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USE OF GROUNDWATER AQUIFERS OVERLAPPING THE BORDERS OF STATES

KORZYSTANIE Z ZASOBÓW GRUNTOWYCH POKRYWA SIĘ Z GRANICAMI PAŃSTW

Waters do not respect the borders of countries. They had been created according to their own logic long time before the states with their borders were established. Establishment of new states is an ongoing process and we are also witnesses of dividing larger states in smaller ones with all attributes that sovereign state should have. Water as a fundamental element of life may also give rise to conflicts and tension between neighbouring countries mainly due to water shortage. Therefore, it is important to foresee and solve such problems to prevent the risk of international conflicts.

Issues related to use of transboundary waters are very topical and important. The world's 263 transboundary lake and river basins cover 45 percent of the Earth's land surface including 40 percent of the world's population. Many of them are situated on the territory of more than two countries. The Danube River flows through 18 countries and in each border area it creates natural surface and ground water environment which can become the source of conflict between countries in utilizing these waters. It is high time to solve also these problems; otherwise, they can lead to different kinds of crises. Our country also experienced some problems related to transboundary waters. Currently, this issue is very important in negotiations on use of groundwater in transboundary regions.

It is very important to foresee and solve problems to the satisfaction of all involved countries. It is necessary to solve this situation through bilateral and other agreements, the observance of which shall be monitored and regulated to satisfy all involved countries. Transboundary groundwater quantity and quality monitoring together with surface waters is in the competence of the committees on transboundary waters.

The experience in the field of groundwater is not such considerable compared to surface water. So far, no bilateral agreements on transboundary groundwater use have been signed. This paper deals with the issue of sharing transboundary groundwater resources mainly with Poland.

1. Introduction

Water is one of the most important elements of landscape and it is essential for human society. Water is the most widespread substance in the nature and fundamental for life on the Earth. A significant feature is that the water is renewable resource dependent on water cycle in the nature (in contrast to other resources such as fossil fuels which is non-renewable).

Water resource can be any part of water cycle in the nature where surface water or ground water is present in technically and economically usable form (e.g. watercourse, water reservoir, spring, well, etc.). Concerning occurrence, usability, protection and assessment we distinguish between surface water and ground water resources.

Water is the most widespread substance on the Earth. The relationships among the number of population, development trends, hydrological cycle and actual available fresh water resources show the pressure that increases with demand for availability of water resources all over the world. In many regions of the world the demand for water and available water resources can lead to political conflicts.

Water does not recognize state borders and as a shared resource it requires international cooperation. Water resource management should be implemented within the natural river basins and not within the political boundaries.

Many of the mentioned problems can also be seen in our region of the Central Europe. The impact of anthropogenic activity (reducing forest areas, land use, urbanization, increase of impermeable surfaces, reduction of alluvial forests, wetlands, etc.) proves the fact that the trend to control water resources prevails over reasonable use of water also in our region. The present conditions of drinking water supply, wastewater collection and treatment in Slovakia falls behind the level of developed countries in Europe and the world and it forces us to search for ways how to get closer to these trends and objectives.

2. Basic Description of River Basin Districts in Slovakia

The area covering 96% of the Slovak territory belongs to the Black Sea Basin. The area of the Danube River Basin in Slovakia is 47 064 km² including sub-basins of lower Morava (2 282 km²), Danube (1 138 km²), Váh (14 268 km²), Nitra (4 501 km²), Hron (5 465 km²), Ipeľ (3 649 km²), Slaná (3 217 km²), Bodva (858 km²), Bodrog and Tisa (7 272 km²) and Hornád (4 414 km²). Water flows from the rest of the territory (4 %) into the Baltic Sea. The total area of the Poprad and Dunajec sub-basin is 1 950 km².

The total length of streams in Slovakia is 49 775 km. The average density of river system is 1.1 km.km⁻².

The state borders of Slovakia with five neighbouring countries mostly do not pass along the boundaries of hydrological units (watershed divides, fall lines, streams) in most cases. Some large rivers, namely Danube (flows from Austria), Tisa (from Hungary), Morava (from the Czech Republic) and Dunajec (from Poland), flow through the boundary regions of our country. Long-term average discharge of rivers in Slovakia is approximately 3 328 m³.s⁻¹ (including tributaries from neighbouring countries) where only 398 m³.s⁻¹ rises in our territory (12 %).

3. Waters flowing into the territory of Slovakia

The following water volumes (expressed as long-term average discharge) flow into the territory of Slovakia through the inflow boundary profiles:

- from the territory of Poland – about $39 \text{ m}^3 \cdot \text{s}^{-1}$ by the Dunajec and Poprad rivers and their tributaries,
- from Ukraine – about $58 \text{ m}^3 \cdot \text{s}^{-1}$ by the Uh and Latorica rivers,
- from Hungary – about $379 \text{ m}^3 \cdot \text{s}^{-1}$ mainly by the Tisa River and left tributaries of the Ipeľ River,
- largest volumes flow by the Danube River from Austria – about $1\,976 \text{ m}^3 \cdot \text{s}^{-1}$ in total,
- from the Czech Republic – about $62 \text{ m}^3 \cdot \text{s}^{-1}$ mainly by the Morava River and other smaller rivers

The total discharge is $2\,514 \text{ m}^3 \cdot \text{s}^{-1}$, i.e. 86 percent.

The long-term average volume of water flowing out of the territory of Slovakia (expressed as discharge) is $2\,912 \text{ m}^3 \cdot \text{s}^{-1}$.

4. Spatial and Temporal Distribution of Groundwater Resources in the Slovak Republic

Groundwater resources of Slovakia are distributed very unevenly. Their quality and possibility to exploit them are given by the characteristics of geological formations, their surface distribution, thickness and permeability of rocks that create more or less favourable conditions of hydro-geological structure for occurrence and accumulation of groundwater.

Available volumes of groundwater represent maximum amount of groundwater that can be abstracted from a given water system for water supply during whole planned period of exploitation. The use of groundwater resources is considered at acceptable ecological, technical and economic conditions without the influence of natural runoff that can be regarded as unacceptable and without unacceptable water quality deterioration.

The qualitative assessment of natural groundwater serving as a basis for determining available supplies is a fundamental problem in assessment of available groundwater resources. Natural groundwater resources are $146.7 \text{ m}^3 \cdot \text{s}^{-1}$ in average (source: Slovak Hydrometeorological Institute, 2000), out of which documented available resources represent 51.6 %. Available groundwater resources are located mainly in the areas with large permeable aquifers where significant amounts of groundwater can be abstracted by smaller number of intake structures. These are usually alluvial deposits of large rivers with thick layers of gravel-sands and very good porosity and permeability. In mountain regions there are many available resources located in zones with crevice-carstic permeability of main aquifer. These are zones formed by limestone and dolomites. More than 80 percent of all available resources are found in Quaternary and Mesozoic structures of Slovakia.

On the other hand, zones with poor permeability of aquifers have low number of available resources. These are zones formed mainly by paleogenic flysch sediments,

neogenic clay sediments, crystalline formations, vulcanites and some mesozoic rocks of low permeability such as claystone. Unfavourable situation is improved in some locations by drainage of tectonic zones where higher accumulation of groundwater occurs and significant resources are formed. Most of resources are diffused and suitable only for local use.

The total available groundwater resources of Slovakia are represented by the total number of resources approved by the Sub-committee for Classification of Resources and Supplies. This number is defined based on documented amounts resulting from hydrological researches and surveys. Available groundwater resources of Slovakia were 76 748 l.s⁻¹ according to data of the Slovak Water Management Balance as of December 31, 2006.

The total capacity of groundwater resources managed by water companies and municipal authorities was 27 713 l.s⁻¹ in 2000. However, only 42 % out of this capacity is used for drinking water supply.

5. Water Quality

Industrial and agricultural activities on both sides of the borders give rise to long-lasting problems with quality of water resources. There are localities known for the presence of contaminants such as NO₃, NH₄, PO₄, pesticides and other. It is important to solve these problems in a short-time perspective to eliminate further contamination of water resources on both sides of the state borders.

There are several guidelines for protection and management of these water resources, e.g. Directive on the protection of groundwater against pollution (2006/118/EC), Directive 91/676/EEC concerning the protection of groundwater against pollution caused by nitrates and the Directive 91/414/ECC concerning the placing of plant protection products on the market. Many other directives provide instructions for users for example how to use the areas inside the protection zones of water-supply resources, etc.

Basic measures for protection of water resources are as follows:

- preservation of unspoiled environment
- regulation of groundwater abstraction
- increase in retention capacity and erosion protection measures
- change of land use pattern in catchment area
- protection of infiltration areas
- increase in retention capacity of forest ecosystems
- other measures

6. International Cooperation in Water Management Sector

6.1. Cooperation on Transboundary Rivers

International cooperation of the Slovak Republic in water management sector is done through cooperation on transboundary waters. This cooperation is in accordance with the Convention on the Protection and Use of Transboundary Watercourses and International Lakes UNECE (Helsinki Convention), the Convention on the Cooperation in Protection and Sustainable Use of the Danube River and many other agreements or conventions. The cooperation with neighbouring countries results from agreements and treaties concerning the cooperation on transboundary waters. The treaties were signed also in the past. Later they were reviewed and followed by new treaties and agreements with regard to establishment of new countries (Slovakia, Czech Republic) and changes in approach to given problems.

Bilateral agreements were signed with neighbouring countries (with Poland, Ukraine, Hungary, Austria and the Czech Republic). In the region of the Poprad and Dunajec River Basin, the Agreement between the Government of the Czechoslovak Socialistic Republic and the Government of the Peoples Republic of Poland of October 3, 1986 on fisheries in transboundary waters is still in effect and it was recognized within the succession of international treaties. In 2001, the new Agreement between the Slovak Republic and Poland on fisheries in transboundary waters was signed.

The Joint Committees on Transboundary Waters were established in accordance with the treaties and agreements. These committees discuss all water management measures implemented in transboundary waters at annual meetings. The committees carry out measurements, marking and identification of the state borders. Moreover, they cooperate in regulation of stream channels to prevent shift and change of the state borders as well as damage of signs used for demarcation of the state border. International cooperation is mainly aimed at the following:

- warning and forecasting hydrological service,
- maintenance and training of watercourses, change of water regime,
- stabilization of state borders,
- protection against floods, risen levels of reservoir water and dangerous ice run,
- construction of hydraulic structures affecting changes in runoff ratios,
- use of transboundary waters – abstraction for economic purposes, utilization of water for navigation, use of hydropower potential and use of water for recreation and sports,
- ecologization of water resources including water quality monitoring and measures for protection of water from accidental pollution,
- emergency information service
- measures for emergency water quality deterioration and emergency hydrological events including warning system
- abstraction of surface water and groundwater
- discharge of wastewater and other types of water

- protection of surface water and groundwater against pollution; maintenance and improvement of their quality,
- protection zones of water-supply resources,
- amelioration measures,
- use of water power,
- exploitation of sands, gravel sands, stones and other materials from river beds,
- measurements and monitoring, their evaluation and result Exchange,
- water management planning and balance
- protection of aquatic and litoral habitats
- protection of transboundary waters as a part of environment
- other water management measures.

The committees on transboundary waters carry out the monitoring of quality and quantity of transboundary groundwater resources.

Experience in this field is not sufficient compared to surface waters. Moreover, no bilateral agreements on groundwater use are signed between neighbouring countries. Today, the solutions to problems such as declared areas (bodies) are sought. These problems also include the following:

- use of dynamic water resources (water flow direction, regulations for sampling, etc.),
- potential impact on use of these waters (protection, pollution, methods of contamination removal, etc.),
- regulations for their use,
- information exchange methods,
- ecologization of water resources (quality monitoring) and measures in case of accidents,
- emergency information service, etc.

Another problem is geothermal water located in transboundary bodies (for instance the Slovak-Hungarian Region). Geothermal water can have larger zone (area) compared to surface and ground water resources. The official talks in this field have begun with the Czech Republic and Hungary.

7. Present Activities of the Slovak Republic Related to Use of Transboundary Groundwater Resources

Transboundary activities also include the development of case studies within the cooperation between Slovakia and Poland. For groundwater monitoring in the boundary region between Slovakia and Poland, the experts from both countries provide performance of the tasks under the WFD requirements.

At present, the assessment of quantitative status and chemical status of the groundwater bodies is carried out for the river basin management plans by 2010. Unless

the mentioned plans are completed, no transboundary groundwater body will be identified in the boundary region of Slovakia and Poland.

The following activities are in progress:

- localization of sites for groundwater quality and quantity monitoring in 2007 including X and Y coordinates of monitoring objects and depth of wells;
- monthly averages of groundwater quantity monitoring for 2007 at the objects according to point a);
- complete analyses of groundwater quality monitoring carried out in 2007;
- localization of sites for groundwater quality and quantity monitoring in 2008 including X and Y coordinates of monitoring objects.

The first programmes and experience exchange from the cooperation on transboundary groundwater supporting the use of transboundary zones of groundwater have begun in 2006 within the INTERREG Programme. These waters are of interest to Slovakia, Hungary and Ukraine. The activities within the ENWAT programme with participation of the Hungarian Geological Institute and the Geological Institute of the Slovak Republic include development of several documents such as hydrological maps, characteristics of groundwater and aquifers, contamination index, groundwater pH value, total mineralization, and distribution of arsenic, chlorides, hydrogen carbonates, nitrogen, sodium, nitrates and pesticides. The Slovak experts make an effort to achieve similar objectives for all transboundary waters.

The general objective of the project is to improve qualitative and quantitative parameters of groundwater in transboundary bodies by 2015. The main goal was aimed at the development of integrated geological, hydro-geological and environmental space-information system, which should serve as useful and supporting tool in the WFD implementation in both countries and it should be the basis for further activities in respective regions related to groundwater and environment.

Detailed information on the project is available on the website (www.enwat.eu).

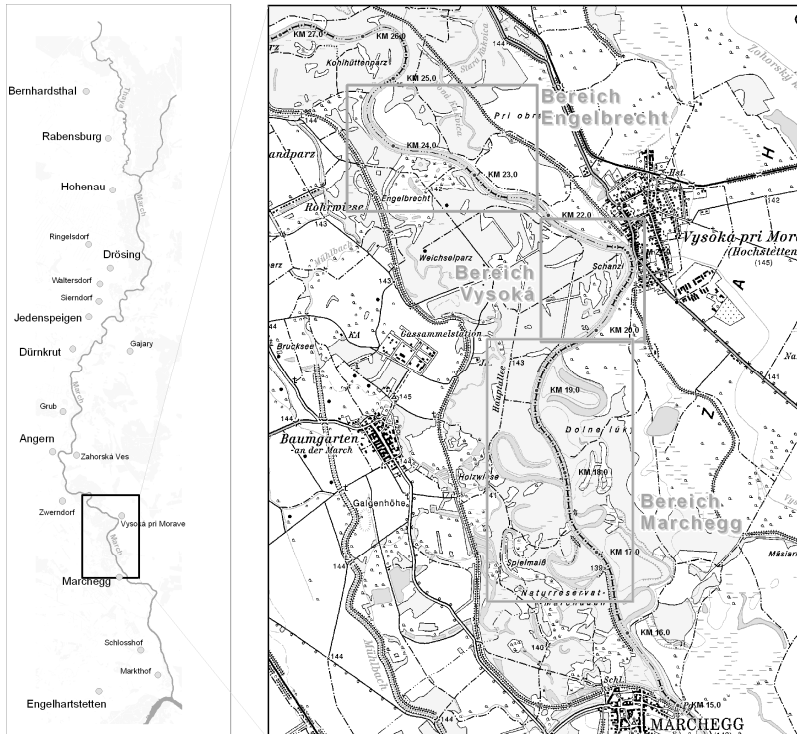
The activities with Austria are currently focused on the assessment of groundwater in the Hlildeboden groundwater body in the region of Pama. These activities include monitoring of hydro-geological structures of bedrock, measurement of well capacity together with short-term pumping for identification of biochemical composition of groundwater. In addition, there are activities aimed at monitoring of groundwater quality and quantity in the right boundary region of the Danube River between Wolfstahl and Petržalka near the municipality of Berg. This groundwater resource is influenced by water levels of the Danube River and other factors.

The survey in particular regions provides relevant and the most current information on quality and quantity of groundwater bodies and helps experts and public in decision-making process. The results of the joint project should improve the quality of life in assessed transboundary regions. The effort of the projects is to solve all problems related to water management in particular regions. The project results will be useful in protection and efficient management of groundwater to assure the resources for public water supply. Moreover, groundwater resources will be important element of protected areas. The outcomes can be also used as a basis for other projects with similar scope providing that the plans for groundwater quality exchange will be observed. Finally, the results of the project should be used in proper monitoring and use of groundwater resources and relevant groundwater bodies in transboundary regions.

8. Case Study

The case study deals with the training of certain stretch of the Morava River which forms the state border between Slovakia and Austria. Although this study solves the problem with discharges, sediments and river bank regulation, it also has direct influence on the quality of water along the river banks on both sides of state border.

The name of the project is „Measures for regulation of river banks and cross sections as well as measures for connecting the meanders of the Morava River at the river stretch Marchegg (rkm 15 –25).



Fi. 1 Map of structure location

The objectives of the project submitted for approval are as follows:

- increase in smooth development, reduction of vertical alignment gradient,
- increase in occurrence of bank overflows
- support of groundwater recovery (groundwater production)
- recovery (production) of side waters (= trenches communicating with the Morava River)
- improvement of hydrology of side waters
- formation of bank structures in accordance with patterns
- increase in bank slopes with compact riparian stands
- structures for low water levels

Time interval for construction works in the area of Austrian river bank was planned from the half of June to the end of September 2002. Flood caused that construction works had to be interrupted from the half of August to the beginning of September 2002. Already implemented measures were not affected by the flood. Deadline for finishing the construction works (30 March 2003) given by water legal decision was met. Construction works were smooth and the weather was favourable in July and September 2002 and therefore most construction sections were completed sooner than it had been planned while roads and land properties were disturbed minimally. After completion of construction works the disturbed areas were returned into original condition in line with the order.

Tree selection for cutting down as well as specification of most suitable access roads and transport roads were made in cooperation with the water legal building supervision. The emphasis was put on showing as much consideration as possible towards surrounding territory of floodplain forest.

In connection with individual measures it is necessary to say that construction works at both banks of river were basically implemented in line with the project with legal permission. Tiny deviations originated mostly due to more practical construction or optimal adjustment to local conditions and were discussed among water legal, local and ecological building inspectors.

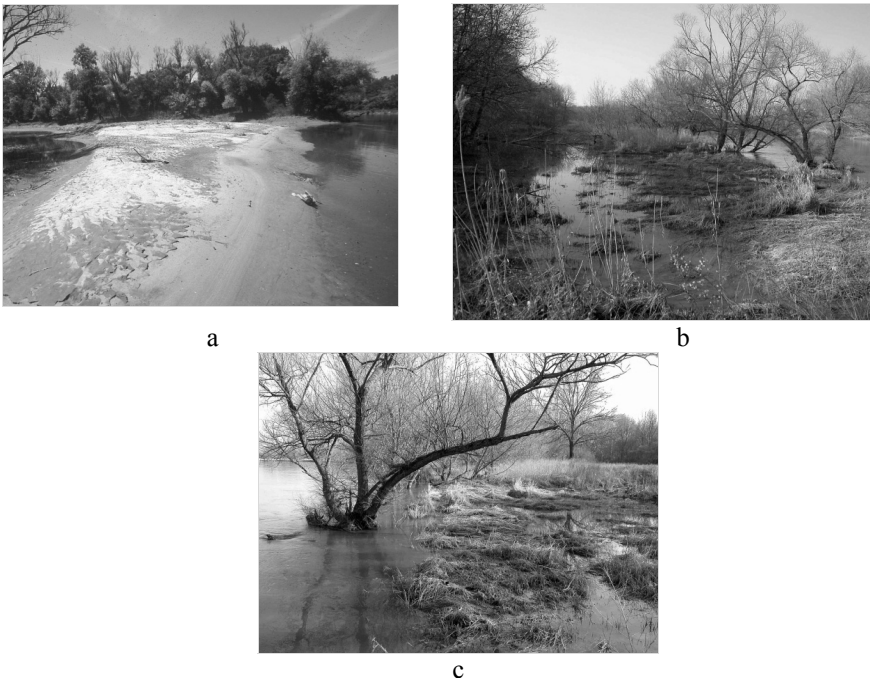


Fig. 2. Views on the interest territory a – view on the river bank, b – meander mouth, c – decrease of the river bank line – flooded mould

It can be said that during construction works in line with the project the water legal conditions were satisfied and the expected result was achieved through taken measures.

9. Conclusion

Issues of transboundary water utilization are very topical and urgent. In the world there are approximately 263 river transboundary regions (basins) covering more than 45 % of the world surface and hosting 40 % of the world population. Many of them pass through more than two countries. Some of them pass through 9 to 11 countries. For example the Danube flows through 18 countries and in each transboundary area it creates natural surface and ground water environment which can also be a conflict between the countries when using these waters. Therefore it is high time to solve also these problems because ignoring them can lead to various crises. We can experience some of them also in our territory. In 2009 these issues were of priority importance when negotiating the usage of ground water in transboundary regions.

Water resources as such do not recognize state borders because they had been created much earlier observing their own logic than the states with their borders originated. Nowadays the process of formation of new countries still continues when larger states disintegrate to smaller ones with all necessary attributes. Water as a basic consumable and inevitable element for our lives can bring tension and hostility to coexistence of neighbouring states mainly when there are floods or water scarcity. Therefore it is necessary to predict these problems and solve them to satisfaction of all related countries mainly through bilateral contracts or other conventions, the observation of which should be constantly monitored in a way all related countries are satisfied.

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