Use of water from the WVII-16 leak in the Wieliczka Salt Mine (Poland)

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Abstract The Wieliczka Salt Mine (Poland) deals with water hazard every day. The most dangerous groundwater inflow occurred in the Layer 2 chamber (called WVII-16) in December 1972. This continuous inflow comes from sandstones belonging to the Chodenice formation. Water captured from this leakage is considered a brine, with medicinal properties, with low salt concentrations (ca. 60 g/L). This studiy shows that this leakage has a stable chemical and isotopic composition and its flow has a downward trend. This work its presents balneotherapeutic use in case when enclosure of the leak is possible in a stable and controlled way.

Key words Wieliczka Salt Mine, water hazard, use of salt water

Introduction

The Wieliczka Salt Mine is a unique facility in the Word, where mining dates back to the 13th century. That means, more than 700 years of an uninterrupted exploitation, which eventually ended in 1994. Currently, mining works in this facility are performed only for securing, or liquidation of excavations. It is one of the most interesting mining facilities in the world, and in 1978 it was listed on the UNESCO World Heritage List. Today it plays the role of a museum, cultural and touristic place, and also balneotherapeutic facility, where an innovative method of treatment with use of salt microclimate is applied. Wieliczka became famous in the 19th century thanks to Dr. Feliks Boczkowski,. Boczkowski's activity was continued by Prof. Mieczysław Skulimowski, who worked in Wieliczka Salt Mine as a medical doctor. He used, as a first one,the microclimate of salt excavations for treatment (d'Obyrn, Rajchel, 2015). The aerosol in salt chambers, containing chloride, sodium, magnesium and calcium ions, has beneficial properties in the treatment of respiratory diseases. . The microclimate of inactive excavations is characterized by extraordinary bacteriological purity, constant air temperature about 10–12°C, and high humidity of 80–90%. In 2011, the mine has been granted the status of a health resort. Patients come to Wieliczka to treat upper and lower respiratory diseases of nose, sinuses, or bronchus (Obtułowicz, 2002). For treatment purposes, brine from the WVII-16 leak is used from the depth of 250 m.

Geological and hydrogeological setting

Salt deposit in the Wieliczka area is a part of the Miocene salt-forming formation of the Carpathian Foredeep (Fig. 1). The Wieliczka salt deposit extends from west to east, for about 10 km, with the average width about 1.2 km. This deposit has a complex geological structure, due to the Carpathian flysch strukture, which has been folded and moved towards the north on the salt-forming formation. The Layer 2 Chamber with the WVII-16 leakage is located in the western zone of the mine.

In the area of Wieliczka there are four Tertiary water-bearing horizons. and one located in Quaternary sediments. The Quaternary aquifer in the mine area is composed of varigrained sands, gravel, and rubble. The water table in this aquifer is unconfined, and only in a few places is confined. Depth of this water table reaches several meters. The youngest aquifer in the Tertiary formations occurs in the Grabowiec Beds. These formations are localized directly above the Chodenice Beds, andthese rocks are in contact with the Quaternary formations. The hydraulic conductivity of these layers is high, due to the occurrence of sandy layers in Grabowiec Beds, and ranges from $2.4 \cdot 10^{-5}$ m/s to $8.5 \cdot 10^{-5}$ m/s. These formations are located outside of the area of presented study. Another Tertiary level occurs in the Chodenice Beds. These formations are poorly permeable, and mostly consist of mudstones and clay shales, but also contain fragments of poorly consolidated coarse sandstones with sand lenses, and mudstone. These sandstones represent water preferential flowpaths. The hydraulic conductivity of these formations ranges from $5.8 \cdot 10^{-9}$ m/s to $6.4 \cdot 10^{-6}$ m/s. The evaporate formation is characterized by confined water table and poor permeability of rocks with hydraulic conductivity of $2.5 \cdot 10^{-9}$ to $7.2 \cdot 10^{-6}$ m/s. Within this formation there are two types of aquifers: karst-fissured and porous-fissured. The oldest aquifer (Tertiary) is associated with the Skawina Beds, which consists of sandstones, mudstones, and fissured marly claystones. The Skawina Beds are characterized by a hydraulic conductivity rate of 10^{-7} to 10^{-9} m/s, creating a confined, fissured aquifer (Brudnik et al., 2010).

In this part of the mine, the hydrogeological conditions are formed by sandy series of Chodenice Beds contacting with the deposit from the north. These layers have many cracks and suffosion deformation , and the outcrops of these layers are covered by permeable Quaternary rocks. This results in a continuous supply of atmospheric water. At present, the water hazard at the Wieliczka salt mine is mainly related to the Chodenice Beds. The inflow attributed to these layers constitutes about 85% of the total inflow to the mine, of wich about 60% comes from the WVII-16 leakage in the Layer 2 Chamber (Maj, d'Obyrn, 2015).

Area of the Layer 2 Chamber contains layers of evaporate formation bordering at the north with Chodenice Beds. In evaporate formation there are Spiza salts, extracted in the space of the Layer 2 Chamber. The Chodenice Beds are primarily sandy, with concentration of conglomerates, and crumbling rocks. The WVII-16 leakage is located at the clay-gypsum cap boundary, which surrounds salt deposit and salt layers, and is supplied through sandy series of Chodenice Beds by precipitation (Fig. 2).

The leakage of WVII-16

The Layer 2 Chamber was created in the middle of the 20th century, near boundary of the deposit. When exploitation in this mining area ended, this chamber was used as the tank that was used to increase the concentration of the brine by leaching of salt rock surrounding it. As a result of operation of this tank, the pillars of the chamber were dissolved, resulting in hydraulic contact between the sandstone of the sandy series of the Chodenice Beds and the Layer 2 Chamber cavity. At the bottom of this chamber exist poorly permeable, non-dissolving rocks, which limit the contact of brine with water from the outside of the deposit. Leakage in the northern side of the Chamber was confirmed in December 1972. It consisted

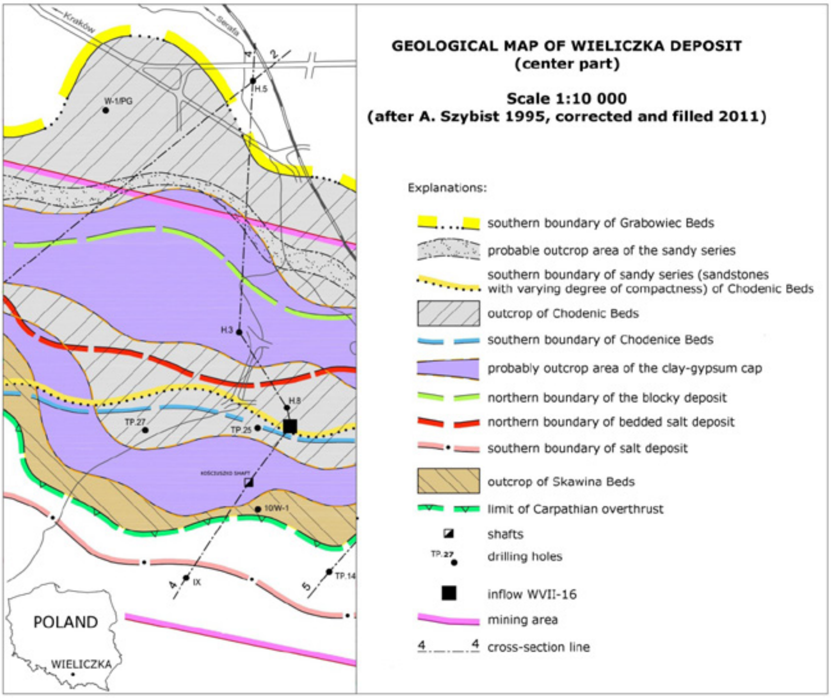

Figure 1 *Geological map of the Wieliczka salt deposit (after Szybist, 2011)*

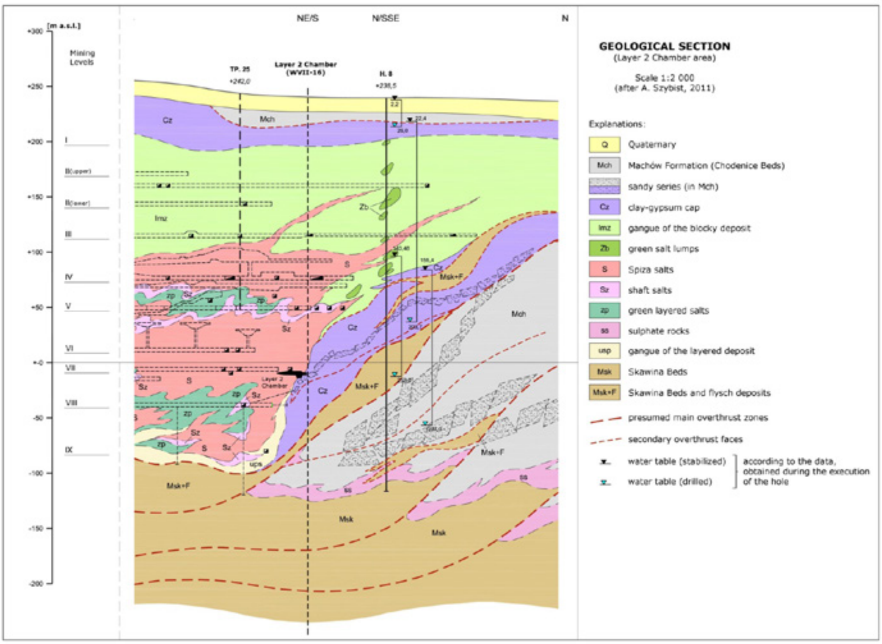

Figure 2 *Geological section of the Wieliczka salt deposit in the near of the Layer 2 Chamber (after Szybist, 2011)*

of brine with low content of NaCl (about 60 g NaCl/L_.and initial discharge of of 22 m³/h. The WVII-16 leakage was captured in the support pavement in the northern part of the Layer 2 Chamber, which construction was completed in March 1977. This water flows naturally from behind the pavement casing to the metal hopper, from where is piped to tanks on level VIII. Then is pumped to the surface, by the Kościuszko shaft (Witczak et al. 2016).

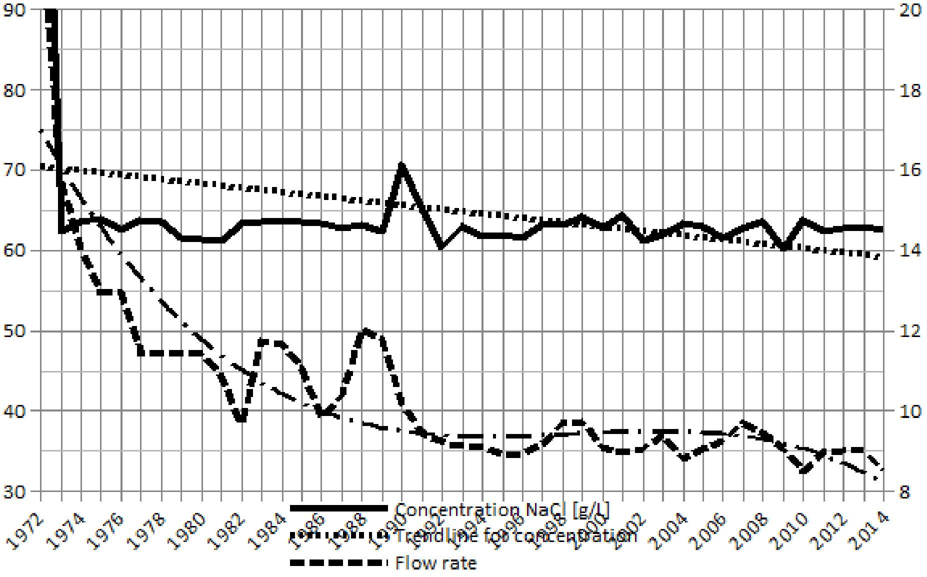

Figure 3 *Trends in the leak WVII-16 flow rate and the NaCl concentration in years 1972-2014 (own work).*

Balneological characteristics of brines from WVII-16 leak

Changes in flow and Na Cl concentration are shown in the graph (Fig. 3). In the case of the leak discharge an explicit downward trend can be observed, with the average discharge in 2014 of 8.74 m³/h. Decreasing discharge without substantial change in isotopic composition (Fig. 4) may suggest that we are dealing with a large volume and limited supply system, which is slowly draining (Brudnik et al., 2007). In terms of NaCl content in the leak there is no clear trend. Average content of NaCl from 1972–2014 is 64.80 g/L (Witczak et al., 2016). Analysis of chemical composition of waters from this leakage indicate slight variations, qualifying these waters as a Cl-Na brine.

No substantial tritium content was detected in the leak, and low values of $\delta^{18}O$, indicate origin of this water from a colder climatic period, and possible precipitation during the Pleistocene period. As a result of this leak, the original flow direction (W–E) was reversed and made changes in the pressure pattern. In the future it may increase amount of modern water with lower mineralization in the inflow into the the Layer 2 Chamber (Witczak et al., 2016)

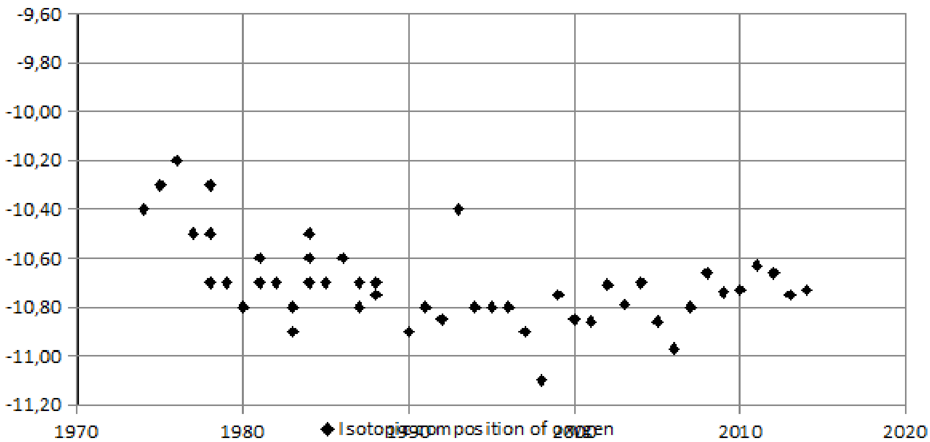

Figure 4 *Isotopic composition of oxygen in the leak WVII-16 in the period 1974-2014.*

Balneotherapy use of brines from WVII-16 leak

Relatively high inflows to the mine, around 130,000 m³/year, require safe system of collection. Water from the inflows to the Wieliczka Salt Mine is currently used for the production of brewed salt, and partly as a medium for backfilling sand, used to eliminate unnecessary excavations.

The WVII-16 leakage brine was considered a medicinal water in 2013, and has been used in the Graduation Tower at the Wieliczka Salt Mine since 2014 (Fig. 5). The active surface of the graduation tower, where brine flows through the blackthorn twigs to form an aerosol is 3200 m² and brine tanks have capacity of 275 m³ (d'Obyrn, Rajchel, 2015). In the Graduation tower brine flows down from the top of the construction, along the walls covered with blackthorn. As a result of splashing, microscopic droplets of brine are formed. Eventually, brine is accumulated in the tanks at bottom of the construction. Mineral-rich brine droplets in the air form specific microclimate which is regarded as having beneficial health effect, and provides a space for inhalation in the open area.

Conclusions

Current study allows to conclude that the WVII-16 leakage is characterized by a constant and stable isotopic and chemical composition. There is also the clear downward trend in leak capacity.

So far, on the basis of isotopic studies, in the WVII-16 leakage originate from Pleistocene waters have been detected, whose composition was stable. However, it cannot be excluded that in several decades contemporary waters influenced by atmospheric precipitation occur in the leakage. That modern water would come from the outcrop of sandy series of the Chodenice Beds. WVII-16 leakage can be considered as a stable and does not threaten to the safety of the Mine.

Figure 5 *Graduation Tower in Wieliczka Salt Mine (photo: K. d'Obryn)*

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