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title: **Natural and anthropogenic factors that participate in the formation of the water environment and its biotic elements in the karst area of Cracow-Czestochowa upland, Poland**

author(s): **Jacek Różkowski**
University of Silesia, Faculty of Earth Sciences, Poland,
jacek.rozkowski@us.edu.pl

Elżbieta W. Dumnicka
Jan Długosz University of Częstochowa, Institute of Chemistry and Environmental Protection, Poland, dumnicka@iop.krakow.pl

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The necessity for groundwater protection is considered in the European Union in the context of its influence on the state of surface water and connected directly with terrestrial and aquatic ecosystems as well in the context of its significance for the drinking water supply of the human population. An estimation of surface water quality includes among others the recognition of its biological elements of quality: plankton, macrophytes, phytobenthos and benthic invertebrates (Directive No 2000/60/EC, 2000).

The authors have carried out their investigations at the karst carbonate massif of the Cracow-Czestochowa Upland (the CCU) since the 90s of the XX century. The CCU is located within the Silesian–Cracow monocline formed during the Alpine diastrophic cycle. This is the area of an upland karst not fully developed and diversified in its inner structure. The Upper Jurrasic aquifer, which is a Major Ground Water Basin (MGWB No 326), was delimited in this area. Water-bearing carbonate formations are represented by limestones of diversified facies, underlain by marly deposits of Oxford age. The Upper Jurassic carbonates form an extensive generally unconfined aquifer of fractured-karstic-porous type. The carbonate series are strongly cracked and fractured. Wells draining water from the Upper Jurassic aquifer characterize with a large range of yields from 0.4 to 567 m^3/h and drawdowns from 0.11 to 26 m. The specific discharges of wells range from 0.1 to 416 $m^3/h \cdot 1m$. Among 153 wells predominate discharge values from 0.1 to 5 m^3/h (35% of statistical population). Hydraulic conductivity of the rock complex determined by the well tests ranges from $1.3 \cdot 10^{-7}$ m/s to $6.19 \cdot 10^{-3}$ m/s, while the mean value is $1.14 \cdot 10^{-4}$ m/s. Diversification of aquifer water storage capacity is measured by a spring discharge. The spring discharges vary from 0.5 to 187 l/s. Springs of high discharges are mostly ascending karstic springs located along fault zones. Single springs of high discharge occur mainly at the Częstochowa Upland. Their yields amount usually 40–187 l/s, only the yield of the spring group Julianka, located at the catchment of Wiercica river exceeds 400 l/s. Index of springs multiyear variability changes from 2 to 10. The hydrological system of the Upper Jurassic aquifer at the elevated Upland area usually reacts to preceding precipitation with a delay and "inertia". It is, at the same time, an internally diversified system. In the Rudawa catchment area (southern part of the CCU) the water residence time in the aquifer measured as a result of the spring recession curve analysis, ranges from 31–68 days concidering small yield springs (<1 l/s), 52–290 days in the case of up to 10 l/s springs, and 103–340 days for up to 20 l/s springs (Różkowski, 2006). Observations of Wiercica catchment basin pressure fields showed that its reaction time to spring snow melting or continuous rains varies from 3 to 6 months. The recharge of the aquifer takes place at the entire area, directly at the outcrops, or indirectly through the permeable Quaternary sediments. Predominate diffusive recharge. A clear relationship between precipitation intensity and groundwater run-off was determined. Long-term observations conducted in the Upper Jurassic drainage basins revealed considerable diversification of the groundwater run-off modulus during both: low and high-water periods, reaching values from 2.9 to 7.3 $dm^3/s \cdot km^2$ at the Wiercica drainage basin, 2.8–6.0 $dm^3/s \cdot km^2$ at the Prądnik drainage basin and 2.5–6.4 $dm^3/s \cdot km^2$ at the Czarna Przemsza drainage basin**.** The waters of the Upper Jurassic aquifer form in the system of shallow circulation, in the carbonate rock environment. They are typical HCO_3–Ca type, two–ion waters. The calculated saturation indices (SI) for carbonate minerals oscillate around the values indicating a saturation state. Sampled waters are low mineralized (200–450 mg/L), slightly alkaline (pH<8.3) and of moderate hardness (170–300 mg $CaCO_3$/L), with mean concentrations of biogenic elements in springs: 5–25 mg NO_3/L, <0.01–0.15 mg PO_4/L (Różkowski, 2006, 2009).

The Upper Jurassic aquifer is closely connected with surface waters and its biocenoses. In a mineral composition of springs bottom deposits dominate calcite and quartz originating from the overburden strata erosion and accompanying in the minority clayey minerals, dolomite, iron compounds and locally among others metallurgical wastes. The organic matter content (measured at fine sediments only) was low in the majority of studied springs, especially in northern part of the Upland (Galas, 2005).

In the land use of the CCU area predominate farming. In particular catchment areas arable land have 55–80% share, forests — till 20%, while orchards, meadows and pastures have minor meaning. Urban-industrial agglomerations are situated on margins of the CCU area. Local pollutions are connected with farming (mainly with water-supply-and-sewage-disposal management), aerial sources – with air pollution and use of fertilizers and pesticides. Due to protection of the natural environment and groundwater resources, most of the area of the CCU is protected by law (Ojców National Park, Landscape Parks, Nature 2000 area).

The presented investigations refers to hydrogeoecological studies. Investigations have dealt with the water environment regime and also with the presence of invertebrates in it (Humphreys, 2009). These habitats connected directly with groundwater outflow are treated in the Habitat Directive of the European Union as very valuable and they have the rank of European cultural heritage.

In the area of the CCU there are several hundred springs. They are not only the local groundwater drainage points but they also set composite ecosysytems depending on hydrologic conditions (Springer, Stevens, 2009).

Up to now the entire invertebrate fauna have been studied in about 30 springs only whereas single taxonomic groups such as water mites (Biesiadka et al., 1990) and caddisflies (Czachorowski, 1990) have been investigated in numerous objects. Studied springs differed by discharge values, type of bottom sediments (fine or coarse grains), amount of organic matter accumulated on the bottom and concentrations of nutrients in water. Moreover several studied springs were encased what changes some abiotic parameters e.g. temperature, organic matter content in the sediments (Galas, 2005) and in consequence – had influence on the composition of benthic fauna communities and their densities.

The durability and stability of habitat conditions in springs results in the occurrence of a specific fauna. In the area of the CCU the species living exclusively in the springs (named crenobionts) are represented by a few species of water mites (Hydracarina) (Biesiadka, Kowalik, 1999) and small crustaceans (Ostracoda) (Matolicz et al., 2006). Strictly crenobiontic species are not found in other invertebrates groups, but crenophilic taxons are common in various groups. Sometimes even taxonomic name of genera shows their connections with the springs e.g. *Krenopelopia, Krenosmittia* or *Crunoecia*. Typical mountain species living in cold waters with small temperature fluctuations (named oligostenothermic species) are the most important group of spring fauna in the area of CCU. Among them there are some relict species, e.g. flatworm *Crenobia alpina* and snail *Bythinella austriaca*. The populations of these species living in the CCU area are isolated from mountain populations probably since the end of the last glacial epoch, but genetic studies are necessary for the confirmation of their actual separation. Numerous specimens of *Bythinella austriaca* are present in almost all the studied springs (Dumnicka et al., 2007) but *Crenobia alpina* is known from a few localities only. This species inhabits springs located along the middle course of Sąspówka stream, moreover it was found recently in one spring situated in Pilica–Piaski village (Tyc, 2004). It seems that other population, known from Źródło Zygmunta spring disappeared in 80. totally (Skalska, Skalski, 1992). Larvae of a few insect species such as *Diura bicaudata* (stonefly, Plecoptera) and *Drusus trifidus*, *D. annulatus* and *Plectrocnemia conspersa* (caddis-fly Trichoptera) were also found exclusively in the springs and a short sector of headwater streams (hypocrenal) characterizing by low temperature. Several beetles (Coleoptera) live permanently (as larvae, pupae and imago forms) in such waters. In the CCU area they are represented by species from the genera *Agabus*, *Hydraena* and *Elmis*. The highest densities of these species were stated in the spring niches and they decreased along the stream very quickly. Only in Sąspówka stream the above mentioned species and others which prefer low temperature but can survive its fluctuations, inhabited long stream sectors due to the presence of numerous near-channel or channel springs. It seems that the populations of oligostenothermic insects living in remote springs are not so strictly isolated as populations of flatworms or snails because adult forms of insects can actively migrate.

The most common species in karst running waters in the CCU area is *Gammarus fossarum* (Crustacea), which was found in all the studied springs. In some of them this detritivorous species forms about one half of the benthic community (Dumnicka et al., 2007).

Interesting group of species, which may possibly be found in the springs, are stygobionts (the name originated from the underground Styx river known from Greek mythology). In the area of CCU the presence of a few such species was confirmed (Dumnicka, 2005, 2009). Crustacean *Niphargus tatrensis* vastly distributed in underground waters of Poland, in karst and non-karst areas (Skalski, 1981), was found in a small number of springs situated along Prądnik and Sąspówka streams and in Źródło Zygmunta spring (Dumnicka, 2005). Moreover two species of stygobiontic oligochaetes were present in the studied water bodies: *Trichodrilus cernosvitovi* in the southern part of CCU (Dumnicka, 2005) and *Gianius aquedulcis* in the northern part, exclusively in springs situated along Warta river in Mstów village (Dumnicka, 2009). Stygophilous species were more common and they had representatives in more invertebrate groups such as ostracods, hydracarins and oligochaetes. In Poland among insects larvae, widespread in surface aquatic environments, stygobiontic as well as stygophilous forms are absent.

Many semi-aquatic species were also present in the studied springs, what is typical for small water bodies. Among them the most numerous were oligochaetes (Dumnicka, 2006) and larvae of flies (Diptera) (Dumnicka et al., 2007).

Beside remarkable groups of fauna shortly presented above, there are many eurybiontic species living in the springs. They belong to various taxonomic groups and their percentage share in the whole benthic fauna usually increased in encased or polluted springs, where typical inhabitants of such water bodies disappeared.

The majority of springs situated on CCU area, above all in its southern part, are small, that is why the diversity of benthic fauna in particular spring is not high. Existing faunistic and ecological studies on the springs located in the CCU indicate that they are highly diverse what resulted in a high number of species found in this area.

The composition of fauna living in springs is influenced by hydrogeological conditions such as spring discharge, spring variability index, chemical composition of waters, physical–chemical properties (temperature, water reaction — pH, oxidability, redox potential — Eh), hydrostatic pressure, their surroundings, what decides about the input of biogens and allochtonic organic matter into the spring and by disturbances, especially in the form of anthropopression. Springs are situated mainly in the areas covered with forests and protected by law. Even the localisation on protected areas does not assure the preservation of natural biocenoses in such springs, what could be observed in Źródło Zygmunta spring where the invertebrate fauna almost disappeared (Dumnicka et al., 2007) due to the strong penetration by tourists.

About 50% of springs preserve their natural character. The most important threat for springs and their biocenoses set stream regulation works and direct intervention in zone of spring niche (among others spring tapping-seizing, municipal waste dumping, tourism, road traffic). Up to now the information about diversity of fauna and the composition of spring-living communities is only fragmentary. Moreover, there are no complex studies on fauna which take into account the presence and conditions of populations of crenobiontic and oligo-stenothermic species in individual springs. That is why the more strictly protection is necessary and multidisciplinary studies are needed. The study, done together with the recognition of regional management and pollution sources, will allow the influence of natural and antropogenic factors on water environment and its biotic elements within the karstic area of the CCU to be estimated. They will also show the current trends of this environment is development. In addition to the study aspect the investigations also have practical and methodological aims. For the purpose of providing the effective protection of karst water and its ecological environment in the area of the CCU, the further development of research procedures typical for the karstic areas is necessary.

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