3.5 Radioactive Waste Management (RWM) in Korea

The safe management of radioactive waste is a national task required for sustainable generation of nuclear power and for energy self-reliance in Korea. Nuclear power generation was first introduced in 1978 in Korea. Since then, a rapid growth in nuclear power development has been achieved to have the total installed capacity of 13,716MWe in 2000. And the future nuclear power plants (NPPs) construction program is also ambitious. Such a large nuclear power generation program also produced a significant amount of radioactive waste, both low and intermediate-level radioactive waste and high-level radwaste, and it will do more.

At the early stage of nuclear power development in Korea, the philosophy of the radioactive waste management was to reduce the waste volume by conditioning and to store the waste within the nuclear site boundary. The final disposal facilities were to be constructed later. However, as the wastes were piled up within the sites, the necessity to find a final repository for the wastes was also increasing. Moreover, due to a wide application of radioisotopes (RI), the RI waste generation from industries, hospitals, and research organizations is also increasing.

For the past two decades, a great deal of effort has been exerted to secure a candidate site for the radwaste repository without any success. In June 1996, the Korean Atomic Energy Commission decided to create a dedicated organization, the Nuclear Environment Technology Institute (NETEC) under the Korea Electric Power Corporation (KEPCO), for radioactive waste management. Since the nuclear power generation business has been separated from KEPCO to a new company, Korea Hydro & Nuclear Power Co., Ltd. (KHNP) in April 2001, NETEC was also transferred to KHNP.

3.5.1 RWM Policy

In 1997, NETEC performed a study on the national radioactive waste management policy of Korea. And the study report was presented to the government. Based on this report, a new national program for radioactive waste management policy was approved, on September 30, 1998, by the Atomic Energy Commission (AEC) which has full authorities to determine policies about atomic energy use.

The fundamental principles of the national radioactive waste management policy are as follows:

- Direct control by the government
- Top priority on safety
- Minimization of waste generation
- "Polluter pays" principle
- Transparency of siting process

The implementation plans are as follows:

- Low and intermediate level radioactive waste (LILW) and spent fuel (SF)
  - LILW should be managed to minimize its generation at nuclear reactor sites until the opening of a repository.

  - SF should be stored at reactor sites until 2016 with expansion of on-site storage capacity.
- Construction plan for a national radioactive waste management complex
  - An LILW repository will be operated from 2008.
    Repository capacity: 100,000 drums at the first stage; 800,000 drums finally
    Disposal type: to be decided upon site condition (rock cavern or near surface vault)
  - A centralized spent fuel interim storage facility will be built by 2016.
    Storage capacity: 2,000 MTU at the first stage; 20,000 MTU finally
    Storage type: to be decided later (dry or wet)
- Main area of Research and Development (R&D)
  - Volume reduction technology
  - LILW disposal and safety assessment technology
  - Improvement of existing technology for spent fuel storage and transportation, and development of advanced technology in consideration of domestic conditions

3.5.2 RWM Practices

3.5.2.1 Legislative Framework

The regulation and licensing of nuclear facilities in Korea are based on the provisions of the Atomic Energy Act, the Enforcement Decree and Enforcement Regulation of the Act, and the Notice of the Ministry of Science and Technology (MOST). The basic concept of nuclear safety, underlain in the Atomic Energy Act, is not only to protect the public health and safety from radiation hazards, but also to protect the environment from any potential harmful effects. This concept provides with the basic legal foundation for nuclear regulations in Korea.

Atomic Energy Act.

The Act is the basic law for utilization and safety regulation of atomic energy. This Act has been amended several times in accordance with the environmental changes of the Korean society since it was promulgated in March 1958. Especially at the amendment of May 1986, the Act provided the legal basis for the establishment of nuclear waste management fund.

Enforcement Decree of the Atomic Energy Act: Presidential Decree.

The Decree systematically defines the technical standards and administrative matters necessary to enforce the Atomic Energy Act. The Decree was enacted in September 1982, and has been amended appropriately according to the amendments of the Act.

Enforcement Regulation of the Atomic Energy Act: Prime Ministerial Ordinance.

The Regulation provides the licensing procedures and application methods necessary for the implementation of the Atomic Energy Act and Enforcement Decree. The Regulation was enacted in April 1983, and has been amended appropriately according to the amendments of the Act and the Decree.

Notice of the MOST.

The Notice provides technical standards and procedures in detail. A total of 47 Notices have been developed and stipulated as of November 1999. Ten more Notices are still in the process of stipulation. Especially several kinds of technical standards and criteria for radioactive waste management practices have been promulgated as Notices. These are Notices on performance, general waste acceptance, siting, design features and quality assurance criteria for the repository and the SF interim storage facility, and on the guidance for preparing environmental impact assessment and site characterization reports, etc.

Regulatory Guides on Licensing Review and Inspection.
The Regulatory Guides provide detailed guidance on the licensing review and inspection for the regulatory body staff. These are not legally binding but utilized as references for regulatory review and inspection.

3.5.2.2 Regulatory Framework/Body

Regulatory framework and/or bodies related to nuclear safety regulation and licensing in Korea are shown in Figure 3.5-1. The duty and responsibility of the major organizations are as follows:

- The AEC is the highest policy-making body on nuclear matters. The Deputy Prime Minister is the chairperson of the AEC.
- The MOST is the regulatory authority of Korean Government. It is responsible for establishing and implementing nuclear regulatory policies for the control of nuclear activities related to power and research reactor, radiation applications, etc. It is also responsible for making R&D policies for peaceful use of nuclear energy.
- The principal function of the Nuclear Safety Commission (NSC) is decision-making on major nuclear safety and regulatory policies and licensing issues.
- The Korea Institute of Nuclear Safety (KINS) was established to support the MOST with its technical expertise, and entrusted with the duty of safety regulations. The KINS performs safety review and inspection, and develops safety standards.

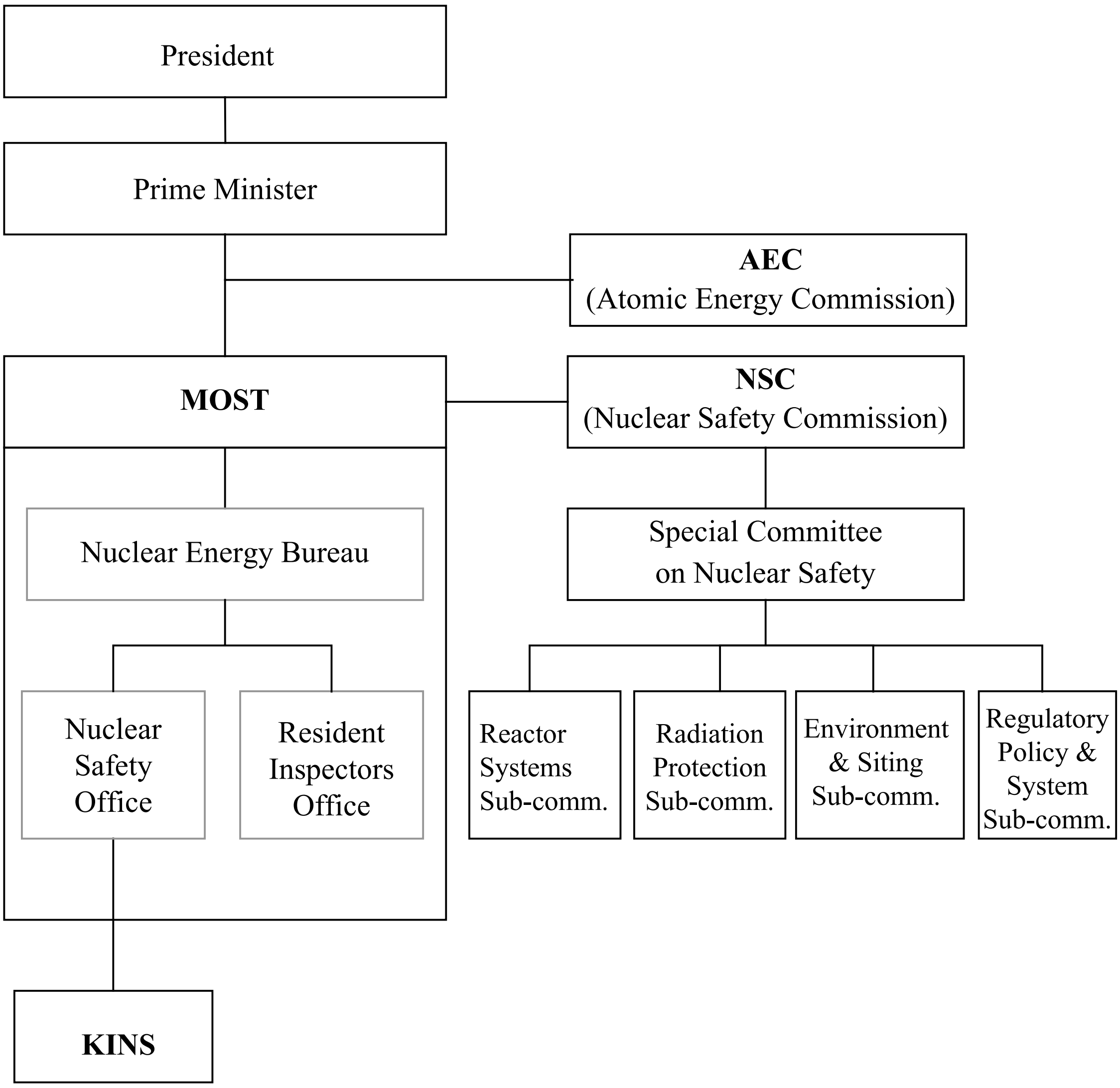

Figure 3.5-1 Government Organization on Nuclear Safety Regulation and Licensing

3.5.2.3 Responsibility of License Holder

Regarding the responsibility for the treatment and storage of waste, it basically lies with waste generators. The generators who produced wastes during generation of nuclear power and the use of radioactive materials in industry, research and medicine shall meet standards and requirements of nuclear regulations and licensing.

3.5.2.3.1 The Responsibility of RWM within the Nuclear Site

As soon as the operation license is issued, the operators have the full responsibilities to meet the regulations. The regulations call for the following measures in common:

- Gaseous radioactive wastes:
  - to be released after filtration of major particulates.
  - to be stored or to be decayed enough for the short-lived radionuclides.
- Liquid radioactive wastes:

  - to be released after diluted
  - to be stored in liquid waste tanks which have enough radiation shielding functions
  - to be enclosed in containers or solidified in containers and put into storage facilities which have radiation hazard prevention functions, etc.
- Solid radioactive wastes:
  - to be enclosed in containers or solidified in containers and put into storage facilities which have radiation hazard prevention functions, etc.
  - The record about the characteristics of the wastes must be kept.

When gaseous or liquid radioactive wastes are released, they are continually monitored to ensure that they do not exceed the concentration levels of radioactive materials in the air or water prescribed in the law.

3.5.2.3.2 The Responsibility of RWM in the LILW Repository

General acceptance criteria of the radioactive waste disposal are addressed in Korean Atomic Energy laws. But the detailed plan to meet the criteria should be prepared by both waste generators and repository operators, and then be approved by MOST. Therefore, specific acceptance criteria will be ready when disposal site is selected and basic design of the repository is determined.

3.5.3 Criteria Used to Define and Categorize Radioactive Waste

Radioactive waste is defined as radioactive materials or materials contaminated by them which are the object of disposal (including the spent nuclear fuel) in the Atomic Energy Act. In Korea, radioactive wastes are categorized into only two types: low- and intermediate-level waste and high-level waste according to its radioactive concentration and degree of heat generation. Korea has no plan to reprocess SFs. Therefore, there is no other high-level waste than SF. According to the Atomic Energy Act and MOST Notice, the radioactive concentration of LILW is less than 4,000Bq/g of alpha emitting nuclides with half-lives longer than 20 years, and its heat generation rate is less than 2kW/m^3.

Wastes meet the limiting criteria of both the individual dose of less than 10μSv/yr and the collective dose of less than one person-Sv/yr can be arbitrary disposed under the current regulation in Korea.

3.5.4 RWM Facilities

3.5.4.1 RWM in Nuclear Power Plant Sites

Korea now has 16 commercially operating nuclear units: twelve pressurized light water reactors (PWR) and four pressurized heavy water reactors (PHWR), and four PWRs under construction as shown in Table 3.5-1. All radioactive wastes are stored in on-site temporary storage facilities before the national RWM complex is operated.

Table 3.5-1 Status of Nuclear Power Plants in Korea (As of December 2000)

Site	Kori	Yonggwang	Ulchin	Wolsong
Operation	4	4	4	4
Under Construction	0	2	2	0
Reactor Type	PWR	PWR	PWR	PHWR

3.5.4.1.1 LILW Management

Volume and exposure reduction is very important to achieve the objective of radioactive waste management. In case of LILW from nuclear power plants, volume reduction equipment, such as concentrate waste drying system (CWDS), spent resin drying system (SRDS) and super compactor, has been utilized. The gaseous waste is released to the environment after filtration. The spent filters are compacted with high pressure and stored in a steel container. The liquid waste is divided into two streams, according to the waste characteristics. The liquid waste is separately processed according to its total dissolved solid (TDS). The waste with low TDS is treated by ion exchange. Spent resins are dried by SRDS and packed in high integrity containers (HIC). On the other hand, the waste of high TDS is evaporated. Evaporator with ion exchanger is being used in all PWRs. Especially liquid treatment system of Kori unit 2 and Ulchin unit 1&2 consists of evaporating system and selective ion exchange system in parallel. Korean Standard NPP being constructed is designed to treat liquid waste with high-speed centrifuge and selective ion exchanger. The concentrated liquid after evaporation is dried by CWDS and then solidified. The other miscellaneous dry active waste (DAW) is processed using movable type super compactor for both combustibles and non-combustibles instead of using incineration process. Radioactive waste treatment processes of NPPs are summarized in Figure 3.5-2.

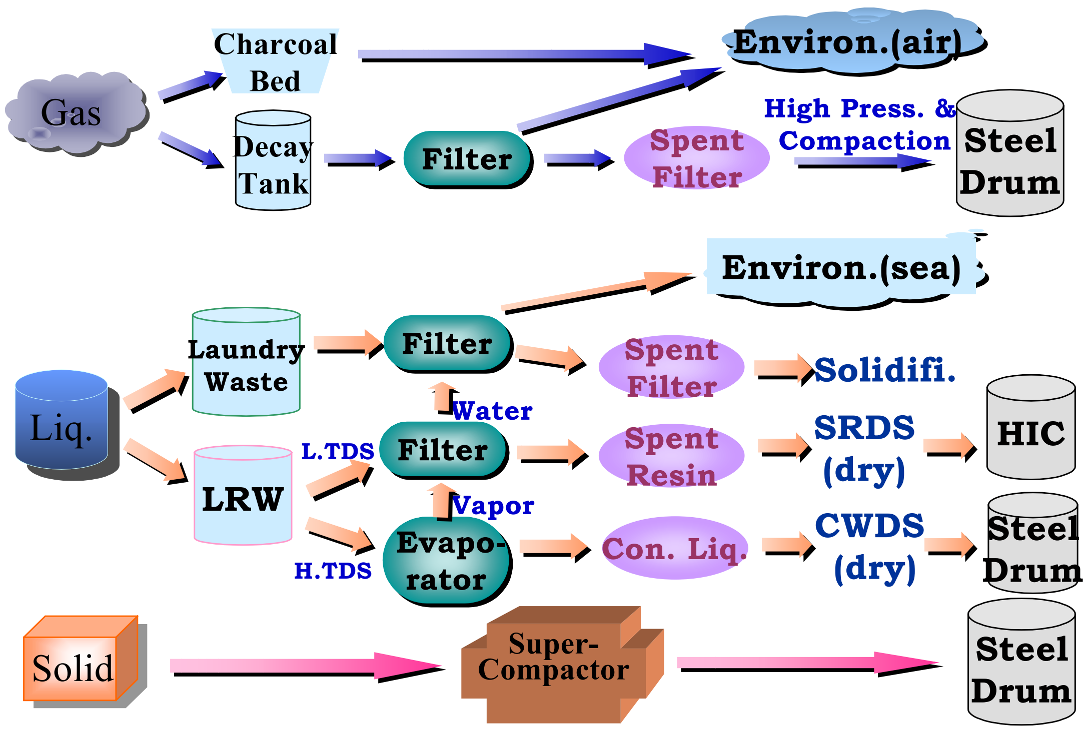

Figure 3.5-2 Radioactive Waste Treatment Process Flow

As a result of implementing the above radioactive waste treatment system, the volume of radioactive waste has been reduced from 550 drums per reactor-year in early 1990s to 146 drums in 1999. And it is also contributed to reduce the exposure of worker. Table 3.5-2 shows the effects of improvement of waste treatment system. An aggressive long-term plan is to reduce the volume of solid waste to be 35 drums per reactor-year in the near future and it can be achieved by commercializing the LILW vitrification technology.

Table 3.5-2 Effects of Improvement of Treatment System

System	Treatment	Volume Reduction	Exposure Reduction
Super compactor	DAW	1/2	-
CWDS	Concentrated waste	1/8	4/5
SRDS	Spent resin	1/2	1/8

3.5.4.1.2 SF Management

Currently, the spent fuels generated from each NPP are being stored in its storage pools or bays. However, the current storage capacity at reactor site is insufficient to meet the target year of 2016 for operation of the centralized interim SF storage facility. Therefore, the expansion of at reactor (AR) storage capacity is implemented in each site on the basis of the appropriate combination of technical and economic factors.

For PWRs, the AR expansion has been and is being carried out by transshipment between neighboring reactors and re-racking with high-density storage rack modules. High density storage rack (HDSR), which increases the storage density by using Boral or Borated Stainless Steel neutron absorbers, has been installed partially or fully in spent fuel pools. Storage density was increased up to about 200 percent by replacing old storage rack with HDSR. In case of PHWR, spent fuel bundles after at least six-years cooling in spent fuel bay are put into stainless steel baskets and transferred to the on-site concrete silo type dry storage facility. A silo can hold nine fuel baskets and each basket accommodates 60 bundles. Table 3.5-3 shows the status of AR storage capacity expansion in each nuclear power station.

Table 3.5-3 Status of AR Spent Fuel Storage Expansion

Location of Nuclear Power Stations	Method of Expansion	Installation Year
Kori	Unit 1, 2: Transshipment to Unit 3,4	1991, 1995, 2000, 2001
	Unit 3: Adding HDSR in empty space of spent fuel pool Full re-racking with HDSR	1993 2001
	Unit 4: Adding HDSR in empty space of spent fuel pool	1996
Yonggwang	Unit 1, 2: Adding HDSR in empty space of spent fuel pool	1997
Ulchin	Unit 1, 2: Re-racking with HDSR	1995
Wolsong	Construction of concrete silo	1991

3.5.4.2 LILW Vitrification Demonstration Facility

Apart from conventional treatment method, such as evaporation, compaction, drying, cementation, etc., advanced technology for LILW is being developed for omnibus waste treatment. From the needs for environmentally sound innovative technology that should be able to reduce LILW volume remarkably and to improve the stability of waste forms in addition to enhanced public acceptance of their final disposal, vitrification has been singled out as the most promising technologies. It is a technology immobilizing radionuclides in very stable glass form. Therefore, if the vitrified wastes were stored in a repository, the safety of the repository would be improved because of its low leachability. Another advantage of the vitrification is that the volume can be reduced to 1/20 ~ 1/30 of the original volume of LILW generated from NPPs. The volume reduction would result in an efficient and prolonged use of a repository in this small and populated country.

Based on a feasibility study, NETEC has developed its unique vitrification process for LILW. A pilot-scale vitrification facility was constructed at Taeduk Science Town in 1999. This facility consists of an induction heated cold crucible melter (CCM) for combustible waste, a plasma torch melter (PTM) for non-combustible waste, and an off-gas treatment system, as shown in Figure 3.5-3. In September 22, 2001 NETEC successfully completed a long-term vitrification pilot test which lasted 130 hours. Total 1.1 ton of simulated dry active waste (DAW) and spent resin were vitrified with volume reduction ratio of 80 in the test. The test aimed at demonstrating overall performance requirements of the NETEC vitrification process, which are expected to be essential for commercialization. As a next step, NETEC plans to design and construct the first commercial vitrification plant at one of the nuclear power plant sites by 2004.

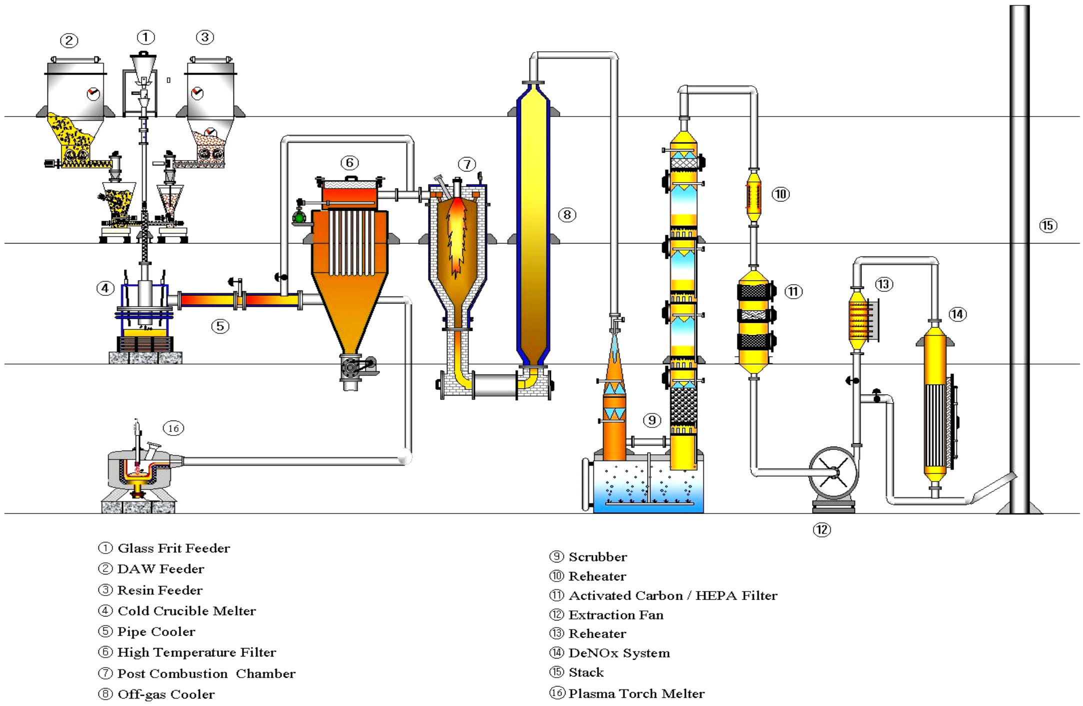

Figure 3.5-3 Schematic Diagram of LILW Vitrification Pilot Plant

3.5.4.3 Radioisotope (RI) Waste Management Facility

There are 1,692 RI users and organizations in Korea, and RI waste has been increased in accordance with the wide spread of the RI utilization. Annually, about 400 drums of RI waste are being collected and stored at a dedicated RI waste management facility at NETEC in Taeduk Science Town. RI waste is classified into unsealed sources and sealed sources based on its physical and radiological status. Unsealed sources are composed of combustible, incombustible, liquid wastes, spent filters, and carcass. Typical RI waste is plastic tubes, injections, paper towels, glass vials, frozen animal carcass used for experiments, and off-gas filters. The major radionuclides are I-125, Tc-99m, P-32 and S-35. The unsealed sources are mainly used for the treatment of thyroid and diagnosis and treatment of hepatitis. The sealed sources are used in non-destructive test companies to measure thickness and to find the defects.

NETEC is implementing plans to reduce volume to solve the space problem of increasing RI waste. Non-combustible waste and spent filter are compacted by high-pressure compactor after segregation of the exemption level waste. Spent sealed sources are stored in a special container after consolidation. Combustible dry active waste, hepatitis waste and organic liquid waste will be incinerated at NETEC. Radioactive waste incineration system to accept these wastes except α-bearing waste is under license. Safety assessment and environmental impact assessment reports are submitted for regulatory review. The system consists of two incinerators, which have the capacity of 30kg/hr for combustible DAW and 8 {/hr for organic liquid waste, respectively, and a common off-gas treatment sub-system. It has also equipped with the emission monitoring system in stack to continuously tele-measuring hazardous off-gas such as SOx, NOx, Cl_2, etc.

3.5.4.4 A Planned LILW Disposal Facility

NETEC is considering the two alternative disposal methods, the rock cavern and the engineered vault disposal, and a preferred type will be determined in consideration of site conditions. Conceptual design studies and preliminary safety assessments for both rock-cavern type and engineered vault type disposal facilities were completed in 1993 and 1999, respectively.

3.5.4.4.1 Rock Cavern Disposal Facility

Waste drums will be placed in baskets or containers for easy and safe handling at the facility. Five disposal caverns are divided into caverns for low level waste (LLW) and intermediate level waste (ILW). Each cavern is connected with operation and construction tunnels. Three types of caverns for low-level waste will be constructed according to waste types: LLW I cavern for dry active wastes; LLW II caverns (two caverns) for DAW and concentrated wastes; and LLW III cavern for spent resin, spent filter and concentrated wastes. The LLW caverns have an inclination of 1% toward the cavern entrance in order to facilitate the drainage of inflow water to water basin. The LLW will be handled by the forklift truck in these caverns. The ILW cavern has large concrete compartments with the same inclination as the LLW caverns. An overhead crane will handle the waste package remotely.

3.5.4.4.2 Engineered Vault Disposal Facility

The vault disposal facility will consist of three main systems: disposal vault, disposal cap and drainage system. The disposal vault provides a long-term isolation of LILW from biosphere, the radiation protection of operators during operating period, and the collection of infiltration water. The disposal cap protects the disposal vault from rainwater, and plant and animal intrusion. The infiltration water is separately collected from rainwater. The disposal facility consists of three types of vault depending on the durability and/or size of waste packages: Vault I (waste packages with long durability and backfilled with gravel; Vault II (standard size waste packages with short durability and grouted with cement mortar; and Vault III (large size waste packages with short durability and grouted with cement mortar).

The capacity of a vault will be 5,000 drums (based on 200l drum). Seventeen grouted vaults (ten for vault II and seven for vault III) and three backfilled vaults will be constructed in the initial phase. The disposal vault is covered with a mobile roof during the waste package loading. The mobile roof equipped with waste package handling crane can be moved to the next vault for another loading operations. The final disposal cover will be constructed when the disposal vaults in a disposal area are completely filled. The final cover consists of a 6.2m thick multi-layer system to ensure low percolation, water drain, and intrusion resistance. Figure 3.5-4 shows a bird's-eye view of the engineered vault type near surface disposal facility.

Figure 3.5-4 Bird's-Eye View of an Engineered Vault Type Disposal Facility

3.5.5 Inventory of Radioactive Wastes (RW)

3.5.5.1 Inventory of RW in Storage

It can be make a general distinction of RW currently being generated in Korea as LILW and SF from the nuclear power plants (power source) and RI from medicine, industry and research activities (non-power source). The amount of LILW stored by the end of 2000 is 57,270 drums from power source. The temporary storage in nuclear power plant sites has a capacity of 99,900 drums and is able to store the radioactive wastes generated by 2008 as shown in Table 3.5-4.

Table 3.5-4 Status of LILW Storage in Nuclear Power Plants (As of December 2000)

Nuclear Power Stations		Storage Capacity (drum)	Cumulative Amount (drum)	Year of Saturation (expected)
Location	Number of Reactors			
Kori	4	50,200	30,597	2014
Yonggwang	4	23,300	11,388	2011
Ulchin	4	17,400	10,625	2008
Wolsong	4	9,000	4,660	2009
Total		99,900	57,270	

The spent fuels stored at reactor sites as of the end of 2000 are shown in Table 3.5-5.

Table 3.5-5 Status of AR Spent Fuel Storage (As of December 2000)

Nuclear Power Stations		Storage Capacity (MTU)	Cumulative Amount (MTU)	Year of Losing FCR
Location	Number of Reactors			
Kori	4	1,737	1,154	2008
Yonggwang	4	1,696	769	2008
Ulchin	4	1,563	524	2007
Wolsong	4	4,807	2,311	2006
Total		9,803	4,758	

The accumulated amount of RI waste from industries and hospitals by the end of 2000 is 4,217 drums (based on 200-liter drum). The temporary storage has a capacity of 9,277 drums and is able to store the RI waste to be generated by 2010 as shown in Table 3.5-6.

Table 3.5-6 RI Waste Generation (As of December 2000)

Waste Type	Storage Capacity (drum)	Cumulative Amount (drum)	Year of Saturation (expected)
Unsealed source	8,917	4,133	2010
Sealed source	360	84	
Total	9,277	4,217	

3.5.5.2 Inventory of RW which has been Disposed of

None.

3.5.6 Nuclear Facilities in the Process of being Decommissioned and the Status of Decommissioning Activities at those Facilities

There are three research reactors in Korea. KRR-1, the first research reactor in Korea (TRIGA Mark-II, 250kWt), and KRR-2, the second one (TRIGA Mark-III, 2,000 kWt) has been operated since 1962 and 1972, respectively. After a new multipurpose research reactor named HANARO (High-flux Advanced Neutron Application Reactor) in Taejon was began its operation, both of them were shut down in 1995. The decommissioning project for these two TRIGA type research reactors was started in January 1997. Meanwhile, according to the fifth th long-term power development plan of January 2000 of Korea, the Kori unit 1 (587 MWe, PWR) will cease the operation in 2008, and Wolsong unit 1 (679 MWe, PHWR) in 2013, respectively.

When it has been decided to shut down a nuclear facility, the operator shall submit an application for permission to decommission the facility for approval by the regulatory authority, together with the proposed final decommissioning plan, including:

- Decommissioning method and schedule
- Decontamination method of the contaminated materials
- Treatment and disposal method for the radioactive wastes
- Countermeasure for the protection from the radiation damage
- Environmental impact assessments and its countermeasure
- Other matters required by the MOST

Before a site may be released for unrestricted use, a survey shall be performed to demonstrate that the end point conditions, as established by the regulatory body, have been met. If a site cannot be released for unrestricted use, appropriate control shall be maintained to ensure protection of human health and the environment.

For KRR-1 & 2, the decommissioning plan documents for licensing including the environmental impact assessment were prepared and submitted to the MOST in December 1998. After regulatory review by the KINS, the decommissioning plan was approved in November 2000. The decontamination and decommissioning works for KRR-1 & 2 are to be performed until the end of 2007.

According to the decommissioning plan proposed by KHNP, dismantling and demolition of nuclear power plants will be conducted after the safe store of 5~10 years, which comes subsequent to decay of radioactivity and system decontamination with the consideration of dismantling two adjacent units together. Dismantling and decontamination techniques which minimize waste arisings and airborne contamination will be chosen. Decommissioning activities such as decontamination, cutting and handling of large equipment and the progressive dismantling or removal of some existing safety systems have the potential for creating new hazards. Proven techniques and equipment are now available to dismantle nuclear facilities safely. The safety impacts of the decommissioning activities will be assessed and managed so that these hazards are mitigated. As an effort to develop the enhanced decontamination and decommissioning technologies, Korea is participating in the International Co-operative Program for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects of the OECD Nuclear Energy Agency. For the implementation of decommissioning projects for nuclear power plants, KHNP puts aside the required funds that cannot be used for other purposes than decommissioning by the law.