Current Status of the Radioactive Waste Treatment Facility in KAERI

D.S. Hong, S.J. Ahn, J.S. Shon, Y.Y. Ji.
Korea Atomic Energy Research Institute
150 Duckjindong, Yuseong, Daejeon, 305-353
Korea

ABSTRACT

The radioactive waste generated at KAERI (Korea Atomic Energy Research Institute) is collected, treated and stored in the RWTF (Radioactive Waste Treatment Facility). In the storage facilities of the RWTF, there are about 12,000 drums of solid wastes. These wastes should be treated and sent to a disposal facility in the future. The activities in 2005 for the disposal of this radioactive waste were the preparation of a radioactive waste certification program, a characteristics analysis of the radioactive waste for a regulatory clearance and the development of a treatment method for the uranium containing chemicals. The waste certification program was established to cover the requirements for a radiological, physical and chemical characterization, a physical/chemical restriction, prohibited items, packaging, identification, labeling and documentation. This program was set up as a preliminary program for a certification of the radioactive waste generated at KAERI and should be revised to meet the WAC (Waste Acceptance Criteria) of a disposal agency. On the other hand, the objective of the characteristics analysis was a regulatory clearance of the contaminated soil and concrete. These wastes were generated during the decommissioning process of a research reactor in 1988. The analysis results showed that more than 70% of the soil can be regulatory cleared without any treatment. Finally, a method for the treatment of a radioactive chemical waste with uranium was developed. During the development process, an acid dissolution was applied to extract the uranium from the waste sludge. The uranium concentration of the dissolved solution was estimated to be 6.97E-01 Bq/ml, and the specific activity of the final waste sheets was evaluated to be 4.3 Bq/g. Based on the efforts to reduce the amount of radioactive wastes for a disposal, the RWTF can considerably save on the disposal cost. In addition to that, a disposal can be progressed smoothly based on the developed waste certification program by meeting the requirements that will be suggested by a regulatory body or a disposal agency.

INTRODUCTION

In KAERI, radioactive wastes are generated from the HANARO Research Reactor, nuclear fuel cycle facilities and research laboratories. All these wastes are collected, treated and stored in the RWTF. The RWTF is located within KAERI and is composed of a treatment facility, a solar evaporation facility and storage facilities.

In the storage facilities, there are about 12,000 drums of solid wastes. These wastes should be treated and sent to a disposal facility in the future. As a disposal site for the low and intermediate level radioactive waste was determined in 2005 and will be operated from 2009 in GyeongJu, Korea, the RWTF is preparing to treat these radioactive wastes before sending them to the disposal facility safely.

The activities in 2005 for the disposal of this radioactive waste were the preparation of a radioactive waste certification program, a characteristics analysis of the radioactive waste for a regulatory clearance and the development of a treatment method for the uranium containing chemical.

In this study, the RWTF is briefly introduced and then the activities for the treatment of the radioactive wastes are described.

DESCRIPTION OF THE RWTF [1]

The RWTF has been operating since 1990 and has collected, treated and stored all types of low and intermediate radioactive waste generated at KAERI. The RWTF consists of the Treatment facility with 9 processes, the Solar Evaporation facility and the interim Storage Facilities. The composition of the RWTF is shown in Table I.

Table I. Facilities and Composition of the RWTF

Facility	Composition
Treatment Facility	· Liquid Waste Treatment - liquid storage process - liquid evaporation process - bituminization process · Solid Waste Treatment - compaction process - cementation process - shredding process · gas waste treatment process · decontamination process · laundry treatment process
Solar Evaporation Facility	(based on the zero release of effluent concept)
Interim Storage Facilities	· low level waste storage · Intermediate level waste storage (Monolith)

First, liquid wastes are treated by using a Solar Evaporation, Evaporation and Bituminization. Most liquid wastes generated at KAERI are a low or a very low active waste. Among them, the very low active liquid waste with a radioactivity concentration below 5E10-6 μCi/ml is transported directly to the Solar Evaporation facility and treated there. On the other hand, the low active liquid waste with a radioactivity concentration of 5E10-6 ~ 0.1 μCi/ml is treated by the evaporation process. The vapor generated from the Evaporator becomes water after being past through the condenser and the cooler. This condensate is transferred to the feeding tank of the Bituminization process.

In addition to this, a very small amount of medium active liquid waste with a radioactivity concentration above 0.1 μCi/ml is transported directly to the feeding tank of the Bituminization process. Into the Feeding tank, ground spent resin with a size below 100 μm is also transported and introduced to the Bituminization process later.

Second, solid wastes are volume-reduced or decontaminated and stored or reused depending on their radioactive level. Low active solid waste is immobilized after a volume reduction by a compacting or a cutting process. On the other hand, a medium active solid waste is cemented into a concrete cell. Additionally, contaminated equipment can be decontaminated by an ultrasonic cleaner or a sand blaster for reuse.

Third, the radioactive gas generated during the waste treatment process is filtered and released to the environment through a ventilation system after a radioactive monitoring.

Treatment Facility

The Evaporator is for the treatment of a low active liquid waste. It is a semi-batch forced circulation type and has a capacity of 1.0m^3/hr and a decontamination factor of 10E5. The heating source for the Evaporator is a steam of 105 .

Bituminization equipment is for the treatment of the concentrate of the liquid evaporation process, the medium active liquid waste and the grinded spent resin. It is a Thin Film Evaporator type with a capacity of 4 drums/day and a decontamination factor of 10E3. Straight run asphalt 60/70 for a solidification agent and thermo-oil of 230 for a heating source are used respectively. The feeding rate of the waste is 5~40 liter/hr and the flow rate of the asphalt is 5~20 liter/hr. The waste is mixed with asphalt and then they are vaporized simultaneously. After this process has been completed the vapor is sent to the low active waste storage tank through the condenser and the asphalt mixture drops down into the drum. The temperature of the dropped bituminized product is about 160 . When the bituminized product has half-filled the drum, the drum is replaced. After a cooling, the half-filled drum is filled-up more.

The Solar Evaporation Facility for the treatment of very low active liquid waste is an isolated building. It is operating under the basic of a 'Zero Release of radioactive effluent' outside of KAERI. It has 4 floors above ground and a basement. The second floor and the third floor have glass walls to receive the solar energy efficiently. In the Solar evaporation facility there is a storage pool, evaporation units, exhaust fans and an air monitoring system. The liquid waste for a treatment is transported by using a tank lorry and stored in a storage pool with a capacity of 860 m^3. This effluent is transferred to the intermediate buffer tank by a pump. And then the effluent is sent to the supply tank by a circulation pump through a filter. In the evaporation unit, the effluent flows down along the cloth sheets in contact with the air blowing upward. The Solar Evaporation Facility is not operated during the winter as the water freezes and the evaporation efficiency is very low. The spent evaporation media and the concentrate generated from the facility are sent to the RWTF.

Storage Facilities

There are two interim storage facilities at KAERI. One is for the low level waste and the other is for the intermediate level waste. The low level solid waste is collected in a 200 liter drum and the annual generation rate is about 350 drums.

The intermediate level wastes generated in a hot cell are stored in a facility called Monolith. In the Monolith facility with a capacity of 1,132 drums, the intermediate wastes are stored in a 50 liter drum. After 5~6 years of storage, the intermediate level wastes are reclassified depending on their radioactivity level. Medium active solid waste is cemented in a concrete cell while low active solid waste is immobilized after a volume reduction by a compacting or a cutting process.

PLAN FOR WASTE CERTIFICATION PROGRAM [2]

The regulations for the low and intermediate level radioactive waste to be transferred to the disposal facility were revised recently and now they require that radioactive waste generators should set up a waste certification program (WCP). The objective of the WCP is to verify that the radioactive waste conforms to the waste acceptance criteria (WAC) before a disposal. This WAC is composed of the requirements for a radiological characterization, physical and chemical characterization, a physical/chemical restriction, prohibited items, packaging, identification, labeling and documentation. For a compliance with these criteria, waste generators should verify that all the radioactive wastes meet the WAC through their own WCP and they are also responsible for submitting all the certification documents to the disposal facility. This WCP plan was set up as a preliminary program for a certification of the radioactive waste generated at KAERI and it needs to be further revised for the preparation of a WAC by a disposal agency. The WCP plan is described in detail in the following.

Waste Management Records [3]

Each waste management organization should have a documented records system. The system should be established by each organization and be integrated with the overall waste management record keeping system. The system should provide for a generation, approval, transmittal, possible correction and/or supersedence, maintenance, retention and disposition of all records important to safety. As a result, these records should include the following

- Data for a waste inventory
- Data for a characterization of a waste
- Records from the treatment, conditioning and packaging
- Documents on the procurement of containers required to provide a confinement for a specified period
- Specifications for waste packages and audit records of individual containers and packages
- Reports on a non-compliance with the specifications for waste packages and the actions taken to rectify them
- Records on a radiation monitoring
- Operational procedure
- Any additional data required by the regulatory body.

All the records should be classified as permanent records or non-permanent records by each organization involved in a radioactive wastes management. Generally, procedures may not be permanent if the recorded results can be interpreted without recourse to them. However, when the interpretation of results depends on knowledge of the procedures, both the results and records should be classified as permanent.

As a plan for a radioactive waste certification, minimum content of records during a waste processing, storage and transporting was identified. For the requirements of the record contents, the related organizations were classified as a generator, conditioner, storage facility, transporter, and disposal facility. Among these organizations, the RWTF can be a generator, a conditioner, a storage facility and even a transporter. So, the minimum content of the records during a waste processing and storage is as listed in Table II.

Table II. Minimum content of the records during a waste processing and storage

Organization	Required record content
Generator	- Documentary process knowledge - Traceability to assay reports - Analytical characterization of raw waste - Pretreatment and treatment processing - Traceability of package sent for conditioning to raw waste source
Conditioner	- Traceability from a generator documentation to a final package identification - Processing records including data on critical processing parameters - Assay records - Chemical and radionuclide characterization of conditioned waste - Records of inspections required by the waste acceptance criteria - Other specific attributes required by the waste acceptance criteria - Independent inspection records - Non-conformance records
Storage facility	- Traceability of container identification to waste package records - Location of individual packages - Records of periodic inspection/monitoring - Records of storage conditions
Transporter	- Radionuclide inventory, external radiation field, surface contamination, presence of shielding, fissile mass - Venting of container and flammable gas generation rate, if applicable - Records of incidents or accidents during transport

Organization and Responsibilities

To assure a wastes management activities such as a collection, treatment, interim storage and disposal meet the WAC of a disposal facility, a specific organization at KAERI should be established. The organization for a radioactive waste certification will be composed of a head for a radioactive waste management, a leader for radioactive waste certification, a certification manager, a certification inspector and a quality assurance manager.

The head of the radioactive waste management is in charge of the safe management of the waste and keeping and recording all the data generated during the management process. In addition to that, he/she should manage the waste certification program efficiently and submit all the related documents to the disposal facility with the waste.

On the other hand, the leader of the radioactive waste certification has the responsibility for a waste certification. The leader should develop and revise the certification program to maintain the certification activity efficiently and he/she should manage and supervise a correction of the records for all the certification data.

And the certification manager has the responsibility of certifying all the records and data necessary for the documentation in that all the waste drums transferred to the disposal facility meet all the criteria. The certification manager has to take part in all the processes such as collecting, testing, treating, and storing the radioactive waste. So, the manager must check to see whether the data are produced correctly and the records are complete.

Also the certification inspector is in charge of inspecting all the waste drums and certification documents and certifying that the waste drums meet the requirements of a disposal facility in terms of their packaging and recording. When any non-compliance is detected, the inspector should report a non-compliance with the specifications for the waste packages and take action to rectify them.

Finally, the quality assurance manager has to perform a quality assurance and to supervise the waste characterization and certification to ensure they need the quality requirements of the waste certification plan.

Certification Procedure

Certified waste is a waste that has been confirmed to comply with the WCP of the disposal agency under an approved certification program. Certification is the process of assuring that each waste package complies with all the applicable criteria for an offsite shipment, storage and disposal.

The management of a radioactive waste can be divided into 4 phases; generation phase, waste treatment/packaging phase, storage phase, and transport phase. The waste certification should be achieved in these 4 phases.

RADIOACTIVITY ANALYSIS OF CONTAMINATED SOIL AND CONCRETE [1]

In the radioactive waste storage facilities at KAERI, about 3,200drums of contaminated soils and concretes have been stored since their generation in 1988. The soils and concretes were generated during the decommissioning process of a research reactor and its attached facilities in Seoul. To secure the storage capacity and to reduce the disposal and management cost, these soils and concretes must be treated and reduced in volume. For a treatment, the radiological characteristics of the soils and concretes need to be analyzed. So, the RWTF not only developed the equipment and working procedure but also analyzed the radioactivity concentration of the soils and concretes.

Equipment Development

For an easy and safe treatment of a drum containing soil or concrete and for a contamination restriction, some tools were developed and applied to the sampling and the classification operation.

As the equipment for a contamination restriction, two airtight working booths and a ventilation system were developed. One of the booths was for a soil sampling and the other was for a concrete sampling which was more complicated due to a crushing process. When the samples for the analysis were being taken in the working booth, a ventilation system was attached to the working booth and operated. The purposes of the ventilation system were the provision of fresh air to the workers and a reduction of the internal dose to the workers by removing the radioactive dust released from the soil and the concrete.

For an easy sampling, a stainless steel tray and a sampling grid were designed. The tray can hold the soils or the concretes contained in a package drum and a 10 × 10 grid which can create 100 even sections of the poured soils or concretes in a tray. As a hole with a cover is located in the center of the tray, after a sampling, the remaining soils can be discharged to the packaging drum easily.

Working Procedure Development

For an identification of the radioactivity in the soils and concretes, a systematic working process was developed. This process is briefly described below.

First, a drum appropriate for a sampling is selected. Then, by unsealing it, the contents of the drum are re-identified. After recording the surface dose rate, the contents of the drum are poured onto a tray. Following a homogenization of the soil or the concrete, a sampling is performed. The sample is then transferred for an analysis. By the result of the radioactivity measurement, the waste drum is categorized as a radioactive waste or an objective for a regulatory clearance. Figure 1 shows a schematic diagram of the working procedure.

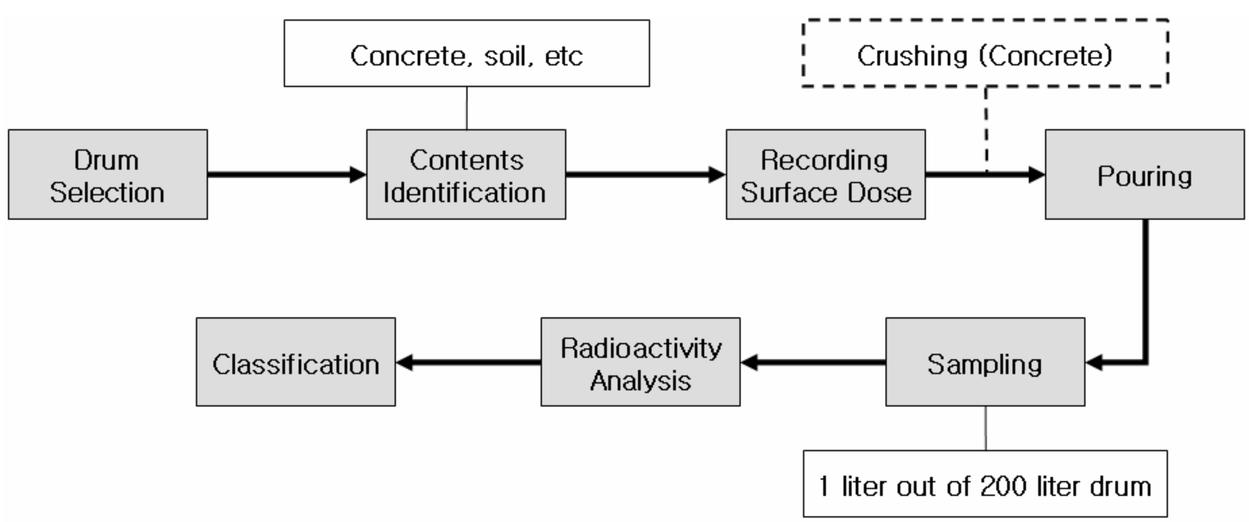

Fig. 1. Working procedure for sampling and classification

Results

According to the analysis results, the major radionuclides in the contaminated soils concretes were Co-60 and Cs-137. On the other hand, as minor nuclides, small amounts of Mn054, Fe-59, I-131, Cs-134 and Eu-15 were detected. The distribution of the radioactivity concentration based on the analysis result of about 2,600 drums of the soil and concrete is shown in Figure 2. As shown, about 70% of the waste drums show a radioactivity concentration below 0.1 Bq/g. These drums can be regulatory cleared without any treatment.

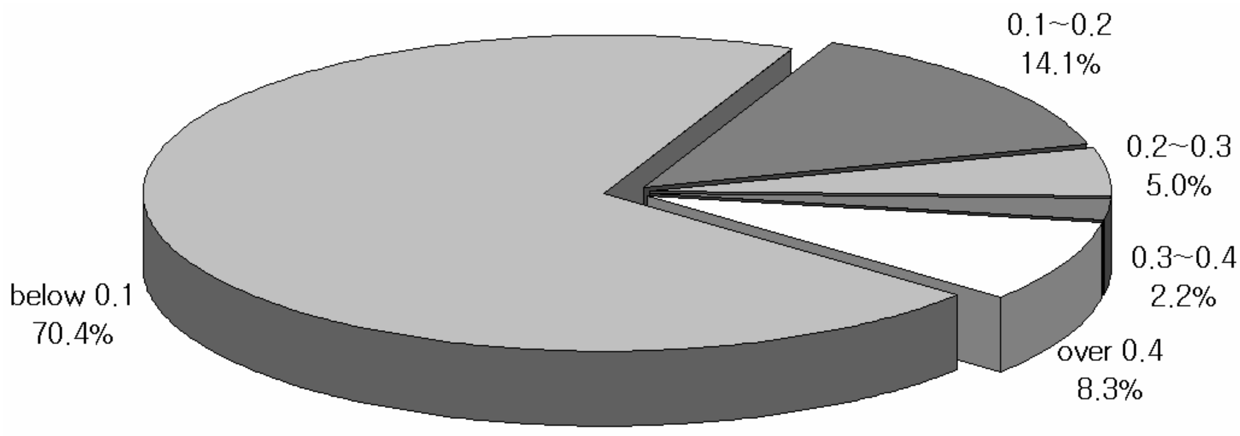

Fig. 2. Distribution of radioactivity concentration [Bq/g]

METHOD FOR THE TREATEMENT OF CHEMICAL WASTES WITH URANIUM [4]

Chemical liquid wastes are generated during the operation of nuclear facilities and the experiments at R&D laboratories. After a treatment of these wastes using a precipitation method, the analysis result of the dry cake produced as a byproduct of a treatment shows that the uranium concentration in the final dried cake is about 11.2 Bq/g. This concentration exceeds the exemption level of 10 Bq/g for each uranium isotope of U-234, U-235 and U-238, so the cake is categorized as a radioactive waste and a treatment method is necessary.

Material and Method

Acid dissolution was applied to extract the uranium from the waste sludge, and a uranium adsorption of the dissolved solution was investigated. At the experiment, as ion exchange resins for the uranium adsorption, IRN-77 and bead resin with 4% Diphosil in which the Diphosil powder is fixed to a sodium alginate phase were applied. The Diphosil was a silica diphonix resin with 60-100 mesh powder and the IRN-77 was an amberlite, cation (H^+) with a size of 1.18-0.3mm.

To separate the uranium from the precipitate in the sludge generated during the waste treatment process, an elution by using a strong nitric acid was applied. To investigate the characteristics of the dissolution in the acid, the ratio of acid solution added to the sludge was varied at 1/4, 1/2, 1 and 2 and the differences were observed. Additionally, to identify the precipitation property of each resin, uranium removal from the waste liquid and the uranium dissolved acid solution was measured.

Results

Uranium dissolution results are shown in Table III. As shown, the dissolved uranium concentration decreases as the amount of added acid increases. But when the uranium concentrations are converted based on the sludge contents, they are in a similar range. So, it can be concluded that the reaction does not depend that much on the amount of nitric acid or heating. Also, as the uranium concentration in the precipitate decreases to less than 0.25ppm after an acid dissolution, it is concluded that the uranium can be eluted from the sludge precipitate.

Table III. Effect of Amount of HNO_3 on a Uranium Dissolution from the Waste Sludge

Sludge : Acid [ml] (ratio)	Uranium Concentrations [mg/liter] (measured value × sludge ratio)	
	Stirring	Stirring and heating (65)
24:6 (4:1)	2.0	2.2
20:10 (2:1)	1.7 (2.04)	1.7 (2.04)
15:15 (1:1)	1.4 (2.4)	1.3 (2.08)
10:20 (1:2)	1.0 (2.4)	0.9 (2.16)

The results of the precipitation experiment with 10ml dissolved solution show that a large amount of resin was required to obtain more than an 80% uranium removal. The result was found to be due to the large amount of metal ions simultaneously dissolved from the precipitates with the uranium. The adsorption characteristics of IRN-77 and the Diphosil bead are shown in Figure 3. So, it can be concluded that an ion exchange method for a removal of uranium from a dissolved acid solution is not efficient.

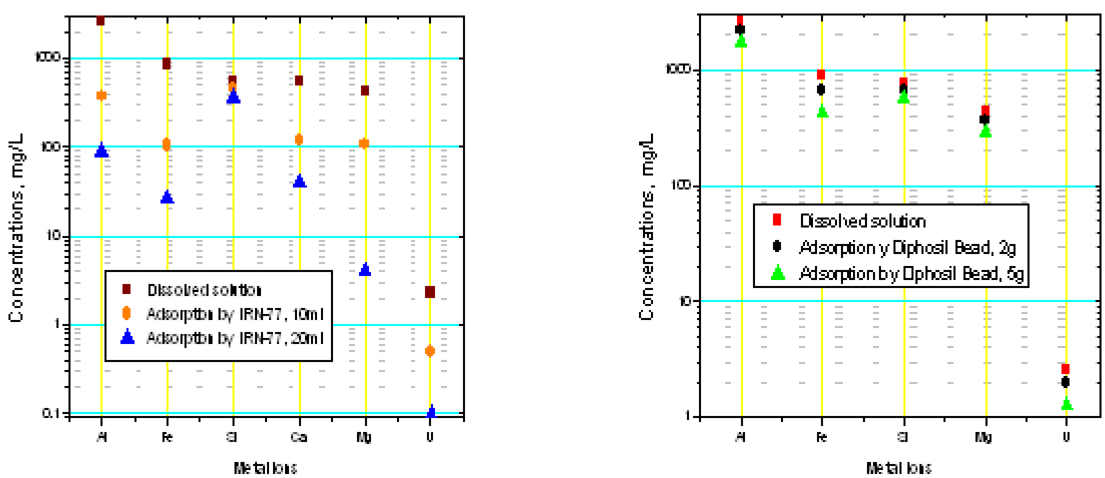

Fig. 3. Adsorption of uranium by IRN-77 and Diphosil bead

As an alternative method, an acid dissolution was applied to the dewatered wet cake of the sludge, and a solar evaporation was applied to the dissolved solution. The uranium concentration of the dissolved solution was estimated to be 6.97E-01 Bq/ml, and the specific activity of the final waste sheets (solar evaporation media) was evaluated to be 4.3 Bq/g as shown in Table IV. As the radioactivity concentration of the final waste sheets is below the exemption level, these sheets are most likely to be regulatory cleared. These results lead to the suggestion that the application of an acid dissolution to a wet cake and a solar evaporation for a dissolved solution is an effective treatment method for chemical wastes containing uranium.

Table IV. Evaluation of the Activity in the Spent Evaporation Media

Dry cake [m^3/yr]	Precipitates [m3/yr]	U concentration [Bq/g]	Annual activity [MBq]	Evaporation media		Dilution Factor	Specific Activity [Bq/g]
				Units [Sheets]	Weight [g/SH]		
4.0	2.4	11.2	26.88	1,000	788	8	4.3

CONCLUSION

The RWTF at KAERI has collected, treated and temporary stored all the radioactive wastes generated at KAERI during the operation of HANARO Research Reactor and the R&D activities. Also, the RWTF has developed and applied equipment and a procedure for a waste treatment. In addition to this, as a disposal site for the low and intermediate level radioactive waste was determined in 2005 and will begin operation from 2009 in GyeongJu, Korea, the RWTF is preparing to treat radioactive wastes before sending them to the disposal facility safely.

In 2005, the RWTF set up a plan for a waste certification program. From this, the records necessary for a waste management and a relevant organization as well as its responsibilities were identified. Also, the certification procedure was briefly determined.

To reduce the volume of the radioactive waste and to save on the disposal and management cost, the radioactive characteristics of the contaminated soil and concrete were analyzed. For the analysis, equipment such as an airtight working booth, a ventilation system, a stainless steel tray and a 10×10 sampling grid were developed and applied to the sampling operation. The analysis result shows that among the 2,600 drums of soil and concrete, about 70% of the waste can be regulatory cleared without any treatment. By this regulatory clearance, we can save on the disposal cost by ten billion Korean Won.

To treat a uranium containing chemical waste, an acid dissolution was applied to extract the uranium from the waste sludge. The uranium concentration of the dissolved solution was estimated to be 6.97E-01 Bq/ml, and the specific activity of the final waste sheets was evaluated to be 4.3 Bq/g

Based on all the efforts to reduce the amount of radioactive wastes for a disposal, the RWTF can considerably save on the disposal cost. In addition to this, a disposal can be progressed smoothly based on the developed waste certification program by meeting the requirements that will be suggested by a regulatory body or a disposal agency in Korea.

REFERENCES

1. KAERI, 2006, *Operation of Radioactive Waste Treatment Facility*, KAERI/MR-438/2005.
2. S. J. Ahn, T. K. Kim, Y. H. Lee, and I. S. Kang (2006). Low and Intermediate Level Radioactive Waste Certification Program Plan*. J. of the Korea Radioactive Waste Society. Vol. 4(2), P. 187-195*
3. IAEA, 2005, *Methods for Maintaining a Record of Waste Packages during Waste Processing and Storage*, Technical Reports Series No. 434.
4. K. J. Kim, J. S. Shon, and K. P. Hong (2006). Alternative Method for the Treatment of Chemical Wastes Containing Uranium*. J. of the Korea Radioactive Waste Society. Vol. 4(2), P. 179-186*