JAN MARIVOET

WASTE DISPOSAL: LONG-TERM PERFORMANCE STUDIES FOR RADIOACTIVE WASTE DISPOSAL AND HYDROGEOLOGICAL MODELLING

Background

Geological disposal into clay formations is considered a realistic solution for the final disposal of high-level and long-lived radioactive waste. For low-level radioactive waste the Belgian waste management programme examines the possibilities to dispose of the waste in shallow land burial facilities or in clay formations. Performance assessment studies evaluate the long-term safety of the designed geological or shallow disposal systems by identifying possible scenarios that might lead to the exposure of man to radioactivity or toxic substances, by analysing the consequences of the most relevant scenarios, and finally by comparing the estimated concentrations, doses and risk with appropriate safety criteria. Since aquifers are essential components of deep and shallow repository systems for the disposal of radioactive waste, accurate hydrogeological modelling is a critical element for assessing the long-term safety of a repository.

Objectives

- to develop a methodology and associated tools for assessing the long-term safety of geological disposal of all types of radioactive waste in clay layers and of the shallow-land burial of low-level waste;
- to assess the performance and to identify the most influential elements of integrated repository systems for the disposal of radioactive waste;
- to collect geological, piezometric and hydraulic data required for studying the hydrogeological system in north-eastern Belgium;
- to develop a regional aquifer model for north-eastern Belgium and to apply it in the performance assessments for the Mol site;
- to test, verify and improve computer codes used in the performance assessment calculations of waste disposal concepts and contaminated sites; the computer codes simulate water flow and transport of radionuclides in engineered barriers, aquifers and contaminated sites.

Programme

Our performance assessments are elaborated in the framework of the following contracts and research agreements with NIRAS/ONDRAF and the EC:

- a multi-year research programme for elaborating the performance assessment of the potential geological disposal of radioactive waste in the Boom Clay layer at the Mol site;
- the SPA (Spent Fuel Assessment) project: a performance assessment of the direct disposal of spent fuel at the Mol site;
- complementary assessments of concepts for shallow-land or deep burial of low-level wastes in Belgium;
- performance assessments of a designed repository in hard rock for the disposal of low-level and medium-level waste in the Murmansk area (NW Russia) and at Üveghuta (Hungary).

The hydrogeological studies sponsored by NIRAS/ONDRAF are piezometric measurements in the boreholes of SCK•CEN's regional hydrogeological network and the elaboration of a data acquisition campaign aiming at the collection of data needed for the further development of the multi-layer regional aquifer model of north-eastern Belgium. The data-acquisition campaign is complemented by an internal R&D project in which the spatial variability of the hydraulic conductivity of the Boom Clay is investigated. In the PHYMOL (palaeohydrogeology of the Mol site) project, sponsored by the EC, we look for indications in geochemical and isotope distributions measured in groundwater samples on the groundwater flow in the Mol region during a glaciation.

Achievements

A detailed performance assessment for the Mol site is elaborated. The first step of the assessment consisted of a systematic scenario study. All phenomena that are about certain to occur are treated within the normal evolution scenario. Eight altered evolution scenarios were identified. In 1999 we updated the consequence analyses of the disposal of vitrified high-level waste and of hulls conditioned in a concrete matrix, in the case of the normal evolution scenario. The use of data collection forms ensures the traceability between the parameter values used in the assessments and the large number of- available research reports.

The transport of radionuclides released from the host clay layer through the Neogene aquifer into the biosphere is simulated with the MT3D code, which is integrated in the GMS (Groundwater Modelling System) package. Radionuclide concentrations in the ground water and fluxes discharged into the rivers have been calculated. The calculations show that about 95 % of the radionuclides released from the host clay layer will reach the rivers Witte and Kleine Nete. The maximum dose that might result after a

few tens of thousands of years from the use of water from these rivers as drinking and irrigation water is many orders of magnitude lower than the dose due background radiation.

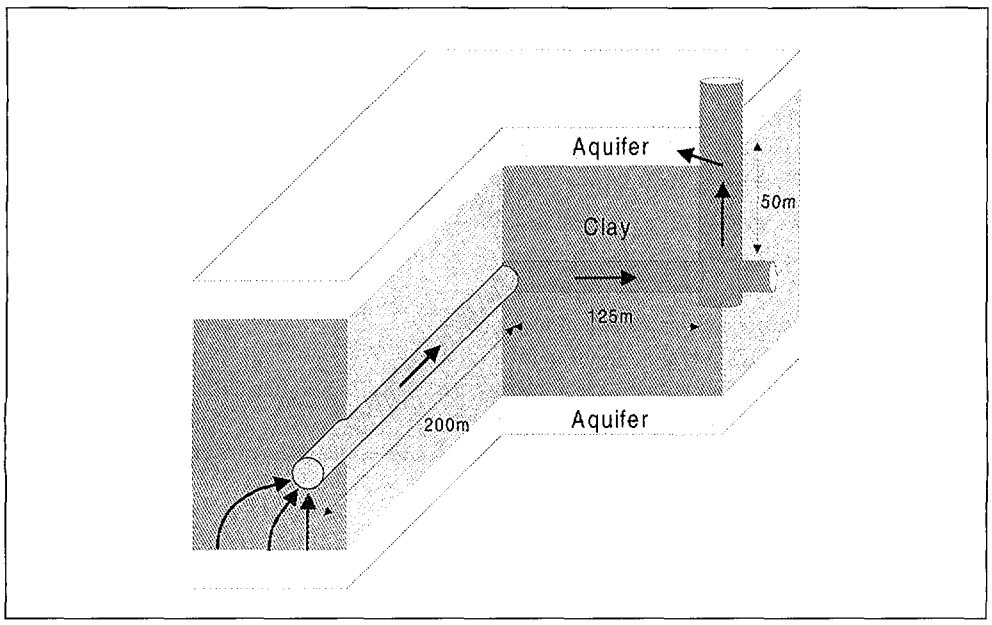
For the SPA project we performed deterministic consequence analysis for the following altered evolution scenarios: poor sealing of the galleries and access shaft, exploitation (i.e. deep well), and exploration (i.e. geological examination of a core containing remnants of the disposed spent fuel). The repository configuration considered in the analysis of the poor sealing scenario is given in Fig. 1. The consequences calculated for the poor sealing scenario are comparable with those obtained for the normal evolution scenario because only very small amounts of water penetrate into the galleries as a consequence of the very low hydraulic conductivity of the Boom Clay. Stochastic calculations were carried out for the case of the normal evolution scenario to perform uncertainty and sensitivity analyses. The latter show that the effective thickness of the Boom Clay barrier and the diffusion parameters of the main radionuclides are the most influential parameters.

In the framework of the safety studies dealing with the disposal of low-level waste in Belgium, we prepared documents that describe all relevant data required to perform safety-assessment studies. The data includes parameters used to characterise the waste forms and to simulate water flow and solute transport in engineered barriers and aquifers. In addition to the definition of each parameter, we also provide a list of common procedures used to determine the parameters.

SCK•CEN also contributed to an EC-TACIS project on the improvement of the safety of the radioactive waste management in the North West of Russia (Kola peninsula). The primary role of SCK•CEN is to transfer technology to the Russian partners (i.e. performance assessment methodologies including numerical models, parameter databases, etc.) and to assist them in performing safety studies for potential repositories in hard rock.

In the framework of the management of L/ILW in Hungary technical support was provided in the selection of a disposal option and candidate disposal site. A PHARE-sponsored preliminary safety assessment study was done for the subsurface disposal site "Üveghuta". The study included site characterisation and evaluation, consequence analysis, and training of local staff in safety assessment methodology.

The hydraulic conductivity of clay cores taken from boreholes at Zoersel, Mol and Weelde are measured in our laboratory to study the variation of the hydraulic conductivity of the Boom Clay with depth and to look for correlation with the lithostratigraphy of the clay layer. In the framework of an internal R&D project we collected clay cores in clay pits, during the excavation of the second shaft on the SCK•CEN site and at Doel. On these cores we measured the hydraulic conductivity. At Doel also in situ measurements of the hydraulic conductivity of the Boom Clay were carried out. The values obtained from the in situ experiments correspond well with



Configuration considered for the analysis of the poor sealing scenario

those obtained from the laboratory measurements. The results of these measurements together with those obtained from the measurements on clay cores taken during the data-acquisition campaign will allow us to study the spatial variability of the hydraulic conductivity of the Boom Clay on a regional scale.

Within the PHYMOL project we developed a methodology applicable in performance assessments of geological disposal of radioactive waste in clay formations for treating the variability of the hydrogeological system over long time scales as a consequence of the expected evolution of the climate. Especially during glaciations drastic changes in the groundwater flow patterns are expected to occur. The analysis of the measured concentrations of stable and radioactive isotopes and dissolved noble gases strongly indicates that the infiltration is drastically reduced during glacial periods. An important consequence for performance assessment is that the dilution of radionuclides released from the host clay layer into the aquifers surrounding the host layer can be lower and that higher radionuclide concentrations can occur than estimated on the basis of present flow conditions.

Perspectives

The performance assessments of the geological disposal of reprocessing waste in the Boom Clay layer at the Mol site will continue in 2000. Consequence analyses will be made for the most relevant medium-level waste types. We will make calculations of the temperature distribution in the host clay layer and of the resulting thermal convection in the overlying aquifer. The next phase of the performance assessments for the Mol site starts with the elaboration of a comprehensive catalogue of features, events and processes that have the potential to influence the behaviour of the repository system.

Starting from 2000 we will participate in three new projects within the 5th Framework Programme of the EC:

- the BENIPA project focuses on the role of bentonite barriers in the performance of deep repositories for the disposal of spent fuel and vitrified high –level waste in granite and clay formations;
- the SPIN project evaluates the applicability of various safety and performance indicators to demonstrate the safety of a repository system;
- the BORIS project evaluates the applicability of the Siberian sites at Tomsk and Krasnoyarsk, where liquid radioactive waste has been injected into aquifer layers, for testing and validating geochemical and transport codes used in performance assessments.

In the framework of the programme for the disposal of low-level radioactive waste we will start a performance assessment of a fully engineered facility at the candidate sites at Dessel and Mol.

During the next years we expect a continuation of our collaborations with East-European countries, especially with Slovenia and Slovakia for their performance assessments of designed facilities for the disposal of low-level radioactive waste.

We will continue the collection of hydrogeological data and develop an updated version of the regional hydrogeological modelling by taking into account the results obtained from the 1996-99 data acquisition campaign.

We will also apply our experience gained in site characterisation and in flow and transport modelling in aquifer systems and variably saturated soils to the SCK•CEN programme on environmental restoration and site remediation.