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Transport of anthropogenic pollutants through the unsaturated zone, traced by isotope chemical indicators: a case study from southern Poland

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Migration of anthropogenic pollutants through the unsaturated zone, originating from both point and diffuse sources, is nowadays a common phenomena in many parts of the world. This process is of particular importance in heavily populated and industrialized regions, such as the European continent, where anthropogenic impact is persisting since many decades. Adequate assessment of the migration parameters, such as transport velocity and rates of geochemical interactions within the matrix, is of utmost importance for assessing the vulnerability of shallow groundwater systems against pollution. Such systems often serve as important source of potable water.

The presented study was focussed on assessing the migration parameters of pollutants of industrial origin (SO_4, heavy metals) to shallow groundwater system located nearby a large metallurgical plant. The plant, located on the outskirts of Krakow, a large town in the south of Poland, was established in the 1950s. Since that time, the unsaturated zone of this system is receiving heavy loads of pollutants mainly as airborne particulates (heavy metals) and as sulfur compounds (wet and dry deposition). The depth of unsaturated zone consisting mainly of loess, varies between 8 and 15 meters. The aquifer is continuously exploited since the 1960s by a system of boreholes supplying potable water to the factory. Some wells are already affected by the pollutants.

The water and pollutant transport through the unsaturated zone was studied using a multi-level lysimeter system and by analysis of soil cores drilled in different parts of the aquifer. The infiltration velocity of water was determined using bomb-tritium, as well as chloride and bromide ions. The distribution of bomb-tritium in the unsaturated

zone was measured twice: in 1993, when the tritium peak was detected at around 10 m depth, and in 2003 when only the tail of the peak was still in the unsaturated zone. The average infiltration velocity derived from tritium measurements carried out in 1993 is equal around 30 cma^{-1}. Tracer experiments with Cl and Br ions yield the values between 30 and 90 cma^{-1}, depending on the location within the system.

Sulfates were measured both in the multi-level lysimeter system and in the soil cores. The recorded concentrations in the unsaturated zone varied in the range between 50 and 900 mgl^{-1}, exceeding in major part of the profile the maximum permissible level of SO_4 in drinking water (250 mgl-1). Assuming that sulfates are transported in the unsaturated zone without significant delay with respect to the water flux, the arrival time to groundwater table of this pollutant in the studied groundwater system was estimated to be between 10 and 50 years. Heavy metals are confined within the first 50 cm of the profile.

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