THE INFLUENCE OF WATER CIRCULATION ON STREAMWATER CHEMISTRY IN CATCHMENTS OF DIFFERENT LAND USE DURING FLOOD PERIODS (THE CARPATHIANS, POLAND)

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Alongside geochemical properties a fundamental role in ion concentration changes during flood events is played by the water circulation pattern. It determines the timing of the arrival of water to the stream channel through different flow paths and therefore different chemical properties. The water circulation pattern is strictly dependent on other factors such as a nature of a basin (its geomorphology, land use and soil and rock-waste cover), nature of flood event and the condition of the soil covers (water content and freeze status). The aim of the study was to recognize the influence of water circulation pattern in the catchments of different land use on streamwater chemistry changes during floods caused by rainfalls or by snowmelt.

The research area was located in the marginal zone of the Carpathian Foothills (Poland) in the Stara Rzeka catchment (mixed landuse) and its two subcatchments: Leśny Potok (wooded) and Kubaleniec (farmed) (Figure 1). In 2002-2004, the samples were taken during 26 flood events caused by rain (short torrential rainstorms and long-duration rains), snowmelt or snowmelt-rain. Measures used included specific conductivity (SC), pH and concentration of main ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}) and nutrient compounds (NH_4^{+}, NO_2^{-}, NO_3^{-}, PO_4^{3-}).

During intensive summertime rainstorm floods in the farmed basin of Kubaleniec overland flow forms very quickly. Areas particularly prone to the development of overland flow include highly compacted field roads and paths, as well as furrows separating plots. During torrential (intensive) rains, overland flow is also formed on slope-side fields, albeit with a certain delay to runoff along field roads and furrows; once top soil layers have been saturated and the infiltration rate has dropped. The quick supply of overland flow water causes the extreme ion concentrations – i.e. extremely low for most main ions and extremely high for most nutrient compounds – to occur prior to the peak discharge (Figure 2). As the rain stops, the overland flow disappears from the slopes rapidly. From then on, it is the subsurface (mid-cover) flow that plays a major role in the further development of the flood wave, causing SC and main ions concentration to be higher during the recession of the hydrograph limb than during its build-up.

In the wooded Lesny Potok, in contrast to the farmed basin of Kubaleniec, overland flow plays a minor role in shaping the hydrograph of rainstorm floods. The most important role is played by subsurface flow, with a major role played also by a dense network of badlands and v-shaped valleys cutting the slopes. The infiltrating water is drained very quickly and after resurfacing accelerates up to 100-500 times faster as compared to its subsurface flow velocity (Dunne and Black,1970). At first the main channel reaches the water from side valleys draining the ground water table (V-shaped valleys). The greater the depth of the water table the more time

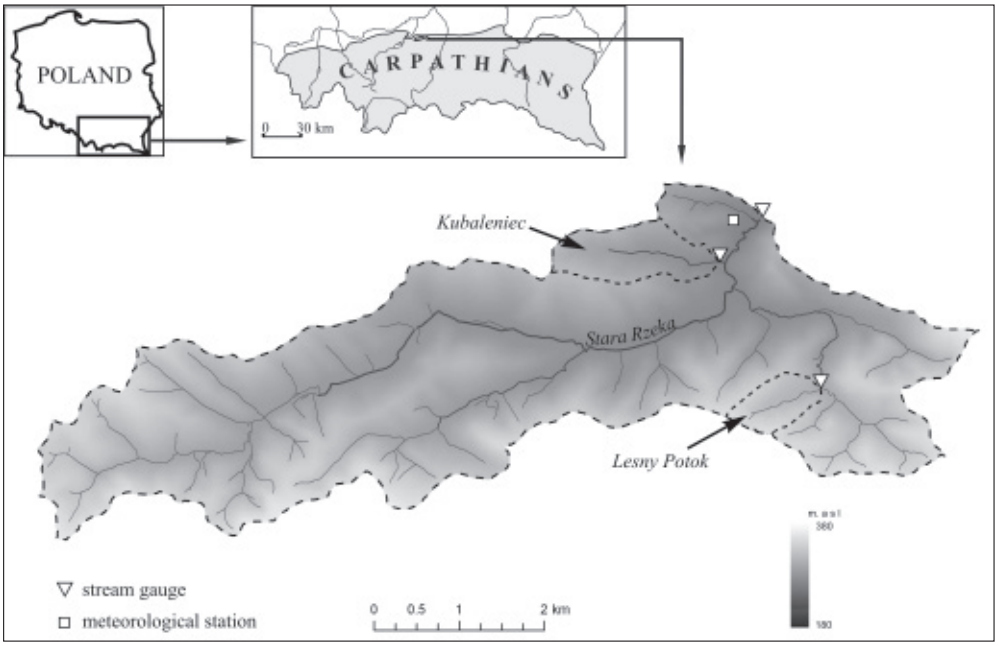

Figure 1. Study area

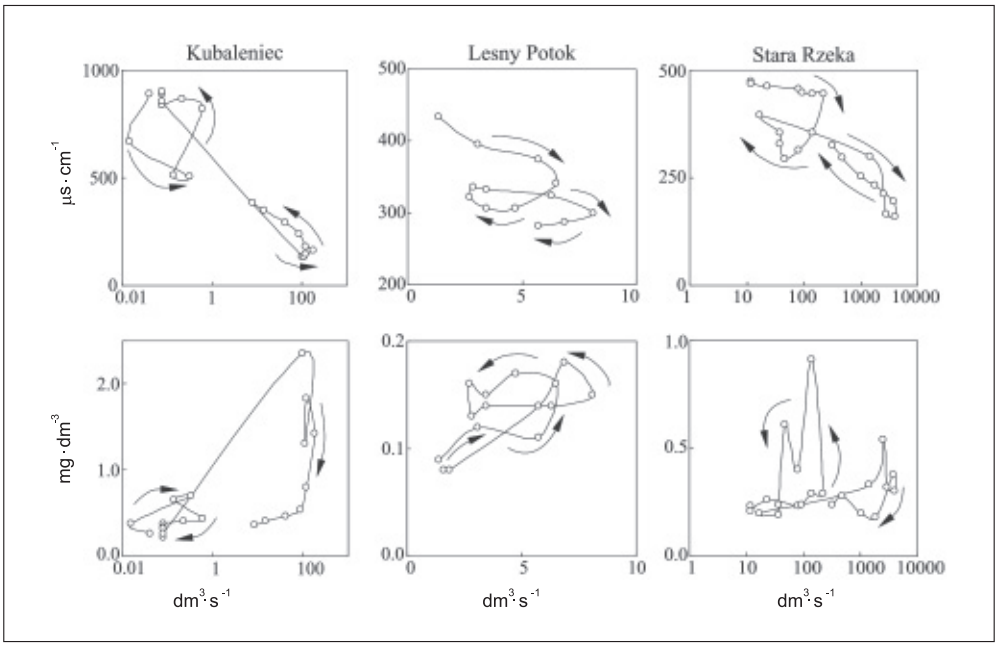

Figure 2. SC and PO_4^{3-} concentration vs. discharge of Kubaleniec, Lesny Potok and Stara Rzeka during intensive rainstorm floods (effect of hysteresis)

it takes for the waste covers to be water-saturated and subsequently for water to resurface. Overland flow plays a minor role in the supply of the watercourse and surfaces only after a time lag along forest roads and paths and in the wet valley bed. The essential role of the subsurface flow and the marginal role of the overland flow causes that the extreme values of the parameters (low for SC and most main ions and high for nutrient compounds) occur after the flood wave peak (Figure 2). The flushing effect on the covers results in SC values and main

ions concentrations tending to be higher during the rising limb of the hydrograph than during its falling part. Chemical hysteretic loops in the Stara Rzeka (complex land use) varied in terms of direction: sometimes they appeared similar to those in Leśny Potok (wooded) and sometimes to those in Kubaleniec (farmed). Extreme chemical parameters occured prior to or after the peak discharge (Figure 2).

Similar shape and direction of hysteresis loops indicate similar water circulation patterns in the drainage basins, independent of their land uses. During such events, the watercourses are supplied mainly with the snowmelt water that is characterised by similar chemical composition throughout the Stara Rzeka drainage basin. The subsurface flow, which differentiates the chemistry of the rainstorm floods in the farming and wooded basins, plays a minor role during snowmelt floods. With frozen covers, i.e. during short floods or at the beginning stages of longer events, subsurface flow represents a negligible proportion in the main watercourse supply because of the restricted infiltration of the snowmelt water. The watercourses take water primarily from the snowmelt water running on top of snow, ice or frozen ground. The thickness of the soil layer actively supplying water to the stream changes dynamically. On the other hand, during snowmelt floods, when the covers are unfrozen but soil saturated, the subsurface water flow into the watercourse shows very little variation of quantity and quality of water. According to research by Laudon *et al.* (2004) performed in a small Swedish drainage basin, frozen soil has an impact on the ways of water access to the channel, especially at the initial phase of the floods.

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