertiary treatment used (EAGRI, 2003; PRVKJM, 2009).

WWTP Veverská Bítýška at marker 69 km is situated on the left river bank. 2730 inhabitants are connected to it. WWTP burden corresponds to 2730 PE. WWTP capacity after reconstruction is 6500 EO. There is mechanic-biological technology without tertiary treatment used. When constructed, sewage works was designed for 15000 PE. Currently, the project for the reconstruction and modernisation is in operation (EAGRI, 2003; PRVKJM, 2009).

During the samplings, water flow from WWTPs was estimated from pipe profile, water column height and water stream velocity based on the collected water amount (10 l) per monitored time interval.

For comparison, data about discharged water amount and its quality were requested from particular sewage works keepers.

Chemical Methods

Directly in the field, basic chemical and physical parameters of water were measured. For this purpose portable automatic devices were used. 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. Water samples were drawn from depth about 10 cm to the plastic (PE) bottles.

Ammonium ions ($N\text{-}NH_4$) were measured using the indophenols method, nitrite nitrogen ($N\text{-}NO_2$) by a method using N-(1-naphthyl)-ethylenediamine and nitrate nitrogen ($N\text{-}NO_3$) by a method using sodium salicylate. Total nitrogen (N_T) was measured with dimethylphenol after the transformation of all nitrogen compounds into nitrate by Koroleff's method. Total phosphorus (P_T) and orthophosphate ($P\text{-}PO_4$) were measured using ascorbic acid and ammonium molybdenite. 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 and calcium (Ca) levels were measured by EDTA titration. 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 standard methods (APHA, 1998).

RESULTS

Tributaries and localities on the Svratka River meet the requirements of Environmental Quality Standards (EQS) in most of parameters (following

I: *Physical characteristics (mean ± SD) of the sites from April to October 2012 (N = 5)*

Locality	O_2 (%)	Temperature (°C)	pH	Conductivity ($mS.m^{-1}$)
Svratka upper	96.6 ± 6.2	10.0 ± 3.3	8.2 ± 0.3	19.1 ± 0.8
Nedvedicka	108.5 ± 14.2	14.8 ± 6.9	8.8 ± 0.4	59.0 ± 19.5
WWTP Nedvedice	61.2 ± 8.6	15.5 ± 3.5	7.4 ± 0.1	80.6 ± 8.9
WWTP Doubravnik	32.6 ± 7.5	13.5 ± 3.7	7.7 ± 0.2	74.8 ± 4.1
Loucka	113.2 ± 9.5	14.9 ± 7.5	8.8 ± 0.3	38.8 ± 4.1
Besenek	97.6 ± 5.3	12.7 ± 5.0	8.5 ± 0.2	52.9 ± 1.9
WWTP Brezina	69.0 ± 1.4	16.5 ± 3.3	7.6 ± 0.2	110.2 ± 7.0
Lube	69.5 ± 7.9	14.1 ± 4.8	7.8 ± 0.7	85.6 ± 6.4
Bily brook	116.5 ± 17.6	13.8 ± 5.7	8.8 ± 0.4	47.5 ± 6.5
WWTP V. Bityska	70.5 ± 24.6	12.6 ± 2.8	7.8 ± 0.5	77.3 ± 22.0
Kurimka	61.3 ± 15.4	13.0 ± 5.4	8.0 ± 0.4	82.7 ± 15.2
Svratka lower	107.0 ± 34.0	14.2 ± 6.0	8.2 ± 0.9	27.2 ± 1.8

II: *Chemical characteristics (mean ± SD) of the sites (N = 5)*

Locality	TOC (mg.l⁻¹)	N_T (mg.l⁻¹)	P_T (mg.l⁻¹)	$P\text{-}PO_4$ (mg.l⁻¹)	COD_{Cr} (mg.l⁻¹)	$N\text{-}NH_4$ (mg.l⁻¹)	$N\text{-}NO_2$ (mg.l⁻¹)	$N\text{-}NO_3$ (mg.l⁻¹)	ANC (mmol.l⁻¹)	Ca^{2+} (mg.l⁻¹)
Svratka upper	11.4 ± 4.4	3.9 ± 0.6	0.17 ± 0.16	0.08 ± 0.03	18 ± 5	0.02 ± 0.01	0.013 ± 0.005	3.36 ± 0.70	1.39 ± 0.88	20.9 ± 0.39
Nedvedicka	12.5 ± 3.8	4.0 ± 2.1	0.16 ± 0.06	0.12 ± 0.05	17 ± 3	0.03 ± 0.02	0.017 ± 0.007	3.26 ± 2.48	1.98 ± 0.29	64.5 ± 21.9
WWTP Nedvedice	19.3 ± 5.0	16.1 ± 9.7	4.52 ± 1.88	2.45 ± 2.07	27 ± 7	0.75 ± 0.74	0.118 ± 0.051	15.63 ± 8.62	2.78 ± 0.72	49.7 ± 8.3
WWTP Doubravnik	22.8 ± 8.2	19.0 ± 6.6	1.55 ± 0.79	1.08 ± 0.88	28 ± 14	0.84 ± 0.49	0.945 ± 1.391	8.75 ± 7.09	4.19 ± 1.02	68.1 ± 5.52
Loucka	11.4 ± 6.7	3.7 ± 2.0	0.22 ± 0.10	0.16 ± 0.12	17 ± 4	0.05 ± 0.07	0.035 ± 0.012	3.20 ± 2.02	2.20 ± 0.29	46.9 ± 3.9
Besenek	10.4 ± 6.3	5.0 ± 1.1	0.23 ± 0.08	0.23 ± 0.19	11 ± 3	0.03 ± 0.02	0.028 ± 0.020	4.44 ± 1.22	3.60 ± 0.39	69.8 ± 2.3
WWTP Brezina	22.2 ± 6.4	10.4 ± 6.0	0.85 ± 1.01	0.84 ± 0.98	19 ± 5	0.69 ± 0.24	0.196 ± 0.217	10.79 ± 7.23	4.66 ± 0.75	67.7 ± 24.4
Lube	31.1 ± 12.4	6.9 ± 3.4	0.70 ± 0.15	0.55 ± 0.24	18 ± 3	0.44 ± 0.49	0.129 ± 0.03	6.17 ± 2.82	5.95 ± 0.43	70.9 ± 37.6
Bily brook.	15.0 ± 7.2	3.2 ± 0.5	0.29 ± 0.08	0.17 ± 0.10	20 ± 11	0.03 ± 0.02	0.024 ± 0.012	2.47 ± 0.99	2.60 ± 0.22	49.4 ± 7.0
WWTP V. Bityska	40.8 ± 17.8	2.8 ± 1.3	0.54 ± 0.48	0.21 ± 0.21	24 ± 14	0.22 ± 0.16	0.064 ± 0.052	2.81 ± 0.89	5.53 ± 1.97	59.7 ± 31.6
Kurimka	31.4 ± 13.0	4.6 ± 0.9	0.44 ± 0.11	0.32 ± 0.15	18 ± 8	0.54 ± 0.19	0.175 ± 0.077	3.73 ± 0.35	5.59 ± 1.50	87.5 ± 24.3
Svratka lower	13.3 ± 4.4	4.4 ± 0.4	0.20 ± 0.18	0.12 ± 0.06	20 ± 6	0.18 ± 0.29	0.030 ± 0.013	3.28 ± 0.95	1.31 ± 0.30	29.2 ± 4.8

the Annexe No. 4 to Government Regulation Act No. 61/2003). Requirements EQS were slightly exceeded on every locality in TOC and P_T parameters. Lube locality did not meet the EQS also in the N_T, $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ parameters. Requirements for salmonid (Svratka upper, Nedvedicka, Loucka, Besenek, Bily brook) or cyprinid (Lube, Kurimka, Svratka lower) waters quality meet all localities.

WWTP meet the limits according to Government Regulation Act No. 61/2003 as amended.

Tabs. I and II show the average and standard deviations of monthly measurements of the physical and chemical characteristics at the sites.

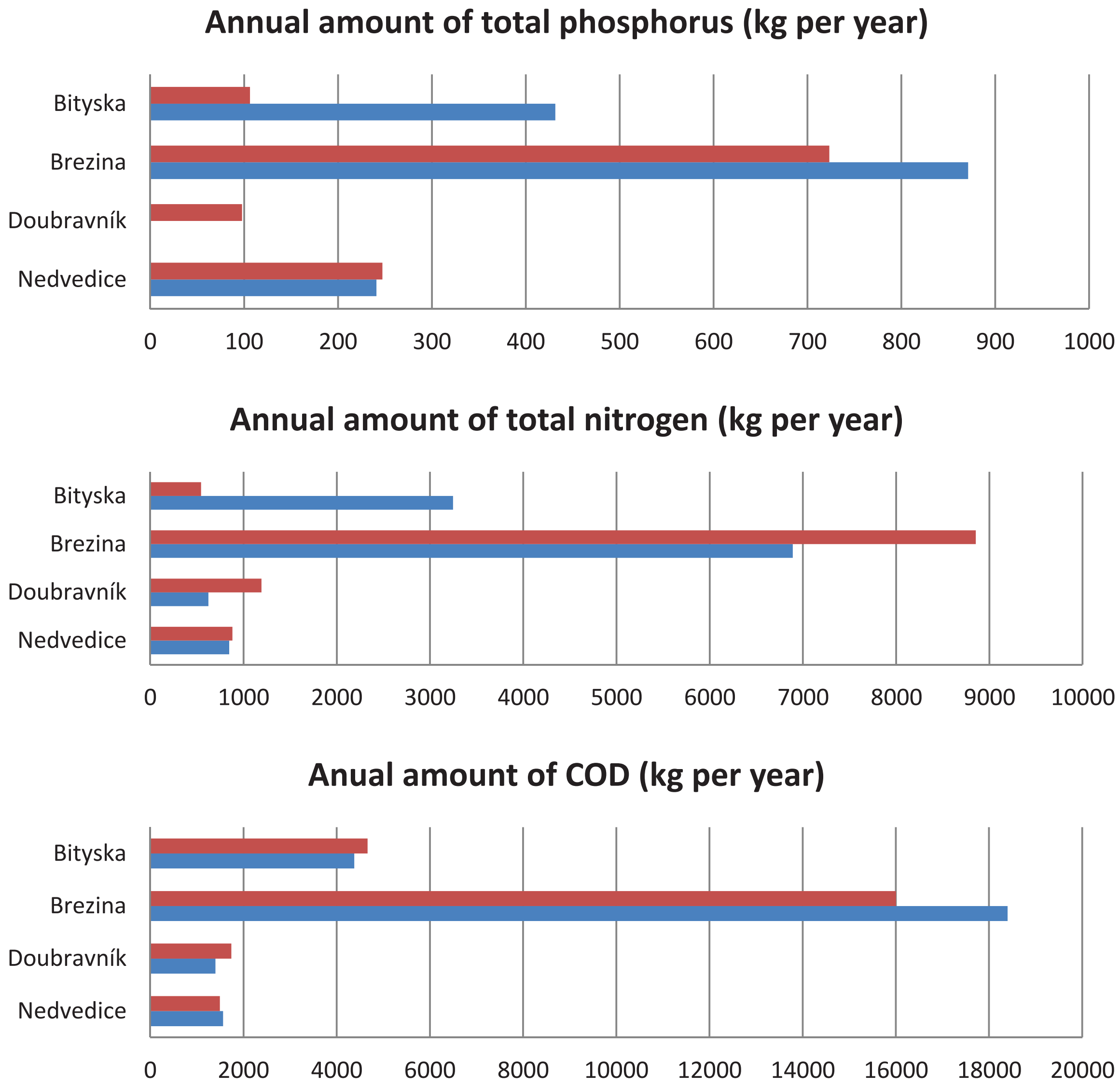
Fig. 2 shows the ratio between values measured during our monitoring and values stated by WWTP keeper. It is significant from the graph that data are practically the similar. The only difference is obvious on Bítýška locality. The place of sampling is situated in the point of mixing water from WWTP with water in the river. Especially when flow decreased through the sewage treatment, the real values of monitored parameters are significantly influenced by watering down of Svratka River. Taking sample directly from the drainpipe was technically not possible. Readouts about total phosphorus from WWTP Doubravník are not available due to Government Regulation Act No. 61/2003 as amended which does not assign an obligation to monitor total phosphorus for sewage works until size of 2000 PE.

DISCUSSION

The eutrophication is natural process of increasing the carrying capacity of standing waters by accumulation of nutrients. Man activity contributes to its excessive acceleration. Typical and mostly apparent display of eutrophication is regular occurrence of cyanobacterial blooms which causes intensive green coloration of water surface. The consequences of eutrophication are extensive and complex. In extreme cases, irreparable damages of ecosystem occur. Due to cyanobacterial bloom, decreasing of biodiversity, oxygen regime unstableness etc. occur (Lund, 1967; Smith, 1999; Kočí *et al.*, 2000; Pitois *et al.*, 2001; Conley *et al.*, 2009).

The most important for development of phytoplankton is the presence of nitrogen and phosphorus. The ratio 100N: 1P is needed for optimal growth of organisms (Kočí, 2000). According to Liebig's law of the minimum, phosphorus is the limiting factor for water bloom growth (Smith, 1999; Correll, 1999; Kočí, 2000; Pitois *et al.*, 2001). Excessive concentrations of phosphorus are the most frequent reason for eutrophication of freshwater reservoirs, lakes and brooks (Correll, 1999).

Natural source of phosphorus is apatite mineral (Kočí, 2000). The artificial sources of phosphorus originate in human activity. The ways for phosphorus entrance into environment are nonpoint and diffusion sources including the municipal pollution.



2: *Phosphorus, nitrogen and organic substances emissions from monitored WWTPs. Red column represents our measured data, blue column represents data stated by particular WWTP keepers.*

Eutrophication potential of WWTP is closely connected to phosphorus amount discharged into recipient. According to Gardavská *et al.* (2012), municipal pollution contributes to 75% of total pollution. This corresponds with Potužák *et al.* (2013), who reports that based on the balance studies, point sources show the main part of total amount of brought phosphorus. Balance study on Orlík reservoir proved the 55% share of phosphorus from pollution point source, on Mostiště reservoir 51% share (Hejzlar *et al.*, 2007). Pollution from point sources gets recipients via WWTP (Potužák *et al.*, 2013; Jarvie *et al.*, 2002). Monitored quality of discharged waste waters depends on the size of sewage works. WWTP in this study belong to the category of sewage works without the obligation of continual monitoring by law (Government Regulation Act No. 61/2003). Sewage works from 500 to 2000 PE (Doubravník) are not obliged by law to monitor even phosphorus (Government Regulation Act No. 23/2011). According to Potužák *et al.* (2013) principal underevaluation of nutrients amount discharged by WWTP comes about. The amount of nutrients outflowing from WWTP is not monitored at extreme flows at all. From the balance point of view, these calamity waters are fundamental for emission of phosphorus, mainly from point sources.

According to balance model, inflow of phosphorus into Brno reservoir is 32.3 t per year (Gardavská *et al.*, 2012). But our monitoring shows higher numbers. Based on our results, the phosphorus inflow into Brno reservoir would be up to 50 t per year in the case of average flow 7.96 $m^3.s^{-1}$ of Svratka River in Veverská Bítýška (CHMÚ, 2013). Difference between the balance model and our monitoring might present the issue described by Potužák *et al.* (2013) because the balance models labour under the data acquired from sewage works keepers who do not monitor the water quality during the extreme flows.

Based on the monitoring of water quality in Svratka river tributaries (Grmela *et al*., 2012), the most significant sources of phosphorus are Nedvedicka, Loucka and Besenek. Monitoring did not include tributaries Lube and Bily brook. Balance model of catchment area (Gardavská *et al*., 2012) reports the biggest producers of phosphorus in catchment area. First comes WWTP Nové Město na Moravě (11327 PE) by producing 1.83 t of phosphorus in the year 2012. This sewage work discharge the waste water into the Loucka River. Next important WWTP from the phosphorus production point of view is situated at Bily brook in the Velká Bíteš village (5080 PE) by producing 0.55 t of phosphorus in the year 2012.

Considering the possibilities of decreasing the input of nutrients into recipients solves often the issues of diffusion sources of pollution and small units without WWTP. A possibility of decreasing the phosphorus input from point sources mainly meets the technological problems or unskilled operation of WWTP. However, decreasing the phosphorus emission is relatively easily solvable (Foller 2012, Očásková 2013). Balance model of Svratka River reports more than 40 WWTP s in its catchment area. Based on the balance WWTP monitoring of Potužák *et al.* (2013), production of phosphorus from these facilities can be approximately two to four times higher than data reported by keepers. According to this data it is obvious that fundamental decreasing of phosphorus emission into recipients is solvable by technology modification and skilled management of WWTP. There is a thorough monitoring necessary for assessment of real data of phosphorus production in these facilities, mainly during the extraordinary situations (intensive rainfall, increased water flows). Also modification of legislation (obligatory monitoring of phosphorus emission in lower capacity WWTPs) is essential.

SUMMARY

During the year 2011 thirteen selected sites were monitored in the stretch between Brno reservoir and Nedvědice village. Based on the former monitoring, major tributaries (Besenek, Loucka, Nedvedicka, Lube, Kurimka, Bily) and Svratka River above and below monitored area were sampled. Besides the water from tributaries and the river also samples of water discharged from wastewater treatment plants in villages Nedvědice, Doubravník, Březina and Veverská Bítýška were taken.

Basic chemical and physical parameters of water were measured. Major impact of monitoring was to target the amount of nutrients, especially phosphorus. Tributaries and localities on the Svratka River meet the requirements of Environmental Quality Standards (EQS) in most of parameters (following the Annexe No. 4 to Government Regulation Act No. 61/2003). Requirements EQS were slightly exceeded on every locality in TOC and P_T parameters. Lube locality did not meet the EQS also in the N_T, N-NH_4^+ a N-NO_3^- parameters. Requirements for salmonid (Svratka upper, Nedvedicka, Loucka, Besenek, Bily brook) or cyprinid (Lube, Kurimka, Svratka lower) waters quality meet all localities. WWTP meet the emission standards. The ratio between values measured during our monitoring and values stated by WWTP keepers are practically the similar.

Based on our results, the phosphorus inflow into Brno reservoir would be up to 50 t per year in the case of average flow 7.96 $m^3.s^{-1}$ of Svratka River in Veverská Bítýška. According to balance model, inflow of phosphorus into Brno reservoir is 32.3 t per year. Difference between the balance model and our monitoring can be caused by deficient of dates used for model calculation. The balance models labour under the data acquired from sewage works keepers who do not monitor the water quality during the extreme flows. Production of phosphorus from these facilities will be approximately two to four times higher than reported data. There is a thorough monitoring necessary for assessment of real data of phosphorus production in these facilities, mainly during the extraordinary situations (intensive rainfall, increased water flows). Also modification of legislation (obligatory monitoring of phosphorus emission in lower capacity WWTPs) is essential.

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