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Water quality in the Berounka river basin

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Abstract

The article presents a complex evaluation of the development of water quality in the Berounka river basin during the 1990s and of its main influencing factors – point and nonpoint sources of pollution of surface water. During this period there occurred a partial improvement in the water quality in the Berounka river course. This decline of pollution was not followed by the same development at its key tributaries. Main affluents – Střela, Litavka, Třemošná, Rakovnický creek and Kaznějovský creek remain even at the beginning of the 21st century under the heavy influence of intensive pollution from local communal and industrial sources as well as point and nonpoint pollution of agricultural origin. This development causes gradual increase of differences in water quality between the main course and its main tributaries, which is analogical to the general situation of a large part of the Czech part of the Elbe river basin.

Key words: hydrology, water quality, pollution, environment, Elbe river basin

1. Introduction

During the course of the 1990s there occurred a fundamental change in the Czech part of the Elbe River Basin as far as the development of the quality of surface waters. After many years of growth in the level of pollution, a decrease occurred in the level of pollution to the Elbe and its main tributaries thanks to a decrease in emissions from main industrial and communal sources. The extent and speed of these changes in the quality of water is without precedence both on a Czech and a European scale.

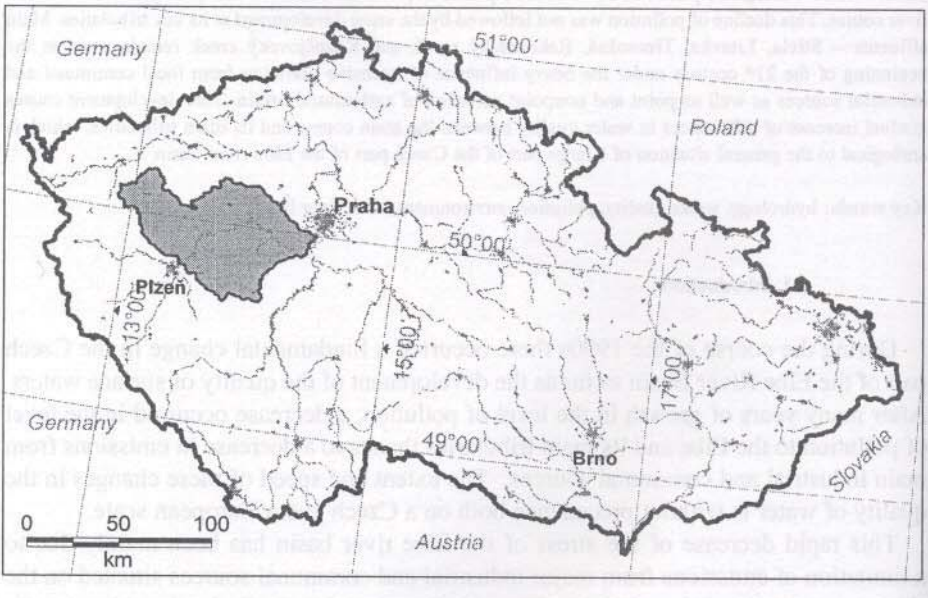
This rapid decrease of the stress of the Elbe river basin has been mainly due to a limitation of emissions from major industrial and communal sources situated on the Elbe river or on its major affluents. Thus the decrease of the pollution level is spatially limited generally more or less to the major rivers. At the same time many smaller streams, mainly in agricultural regions, still suffer by non-declining pollution loads from local industrial and communal sources, as well as from intensive agricultural production.

An example of region where both of these tendencies meet up is the Berounka river basin situated between Pilsen and Prague. The main stream draining the region – Berounka has been recording, similarly to the majority of major Czech streams during the 1990s, a partial decline of the pollution load, mainly thanks to modernization of a key sewage works at Berounka in Pilsen. As opposed to this the main affluents, formed by small streams, remain under the stress of industrial, communal and agricultural pollution sources.

This article presents a complex evaluation of the development of the quality of water in the Berounka river basin during the 1990s and analysis of its main influencing factors – point and nonpoint sources of pollution of surface water.

2. Study area

The Berounka river basin, situated southwest of Prague with a total area of 4068 km² represents an important portion of the Czech part of the Elbe River Basin (see map 1). The upper limit of the basin is at the confluence of the Mže and Úslava rivers below Pilsen. The confluence of the Berounka with the Vltava river on the outskirts of Prague represents the lower limit of the studied basin. The Berounka river represents the largest tributary to the Vltava river and has key influence to its hydrological regime and water quality on its down course.



Map 1 Study area

The Berounka river basin is exceptionally rich from geographical point of view. In the extensive area of the basin we find large forests, natural countryside with scarce settlement, as well as agricultural regions, urban areas with large industrial complexes or opencast mines. In the basin there are two large-scale protected reserves – Křivoklátsko and Český Kras and a series of smaller protected natural reserves.

2.1. Hydrological conditions

The high imbalance of the discharge regime during the year, connected with the frequent appearance of flooding situations characterizes the hydrological conditions of the Berounka river basin. This fact stems mainly from its geographic position and its resulting frond stream network pattern of the basin. This appears negatively in the side run of culminating waves in the area of Pilsen and the consequent evocation of flooding situations mainly in the spring.

The irregularity of the outflow regime is clearly visible in the data on the monthly distribution of runoff: 45% of the annual runoff flows off the river basin in 3 months from February to April, on the contrary during 4 months from July to October only 21% of the annual runoff occurs. We can also observe important variations in the yearly runoff rate, when in approximately ten-year interval dry and wet periods alternate. This is exemplified by the dry periods at the beginning of the 1970s and 1990s, when the average annual discharge of the Berounka in the mouth profile did not even attain 20m^3/s, while the long-term average discharge is nearly double that at 39.03 m^3/s. On the other hand during the period of overall high precipitation such as in the mid 1960s and 1980s, the average annual discharges often exceeded values of 60 m^3/s.

2.2. Landuse

Data on land use structure and spatial distribution are one of the basic information for the analysis of human impact in the basin. In the Berounka river basin the GIS analysis of the geo-database CORINE was performed to assess the main quantitative proportion of individual classes of land use, and their spatial distribution.

From the evaluation (see Table 1) it is seen that a more than half majority of the territory of the Berounka river basin has an agricultural character. Meanwhile 43% of the entire area of the basin is made up of forested areas, which is an above-average value in comparison of the overall area of the Czech Elbe River Basin. A full 51% of the territory is then covered by fields, orchards, hops farms and other agricultural areas. Areas of an artificial nature – houses, industry, roadways and raw materials mining, represent 4.7% of the area.

Table 1 Berounka river basin – landuse structure

Landuse class	*Share*
Urban and industrial areas	4.7%
Agricultural areas	50.9%
Forrest land	42.8%
Meadows and pastures	1.4%
Water and wetlands	0.2%
Total	***100.0%***

The largest areas of the forests in the basin are concentrated on the central part of the basin in Křivoklátsko natural reserve and further in the peaks of the Brdy, at the Litavka and Klabava basins. Coniferous forests form the vast majority of forest growth

– over 25% of the entire area of the basin – only 1,8% is made up of deciduous trees, with the rest mixed and with low forest undergrowth.

The agriculturally managed territory lies in relation to the configuration of the relief mainly at the outer parts of the basin, formed by even surfaces. This relief configuration and land use are very unfavorable from the aspect of development of the quality of the surface water. That is these waters are polluted already in the source locations, where just a little pollution is enough to attain critical concentrations of ecological load. For this reason at the consequent segment it's not possible to remove the pollution by natural self-cleaning processes due to intensive socio-economic use. In the Berounka river basin this phenomenon mainly concerns the confluences running on the left side, mainly the Střela, Rakovnický creek and Loděnice.

Less than 5% of the area of the Berounka river basin lies on an anthropgeneously transformed area – settlements, industry and mining areas. Aside from the main settled areas of Příbram, Rokycany, Beroun and Rakovník, where besides settlements we find intensive industrial production, there are in the Berounka river basin a number of locations with present and also closed mining of mineral raw materials. Aside from the Příbram region there is also limestone mining in Český Kras, kaolin mining at Horní Bříza and the coal mining area around Kladno.

3. Pollution sources

Pollution of surface water in the Berounka river basin occurs almost exclusively from anthropogenous activities. This concerns activity connected with the mining of mineral raw materials and industry, as well as the influence of intensive agricultural production. It also refers to waste from the communal sphere – concentrated as well as spread out settlements. Based on the main form of production and transport of polluting substances we can break down these sources of pollution into three main groups – point sources, dispersed sources and diffuse sources. According to the spatial concentration of the pollution sources we can distinguish areas with exceptionally strong concentration of sources of pollution and a large influence by emissions to the natural environment – the emissions centers.

3.1. Point sources of pollution of surface waters

Perhaps the most significant factor influencing the immediate condition of water quality in the river channel is made up of point sources of pollution. For the balance evaluation of the volume of emissions from individual sources, a central registry of pollution sources was used as a base resource – the State Water Management Balance (hereinafter "SVHB") containing monthly sums of the volume of emitted wastewater and average annual concentration of selected pollutants. In the Berounka river basin this database has recorded more than 100 point pollution sources. The SVHB database was linked to the GIS layer of geographical position of pollution sources and analyzed both from the aspect of substance flows as well as the aspect of spatial concentration of the load in individual parts of the basin.

3.2. Emissions development

The development of the emissions of pollutants was evalutaed on the basis of an analysis of the mentioned SVHB database, containing data on the volume and chemism of the expelled pollution from 1990 to 1998. This time period generally represents a turning point in the development of the quality of surface waters on the Czech side of the Elbe River Basin. Three main pollution indicators were evaluated – BOD-5 (biochemical oxygen demand), COD (chemical oxygen demand) and NH_4. From the data found in the SVHB database, data was gathered by area aggregation concerning the summarized level of pollution from expelled wastewater from all documented sources of pollution for individual basins and years.

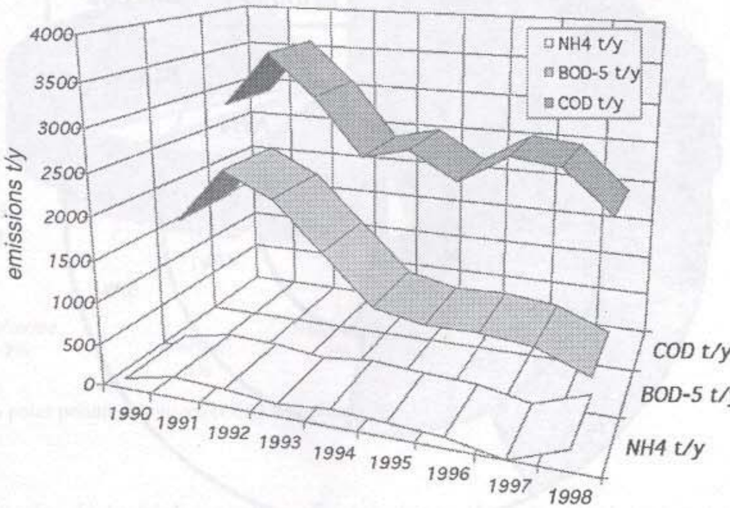


Fig. 1 Berounka – development of point pollution sources emissions

On the graph of the total development of emissions in the Berounka River Bain in individual parameters we can see a relatively fast decline in emitted pollution in the mid-1990s. The causes of the decrease of expelled pollution are different for individual parameters. While in the case of the indicator BOD-5, this concerns the consequence of gradual construction and intensification of waste water cleaners at communal sources, for the COD level there is a decrease in the emitted load also related to the stagnation in industrial production in certain regions.

3.3. Pollution sources structure

The knowledge of the structure of the sources of emissions is important for evaluating their impact to the water quality and character of the resulting pollution. On Fig 2 we see the division into two categories of point pollution sources – communal and industrial. Mining companies, the manufacturing industry and intenstive agricultural production were included into the group of industrial sources during evaluation. Aside from these two categories another category was formed – "mixed", into which those sources were included where definite differentiation is impossible thanks to the mutual cleaning of waste water from industry and settlements. A typical example is Rakovník, where two of the largest sources of pollution in their categories, the city Rakovník and the chemical plant Procter & Gamble process waste at a mutual wastewater treatment facility, and here it's difficult to exactly separate out the portion of individual contributors.

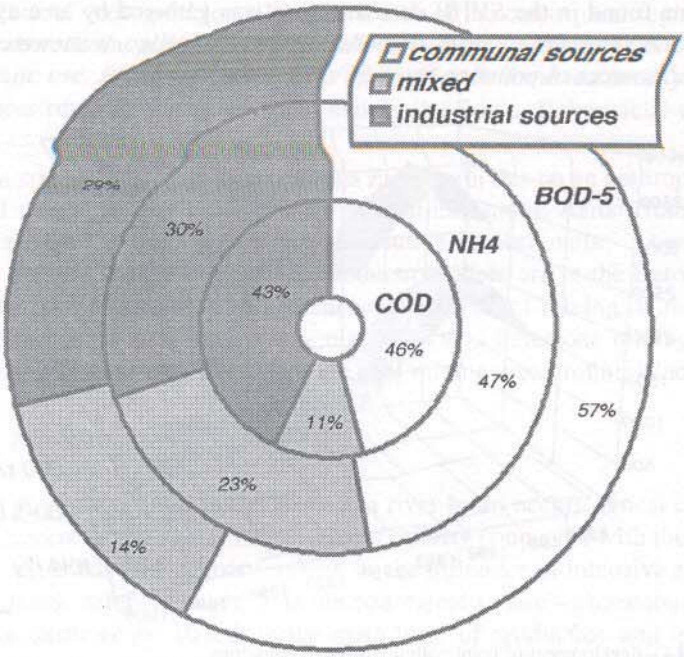


Fig. 2 Point pollution sources structure

According to the results of the analysis for three main indicators it is seen that the organic pollution of the Berounka river basin in the indicator BOD-5 in 57% comes from communal sources. If we add to these values the corresponding part from the Rakovník wastewater treatment facility, the share of communal sources grows up to 66% of the total volume of emissions. In the case of the indicator of total organic pollution COD the share of communal and industrial sources in total emissions is roughly even. A similar situation is found for emissions of ammonia, even though the share of positively industrial emissions is here lower than 30% at first glance. Here is where the un-included part of mixed pollution from wastewater treatment facility Rakovník comes into play, where due to the character and volume of production it's necessary to include the vast majority of NH_4 emissions to the debit of industrial sources, mainly the Procter & Gamble factory. The share of industrial sources on NH_4 emissions into surface waters then reaches roughly 50%.

3.4. Main point sources of pollution

The spatial distribution of the main sources of point pollution stem from the long-term concentration of the population and industrial activities into individual territorial units, found on Map 2. This thematic map shows the point sources of pollution according to the volume of COD in 1998 and the position of the main emissions centers. The share of the largest sources of pollution on the entire emissions in the indicator COD for 1998 is summarized in Fig. 3.

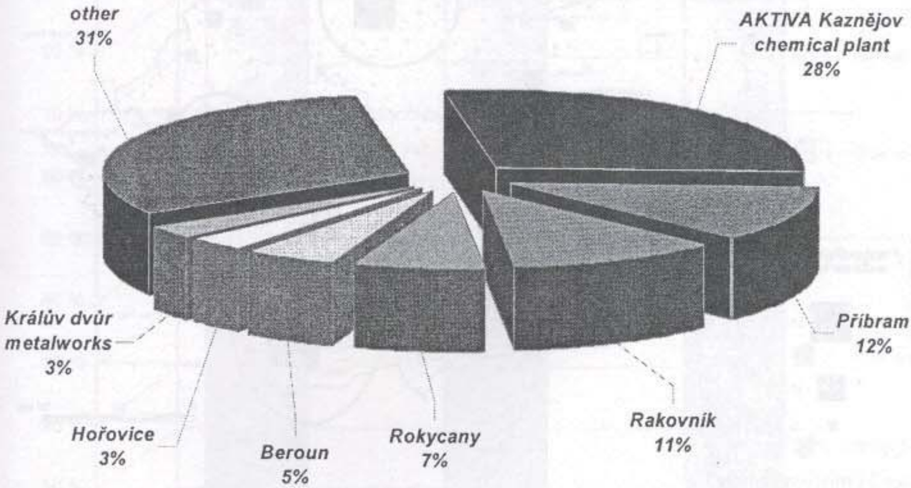
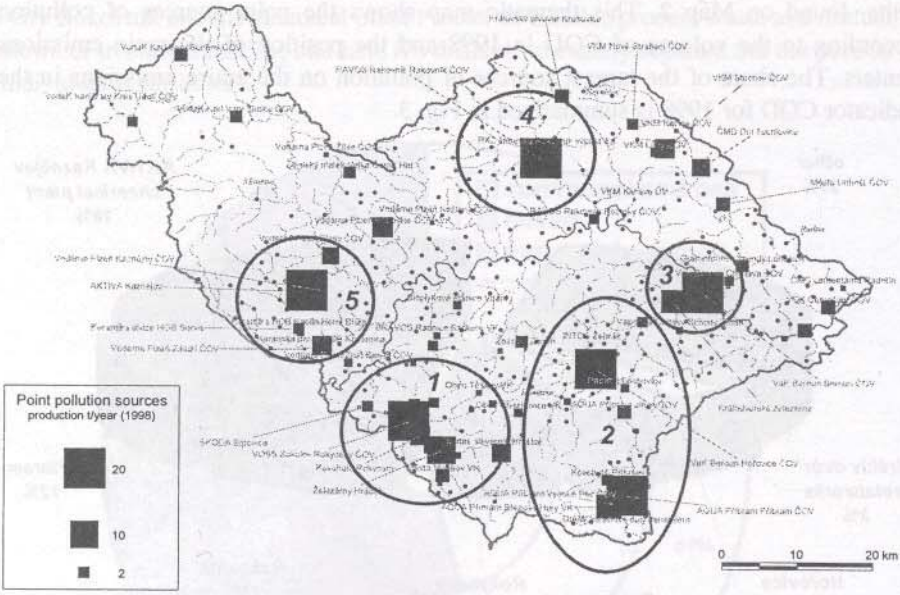


Fig. 3 Main point pollution sources (COD emissions, 1998)

Among the industrial sources of emissions, the chemical company Aktiva Kaznějov, situated on the lower basin of Střela river near Pilsen, holds the lion's share of responsibility. This is the absolute largest source of emissions of organic pollution and ammonia nitrogen in the entire Berounka river basin, which contributes to a full 66% of the emissions of COD from industrial sources. The chemical industry in the area of Rakovník and the machine industry in the regions of Rokycany, Beroun and Příbram also represent large sources of pollution.

Pollution from communal sources corresponds to the spread of main residential areas in the Basin. Similarly to that of industry, here dominate the areas of Příbram, Rakovník, Beroun and Rokycany. A decisive portion of these larger cities on the total emissions supports the fact that the cities of Příbram, Rakovník, Rokycany, Beroun and Hořovice produce 84% of the total volume of BOD-5 from the total of communal sources.

Beside the industrial and communal sources it is important to note the note the stress caused by point sources of agricultural origin. Typical example is a large capacity pig farm Velká Černá Hať, situated in relatively undisturbed area of the central Střela river basin, which takes the lead position among the other industrial complexes. The strong impact is caused mainly by extreme concentrations of nitrate nitrogen and organic material in the untreated wastewater, while the total volume of emissions is relatively low.



Map 2 Emission centres

3.5. Emission centres

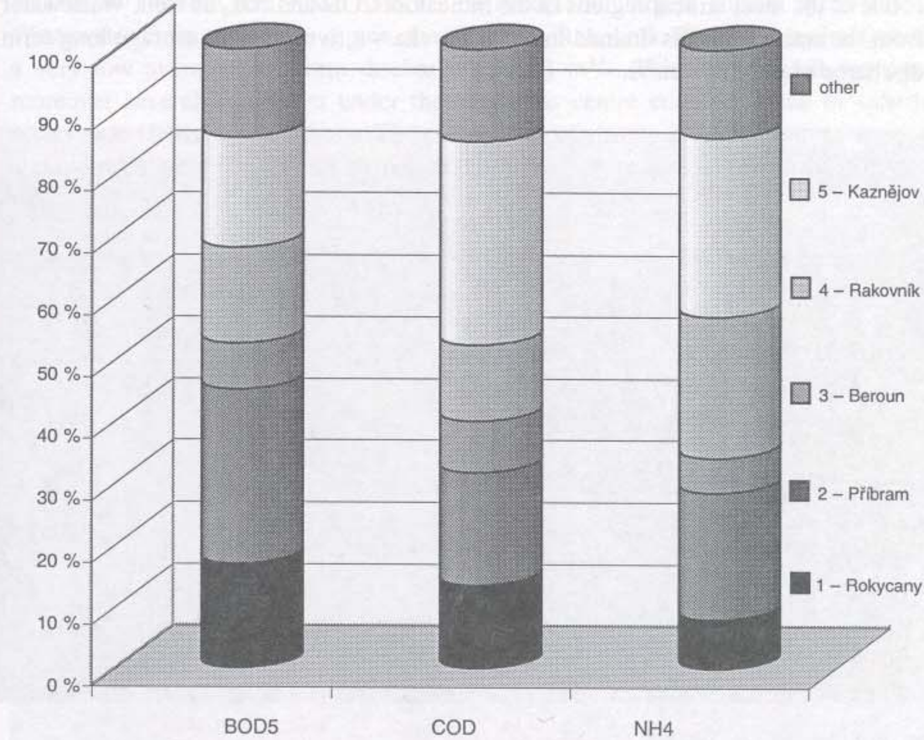
The level of spatial concentration of emissions of pollution and their can be characterized with the help of delimitation of so-called emissions centres. These generaly represent regions, characteristic by structure, type and territorial concentration of individual included sources of pollution and by their influence on the environment (Langhammer, 1999). On the basis of an analysis of spatial distribution of point and diffision sources of pollution and material balance of emitted pollution by them, it is possible in the Berounka river basin to mark out 5 main emissions centres (Map 2).

These regions take part in decisive measure on the overall material balance of pollution emitted in the Berounka river basin and on the impact on the quality of surface waters in local and regional measure.

The high level of concentration of emissions of pollutants in the Berounka river basin into five emission centres is supported by the fact that in all three main pollution indicators – BOD-5, COD and NH_4, the portion of these 5 regions on the overall emissions in the basin represents around 85% (Fig 3).

The importance of individual regions from the aspect of the influence on the quality of water is underscored by the generally low water level of recipients – the highest average discharge of all the streams, draining the main emission centers – Litavka and Klabava have an average discharge of around 2.5 m^3/s, the Rakovnický creek less than

1m³/s and the Kaznějovský creek under 0.2 m³/s. A minimum amount of polluiton from the total produced quantity runs directly into the main course of the Berounka.



	BOD5	COD	NH4
other	59.5	271.5	33.0
5 – Kaznějov	74.0	595.8	67.1
4 – Rakovník	64.4	224.2	53.3
3 – Beroun	31.3	150.7	12.9
2 – Příbram	117.0	328.6	47.5
1 - Rokycany	70.1	243.8	18.4

Fig. 4 Emission centres – emissions 1998 (t/y)

The first evaluated emission center is the industrial and residential region of *Rokycany*, situated on the central and lower course of the Klabava river NE from Pilsen. The concentration of mainly machine industry and relatively dense settlement in the area of Rokycany and Hrádek has an influence on the high overall volumes of emissions mainly in indicators of organic pollution – BOD-5 and COD. The negative impact of the region to the quality of surface waters is empowered by low average annual discharge level (2,1 m³/s) of Klabava river, draining the region into the Berounka river.

The second evaluated emissions centre is the region of the *upper and central Litavka river basin*, including the area of Příbram and Hořovice. This area dominates in production of organic pollution from communal sources in the indicator BOD-5, but is one of the most critical regions in the indicators COD and NH_4 as well. Wastewater from the entire region is drained into the Litavka – a river with an average long-term discharge of only 2.71 m^3/s.

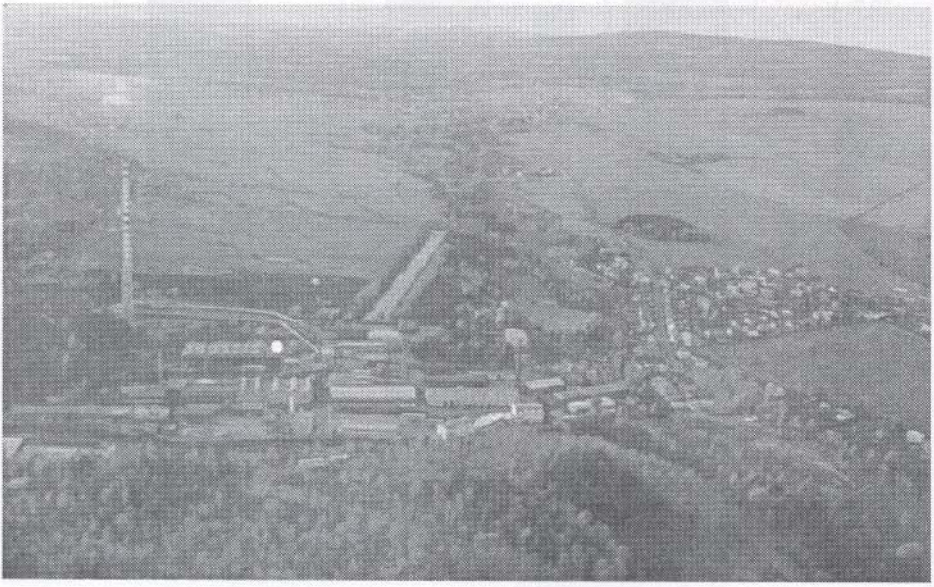


Photo 1 Příbram – metal works

In this area mainly machine, metalurgic and mining complexes around Příbram have an influence on pollution of surface waters, just as urban complexes. Moreover thanks to the traditional mining of non-ferrous metals and uranium, this area is an exceptionally meaningful source of emissions of heavy metals and radioactive materials. The risk of contamination of surface waters by mining water seepage continues even today despite the decline of mining activities in the area of Příbram at the beginning of the 1990s.

The emissions centre of *Beroun* represents the only more important region of direct emissions into the Berounka river body between Pilsen and Prague. From the aspect of the overall volume of emissions, this area is the weakest of the evaluated regions and includes in it aside from residential groupings of individual cities mainly the traditional heavy industry. These mainly include the Králův Dvůr metal works and cement factories in Beroun and Zdice, processing limestone mined from nearby Český Kras. The main element influencing the quality of surface water in this area though are emissions from the communal sphere, mainly waste from wastewater treatment facility of the city of Beroun.

The first evaluated emissions centre on the left bank of the Berounka river is the *Rakovník region*. Here we meet with a heavy residential and industrial concentration mainly in the city of Rakovník. There is a strong chemical industry – the factories of Procter & Gamble and RKZ Šamotka represent the largest source of pollution. Wastewater from the entire region runs into the Rakovník River – a recipent with a very low average long-term discharge of 0.83 m^3/s. This heavily polluted river moreover several kilometers under the emissions centre enters into the biospheric reservation CHKO Křivoklátsko. The coexistence of strictly protected natural reserve and industrial waste of the heavily polluted flow here represents an interesting paradox from the aspect of environmental protection.

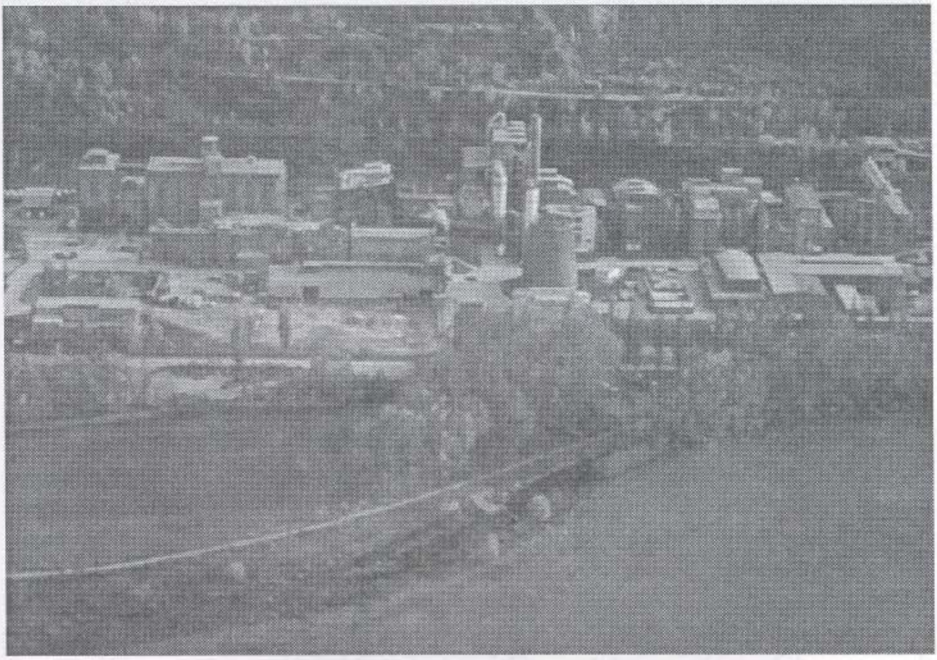


Photo 2 Králův Dvůr iron works

From the aspect of infuence on the quality of water in the Berounka river basin, the most critical is the smallest evaluated region – *Kaznějov*. This is a small area with a single but strong source of emissions – the chemical factory Aktiva Kaznějov. The region is first in overall balance of pollutions in the indicators NH_4 a COD, and the indicator BOD-5, in spite of the minimum residential density, ranks second behind the region of the Litavka river basin. Emitting a large amount of wastewater into the low capacity Kaznějovský creek evokes the occurrence of high concentrations of pollutants and heavy load to the consequent river system – the lower course of the Střela and section of the Berounka River below the confluence with the Střela, just as with the entire ecosystem of the area.

Photo 3 Rakovník – Procter & Gamble chemical plant

3.6. Dispersed sources of pollution

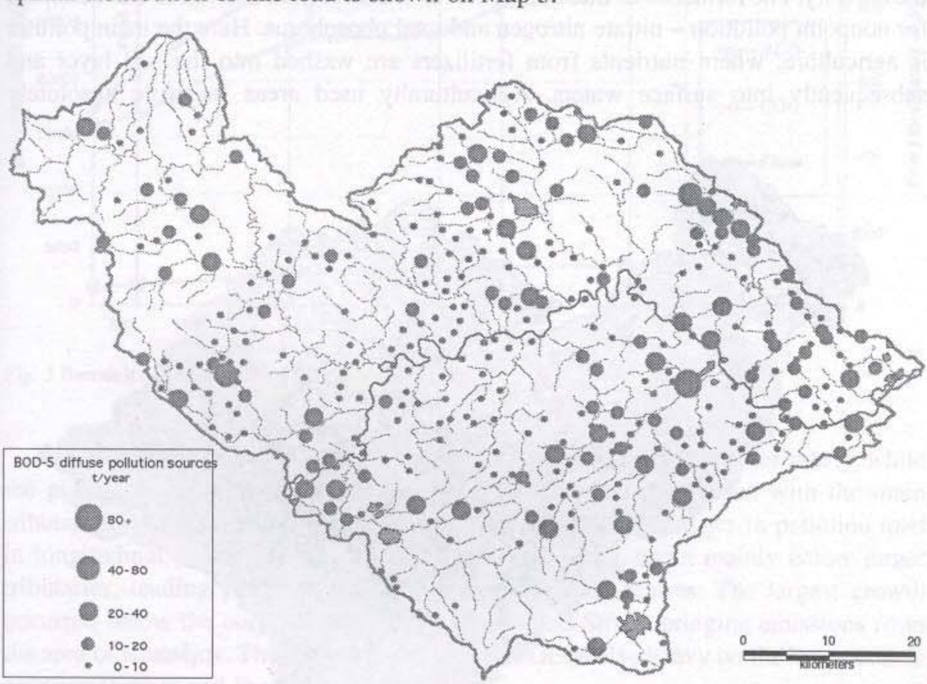
Communal sources, as the results of the emissions data analysis indicate, represent a fundamental part of the volume of expelled pollution. This data though cannot be considered to be final, since a large part of the population lives in small country communities, which don't have sewage works or even sewerage network and thus are not registered in the pollution sources registry – the SVHB database. The part of population, not connected to the wastewater treatment facility is high – in the Berounka river basin reaches 41%. For us to include pollution produced in these areas into processing, it's necessary to derive necessary data on the basis of a recalculation from indirect data, since direct data on expelling pollution from these small, "dispersed" sources of pollution, doesn't exist.

Many authors, mainly Piter (1996), Nesměrák (1997), Damaška and Jurča (1997), Just (1997) have developed various methods of calculation of pollution produced from dispersed sources from indirect sources. The most common ways of calculation are based on estimation of the average pollution load from one inhabitant per time unit. Various authors list values, which slightly differ from one another, and regularly take into account different conditions in various countries and times, while generally the consumption and production of waste related to it in the past decades has grown. For evaluating the balance of the load from diffusion sources in the Berounka river basin, values were used as introduced by Pitter (1990) – see Table 3.

Table 2 Average production of pollution

Indicator	Average pollution production g/ inhabitant/day
BOD-5	60
N	12
P	1.6

The actual calculation of the production of pollution from diffusion sources was based on a combination of the listed table of the average production of pollution with data from the Czech Statistics office on the number of residents in communities from 1991 to 1997. These were connected with the GIS layer of settlements, while communities connected to wastewater treatment facility were excluded. The recalculation was made according to the listed coefficients for the indicator BOD-5. The overall volume of potential production of BOD-5 from diffusion sources of pollution on the Berounka river basin in the overall calculation of 144, 649 citizens not connected to wastewater treatment facility in 1997 amounted to 3,167 tons/year. Spatial distribution of this load is shown on Map 3.



Map 3 Dispersed pollution sources

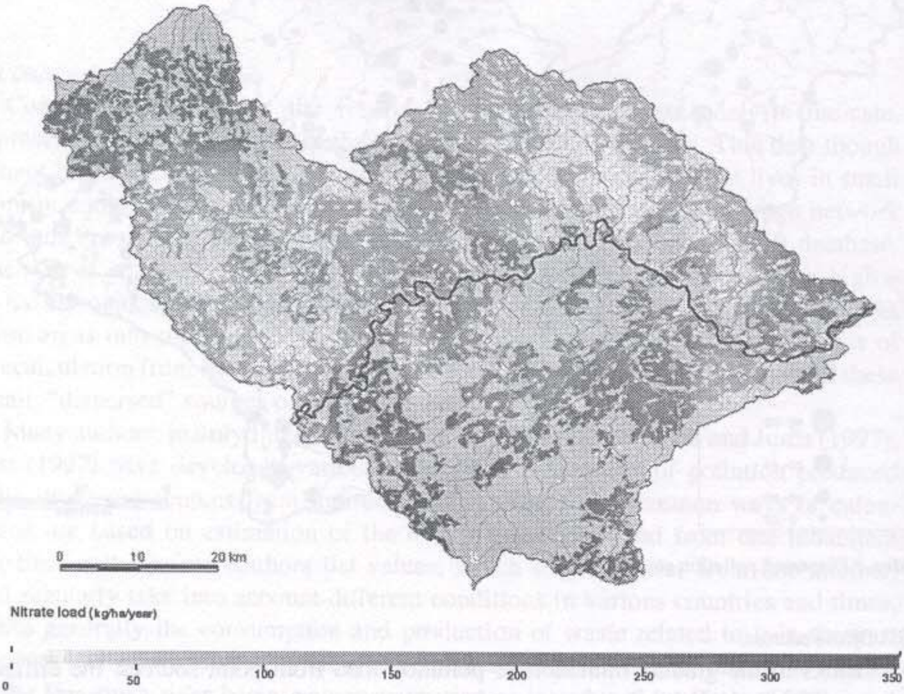
3.7. Diffuse sources

Thanks to the gradual limitation of pollution load from point sources, the diffuse sources of pollution of surface waters represent an every-growing component of the total material balance of the Elbe River Basin, while the Berounka river basin is no exception.

However, the quantification of non-point pollution sources impact on the pollution of surface water meets with a number of obstacles in practice. The fundamental problem is that the degree of pollution removed by surface and sub-surface runoff from a basin area cannot be directly measured, unlike the pollution from point sources. Therefore all methods of evaluation of nutrient load from non-point pollution sources represent more or less indirect approaches.

The calculation of the pollution load from diffuse sources was performed with the help of a grid-based model NPSm, developed by the author (see Langhammer, 2002).The model stems on application of method of typical concentrations in the GIS MapInfo Professional/Vertical Mapper environment. The key elements of the model were runoff volume and landuse structure expressed in a regular grid with cell size of 100 x 100 m. These values were combined with the table of typical concentrations of pollutants for individual land use classes. The annual material loss was simulated in the parameters BOD-5, N-NO_3, total Phosphorus and suspended solids.

The results of the simulation confirmed the decisive influence of two main driving forces of the model – the runoff height and landuse, on the resulting material loss from the territory. The influence of these components is best seen in indicators characteristic for nonpoint pollution – nitrate nitrogen and total phosphorus. Here the main polluter is agriculture, where nutrients from fertilizers are washed into the soil layer and subsequently into surface waters. Agriculturally used areas therefore absolutely



Map 4 Diffuse pollution sources – nitrate load 1998

dominate in the loss of nitrates, while the actual size of the loss depends on the character of the land use more so than on total organic pollution. We can see the greatest loss in agricultural areas of the Klabava and Litavka River Basins, but also in the dry regions of the Střela river basin.

4. Water quality

4.1. Growth of pollution load in the longitudinal profile

The volume of the pollution load in the longitudinal profile of the Berounka more or less mimics the growth of the overall runoff from the surface of the basin, while the basic level of pollution is set by the level of emissions from the Pilsen Agglomeration.

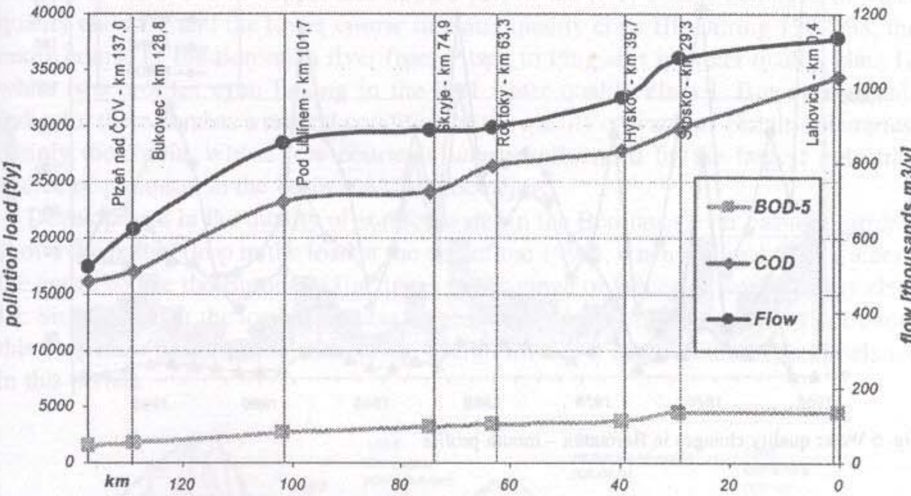


Fig. 5 Berounka – pollution load in longitudinal profile

The growth in the BOD-5 load in the longitudinal profile is moreover steady, while the places of the highest growth are represented by the confluence with the main tributaries – Klabava, Střela and Litavka. More significant changes in pollution load in longitudinal profile are found for the indicator COD, again mainly below larger tributaries, leading pollution from the main emissions centres. The largest growth occurred below the confluence of the Berounka and Střela, bringing emissions from the area of Kaznějov. The growth in the loss of COD is also heavy on the lower course between Beroun and Prague.

4.2. Development of water quality of Berounka river

The quality of water in the Berounka, similar to the majority of rivers in Europe, underwent significant changes throughout the 20^{th} century. Thanks to strong industrialization of mainly Pilsen, but also of other emissions areas, pollution of the Berounka has sharply increased since the mid-20^{th} century. The first turning point from the aspect of long-term development occurred in the mid- 1970s, when production using cellulose sulfite technology ended in the Pilsen paper mill, which was emitting practically untreated wastewater with extreme concentrations of organic pollution. Also at this time limitation was enforced on the load of wastewater from the Aktiva Kazнějov chemical factory. These steps evoked rapid and strong improvement of the otherwise long-term poor state of the water quality of the Berounka. Since the 1970s there have also been other minor improvements, mainly in the second half of the 1990s thanks to modernization of wastewater treatment facility in Pilsen at the end of the 1990s. A drop in pollution is mainly apparent in organic pollution, just as in the load by ammonia.

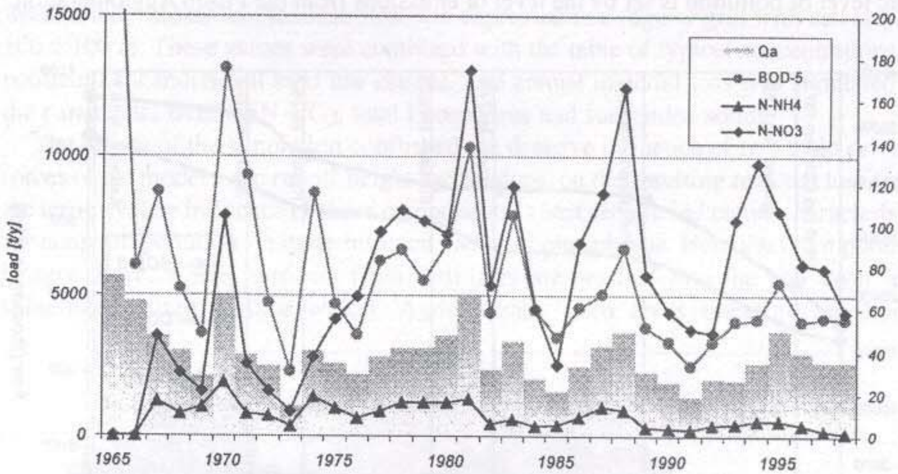


Fig. 6 Water quality changes in Berounka – mouth profile

4.3. Quality of surface waters in the Berounka river basin

Evaluation of the development of the quality of surface waters in the Berounka river basin is based on analysis of time series of water quality analyses on a total of 14 control profiles. This data was connected with the GIS layer and from this was created a set of thematic maps of the chronological development of the water quality of surface waters in the Berounka river basin. For mutual comparison of data from different waterbodies, classification was used according to the characteristic values pursuant to Standard ČSN 75 7221 and consequent classification into one of five water quality classes.

Four time levels of evaluation were chosen – the period of 1988–89, 1992–93, 1994–95, and 1997–98, which represent the main stages in the development of the water quality in the Berounka river basin during the 1990s. The evaluation was performed for the main indicators of pollution by organic matter and components of nitrogen and phosphorus.

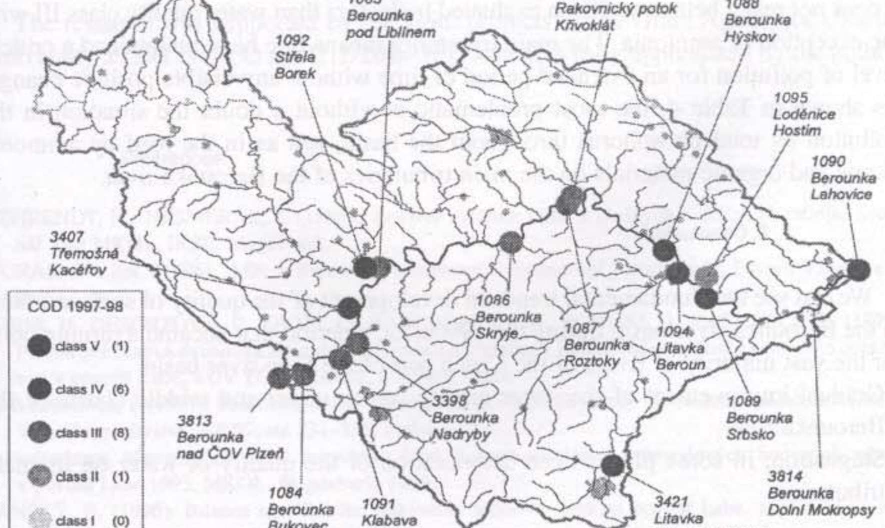
The analysis showed that in the pollution of surface waters of the Berounka river basin by organic materials, mainly *BOD-5*, in the 1990s there occurred only partial and overall not very significant changes. The entire main course of the Berounka lies in the water quality class III even at the end of the 1990s, where it was in the period from

1988 to 1989. The quality of water in the mouth of the profile of the Střela and the profile of the Litavka below Příbram agglomeration is constantly critical, where in the last evaluation period the load reached its worst level, i.e. water quality class IV.

Minor improvement can be seen in the upper and mid course of the Berounka in overall organic pollution – *COD*. While at the turn of the 1990s the entire course of the Berounka river between Pilsen and Prague belonged in water quality class IV, in the period from 1997 to 1998 the profiles between Pilsen and Hýskov have shifted to class III. The trend of the gradual increase in water quality in this indicator appeared already in the mid-1990s.

Perhaps the most significant qualitative jump was made by the development of pollution of watercourses in the Berounka river basin in the indicator of *ammonia*. At the end of the 1980s the upper and middle part of the river course belonged to water quality class IV, and the lower course in water quality class III. During 1997–98, the entire course of the Berounka river from Pilsen to Prague is in water quality class II, while two profiles even belong in the best water quality class I. But even in this indicator there persists a critical condition of the quality of water of certain tributaries, mainly the Střela, whose low course is utterly influenced by the largest industrial source of pollution in the basin – Aktiva Kaznějov.

Development in the quality of surface water in the Berounka river basin in *nitrates* shows the partial drop in the load at the end of the 1990s, when the quality of water of the entire course the Berounka fluctuates in the range of values of water quality class III. Since however the load of nitrates comes mainly from diffuse sources of pollution, this drop must be seen in relation to the overall low level of the rainfall-runoff balance in this period.



Map 5 Berounka river basin – water quality in the profiles – COD 1997–98

Pollution of surface waters of the Berounka river basin by *phosphorus* hasn't recorded any important changes during the 1990s. In the section of the Berounka below Pilsen there occurred a partial drop in the load as a consequence of opening the new Pilsen wastewater treatment facility. The quality of water in this section reaches values of water quality class III, while the remainder of the course is still in water quality class IV. Constantly critical is also the quality of water of the Rakovnický creek and the Litavka river below Příbram, which even in the period 1997–98 reached the worst water quality class V.

Table 3 Water quality profiles in class IV or V.

Water quality profile	*Declassing parameter (water quality class IV. or V.)*
Berounka-Hýskov	Total phosphorus
Berounka-Lahovice	Total phosphorus
Berounka-Nadryby	Total phosphorus
Berounka-Beroun	Total phosphorus
Berounka-Srbsko	Total phosphorus
Berounka-Lahovice	Total phosphorus
Berounka-Srbsko	COD
Litavka-Beroun	COD, Total phosphorus
Litavka Trhové Dušníky	COD, N-NH4, Total phosphorus
Loděnice	Total phosphorus
Rakovnický potok	N-NH4, Total phosphorus
Střela	BOD-5, COD, N-NH4, Total phosphorus
Třemošná	BOD-5, COD, N-NO3, Total phosphorus

Despite indisputable positive changes in the quality of water in the Berounka river, it does not reach better results on evaluated indicators than water quality class III with the exception of ammonia. The main tributaries meanwhile have maintained a critical level of pollution for an extended period of time without any visible positive change. As shown in Table 4, the most problematic is without a doubt the situation in the pollution by total phosphorus throughout the basin, just as in the load by ammonia nitrate and organic materials on the main tributaries of the Berounka river.

5. Conclusion

We can see two fundamental trends in development of the quality of surface waters in the Berounka river basin during the 1990s, i.e. a period that became a turning point for the vast majority of rivers of the Czech part of the Elbe river basin:

- Gradual improvement of the water quality on the upper and middle course of the Berounka river.
- Stagnation, in some places even deterioration of the quality of water on its main tributaries.

The causes in the drop in pollution of the Berounka river in the upper and middle course must be found mainly outside the boundaries of the Berounka river basin. To a large extent the City of Pilsen itself determines the quality of water in the Berounka river. It was the startup of operation of the new water treatment plant in Pilsen at the beginning of the 1990s that really stands behind the drop in the load to the Berounka on its upper and middle courses.

As opposed to this the tributaries, represented in general by small streams, remain even at the end of the 20th century under the heavy influence of massive pollution. The origin of this pollution is in both the slower drop of emissions from local industry and settlements, and also in large extent in agriculture. The problem of the load from agricultural sources, so far not solved, is more and more taking part in the slowing of the further drop in pollution of surface waters of Berounka river. For the Berounka river basin, this development has caused gradual increases in the differences in water quality of the main course and its main tributaries, and analogically is the general situation of a large part of the Czech part of the Elbe River Basin.

Results of the performed analysis show that partial improvement in the quality of water in the Berounka river, occurring in the majority of indicators in the 1990s was not accompanied by the same development at key tributaries. Further development in the water quality of the Berounka river is closely tied to the development in these affluents. This is mainly a question of the Střela river basin, the Rakovník region, the Litavka and the Třemošná river basins. Without a decrease in the constantly high level of emission load on these tributaries, it is not possible to expect any significant changes in the quality of water of the Berounka, mainly on its middle and lower course

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KVALITA POVRCHOVÝCH VOD V POVODÍ BEROUNKY

Résumé

V průběhu 90. let došlo v české části povodí Labe k zásadnímu obratu ve vývoji kvality povrchových vod. Po dlouholetém nárůstu úrovně znečištění došlo díky snížení emisí z hlavních průmyslových a komunálních zdrojů k poklesu úrovně zátěže Labe i jeho nejdůležitějších přítoků. Rozsah a rychlost těchto změn v kvalitě vody je bezprecedentní jak v rámci ČR, tak i v evropském měřítku.

Pokles úrovně znečištění však je však omezený víceméně pouze na Labe a jeho hlavní přítoky. Velká část drobných vodních toků, zejména v zemědělské krajině i nadále trpí nadměrným znečišťováním z průmyslových a komunálních zdrojů, stejně jako intenzivní zemědělskou výrobou.

Příkladem povodí, kde se střetávají obě tyto tendence je tok Berounky mezi Plzní a Prahou. Hlavní tok – Berounka zaznamenává obdobně jako většina významných toků v průběhu 90. let pokles zátěže emisemi, především díky modernizaci ČOV v klíčovém bodě – Plzni. Naproti tomu přítoky Berounky, tvořené drob-

nými vodními toky zůstávají pod silným vlivem průmyslového, ale i komunálního znečištění z jednotlivých regionů. Díky postupnému omezování emisí z bodových zdrojů navíc stále významnější roli hraje zátěž ze zemědělství.

Výsledky provedených analýz ukazují, že částečné zlepšení jakosti vody v toku Berounky, ke kterému ve většině ukazatelů v devadesátých letech došlo především díky zprovoznění nové ČOV Plzeň, nebylo doprovázeno stejným vývojem u klíčových přítoků. Další vývoj kvality vody Berounky je úzce spjatý s vývojem v těchto povodích. Jedná se přitom především o povodí Střely, Rakovnického potoka, Litavky a Třemošné. Bez snížení stále velmi vysoké úrovně imisní zátěže těchto toků nelze počítat s výraznými změnami v kvalitě vody Berounky, zejména na jejím středním a dolním toku.