Chapter 29
Contamination and Protection of Surface Water Source in Czech Republic

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Abstract There have been numerous changes regarding legislative framework for water during the last years. This article deals with the problem of Kruzberk water reservoir, situated in Odra river basin (that empties into the Baltic Sea) in the northeast of the Czech Republic. The objective of this work was to evaluate the evolution tendency of reservoir water quality, determine the problematic parameters and to carry out balance evaluation of selected parameters from among the reservoir profiles in vegetation periods of the years 2006–2008. The most important profile is the profile number 1 (start of backwater) and number 5 (dam). The risk analysis based on hydrogeological exploration and area survey was carried out to protect the water quality and quantity. An optimization study and revision of protection zones were also carried out according to the valid legislation. When evaluating the concentrations, the following problematic parameters were verified: DQO – permanganate, pH, iron, manganese, calcium and magnesium, thermotolerant bacteria and Enterococcus. The regulation of activities in level 2 protection zone should positively influence water quality of the water reservoir in the future.

Keywords Reservoir water quality • Surface water protection • Contamination • Protection zones • Czech Republic

29.1 Introduction

The problem of contamination and protection of surface water sources is a theme of great importance. In the Czech Republic, most drinking water is obtained from surface and groundwater resources. Generally, groundwater resources have a lower tendency of anthropogenic pollution than surface water. However, the situation of groundwater

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resources in soil is not perfect with regard to a drinking water supply. Therefore, the water reservoirs are used as a source of drinking water. For water quality and quantity protection it is necessary to establish protection zones. The protection zones are very important for the protection of the environment and significantly influence landscape conservation and improvement.

There have been numerous changes regarding legislative framework for water during the last years. One of the reasons for these changes was ingression of the Czech Republic to the European Union in 2004. Then, it was necessary to transpose European legislation into national law. Since both Spain and the Czech Republic are members of the European Union, they have the same legislation and therefore both countries resolve the water problems in a similar way. The most important European Directives transposed to the national legislation are: Directive 2000/60/EC and Directive 91/676/EC.

29.2 European and Czech Legislation

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 established a framework for Community action in the field of water policy (Water Framework Directive). By this Water Framework Directive, the European Union organizes management of surface water, continental water, transitional waters, coastal waters and groundwater to prevent and reduce its pollution, promotes sustainable water use, protects and enhances the status of aquatic ecosystems and reduces the effects of floods and droughts (The Water Framework Directive, 2009, http://www.directivamarco.es/). Its fundamental principles are:

- Hydrographic basin as the management unit, which corresponds to the unit with natural hydrological cycle;
- Cost recovery in the price of water that includes externalities;
- Achievement of good eco-biological, hydromorphological and physical-chemical status;
- Water and aquatic ecosystems recovery as a best guarantee of water quantity and quality – ecological aspect for sustainable water use;
- Reduction of groundwater pollution and elimination of dangerous substances at source.

According to this Directive, all bodies of water used for the abstraction of water intended for human consumption providing more than 10 m^3 a day as an average or serving more than 50 person (The Water Framework Directive, 2009, http://www.directivamarco.es/) must be identified.

Member States shall identify the individual river basins lying within their national territory and shall assign them to individual river basin districts. The river basins covering the territory of more than one Member State shall be assigned to an international river basin district.

The principles of the Water Framework Directive were adopted into Czech legislation by amending the Water Law 20/2004 Sb. (which came into force on January 23, 2004) and into the Drainage, sewers and public water supply law 274/2001 Sb.

Another very important European legislation is the Directive 91/676/EC – referring to protection of waters against pollution by nitrate from agricultural sources. Its principles were adopted into Czech legislation in the Regulation 103/2003 Sb. and its amendment. According to this Directive, nitrate vulnerable zones are areas where surface waters or groundwaters have nitrate concentrations of more than 50 $mg.L^{-1}$ or are thought to be at risk of nitrate contamination. The purpose of this Directive is to protect water quality by preventing high nitrate concentrations polluting ground and surface waters and especially by reducing polluting effects of the intensive cultivation and reducing the use of chemical fertilizers. It also includes regulations for wastewater treatment and good agricultural practice, such as nitrogen fertilizer use and storage, and livestock effluents. Action programs should be implemented by farmers within the nitrate vulnerable zones to prevent and reduce pollution due to nitrates from agricultural sources and should be revised every four years.

Protection zones have been defined to protect quality and quantity of drinking water sources (Water Law 254/2001 Sb.). Three water protection zones were established by previous legislation (level 1 protection zone; level 2 protection zone divided into outer protection zone and inner protection zone; and level 3 protection zone defined in surface water sources). In the actual water legislation only two levels of protection zone are defined: level 1 protection zone where more severe measures regime exists and level 2 protection zones. The actual tendency in water protection consists in determination of protection areas more defined, in result of which the water source area and the vulnerable area are not totally included in the established protection zone. It is also possible to establish more level 2 protection zones. It is of great importance, especially for agricultures, to know and observe the regulation, especially with respect to the reduction of mineral and organic fertilizers use, as well as herbicides and pesticides use. Very often it is also necessary to elaborate special programs for stock breeding prohibiting new constructions, establishment of new sewers and the use of chemicals for winter road maintaining within these zones (Oppeltová and Novák 2007).

The owners whose land is within the protection zone receive subsidy to reduce disadvantages caused due to limitation they are subjected to. In view of the large initial area of protection zones and in view of the fact that the users of water sources did not want to pay high price for the subsidy paid to affected owners, new and more reduced protection zones have been gradually delimited (Oppeltová and Novák 2007).

29.3 Kruzberk Water Reservoir and Its River Basin

Kruzberk water reservoir is situated northeast of the Czech Republic, in Odra river basin (that empties into the Baltic Sea). The water reservoir was built in Moravice River in the years 1948–1955 and is intended for accumulation of water (as a source of drinking water), Moravice River, Opava River and Odra river improvement, and floods prevention and for hydroelectrical production. This is a source of water supply for Ostrava city and surrounding municipalities, in total 200,000 inhabitants (Povodí Odry, 2009, http://www.pod.cz).

The reservoir is situated at a height of about 400 m, its river basin area is 567 km^2, the length of the reservoir is 9 km, the width is 0.5 km and its area is 280 ha. The average annual rainfall in this region is 825 mm and the average annual temperature is 7 °C, 8 °C (http://www.pod.cz). Forest area occupies approximately half of the river basin and the other half consists of agricultural land (grassland, potatoes and flax cultivation and stock breeding) (Výzkumný ústav vodohospodářský T.G. Masaryka, v.v.i., 2009, http://www.vuv.cz). A natural park is situated within the river basin where special regime must be followed. In this river basin there are also several industrial cities – Bruntál (automobiles), Bridlicna (aluminium processing) and other cities engaged in basalt extraction and plastics processing. Tourism has recently developed in this region.

There are no nitrate vulnerable zone within the basin (Výzkumný ústav vodohospodářský T.G. Masaryka, v.v.i., 2009, http://www.vuv.cz).

In the year 1967, water reservoir protection zones were established – to protect quality and quantity of drinking water. Three levels of protection zone were defined – level 1 zone, level two zones and level three zones, and the entire reservoir basin belonged to the protection zones – in total 567 km^2 (Cermak 1969; Zenaty et al. 1984).

29.4 Materials and Methods

The data on water quality and the reservoir flow values have been obtained from the state water enterprise Povodí Odry (Odra river basin). The aim of this work was to evaluate evolution tendency of water quality, determine the problematic parameters and to carry out the balance evolution of selected parameters from among the reservoir profiles (Fig. 29.1) in vegetation periods of the years 2006–2008. The analyses of all the selected water quality parameters were not performed all year long but only during the vegetation periods.

The following parameters were evaluated: iron, manganese, magnesium, calcium, carbonates, sulfates, nitrates, nitrites, ammonia, phosphates, total phosphorus, pH, oxygen, DQO – permanganate, DBO5, thermotolerant bacteria, Enterococcus bacterias and chlorophyll-alfa.

These water quality analyses were performed in five reservoir profiles (Fig. 29.1). The most important profile is the profile number 1 (start of back water) and number 5 (dam). The balance evaluation was carried out from among these profiles. The monthly weight of the water quality parameter *[1]* was calculated according to the monthly flows and concentrations and than the weight for the entire vegetation period was calculated. The quality of the water in the reservoir can be evaluated by a difference between the weight in the profile 1 and the weight in the profile 5.

Formula for calculation of monthly total substance weight (Eq. 29.1):

$$\frac{k.Q.x.c}{1000} = \text{Weight per month (kg)} \tag{29.1}$$

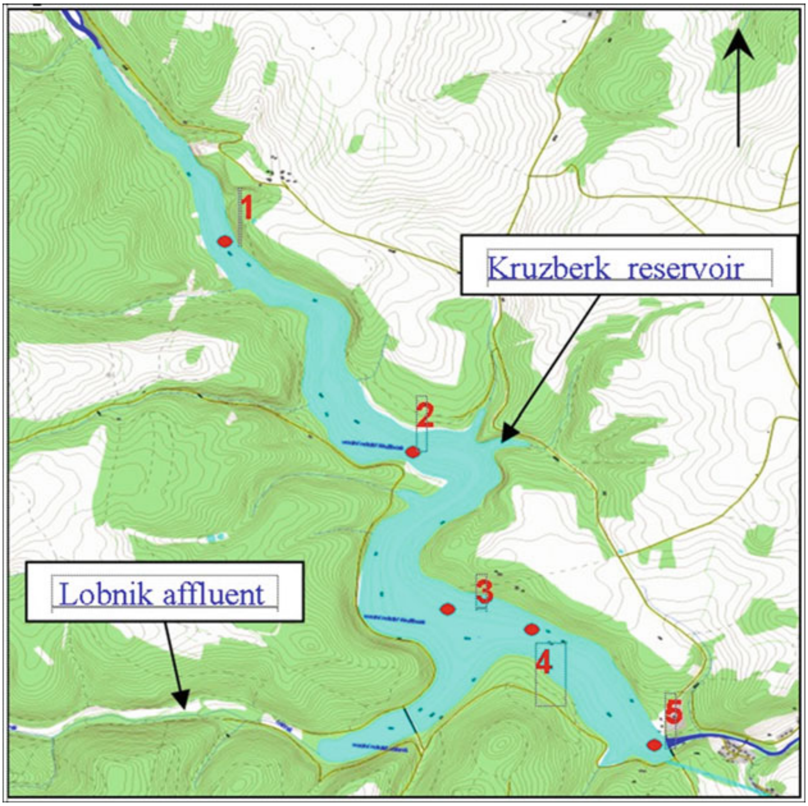

Fig. 29.1 Profiles of water quality measurement in Kruzberk reservoir

Q – Monthly flow ($m^3.s^{-1}$)
c – Substance concentration ($mg.L^{-1}$)
k – Coefficient expressing the daily amount $k = 60 \times 60 \times 24$
x – Number of days in a month

The risk analysis based on hydrogeological exploration and ground survey was carried out to protect the water quality and quantity. An optimization study and checks of protection zones were also carried out according to the valid legislation.

29.5 Results and Discussion

29.5.1 Optimization and Checks of Protection Zones

Water quality and water quantity are obviously influenced by both the natural environment and human activity. The measures to be taken in the protection zones cannot influence the aspects that depend on the natural environment. In 2007, the protection zones were revised according to the water quality results and river basin area surveys. Level 1 protection zone was defined – the basin and its surroundings (120.87 ha). Then, two individual level 2 zones were established – woodland and agricultural land surrounding the basin (247.49 ha) and the basin affluents (81.8 ha). Erosion control measures in this area must be followed and regulations with respect to the reduction of mineral and organic fertilizers use, as well as herbicides and pesticides use and special programs for stock breeding must be observed by the farmers.

29.5.2 Balance Evaluation

Important results of balance evaluation are shown below:

The limit for iron in drinking water is 0.2 mg.L^{-1} (Regulation 252/2004 Sb.) and the limit for iron in A2 non-treated water is 2 mg.L^{-1} (Rule 428/2001 Sb.). The legal limit for iron in drinking water was exceeded in the profile number 3 in May 2006 and in the profile number 1 in September 2008. All analyzed parameters correspond to the limits of A2 raw water.

Balance evaluation of iron:

Year 2006	5,249.09 – 3,543.45 = **1,705.64 kg**
Year 2007	6,232.59 – 6,837.67 = −**605.08 kg**
Year 2008	1,676.66 – 3,977.27 = −**2,300.61 kg**

A positive result means that the amount of iron was higher in the profile number 1 (start of back water) than in the profile number 5 (dam). The difference represents the iron retained in the reservoir. The vertical stratification of iron is produced in the reservoir. A negative result means that the amount of iron was lower in the vertical profile number 1 than in the dam. This effect can be caused by sedimentation and posterior separation of sediment from water.

The limit for manganese in drinking water is 0.05 mg.L^{-1} (Regulation 252/2004 Sb) and the limit for manganese in A2 non-treated water is 1 mg.L^{-1} (Rule 428/2001 Sb). The legal limit for manganese in drinking water was exceeded in the vertical profile number 2 in September 2006 and in the profile number 4 from April to August 2006. All analyzed parameters correspond to the limits of A2 non−treated water.

Balance evaluation of manganese:

Year 2006	2,736.55 – 1,852.44 = **884.11 kg**
Year 2007	2,730.50 – 2,502.46 = **228.04 k**
Year 2008	565.15 – 895.07 = −**329.92 kg**

The total amount of manganese is lower than the amount of iron. A positive result means that the sedimentation of manganese compounds occurred. A negative result shows the liberation of manganese from the water sediment.

The limit for sulphates in drinking water and in A2 non-treated water is 250 mg.L^{-1} (Regulation 252/2004 Sb.). This limit was not exceeded in any case.

Balance evaluation of sulphates:

Year 2006	1,479,129 – 1,459,875 = **19,254 kg**
Year 2007	1,761,340 – 1,514,393 = **246,947 kg**
Year 2008	38,073.3 – 739,174.1 = −**1,100.8 kg**

Anthropogenic sources of sulphates are emissions containing SO_2 and SO_3 coming from the combustion of fossil fuels. A positive result means an accumulation of sulphates in the reservoir (reduction of sulphates in anaerobic environment).

The amount of sulphates in the profiles 1 and 5 are nearly equal.

The limit for nitrates in drinking water and in A2 non-treated water is 50 $mg.L^{-1}$(Regulation 252/2004 Sb; Regulation 428/2001 Sb.). This limit was not exceeded during the analyzed period.

Balance evaluation of nitrates:

Year 2006	294,513.00 – 322,339.60 = −**27,826.60 kg**
Year 2007	482,711.00 – 541,050.88 = −**58,339.88 kg**
Year 2008	182,292.29 – 209,221.26 = −**26,928.97 kg**

The most important source of nitrates is agricultural land. The nitrates level was always higher in the dam due to river Lobnik, an affluent that runs through agricultural land and flows into the reservoir.

The limit for phosphates in A2 non-treated water is 0.5 $mg.L^{-1}$ (Regulation 428/2001 Sb). This limit was exceeded in the profile 3 in June 2006.

Balance evaluation of phosphates:

Year 2006	2,283.67 – 2,024.27 = 259.40 **kg**
Year 2007	2,710.27 – 3,762.53 = −**1,052.26 kg**
Year 2008	585.62 – 852.49 = −**266.87 kg**

The most important anthropogenic sources of inorganic phosphorus are the chemical fertilizers and waste waters. The organic source of phosphorus is the phosphorus from animal residues and decomposition of phytoplankton and zooplankton settling on the reservoir bottom (Pitter 2008). Phosphorus influences the reservoir water eutrophication. A positive result shows its accumulation in the reservoir (as sediment). A negative balance could be explained by phosphate supply to the reservoir, coming from fertilizers used on the agricultural land along Lobnik affluent and also from decomposition of dead organisms.

The results of the balance evaluation of total phosphorus are similar to those of phosphates – a positive result in 2006 and a negative result in 2007 and 2008.

Balance evaluation of total phosphorus:

Year 2006	5,249.09 – 3,543.45 = **1,705.64 kg**
Year 2007	6,232.59 – 6,837.67 = −**605.08 kg**
Year 2008	1,676.66 – 3,977.27 = −**2,300.61 kg**

The limit for DQO – permanganate in drinking water is 3 mg.L^{-1} (Regulation 252/2004 Sb.) and in A2 non-treated water is 10 mg.L^{-1} (Regulation 428/2001 Sb.). The legal limit DQO-permanganate in drinking water was exceeded in all the profiles and in A2 non-treated water was not exceeded in any case.

Balance evaluation of DQO – permanganate:

Year 2006	111,637.7 – 106,934.30 = **4,703.40 kg**
Year 2007	302,410.3 – 327,369.7 = −**24,959.40 kg**
Year 2008	88,582.08 – 92,330.58 = −**3,748.50 kg**

Negative results mean that there have been more organic substances in the profile 1 than in the profile 5 and vice versa.

The concentration of dissolved oxygen is an important indicator of surface water purity. Furthermore, it influences taste of drinking water (Pitter 2008). The minimum concentration of oxygen dissolved in surface waters used as drinking water is 7 mg.L^{-1}(Regulation 252/2004 Sb.). The concentrations in the reservoir evaluated vary between 4 and 14 mg.L^{-1}.

Balance evaluation of dissolved oxygen:

Year 2006	468,969.20 – 432,699.30 = **36,269.90 kg**
Year 2007	781,516.10 – 697,808.30 = **8,370.80 kg**
Year 2008	285,003.70 – 213,784.60 = **71,219.10 kg**

All results of balance evaluation are positive (the amount of oxygen in the profile 1 was always higher than in the dam). This effect can be explicated as oxygen consumption in the reservoir (decomposition of organic substances, dissasimilation, nitrification, zooplankton respiration, etc.)

The presence of thermotolerant bacteria indicates faecal contamination. Non-treated water of category A2 may contain 20,000 faecal coliform bacteria per 100 mL of water (Regulation 428/2001 Sb). This limit was not exceeded. The faecal coliform bacteria must not be detected in any 100 mL sample of drinking water (Regulation 252/2004 Sb.). This limit was exceeded in all profiles.

Balance evaluation of thermotolerant bacteria:

Year 2006	$4.60\ .10^{12} - 6.91\ .10^{11} = \mathbf{3.91\ .10^{12}}$
Year 2007	$6.77\ .10^{11} - 2.30\ .10^{11} = \mathbf{4.47\ .10^{11}}$
Year 2008	$1.66\ .10^{11} - 1.40\ .10^{10} = \mathbf{1.52\ .10^{11}}$

The maximum amount of thermotolerant bacteria was always present in the summer. A positive result of balance evaluation indicates abundance of bacteria in the profile 1.

29.6 Conclusions

In the 1990s of the twentieth century, the concentrations of nitrates were very high (Zenaty 1980). Since then the concentrations have been decreasing and nowadays they do not represent a problematic indicator. On the contrary, when evaluating the concentrations, problematic parameters were verified: DQO-permanganate, pH, iron, manganese, calcium and magnesium, thermotolerant bacteria and Enterococcus. The regulation of activities in level 2 protection zone should positively influence the reservoir water quality in the future.

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