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Modeling of radionuclide migration in fractured rock aquifer and assessment of groundwater contamination risk

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The modeling of radionuclide migration from the low-level and medium-level radioactive wastes storage and the assessment of groundwater contamination risk are considered. Hypothetical emergency situation was analyzed when radionuclides enter to the groundwater through microcracks in radioactive wastes storage. The main object of groundwater contamination risk was the aquifer in fractured intrusive rocks. The considerable uncertainty in forecasting of groundwater contamination and risk assessment could be connected with the fault zone impact on the radionuclide migration.

The features of hydrogeological conditions in the study area, which must be taken into account at geofiltration schematization, were as follows: 1. the existence of faults in the surrounding areas where increased permeability coefficients were marked during the testing for underground waters inflow; 2. the aquifer location in the bend of the river and formation a radial flow with spreading; 3. shallow groundwater levels, combined with low flow velocities, and accordingly a strong dependence the depth of groundwater level on the seasons and the quantity of precipitation; 4. the existence of low permeable alluvial deposits in the river bed. For numerical three-dimensional groundwater flow modeling Processing Modflow Pro, v. 7.0.26 was used. Simulation of contaminant transport was performed using MODFLOW/MT3DMS codes.

Modeling of strontium-90 migration in groundwater without taking into account sorption showed that on the model without the fault zone the contamination front will go to the north-east and will reach the water intake well near the river in 30 years. When taking into account in the model the fault zone the main direction of contaminant migration will be to the north-west, and the contamination will reach the water intake well in 9 years. These results showed the importance the tectonic analysis and filtration testing of near-fault and fracture zones. The fault zone could not be characterized using the conducted testing for groundwater inflow, represented by single pumping. Assuming that the average value of permeability coefficients in the fault were normally distributed, dispersion flow parameters were adopted based on the object-analog, and mathematical expectation was accepted according to the results of testing works. The permeability coefficients of the fault zone for different quantiles were calculated on the basis of these characteristics. According to numerical calculations the probability of water well captured zone contamination equal to the level of intervention through 13 years was about 90%.

Using the geofiltration model the calculations of groundwater contamination by strontium-90 with considering sorption processes were carried out. It was assumed that: 1) strontium-90 in the groundwater was in the form of uncomplexed ion Sr^{2+}, 2), adsorption isotherm was described by Henry equation, the main parameter - the distribution coefficient (K_d), 3) the K_d value of strontium-90 was

0.086 l / kg in accordance with the calculated values obtained the others researches when studying the strontium-90 migration in fractured rocks in this area. The technique of accounting the sorption capacity of water-bearing rocks using effective porosity was performed. The solutions obtained on the distribution of concentrations of strontium-90, virtually repeated the estimates obtained without sorption. Difference was the lower rate of contamination halo changes due to a high value of effective porosity strontium with sorption. In this case the contamination equal to the level of intervention will occur in water well captured zone with the probability equal 90% in 20 years. Damage caused by contamination of drinking water to population was estimated at the value of treatment facilities that allowed one to evaluate economic cost of risk.