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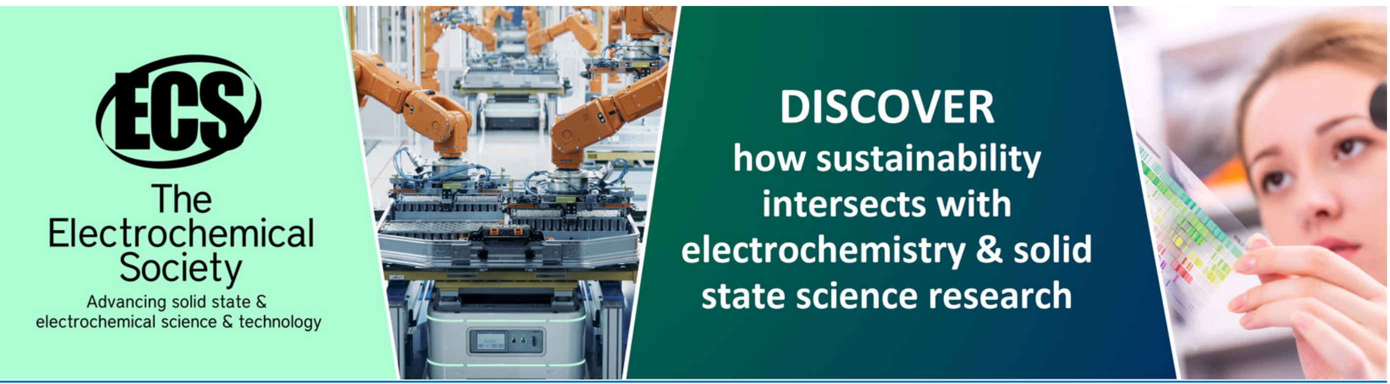

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Possibilities of application of artificial groundwater recharge in the catchment areas of the Odra and Bečva rivers

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Abstract. The paper deals with supplies of drinking water in times of drought. Facing the climatic changes, it is essential to look for alternatives sources of drinking water. Artificial infiltration ranks among such options. Two sites, Hranice na Moravě and Odry, have been monitored and evaluated. In those sites, it would be possible to use artificial infiltration and increase supplies of ground water.

1. Introduction

In times of drought, one should manage yield and quality of ground water that is used as a source of drinking water for people.

Badly-advised straightening of water courses caused by agricultural self-interest (mostly in the 1970s) and construction of industrial plants/other buildings has resulted in faster outflow of surface water from the Czech landscape, reducing, in turn, natural infiltration.

Infiltration is a part of a water cycle in nature. Water penetrates into soil and permeable rock. Infiltration is, in addition to condensation of water vapours in soil and condensation of water vapours in magma, the key source of ground water. One differentiates between natural infiltration and artificial infiltration. In case of infiltration, the penetrating water results from rainfall, surface water (embankment infiltration) or thawing snow. Artificial infiltration is when the infiltration is caused by artificial flooding of the landscape surface [1]. Water, while passing through rock, is being filtered and physical/chemical/biological contaminants are being removed [2].

Infiltration facilities that have been used most frequently include drainage tanks, infiltration bores, infiltration pipes (drainage), surface splashing and surface spraying.

The ground water will increase its supplies thanks to artificial infiltration only if the quality of original raw water is sufficient and only if suitable rock environment is available [3].

A coefficient of filtration is used to describe sufficient permeability of soil or the rate of water flow through rock in m/s (table 1).

Recently, the artificial infiltration has been becoming more and more popular. This technology is able to response promptly to such opposite water management problems as floods and drought [5]. It may solve many water management issues and environment problems. It may support management of economic and national problems. This process is really unique.

Table 1. Reference value of the coefficient of filtration for soil [4].

Soil	Permeability in m/s	Coefficient of filtration
Coarse grain gravel	0.1 to 0.005	10^{-1} to 5×10^{-3}
Fine through medium grain gravel	0.03 to 0.0005	3×10^{-2} to 5×10^{-4}
Sand gravel	0.01 to 0.0001	10^{-2} to 10^{-4}
Coarse grain sand	0.004 to 0.0001	4×10^{-3} to 10^{-4}
Medium grain sand	0.001 to 0.00006	10^{-3} to 6×10^{-5}
Fine grain sand	0.0004 to 0.000006	4×10^{-4} to 6×10^{-6}
Clay sand, sandy clay	0.000075 to 0.00000005	$7{,}5 \times 10^{-5}$ to 5×10^{-8}
Clay	0.000005 to 0.0000000001	5×10^{-6} to 10^{-10}
Argillaceous clay	0.000004 to 0.0000000001	4×10^{-6} to 10^{-10}
Clayey loam	0.00000001 to 0.0000000001	10^{-8} to 10^{-10}
(pursuant to DWA-A 138, April 2005)		

2. Selecting a site for artificial infiltration

This paper deals with selection of a site for potential installation of artificial infiltration for water purposes in river basins of the Odra River and Bečva River. In each location, there should be a shallow well or hydro-geological drill hole that could be used as a potential collection facility.

The first place where the artificial infiltration for water systems could be used is the Čs. legií Park in Hranice na Moravě (District of Přerov, Region of Olomouc) (figure 1). The site is located close to the Bečva River and was used in past for artificial infiltration. Another possibility is to use the land next to groundwater drill bores in Odry (District of Nový Jičín, Moravian-Silesian Region) (figure 1). Fluvial rock environment next to the Odra River can serve as a potential supply of infiltered water.

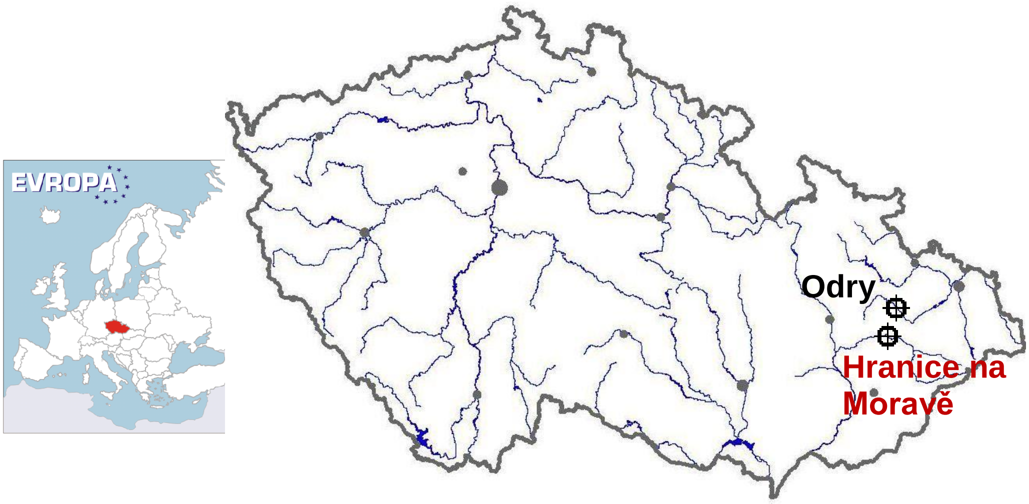

Figure 1. Blank map of water systems in the Czech Republic [8]. Odry on the Odra River and Hranice na Moravě on the Bečva River.

2.1. Hranice na Moravě on the Bečva River – the Čs. legií Park

Hranice na Moravě is located in the geomorphological system that is referred to as the Moravian Gate. Its territory is dewatered by the Bečva River which is the biggest left-hand tributary of the Morava River [6].

The average annual flow in the profile measured at Teplice nad Bečvou (at 41.4 river kilometer) is 15.5 m^3/s [7]. The Čs. legií Park where the artificial infiltration could be installed is located at 39.4 river kilometre.

Water management of the territory. The key source of drinking water for Hranice na Moravě is the water conduit from the Ostrava Area Water System. It supplies water from the water treatment plant in Podhradí. Hranice also receives underground water from the spring area in Lhotka. Valšovice, which is a part of Hranice, receives groundwater from the spring area of Ústí. Středolesí, another local part, is supplied water from the Radíkov water treatment plant that treats surface water. The group water system Hranice a Záhoří is owned by Vodovody a kanalizace Přerov a.s. [9].

Hydro-geological composition of the territory. The sedimentary fill of the Bečva River valley consists of bulk river gravel and sand. From the mechanical point of view, it can be regarded as sand gravel with round stones being as much as 30 cm big. The typical size is, however, 2-6 cm. Towards the rock cover, the gravel sand changes into humus medium-grain sand which forms the surface of the territory. The layer of sand/gravel is 7-8 mm at least. Approximately in that level under the surface, they sediment on sea deposits of Miocene Epoch. The gravel sand represent a water horizon which is relatively easy permeable. The shallow groundwater forms a single flow with a slightly tense level. The permeability corresponds approximately to 6.10^{-4} m/s. From the chemical point of view, this is alluvial water that contains iron and manganese ions [10].

Supplying the drinking water through artificial infiltration in past. The Hranice weir on the Bečva River with its storage level of water plays an important role in collection of shallow groundwater. The wells that are positively influenced by embankment infiltration have a relatively higher specific yield – about 10 l/s [11]. Water from alluvial sediments in the Čs. legií Park was collected in two collection wells (3 m and 4 m diameters) in ca. 8 mm depth. Then, the water was supplied to the “Nový odbyt” pumping station with a collection well that was used as both recharging and collection facility.
Downstream the facility, the water was pumped into a ground reservoir on a hill.

Since 1960 consumption of drinking water in Hranice has been increasing gradually and significantly. From 1960 until 1965 consumption of drinking water increased almost by 50 % [12]. In order to improve the yield of water sources, an artificial infiltration system was designed for the Čs. legií Park. It was in operation from 1965 until 1985.

A submersible pump transported water from the Bečva River through a steel pipe to the infiltration area which was located in a 100 m distance. The water flowed onto a grass area. This created a wetland where water infiltrated into rock environment. A suction pipeline sucked water from existing wells into a pumping station. Using the artificial infiltration, it was possible to increase the capacity of a water source by 5 l/s. That process was used until new sources of water were discovered in Lhota.
Now, the shallow water from the Čs. legií Park is not used anymore as storage of the drinking water to people.

Conclusion. Recommended solutions. First proposals to renew the artificial infiltration include the project focused on renewal of the original infiltration in the Čs. legií Park. The second project for artificial infiltration is infiltration of surface water from the Bečva River in the “Nový odbyt” pumping station. There is a subsidence in landscape and it is possible to flood the lend. Between the Čs. Legií Park and pumping station, there is a road. The infiltered water could be collected using the monitoring bore P3 (7 m deep) or the recharging/collecting well in the pumping station. The artificial infiltration in the pumping station can be improved, it a water reservoir (ca. 20 m^3) is used for storage of water to be infiltered.

Possible risks. Since 1980s, intensity of road transport has been increasing (more vehicles, more traffic on roads). This increases the risk of contamination of water for infiltration with oil and oil substances from nearby roads. Another threat is increased biological and micro-biological activation of water sources in times of drought.

2.2 Odry on the Odra River

Odry is a town located on both banks of the Odra River in the Odra Fold. Springs of the Odra River are located in Oderské vrchy, Odra hills, in a military zone (Libavá). The average annual flow of the Odra River in Odry is 3.58 m^3/s [13]. Close to the town, there are several tributaries: Vítovka and Zlatý potok on the left-hand bank and Mlýnský potok and Stodolní potok on the right-hand bank.

There is also a 6 km long millrace that supplies water to five ponds [14]. The Odra Fold that opens towards the Moravian Gate is approximately of a rectangular shape, 2 x 3 km long, where the longer axis is oriented from south-west to south-east [15, 16].

Water management of the Odry Fold. Drinking water for Odry is supplied from drill bores. There are four drill bores: OVHS 1 (d = 159.6 m), OVHS 2 (d = 250 m), NP 757 + HV2 (d = 260 – 270 m) and NP 769 (d = 125 m). The raw water from three drill bores OVHS 1, OVHS 2, NP 757 is pumped into the dumping station in Odry. There is an aeration tower and a 30 m^3 reservoir. Then, water is pumped into water tanks. Raw water from NP 769 is supplied for consumption in Mateiciuc (producer of plastic pipelines) [17].

Hydro-geological composition of the Odry Fold. Approximately 25 l/s of ground water is used now in the hydro-geological structure of the Odra Fold. Natural resources of ground water in the Neogene and Quarternary sediments were estimated by Hrouzková et al. (1984) to reach as many as 70 l/s.
The following water-bearing strata (a., c., d.) are located in the surroundings:

- Shallow strata of Quarternary clayey gravel with free level. Collector with 6.5 – 9 m thickness.
- Insulator: lime clay of the Lower Badenian layer.
- Depth level formed by filled-in sand in politic facies (clay rock) and basal clastics (detrite) of Lower Badenien layer located 130-290 m under the landscape with tense level.
- Deep fissure rangers in culm.

Considering the area under study, what is important for us is the shallow circulation of ground water (see a.).

The shallow Quarternary aquifer on the site is linked to fluvial clay gravel of the main platform in the original riverbed of the Odra River. The ground water has free surface there and does not seem to be linked directly to the level of the nearby Odra River. The embankment infiltration occurs only if there is increased level of water in the Odra River. The collector receives water mostly from rainfall. The general direction of ground water flow in the shallow circulation in fluvial sediments of the Odra River corresponds to the landscape slope and direction of flow of the Odra River, from north to south. Permeability of the collector that consists of the fluvial clay gravel is estimated to reach 3.10^{-4} m/s. Potential sources of water that are related to the shallow aquifer tend to change the yield considerably with each change in outflow in the shallow collector (any construction, excavation, burying of new or reconstruction of old pipelines/ducts in deeper layers…). [18].

Conclusion and recommended solutions. The drinking water for people living in Odry is supplied from bore holes drilled down to 125 - 270 m deep in the basal clastics collector in the Lower Badenian layer. In the Odra Fold, there are several monitoring bores (both deep and shallow ones).
When employing the artificial infiltration for supplies of drinking water in times of drought, it is possible to use the existing shallow bores for collection. That is why we are looking for shallow Quarternary sediments close to the Odra River. In the Odra Fold, there are either fluvial or Aeolian sediments. The fluvial sediments consist often from clayey gravel that is covered with a layer of flood clay. The total thickness of layers ranges between 4 and 7 m. The Aeolian sediments consists of floury soil, the maximum confirmed thickness of which is 12 m – to the east from Odry [15].

The best location for the artificial infiltration seems to be the surroundings of the drill hole NP 769 where a shallow hole, V36, is located (6.5 m). Another advantage is that there are not any obstacles such as roads or buildings between the drill hole and Odra River (which is not often the case with other drill holes). The distance between the Odra River and the infiltration area would be 150 m across the grass area.

Aknowledgements
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