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 17,716MWe in 2005. 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 spent fuel, 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 considered to construct 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. As a result of the effort, Gyeongju has been finally chosen as the location for the construction of the nation's first radwaste repository by producing the highest support rate of 89.5 percent of votes by residents conducted in four candidate communities on November 2, 2005.

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

But the policy on low-and intermediate-level radioactive waste management has been changed after the meeting of the Atomic Energy Commission on Dec. 17, 2004. The new plan for a radwaste management facility is basically to separate the site each for the low- and intermediate-level radwaste disposal facility and the spent fuel interim storage facility instead of constructing both in one site. The separated construction plan comes after the government failed to find a candidate site for a radioactive waste management complex site as none filed applications by the deadline of Nov. 30, 2004.

Meanwhile, the due date of LILW repository operation is expected to be delayed considering the construction period.

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 radioactive 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. 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 Fig. 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 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.

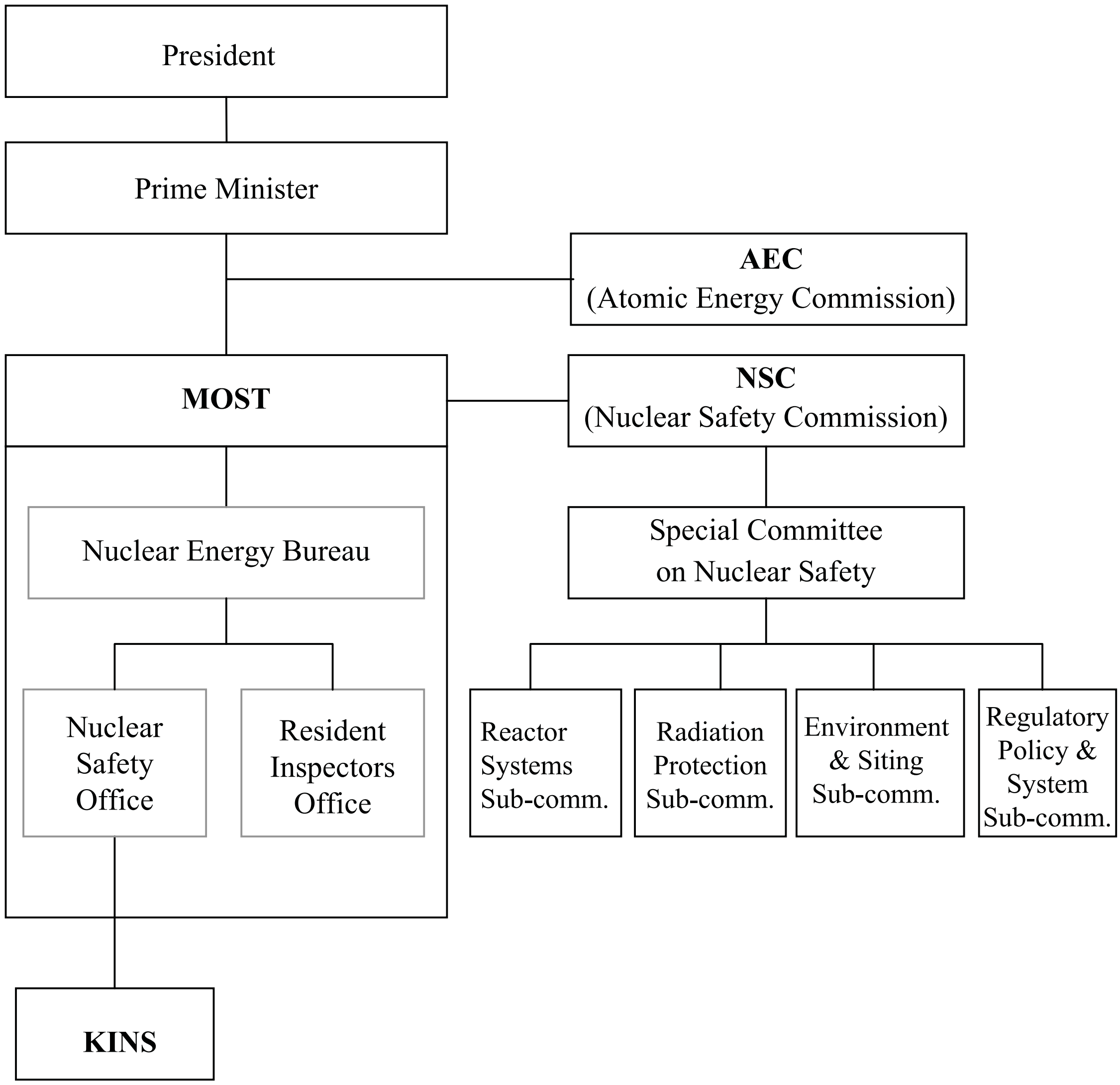

Fig. 3.5-1. Government organization on nuclear safety regulation and licensing

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 to Categorize Radioactive Waste

Radioactive waste is defined as radioactive materials or materials contaminated by them which are the object of disposal (including spent 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 4,000 Bq/g of alpha emitting nuclides with half-lives longer than 20 years, and its heat generation rate is less than 2 kW/m^3.

Wastes meet the limiting criteria of both the individual dose of less than 10 μSv/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 has now 20 commercially operating nuclear units: sixteen pressurized light water reactors(PWR) and four pressurized heavy water reactors (PHWR), and two 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 2005)

Site	Kori	Yonggwang	Ulchin	Wolsong
Operation	4	6	6	4
Under Construction	2 (Shin-Kori)	0	0	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 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 Fig. 3.5-2.

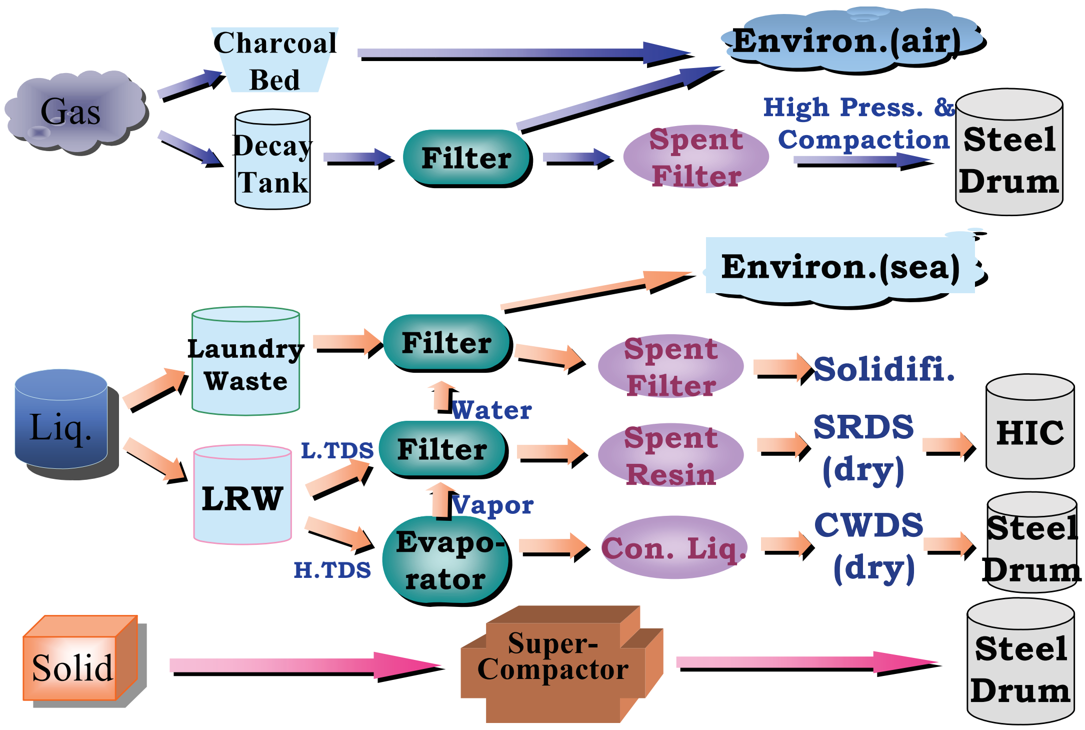

Fig. 3.5-2 Radioactive Waste Treatment Process Flow

As a result of implementing the above radioactive waste treatment system, the volume of radioactive waste had been reduced from 550 drums per reactor-year in early 1990s to 140 drums in 2003. 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, 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 based on 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 6-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.

3.5.4.2 LILW Vitrification Facility

The idea of using vitrification technology to process low-and intermediate-level radio-active waste (LILW) was considered by NETEC in the early 1990s.

An option study has demonstrated the cost effectiveness of the solution applied to the waste produced by the Korean Nuclear Power Plants (NPPs).

In 1997, NETEC conducted an investigation of high temperature technologies available on the market to process the LILW produced by NPPs. Finally, NETEC has selected the cold crucible melter (CCM) concept as the most promising vitrification technology for conditioning concentrates, ion exchange resins, and combustible solids.

In 1994 and 1995, a feasibility study was performed to assess melter technologies, to examine how innovative high temperature technologies could be implemented to achieve a large volume reduction, and to evaluate and compare these technologies from a technical and economic viewpoint.

Technical and economic assessments concluded that the best candidate was the cold cru cible process for all combustible waste. A joint NETEC-SGN-MOBIS program was launched in 1997 to develop the industrial application of the CCM for the vitrification of waste produced in the Korean NPPs.

The first step of the program, completed in 1998, was decided to orientation tests to optimize the processing of the Korean waste in the CCM and to design the off-gas treatment system.

The second step of the joint collaboration, completed in October 1999, was devoted to the design and construction of an industrial pilot plant at NETEC. This pilot facility has been
in operation since October 1999. All necessary R&D activities were completed by Aug ust, 2002.

Thereafter, a commercial vitrification program has been launched in Korea. The com mercial vitrification facility with the cooperation of the Korean government, i.e., MOCIE (Ministry of Commerce, Industry and Energy), is now being built within the radwaste bui lding at the Ulchin NPP site. The capacity of the CCM in the commercial vitrification faci lity will be about 400kW/300kHz. It may be the world first commercial vitrification facili ty to treat the LILW to be generated from commercial NPPs. In the meantime, the output of the R&D was used to the basic and detailed designs of the commercial vitrification faci lity. All designs of the vitrification facility were completed by March of 2005. The procur ement was started in June, 2006. NETEC plans to begin its commercial operation in 2008 after obtaining its operational license through the hot and cold tests. Therefore, the impl ementation of the versatile CCM technology in an industrial facility will soon be a reality and utilities will benefit from the important advantages associated with the vitrification of the waste produced in NPPs. Fig. 3.5-3 shows the bird's eye view of Ulchin vitrific ation facility.

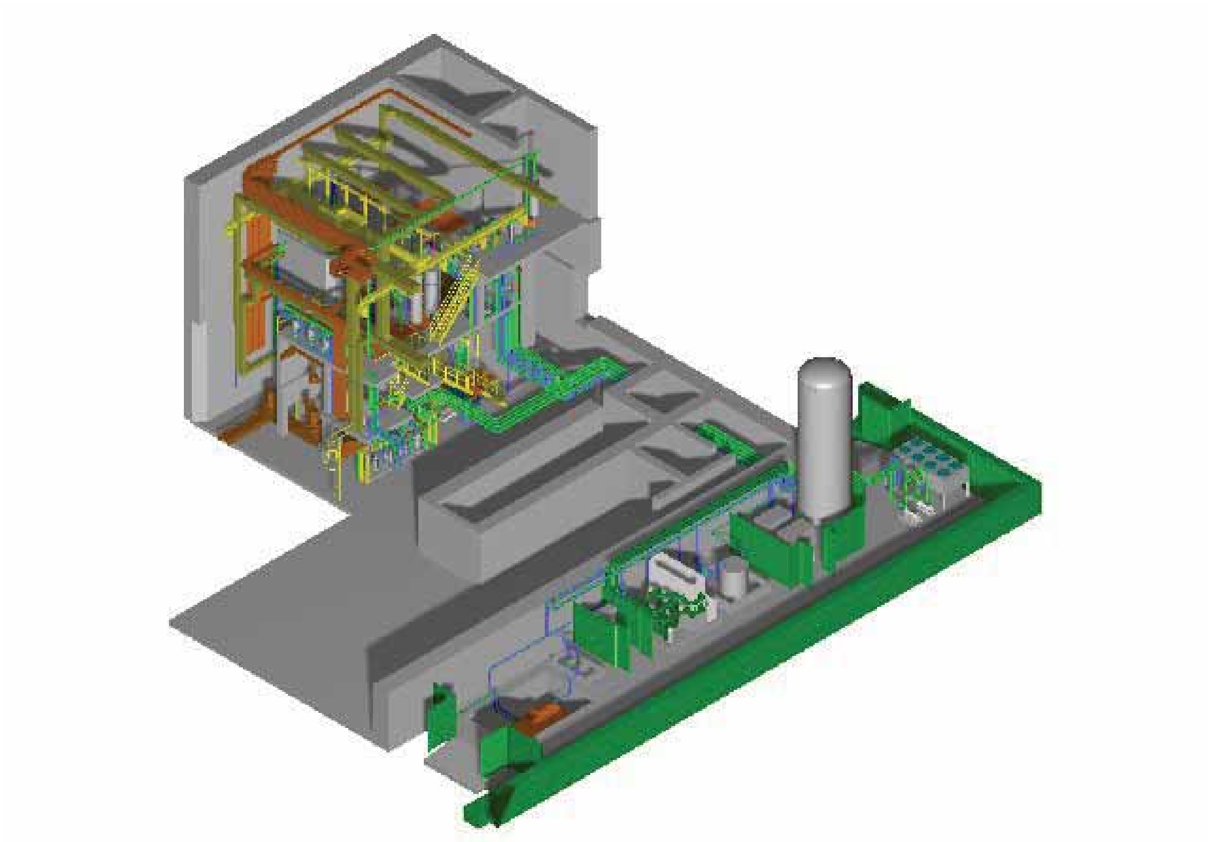

Fig. 3.5-3 Bird's eye of Ulchin vitrification facility

It is expected that the commercial vitrification facility has a sufficient capacity to vitrify all LILW generated from 4 PWR units of 1,000MWe each. Therefore, the facility would contribute to remarkable waste volume reduction effect. Accordingly, it is expected that the vitrification technology will not only enhance the safety of the waste disposal repository, but also greatly contribute to the further promotion of Korea's nuclear power generation program.

3.5.4.3 Radioisotope(RI) Waste Management Facility

There are 2,778 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 Daeduk 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 developed a system 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 clearance level waste. Spent sealed sources are stored in a special container after consolidation. Combustible dry active waste, hepatitis waste and organic liquid waste are incinerated at NETEC. The system consists of two incinerators, which have the capacity of 30 kg/hr for combustible DAW and 8 kg/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

Two alternative disposal methods, the rock cavern and the engineered vault disposal, have been considered, and the rock cavern type was determined in consideration of site conditions. Conceptual design studies and preliminary safety assessments for rock-cavern type were completed in 1993 as follows.

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.

3.5.5 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 2005 is 66,888 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 3.5-3.

Table 3.5-3 Status of LILW Storage in Nuclear Power Plants (As of December 2005)

Nuclear Power Stations		Storage Capacity (drum)	Cumulative Amount (drum)	Year of Saturation (expected)
Location	Number of Reactors			
Kori	4	50,200	34,099	2014
Yonggwang	6	23,300	14,325	2012
Ulchin	6	17,400	13,136	2008
Wolsong	4	9,000	5,328	2009
Total		99,900	66,888	

The spent fuels stored at reactor sites as of the end of 2005 are shown in Table 3.5-4.

Table 3.5-4 Status of AR Spent Fuel Storage (As of December 2005)

Nuclear Power Stations		Storage Capacity (MTU)	Cumulative Amount (MTU)	Year of Losing FCR
Location	Number of Reactors			
Kori	4	1,737	1,475	2008
Yonggwang	6	1,696	1,249	2008
Ulchin	6	1,642	949	2008
Wolsong	4	4,960	4,287	2006
Total		10,035	7,960	

The accumulated amount of RI waste from industries and hospitals by the end of 2005 is 5,185 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 3.5-5.

Table 3.5-5 RI Waste Generation (As of December 2005)

Waste Type	Storage Capacity (drum)	Cumulative Amount (drum)	Year of Saturation (expected)
Unsealed source	8,917	4,983	2010
Sealed source	360	202	
Total	9,277	5,185	

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 multi-purpose research reactor named HANARO (High-flux Advanced Neutron Application Reactor) in Daejon was begun 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.

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.