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Simulation of Bacteriological Pollution in the Unsaturated Zone of Karst Rock in Slovenia

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In karst areas, pathogenic micro-organisms and solute contaminants can infiltrate into the subsurface, either diffusely through shallow soils and fractured rock or point-like via swallow holes. In the first case the pollutants can be retained, degraded and thus retarded, whereas in the second case the pollutants can be rapidly transported over large distances, often without effective attenuation. Karst groundwater is thus highly vulnerable to contamination and therefore has special protection needs. Bacteriological pollution resulting from agriculture is the most important problem in groundwater protection, especially in karst springs discharging high karst plateaus.

The infiltration and migration of health-hazardous human viruses, such as enteroviruses, were studied in the unsaturated zone of fractured and karstified rock, since these rocks present important aquifers in Slovenia. As a possible model for the behaviour of health-hazardous viruses, salmonella bacteriophage P22H5 (400-800 nm) and fluorescent microspheres (yellow green, 1 μm) were used. Phages have served as useful models for the behaviour of human enteric viruses in water treatment processes because of their similarity to enteric viruses in structure, size, and resistance to inactivation.

In the frame of Association of Tracer Hydrology project a multi-tracer experiment was performed at the research field site (RFS) Sinji Vrh where beside phages and microspheres also conservative tracers were injected into the borehole. RFS presents an underground tunnel in the karst limestone in the western part of Slovenia. A special construction (1.5 m long segments) for collecting water seeping from the ceiling of the research tunnel was developed.

The peak value of phages (3.1 E+9 pfu) appeared in the first sample after the injec-

tion in the segment MP5 (four days after the injection and immediately after the first rain event). The highest phages amount in MP4 appeared after five days with the peak value of 1.1 E+8 pfu. It should be pointed out, that tracers were injected at a high enough concentration in order to get significant concentration in fracture system, but this caused a high concentration in the fast pathways, which are drained by the segments MP4 and MP5. In other sampling points, where water is flowing out of the rock with significantly lower hydraulic conductivity (fracture system), the maximum phages amount was from E+3 to E+4 pfu. The same behaviour was observed in the case of microspheres: for sampling points that are well connected to the large fracture below the injection borehole (MP5 and MP4), the highest amount of microspheres was observed in the first samples taken after the rainfall. For the sampling points that are discharging the microfracture system, microspheres are not observed until several days later. Results of the colloidal tracers were compared with the results of conservative tracer deuterium.

After the injection of tracers, they remain in the microfracture systems of the unsaturated zone and are rinsed by subsequent larger precipitation events even up to several years after the injection. The results from Sinji Vrh have shown that the unsaturated zone in the fractured and karstified rocks plays an important role in pollution retardation and storage. The rinsing of pollutants to deeper parts of the karst aquifer depends on the saturation rate of the soil and the unsaturated zone (precipitation events). The field experiments have shown different flow patterns depending on the fractured rock structure. In the research area some fast conduits (large fractures or faults) exist where water runs faster than in the total conductive part of the rock, as in the case of MP4 and MP5. Tracer delay in microfracture system areas was also observed.