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TCE contamination plume spreading in highly productive aquifer of Ljubljansko polje

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The aquifer of Ljubljansko polje is the most important water resource for water supply of city Ljubljana. Groundwater abstracted from the aquifer represents 90 % of required amount of drinking water. The aquifer is situated below the city Ljubljana and is characterised as unconfined and intergranular aquifer. It consists mainly of coarse sand and gravel that is partly conglomerated. The sediments are up to 100 m thick and the groundwater table is in average about 20 m below the surface. The hydraulic conductivity of the aquifer is high, up to 10^{-2}m/s and in general higher closer to the river Sava. Estimated groundwater velocities in the aquifer range from few m/day up to 20 m/day. There is a good hydraulic connection between the aquifer and the Sava river, which has strong influence on groundwater dynamic. The aquifer is recharged from infiltration of precipitation and river Sava that recharges aquifer mainly in the western part and drains in the eastern part of Ljubljansko polje. Consequently the groundwater flow direction is in general from west to east. Due to the characteristics of the aquifer and its position it is highly vulnerable.

In this paper the activities undertaken after the discovery of TCE (trichloroethylene) contamination of Ljubljansko polje aquifer are described. Very high concentration of TCE (over 500 μg/l) were found in the monitoring well situated in the protection zone of the Hrastje water field that is located in the south-eastern part of Ljubljansko polje. To localize the origin and the distribution of the plume numerous activities were undertaken. Among them are the most important:

- construction of the new observation well in the vicinity of the anticipated location of contamination,

- construction of the new multilevel observation well located between the anticipated location of the contamination and Hrastje water field,
- measurements of TCE concentration in observation wells downstream from the anticipated location of contamination,
- modelling the spreading of the contamination plume from the anticipated location of pollution.

Measurements of TCE concentration in the new observation well in the vicinity of the anticipated location of contamination showed no high concentration of TCE in groundwater. This data confirmed the idea of dissolution of TCE contamination in the saturated zone due to the high velocity and discharge of groundwater at the location of the anticipated location of contamination. Possibility of TCE accumulation on the bottom of the aquifer due to its higher density (1.5 g/ml) is accordingly relatively low.

The forecast of TCE dissolution was confirmed also in the multilevel observation well. Samples taken from filter sections at different depth (20 m – 30 m, 36 m – 50 m, 64 m – 97 m) showed the highest concentrations of TCE in the middle part of the aquifer, followed by the upper and lower part of the aquifer.

Measurements of TCE concentration in 29 wells in different time intervals over 10 months showed spreading of contamination plume in 3.5 km long and 500 m wide area. Detail interpretation of the plume spreading plume is difficult due to the fact that measured concentrations in very closely located wells are often very different. Described facts could be caused by the presence of conglomerate layers and lenses that are often karstified and can cause very complex groundwater flow pattern which is very difficult to interpret.

Modelling of TCE pollution transport with hydrological model MIKE SHE/MIKE 11 confirmed possibility of contamination spreading from the anticipated location of contamination. Simulated and observed velocity of plume spreading are comparable, around 15 m/day. Comparison of model results and measured concentrations in the observation wells closer to the Hrastje water field showed disagreement in the simulated direction of the contaminant plume spreading. Uncertainty in the model is most probably caused by not optimal distribution of the parameters values that were calibrated on the regional scale. Optimal distribution of the model parameters is especially difficult in the areas where conglomerate layers are present. Also the use of simulated and observed piezometric levels differences as main criteria in the calibration and validation of the model does not necessary lead to the optimal simulation of the groundwater flow pattern (direction).