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Conception of vadose zone research in the area of Goczałkowice reservoir.

KEY WORDS:

Quaternary aquifer,
Goczałkowice reservoir,
groundwater monitoring,
MacroRhizons sampler

ABSTRACT.

Goczałkowice reservoir is one of the main source of drinking water for Upper Silesia Region. In reference to Water Frame Directive matter since 2010 the strategic research project: „Integrated system supporting management and protection of dammed reservoir (ZiZoZap)”, which is being conducted on Goczałkowice reservoir, has been pursued. In the framework of this project complex groundwater monitoring is carried on. One aspect is vadose zone research, conducted to obtain information about changes in chemical composition of infiltrating

water and mass transport within this zone. Based on historical data and the structural model of direct catchment of Goczałkowice reservoir location of the vadose zone research site was selected. At the end of November 2012 specially designed lysimeter was installed with 10 MacroRhizon samplers at each lithological variation in unsaturated zone. This lysimeter, together with nested observation wells, located in the direct proximity, create the vadose zone research site which main aim is specifying the amount of nitrate transport in the vertical profile.

Introduction and main aim of research

Groundwater chemistry is formed due to various cooperating processes and factors. Among the physico-geographical factors, such as topography and hydrology, climate, especially precipitation, dominates. Precipitation is main source of groundwater recharge but also can be a carrier of contamination. Decisive role in the formation of the chemical composition of the groundwater, however, plays a geological environment. Vadose zone, the area between the surface and capillary fringe, is of great importance in the process of formation of the groundwater chemistry - first chemical composition transformation of infiltrated water (Małecki J.J., 1998). Investigations of vadose zone for many years were the subject of numerous studies (eg Heisslein, 1976, Watson and Frickers, 1990, Knight et al., 1998).

The degree of contamination and mass transport in unsaturated zone are often difficult to

assess due to variability in precipitation or irrigation and anisotropy in physical properties of solid phase. For this reason, geochemical modeling and contaminant migration modeling is crucial in determining the extent of the contamination in vadose zone. (Singer J.H. et al., 2007). The most effective investigation method is sampling in situ using the appropriate equipment, such as Rhizons samplers (Shotbolt I., 2009).

As part of the strategic research project zizozap complex groundwater monitoring including saturated and unsaturated (vadose) zone have been planned. Vadose zone monitoring was designed to determine changes in the pore water chemistry and to identify the migration of nitrates from terrain surface to groundwater table.

Study area

Goczałkowice reservoir was built on the Vistula River (fig. 1). Study area – the direct catchment of Goczałkowice reservoir - is located in Polish Carpathian Foredeep.

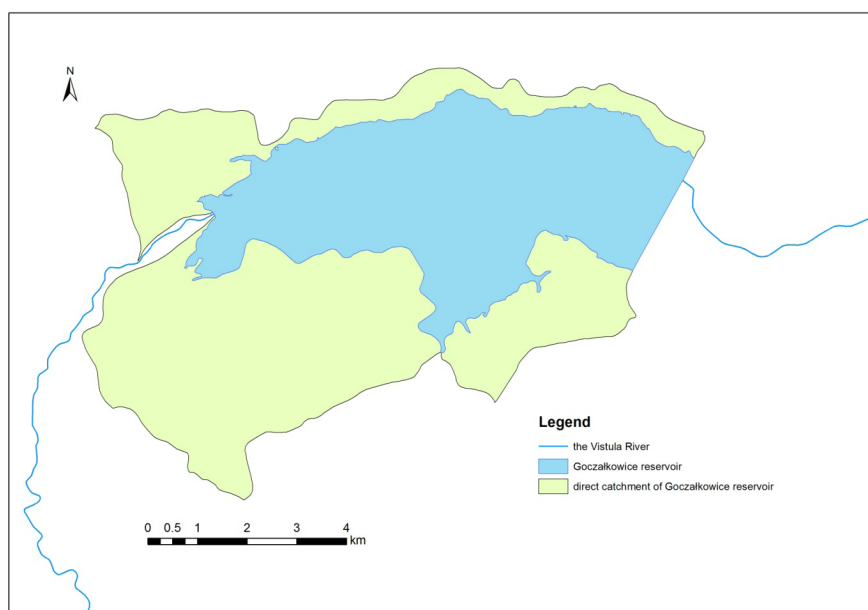


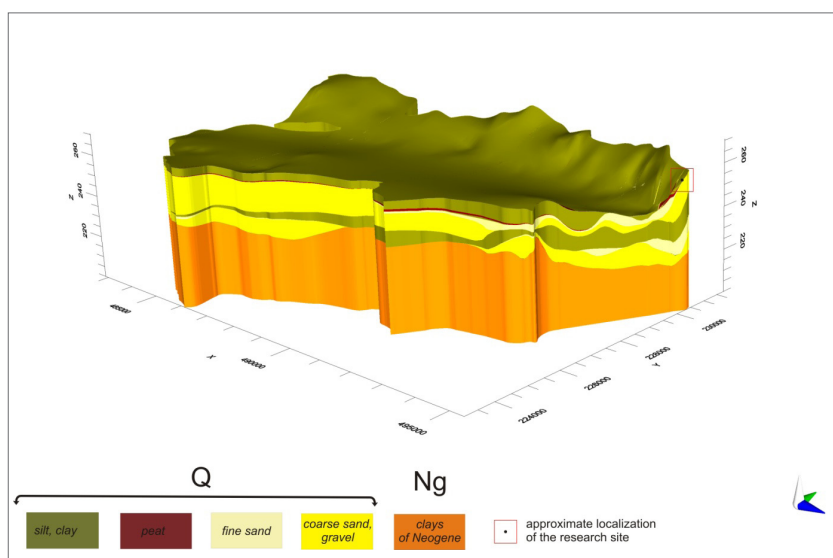
Fig. 1. Localization of Goczałkowice reservoir.

Useful aquifer – Quaternary aquifer, is comprised of mainly alluvial sediments. Beyond the areas of the river valleys Quaternary aquifer is associated with the accumulation of glacial and fluvioglacial sediments.

Aquifer capping is built by aquitard about 5 m thick. Groundwater table is mainly confined, it is unconfined within alluvials (Kempa, Bielewicz, 2006). Two Quaternary aquifers (upper and lower) are observed in the area of head dam (fig. 2). On south – west side of the study area aquifers integrate into one. The thickness of aquifers ranges from 2 to 20 m. Hydraulic conductivity, according to the hydrogeological documentations, ranges from 5.35×10^{-6} to 6.5×10^{-3} m/s. Direct groundwater recharge in this area is difficult due to aquifer capping. Current research indicates that the Goczałkowice reservoir generally has a drainage character.

Methodology

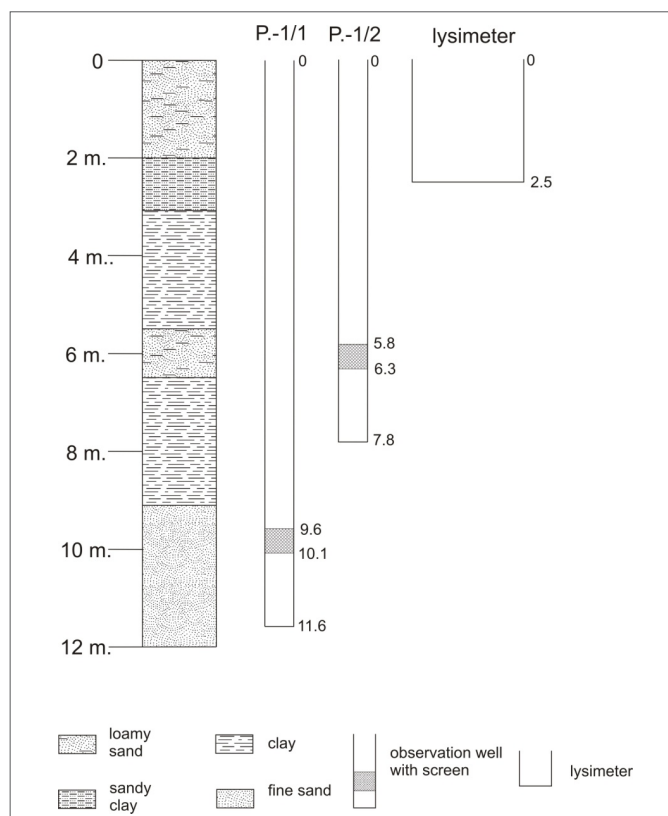
Vadose zone monitoring, conducted on direct catchment area of Goczałkowice reservoir, consist of lysimeter with 10 porewater samplers. Together with two nested observation wells these lysimeter create complex groundwater monitoring site.



Research Site

Pore water research is carrying on in permeable formations, where vertical infiltration through unsaturated zone is impeded. Due to aquitard as an aquifer capping, localization of research site was problematic. The area of head dam was the only possible localization (fig. 2). On September 2011, 2 nested observation wells were installed (P-1/1 and P-1/2), as a base of a complex groundwater monitoring site (fig. 3). First observation well – P-1/1, reaches 11,6 m depth, screen is installed at fine sands of upper aquifer. Second one – P-1/2 is installed at a perched aquifer – screen is installed at loamy sands between 5.8 and 6.3 m. As a replenishment, in turn of November and December 2012, was carrying on field research and installation of lysimeter with specialists Rhizon samplers.

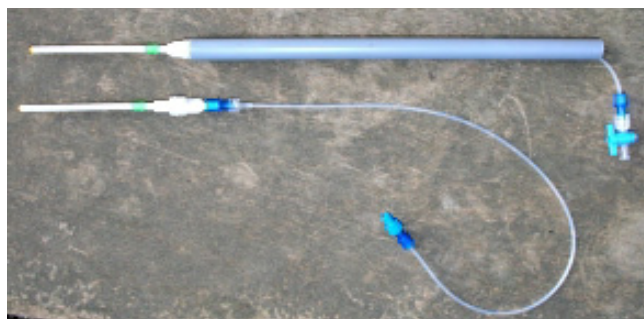
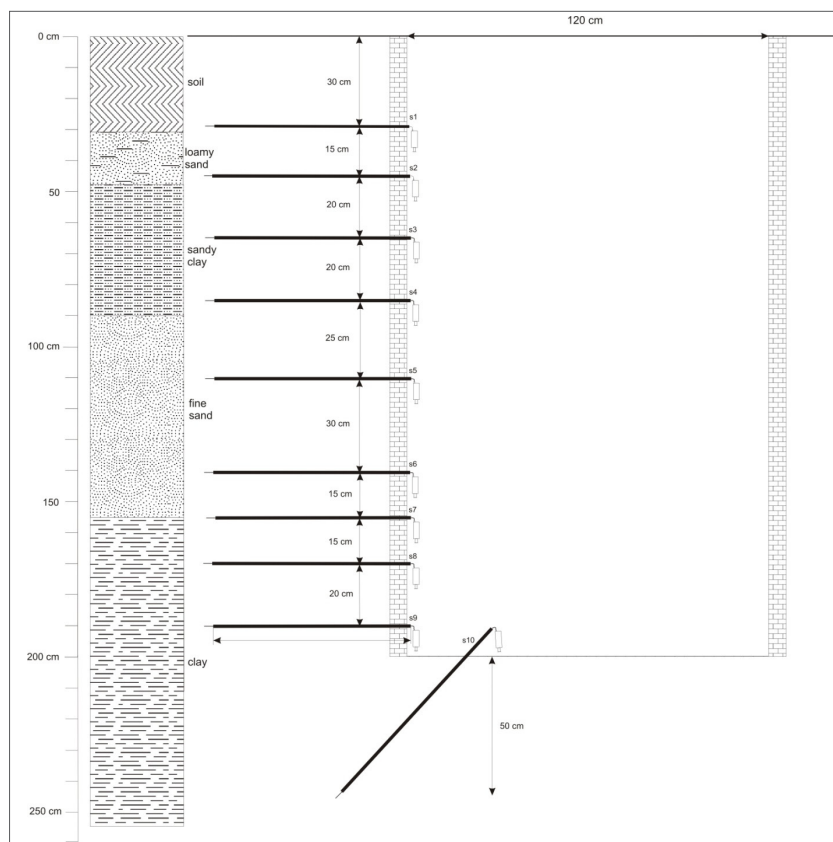
Fig. 2 Structural model of the direct catchment of Goczałkowice reservoir (Czekaj J., Witkowski A.J., 2012, modified).



Lysimeter

Field research, carried on direct before lysimeter installation, has showed anisotropy in Quaternary lithology. On the depth of 2,5 m very compact clays were drilled which also caused limitation in lysimeter depth. Lysimeter is built of concrete rings with perforation (9 drilled holes). Holes were done every 15- 30 cm, due to every lithological change in profile. Nine Rhizons samplers was installed in perforation and 1 in the lysimeter bottom (fig. 4). MacroRhizons reach about 70 cm depth horizontal in the vadose zone sediment.

Fig. 3 Schematic diagram of complex groundwater monitoring site (unsaturated and saturated zones)



Rhizon samplers

Rhizon samplers are thin, inert, tubes of hydrophilic microporous polymer designed to extract water from porous sediment using a vacuum (vacuum tube or syringe) (Dickens G.R. et al., 2007). They are also inexpensive and disposable. Several studies have used Rhizon samplers to collection of in situ vadose zone pore water (e.g., Knight et al., 1998; Tye et al., 2003). To pore water quality monitoring in the area of Goczałkowice reservoir vacuum samplers – MacroRhizons by Eijkelkamp (type 19.21.36) are used. MacroRhizon sampler is made of porous material (9 cm long with outside diameter of 4.5 mm, strengthened by a glassfiber epoxy rod coated with ABS, connected to a pair of large bore ABS connectors (outside diameter 14 mm) with female Luer Lock (Eijkelkamp manual) (fig. 5). Additional connected 90 cm PCV pipe is used to protect and stabilize. To extract pore water by MacroRhizon 50 ml syringes, with Luer Lock connectors, are used. Rhizons installation is not complicated, special driller is added.

Fig. 4. Lysimeter schema.

Fig. 5. MacroRhizons by Eijkelkamp (source: <http://www.rhizosphere.com/macrorhizons>)

Conclusions

Research of vadose zone for many years was the subject of numerous studies because of its role in the fate and transport of chemicals resulting from waste disposal and agricultural practices. The most effective research method is sampling in situ using the appropriate equipment, such as Rhizons samplers (Shotbolt I., 2009).

Vadose zone monitoring, conducted on direct catchment area of Goczałkowice reservoir, consist of 2 observation wells and lysimeter with 10 pore water samplers. Observation wells, installed at various depths, take first aquifer. Lysimeter is used as a protection for MacroRhizon samplers, which are installed at

every lithological change in profile. Used samplers are inexpensive and disposable. Pore water samples will be collected to 50 ml syringe. Chemical composition will be determined in certified laboratory.

Unsaturated zone monitoring in the area of Goczałkowice reservoir will determine spatial and temporal changes in pore water chemistry and identify the migration of nitrates carries with the water infiltrating from land surface to aquifer.

Acknowledgement

Investigations are conducted as a part of strategic research project: POIG 01.01.02-24-078/09: Integrated system supporting management and protection of dammed reservoir (ZiZoZap).

Co-author of above paper is a scholarship holder under the „DoktoRIS – a scholarship program for innovative Silesia region” co-financed under the European Social Fund.

References

- Czekaj J., Witkowski A.J., 2012: Model budowy czwartorzędowego piętra wodonośnego w rejonie zbiornika Goczałkowice. *Biuletyn Państwowego Instytutu Geologicznego, Hydrogeologia XII*, nr 451, p. 27-33
- Eijkelkamp, 2003: Operation instruction. MacroRhizon soil moisture samplers 19.21.35/36. <http://www.rhizonsphere.com/macrorhizons>; available at 28.07.2013
- Kempa J., Bielewicz R., 2004: Baza danych GIS mapy hydrogeologicznej Polski 1: 50 000. Pierwszy Poziom Wodonośny. Występowanie i hydrodynamika. *Objaśnienia. Arkusz Pszczyna (992)*.
- Knight, B.P., Chaudri, A.M., McGrath, S.P., and Giller, K.E., 1998: Determination of chemical availability of cadmium and zinc in soils using inert soil moisture samplers. *Environmental Pollution*, nr 99, p. 293 – 298
- Małecki J.J., 1998: Rola strefy aeracji w kształtowaniu składu chemicznego płytkich wód podziemnych wybranych środowiska hydrogeochemicznych. *Biuletyn Państwowego Instytutu Geologicznego*, nr 381
- Shotbolt I., 2010: Pore water sampling from lake and estuary sediments using Rhizon samplers. *Journal of Paleolimnology*, nr 44, p. 695-700
- Singer J.H., Seaman J.C., Aburime S.A., Harris J., and Karapatakis D., 2007: An improved technique for soil solution sampling in the vadose zone utilizing real-time data. *Conference Materials of the Georgia Water Resources Conference*, 27 – 29.03.2007
- Tye, A.M., Young, S.D., Crout, N.M., Zhang, H., Preston, S., Barbosa-Young, S.D., Crout, N.M., Zhang, H., Preston, S., Barbosa-Jefferson, V.L., Davison, W., McGrath, S.P., Paton, G.I., Kilham, K., and Resende, L., 2003. Predicting the activity of Cd²⁺ and Zn²⁺ in soil pore water from the radio-labile metal fraction. *Geochimica et Cosmochimica Acta*, nr 67, p. 375 – 385