National Water Quality Monitoring Programmes In the Slovak Republic

ADAMKOVÁ, J., CHRIAŠTEĽ, R., RONČÁK, P., VANČOVÁ, A. and VYDARENÝ, M.

Slovak Hydrometeorological Institute, Jeséniova 17, Bratislava, 833 15, The Slovak Republic

Abstract. At present the Slovak Hydrometeorological Institute (SHMI) is responsible for national water quality monitoring programmes. In 1963 a systematic surface water quality monitoring programme was started and in 1992 groundwater quality monitoring programme was added. At present 333 sampling sites are monitored for the groundwater quality programme , at which sampling frequency is 2 - 4 times per year.
The surface water quality monitoring network consists of 250 sampling sites, from most of which samples are taken 12 times per year but some of them only 6 times per year, depending on the location and sources of pollution.

The recent trend has been to add biological monitoring and ecotoxicological testing as a part of water quality monitoring programme. This approach enables the Institute to forecast risks on the ecological systems.

As part of monitoring programmes the GIS application will be used mainly to interpret data for decision making processes.

Key words: Surface Water Quality, Groundwater Quality, Monitoring, Bioassay and Biological methods, GIS (8 figs, 2 tabs)

Introduction

Anthropogenic activities performed in river basins may result in a deterioration of water quality with detrimental effects on the ecosystems. Therefore, the use of such polluted water for drinking purposes, irrigation, industrial use, fishing or for recreation may be limited and the ecological functioning of a river is also threatened. In the decision making processes of water management authorities it is very important to have sufficient and reliable information on the water quality status.

National Groundwater Quality Monitoring Programme in the Slovak Republic

Objectives

A systematic groundwater quality monitoring programme in the Slovak Republic has been in use since 1982. The main objectives of the groundwater quality monitoring programme are as follows (Remenárová 1982a, 1982b):

- to evaluate the state of the groundwater quality in the Slovak Republic
- to define the long-term trends of groundwater quality in the Slovak Republic
- to provide details to governmental institutions for decision making processes in the field of groundwater quality protection.

In addition to these purposes, the obtained groundwater quality data may also be applied in experimental and scientific activities such as mathematical modelling.

Network design

The territory of the Slovak Republic is subdivided into 26 water resources areas, in which 291 sampling sites are located in the year 1998 (261 wells and 30 springs). The selection of a sampling site depends on water management objectives, information on hydrogeology and the occurrence of pollution sources (Fig. 5). Generally there are several aquifer levels. The upper aquifer is the most influenced by anthropogenic pollution. Sampling sites are currently situated mainly in the upper aquifer, typically in Quarternary sediments, and the monitoring network particularly covers the Mesozoic rocks (limestones, dolomites, marls), Neovolcanic rocks (andesites, rhyolites and their tuffs) and crystalline rocks (granitoids and metamorphic rocks) from which come about 50 % of groundwater resources in Slovakia. The sampling frequency is 2 times per year (spring and autumn).

It was agreed in 1986 to create a network of recording stations in the pre-Quarternary (mountainous) areas in cooperation with the Slovak Geological Institutions. In the framework of the pre-Quarternary project 65 sampling sites were monitored from 1990 to 1997 (Ftorková et. al 1997). Due to the lack of data from mountainous areas, there is strong interest from SHMI to incorporate existing network in pre-Quarternary areas into the national groundwater quality monitoring programme.

Special interest is given to Žitný Ostrov area. Groundwater from this area is the most important source of drinking water in the Slovak Republic.

The monitoring programme of Žitný Ostrov is subdivided into basic and supplementary monitoring programmes. These particular programmes differ in the extent of the analysed determinands and location of sampling sites.

The „Basic monitoring programme" consists of 15 sampling sites (piesometric wells) in the period of 1997-1998 (5 at 2 and 10 at 3 levels), which represents 40 observations during every sampling cycle. The frequency of sampling is 4 times per year.

The „Supplementary monitoring programme in Žitný Ostrov" is carried out biannually (spring and autumn) at 18 sampling sites (piesometric wells), 2 at 1, 7 at 2, 8 at 3 and 1 at 4 levels, which represents 44 observations during a sampling cycle.

Assessment of groundwater quality

The chemical analyses cover basic and supplementary groups of determinands (Tab. 1). The basic set of determinands is analysed for every sampled locality. Determinands from the supplementary set are chosen based mainly on specific local conditions (water uses, sources of pollution, etc.).

Table. 1: List of analysed groundwater quality determinands

basic group of determinands	supplementary groups of determinands
temperature of water, pH, conductivity, dissolved oxygen, alkalinity, acidity	chlorinated pesticides
sodium, potassium, ammonia, calcium, magnesium, manganese, iron	chlorinated phenols
chloride, nitrate, nitrite, phosphate, sulfate, hydrogencarbonates, carbonates, silicates	halogenated hydrocarbons
COD	PCBs
forms of CO_2	Aromatic hydrocarbons,
arsenic, aluminum, cadmium, copper , lead, mercury, zinc, chromium, nickel	PAHs
humic substances, nonpolar extractable substances, cyanides, phenol compounds, TOC	Sulfide

The results from the monitoring programme are assessed in accordance with the Slovak Standard STN 75 7111 „Drinking water". The standard defines allowable concentrations of chemical substances in groundwater. The evaluation is published in annual reports „Groundwater quality in the Slovak Republic" and „Groundwater quality in Žitný Ostrov". The reports give basic information about groundwater quality, surface water quality and main sources of pollution having impact on the water quality.

Furthermore, in the framework of the groundwater quality monitoring programme, the GIS application will be used to interpret data as a tool for decision making process, mainly to identify „hot-spot" areas where actions should be taken.

National Surface Water Quality Monitoring Programme in the Slovak Republic

Objectives

The national surface water quality monitoring programme in the Slovak Republic was started in 1963. Since 1981 the Slovak Hydrometeorological Institute has been responsible for the surface water quality monitoring and assessment.

The main objectives of surface water quality monitoring programme are:

- characterisating of the present state of surface water quality
- establishing the trend in surface water quality
- classifying the surface water quality in accordance with the Slovak Technical Standard STN 75 7221
- providing information on water quality to water management authorities for decision making process
- elaborating „The State Qualitative Water Management Balance" based on the Governmental Decree No. 242/1993, by which state of recipient water pollution is determined
- calibrating and verifying the models.

Network design

The sampling sites are situated in important water management areas, based on the catchment area approach. The selection of sampling sites is based on the information of a hydrological conditions, settlement and industrial and agricultural activities. The monitoring network is divided into 4 river basins, the Danube River Basin, Váh River Basin, Hron River Basin and Bodrog and Hornád River Basin. It consists of 250 sampling sites (Fig. 6), from which samples are taken monthly. At some of them, sampling frequency is decreased to 6 times per year.

Measured determinands are subdivided into basic and supplementary group (Table 2.). The set of basic determinands is measured in each sampling site, determinands from supplementary group (and also frequency) are chosen on the basis of specific conditions in particular sampling site.

The monitoring network is evaluated yearly in accordance with the requirements on information needs and budgetary conditions.

Table 2: List of analysed surface water quality determinands

basic group of determinands	water temperature, biochemical oxygen demand (BOD_5), dissolved oxygen, chemical oxygen demand (COD_{Cr}), pH, conductivity, chlorides, sulphates, ammonium, nitrates, nitrites, total phosphorus, coliform bacteria, saprobic index of bioseston, dissolved salts and suspended solids
supplementary group of determinands	calcium, magnesium, sodium, potassium, iron, manganese, chromium, mercury, copper, zinc, cadmium, lead, nickel, arsenic, phosphates, chlorophyll-a, organic nitrogen, non-polar extractable substances, phenols, cyanides, tensides, pesticides, polychlorinated biphenyls, polyaromatic hydrocarbons, aromatic hydrocarbons, gross alpha and beta radioactivity

Assessment of surface water quality

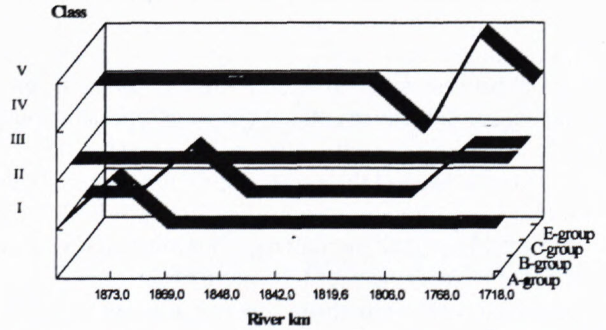
The surface water quality is assessed by using the Slovak Technical Standard STN 75 7221 "Classification of surface water quality" and the Governmental Decree No. 242/1993.

Five classes are used in the national classification system. The first class represents very clean and the fifth one very highly polluted water. The determinands are divided into 6 groups by the STN 75 7221 as follows:

- oxygen regime determinands
- basic chemical and physical determinands
- supplementary chemical determinands
- heavy metals
- biological and microbiological determinands
- radioactive determinands.

For each determinand the "characteristic value", representing 90% probability of not being exceeded, is calculated. The characteristic value is calculated from 24 measurements. This means that water quality data from a 2-years span of time are used for classification. By comparing the characteristic value to the limit values given for each class by the STN 75 7221 a particular determinand is assigned into one of 5 classes of water quality. The final water quality classification is based on the most unfavourable determinand. The evaluation is published in the yearbook „Surface water quality in the Slovak Republic".

In figure 1 the classification of surface water along the Danube River is shown in a group of oxygen regime determinands, basic physical and chemical determinands, supplementary chemical determinands and biological and microbiological determinands.



A-group - oxygen regime determinands
B-group - basic chemical and physical determinands
C-group - supplementary chemical determinands
E-group - biological and microbiological determinands

Figure 1: Classification of water quality in the Danube River during 1996-97 (Adamková et. al, 1998).

The State Qualitative Water Management Balance is elaborated yearly by using the Governmental Decree No.242/1993, through which states of surface water pollution are defined. The balance is performed for 5 determinands such as BOD_5 (biochemical oxygen demands), COD_{Cr} (chemical oxygen demand), suspended solids, $N\text{-}NH_4$ and $N\text{-}NO_3$ as a ratio between permissible and actual concentration. An actual concentration is a characteristic value (90 percentile) used also for water quality classification. The balance criteria are as follows (Governmental Decree No. 30/1975):

A active state $\geq 1,1$ **B** $0,9 <$ balanced state $< 1,1$
C $0,9 \geq$ passive state

This assessment is published yearly and is also supplemented by information on the produced and discharged pollution from point sources of pollution, information on Waste Water Treatment Plants under the administration of waterworks and the information on accidental pollution provided by the Slovak Environmental Inspection.

Quality system

Recently more importance was given to the establishment of a quality system in the monitoring programme, with the purpose of obtaining reliable and comparable data.

Although most laboratories included in the national monitoring programme have not been fully accredited process by Slovak National Accreditation Service (SNAS), they have developed their internal Quality Assurance/Quality Control System. The laboratories are also obliged to provide information about this system to SHMI.

At each laboratory standardized methods are used exclusively for the analytical measurements of samples and Slovak Hydrometeorological Institute set the requirement on the detection limit values for water quality determinands to the laboratories. In the case of surface waters, the detection limit should fall within 10% of the actual value set up for the first class of water quality, in accordance with the national classification system STN 75 7221. Detection limit values for groundwater quality determinands have to be up to 10% of limit value at defined by national standard STN 75 7111.

The results and activities performed in the analytical process are documented and archived by each laboratory. Internal quality control is ensured using control charts and analyse of control samples (blanks, spiked samples and replicates). External quality control is carried out through the participation of the laboratories in proficiency testing, which is organized mainly by the National Reference Laboratory for Water in the Slovak Republic. The organization of the proficiency testing is in accordance with standards valid in the European Union.

The methods of groundwater sampling and in situ measurements were designed by Perútka Ltd., according to the national standards STN 65 6005, STN 73 6614, STN 73 6615 and STN 83 0521 (Perútka, 1995). The surface water sampling, transport conditions, sample conservation and storage before analytical measurements are in accordance with Slovak Technical Standard STN 83 0530.

Data storage

The laboratories send data to SHMI in defined structure and units (codes of river basins, rivers, sampling sites, determinands and analytical methods are unified). Also, secondary data concerning sampling sites,
time and date of sampling, analysis methods, etc. are stored. Data needed to be checked (outliers, data that doesn't conform to the general pattern of a data set) are reviewed by the representatives of the laboratories. After checking the data, they are recorded into a database system and are archived. A statistical analysis of data is performed by computerised processing.

In the database system of Slovak Hydrometeorological Institute surface water quality data has been archived since 1963. Through its use changes and trends in water quality can be detected. For example figure 2 illustrates changes in the level of dissolved oxygen, non-polar extractable substances content and BOD_5 values from the sampling site Malý Dunaj - Podunajské Biskupice during period 1983-97 are illustrated. This sampling site is situated below the discharge point of cooling waste waters from the refinery Slovnaft. The surface water quality has improved significantly due to a decrease of waste water pollution entering the river.

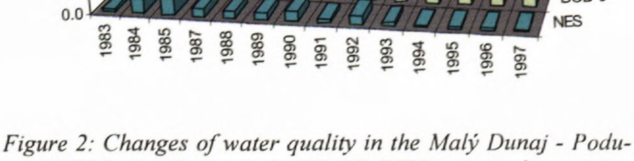


Figure 2: Changes of water quality in the Malý Dunaj - Podunajské Biskupice for period 1983-97. (NES - non-polar extractable substances).

Groundwater quality data in the database system has been archived since 1982. For example, figure 3 illustrates changes of sulphate abundance in the aquifer of Hron River basin during period 1982-97. Annual mean concentrations of sulphate in groundwaters have been calculated for 17 sampling sites in the middle segment of the Hron River basin

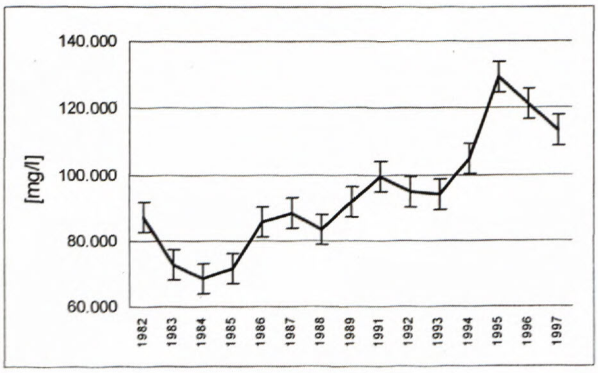


Figure 3: Annual mean concentrations of sulphates in alluvial groundwaters of the Hron River basin (from Hliník nad Hronom to Želiezovce) calculated from 17 sampling sites.

Biological Monitoring Programme

Until recently, experts in the field of water quality belived that physical and chemical analyses alone provide sufficient information for an assessment of the degree of pollution of surface waters. However with the development of industry, especially of the chemical industry, an increasing amount of chemical substances and their mixtures has been entering the rivers with waste waters. The question, of how these chemicals effect aquatic flora and fauna, of how great their negative impact is on the environment and of ways in which they effect the ecology may be answered only through additional biological testing.

If hazardous substances are entering the water environment, they may affect the water ecosystem, which reacts to the given situation in the form of the biological response. Water systems monitoring is focused on ecosystem complexity assessment and the search for connections with extrinsic stresses as causes of observed disturbance of this complexity. It is a matter of evaluating species composition, frequency, diversity, presence of indicator species, evaluating of basic ecological and physiological processes velocity, etc. The environment forms a composit of biocenosis, and at the same time eliminates all organisms with an unsuitable facility for surviving.

We plan to expand the context of surface water quality monitoring programme in two ways beyond the hitherto performed biological monitoring (microbiological parameters, saprobity indices of bioseston, etc.)

- macrozoobenthos analysis – the assessment of global contaminated water effect on water ecosystems (ecological monitoring) by biological analysis of communities at the riverbeds
- bioassay (toxicity) tests – the assessment of toxic effects of contaminated waters and sediments on water organisms under strictly defined conditions.

Saprobity

A very important index of the surface water purity, from the biological point of view, is the amount of organic substances present and the degree of their decomposition, i.e. saprobity (sapros - rotten). Saprobity expresses the hygienic-health state of the water system. The greater the degree of the saprobity, the more risky the water quality is from the epidemiological point of view. Determination of the saprobity is an important part of the water purity assessment and has been performed by the method of biological (saprobity) indicators (Kolkwitz & Marson, 1909).

Any water organism can act as an indicator. For example, planktonic organisms provide information on the quality of stagnant water, relative to flowing water. Littoral or benthic organisms reflect the situation of the river side, or river bottom of a given locality. According to national standard STN 8305 32/6, the bioseston saprobity index is currently observed in the surface water quality monitoring programme in the Slovak Republic. For example, the bioseston saprobity indices are presented in figure 4 along the Váh River, where a rise in the index values corresponds to the entering of waste waters from large cities (river km 308.8, Ružomberok - below, river km 157.2. Trenčín)

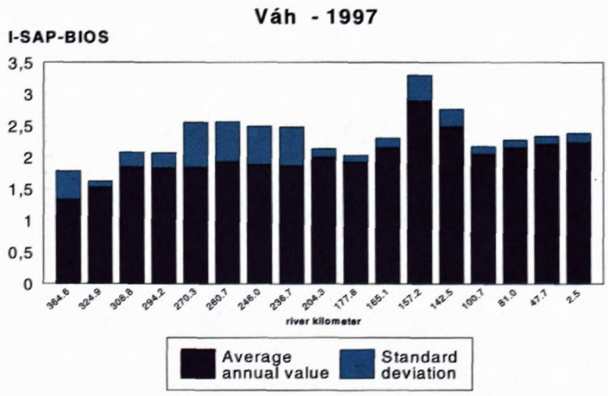


Figure 4.: Bioseston saprobity indices along the Váh River in 1997 (mean yearly values)

Macrozoobenthos analyses

The bottom organisms communities (insect larve, crustaceans, molluscs, leeches, worms and others), i.e. benthos, seem to be the most suitable for study and monitoring water quality from spring to estuary. Point sample analysis of the bottom revival in given profile provides a result characterizing longer than is the situation in momentum state of water sampling. Reason for this is the fact that bottom organisms community has been created for a long time, under influence of all local conditions, including of the water quality changes. Relation of the organisms and aquatic system is very close. Because of this, there are very good possibilities of bioindication - it means, a retrospective assessment of physical and chemical properties of the aquatic environment by organisms. The changes of physical and chemical composition of surface water, for instance an increase of chemical substances concentrations may effect both qualitative and quantitative composition of natural fauna and flora in the river. The most sensitive species are due to pollution gradually eliminated.

Sampling for subsequent macrozoobenthos analysis has been performed by semiquantitative sampling method "kick sample" into hydrobiological net according to international standard ISO 7828-1995. Net content is analysed, abundance is assessed and individual organisms on the level of species are determined (in some indices a determination of organisms on the level of family is sufficient). Community can be assessed by various biological indices, for instance saprobity index.

Ecotoxicological analyses

Benthos analysis allows to set a global effect of contaminated waters on water ecosystems, but do not allow neither to find out which components of liquid wastes are responsible for toxic effect on living organisms, nor to determine their maximum admissible concentrations in recipients and demanded degree of liquid waste dilution. These problems can be solved within the framework of the second approach based on measurements of inconvenient impacts on living organisms, biological systems and processes due to chemical substances. Evaluation of these effects is performed by bioassay approach, at which liquid waste or substances are getting into contact with specified organisms under controlled conditions. Toxic effects could be defined in terms of acute (short - term) and chronic (long - term) toxicity. Acute effects have been occurring following the short-term exposition, usually with lethal consequencies on organisms. Chronic effects are found out following the long-term exposition comparable with lasting of life cycle, respectively longer, and usually they are monitored on the basis of a number of biological criteria such as time of surviving. An advantage of bioassay method is that combined toxic effects of all dangerous substances in water sample even if such substances were found out in the very low concentrations. A shortage of these methods is, in spite of the fact that given sample is always tested by help of organisms at various troffic levels, that organisms need not to be sufficiently sensitive for given sample composition. Because of this reason there is a continuous development of new more sensitive methods, based on sensitive stages of life cycle, in-vitro systems, or biomarkers (Kristensen & Krogsgaar, 1997).

There is a general tendency for using of the ecotoxicological testing as a part of water quality monitoring programme.

Methods of ecotoxicological tests for waste water, surface waters and sediments analyses have been applied in the Ipeľ river basin as pilot area. Here a set of acute tests of toxicity was established and performed: on bacteria *Vibrio fisheri* (MICROTOX), *Sinapis alba* (root prolongation test), *Daphnia magna* (immobilisation test), *Lemna minor* (growth inhibition test) and *Brachionus calyciflorus* (ROTOXKIT).

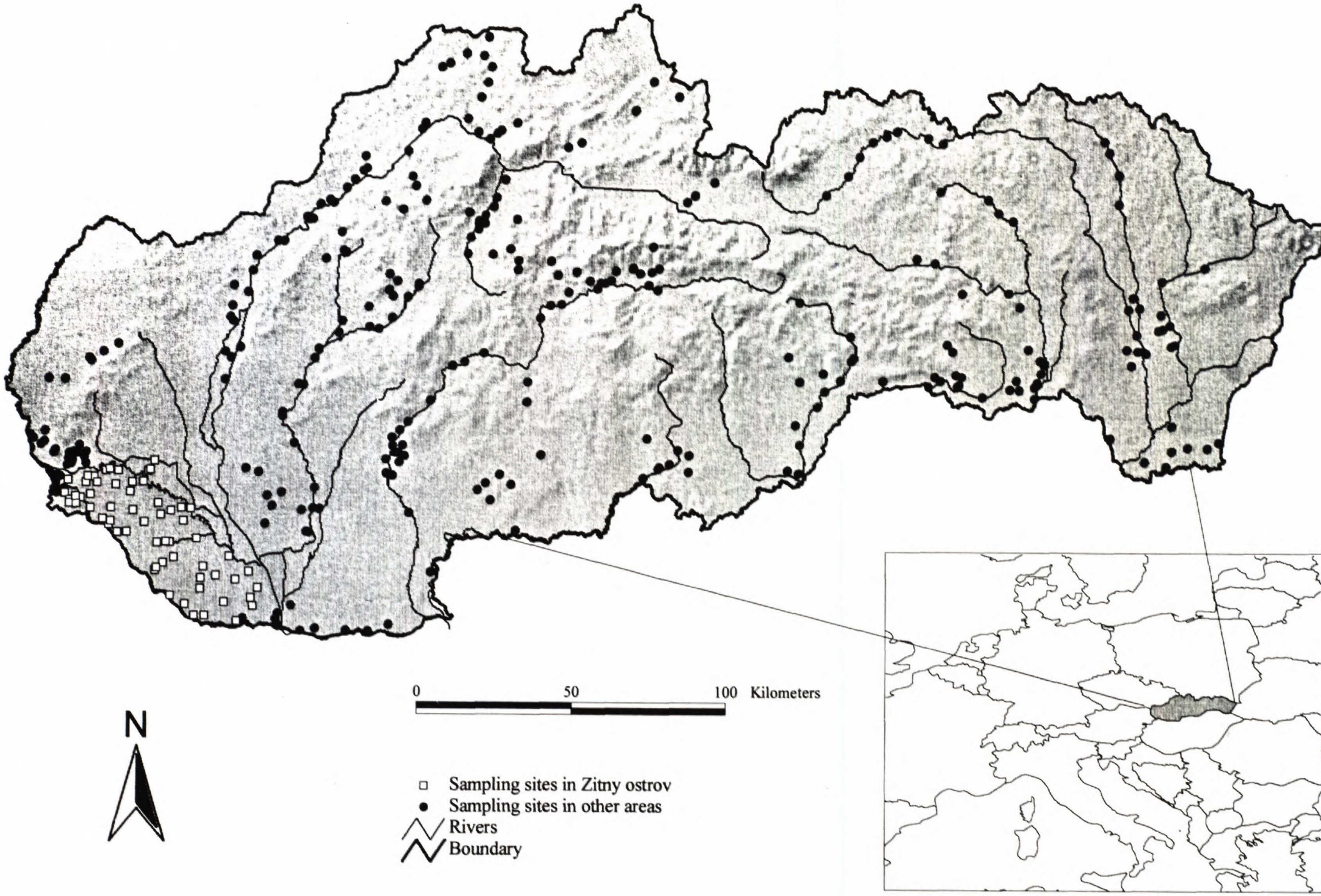


Fig. 5 Groundwater quality monitoring sites in Slovakia

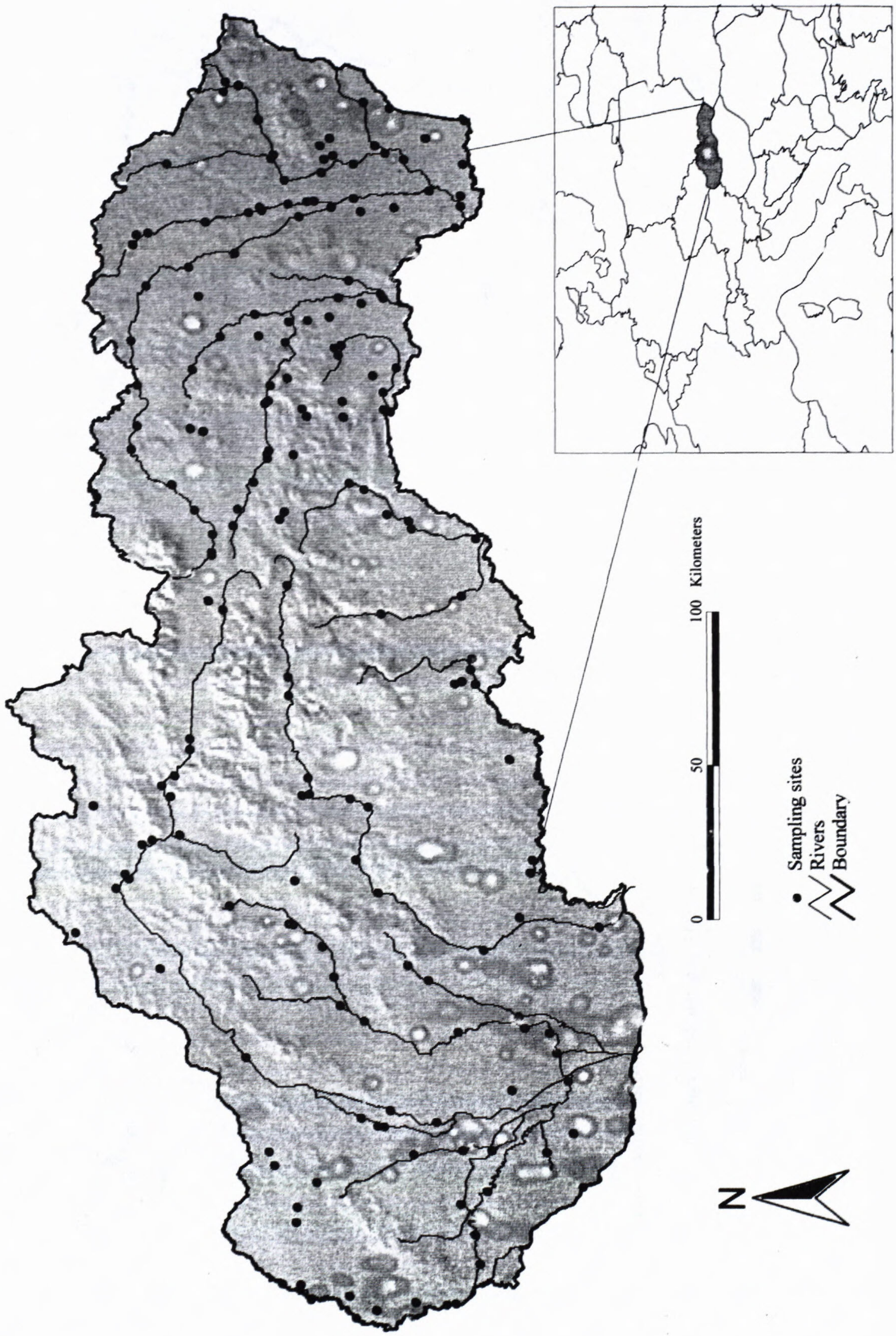


Fig. 6 Surface water quality monitoring sites in Slovakia

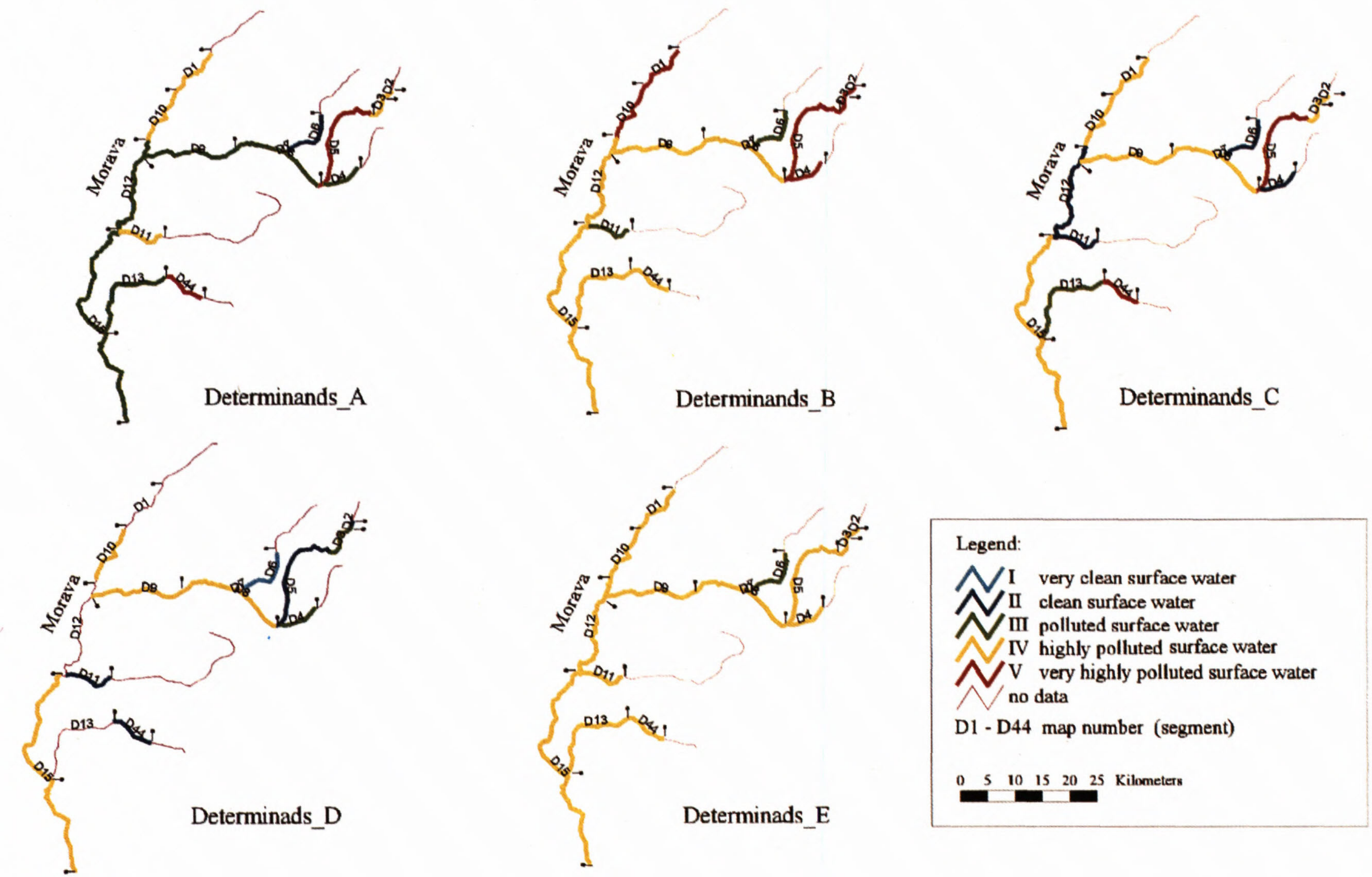


Fig. 7 Classification of water quality in Morava river basin (STN 75 7221 – Slovak Standard) Data Dynamic Segmentation Model

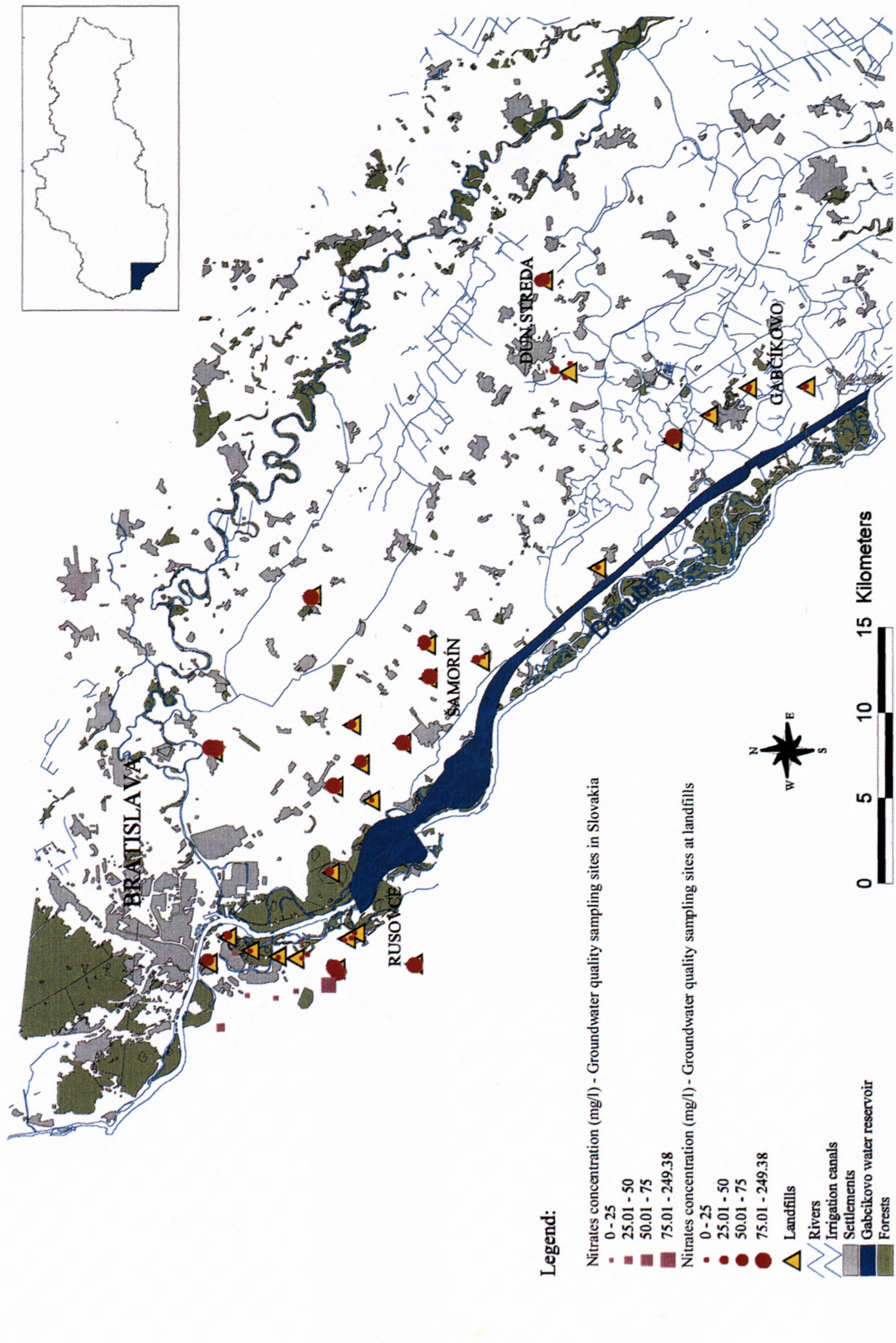


Fig. 8 Impact of landfills on groundwater quality in the Žitný ostrov area of Slovakia

Based on the findings from the pilot study the surface water quality monitoring programme may be extended by the biological and ecotoxicological methods which allow an effective assessment of the aquatic systems and provide a sufficient complex information for decision making process in the field of water quality protection.

GIS – tool for water quality data evaluation and presentation

The utilization of GIS for surface water quality monitoring programmes will be focused mainly on the following items:

- characterisation of the actual state of surface water quality situation
- presentation of the classification of surface water quality in accordance with Slovak Technical Standard STN 75 7221 (Fig. 7).

The use of GIS in groundwater quality monitoring programme will be aimed at:

- presentation and analysis of results based on using of GIS technology
- presentation of an overview of monitoring stations and relationship with their both station and monitoring informations (type of station, year of construction, owner, X–Y–Z top of pipe, Z ground level; basic monitoring frequency, metod of sampling, metod of analysis etc.)
- regionalisation of the local water quality measurements
- optimization of monitoring network.

Workplan of GIS preparation

The objective of workplan is to develop a GIS model with available information on the water quality and quantity from national monitoring programmes in the Slovak Republic. It should allow the following evaluation procedures:

- overview of sampling sites with basic information and characteristics
- selection of monitoring stations based on the defined selection criteria related to station characteristics, sampling frequency and determinand sets.

The following data sources will be used in the process of the using of GIS application:

- groundwater and surface water quality and quantity data from the SHMI databases
- basic topographical and thematic maps
- land use data.

The GIS model has already been used in the field of water quality in the PHARE project, „Ecological risk assessment of pollution by heavy metals and organic micropollutants in the Danube catchment area", to present both chemical and ecotoxicological data (Fig. 8) in connection with basic topographic maps (PHARE, 1998). Furthermore, simple regionalisation of local data has been used by SHMI in the landfill monitoring programme in the Žitný Ostrov area (Adamková et. al, 1997).

References

Adamková J., Borodajkevyčová M., Čecho M., Gavora J., Marikovičová J., Murín M., Paľušová Z. & Vydarený M., 1997: Monitorovanie vplyvu skládok odpadov na kvalitu podzemných vôd na území ovplyvnenom VD Gabčíkovo, záverečná správa, Bratislava, Slov. Hydrom. Úst, 1-52.

Adamková J, Ďurkovičová D., Matyšková M., Ševčíková V., Vančová A., 1998: Kvalita povrchových vôd na Slovensku 1996-97, Bratislava, Slovenský hydrometeorologický ústav

Ftorková M, Pospiechová O, Frličková F, Petrivaldský P, Roháčiková A, Bučkuliak J, Kečková Ľ, 1997: Sledovanie vývoja kvality v predkvartérnych útvaroch na území SR pre zabezpečenie ich ochrany, čiastková záverečná správa, IGHP Žilina, 1-53

Kolkwitz, R. & Marsson M., 1909: Ökologie der tierischen Saprobien.- Int. Rev. Ges. Hydrobiol. 2, 126-152.

Kristensen P., Krogsgaard J., 1997: Integrated approach for chemical, biological and ecotoxicological monitoring – tool for environmental management, European Water Pollution Control, Vol 7, No 4, EWPCA, 36-42.

Perútka I., 1995: Postup pri odbere vzoriek vôd a meraní parametrov in situ, Manuscript, Bratislava, Slov. Hydrom. Úst, 1-13.

Remenárová, D 1982a: Koncepcia dlhodobého sledovania kvality podzemných vôd na Slovensku, Manuscript, Bratislava, Slov. Hydrom. Úst.

Remenárová, D 1982b: Metodika vyhodnocovania sledovania kvality podzemných vôd na území Slovenska, Manuscript, Bratislava, Slov. Hydrom. Úst, 1-7.

PHARE, 1998: Ecological risk assesment of pollution by heavy metals and organic micropollutants in the Danube catchment area. 3rd phase report, PCU Vienna.