

Healing waters of the Paleozoic carbonate series of the Cieszyn's block in the Ustroń region

The study of the influence of natural and anthropogenic factors on the groundwater is one of the main tasks of hydrogeology. A comprehensive analysis of the physical and chemical properties of water and the exploitation parameters of the water's intakes is the basis for the proper recognition of the aquifer structure. The identification of the hydrogeological conditions of the Palaeozoic block of Cieszyn was based on the interpretation of the results of drilling works carried out in the 1970s.

In the structure of the Cieszyn's block, a smaller geological unit is separated, defined in the literature as the Cieszyn-Kętski bump. Compared to the entire Cieszyn's block, it is characterized by increased values of permeability and water-bearing capacity. In the Paleozoic carbonate series of this unit, the hydrogeological conditions are very similar, therefore, the results of stationary observations from the "Ustroń" health resort can be used to design new balneotherapy and recreational investments. Consequently, comprehensive research was carried out in the area of Ustroń on a proper place which was U-3 (depth 1837m) and U-3A (depth 1753m) intakes of waters from the Paleozoic carbonate series. In addition, the health resort has a C-1 absorptive borehole (1695 m deep) intended for injection of post-treatment brine.

The following materials and archival materials were used to complete this dissertation: geological profiles, measurements of the dynamic and static position of the water table, the efficiency of intakes, the value of the gas exponent and the general mineralization of waters. Approximately 40,000 data from May 1995 to December 2021 were analyzed. On the basis of archival materials, spatial models of the geological structure of the Cieszyn's Block and maps of the thickness of formations lying in the roof and bottom of the carbonate series were constructed. On this basis, the main elements of the water balance of the mineral water deposit were estimated. Using the results of physicochemical analyzes of waters in the research area, thermodynamic modeling (water saturation state) and hydrodynamic modeling were carried out, and hydrochemical indices were determined.

The obtained results made it possible to present a detailed description of the deposit of thermal healing waters of Ustroń compared to all of the water on the entire unit of the Cieszyn's block. Calculated hydrochemical indices and the results of stable oxygen and hydrogen isotopes tests were used to assess the origin of the waters under study.

The calcareous-dolomite rocks series of the Lower Carboniferous and the Upper and Middle Devonian build a common aquifer complex in the area of the Cieszyn's block. The thickness of these rock series increases towards the north, reaching a maximum depth of 1000 m. In the dolomitic layers, as they deepen, the effective porosity decreases from 1.14 to 0.12%. Locally, in places where the roof of the dolomitic strata is uplifted and caverned, an increase in effective porosity and secondary dolomitization is observed. The groundwater table of the carbonate series stabilizes at depths from 142 m below ground level (the Kozy MT-3 borehole) up to 250 m below ground level (the Kęty -1 borehole) and does not have any hydraulic contact with overlying formations. The Upper Carboniferous sediments, due to numerous faults occurring within them, do not cause an increase in piezometric pressure in this aquifer layer. The layer confining the water table consists mainly of Miocene deposits and, in the southern part of the study area, a series of Carpathian flysch. The values of pressure gradients range from 0.98 to 1.4 MPa/100 m. With the increase in the depth of water occurrence, their mineralization gradually increases, with an average of approx. 120 g/dm³.

Analyzes of the results of archival research showed no relationship between the pH values of brines and the depth of their occurrence. The chemical composition of the waters is dominated by chloride ions (from 48 to 107 g/dm³) with an average content of 88 g/dm³. The highest concentrations of these ions occur at a depth of 2030 m in the Goczałkowice IG-1 borehole and the lowest in the Ustroń IG-2 borehole (at a depth of 1108 m). Vertical changes in the content of chloride ions in individual holes indicate the presence of three zones differentiated in terms of concentrations of these anions. Among the cations, sodium is in the largest amounts, and the concentrations of this component increase with depth, as in the case of chloride ions. Among the minor components, bromide ions are present in significant amounts. Depending on the amount of these ions, two groups of waters can be distinguished in the discussed area. The first group of water, with waters containing of these ions below 0.08 g/dm³ occurs in the Lachowice-2 borehole at a depth of 2700 m and the Lachowice-7 borehole at a depth of 3500 m. The second group includes waters containing bromide ions ranging from 0.19 to 0.47 g/dm³ (waters from the remaining analyzed boreholes).

The results of isotope tests and the values of hydrochemical indices indicate that the discussed Paleozoic reservoir of the carbonate series is characterized by complete, tight isolation from the ground surface. These observations are confirmed by the values of hydrochemical indices rNa^+/rCl^- (from 0.62 to 0.87) and $rSO_4^{2-} \cdot 100/rCl^-$ (from 0.14 to 0.33). Moreover, these values suggest the progressive development of ion exchange processes and/or metamorphism of primary brines. Based on the ionic ratios $rCl^-/rHCO_3^-$ and $rSO_4^{2-}+rHCO_3^-/Cl^-$, it can be assumed

that the water flow conditions between the U-3 and U-3A wells are deteriorating. The impact of the lymph well located at a short distance (about 1 km NW) from the intakes in question is probably noticeable here.

The content of stable oxygen and hydrogen isotopes indicates that these are relic, paleoinfiltration waters of a very hot climate. Taking into account the maximum value of $\delta^2\text{H}$ of 20 ‰ (Ustroń U-3), the potential recharge area of the Paleozoic carbonate series from the Permian to the Early Miocene was located at ordinates of approx. 600 m above sea level. This confirms the view that the morphology of the southern part of the Upper Silesian Coal Basin in the Permian was very diverse.

Chemically, the waters from the U-3 and U-3A wells are supersaturated with respect to carbonate minerals (calcite, aragonite, dolomite) and quartz. In the case of post-treatment brine injected into the infiltration well, the values of SI indices suggest the precipitation of carbonate minerals and iron hydroxides. This is confirmed by the results of mineralogical analyzes of sediments taken from the installation injecting post-treatment brine into the infiltration well.

There is observed a cyclical decrease in the absorptivity of this system proving the precipitation of secondary mineral forms. The obtained results of model tests are consistent with the observations and confirmed by a cyclical decrease in the absorption capacity of the C-1 well. The several decades of injection of post-treatment brine into the borehole confirmed the low absorptivity of rocks of the Devonian carbonate series in the area of Ustroń. The analysis of the efficiency of the C-1 borehole absorption indicates that cyclic acid treatments increase the absorption capacity of this intake plenty times.

Keywords: Cieszyn's Block, Paleozoic carbonate series, mineral waters of the Ustroń region, exploitation and acidification of an infiltration well.