터널과 지하공간, 한국암반공학회
Vol. 10, 2000, pp. 553~558

TUNNEL & UNDERGROUND Vol. 10, 2000, pp. 553-558
J. of Korean Society for Rock Mech.

MASCOT-K를 이용한 가상 방사성폐기물 처분장에서의 종합성능 평가

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Radiological Safety Assessment of a HLW Repository in Korea using MASCOT-K

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ABSTRACT Since 1997, KAERI has conducted the fundamental R&D on the permanent disposal of potential HLW repository in Korea. The first ten year project is divided into three short-term phase studies. The first phase study which shall be finished in March of 2000, has the prime target to develop the disposal concept of HLW. Throughout this study the preliminary and generic disposal repository system has been introduced. The potential repository is proposed to be emplaced into crystalline rocks which is the most common rock types in Korea. The proposed depth of the repository is between 300 to 700 meter. The numerical code, MASCOT-K was developed to assess the long term safety of the proposed repository concept. Based on this conceptual design preliminary safety assessment was performed. Results show that for the given disposal system the potential radioactive release is well below the regulatory limit.

Key words : Total system performance assessment, MASCOT-K, Total risk, Scenario and FEP

초 록 : 1997년부터 시작된 국가원자력중장기 연구사업의 일환으로 국내에서 발생하는 고준위 방사성폐기물을 영구 처분하는데 따른 장기 방사선적 안전성평가 연구가 수행되었다. 2000년 3월까지 수행된 제 1 단계 안전성 평가 연구에서는 이 연구와 병행하여 추진된 처분장 개념 정립 연구에서 도출된 기준 처분 개념을 근간으로 지하 약 300-700 미터 단열 암반에 건설될 처분장을 대상으로 안전성 평가를 수행하였다. 이러한 안전성 평가를 위해 우선 MASCOT-K 코드가 개발되었다. MASCOT-K는 다양한 지하매질을 통과하는 핵종 이동을 모사하는 프로그램으로 최종적으로 처분장 주변 주민들이 년간 혹은 누적 피폭 선량을 예측한다. 가상적인 지질 자료들을 근간으로 처분 개념에 대한 평가 결과 예상 유출량은 현재 국내 기술 기준에서 규정한 제한치보다 낮은 것으로 판명되었다.

핵심어 : 종합성능평가, MASCOT-K, 종합리스크, 시나리오와 사건 수목도

1. Introduction

KAERI(Korea Atomic Energy Research Institute) has developed the needed technologies on performance assessment for permanent disposal of High Level radioactive Waste(HLW). The starting point was to identify the characteristics of the potential repository in the Republic of Korea. Followings are turned out to be important issues to construct the conceptual design of the potential repository and consequent performance assessment technologies in Korea[1].

1) It is mostly feasible to locate the repository in the crystalline rock such as granite.
2) The initially proposed depth of the repository shall be between 300 and 700 meters from the surface based on the researches in Sweden and Canada.
3) Based on the thermo mechanical analysis with temperature constraint in buffer where the maximum temperature cannot exceed 100 degree, the tunnel and deposition borehole spacings were identified[2].
4) The repository and surrounding rock shall be fully saturated after a short time span from the closure of the repository operation.
5) The major flow pathways shall be through the fracture network in crystalline rocks.

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접수일 : 2000년 4월 7일
심사 완료일 : 2000년 6월 12일

6) Even though there is no regulations on the permanent disposal of HLW in the republic of Korea yet, some major statements in the regulations on the LILW(Low and Intermediate Level radioactive Waste) disposal can be applicable for the initial phase studies. The important statements are

(1) The performance assessment shall be based on the concept of the probabilistic safety assessment.

(2) The annual risk target is 10^{-6}/yr and the annual individual dose target is 2 mRem/yr[3].

KAERI has developed the concept of deep geological system suitable for crystalline rock in Korea. In this development the spent fuel arising from the reactors to be in operation by 2015 was considered. The expert opinion indicated that among seven disposal options the vertical emplacement separating the CANDU SF(Spent Fuel) with PWR one is the most feasible one. Detailed thermal analysis showed that the optimum distances between deposition holes and tunnels are eight and forty meters respectively. Figure 1 illustrates the potential underground repository excavated by controlled drill and blast[4].

2. Current PA R&D Status

The concept of the HLW repository is currently developed in KAERI. Through the thermo-mechanical assessment the optimum distances between tunnels and deposition holes were estimated. By applying these data the preliminary repository concept is currently under refinement through the R&D cooperation between KAERI and Sandia National Laboratory. Then the next R&D targets are

1) To find out whether the proposed system shall meet the regulatory guidelines such as risk and dose targets

2) To give the feedback to refine the repository concept, and then

3) To give the fundamentals for the regulators to build up the adequate regulatory framework for the HLW disposal in Korea.

These iterative procedures shall be continued until the final disposal concept and needed technologies shall be developed in Korea.

To meet the target, KAERI has focused on the R&D(Research and Development) over PA(Performance Assessment) since 1997 and the second phase study shall be continued until March 2003. In this first phase study, following R&D items were given to KAERI for the overall safety assessment by the national government.

1) To develop the FEP(Features, Events, and Processes) list reflecting the social and geohydrological

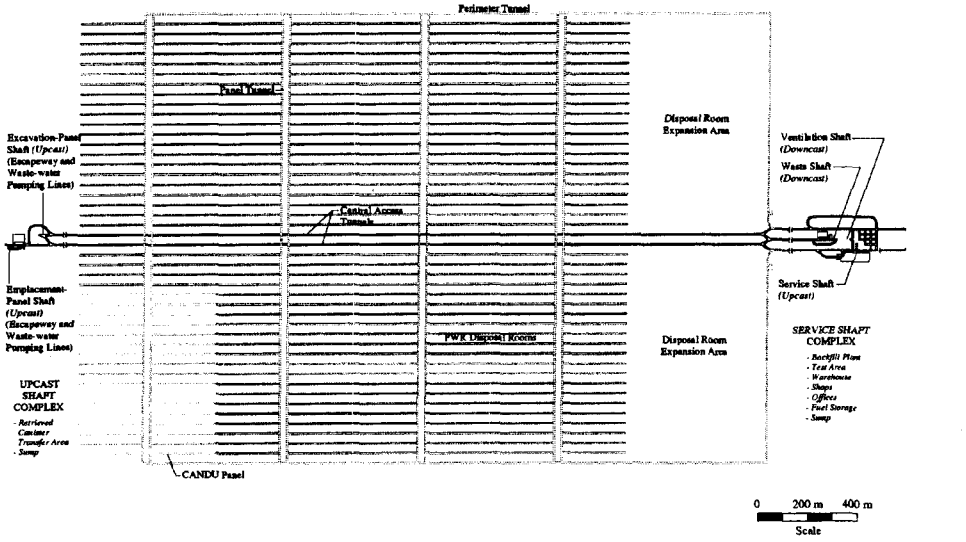

Fig. 1. Preliminary Repository Concept in Korea Developed by KAERI.

conditions in Korea.

2) To develop the modeling technologies for the performance assessment.
3) To gather the generic data sets applicable to the Korean conditions.
4) To assess the safety of the conceptual repository.
5) And to identify the needed R&D for the next phase R&D between 2000 and 2002.

A. FEP/Scenario Development R&D

To assess the safety of the proposed repository, the first job is to find out the most feasible scenarios for the radionuclides once released from the repository and then reached the biosphere after passing through various geological as well as man-made barriers. The scenario is composed of many components called FEP's. KAERI started to develop her own FEP list since 1997. The feasible FEP database set was developed[5] by studying the related OECD/NEA database. At this stage the applicable FEP's were identified as partly shown in Table 1 and these FEP's shall be reviewed by domestic experts in the 2nd phase study. However through the peer review by the internal experts in KAERI, the relevant FEP's, the reference scenario has been developed. For the reference scenario, the once released radionuclides from failed canisters in the solute phase are assumed to migrate through the natural barrier system, fractured rock system, by way of relatively impermeable buffer layer and eventually to enter potential biosphere compartments such as well. Then residents and cattle intake the water from the well and eventually are exposed to the radiation.

Table 1. The KAERI Features Events and Process List.

Characteristics of Waste Form	Inventory
	Long-term physical stability
	Heterogeneity of waste form
	Radionuclide decay and growth
•Waste Form: Radiological effect	Radiolysis
	Radiation damage of matrix
	Gas generation
•Waste Form : TM Effect	Decay heat
	Thermal cracking
	Material property change
•Degradation /Corrosion/Dissolution	Source terms
	Waste leaching

B. Input Data for PA Model Development

In predicting the radionuclide transport in geologic medium, the following estimations are to be studied :

1) Assessment of the radionuclide inventories of the future: Since Korea operates CANDU and PWR reactors with many different burn-up options, it is essential to correctly predict the radionuclide arising.
2) Assessment of groundwater flow paths : The realistic groundwater pathways and associated path lengths from the repository to the biosphere is studied using the groundwater flow code CONNECTFLOW[6]. Even though the crystalline rocks contain fracture network, in this preliminary study the equivalent porous medium approach is adopted. In the near future, the fracture network modeling with probabilistic safety assessment using either response surface method[7] and adjoint sensitivity analyses[8] shall be pursued. In parallel the 1-dimensional thermo-hydraulic-mechanical (THM) assessment was performed and the results[9] showed that the THM effect did not alter the groundwater flow pathways and traveling time significantly.
3) Assessment of geo-chemical data : The retardation coefficients and solubility limits are predicted by thermodynamic codes such as EQ3/6 for the reference groundwater composition.
4) Prediction on the dose conversion factors : Also the dose conversion factors for the two biosphere are assessed from the overseas database using the biosphere assessment code.

Relevant data sets were reviewed by the literature survey. At this moment reference data were gathered from the overseas project such as Äspö in Sweden. These data are used as the input for the calculations. Figure 2 shows the part of the KAERI data sets.

C. Development of PA Code MASCOT-K and Unit Models

The prime code to assess the radiological safety using the above databases is the MASCOT-K[10]. The MASCOT code was developed originally by the AEAT in the United Kingdom. To analyze the radiological safety of deep and shallow land disposal systems for low- and intermediate-level wastes. KAERI has

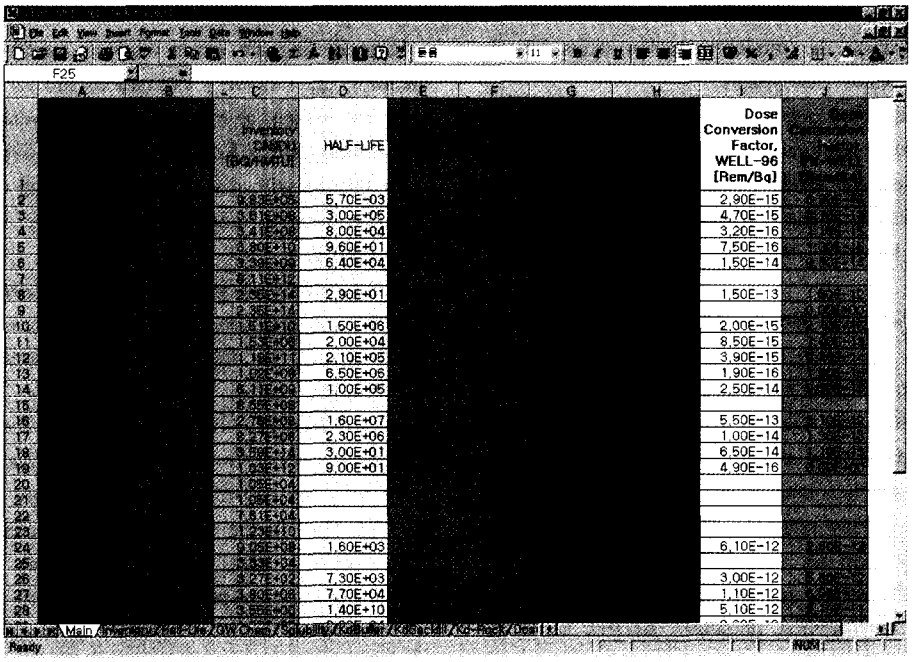

Fig. 2. KAERI Input Data Set for Performance Assessment.

upgraded this code for the HLW study. The prime extension is focused on the dissolution mechanisms such as congruent release with decay chain and advective flow, gap release with buffer, and release of radionuclides in the form of colloids.

In addition to TSPA(Total System Performance Assessment) code development study, unit model development on specific events is underway. To understand the coupling effects of thermo-hydraulic-mechanical(THM) processes on the stability and safety of the repository is studied. The near term R&D target in this study is to find out whether the decay heats from the embedded spent fuels create new significant groundwater flow channels in the vicinity of the deposition holes. The appropriate constitutive laws to govern couplings are reviewed and the evaluations on thermal effects were done[11].

During the fiscal year of 1999, the preliminary TSPA was pursued for the idealized repository in the coastal area as shown in Figure 3. The geologic medium at the location of the disposal tunnels shall be appointed as crystalline rocks such as granite or gneiss.

Then the potential pathways as well as traveling times for groundwater from various locations of the repository shall be calculated by CONNECTFLOW code considering the effect of salt water intrusion which shall influence the pressure profiles in the coastal area. In addition, the retardation coefficients and solubility limits as well as dose conversion factors of major radionuclides were evaluated from the literature survey. In 1999, the preliminary reference data were scrutinized for safety study. Preliminary results in Figure 4 for the

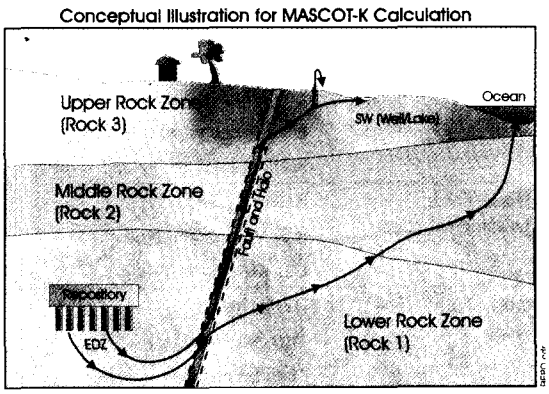

Fig. 3. Potential Radionuclide Pathway Considered in This Study.

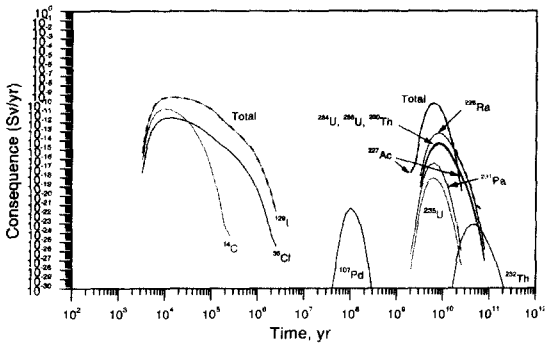

Fig. 4. Potential Consequences from the KAERI Well Scenario.

well scenario where the total consequence stems from the drinking of well water, show that the potential risk from the HLW repository in Korea is lower than the annual risk target.

3. Conclusions

The TSPA approaches are developed in KAERI to assure the radiological safety of the disposal concept. To accomplish this mission, the systematic development of the FEP list was pursued. Based on the KAERI FEP list, reference and alternative scenarios shall be developed. In parallel, the total system performance assessment code for the probabilistic safety assessment has been developed. The features added in the code are focused on the near field radionuclide transport. By applying the TSPA code, preliminary safety assessment was performed using the generic data set. Results showed that the current disposal concept proposed by KAERI satisfies the safety criteria for the given well scenario.

In the future the quality assurance procedures for the data as well as the calculation procedures shall be refined. Based on the QA controlled procedures, field and laboratory data needed for the PA shall be developed. Also the computational tools for the probabilistic assessment of groundwater flow pathways as well as traveling time shall be developed. Then the total system performance assessment on the proposed concept of the potential repository shall be performed and based on the results more reliable repository concept shall be developed.

Remarks

This study has been financially supported by the Long-term National Nuclear R&D Fund Arranged by Ministry of Science and Technology in the Republic of Korea.

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