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WATER QUALITY CHANGES IN SELECTED RURAL CATCHMENTS IN THE CZECH REPUBLIC

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Abstract

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The article presents the results of the analysis of the surface water quality changes in selected rural catchments in the Czech Republic. Three river basins are used as examples – the Blšanka, Loučka and Olšava river basins. These river basins have been facing long-term problems with surface water quality and, as in many similar rural areas there has been lack of information on water quality changes. The areas are located in regions with different physiogeographical characteristics as well as the varying scope and intensity of socio-economic activities. Individual catchments show a range of similar aspects associated with the distribution of pollution load and trends of the surface water quality. However, at the same time, many differences in the dynamics of trends of changes in water quality development exist. In spite of the fact that the crucial problems concerning the surface water pollution are similar, they differ in the characteristics of time changes in water quality as well as in the spatial distribution of load within the water basin. Due to the low average discharges of all recipients, both local municipal and industrial point sources of pollution play significant roles there however they are scarce. Considering the majority of basic indicators, long-term negative trends concerning the water quality development are observed in all assessed river basins. This trend, typical for many rural areas is opposite to the water quality development at the main river courses. Moreover, because of continuing intensive load from the non-point sources no significant improvement in water quality can be expected in the near future. The adoption of effective measures is currently hindered in part by the deferral of the application of the European legislation in the area of the construction of waste water treatment plants at middle-sized and small-sized settlements.

Key words: water quality, pollution, GIS, soil erosion, agriculture, emissions

Introduction

The surface water quality in the Czech Republic has experienced considerable changes during the recent two decades. While the period of the end of the 80s represents historically unexceeded peak of the load of aquatic environment caused by pollution, from the middle of the 90s, the volume of pollutant discharge was radically reduced. Subsequently, the water quality improved in the majority of significant watercourses in the Czech Republic (Langhammer, 2004; Janský, 2002). However, this development is limited to the areas of big watercourses, specifically, to their middle and lower courses. Small watercourses in rural landscape are, on the contrary, still exposed to the intensive pollution and their water quality thus stagnates and in many areas even deteriorates (Langhammer, 2005). For many of such small catchments we do not have sufficient information on trends in water quality changes and on the spatial distribution of load. This impedes the identification of the critical areas as well as the adoption of effective measures to protect river basins against pollution.

The article is focused on the analysis of changes of surface water quality and material transport in three model river basins. These river basins represent source areas of load of important watercourses in different geographical regions of the Czech Republic – the river basins of Blšanka, Loučka and Olšava. These river basins are comparable in terms of their size and structure of land use with prevailing agriculture. They are situated in areas with varying physiogeographical conditions and different socio-economic development. The main attention was focused on analysis of the distribution of main pollution sources, the analysis of the spatial distribution of erosion risk, the analysis of the transport of suspended sediments and on the analysis of surface water quality changes. This was assessed both from the viewpoint of the long-term development and from the viewpoint of the spatial distribution of specific pollution load on the basis of the own network of the water quality sampling sites. The results are discussed and compared with general trends in the spatial and time dynamics of water quality changes in the Czech Republic and Europe.

Material and methods

Model river basins

The selected model river basins of Blšanka, Loučka and Olšava, each of them covering the area of 350–400 km^2, represent different geographical environments in terms of the geology, geomorphology, climate, soils and hydrological conditions. On the contrary, what these areas have in common is the fact that they are mostly used for agricultural activities and are situated at the divides of major Czech river basins (Fig. 1).

The *Blšanka river basin* is situated in a relatively warm and dry area in the rain shadow of the Krušné hory Mts , which is resulting in low average discharge levels. The area of the river basin in its mouth profile in Holedeč is 374.1 km^2. The river basin is situated in the region of Žatecko that is intensively used for agriculture. In the Blšanka river basin no bigger settlement can be found, the total population is 14 thousand inhabitants (ČSÚ, 2008). Almost two thirds of the river basin consists of agricultural land while 90% of the agricultural land is used as arable land (Fig. 2). Further, hop-gardens have a significant position here; they cover 6.4% in total of the river basin area. Besides hop, the growing of grain, colza and forage crops are important.

The *Loučka river basin* is situated in the agricultural area of the Vysočina region. Similarly to the Blšanka river basin, the settlement is scarce. The river basin occupies the area of 385.7 km^2 up to the mouth profile in Dolní Loučky. Agricultural land represents over 70% of the river basin area while the share of arable land reaches almost 60% of the overall river basin area. The number of inhabitants living in this river basin is over 26.5 thousand. The most important city, Nové Město na Moravě, with 10 thousand of inhabitants, is situated in the headwaters of the river basin. The size of other settlements here usually does not exceed 1000 inhabitants. The agricultural production is focused on the growing of root crops, grain, colza, beef and pork farming.

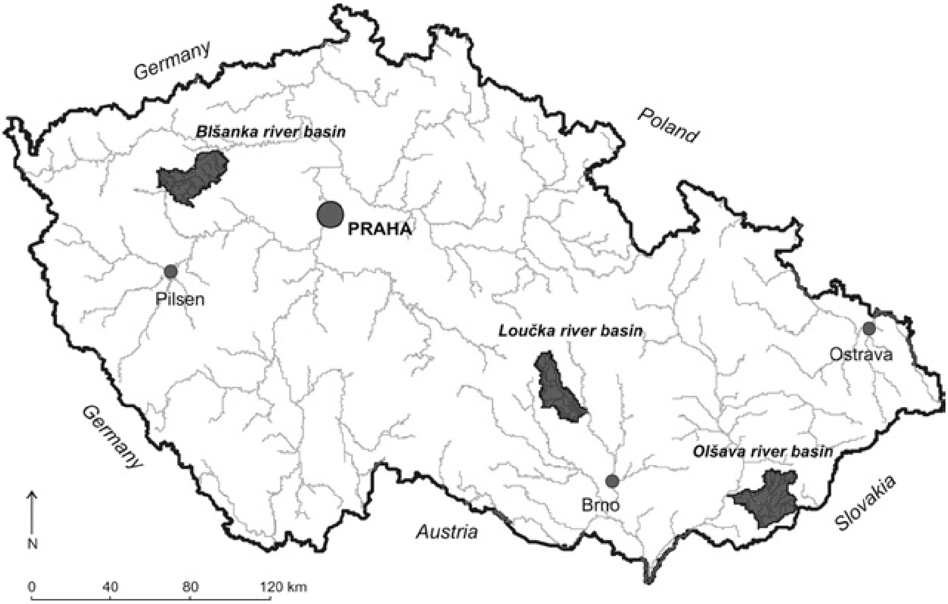

Fig. 1. Geographical position of model river basins.

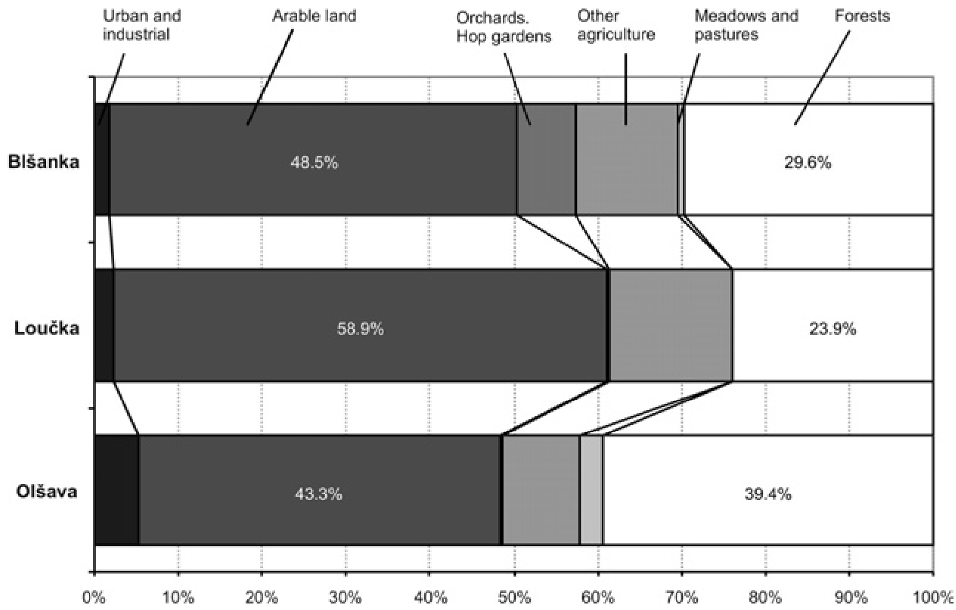

Fig. 2. Structure of land cover in the model catchments. Data: CORINE Landcover, MŽP, 2008.

The *Olšava river basin* is situated in the south of Moravia in the territory of the Zlín region, in the area of the Bílé Karpaty Mts at the border with Slovakia. The total area of the river basin up to the station in Uherský Brod is 401.1 km^2. The total number of 50.3 thousand inhabitants lives in this river basin (ČSÚ, 2008). The biggest settlements are Uherský Brod (17.5 thousand inhabitants) and Luhačovice (5.6 thousand inhabitants). The density of population in this basin is the highest out of the assessed areas. Important role in the pollution emissions here has besides the agriculture and settlement the industry. The centre of industrial activities is concentrated in Uherský Brod (Česká zbrojovka, a.s., Slovácké strojírny), however, some industrial sites can be also found in smaller communities. The agricultural production is focused on the growing of more demanding kinds of grain, and the beef and pork farming is also important (Kliment et al., 2003).

Applied methodology

The performed analyses were focused on the assessment of the source pollution load of the assessed river basins, the analysis of the spatial distribution of erosion risk as a significant factor conditioning material transport from the river basin area, the assessment of the water quality development, the analysis of specific pollution load and the classification of the dynamics of trends of water quality changes. The methodology of erosion risk assessment and the classification of the dynamics of the water quality changes trends and other applied procedures are described in this chapter.

Effect of physiogeographical factors on erosion risk and material transport

The physiogeographical factors have mainly an indirect effect on the material transport and surface water quality. The overall predisposition of the area to the nature and intensity of anthropogenic use is concerned in particular. However, at the same time, direct effects on the mechanism of the material transport from the river basin area are also concerned, mainly in association with water erosion.

The assessment of physical-geographical factors influencing the transport of material from the river basin was performed by means of the model of the river basin erosion risk. This model was established for each individual river basin. The model was based on the multi-criteria assessment of main erosion factors and was implemented in the form of the distributed grid model in the GIS environment. The aim was especially to express spatially the distribution of erosion risk in the model river basins, to compare their potential for the transport of suspended sediments and to define the main risk areas in individual river basins.

When modeling the erodibility, four main factors were selected that influenced the involvement and course of the erosion process: *relief, geological factor, soil erodibility factor and the land use factor. Precipitation factor* was added to these four factors as an independent variant entry. The method is based on point assessment – underlying input data for each factor are classified into a 6-grade scale according to their contribution to the water erosion risk. The values of the resulting assessment range from the possible minimum to the maximum, i.e. from 4 to 24 points. The classification table is organized according to a 5-grade scale (Table 1).

T a b l e 1. Soil erodibility model. Classification of intensity of potential soil erosion risk.

Soil erodibility class	Points	Class description
1	4–7	no risk
2	8–11	low risk
3	12–15	medium risk
4	16–19	strong risk
5	20–24	extreme risk

There were applied three versions of the erosion risk model. The basic version marked as L_G_P_S worked with identical weights for all assessed factors. The model version 2L_G_P_S, emphasizing the land use factor as virtual substitution to the excluded slope length factor. To the extended version marked as L_G_P_S_R there were the rainfall factor added. More detailed description of the model concept and application is given in Kliment et al. (2007).

Analysis and classification of water quality changes dynamics

Analysis of water quality data is based on standard statistical methods of time series treatment. The classification of water quality classes was performed according to the methodology stated in the water quality classification standard ČSN 757221. This standard sorts the observed water quality into 5 classes where class 1 represents the best and the class 5 the worst quality. The assignment is based on comparison of standard value C_{90} with the set of thresholds for individual parameters. The standard value $C_{90}$is calculated as the 90% percentile from two-year time series of measurements.

The classification of water quality changes trends dynamics is based on methodology comparing the trends of changes in main time periods with general evolution models derived for the large-scale areas (Langhammer, 2005). The assessment is based on the statistical evaluation of a set of time series of concentrations of selected water quality indicators in individual profiles. The assessment of the change dynamics at the assessed river basins stems from the calculation of linear regression trend lines for selected time periods representing important stages in water quality evolution in river basin.

T a b l e 2. Thresholds for classification of trend line slopes describing the trend of water quality changes in predefined time period.

Trend	Flag	Threshold
Concentration rise	+	> 0.002
Stagnation	0	–0.002 – 0.002
Concentration decline	–	< –0.002

According to the calculated trend line slopes the trends are classified as rising, stagnating or declining using the thresholds stated in Table 2. The resulting model of evolution for individual parameters at individual profile is derived according to the combination of trends in all assessed time slices. The assignment is based on the classification table (Table 3) and is performed the rule-based classification via database querying.

The following 6 basic models describing the basic types of water quality evolution dynamics specified as A-F were identified in the Czech Republic (Table 3).

T a b l e 3. Main water quality evolution models in the Czech Republic (Langhammer, 2005).

Model	Description	1970–1979	1980–1989	1990–1999	1999– present
A	stagnation	0	0	0	0
B	constant rise	+	+	+	+
C	constant decline	–	–	–	–
D	decline after 1990	+/0	+/0	–	–/0
E	decline before 1990	+/0	-	-/0	-/0
F	rise after 1990	+	+/0	-/0	+

The A model represents the type with the stagnating development of water quality in the long-term. The B model represents watercourses with a continual increase in the pollution concentrations. The C model, on the contrary, represents watercourses with a continual decrease in the load level. The D model is characteristic for many middle-sized and large-sized watercourses which experienced a rapid decrease in pollution after the year 1990. Already before the year 1990, we can observe a decrease in the load of many watercourses that were intensively used in the history (the E model). On the contrary, many small-sized watercourses in particular experience an increase in load after a prior fall during the last decade – the F model.

Source data

The data out of Water balance filed in the HEIS geodatabase (VÚV, 2005) was used as basic information on the production of pollution. The BOD-5, COD and N-NH_4^+ parameters were assessed.

The surface water quality was assessed on the basis of two main data sources:

1. Long-term monitoring of water quality and suspended sediments transport in the profiles of the CHMI state network in the period from 1970 to 2000 (ČHMÚ, 2008).
2., Own monitoring of suspended sediment transport in the Blšanka river basin from 1995 to 2004 in the framework of the presented projects.
3. Own monitoring network of water quality in model catchments of sampling profiles with the sampling carried out in the period from 2000 to 2002 in the framework of the presented projects.

Our own network of water quality monitoring was established for individual river basins in the range of 8 to 10 profiles reflecting the water quality conditions in individual sub-basins. The main objective of monitoring was to analyze the spatial distribution of pollution load within the river basin area. This information supplemented the data from the state network that is available only for the river mouth profile. The sampling was carried out once a year and for the Loučka river basin, four times a year.

The GIS assessments were based on the DMÚ-25 geodatabase originating in digital military maps with precision adequate to 1:25000 (VTOPOU, 2005). The basic topographical layers were complemented by the CORINE Land cover layer (MŽP, 2008) and Digital Water Management Map (VÚV, 2008).

Laboratory analyses based on our own sampling were carried out in the Institute for Environment of the Faculty of Natural Science of Charles University in Prague and in the Elbe River Basin Authority laboratory in Děčín (the assessment of suspended sediments in the Blšanka river basin).

Results

Pollution sources and specific pollution load distribution

In all assessed model river basins the agriculture is a dominant element in land-use structure and thus the agricultural activities are important source of nonpoint as well as point pollution of surface waters. In spite of this, there are significant differences among the assessed river basins in terms of spatial distribution, size and structure of direct point sources of surface water pollution. In the model river basins, there are no significant direct industrial sources of pollution registered and included into the monitoring within international programmes (Behrendt, 1996; ICPDR, 2005; IKSE, 1991). The only registered sources are the municipal wastewater treatment plants in the towns of Uherský Brod and Luhačovice in the Olšava river basin and the waste water treatment plant in Nové Město na Moravě in the Loučka river basin.

The agricultural production is determining for the character of surface water pollution in the *Blšanka river basin*. The population density in the Blšanka river basin is the lowest out of the assessed river basins. The only one direct emission source with the total volume of discharged waste water exceeding 100 000 m^3 per year is the waste water treatment plant in the municipality of Kryry.

In the *Loučka river basin*, there is only one significant point emission source – the wastewater treatment plant in Nové Město na Moravě. Due to its position at headwaters this source sets the level of pollution level for the Bobrůvka and Loučka rivers on the remaining sections of the watercourses as well as due to the low average discharge of the recipient. The load from other sources is of local impact in the overall pollution volume balance, however, it is significant for water quality of small recipients.

The highest concentration of both the settlement and industry out of the assessed river basins can be found in the *Olšava river basin*. The biggest surface water pollution source is the area of Uherský Brod where significant industrial sources of pollution can be found. The second important area is the Luhačovice region where the low number of permanent residents increases considerably during the year thanks to health resort tourism. The volume of discharged waste water exceeds 2 million m^3 per year at both emission centers. Potential load from all municipal sources in the Olšava river basin is two times higher than the values obtained from the Loučka river basin and almost four times higher than the values obtained from the Blšanka river basin within comparable areas (Table 4). The intensive livestock rearing in the middle part and lower part of the watercourse affects the surface water pollution significantly. The livestock rearing represents a strong pollution source of regional impact which is, in addition, not registered within the point pollution sources database.

T a b l e 4. Emissions from direct point pollution sources in assessed river basins. Data: HEIS VÚV.

River basin	Number of registered point pollution sources	Emissions BOD-5 [t/year]	Emissions COD [t/year]	Emissions $N\text{-}NH_4^+$[t/year]
Blšanka	22	18.43	41.89	8.84
Loučka	12	48.93	105.04	3.59
Olšava	30	177.67	422.07	52.48

The differences in load from point sources in individual river basins registered within the HEIS database are substantial. The Blšanka river basin has the lowest level of load. The load of the Loučka river basin reaches more than double values regarding the volume of both BOD-5 and COD emission. The Olšava river basin reaches almost ten times the amount of the volume registered in the Blšanka river basin for BOD-5 and COD indicators.

The analysis of specific pollution load (SPL) based on the results of own monitoring network provided information on the spatial distribution of the intensity of load in assessed river basins. The assessment was based on the data obtained from the monitoring network established in the river basins in the years 2000–2002.

The comparison of values regarding the total pollution load obtained from individual river basins confirms the differences arising out of the different character and intensity of use of the respective areas.

T a b l e 5. Average specific pollution load in model catchments.

River basin	Specific pollution load ($t.km^{-2}.year^{-1}$)			
	BOD-5	COD	N/NO3	Ptotal
Blšanka	0.38	2.18	0.33	0.016
Loučka	0.94	4.40	1.64	0.090
Olšava	1.75	6.02	0.73	0.041

Data: CHMI (Blšanka and Olšava; time period 1970–2004), ZVHS (Loučka; time period 2002–2004)

The Olšava river basin seems to carry the highest amount of pollution load regarding the parameters of organic pollution and to the components of phosphorus and nitrogen with the exception of nitrates. The lowest values of SPL are definitely found in the Blšanka river basin and, with the exception of nitrates, also in the Loučka river basin where the high values of SPL relating to this indicator correspond to the largest area of arable land out of the assessed river basins (Table 5).

The spatial distribution of SPL within the individual basins is highly irregular and generally corresponds to the distribution of causal pollution sources (Fig. 3).

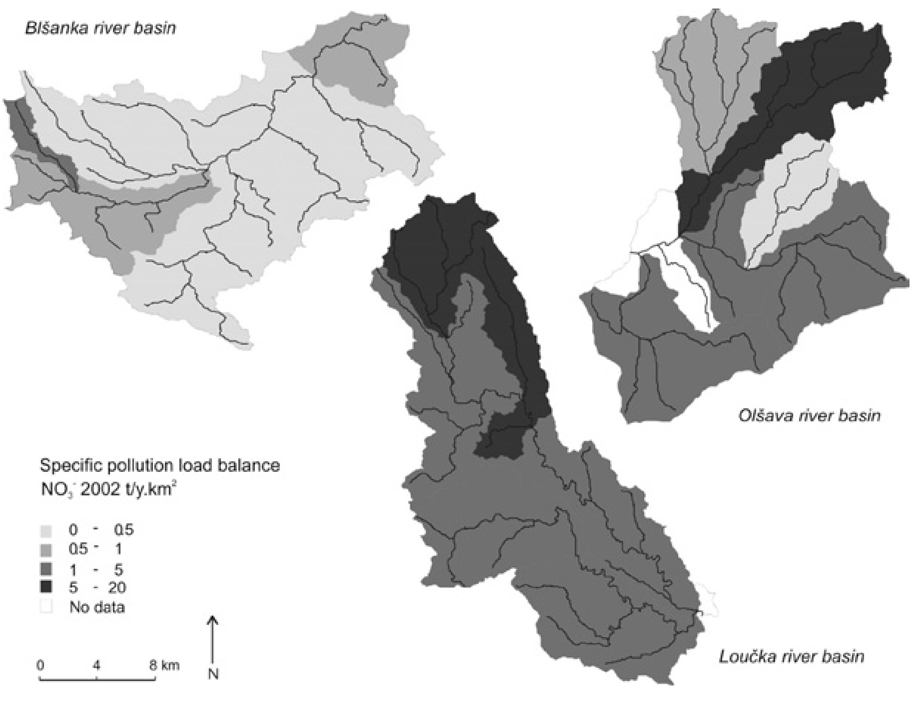

Fig. 3. Spatial distribution of specific pollution load of nitrates in Blšanka, Loučka and Olšava river basins in 2002. Data: Charles University in Prague, 2008.

In the *Blšanka river basin* the nine balance sub-basins were delimited. The areas with higher population density in the middle and lower parts of the river basin carry most of the load of organic pollution as well as of ammonia nitrogen. The SPL of nitrates reaches the highest values in the middle and lower course where the largest areas of arable land can be found including hop-gardens. The lowest SPL rates concerning the total phosphorus indicator are reached in left-side affluents of the Blšanka watercourse, in the middle course (Fig. 5).

In the *Loučka river basin,* divided into eight sub-basins, the maximum values of SPL of organic pollution are found on the contrary in the upper part of the river basin, in the area of Nové Město na Moravě. The lowest values are observed in the middle and lower part of the river basin and on the left-side affluents. The spatial distribution of specific pollution load by ammonia nitrogen is homogenous within the river basin with the exception of the lower part of the river basin.

The highest values of SPL by nitrates correspond to the occurrence of arable land in the upper part of the Loučka river basin and in the area of the middle and lower course of the Libochovka; the lowest values are observed in the lower part of the river basin.

The *Olšava river basin* was divided into 10 sub-basins and, compared to the Blšanka and Loučka river basins it shows the highest SPL values in majority of indicators.

The SPL of organic substances and ammonia nitrogen is concentrated mainly in the downstream area near Uherský Brod and in Nivnička sub-basin where the density of population and the concentration of industry is the highest.

The absolute values of SPL by nitrates reach the maximum among the river basins compared. The distribution of pollution intensity in almost the whole area of the river basin is even. The most important source area of pollution is the Luhačovický potok creek and the middle part of the Olšava river basin. At the Luhačovický potok creek, the pollution is caused by the spa resort center, the concentrated livestock rearing is the most significant source in the middle course of the Olšava river.

Transport of suspended sediments and erosion risk

The spatial distribution of erodibility calculated according to the model described above reflects the spatial distribution of causal factors and highlights the differences in conditions for the material transport and the transport of suspended sediments. With regard to the prevailing agricultural use of the area in all river basins, the water erosion constitutes an important factor affecting the transport of pollutants from the area of river basins into recipients as well as the resulting surface water quality.

The erosion risk model compiled out of the factors of the slope, geology, soil erodibility and the land use suggests a remarkable difference of the Olšava river basin from other river basins in both basic (L_G_P_S) as well as modified (2L_G_P_S) versions. Due to unfavourable high values of all assessed factors and their spatial distribution, the Olšava river basin reaches the total values of the overall risk that are 1.4 times higher in comparison with the least exposed river basin of Loučka (Fig. 4 and Table 6).

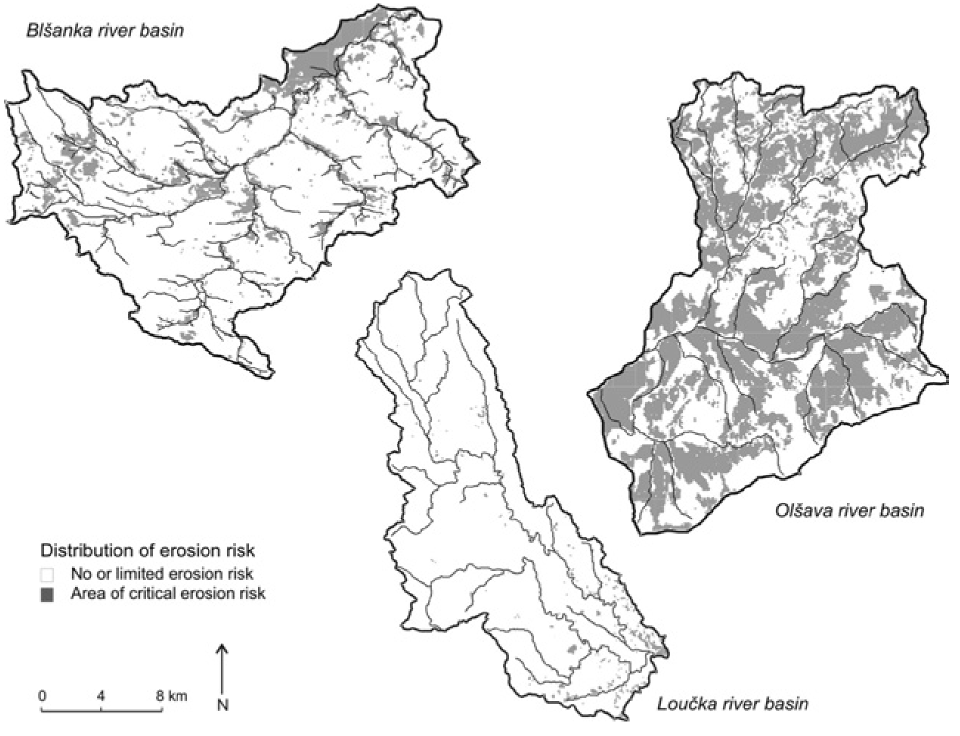

Fig. 4. Areas of critical erosion risk: a – Blšanka, b – Loučka, c – Olšava. Dark colour highlights the areas with critical score or erosion risk (total score > 15, see Table 1).

The *Blšanka river basin* represents a territory with a medium level of water erosion risk. In spite of the lowest values of the degree of incline factor, a considerable length of the managed land and the presence of permocarbon sediments as well as loess that are less resistant to erosion show its negative effects. A developed system of ravines can prove this fact. These high values of erosion risk are significantly influenced by hop-gardens that represent the highest degree of erosion risk from the vegetation cover viewpoint. The areas endangered by erosion are primarily agriculturally used slopes along the main watercourse and its affluents, marginal slopes of the Doupovské hory Mts and the loess-like area in the lower part of the river basin.

The *Loučka river basin* generally seems to have a low degree of erosion risk, mainly due to a small incline of the area and the subsoil resistant to erosion that is evenly spread on the whole area of the river basin. Unfavourable effects are manifested particularly due to a high portion of arable land with a considerable length of managed land. The areas that are threatened by erosion more significantly are located in the lower part of the river basin.

The *Olšava river basin* represents the territory with a high degree of erosion risk conditioned by the occurrence of flysch subsoil with low resistance, high soil erodibility and a higher incline of the territory. The 50% of the arable land area is located on the slopes of 5° and 20% on the slopes of 8°. At the same time, the erosion risk is evenly spread within the whole area including the headwaters where the highest precipitation amount is observed and where the formation of runoff takes place.

T a b l e 6. Output of the erosion risk model for individual river basins in three model versions.

	Slope	Geology	Soils	Land use	Model L_G_P_S	Model 2L_G_P_S	Model L_G_P_S_R
Blšanka	89 492	117 344	87 847	143 655	438 323	581 996	492 329
Loučka	96 221	40 758	99 007	152 122	387 261	540 231	440 794
Olšava	127 273	167 358	117 075	134 512	545 089	680 732	658 826

The manifestation of different conditions of the soil erosion represents differences in the sediments transport. Series of suspended sediments observation of the Czech Hydrometeorological Institute, as well as data from own monitoring on the Blšanka river were used for the analysis. The resulting outflow of suspended sediments is affected in a considerable extent by the different rainfall-runoff balance of individual river basins. The highest outflow of the suspended sediments was found in the case of the Olšava river basin as a consequence of high erosion risk combined with the highest average precipitation amount. The Blšanka river basin, in spite of the high erosion risk, showed the lowest suspended sediments transport with regard to the low average water discharge. In the case of Loučka river, comparable with Olšava river from the viewpoint of average discharge, the generally lower and uniformly distributed level of erosion risk was shown in the resulting lower suspended sediments outflow (Fig. 5 and Table 6).

T a b l e 7. Precipitation (H), hydrological (Q), and sediments transport parameters of model river basins.

River basins	Period observed	H (mm)	Q (m^3/s)	H (mm)	c (mg/l)	G (t/rok)	q_sed. ($t/rok/km^2$)
Blšanka	1995–2004	519	0.67	519	56.3	2485.9	6.6
Loučka	1985–2000	655	2.08	655	44.3	8283.4	21.5
Olšava	1985–2000	713	2.08	713	64.5	18572.7	46.3

Long-term changes in surface water quality in assessed river basins

Blšanka

The long-term development of water quality relating to the parameters of organic pollution reached the peak of load in the 80s and, since then, the values have been gradually decreas-

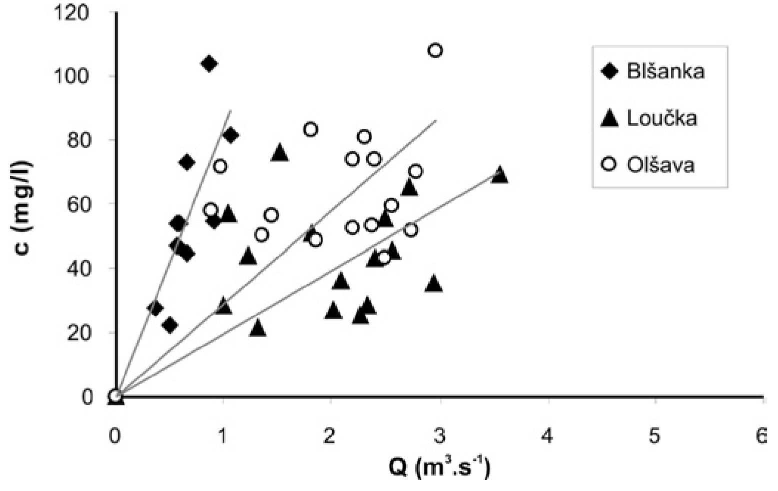

Fig. 5. Relationship between average yearly values of turbidity (c) and discharge (Q) in the period observed.

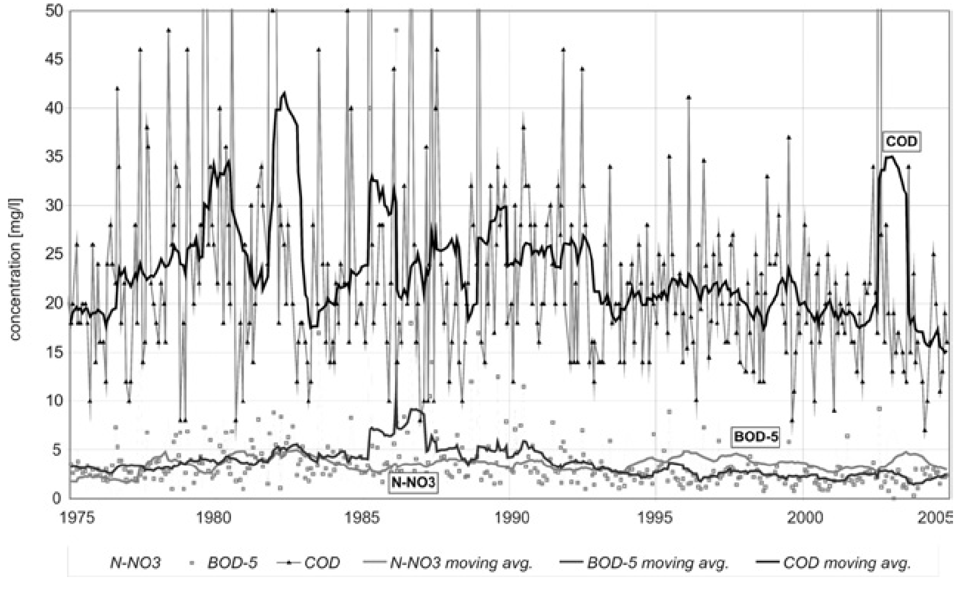

Fig. 6. Blšanka-Trnovany. Long-term changes of BOD-5, COD and $N\text{-}NO_3$ concentration. Data: CHMI.

ing (Fig. 6). The current positive trend in the development is the result of the inhibition of economic activities rather than of investment into the redevelopment of sources of pollution and the construction of wastewater treatment plants. This is proved, among other things, also by the negative development trend in the load of the river basin with the components of phosphorus. The main load factor affecting the river basin related to anthropogenic pollution is agriculture, particularly the crop production, where the hop-growing has a specific position. The absence of conceptual measures for the surface water protection against the pollution from area sources is proved by the persisting trend of load of the river basin caused by nitrates which is the key indicator reflecting the load from agricultural sources.

The pollution level according to the Czech Water Quality Standard (ČSN 75 7221) classification, in organic pollution, corresponds to the Class II of water quality for the BOD-5 indicator and to the quality Class III for the $CSHK_{Cr}$ indicator. As far as the ammonia nitrogen indicator is concerned, the load corresponds to the quality Class I and in the nitrate pollution to the quality Class II. The pollution by the total phosphorus content is the most problematic among the standard water quality indicators as it reaches the quality Class IV. Surprising is the high level of specific pollution in such relatively unspoiled region – particularly the contamination by AOX that due to the local electrical industries in Lubenec reaches the quality Class IV.

Loučka and Svratka

For the Loučka river basin there is an insufficiency of data of regular water quality monitoring. There is no permanent profile for the long-term water quality monitoring in the state network. The ZVHS (Agricultural Water Management Authority) monitoring network covers the river basin by 8 profiles at small watercourses but with varying length and periodicity of observation. The longest time series are here observed in headwaters of Libochovka – the left-side tributary of Loučka where the regular sampling starts in 1993. On most of the profiles the monitoring starts as far as in 2003 (ZVHS, 2008). This was why a supplementary monitoring network was established within the project in order to monitor the state and regional differentiation of water quality within the Loučka river basin. In the years 2001–2003, the reference sampling consisting in 4 measurements per year out of the total number of 8 profiles was carried out.

The Svratka-Tišnov profile that is situated below the mouth of Loučka into Svratka was used as the reference data source on the long-term water quality development in the assessed area (Fig. 7). According to the development of basic physical-chemical parameters of water quality, it is obvious that the surface water load decreased in relation to both organic pollution and nutrient indicators during the first half of the 90s in this area. However, the water quality has been stagnating in recent years as in many other small agricultural river basins for example, the load caused by nitrates has even been on increase again.

The values of organic pollution load both concerning the BOD-5 indicator and the COD indicator are closely above the limit of the quality Class III. The load caused by ammonia nitrogen is also in the range of the quality Class III while the values of nitrate nitrogen

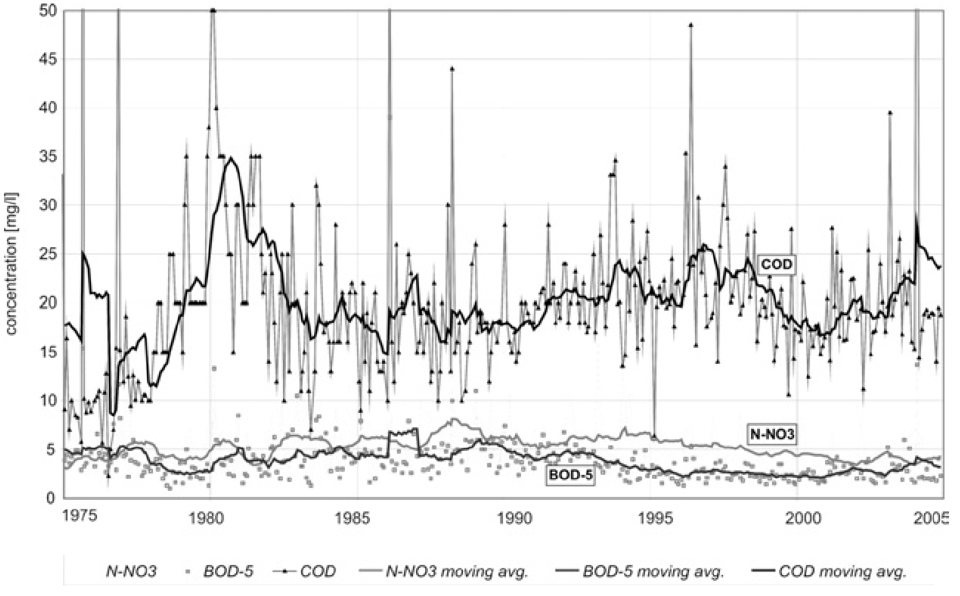

Fig. 7. Svratka-Tišnov. Long-term changes of BOD-5, COD and $N\text{-}NO_3$ concentration. Data: CHMI.

concentrations are in the quality Class IV as well as the concentrations of the total phosphorus content.

The assessment of a short time series from ZVHS monitoring network proved that the river basin load of middle intensity that corresponds to the agricultural character of the area. The trend of slight rise of the pollution level mainly in organic pollution indicators since 2000, which was apparent at the Svratka–Tišnov profile is confirmed in the main stream Loučka (Bobrůvka) as well as in its tributaries (Fig. 8). The higher levels of concentration of organic pollution recorded in the ZVHS network confirmed by the own monitoring is a consequence of high load in headwaters in the area of Nové Město which is inadequate to the low long-term discharges of the recipient.

Olšava

The water quality development in the Olšava river basin has a stagnating character in the long-term with unfavourable trend in recent years (Fig. 9). After positive changes that from the 90s accompanied the water quality development at most of our watercourses, we can observe a repeated increase in load caused mainly by organic pollution in this river basin. The pollution values measured in the years 2003–2004 relating to the BOD-5 and COD indicators belong to the highest reached values within the whole period of monitoring. The

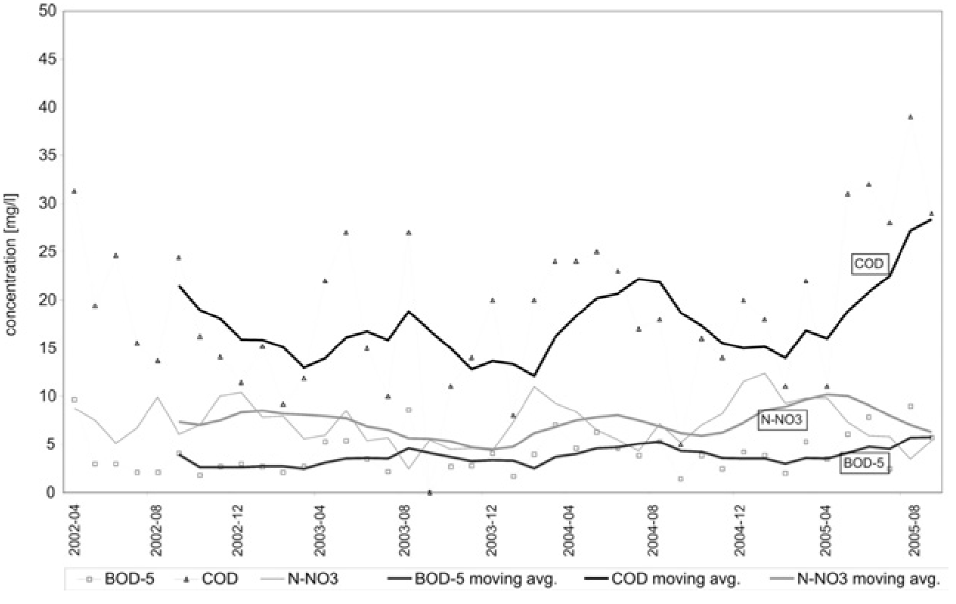

Fig. 8. Bobrůvka (upper Loučka basin). Change of concentrations of BOD-5, COD and N-NO_3. Data: ZVHS, 2005.

changes in load by nutrients are minimal; the trend of load of nitrates stagnates. The negative effect of the low level of investment into the wastewater treatment and into the water protection against pollution is obvious here as well as at other model river basins.

Currently, the level of organic pollution reaches in relation to the BOD-5 and COD indicators the values of the water quality Class III according to the ČSN 75 7221 standard. The pollution related to ammonia nitrogen also corresponds to the level of the water quality Class III, the load of the Olšava watercourse caused by nitrates can, rather surprisingly, be found in the water quality Class II. The load caused by the total phosphorus content appears to be the most problematic aspect of water quality in Olšava. This load reaches the water quality Class IV as well as the load caused by the total organic carbon.

Classification of water quality trends in assessed river basins

In spite of the fact that all assessed river basins are situated mainly in agricultural areas, long-term changes in water quality have different character (Fig. 10).

In the *Blšanka river basin*, the level of load caused by nitrates was stagnating in the long-term, in recent years, the concentrations have slightly increased. The load caused by organic substances relating to the BOD-5 and COD indicators has been decreasing since the middle of the 80s. As far as the classification of dynamics of trends in water quality

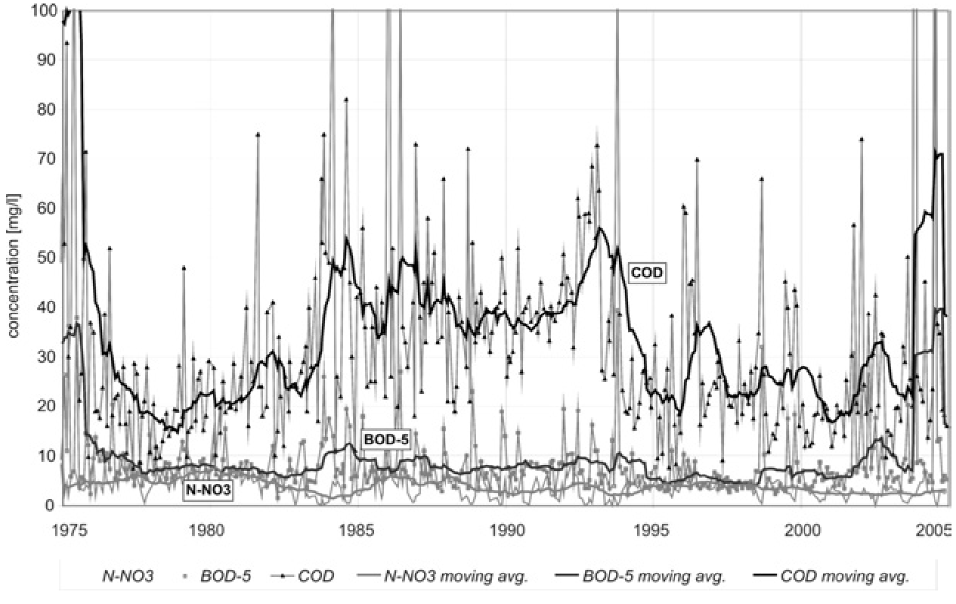

Fig. 9. Olšava-Kunovice. Long-term changes of BOD-5, COD and N-NO3 concentration. Data: CHMI.

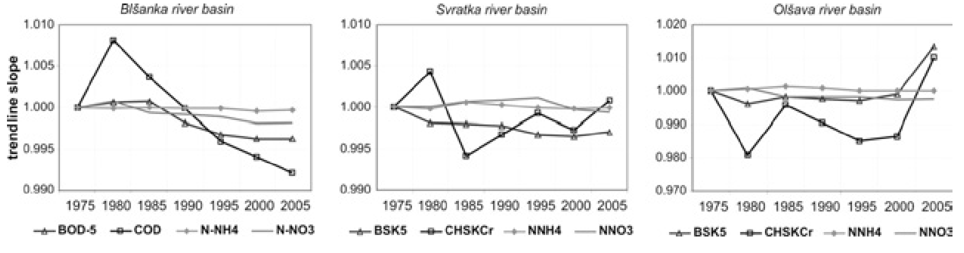

Fig. 10. Dynamics of water quality changes trends in Blšanka, Svratka and Olšava river basins.

changes (Table 6) is concerned, the Blšanka river basin corresponds to the E model regarding the BOD-5 and COD indicators that describes a decrease in load in the period before the year 1990. With regard to ammonia nitrogen, it corresponds to the A model, i.e. the group of watercourses with a stagnating pollution level in the long-term. On the contrary, with regard to the nitrate nitrogen, it corresponds to the C model, i.e. to the group of watercourses where the load decreases in the long-term.

Data from the Svratka-Tišnov profile situated just below the confluence of the Loučka and Svratka rivers were again used for the classification as the *Loučka river basin* does not have its own profile of long-term monitoring in the CHMI network. This data shows general trends in water quality development in a relatively homogenous area. The values concerning the load caused by organic pollution are approximately on the same level as in the Blšanka river basin, however, they were stagnating in the long-term and, during the last 5 years, the concentrations have slightly increased. On the contrary, the load caused by nitrates has been decreasing slightly which can be the consequence of the decrease in the intensity of agricultural production.

According to the classification, the indicators reflecting the load from the point sources, i.e. BOD-5, COD and $N\text{-}NH_4$ correspond to the F model, i.e. the group of watercourses where a re-increase in load was currently observed after a previous decrease. Only in relation to the nitrate nitrogen, it corresponds to the D model describing the decline of pollution level after 1990.

The *Olšava river basin* shows definitely the most unfavourable development of pollution regarding the selected parameters. During the last 5 years, the load caused by organic pollution has been significantly increasing here while the load caused by nitrates has not decreased. The dynamics of changes compared to other assessed river basins is more than two times higher, all assessed indicators – BOD-5, COD, $N\text{-}NH_4$ and $N\text{-}NO_3$ correspond to the F model describing a repeated increase in load after a previous decrease.

T a b l e 8. Classification of water quality changes trends in assessed river basins.

River basin	Water quality changes model			
	BOD-5	COD	$N\text{-}NH_4$	$N\text{-}NO_3$
Blšanka	E	E	A	C
Svratka	F	F	F	D
Olšava	F	F	F	F

Models of water quality changes: A – stagnation, B – continuous rise of concentrations, C – continuous decline of concentrations, D – decline of concentrations after 1990, E – decline of concentrations before 1990, F – rise of concentrations after 1990. The highlighted fields mark the indicators with unfavourable trend of water quality development.

The analysis of the dynamics of trends in water quality changes (Table 7) shows significant differences between the Blšanka river basin belonging to the Elbe water system and the Olšava and Loučka river basins that are located within the system of the Morava river basin. The assessed quality parameters in the Blšanka river basin correspond to the models that express different intensity of the load decrease plus the stagnation with regard to the $N\text{-}NH_4$ indicator. At both the Olšava and Loučka river basins, most of the assessed indicators correspond to the models characterizing unfavourable trends of changes – most of the assessed parameters show the trend of the increase in pollution level after the year 1990 of different intensity. With regard to the agricultural character of the river basin, a fact that the load of the watercourse caused by nitrates has been moderately decreasing is a positive fact.

Discussion

Individual river basins show considerable differences when compared. The differences relate to the overall level of load caused by pollutants, to the long-term development of pollution and to the system and character of the spatial distribution of load within the river basin. These differences are conditioned by variability in the character and intensity of use of individual river basins and by their physiogeographical predispositions.

The prevailing character of land use at all river basins is agricultural – the share of agriculturally used soil exceeds 50% of the total river basin area at each one of them. Therefore the load from nonpoint sources of pollution represents an important element of the overall load balance. However, the total intensity and internal structure of the load distribution within the river basin is different for each one of them. Due to the low discharge of recipients, a significant role is played by local municipal and industrial point sources of pollution. This relates particularly to Olšava and Loučka within the assessed river basins.

In these river basins, we can also observe negative trends in the development of water quality in relation to the majority of basic indicators. In the Blšanka river basin, the load of organic pollution has decreased, however, changes after the year 1990 are minimal. On the contrary, we can observe a repeated increase in the level of load of organic pollution since the middle of the 90s in the Loučka and Olšava river basins.

The analysis of specific pollution load based on own monitoring network displayed that the spread of the organic pollution load within the river basin is spatially more concentrated than the nutrient load. The construction or intensification of wastewater treatment plants at the main emission centers would therefore improve the situation considerably. The current exemption from the application of EU legislation in the area of municipal wastewater treatment allowing deferring the construction of wastewater treatment plants at small sources of pollution until the year 2010 will manifest itself in a very negative way by blocking the opportunities for positive changes in critical areas.

The load of nutrients originating mainly in nonpoint sources has remained without distinctive changes in all river basins. This finding is in line with results of research in other Czech rive basins (e.g. Holas et al., 1999; Procházková et al., 1996; Rosendorf, Prchalová, 1999). Moreover, the experiences from European river basins (De Wit, Behrendt, 1999; EEA, 2002) demonstrate that the solution for the load from nonpoint pollution sources represents a long-term and difficult process and that there are no effective measures available for immediate positive changes in the nutrient load level.

Spatial aspects of the water quality development trends are interesting in association with the location of assessed river basins within the Czech Republic. The most positive changes can be observed in the Blšanka river basin situated at the westernmost region. The development is less favourable in the direction to the east – it is the most critical in the Olšava river basin representing the easternmost location. Here, we can observe the connections with the differences of regional socio-economic development of the Czech Republic during the period of transformation of the post-socialist economy, particularly in relation to the spatial distribution of investment and economic activities in the regions.

The position of individual river basins within the whole hydrographical network is important regarding the viewpoint of water quality changes within the water systems of the Labe and Morava river basins. All assessed river basins are situated in headwaters within the upper courses of the main river basins, in the area of their interstream divides. At Blšanka, it is the water divide of Ohře and Berounka, at Loučka, it is the water divide of Svratka and Sázava and at Olšava, it is the water divide of Morava and Váh in Slovakia. The persisting level of load, or even the increasing level of load at Olšava and Loučka, that is reached already in headwaters therefore impedes a further decrease in pollution on consequential parts of main watercourses.

The comparison of water quality development in the assessed river basins with the overall character of water quality changes in the Czech Republic confirms the deepening of differences between the development of water quality of big and small watercourses. On the profiles in the middle and lower parts of major watercourses – Labe, Vltava, Ohře, Berounka and others, a sharp decrease in concentrations regarding all monitored basic parameters can be observed during the 90s with the exception of the total phosphorus content and nitrates. In small watercourses the water quality stagnates or even deteriorates mainly in peripheral parts of main river basins (Langhammer, 2005). The results of detailed research proceeded in three small river basins situated in agricultural areas have confirmed this general trend and showed the necessity of a comprehensive approach towards the solution of surface water protection problems in the river basins and the urgency to adopt measures in the source areas.

Conclusion

The assessed Blšanka, Loučka and Olšava river basins show a range of identical aspects related to the pollution load distribution as well as to surface water quality development. However, at the same time, many differences concerning the dynamics of trends in water quality and the spatial distribution of pollution load can be observed.

The research in water quality changes at small agricultural river basins has proved persisting problems in this area. Primarily, the problem consists in lack of activity related to a solution for the redevelopment of local point sources of pollution which has additionally been made easier by the deferral of the application of the environmental EU legislation in the area of small municipal sources until the year 2010. Due to the persisting load from area sources, this represents a principle opportunity for influencing the water quality of small-sized and middle-sized watercourses in a positive way within the medium-term horizon. A second, equally serious problem is a lack of information on water quality changes in small-sized and medium-sized river basins. Many of these river basins often significantly contribute to the pollution of watercourses and they are not systematically monitored. The water quality data at such small river basins are often short or incomplete. Therefore, the important information is absent that relates to the spatial distribution of load of watercourses caused by pollution. Subsequently there is no possibility for the identification and redevelopment of emission sources. Negative trends related to water quality changes at small-sized river basins highlight the need for further research in this area and analyses of running processes that would allow the adoption of effective measures for the protection of water against pollution to be defined.

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