Groundwater flow rate and contaminant migration in fissure-karstic aquifer of Opole Triassic system southwest Poland

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Abstract This paper presents hydrogeological problems occurring during municipal water exploitation and mine dewatering. These activities result in groundwater quantity and quality changes in the fissure-karstic aquifer. Increase of nitrate concentration up to 12 mg N\textsubscript{NO}_3/l due to intensive fertilizer use, and high tritium concentration, show water system impact up to 100 m depth. Intensive water exploitation produces large cones of depression with over 40-m water-level depletion in the Opole region. Flow rates of major components and isotopes have been verified by chemical migration history. Some aspects of the protection policy of this type of aquifer are also discussed.

Key words Groundwater · Fissure-karstic aquifer · Contamination

Introduction

Numerous aquifers are endangered with contaminant migration and resulting degradation of groundwater resources. Particularly intensive and deep changes are reported in fissure-karstic aquifers. Opole Triassic aquifer, one of the most significant groundwater systems of southwest Poland, is an example. This well-recognized system has been an object of study of a number of researchers (Różkowski and Wilk 1981; Ciężkowski and others 1989; Kryza 1989, 1994; Staško 1989, 1992a). It covers an area of almost 1000 km\textsuperscript{2} and forms the western part of the Upper Silesian groundwater system (Różkowski and Wilk 1981). Groundwater within this system plays a crucial role in the water supply of a few big cities and hundreds of villages. At the same time, it creates problems in exploitation of lime resources.

Hydrogeology of the test site

The Opole Triassic water system, located in southwest Poland contains two aquifers (Fig. 1). The sandstone formation of Lower Permian and Lower Triassic formations (Bunter Sandstone and Lower Roethian) form the lower aquifer. The upper aquifer consists of carbonates of Middle Triassic Muschelkalk and partly also of Upper Triassic rocks. Water-bearing formations occur in three layers comprising dolomite limestone of Upper Roethian, limestone and dolomite, limestone of Muschelkalk and, locally, the limestone interbed in sandstone-shale formation of Keuper (Fig. 2). Waters from the Roethian formation are exploited only near the outcrop. Going north, an increase of mineralization is observed due to the occurrence of gypsum. The Muschelkalk aquifer contains the most abundant groundwater resources and is the best researched aquifer. Groundwater occurs in a complex system of pores, fissures and karst. The aquifer situated in the monocline structure contains fresh water up to 330 m below the earth surface near Opole City. The Triassic formation dips at 5–7° toward NE and N. In the outcrop area, typical features of the karstic terrain can be observed. They are manifested in the deficiency of surface water and occurrence of single springs of high, variable capacities of up to 100 dm\textsuperscript{3}/s (Staško 1992a). The aquifer is characterized by the water table condition and locally confined in the 5-km-wide zone of recharge. At the distance of 15 km, north to the outcrop, this formation is covered with a confining unit of the clay shale-sandstone Keuper formation (Fig. 2), which creates artesian or subartesian conditions. North of Opole City, this system is covered with more than 200-m-thick sediments of Cenozoic and Upper Triassic. Case studies and research showed that the rocks were characterized by an average hydraulic conductivity amounting to 16.4 m/day (Staško 1992a). Recent studies applying geostatistic methods showed hydraulic conductivity in the range of 0.5–20 m/day in the recharge zone and of 0.2–10 m/day in the confined part of the aquifer, respectively (Zurek and others 1994). Limestone and dolomite limestone showed the total porosity in the range of 0.009–0.31 (Staško 1992a) with a typical value 0.12. These rocks are densely fractured, which is expressed by the fracture porosity in the outcrop ranging from 0.7 to 4.46%. Karstic phenomena’s have been re-
Fig. 1
Hydrogeological map of the Opole Triassic aquifer. 1 spring; 2 well in Muschelkalk aquifer (6-well number); 3 open-pit mine; 4 Lower Triassic aquifer boundary; 5 Middle Triassic aquifer boundary; 6 faults zone; 7 piezometric contours lines in m asl; 8 directions of the local groundwater flow; 9 main groundwater flow direction; 10-impermeable Upper Triassic formation boundary; 11 cross-section line

Groundwater flow system

The area under study belongs morphologically in its southern part to Silesian Upland with the culmination at (Święta Anna Hill) 400 m asl. In its northern part this area constitutes a part of Silesian Lowland with the altitude of 160–250 m. In the analyzed system, the groundwater flow is directed toward north-west and west. A hydrogeological survey, field and modelling studies have made it possible to distinguish three groundwater flow zones. The first zone forms a local flow system discharged mainly by springs. The resident time is short and varies from a few months to few years. The discharge occurs in a narrow strip along the water divide between the towns of Gogolin and Jemielnica, encompassing in its range both Roethian and Muschelkalk sediments.

The second intermediate system has a discharge zone along Sucha and Jemielnica river valleys and the southern part of Odra river valley. Most water intake and mine drainage are located within this system. This intermediate system possesses water circulating to the depth of 50–100 m and the resident time has exceeded ten years.

The third regional system is drained through Odra river....