SUMMARY

HYDROGEOCHEMICAL SYSTEMS OF MOUNTAIN CATCHMENTS OF DIFFERENT LITHOLOGY

The actual systems involving groundwater, rock environment, gases, as well as processes and phenomena occurring among them are extremely complex. For this reason, individual processes are frequently identified in scientific research to facilitate their recognition. However, this approach hinders determination of interactions between them, and thus holistic recognition of natural conditions. A systemic approach stands in opposition to the approach described above, as it facilitates a new, holistic view on the studied issue, while maintaining knowledge obtained in previous studies. In this approach, the hydrogeochemical system of a mountain catchment may be understood as a section of hydrogeological space outlined by its boundary surface and including rock mass, accumulated groundwater, and also a mixture of gases in a zone of incomplete saturation. The solid, liquid and gas phases are intertwined components of this system. Interactions between them can be mathematically described by laws of physics and chemistry, and they depend on attributes assigned to individual components. An inner condition of the hydrogeochemical system also depends on its interaction with the surroundings. This interaction can be expressed by assigning specific input and output states to the boundary surface.

The study characterizes hydrogeochemical systems of three mountain catchments differing in their lithology. It is based on a proprietary concept of a hydrogeochemical system referring to a general mathematical theory of systems. The study covers the Tatra catchment of the Biały Stream, in which mainly dolomites and limestone were found, the Podhale catchment of the Suchy Stream made of flysch formations, and the Pieniny catchment of the Macelowy Stream with both carbonate and flysch rocks. The hydrogeochemical systems of the catchments were separated from the surroundings by distinguishing their components. Each of the components was assigned relevant attributes by using the results of the monitoring studies on groundwater in fully saturated and incompletely saturated zones, determination of rock and weathered waste mineral composition, as well as an output from developed geochemical models.

The hydrogeochemical system is separated from its surroundings by the boundary surface. The ground surface was understood as the top boundary surface of the hydrogeochemical systems. Through this surface loads penetrated into the studied systems, together with infiltrating precipitation water (input conditions) and were carried out of the system together with water drained by springs and streams (output conditions). The lateral boundary surface of the hydrogeochemical systems in the studied catchments is determined by groundwater divides, while the bottom surface is formed by a bundle of streamlines associated with the divide zone. It is difficult to describe clearly the interactions between the system and its surroundings by the bottom and the lateral boundary surfaces in mountain catchments. Considering the results of water chemistry studies, the interpretation of labeling of stable oxygen, hydrogen and tritium isotopes, and water balance of the catchment, it was assumed that the lateral and bottom boundary surfaces formed a tight border.

Identification of the system components, assigning attributes to them and determination of relations between the system and its surroundings allowed describing interactions between the individual components in the hydrogeochemical system. These relations were described qualitatively by identifying the processes occurring in the system, and quantitatively by evaluating mass transfer between the components.

In all studied catchments, a dominant relation common for all system components was dissolution of carbonates in the presence of carbon dioxide. In the Biały Stream catchment, dissolution of dolomite predominated, and in the two remaining systems mainly calcite was dissolved. This differentiation resulted from attributes of the solid phase in the fully saturated and incompletely saturated zones, i.e., from its mineral composition. Regarding mineral composition of rocks, dolomite dominated in the Biały Stream catchment, while in the other areas calcite was a predominant carbonate material. Apart from carbonate dissolution, the processes of plagioclases and feldspars hydrolysis were also important. A share of these processes in determination of the chemical composition of groundwater did not exceed 1% in the Tatra catchment, but reached even 6% in the flysch catchment of the Suchy Stream (Podhale). In the Pieniny catchment, it did not exceed 3%, with a slightly larger share observed in zones where sandstones, shales and marls were present, as compared with limestone. In the catchments of the Macelowy and the Suchy streams, a noticeable role of the processes delivering sulfates to groundwater was observed. One of those processes was the oxidation of pyrite. In the Biały Stream catchment, the main source of sulfates in groundwater was precipitation water infiltrating into the system.

The hydrogeochemical system, facilitating a holistic description of the processes occurring in the studied area, was used here as a tool helpful in the quantitative evaluation of chemical denudation in the researched catchments. The evaluation of chemical denudation, understood as determination of rock mass dissolved in water and removed from land areas requires a thorough understanding of the processes occurring in a given area, together with interactions among them. On the other hand, chemical denudation may be used as a comprehensive measure of functioning of the hydrogeochemical system, provided the calculations consider only loads delivered to groundwater through the processes occurring within the system. When this condition was met, it was possible to include spring drainage areas in the study.

The studies showed markedly higher values of chemical denudations in the drainage areas of springs draining carbonate rocks (in the Biały Stream catchment, springs B5 – 22.0 m^3/km^2/year and B7 – 18.4 m^3/km^2/year, and in the Macelowy Stream catchment, spring M2a – 13.8 m^3/km^2/year) as compared with those draining sandy and shales formations (in the Macelowy Stream catchment, spring M7 – 8.7 m^3/km^2/year and in the Suchy Stream catchment, spring S6a – 8.7 m^3/km^2/year*).

* The provided denudation values were calculated using numerical models.