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IMPLEMETATION OF COMPUTER CODES FOR PERFORMANCE ASSESSMENT OF THE REPUBLIC REPOSITORY OF LLW/ILW MOCHOVCE

V. Hanušík, I. Kopčáni
VÚJE Trnava Inc., - engineering, design and research company
Department of Accident Management and Risk Assessment
Okruzna 5, 918 64 Trnava, Slovak Republic
hanusik@vuje.sk, kopcani@vuje.sk

M. Gedeon
Geological Survey of Slovak Republic
Dept. of Hydrogeology and Geothermal Energy
Mlynska dolina 1, 817 04 Bratislava, Slovak Republic
gedeon@gssr.sk

ABSTRACT

This paper describes selection and adaptation of computer codes required to assess the effects of radionuclide release from Mochovce Radioactive Waste Disposal Facility. The paper also demonstrates how these codes can be integrated into performance assessment methodology. The considered codes include DUST-MS for source term release, MODFLOW for ground-water flow and BS for transport through biosphere and dose assessment.

1 INTRODUCTION

Performance assessment for Mochovce Radioactive Waste Disposal Facility in Slovakia started in 1993 with Pre-Operational Safety Report prepared by experts from the Belgian organization SCK/CEN [1]. Calculation of dose rates was carried out for normal evolution scenario and human intrusion scenario in the safety assessment. For normal evolution scenario a stochastic analysis was made to illustrate the implication of uncertainties in the values of individual parameters. Only six nuclides were considered, namely ^{14}C, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs and ^{239}Pu. Nuclides with half-lives not longer than that of tritium have been neglected because they will have decayed to an insignificant level after the institutional control.

The normal evolution scenario analysis consists of three components: near field (repository) analysis, far field (aquifer) analysis and biosphere (lake) analysis. A number of simplifications of physical processes and features of the repository and site were made for the modeling so that models based on relatively simple mathematical formulae could be used. A

conservative approach was adopted for the simplifications of the models. The calculations were made by means of computer codes MODEMO, NUCDSLB and LAKE [1].

The SCK/CEN assessment codes were later modified for expanded list of scenarios and radionuclides. The deterministic assessment for the new version of the safety report was prepared during 1998 by VUJE Trnava Inc. [2].

In this work we describe computer codes that were implemented in the framework of the performance assessment iterative process in the Mochovce disposal facility during recent years.   The purpose of the implementation is to offer more complicated models and fully documented data set, which greatly increase the flexibility of the approaches to handling a variety of processes occurring in the repository, geosphere and biosphere after repository closure. Another aim is to verify the results of the performance assessment, which were done for the safety report.

2   MOCHOVCE DISPOSAL FACILITY

The low- and intermediate- level waste arising from the operation of the Bohunice and Mochovce NPPs as well as wastes from the A-1 NPP and institutional wastes are being disposed of in the near surface disposal facility at Mochovce. The main waste streams are evaporator concentrates, ion exchange resins and solid wastes of various kinds. All of the wastes after treatment are packed in cubical fibre-concrete containers and backfilled with concrete. Acceptable waste packages can be filled by 200 l drums containing solid or solidified waste, or filled by compacted pellets, or pieces of metal. Homogenous direct filling of containers by cemented waste is the next option.

The Mochovce facility consists of 80 concrete vaults arranged in two double-rows. The reinforced concrete walls are 0.6 m thick. Compacted clay sealing surrounds the individual double-row. The thickness of clay bathtub is 1 m on the bottom and 3.5 m on the side. A high quality 2 m thick clay-layer will be placed as the main barrier of the final cover against rainwater infiltration into the repository after closure. There are two drainage systems beneath the level of dilation units. The first one collects any water in the gravel layer below the disposal vaults. The second one collects water from outside the clay sealing, which surrounds dilation units.

The facility is located in the upper part of valley, approximately in 1.5 km distance from NPP Mochovce. Total repository area is 11.2 hectares. Hydrogeological conditions of the site are very complex. Permeable and impermeable layers interchange in sediments of Sarmat age. There is often a smooth transition between these layers in the vertical direction as well as sideward. The loam thickness was determined between several decimetres and 4-6 m and up to 10 m in the repository southern part. On the valley axis, where repository is situated, a fine and even silt sand layer with considerable area and small thickness changes was found under the Quarternary soils. This layer of permeable sands was identified as the main H aquifer. Another 2-3 aquifers were found in the repository southern part. The groundwater flow velocity is the highest in the aquifer H and rainfall water infiltration controls the groundwater movement here. In the repository northern part the H aquifer is not saturated permanently. Groundwater is passing from the H aquifer to the surface stream south wards to the repository side.

3   METHODOLOGY

3.1   Code selection criteria

The selection process was accomplished with criteria, which follow directly for any code and with criteria describing attributes of computer codes that may not be presently attainable:

- ☑ the code preferably has been extensively used or accepted by the user community,
- ☑ the selected code should be verified to demonstrate correctness of the source code,
- ☑ the selected code should be documented in a technical report which contains description of model theory, assumptions, computation techniques, algorithms and example calculations,
- ☑ the code should allow site- and facility- specific applications, i.e. should be capable to simulate the hydrologic, geologic and geochemical environment of the Mochovce site mentioned above, as well as specific design features of the facility over time,
- ☑ the degree of complexity of the computer code should be consistent with the quality and quantity of data and objectives of calculation,
- ☑ codes should run on personal computers.

The code selection criteria were used to select DUST-MS [3] for near field, MODFLOW and MT3DMS [4] for far field and BS [2] for biosphere analysis. A flow diagram of how the codes are used together in the performance assessment of the Mochovce facility is shown in Figure 1.
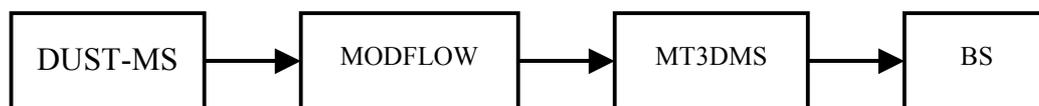

Figure 1   Flow diagram of computer codes

3.2   Source term

Waste form releases and radionuclide transport through engineered barriers to the underlying aquifer are evaluated with the DUST-MS code. The conceptual model considers movement of water and radionuclides through the disposal facility in 1-dimension. The 1-dimensional model represents a transverse section through the disposal facility. The top of the simulation domain is the clay layer and prefabricated concrete. Under prefabricated concrete the three layers of cubical fibre-concrete containers with waste are disposed. The lower part of the domain is concrete floor of the vaults, gravel and clay layer. The vertical dimension of the domain is 10 meters and area of the disposal facility is $7,656.10^3$ m^2. The finite element approach discretizes the domain to be modeled into a 93 small elements for which the flow and transport equations are solved numerically. In order to solve the flow equations, it was necessary to specify boundary conditions and properties of materials present in the simulation domain.

3.3   Saturated zone codes

Results of the DUST-MS simulations provide radionuclide flux to the aquifer H. Visual MODFLOW is used as a modelling environment to build and calibrate two-dimensional

model of ground water flow beneath disposal site to the nearest stream. The model was built according to previous site investigations and measurements. The first step was to develop a conceptual model that means to identify model boundaries (Figure 2) and fluxes into and out of the system. We have identified that the major and only recharge comes from precipitation lowered by estimation of actual evapotranspiration. The modelled area discharges through drains, that we used for simulating both surface drains along the repository and stream at the south of modelled domain. The 3-rd type of boundary condition (general head boundary) was used for simulation of groundwater runoff in quaternary loams (Figure 2).
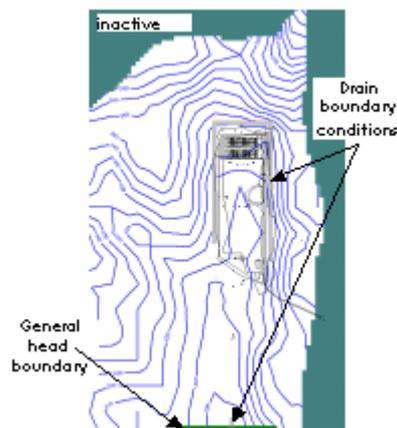

Figure 2   The repository location with altitude isolines and location of boundary conditions
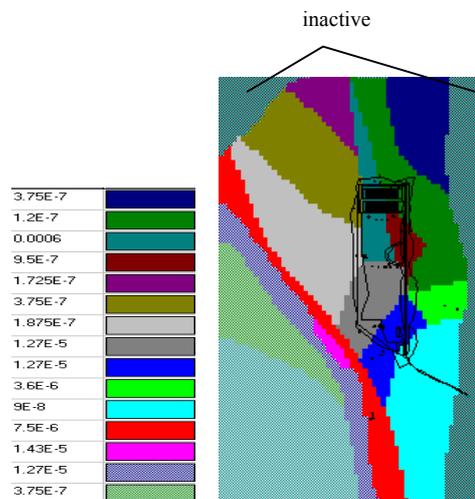

Figure 3   Final distribution of hydraulic conductivities [m/s]

The second step was to use available pumping test data for realistic estimates of hydraulic parameters. The saturated zone groundwater flow model is assumed to be heterogeneous with respect to hydraulic conductivity and these values have been subject of model calibration. The final distribution of hydraulic conductivity is shown in Figure 3. Next parameters that we had to input to the model were effective rainfall, effective porosity, drains conductance and longitudinal dispersivity. Most of these parameters were obtained from the previous investigations and were changed slightly in the calibration process particularly

because of unsaturated zone influence. The next step was the model calibration. Calibration of the model involved comparison of simulated hydraulic head to measured head data from year 1995 to 1999 (Figure 4). For surface water discharges the measurements from 1991 were used as informative figures. Comparison of modelled and computed hydraulic heads indicates that the model reproduces the head gradients in the respective aquifer fairly, and thus should accurately simulate the flow directions and rates in these units.
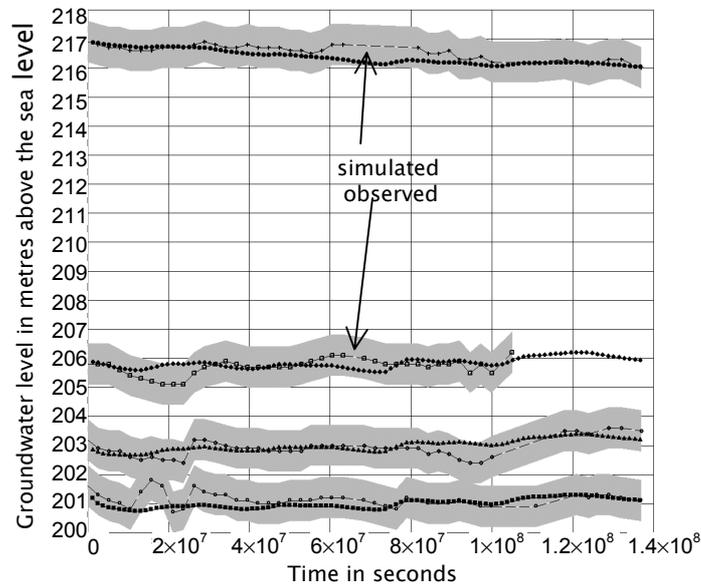

Figure 4   Comparison of simulated and observed groundwater levels

        After calibration and verification process we changed the model in a way that it simulated uniform groundwater flow through the time by inserting average climatic conditions for whole simulations. Using this approach we were able to simulate long-term processes in "quasi" steady state conditions.

        The results of the MODFLOW code simulation are shown in Figure 5. Figure 5 illustrates the distribution of the head equipotential contours with pathlines. The pathlines have direction arrows on them indicating the groundwater flow direction.

        The hydrologic model described above is used to generate a transient flow field for Mochovce site. This flow field is utilized in the transport model MT3DMS to predict movement of radionuclides from their area of contact with the water table through the groundwater to the points of interest. Decay and retardation are accounted for in calculating a groundwater concentration.
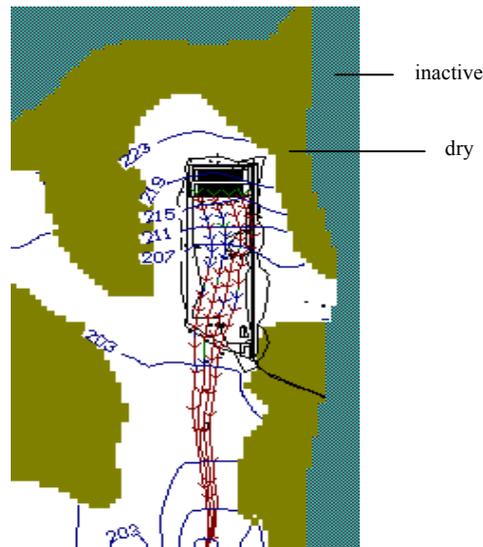
Figure 5   **Groundwater level equipotentials and pathlines**

3.4   The biosphere model

Biosphere transfer model BS considers various interactions between the lake and plants, animals, and humans through the food chain. The exposure pathways to be taken into account are graphically depicted in Figure 6.

Since discharges of radionuclides from the repository into the biosphere are taking place over much longer times than needed by the radionuclides to reach steady-state conditions in the biosphere, only equilibrium concentrations are considered.
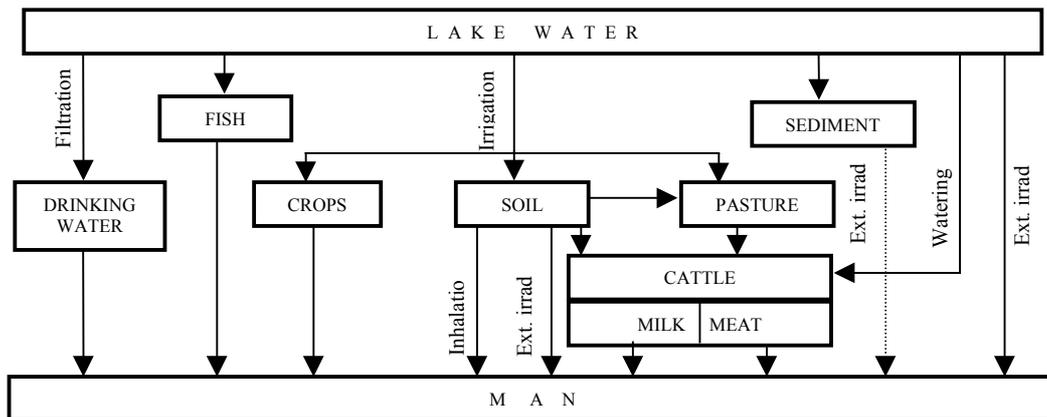

Figure 6   **Exposure pathways of man from releases into the lake**

3.5   Example calculation for normal scenario

In this section example calculation is given which illustrates the use of the implemented codes for normal scenario and [129]I. The example considers failure time of all containers and concrete barrier after 300 years. The clay barriers are efficient so rate of water infiltration into

disposal facility is low-about 10^{-8} cm/s. The diffusion release model from waste form is used because cemented waste are supposed.

The results of calculations of the ^{129}I fluxes which leached from the disposal facility and entered into the aquifer are given in Figure 7. Using peak fluxes the groundwater peak concentrations were calculated. In Figure 8 the concentration plume is shown.
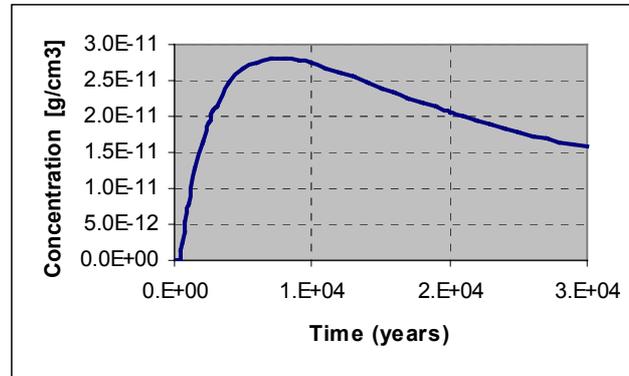

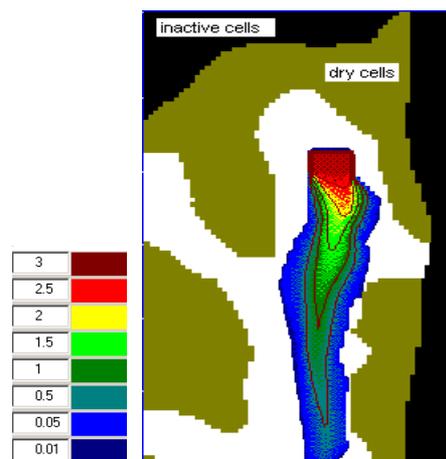**Figure 7   DUST-MS estimated I-129 release to the aquifer**

Figure 8 ^{129}I plume groundwater concentration .10^{-11} [g/cm^3]

Computed concentrations in the ground water at the place where ground water seeps into the stream are used by simple surface water transfer model for assessment of concentrations in the stream and lake. Calculating human dose from the exposure pathways is the last part of performance assessment modelling.

4   CONCLUSION

The performance assessment methodology described upper have interconnected three computer codes into computer system DUSTMS-MODFLOW-BS sequentially to perform source term, ground water flow, transport through biosphere and dose assessment. The tests show that this system can be useful tool to evaluate normal and alternative scenarios for LLW/ILW repository in Mochovce.

5   ACKNOWLEDGMENTS

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