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Hydrogeological Conditions of Lignite Basins in Poland and Its Influence on Reclamation Voids by Flooding

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Abstract In Poland the reclamation of post-mining lignite open pits by flooding is presently used in voids with volume of some thousands cubic meters and it is foreseen in the future, particularly in large-space abandoned open pits with volume of more than 1.5 billion cubic meters. Depending on hydrogeological and hydrological conditions, the mine voids will be flooded by groundwater inflow, water pumped out from dewatering system of neighboring pits, or mainly by surface water from rivers and courses.
Keywords open pit, lignite, reclamation, flooding

Introduction

Poland is one of the world's largest producers and consumers of lignite. The lignite output is in range of 65 mln tons per year. Surface-mined lignite is used mainly for power generation. The main lignite deposits being presently under exploitation are of Neogen age and they are located in four lignite basins named the Adamów, Konin, and Bełchatów located in the central part of Poland and the Turów basin located in the south-west part of Poland. Generally, the floor depth of seams below the terrain surface varies from 40 to 300 m. The thickness of lignite occurring in 1 to 3 seams is from 5 to 60 m and overburden thickness is from 30 m to 200 m. The overburden constitutes Neogene and Quaternary formations consisting of silt and clays (30%–75%) and sands (70%–25% respectively) (Libicki 1987). The lignite seams are flat or is slightly up to ten degrees, they are sometimes cut by faults. All deposits are below the natural groundwater table and they occur most frequently right under the terrain surface. Annual precipitation in the region of lignite basins varies from 500–700 mm/year and the average annual temperature is about +8 ℃. Reclamation by flooding is currently used in post mining voids in the Adamów Lignite Mine and the Konin Lignite Mine with volume up to 200 million m^3. Much more difficult will be the reclamation of final excavations of the Turów Lignite Mine and the Bełchatów Lignite Mine whose volume will exceed 1.5 billion m^3.

The Konin and the Adamów lignite basin

The hydrogeological conditions in these areas are characterized by four aquifers–two over and two below the lignite seam (fig.1). The first aquifer of free water table consists of the sands and gravels just below the terrain surface. Its thickness is from 1 to 20 m and average permeability of 0.000174 m/s, but sometimes in old buried valleys it reaches thickness of 40 m and permeability of 0.000578 m/s. The second aquifer is located in sandy lenses within clays and its permeability varies from 2 to 10 m/day. The third aquifer is located in the fine widespread Neogene sands underlying the lignite seam. Its thickness varies from 2 to 70 m and permeability from 0.0000174 to 0.0000463 m/s. The fourth aquifer occurs in the fissured Cretaceous marls underlying Neogene sands with permeability from 0.000023 to 0.00052 m/s. Groundwater in the Neogene and Cretaceous aquifers occurs under confined conditions. The water inflow to the particular open pits varies from 0.3 to 1.2 m^3/s and the total volume of groundwater pumped out from the active pits amounts from 2.2 to 3.0 m^3/s., when groundwater drawdown is from 25 to 80 m. The cone of depression around the open pits in the Quaternary aquifer varies from 1000 m to 5000 m and in the Neogene and Cretaceous aquifers ranges from 4000 to 9000 m. The deposits are located in the area with the lowest precipitation in Poland 500 mm/year. The lower aquifers are recharged mainly by the Warta River. A very significant element of hydrogeology of this region is presence of big lakes mainly groove and postglacial ones.

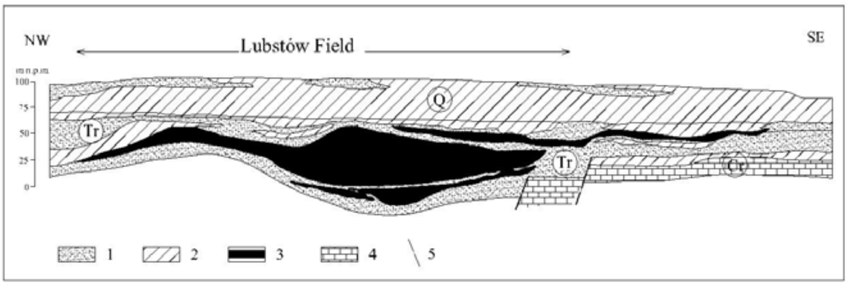

Fig. 1 *The geological cross-section through the Konin deposit area (S–N). Explanations: 1 – fine and medium sands, 2 – clays, 3 – lignite, 4 – marls, 5 – faults, Q – Quaternary; Ng – Neogene; Cr – Cretaceous*

Lignite production in the Adamów Lignite Mine is planned to be ceased in 2023 and in the Konin Lignite Mine in 2037. The final reclamation of abandoned lignite open pits has faced no major problems owing to: the small depth and size of open pits changed into water reservoirs (between 15 m and 80 m), the possibility of their complete or partial backfilling by the overburden from the adjacent open pits and a relatively simple water regime. As yet in the Adamów Lignite Mine (fig.2A) only three voids have been flooded with total area of 0.2 km^2 (210.1 ha) and volume of 11.9 million m^3. In the near future next five pit lakes are planned to be created with area of 8.5 km^2 and volume of 240.0 million m^3. In the Konin Lignite Mine six open pit has been flooded with a total area of 9.7 km^2 and volume of 231 million m^3. The next four open pits with area of 12.5 km^2 and volume of 432 million m^3 is planned to be flooded in the near future (fig.2B).

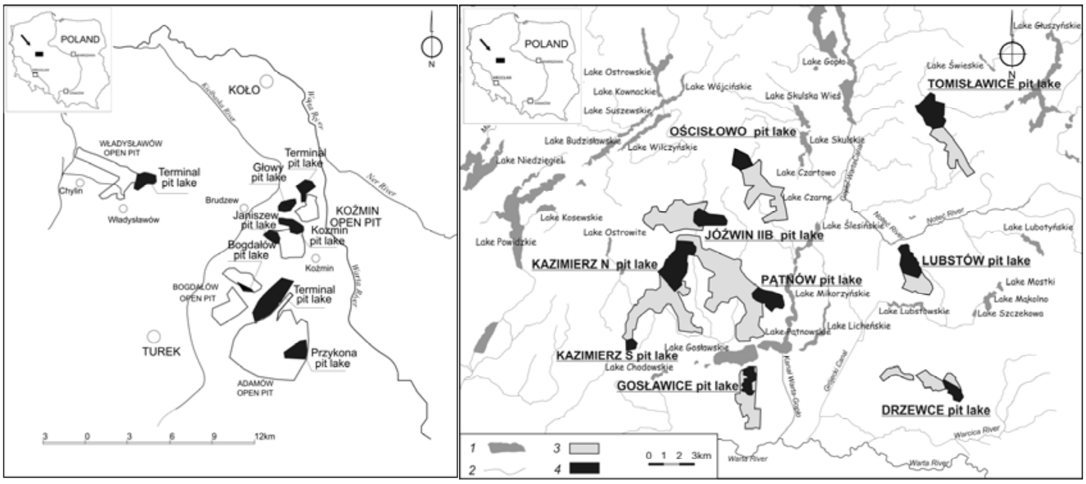

Fig. 2 *Current and proposed location of pit lakes in the Adamow (left) and the Konin post mining area (right). Explanations: 1 – post-mining area, 2 – pit lake, 3 – natural lake, 4 – rivers and courses*

In each case the surface mine voids are flooded by natural groundwater inflow (especially in case of shallow voids) and additionally by water originates from dewatering of the neighboring open pits and natural water courses. Modeling studies reveal that the flooding of post - mining excavations in this area is likely to take about 30 years and it will finish in the late 70-ties of XXI century (Fiszer ed. 2009). In each case there is possibility to speed up this process using more surface water from rivers during the high flow rate.

The Belchatow lignite basin

In the Bełchatow basin, the lignite is deposited in the narrow tectonic rift valley. Quaternary formations occur in the whole area. Their maximum depth reaches from 90 to 300 m in the post - glacial buried valley. The Mesozoic base is formed by Jurassic and Cretaceous rocks - fractured limestone, marls and sandstone (fig.3). The aquifers occurring in this particular stratigraphic series (Mesozoic, Neogene and Quaternary) have many geological and hydraulic connections, so the whole complex of the permeable rocks creates one huge and heterogeneous aquifer in the whole region with average hydraulic permeability of 0.00012 m/s, but it is very diversified in karstified limestones (Szczepiński, Libicki 1999).The dewatering system in the Bełchatów Lignite Mine has been operating since 1975. The mine water inflow amounts to 10 m^3/s. The groundwater table is lowered to about 300 m within the area of mining operation, and the cone of depression is from 3000 m to 9000 m.

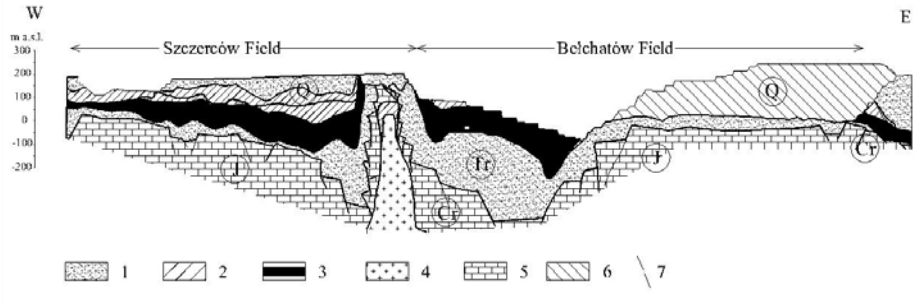

Fig. 3 *The geological cross-section through the Belchatow deposit area (S–N). Explanations: 1 – fine and medium sands, 2 – clays, 3 – deposit, 4 –salt, 5 – limestones, marls, 6 – internal dumping site, 7 – faults, Q – Quaternary; Ng – Neogene; Cr – Cretaceous*

In 2019, it is planned to cease lignite production in the Bełchatów open pit. Lignite production at the adjacent Szczerców open pit will be completed in 2038. A general concept of the reclamation of both abandoned pits is to shallow them with overburden and fill them with water. As a result of reclamation the Bełchatów and Szczerców reservoirs will be formed, with an area of 16.9 and 22.0 km^2 and a volume of 1.3 and 1.8 billion m^3, respectively (Fig.4). The process of filling the post-mining excavations with water in the Bełchatów void will start in 2027 and in the Szczerców void it will start in 2049.

Fig. 4 *Proposed location of pit lakes in the Belchatow mine*

Two conceptions of flooding have been taken into consideration (Kasztelewicz ed. 2008). For the first one the assumption was that the water reservoirs will be filled with groundwater inflow and by additional recharge with water from the well barriers located around the open pits. Groundwater pumped out from the dewatering wells will be discharged to the canals and then it will be transported by pipes into the voids. Calculations revealed that the process of flooding will be finished after 2100. In the second conception the assumption was that the voids will be filled with groundwater inflow with additional recharge from the Warta River flowing on the south at a rate of 2.25 or 4.0 m^3/s. The results of calculations have shown that the flooding will last 45 and 35 years respectively. Water from the pit lakes will discharge into the Widawka River on the north.

The Turów Lignite Mine is located in the geological structure having the shape of a real basin (tectonic depression) and covering an area of about 100 km^2. The bed consists of impermeable Paleozoic rock filled with the Neogene formation at the centre with thickness from 50 m on the boundary to 300 m at the centre of this structure (fig.5). Sands occur in form of closed lenses from 1 to 30 m thick and extend from several hundred meters up to 3000 m. They contain groundwater under confined conditions. At the west side along the open pit contour, the Nysa Łużycka river flows. Its valley with depth from 5 to 20 m is filled with gravel. Groundwater is drained by underground galleries and pumping wells. The recharge from the Nysa Łużycka is cut by cut-off wall. The total groundwater water inflow is stable and amounts to 0.3 m^3/s. Due to the small thickness and isolation from deeper aquifers, the cone of depression in the Quaternary aquifer occurs close to the open pit at the distance of about 2000 m.

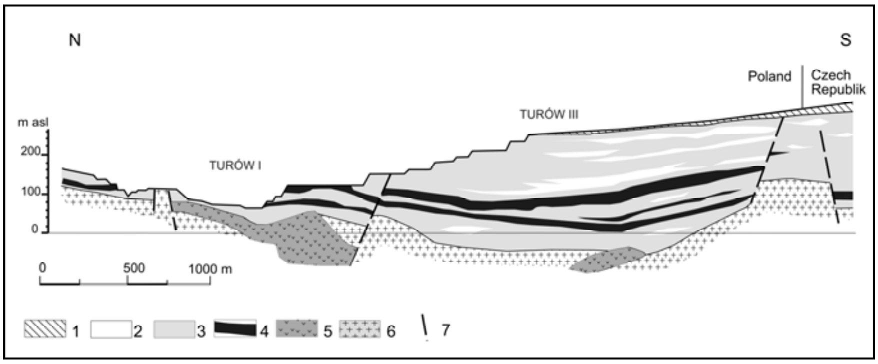

Fig. 5 *The geological cross-section through the Turow deposit area (S–N). Explanations: 1 – silts, 2 – sands, 3 – clays, 4 – lignite, 5 – granite, 6 – basalt, 7 – faults Q – Quaternary; Ng – Neogene; Cr – Proterozic*

Lignite production in the Turów Lignite Mine is planned to be ceased in 2040. The preparation of void for flooding with area of 16.9 km^2 and volume of 1480 mln m^3 will be completed in 2050 (Fiszer et al. 2005). In order to estimate the time of flooding the void the following assumptions have been made: 1. the reservoir will be flooded only with surface water from the Nysa Łużycka and Miedzianka rivers at a rate of 3.87 m^3/s, 2. groundwater inflow into the void will not be possible, because water in the post-mining reservoir will cause excess of hydrostatic pressure on the groundwater in the vicinity of the voids 3. precipitation on the pit lake surface supplements the losses associated with evaporation.

The calculations made for average hydrological conditions reveal that the time of filling the void with water will reach 12 years. At the steady state condition, the pit lake will be recharged from the Nysa Łużycka River flowing on the west, in the amount of 0.075 m^3/s, in order to compensate for evaporation losses. Water from the pit lake will discharge to the east, into the Miedzianka River.

Conclusions

The lignite basins in Poland have variable hydrogeological conditions, which can implicate the method used for reclamation voids by flooding. Generally, good hydrogeological conditions facilitate flooding by direct groundwater inflow and by additional recharge with water from the well barriers, which are located around the voids or are used for dewatering the open pits situated in the neighbourhood. In this case groundwater pumped out from the wells can be discharged to the canals and then it can be transported by pipes into the voids.

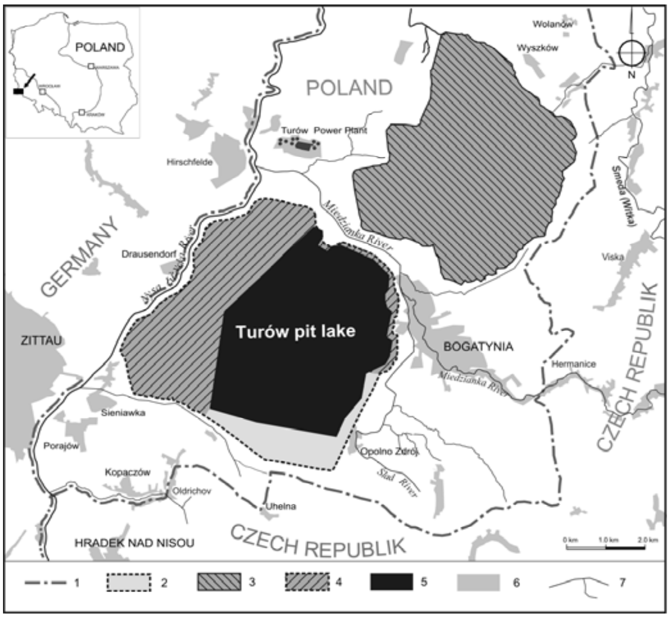

Fig. 6 *Proposed location of pit lakes in the Turów post mining area. Explanations: 1 – state border, 2 – post mining areas,3 – internal dumping site, 4 – external dumping site 5 – pit lake, 6 –post mining areas, 7 – rivers and courses*

The other way of flooding the open pits is the additional recharge with surface waters (from rivers and lakes) located near the voids. This method is used not only in areas with scarcity of groundwater, but also in other conditions. The main advantage is that it speeds up the process of reclamation, especially during the high flow rate. Moreover, in many cases flooding the voids with additional recharge from surface waters can reduce the probable pit lakes deterioration.

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