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Transport Parameter Estimation by Tracer Experiment in the Porous Aquifer in Ljubljana, Slovenia

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The gravel sandy aquifer of Ljubljansko polje is the drinking water source for nearly 300.000 inhabitants of Ljubljana city and vicinity. There are two main waterworks: Kleče and Hrastje. The plain area of Ljubljansko polje is a tectonic sink and consists of river sediments that can reach thickness of more than 100 m in the deepest part. The bedrock is the impermeable permocarbonic shaly mudstone and sandstone. The hydraulic conductivity of Ljubljansko polje sediments is very good, from 10^{-2} m/s in the central part to $3.7 \cdot 10^{-3}$m/s on the borders of the plain. The average groundwater level is 13 m under the surface. A numerical groundwater flow model was established for the wider area of the Ljubljansko polje aquifer. A lack of experimental data on solute transport leads to unreliability in the transport model and its predictions of pollution scenarios. The transport model needs to calculate reliable scenarios of pollution dispersion, which can only be achieved, with the application of real transport parameters. These could be provided from tracer experiments in the Ljubljansko polje aquifer.

Human activities in the area of the Hrastje waterworks of Ljubljana threaten groundwater quality. Despite of a great risk, the experiment was performed on the catchment area of the Hrastje waterworks, meanwhile used for drinking water supply. The research proved that the tracers could be used safely on sensitive area and that the researchers are capable and qualified to carry it out with a highest level of security.

Because of a very poor knowledge on solute transport dynamics in the Ljubljansko polje aquifer, a preliminary tracer experiment with potassium bromide was conducted and followed by a multi-tracer experiment with potassium bromide, uranine, microspheres and tinopal CBS-X. Tracer test design considers differences between pollu-

tant spreading in the unsaturated and saturated zones of the aquifer. Therefore, the tracer injection was performed as spreading on the surface (injection to the unsaturated zone), as well as injecting directly into the saturated zone through observation wells.

Only potassium bromide and uranine gave successful results. Both tracers indicate the dominant groundwater velocity of about 20 m/d. The tracer experiment with uranine has shown sharp differentiation in the field and relatively long retardation times. The dispersivity depends on the length of the flow path and varies from 10 m at short distances to 100 m at long distances.

The experiment has shown that the groundwater flow in the central part of the Ljubljansko polje aquifer on the catchment zone of Hrastje waterworks is generally well known, but in the local scale unpredictable and even faster then had ever been expected. The water supply was proved to be extremely vulnerable. Results of the multitracer experiment improved the flow and transport model. All together, this will enable better knowledge of the hydrodynamic conditions in the Ljubljansko polje aquifer, which will yield more effective measures for waterworks protection. Consistent implementation of these measures will improve the groundwater quality in the Hrastje waterworks.