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Technical Standards and Safety Review of the Low and Intermediate Level Radioactive Waste Disposal Facility

중·저준위 방사성폐기물 처분시설에 대한 기술기준 및 안전심사

Jae Hak Cheong[1], Kwan Hee Lee, Yun Keun Lee, Chan Woo Jeong and Byung Hwan Rho
Korea Institute of Nuclear Safety, 34 Gwahak-ro, Yusong-gu, Daejeon

정재학[1], 이관희, 이윤근, 정찬우, 노병환
한국원자력안전기술원, 대전광역시 유성구 과학로 34

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Abstract

On July 31, 2008, the Government issued the construction and operation permit for the first low and intermediate level radioactive waste disposal facility in the Republic of Korea. In this paper, the fundamental regulatory framework, regulatory requirements and technical standards of the disposal facility are introduced, and the phased review process adopted for evaluation of the safety of the facility is briefly described. The Atomic Energy Act sets forth a stepwise regulatory framework for the whole life-cycle of the disposal facility such as siting, design, construction, operation, closure and institutional control. More detailed regulatory requirements and technical standards are stipulated in the subsequent regulations of the Atomic Energy Act and a series of Notices issued by the Ministry of Eduction, Science and Technology. The Korea Institute of Nuclear Safety, as entrusted by the Ministry under the Atomic Energy Act, conducted safety review on the disposal facility, and evaluated the compliance with relevant criteria in all technical elements (i.e. siting and structural safety, radiological environmental impact, operational safety, systems and components, quality assurance, and total systematic performance assessment, etc.). The overall safety review process can be phased into inception phase, initial review phase, main review phase and completion phase. The review results were reported to and deliberated by the five Sub-committees of the Special Committee on Nuclear Safety, and then reported to the Ministry. The Ministry issued the construction and operation permit of the disposal facility through the deliberation of the review results by the Nuclear Safety Commission. Hereafter, the safety of the repository will be reassured by a series of subsequent regulatory inspections and reviews under the Atomic Energy Act. In addition, the licensee's continuous implementation of the "Safety Promotion Plan" may also enhance the long-term safety of the repository and contribute to build-up the confidence of the safety case.

Key words : Radioactive Waste, Disposal, Safety Review, Technical Standards

1) Corresponding Author. E-mail : radwaste@kins.re.kr

요 약

국내 최초의 중 · 저준위 방사성폐기물 처분시설에 대한 건설 · 운영허가가 지난 2008년 7월 31일 발급되었다. 이 논문에서는 중 · 저준위 방사성폐기물 처분시설에 대한 국내 기본 규제체계, 규제요건 및 기술기준을 제시하고, 동 시설의 안전성 확인을 위해 실제 적용된 안전심사 수행절차를 주요 단계별로 요약 · 기술하였다. 원자력법은 부지선정, 설계, 건설, 운영, 폐쇄 및 제도적관리 등 중 · 저준위 방사성폐기물 처분시설의 전과정에 대한 단계별 안전규제체계를 규정하고 있으며, 하위 법령과 교육과학기술부고시 등은 관련 세부 규제요건 및 기술기준을 규정하고 있다. 한국원자력안전기술원은 원자력관계법령에 근거한 교육과학기술부의 위탁에 따라 처분시설에 대한 안전심사를 수행하였으며, 부지 및 구조안전성, 방사선환경영향, 운영 안전성, 계통 및 설비의 안전성, 품질보증, 종합안전성평가 등 세부 기술 분야별 적합성을 종합적으로 검토하였다. 전체 안전심사 과정은 사전준비단계, 초기심사단계, 본심사단계, 완료단계 등으로 구분할 수 있으며, 한국원자력안전기술원의 심사결과는 원자력안전전문위원회 5개 전문분과의 심의를 거쳐 교육과학기술부에 보고되었고, 교육과학기술부는 원자력안전위원회의 최종 심의를 통해 처분시설에 대한 건설 · 운영허가를 발급하였다. 이후 처분시설의 안전성은 원자력관계법령에 규정된 일련의 규제검사 및 심사를 통해 확인될 것이며, 건설 · 운영자의 지속적인 안전성증진계획 이행을 통해 장기적인 안전성 증진과 안전사례에 대한 신뢰구축이 가능할 것이다.

중심단어 : 방사성폐기물, 처분, 안전심사, 기술기준

I. Introduction

On December 17, 2004, the Atomic Energy Commission revised the "National Radioactive Waste Management Policy" at the 253rd meeting of the commission. The Policy addresses that the low and intermediate level radioactive waste (LILW) should be stored at the existing storage facilities on nuclear power plant sites or at the radioisotope waste storage facilities at first, and then it should be disposed of in the LILW disposal facility (hereafter referred to as "repository"), which should be constructed and operated by 2008 [1].

Therefore, the Government decided to construct a repository that could dispose of 100,000 drums (hereafter "drums" means "200 liter-drum equivalents") of the LILW for the first stage and then gradually expand the capacity upto 800,000 drums. Based upon the "Special Act on Support for Areas Hosting the LILW Repository" [2] legislated and promulgated in 2005, the Ministry of Knowledge Economy implemented the entire site selection process by operating the Site Selection Committee consisting of civilian experts. In June 2005, the Government issued a Public Notice on the selection of a candidate site for the LILW repository [3], and the city of Gyeongju was selected as the final candidate site in November 2005 following the procedures such as site suitability assessments, local referendums, etc. as specified in the Public Notice. In June 2006, the Disposal Method Selection Committee decided on a rock-cavern repository as the disposal method for the first stage.

The Korea Hydro and Nuclear Power Co., Ltd. (KHNP) submitted an application to the Ministry of Education, Science and Technology (MEST), for a permit to construct and operate the proposed LILW repository in January 2007. The Korea Institute of Nuclear Safety (KINS), as entrusted by the MEST in accordance with the Atomic Energy Act (AEA) [4], conducted safety review on the permit application documents. The MEST finally issued the permit for construction and operation of the LILW repository on July 31, 2008, and the KHNP is currently undertaking excavation and construction of the repository in accordance with the permit issued.

II. Regulatory Framework for the LILW Repository

1. Regulatory Body and Relevant Organizations

The safety of the LILW repository is mainly supervised by the MEST under the AEA. However, the Nuclear Safety Commission (NSC), chaired by the Minister of the MEST, deliberates important matters concerning nuclear safety such as licensing of the LILW repository. In practical, safety reviews and most of regulatory inspections on the LILW repository are conducted by the KINS, which is an expert organization of nuclear safety regulation. The KINS has been also performing regulatory research and development (R&D) on the safety of radioactive waste management for the last few decades.

2. Stepwise Regulatory Framework

With a view to improving the long-term safety of the radioactive waste disposal facility, a step-by-step approach throughout the life-cycle of the facility (i.e. site selection, construction, operation, closure, and institutional control, etc.) is needed and now considered to be an international best practice [5]. The AEA also stipulates a stepwise regulatory framework for the disposal facility; through a sequential regulatory review systems of Early Site Approval (if necessary), Construction and Operation Permit, review of Institutional Control Plan, and review of Report for Termination of Institutional Control, and a multiple regulatory inspection system of Pre-

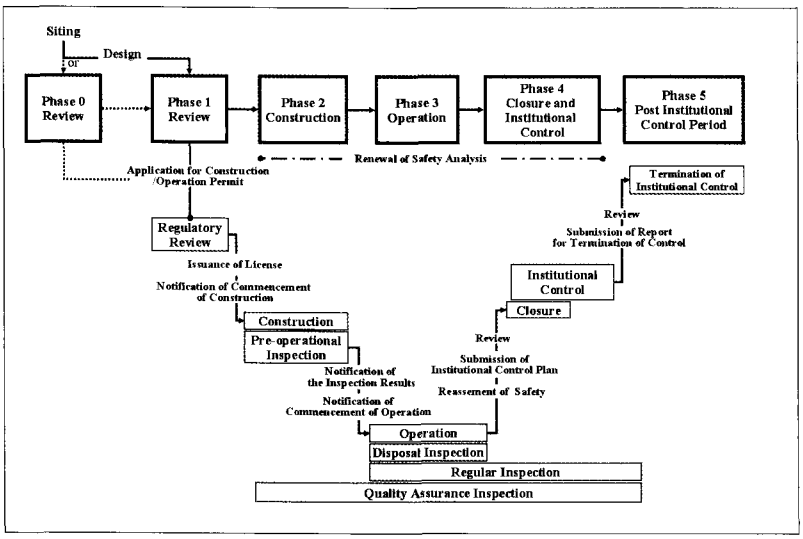

Fig. 1. Stepwise regulatory framework for the low and intermediate level radioactive waste repository.

operational Inspection, Regular Inspection, Disposal Inspection, and Quality Assurance (QA) inspection, etc. (see Fig. 1) [1].

3. Regulations on the Safety of the LILW Repository

The AEA and its subsequent regulations (i.e. Enforcement Decree of the AEA, Enforcement Regulation of the AEA, Enforcement Regulation Concerning the Technical Standards of Radiation Safety Control, etc., and Notices of the MEST), as depicted in Fig. 2, set forth licensing procedures, licensing criteria, technical standards, and other detailed regulatory requirements on the safety of the LILW repository's life-cycle. More detailed regulatory procedures and technical positions on the safety of the repository are addressed in the Safety Review Guides (SRGs) issued by the KINS [6,7].

As shown in Fig. 3, Article 77 of the AEA [4]

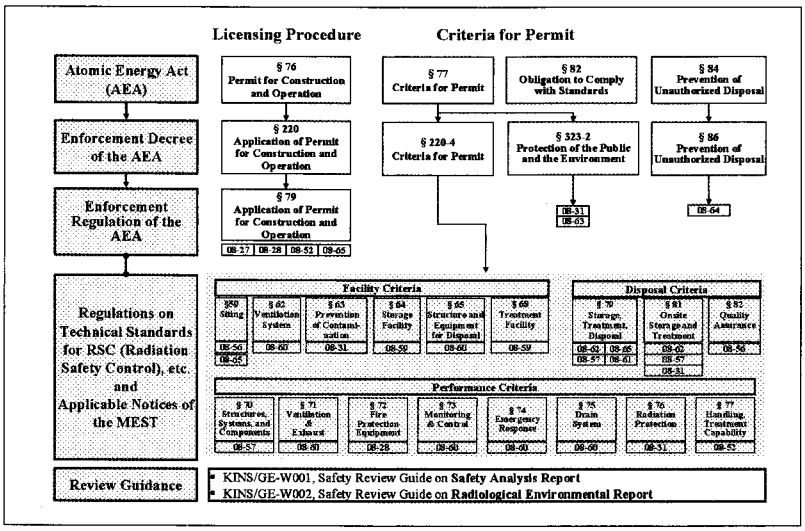

Fig. 2. Structure of legislations and regulations on the low and intermediate level radioactive waste repository under the Atomic Energy Act.

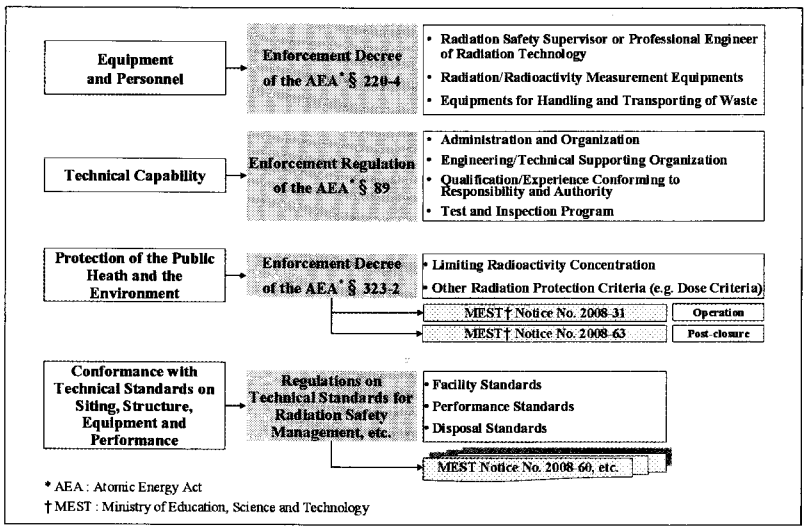

Fig. 3. Criteria of the permit for construction and operation of the low and intermediate level radioactive waste repository.

prescribes the basic criteria for Construction and Operation Permit of the LILW repository as follows:

- Equipment and manpower prescribed by the Presidential Decree are secured;
- Technical capabilities necessary for the construction and operation of disposal facility and related facilities shall be available;
- Location, structure, equipment, and performance of disposal facilities shall conform to such standards in such a way that they may not be any impediment to the prevention of hazards to human bodies, materials and the general public caused by radioactive materials, etc.;
- The construction and operation of disposal facilities etc. do not cause any impediments to the prevention of danger or injury to national health and the environment caused by radioactive materials, etc.

The licensee of the LILW Repository should secure sufficient equipment and manpower, as per Article 220-4 of the Enforcement Decree of the AEA [8]. Therefore, three sets of radiation measurement equipments and radioactivity measurement equipments, and more than one handling/transporting equipments for radioactive waste should be at least furnished in the facility. In addition, more than one staff of the personnel should hold the license of Radiation Safety Supervisor or Professional Engineer of Radiation Technology.

The criteria for technical capabilities are prescribed in Article 29-2 of the Enforcement Regulation of the AEA [9]. The licensee should establish organization and departments necessary for the business, and responsibilities and rights must be clearly endowed to them. The personnel should also have sufficient qualification and experience commensurate with the responsibilities and rights. The licensee additionally needs to be bolstered by engineering and technical supporting organization(s) for reviewing safety-related issues, and to establish test and inspection program for major structures, systems and components (SSCs) important to safety.

More detailed provisions on the site, SSCs important to safety, and performance of the LILW repository and its radiological criteria are prescribed in the Enforcement Regulation Concerning the Technical Standards of Radiation Safety Control (RSC), etc. [10], and relevant Notices issued by the MEST.

III. Technical Standards on the LILW Repository

1. Site Suitability

The fundamental siting criteria of the LILW repository are outlined in Article 59 of the Regulations on the Technical Standards for RSC, etc., which restrains the site to be located at an appropriate place in terms of seismic and ecological characteristics, utilization of water resources and other environmental conditions, and so forth. Detailed technical standards regarding the location of the repository are provided in the MEST Notice No. 2008-56 (Siting Criteria for the LILW Repository), in which a series of factors such as meteorological conditions, ground surface conditions, and geological conditions, the surface water, ground water, occurrence of earthquakes, ecological characteristics, the use of water resources, other land uses for industrial or military purposes, and the supplementary emplacement of engineering barriers are specifically addressed. As for the seismic design, for instance, the repository shall

be designed to prevent the safety-related functions are not failed due to earthquakes and be established on the basis of the geological conditions, the historical records of earthquake damage, and the current seismic activities of the area around the site. Furthermore, the repository shall be designed in consideration of the effect of natural phenomena other than earthquakes, such as flooding, extreme winds, landslides, sedimentation, and upheavals that can be anticipated through past records review and on-site investigations of the area surrounding the site so that the safety-related functions are not failed.

2. Radiological Safety

As shown in Fig. 4, a series of radiological criteria applied to each phase of the life-cycle of the LILW repository are set forth in the AEA and its subsequent regulations.

- Post-Closure Safety

Radiological performance objectives for the post-closure period of the LILW repository are set up in terms of the radiological risks for individuals of critical groups in the future. The annual dose due to normal natural phenomena should not exceed the dose constraint of 0.1 mSv. In addition, annual risk due to unpredictable phenomena caused by natural or artificial reasons should be restricted to the risk constraint of 10^{-6} or less.

The time-frame of post-closure safety assessment is expected to be about 1,000 years. When the predicted risk does not reach to its peak within the period, however, verification that the leakage of radioactive materials into the environment will not increase drastically after the period and that acute radiation risk will not occur to individuals should be duly presented.

- Operational Safety

The Enforcement Decree of the AEA and the MEST Notice No. 2008-31 (Standards on Radiation Protection, etc.) [11] prescribe discharge limits of gaseous and liquid radioactive effluents to be released from nuclear facilities into the environment, along with annual dose constraints to the public in the

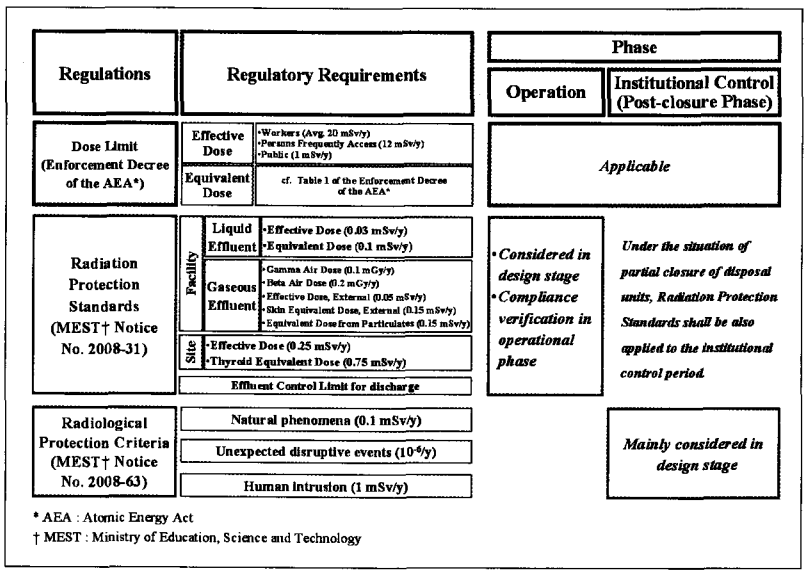

Fig. 4. Radiological regulatory requirements of the low and intermediate level radioactive waste repository along with its life-cycle.

vicinity of the facilities. The same criteria are applied to the operational phase of the LILW repository.

3. Radiological Environmental Impact

The applicant should prepare the Radiological Environmental Report (RER), as per Article 76 of the AEA [4], to evaluate the radiological environmental impacts to be caused by radiation or radioactive materials from construction, operation, closure, and post-closure of the LILW repository. With regard to the radiological environmental impact from closure, the applicant should provide the predicted migration pathways of radionuclides that can leak from the disposal facilities, the predicted doses for local residents per exposure pathways due to potential radionuclide leakage within 10 km from the site, and the predicted radionuclide concentration at groundwater release points located downstream of the site. A series of accident analysis for operational phase of the repository should be also conducted and described in the RER.

In addition, facility information, and the environmental status of neighboring regions should be also provided, and the radiological environmental monitoring programs (REMPs) for pre-operational phase, operational phase, and post-closure phase should be established. Standard format and contents of the RER are set forth in the MEST Notice No. 2008-27 (Regulation on Preparation, etc. of RER of Nuclear Power Utilization Facilities) [12], and detailed technical standards on the REMPs are addressed in the MEST Notice No. 2008-28 (Regulation on the Environmental Radiation Survey and Impact Analysis in the Vicinity of Nuclear Facilities) [13].

4. Structures, Systems and Components, and Construction

The Regulation on the Technical Standards for RSC, etc. sets forth basic technical standards on the SSCs important to safety; such as heating, ventilation, and air conditioning (HVAC), fire protection, monitoring and control, emergency electrical power source, drainage, radiation control systems, waste treatment systems, etc. at the LILW repository. The MEST Notices No. 2008-60 (Criteria for Structure and Equipment of the LILW Repository) [14] and No. 2008-59 (Criteria for Structure and Equipment of the LILW Treatment System) [15] provide more detailed standards on the major SSCs to be installed at the repository. In addition, the SSCs important to safety shall be able to maintain normal operational status as determined in the MEST Notice No. 2008-57 (Technical Requirement for the Operation and Control of the LILW Repository) [16].

The construction works of the repository shall be done by fully proven engineering practices in accordance with applicable QA requirements. New construction technology may be also adopted only if its safety could be verified with valid evidence. More specifically, the repository should be constructed so as to minimize damage to the natural barriers, and the validity of the characteristics of natural barriers assumed at the design stage shall be confirmed through comparison with additional data to be obtained during excavation and construction period, as per the MEST Notices No. 2008-57 and No. 2008-60, etc. [14,16].

5. Quality Assurance

With regard to the QA requirements, totally eighteen QA criteria for the nuclear reactor facilities are also applicable to the LILW repository, as

addressed in Article 82 of the Regulations on the Technical Standards for RSC and the MEST Notice No. 2008-55 (Quality Assurance Criteria for Radioactive Waste Management Facilities) [17]. Furthermore, more detailed QA requirements applicable to the operational period of the repository are set forth in Article 27 of the MEST Notice No. 2008-57. For instance, the operator should establish and perform a QA plan related to the management of waste based on the technical standards on characterization, acceptance, transfer and handling, identification and marking, storage and treatment, and disposal of the radioactive waste. The MEST Notice No. 2008-57 [16] also addresses further requirements on establishment of the QA plan such as adequate consideration of the potential impacts on the safety of the repository to be caused by the components and activities.

IV. Safety Review Process

In the Republic of Korea, the procedure of safety review on the license application of major nuclear installations is formalized, according to the AEA and its subsequent regulations. The safety evaluation of the LILW repository is to be conducted based on the SRGs issued by the KINS under the approval by the MEST. Relevant administrative matters are prescribed in the "Detailed Regulations for Conducting Safety Review of the Radioactive Waste Management Facilities," which was established under the internal QA program of the KINS. Fig. 5 depicts the overall safety review procedure adopted to the licensing of the LILW repository, which is also compatible with the draft recommendations of the Regulatory Review Working Group under the international project, Application of Safety Assessment Methodologies (ASAM), supported by the International Atomic Energy Agency [18].

1. Inception Phase

Prior to receipt of the license application documents, the MEST and KINS set up an initial plan for the safety review and had dialogues with potential applicant. In the inception phase, the

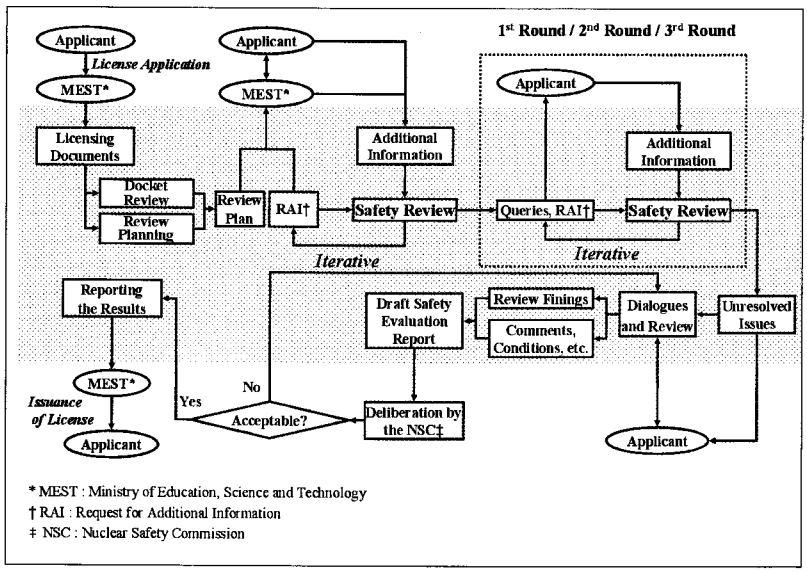

Fig. 5. Overall safety review process on the application of the permit for construction and operation of the low and intermediate level radioactive waste repository.

KINS also provided a series of technical guidance mainly on the extent of information to be provided in the license application documents. As requested by the MEST, the KINS also reviewed the draft radiological environmental report (RER) prepared by the applicant for public consultation, and then the review results and comments of the KINS on the draft RER were notified to the applicant through the MEST for feedback to the revised RER.

2. Initial Phase

On January 15, 2007, the applicant, KHNP, submitted an application form, along with ten kinds of license application documents, to the MEST for the Construction and Operation Permit of the LILW repository.

Based upon the initial review plan and additional information from the applicant, the KINS recruited internal experts having expertises in a variety of technical fields and officially organized a review team (i.e. KINS Review Team; KRT). In addition, the strategy, scope, and time schedule of the safety review were finalized into the Regulatory Review Plan. The KRT undertook its initial evaluation (i.e. Docket Review), mainly on the completeness of information described in the licensing documents before main review. In this initial phase, a preliminary identification of the issues that are important to the long-term safety were also made.

The KINS reported the Regulatory Review Plan and its results of Docket Review to the MEST. The identified partial deficiency of information was notified to the applicant through the MEST, and then the license application documents were amended as appropriate through the subsequent review process.

3. Main Review Phase

The main technical review was conducted through three rounds of queries and answers (Q&As) between the KINS and the applicant. The KRT evaluated all relevant technical elements to be verified for determination whether the application meets all regulatory requirements and technical standards. Major technical areas of the safety review on the LILW repository and their interdependency are summarized in Table 1 and Fig. 6, respectively.

In each round of the Q&A, the KRT's comments and requests for additional

Table 1. Major technical areas of the safety review on the low and intermediate level radioactive waste repository.

Technical Area of Review		Main Subject
1	Total System Performance Assessment (TSPA)	• Post-Closure Safety Assessment, Accident Analysis, Waste Acceptance Criteria, Integration of Review Findings from Other Areas, etc.
2	Site Suitability and Structural Safety	• Site Characterization (Geology, Seismicity, Geochemistry, Hydrogeology, etc.) • Structural Safety and Construction Methods • Site Surveillance Program, etc.
3	Radiological Environmental Safety	• Radiological Environmental Impact • Radiological Environmental Surveillance Program, etc.
4	Operational Safety	• Radiation Protection, Transportation, etc.
5	Systems and Components	• Heating, Ventilation and Air Conditioning, Instrumentation and Control, Radioactive Waste Management, Radiation Monitoring, Fire Protection, Heavy-load Crane, Electric Power Supply, Diesel Generator, etc.
6	Quality Assurance	• Quality Assurance Program
7	Misc. Areas	• Administrative Matters, Unclassified Areas, etc.

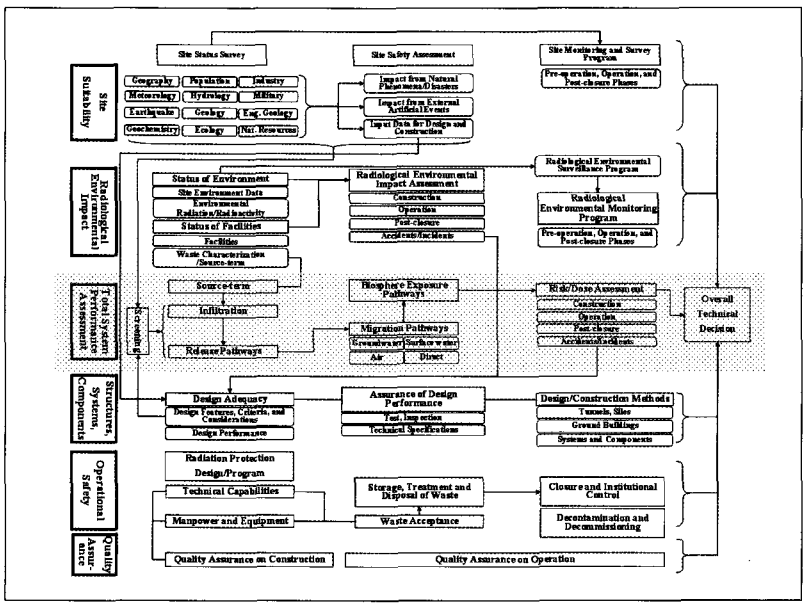

Fig. 6. Interrelations among major technical areas of the safety review on the low and intermediate level radioactive waste repository.

information (RAIs) were notified to the applicant, and then the applicant provided amendments of the license application documents and/or supplementary additional information. Resolved issues were closed at the end of each round and unresolved ones were brought to the next round for further evaluation and discussion. Throughout the rounds of Q&As, there had been also regulatory dialogues between the KRT and the applicant. After completion of three rounds of Q&As, a few Key Technical Issues (KTIs) were brought out and profiled for further intense deliberation. The KTIs were resolved through regulatory dialogues and request for more detailed information along with applicant's amendment of the license application documents reflecting the results of further supplementary site survey, performance assessment and design change, which had been done during the review process.

In the main review phase, the KRT also collected independent technical perspectives on important issues from consultation with external experts.

4. Completion Phase

The KINS wrapped up its review findings and drafted the Safety Evaluation Report (SER) mainly consisting of KRT's review results (i.e. technical positions) on the compliance of the license application with relevant regulatory requirements. However, a series of items to be developed continuously throughout the life-cycle of the repository had been also derived during the review process and incorporated into the SER as a "Safety Promotion Plan". The draft review results were submitted to the five Sub-committees (Site and Structure; Radiation Protection; Reactor System; Nuclear Emergency and Environment; Regulatory Policy) of the Special Committee on Nuclear Safety under the Nuclear Safety Commission (NSC) and deliberated by each Sub-committee manly concentrating on its expertise. Based upon the comments raised from

the deliberations by the Sub-committees, the KINS revised its draft SER and then submitted the final SER to the MEST. On July 31, 2008, the MEST submitted the review results to the NSC as an "Item for Deliberation," and then the NSC approved and resolved the item as submitted. Finally, the MEST issued the permit for construction and operation of the LILW repository and officially requested the applicant to implement the "Safety Promotion Plan".

V. Conclusion

The regulatory framework for the life-cycle of the LILW repository established by the AEA conforms to the international best practice of the step-by-step approach. The long-term safety of the proposed LILW repository, which is now under construction in the city of Gyeongju, was evaluated by the KINS through a formalized safety review process, in accordance with regulatory requirements and technical standards as stipulated in the AEA, its subsequent regulations, and relevant Notices of the MEST. The safety evaluation was conducted by the KRT on major technical areas, such as siting and structural safety, radiological environmental impact, operational safety, systems and components, QA, and Total System Performance Assessment (TSPA), etc., taking into consideration of their interdependency and the stepwise flow of technical findings.

The safety of the LILW repository at each step of repository development will be ensured by subsequent regulatory inspections (i.e. Pre-operational Inspection, Regular Inspection, Disposal Inspection, and QA Inspection, etc.) and reviews (i.e. review of amendment of the permit, review of Institutional Control Plan, and review of Report for Termination of Institutional Control Plan, etc.), in accordance with the AEA. Furthermore, the licensee's continuous implementation of the "Safety Promotion Plan" throughout the life-cycle of the repository will be able to enhance the long-term safety of the LILW repository and to contribute to build-up the confidence of the safety case too.

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