Transboundary aquifer within the mining areas – the case study of the Upper Silesian Coal Basin

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ABSTRACT

The crucial problems for the Debowiec formation aquifer, situated on the borderland of Poland and Czech Republic: mitigation of hydrogeological hazards and water inflows into coal mine workings situated below, restraining the mining drainage responsible for depletion of the non-renewable groundwater resources, estimation of CO2 sequestration potential of the aquifer are discussed in the paper. However the first steps, taken by the research groups from Polish and Czech Universities, in cooperation with mining companies were undertaken, these issues require comprehensive solutions in the spheres of mine safety legislation and improvement of information exchange.

Key words: The Upper Silesian Coal Basin, coal mining, CO_2 geosequestration, mine flooding hazard

1. INTRODUCTION

The Upper Silesian Coal Basin (USCB) – one of the major European Coal Basins - is situated on the borderland of Poland and Czech Republic, within the range of Carpathian foredeep structures. The base overburden units of coal-bearing Carboniferous complex are formed by Tertiary coarse-grained sediments of Lower Badenian (LB). These sediments (so called the Dębowiec formation) fill deep depressions in paleorelief, and they form confined geohydrodynamic structure of the area of 635 sq km (Fig. 1). Groundwater of marine origin contain high amounts of Br^- and I^- enabling their possible utilization in balneology. The groundwater volume is estimated at about $3{,}8 \cdot 10^9$ m^3.

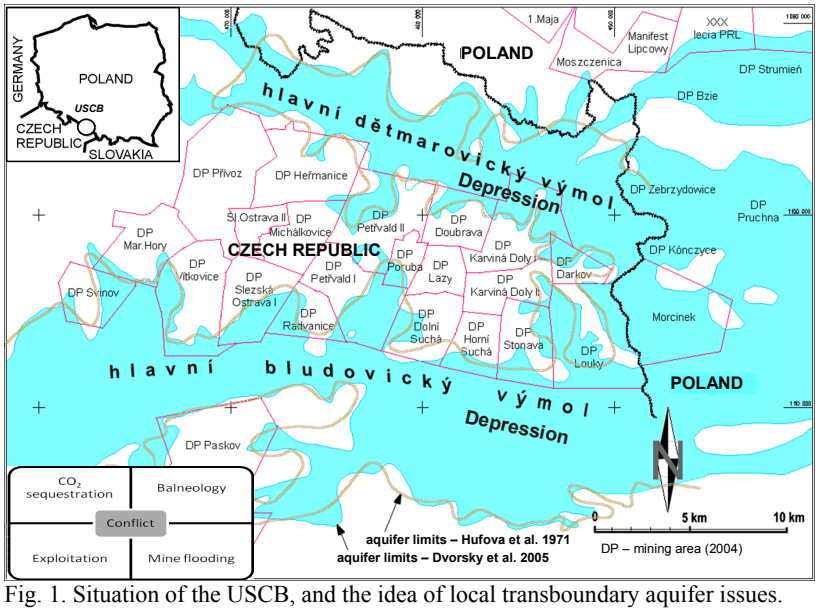

Fig. 1. Situation of the USCB, and the idea of local transboundary aquifer issues.

2. LOCAL TRANSBOUNDARY AQUIFER ISSUES

The crucial issues for the LB aquifer management are: mitigation of hydrogeological hazards and water inflows into coal mine workings situated below, restraining the mining drainage responsible for depletion of the groundwater resources, estimation of CO_2 sequestration potential (amounts of CO_2

than can be stored in the aquifer). The starting point of recent sustainable groundwater management of the aquifer was the database building. The records contain the data: description and XYZ coordinates of sampling points, origin of waters, technical information on sampling and analyses, properties of water and concentrations of major and trace components, water level changes. Thy include also the samples of inflows from water-bearing faults, hazardous to mine workings. The database enabled the definition of hydrochemical zoning, mathematical modeling of groundwater flow – in order to predict the flooding hazard to existing coal mines, and geochemical modeling of CO_2 sequestration capacity.

2.1. Exploitation and mine flooding

This aquifer has been a source of hydrogeological hazards connected with water inrushes and increased water inflows into coal mine workings situated underneath. Accidents of penetration and migration of gases (CH_4 and CO_2) from the Detritus aquifer into underground mines occurred frequently in the Czech part of the Upper Silesian Coal Basin. Moreover flooding (closure) of a coal mine in the Polish (the "Morcinek" mine) increased the inflow and the risk of mining activity in the adjacent Czech colliery - the ČSM. The figure 2 depicts mine water drainage changes, including the forecast elaborated basing on hydrodynamic model of the area (Dvorsky et al., 2007).

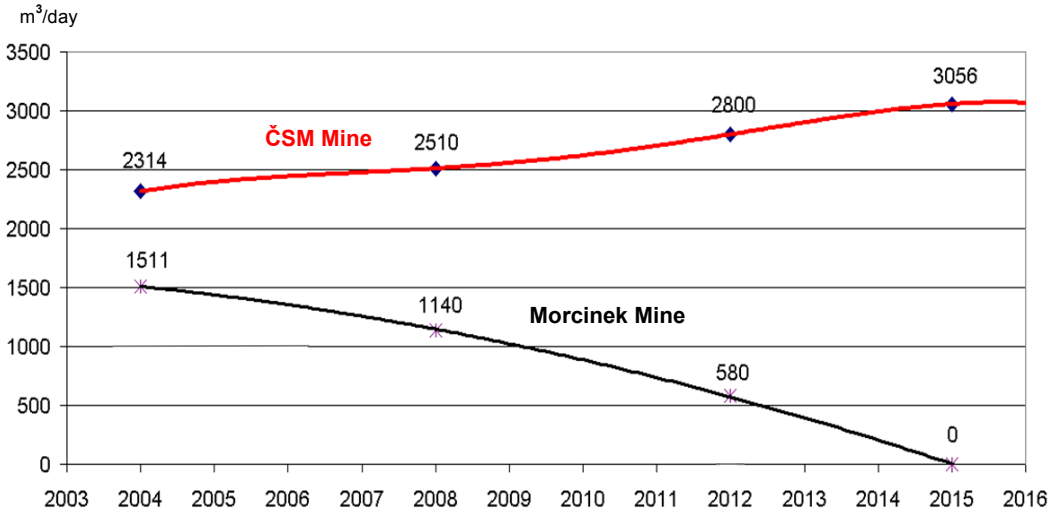

Fig. 2. Mine water drainage changes due to the Morcinek Mine closure.

2.2. Balneology

Mining drainage, caused locally partial depletion of the non-renewable groundwater resources within the aquifer and decreased the possibility of utilisation of the groundwater in balneotherapy. The most of recent studies present opinions about domination of mining activity and drainage as the factors of forming the groundwater flow within the USCB. The disturbances in hydrogeological regime and freshening of waters are caused just by mining activity. According to Różkowski (1995), mining exploitation causes the stress relief, resulting in the increase of rocks permeability, leading consequently to hydraulic contacts between waters of different types. Deep exploitation and intensive drainage lead to widening and deepening (to 450 - 650m and maximum to 850m below the ground surface) of recharge zones. Also in the Czech part of the USCB, the stratification of waters has changed, and the present chemical composition of waters from Badenian is not corresponding with the analyses made 10 years before. The phenomena are explained with the impact of mining. Despite the negative changes, waters from Badenian, considered as fossil connate ones, of mineralisation ranging from 28 to 60 g/l, contain J^- and Br^- at the levels making possible their balnaeotherapeutic application in the Ostrava-Karvina Region (Grmela 1997). The conflict between preservation of groundwater resources, and industrialisation of this part of the USCB was particularly sharp in case of medicinal waters. The Spas of Kokoszyce and Jastrzębie Zdrój, existing here in the past, lost their medicinal

water due to the mining drainage impact. Waters of the Goczałkowice Spa were threatened by the activity of a nearby coal mine. In consequence new exploitation wells had to be drilled there.

2.3. CO_2 geosequestration

Perspective localities for CO_2 sequestration in Poland comprise also the saline aquifers of Tertiary and of Carboniferous productive formation of the Upper Silesian Coal Basin (USCB), on the borderland of Poland and Czech Republic. Hydrochemical modeling was carried out for the purpose of the assessment of amounts of CO_2 than can be stored in the geological space of the LB aquifer. Numerous information was applied, regarding the petrophysical and mineralogical characteristics of the formation, pore water composition, pressure and temperature values, and kinetic reaction rate constants. The effective porosity of rocks representing the Dębowiec Formation ranges from 9,08 to 24,13. The trapping capacity was calculated basing on the balance of the CO_2 contained in the carbonate minerals (mainly dawsonite) precipitating and dissoluting in the modeling period of 20 000 years. For the aquifer rocks it reaches nearly 1,9 $kgCO_2/m^3$, and for cap rocks - 1,42 $kgCO_2/m^3$. The quantity of gas trapped in the form of solution, assessed basing on modeled chemical constitution of pore water, equals for the aquifer to 1,0 $kgCO_2/m^3$, and for the cap rocks - 1,42 $kgCO_2/m^3$. Western part of the LB aquifer is suitable to play a role of specific natural analogue for the case of the USCB, helping to understand the impact of slow flux of CO_2 on such a hydrogeological environment. One-dimensional advective-dispersive-reactive transport model was applied to reconstruct the processes of forming groundwater chemistry in effect of primary pore fluid dilution by infiltrating precipitation waters, accompanied by: geogenic CO_2 inflow, ion exchange and dissolution of carbonates and/or aluminosilicates. It was found that the transformations of primary groundwater chemistry could be presented in stages according to the water type changes: Cl-Na - HCO_3-Na-Mg, connected with the flow of water through the pore space (Labus, 2009).

3. SUMMARY AND CONCLUSIONS

Set of the issues listed above, requires comprehensive solutions in the spheres of mine safety legislation, preservation of valuable groundwater resources, hydrogeological modelling of mine flooding effects and forecasting the risk assessment of CO_2 storage. The first steps, taken by the research groups from the Silesian University of Technology in Gliwice (Poland) and Technical University of Ostrava (Czech Republic) in cooperation with mining companies included:

- Database building – to gather the information on hydrogeological environment of mining areas,
- Identification of hydrogeochemical phenomena in the mining environment
- Mathematical modelling of groundwater dynamics changes due to mining drainage and flooding
- CO_2 squestration impact modelling and experimental testing.

The effects obtained so far, and the atmosphere of transboundary collaboration give an encouraging outlook for the next activities.

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