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Modelling the pollution load from nonpoint pollution sources

JAKUB LANGHAMMER

Charles University in Prague, Faculty of Science,
Department of Physical Geography and Geoecology, Czech Rep.

Abstract

The paper presents a new method of modelling the nonpoint pollution sources. The most significant feature of presented model is its ability to calculate pollution load from medium and large-scale river basins of thousands km^2 per given balance period in a distributed form of a grid. The solution has been designed as a grid model in the GIS environment. The model has been experimentally applied in river basins with different physicogeographical conditions, land use, and anthropogenic impact. The results proved it to be suitable for calculation of balance values and delimitation of areas marked by critical intensity of pollutants load from the river basin area. Due to its abilities, it can be used for water quality protection planning in river basins and in their environmental management.

Key words: Modelling, area sources, water quality, erosion, hydrology

1 Introduction

Nonpoint pollution sources have not been of particular interest to hydrologists and water managers for long years. Due to enormous emission volume from point sources, pollution load caused by surface runoff from agricultural areas wasn't seen as significant. Due to successful treatment of big industrial and municipal pollution sources in recent years, the importance of diffusion and area sources is growing. Now it's vital to find adequate tools for their assessment and control of water quality.

Contrary to point pollution sources, pollution from non-point sources can't be measured directly. The majority of assessment activities is therefore based on indirect balance recalculations, analogies, qualified estimates and models. Each method has its limits, mainly in relation to spatial precision and scale of assessed area.

The objective of the presented research was to formulate and practically verify a new assessment methodology of area and diffusion sources of surface water pollution, enabling spatially accurate assessment of pollution load intensity from the river basin, and identification of critical pollution areas. The methodology has been implemented in the form of a distributed grid model in the GIS environment and experimentally verified by its application in three model river basins. As a result, we have assessed various possibilities and limits of its use, its sensitivity to the amount, character and accuracy of input data, and its practical employment in control of water quality, protection from pollution, and environmental management.

2 Material and Methods

2.1 Analysis of Current Approaches

As direct measurements of pollution load from river basin areas aren't available, various methods of recalculation, balance, or model calculation are used to quantify this type of pollution load of surface water. The methods can be classified into four main groups in terms of their approach to assessment – traditional balance and additive methods or assessment through mathematical models.

2.1.1 Balance Methods

Balance assessment draws on pollution load measured in a given watercourse profile. Such load volume is increased by values of loss processes undergoing in the river basin above the profile, supported by measured or estimated data. This concerns values of nitrogen losses caused by denitrification in river-beds and sewage systems or values of retained nitrogen and phosphorus in dams etc. Thus acquired values are then reduced by the load volume attributable to known point sources and contributions from atmospheric deposition. Resulting values can be considered to be the minimum estimates of nutrient load from area sources in the given river basin because they don't include the overall substance retention of the river basin, or soil loss, deposited in alluvial plains or sediments. Load volumes from area sources estimated on the basis of balance methods represent the amount of nutrients having a direct impact on water quality in the given profile.

2.1.2 Statistic Methods

Statistic methods of area pollution sources assessment are based on analysis of water quality data monitored in quality profiles closing a partial balance river basin. There are various methods for data analysis and load separation from other than point sources. One of them was used by Janský (1990) to assess pollution load from area sources in the Elbe river basin. To separate profiles under influence of area and point pollution sources, Janský applied dependency analysis of concentration values of selective indicators in exceeded discharge volume and day number in the year. After eliminating profiles influenced by point sources, he calculated specific pollution load linked to exceeded discharge volumes. Resulting values of specific pollution load were then attributed to corresponding river basin areas over assessed profiles. Cartographically, they can be depicted by isolines.

Another method applies recalculation of pollution load values per constant discharge, as specified by Nesměrák (1978). Recalculation of pollution load per corrected discharge enables us to shade away the impact of annual discharge variability reflected in load from area and diffusion sources. Firstly, we calculate regression dependence of pollution load on discharge per each year. Resulting dependency values then serve as a base for calculation of corrected pollution load per discharge, corresponding to the average of the total period. The difference between actual pollution load in individual years and recalculated load reflects the load volume generated by area and diffusion sources.

2.1.3 Additive Approach

Methods drawing on the additive approach split the total load from a river basin to partial load from various areas grouped by their landuse (forest, agricultural area, built-up areas etc.), and further to surface and underground components of load. The load of a particular substance is calculated using measured or estimated values of pollution load values that may be subject to other parameters (e.g. temperature, season, landscape morphology, soil type, discharge, substance contribution into the river basin driven by fertilizers and precipitation). Total load is then calculated as a sum of all individual components. This approach is applied by Damaška, Jurča et al. (1997), Rosendorf et al. (1995) etc.

To calculate production of two main nutrients, i.e. nitrogen and phosphorus, the procedure differs as nitrogen production is considered to have just one component, while total phosphorus load has surface and subsurface components. The first reflects direct load of phosphorus from surface as a consequence of precipitation or ice and snow melting, leading to soil erosion. In this case, phosphorus load is linked to eroded particles. The second part of the calculation refers to the groundwater phosphorus load. Its two main factors – groundwater load (from saturation areas) and hypodermic load (from aeration areas) are considered as one whole, i.e. the total subsurface load, due to their problematic division.

2.1.4 Models

Unlike traditional approaches, assessment based on modelling doesn't characterise pollution load on the basis of measured values, but rather models such values. Simulation draws on physical and mathematical definition of the process and known input quantities and boundary conditions. In comparison with the traditional approach, the assessment procedure is thus reverse. Analysing known and measured values, we identify links and relations among individual process components applying methods of statistical analysis (see Langhammer, 2000).

The progress of new computing technologies led to creation of many models reflecting pollution load from river basin areas, differing by their overall concepts, purpose, process interpretation, size of assessed areas, and practical implementation. As pollution load is firmly linked to erosion processes, many assessment models of area pollution sources draw primarily on erosion processes descriptions treating quality features as a superstructure.

Currently used models can be grouped in terms of main assessment perspectives, i.e. area size or model concept.

The criterion of area size is very important because the spatial level of the solution predetermines the extent of process description generalisation, influencing the overall concept, character and possibilities of model application. Various spatial levels open up different possibilities of assessed processes descriptions, require different data and provide different application alternatives. Generally, the larger the assessed area, the broader generalisation of assessed processes description, the lower the requirements for input data volume and accuracy and the smaller the spatial and time differentiation of output, and vice versa.

Tab. 1 Classification of nonpoint pollution sources models

Spatial Level	**Assessed Area Size**	**Area Type**	**Assessment Time Scale**	**Assessment Methods**	**Application**	**Required Input Data Volume**	**Model Type**
Macro level	Hundreds up to thousands of km^2	Large closed river basins of a regional scale	Longer uninterrupted period	Simplified methods of risk estimation of erosion, pollution load and calculation of balance values	To delimit areas or erosion risks and balance values of pollution load	Low up to medium	Regression models
Middle level	Up to hundreds of km^2	Small and medium size river basins	Mixed	USLE and its modification, empirical quantification of processes	To calculate medium-term pollution load from partial river basins and agricultural land	Medium up to high	Empirical models
Micro level	Up to tens of km^2	Small river basins and their parts, individual slopes	Continuous simulation of individual events	Physically based assessment, dynamic continuous simulation	To calculate rainfall-runoff process, accurate volume of eroded and transported substances in individual process phases	High	Physically based models

Models of a balance character are mostly used at a macro level represented by river basins of acreage between hundreds and thousands km^2, enabling identification of long-term pollution load values from large areas, assessment of total participation of area sources in pollution, and delimitation of critical load areas.

The middle level, covering individual river basins ranging up to hundreds of km^2, is probably open to the largest number of assessment approaches. Many models used in practice, drawing on erosion processes assessment, have been designed for this level. What prevails, are solutions based on empirical relations, as USLE (Universal Soil Loss Equation) and its modifications.

Physical and dynamic models based on events are applied mostly on the micro level represented by partial small river basins, individual agricultural areas, or erosion slopes. They enable continuous simulation of rainfall-runoff processes, erosion, and substance transport in time and represent an excellent tool for a detailed analysis of erosion transport processes. Possibilities and limits of models application per each spatial scale are stated in Table 1.

2.2 Concept of NPSm Model

At the macro level, environmental management, water management and quality control systems are still lacking practical tools enabling as accurate calculation as is facilitated by models at the middle level. With sufficient spatial accuracy and reasonable input data volume, such tools should enable assessment of large areas of regional and superior scale.

Under this project, a new methodology has been developed by the author to assess pollution load, in the form of a grid balance GIS model. The resulting NPSm model enables assessment of long-term pollution load of selected pollutants in medium and large river basins and delimitation of critical areas of pollution load with spatial accuracy given by the selected size of the grid field.

2.2.1 Solution Principle

Empirical grid model draws on the presumption that surface water drained from a particular area shows the same pollution characteristics in areas of the same land-use reflected in concentrations of selected pollutants. Spatially differentiated surface runoff and the type of land use can be identified as the main driving forces of the pollution load process depicted by the model. The calculation is based on combination of available distance data, i.e. satellite images, digital relief model, and measured empirical data integrated into the grid GIS model. The process of pollution load calculation employing the methodology of typical concentrations is indicated in Figure 1.

Three groups of input data are needed:

- Runoff volume per assessed time period;
- Land use distribution map;
- Table of typical concentration values.

Calculation is done in a grid of fields of a given size. For each grid field, we calculate the runoff height and derive the type of land use. Knowing typical average pollution concentration for each type of land use, we calculate the pollution load per given field by multiplying the concentration value and discharge volume (equation 1). The overall volume of pollution load from the river basin equals to the sum of all pollution load values from all grid fields of the assessed area (equation 2).

(1) $$L_n = C_n \times Q_n \times A_n$$

(2) $$L = \sum_{n=1}^{k} L_n$$

L = pollution load, C = concentration, Q = discharge, A = grid cell area,
n = grid cell number, k = the amount of grid cells in the assessed area.

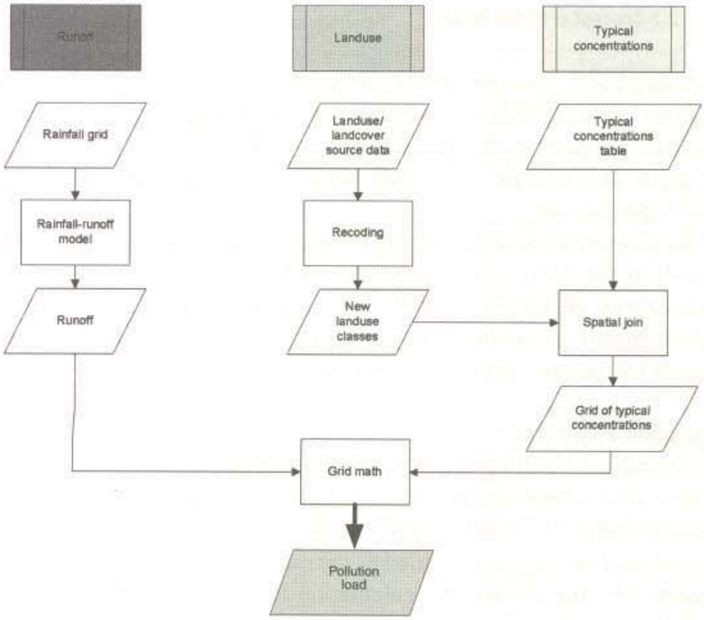

Fig. 1 Scheme of NPSm-Based Calculation

2.2.1.1 Runoff Calculation

The runoff height from each grid field is the main driving force of the total substance transport mechanism. The calculation can be done in various ways – from simple interpolation to application of output data from specific rainfall-runoff models. In the study, the calculation is done in two phases. Firstly, we determine the field of precipitation height distribution by orographically corrected interpolation and then derive the runoff field through interpolated runoff coefficient.

Before further application in the model, the runoff height field has to be compared with runoff balance values, measured in mouth profiles of the assessed area, and resulting values may need to be calibrated.

2.2.1.2 Land Use

Prior to calculation, land use data are reclassified into new categories (Tab. 2) and transferred into the grid. Grids of assessed indicators concentrations are derived by combination of the typical concentration data table.

To categorise land use types, we have used classified satellite images Landsat TM as general underlying data, but current data sources on land use or land cover, e.g. the CORINE land cover geodatabase could be also applied.

2.2.1.3 Table of Typical Concentration

The table of typical concentration (Tab. 2) is the key component of the whole pollution load calculation. It summarises average concentration values of selected pollutants, indicating quality of water flowing out of areas with similar land use.

Average typical concentration values of each category were determined drawing on various documents, namely table values stated in literature (Goudie, 1993; Krysanova & Becker, 1998; Maidment & Saunders, 1996; Quenzer, 1998), values of pollution indicators average concentration measured in quality profiles in areas of a similar land use. These values were verified by comparison with concentration values measured in assessed river basins and the Elbe river basin and further adjusted during model calibration. The resulting table, used in the calculation, is a composite product enabling us to model pollution load in heterogeneous areas with different natural conditions and anthropogenic use.

The values are used to indicate pollution load from area sources, leaving aside pollution load from point and diffusion sources and atmospheric deposition that, for the purpose of balance assessment, have to be calculated separately.

Tab. 2 Table of Typical Concentrations

Code	Landuse class	BOD- mg/l	N_{total} mg/l	P_{total} mg/l
1	Urban areas	38.0	5.0	0.40
2	Industrial areas	42.0	8.0	0.70
3	Mining, scrap-heaps, bare land	31.0	4.0	0.30
4	Arable land	6.0	16.0	0.80
5	Orchards, vineyards, hop-gardens	3.0	7.0	0.20
6	Parks, sport grouds, scarse vegetation	5.0	12.0	0.70
7	Meadows and pastures	1.5	1.5	0.15
8	Forests	1.0	0.7	0.05
9	Wetlands and waterbodies	0.0	0.0	0.00

2.2.1.4 Pollution load Calculation

In terms of individual pollution parameters, pollution load equals to the product of runoff grids and average concentration of each substance – see equation (1) and (2). Then we deduct resulting values of annual pollution load in corresponding units from the map. If the edge length of the grid field is 100 m, which is sufficient for medium size river basins, pollution load results are expressed in commonly used kg/ha.

2.3 Model Areas and Used Data

To test the model, we have selected three model river basins with different geographical conditions, land use and anthropogenic load, namely the upstream Vltava river basin situated in the central part of the Bohemian Forest (*Šumava*), the Bílina river basin located in the basin below the Ore Mountains (*Podkrušnohorská pánev*) in north-western Bohemia, and the Želivka river basin in the Czech and Moravian Highland (*Českomoravská vrchovina*).

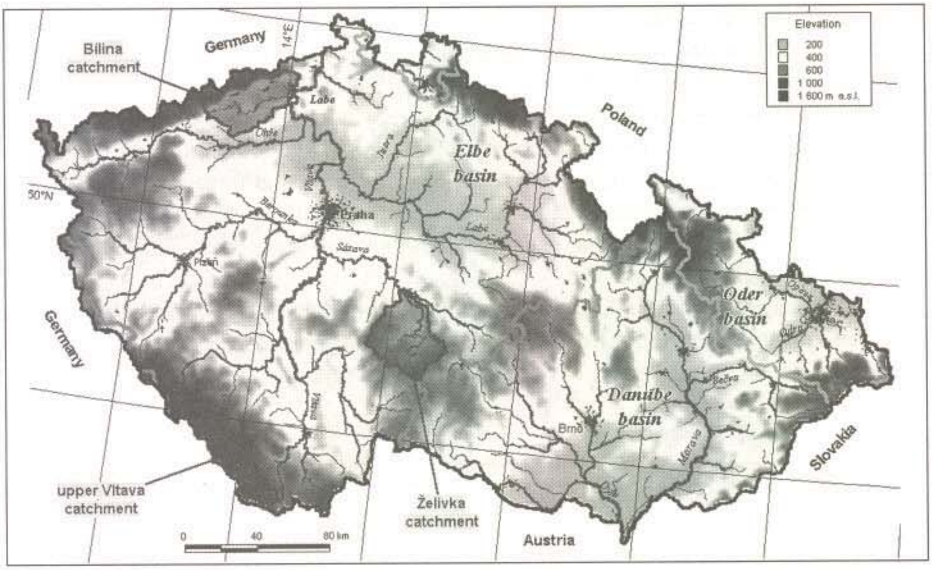

Fig.2 Position of Model River Basins

2.3.1 Physicogeographical Characteristics of River Basins

The river basins differ in terms of landscape character and landuse structure, and physical and geographical conditions. Assessing area pollution sources, we are interested mostly in characteristics that affect the runoff from the area, i.e. the relief type and its slope characteristics, climatic parameters as precipitation volume and spatial distribution, and land use. The upstream Vltava river basin is situated in the central part of the Bohemian Forest, the Bílina river basin is located in Ore Mountains and the Želivka river basin is positioned in the Czech and Moravian Highland.

2.3.1.1 Relief and Slope Characteristics

As for the sea level, the upstream Vltava river basin is located in the highest area. The height above sea level varies between 557–1366 meters asl and the majority of the river basin is situated higher than 700 meters asl. The height above sea level of the Bílina river basin varies between 136–944 meters asl, mainly in the Ore Mountains areas, but its distribution is rather irregular. The river basin covers three different geomorphological areas – the top part of the Ore Mountains ridge and its hillsides, the basin below the Ore Mountains representing 70% of the river basin area, and peaks of *České středohoří* on the east.

The Želivka river basin is located in a moderately hilly country and the height above sea level is distributed quite regularly (319–762 meters asl).

The analysis of slope values confirms differences indicated above. The Želivka river basin shows the most balanced values as the slopes of 54 percent of the area are under 3° and 97.7 percent of the area is under 8°. The steepest slopes are situated in valleys of the central river basin and jointly with agricultural land negatively affect erosion and related pollution load.

Slopes of the upstream Vltava river basin are moderate thanks to levelled surface of the central Bohemian Forest. Lower slopes cover a significant part of the river basin, mainly around the Lipno dam. In total, slopes under 8° cover 86.6 percent of the area while critical slopes of 12° and steeper are found only at 2 percent of the river basin.

Due to significant relief variability of the Bílina river basin and its distribution, it shows the highest absolute values of slopes and the most frequent incidence of critical slope values. Areas of 8° and steeper slopes cover 20 percent of the river basin while critical slopes over 12° are detected at 8.5 percent of the river basin area. These factors jointly with a significant vegetation disturbance and major anthropogenic transformation of the environment negatively affect the intensity of erosion processes and pollution load from the river basin.

2.3.1.2 Precipitation

Precipitation is most evenly distributed in the Želivka river basin. Its location in the Highlands (Vysočina) area with a low absolute and relative superelevation predestines the river basins to well balanced total precipitation values with minimum geographical differences.

The Bílina river basin is comparable to Želivka in terms of average long-term precipitation height, but it shows the most significant irregularity in precipitation distribution in the river basin. The area is subject to the precipitation shadow of the Ore Mountains where the ridge precipitation rate reaches the rate comparable to stations in upstream Vltava in the Bohemian Forest, but it drops down at the base and the basin below the mountains to statistically the lowest values of the whole Czech part of the Elbe river basin.

Upstream Vltava shows the highest precipitation rate with major differences between the minimum and maximum amount. The top area of the Bohemian Forest around Churáňov is most humid, while the downstream area around the Lipno dam is the driest zone.

Tab. 3 Precipitation Characteristics of Model River Basins

	Bílina	*Želivka*	*hor. Vltava*		*Bílina*	*Želivka*	*hor. Vltava*
Rainfall 1961–91 avg	**605.2**	**661.3**	**844.0**	**Rainfall 1999 avg**	**554.8**	**603.6**	**755.5**
min	445.6	576.2	592.0	min	418.2	505.1	532.2
max	1025.8	761.4	1086.1	max	975.1	685.9	1080.6
diference	580.1	185.3	494.1	diference	556.9	180.8	548.4

2.3.2 Land Use Structure of Model River Basins

Assessed areas show substantial differences in main categories of land cover.

The upstream Vltava river basin, least affected by intensive agricultural activities and settlement, has twice as many forest areas, three times less agricultural land and the highest number of meadows and pastures than the Želivka and Bílina river basins. In terms of potential pollution load, its land use structure has the most favourable conditions out of all three areas.

The Želivka river basin has an agricultural character. Arable land jointly with other agricultural areas represents over two thirds of the river basin, forests cover 28 percent and meadows and pastureland only 1 percent. Due to the overall scope and spatial structure of agricultural areas in relation to the relief, the Želivka river basin is potentially most endangered by nonpoint pollution, mainly by nitrates, from agricultural land.

Regarding anthropogenically transformed areas, the Bílina river basin ranks first. Over 21 percent of the river basin is covered by urban areas, industrial and mainly mining facilities, and bare areas. At the same time, the incidence of agricultural land is relatively high (41 percent) and natural areas as meadows and pastures, water planes and wetland are scarce. Forests cover more than 30 percent, which is the second highest percentage, but they are located mainly in the Ore Mountains, marked by a bad state of forest vegetation caused by long-term industrial emissions. The Bílina river basin therefore shows unusually high potential for dissolved substances release into surface water, organic contamination being the prevailing form of the total pollution load.

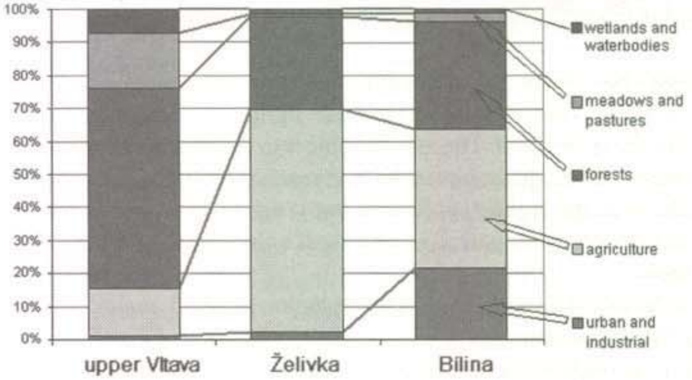

Fig. 3 Land Use Structure of Model River Basins

2.3.3 Data sources

To integrate results into GIS, we have used underlying topographic documents comprising digital military maps of scale 1 : 25 000, the digital Water Management Map, the CORINE land cover geodatabase, database of surface water pollution sources SVHB, climatic data from selected climatic and precipitation measuring stations, the Czech Hydrometeorological Institute (CHMI), and data from the CHMI water quality control profiles.

3 Results

Pollution load simulation from area pollution sources was performed focusing on the BOD-5 indicator, total nitrogen, total phosphor, and dissolved and undissolved solids. We have chosen the year 1999 as a reference period. Following chapters present results of the BOD-5 parameter, total *n* and total *P*, while showing detailed model results of total nitrogen load from area sources as a key pollution indicator.

3.1 BOD-5 load

In the Bílina river basin, load of organic pollutants is in its total caused mainly by two big point pollution sources of industrial and communal character.

The highest values are reached in the mining and industrial area of the Ore Mountains basin. In 1999, the total load volume from area sources of the Bílina river basin was 235 t/y according to the model.

In the upstream Vltava river basin, the total load of BOD-5 from area pollution sources was the lowest. Spatial distribution of load is irregular and concentrated mainly to isolated settlements and agricultural areas.

In the Želivka river basin, load of organic pollutants from area sources reflected by parameter BOD-5 is higher due to intensified land use than in the mountainous upper Vltava river basin. The load is concentrated into settlement zones and agricultural areas.

Tab. 4 BOD-5 Load

River basin	BOD-5 (t/year)
Bílina	1235
Želivka	879
Vltava	504

3.2 Total Nitrogen load

Looking at water quality, the key problem is the volume of total nitrogen load from the **Želivka** river basin.

Due to intense agricultural use of the area, surface water is contaminated by nutrients in the extent endangering water quality in the Želivka water reservoir.

The total volume of nitrogen from area sources amounts to 1756,4 t/y under the model conditions of 1999.

In the **Bílina** river basin, the spatial distribution of the total nitrogen load is different in comparison with organic pollution. It's due to links of load to different type of land use, i.e. to agriculture. Although industry prevails, agricultural land represents 40 percent of the Bílina river basin and load from area sources is a significant component of the overall pollution balance.

The highest local load values are detected in the upstream and downstream river basin in agricultural area of the lowlands. According to the model, in 1999 the annual load of total nitrogen was 821 t/y.

In the **upstream Vltava** river basin, in 1999 the total volume of total nitrogen load from area sources amounted to 617 t/y.

Tab. 5 Total nitrogen load

River basin	N_{total} (t/year)
Bílina	821
Želivka	1756
Vltava	617

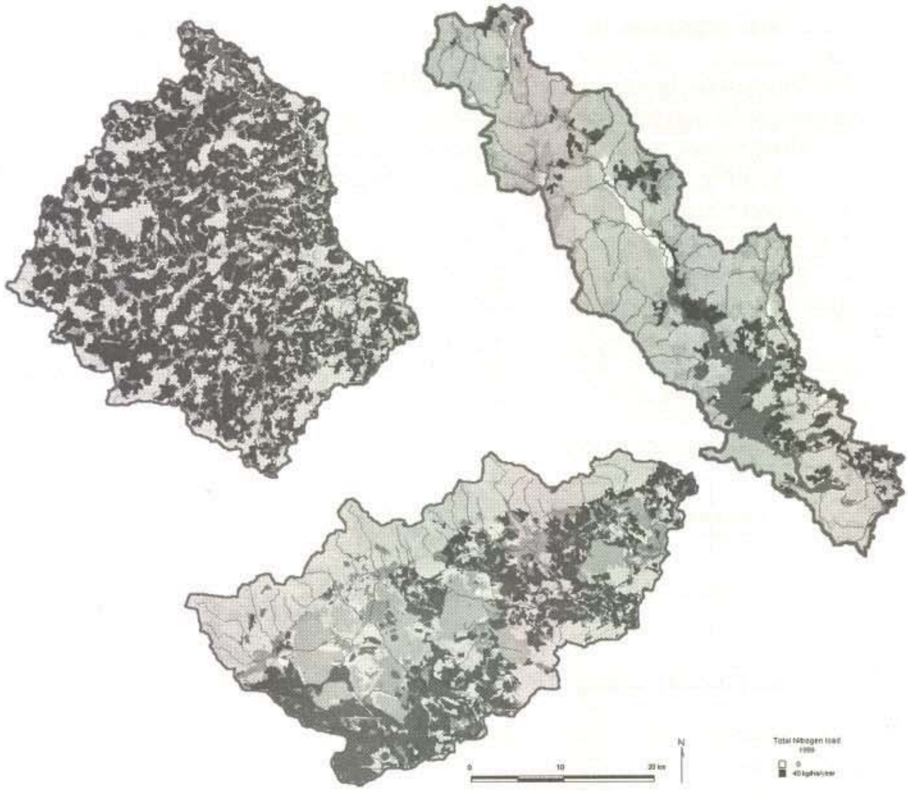

Fig. 4 Total nitrogen load from nonpoint pollution sources

3.3 Total Phosphorus load

The contamination of surface water in the **Želivka** river basin by nutrients is critical also in case of the total phosphorus. The main problem is an excessive load linked to intense agricultural production in the area. Emissions from agriculture are increased by load from populated areas, mainly small villages.

According to the model, in 1999 the volume of total phosphorus emissions from area sources was 90.4 t/y.

In the **Bílina** river basin, spatial distribution of total phosphorus load is clearly more regular than of total nitrogen. This is due to different emission sources of both parameters and their distribution in the area. In terms of phosphorus, high importance can be attributed also to non-agricultural anthropologically used and transformed areas.

According to the model, in 1999 the resulting value of the total nitrogen load from the Bílina river basin was 46.7 t/y.

In the **upstream Vltava** river basin, pollution load of total phosphorus is more complex than in case of total nitrogen due to links of phosphorus emissions to various types of emission sources. They are related to municipal sources, industry, and agricultural activities.

According to the model, in 1999 the resulting value of the total phosphorus load amounted to almost 38 t/y.

Tab. 6 Total phosphorus load

River basin	**P_{total} (t/year)**
Bílina	46.7
Želivka	90.3
Vltava	38

3.4 Critical Areas

We depict as critical those areas that due to high intensity of pollutants load significantly participate in the overall pollution load of the river basin, even if their acreage isn't large.

To delimit areas of critical load per each pollutant, we have applied thresholding of critical values of pollutants load intensity. Threshold values of critical load are determined by analysing frequency histograms of load values distribution in the river basin.

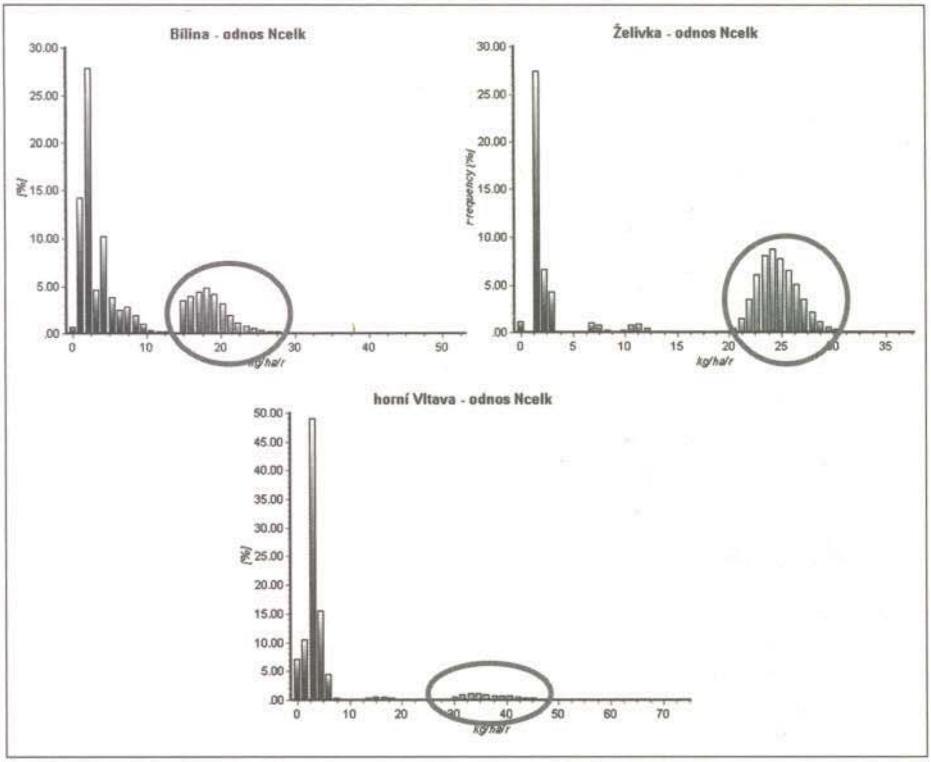

Fig. 5 Delimitation of Areas with Critical Pollutants Load Intensity

Defining areas of critical intensity of total nitrogen load, we identified the threshold equal to 20 kg/ha per year by separating histograms. According to the intensity of total nitrogen annual load, we have defined two main areas:

1) The area of low load intensity with values less then 20 kg of total N/ha per year.
2) The area of critical load intensity, representing a complete group in the frequency histogram, with load intensity values over 20 kg/ha per year.

Tab. 7 Total Nitrogen Critical Areas

N_{crit}	Area %	Load %
Bílina	7,6	21,9
Želivka	55,6	92,3
Vltava	10,0	55,0

4 Discussion

Comparison of balance model values shows that differences in pollutants load among individual river basins correspond to their main differences in substance balance and land use.

In terms of organic pollutants, the Bílina river basin is clearly the most polluted area with annual production of 1235 t/y, the Želivka river basin comes second and the lowest pollution volume reflected by the BOD-5 indicator is produced in the upstream Vltava river basin.

In terms of nutrients, the situation is different. Due to dominant agricultural character of river basins, the model correctly generated the highest final values of the total nitrogen load in the Želivka river basin (1756 t/y), which more than doubles the annual load volume of the second area, the Bílina river basin with 821 t/y. Differences in total nitrogen emissions from area sources between Bílina and upstream Vltava (618 t/y) are not so significant.

The total phosphorus results are analogical. The highest load has been detected in the Želivka agricultural river basin (90 t/y) while the Bílina river basins shows almost half values (46.7 t/y). The upstream Vltava river basin again shows the lowest values of pollution load, but it doesn't differ from Bílina so significantly.

The model results have been compared with values published by authors working on calculation of pollution substance balance in individual river basins (Fuksa, 1996, Havlík, 1997, Hejzlar et al., 2000, Jurča et Damaška, 1997, Rosendorf, 1996 etc.). Due to the character and methodology of their works, in calculation of the load from area sources they focused only on indicators of total nitrogen and phosphorus. The Želivka river basin has been studied most thoroughly as many large investigation projects have been centred there. However, there are often significant differences between the values published in the works mentioned above due to applied methodologies. Authors always picked either the balance or additive methodology.

Mostly, the results of the NPSm model fall into the intervals of values measured by individual authors through different methods. What's more, comparison with the balance of the total pollution load from each river basin confirms that such values really can exist in these areas and therefore we can consider them reliable.

5 Conclusion

The main objective of the project was to analyse assessment methods of area sources of surface water pollution and to formulate new methods. With this aim, we studied and analysed current methods and approaches to the assessment of area pollution sources. Drawing on resulting facts, a new methodology was designed enabling spatially targeted assessment of load from area sources through a model performed in the GIS environment.

The results of the model and its gradual calibration confirmed practical applicability of the new calculation method. The results of pollution load calculated by the model were compared with values measured in control profiles and values indicated by experts in the field of water quality in the given river basins. We identified a relatively high agreement of results that fall into interval corresponding to real values even if applied in different areas.

In terms of practical use, it is significant that the model is able to reflect spatial differentiation of the pollution load intensity and subsequently delimit critical areas. This indicates further application possibilities of the model for the purposes of environmental management and water quality control in river basins of regional and superior level.

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