THE STATUS OF RADIOACTIVE WASTE MANAGEMENT

AND

ITS POLICY IN THE REPUBLIC OF KOREA

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ABSTRACT

This paper covers the status of radioactive waste management and the national policy for radioactive waste management in Korea, including current and projected radioactive waste management practices and organizational responsibilities. It develops and discusses the recently formulated criteria for the acceptance of packaged radioactive waste for disposal. Possible disposal methods are discussed, along with further considerations including research and development (R&D) on radioactive waste management and disposal which are especially directed to the situation of Korea as a developing country embarking on a nuclear power program.

STATUS OF RADWASTE MANAGEMENT

The Republic of Korea has five nuclear power units in operation and four others under construction. Current plans are to construct around five more nuclear power units during the next 14 years. Consequently, around 14 nuclear power units should be in operation in Korea by the year 2000. These units will range from 550 to 950 Mwe and, by the year 2000, are expected to produce about 4000 MT of spent nuclear fuel and around 350,000 200 L drums of low- and intermediate- level radioactive solid wastes which, for purposes of this paper, will hence forth be designated as radwaste.

A significant amount of radwaste also is expected to arise eventually from the industrial and institutional application of radioisotopes and some R&D activities. While the amount of this waste still is relatively small with respect to that coming from the nuclear power units, its quantity will be increasing with the economic development of Korean industry. There currently are around 350 licensed users of radioisotopes in Korea.

Spent nuclear fuel is being stored at each nuclear power plant site. The current sites are expected to fill their fuel storage capacities by 1995. The packaged radwastes are also being stored on-site in concrete, interim storage buildings at the nuclear power plants. Current storage capability at each site is for packaged radwaste resulting from 10 years of operations. With respect to this storage, there are some serious concerns regarding corrosion of the containers and the radiological hazard to the operators.

The expected accumulation of spent fuel and packaged radwaste in Korea is depicted in Fig. 1. In view of these accumulations, the Korea Advanced Energy Research Institute (KAERI) initiated research and studies in the early 1980's to develop a suitable radwaste management policy for Korea. Interested organizations including the Korea Electric Power Corporation (KEPCO), Korea Institute of Energy and Resources (KIER) and Korea Power Engineering Company (KOPEC), later participated in this research and the studies[1] that, during 1984, were reviewed and considered by a special task force, established to recommend a radwaste management policy to the Korea Atomic Energy Committee (KAEC). On the basis of the task force's recommendations, the KAEC established in October 1984 a radwaste management policy that stipulates:

1. Low and intermediate-level radioactive wastes (radwastes) are to be disposed into a terrestrial environment (land disposal). Disposal into the deep ocean (ocean disposal) may be considered later;
2. A centralized disposal site for the packaged low- and intermediate-level radioactive waste (radwaste) is to be located outside of the existing nuclear power plant sites;
3. The costs or expenses needed for the management and disposal of the radwaste are to be paid by the waste generators;
4. A radwaste management agency will be established as a national non-profit organization to carry out the foregoing responsibilities; and
5. The activities of the agency will not include the management of spent nuclear fuel for the time being. However, the agency is to assess and recommend a management plan and policy for spent nuclear fuel.

In June 1985, KAEC designated the Korea Nuclear Fuel Company (KNFC) as the organization with the exclusive responsibility for radwaste management in Korea which included:

1. The establishment of appropriate radwaste management technology and guidelines for its use;
2. The collection and treatment of radwaste resulting from the application and uses of radioisotopes;

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3. The safe disposal of solid and solidified low- and intermediate-level radioactive wastes (radwastes); and

4. Execute the decommissioning of nuclear facilities and the management of spent fuel.

Figure 2 presents the current licensing and regulatory responsibilities for nuclear energy in Korea which come under the Ministry of Science and Technology (MOST). The darkened blocks indicated the organizations that are directly involved in the safe management and disposal of the radwastes. The Nuclear Safety Center (NSC), under KAERI is responsible for developing standards suitable to the Korean environment. The NSC also services the Atomic Energy Bureau by evaluating and assessing all safety analysis reports and deals with radiation protection, emergency preparedness, inspection, and audit of nuclear facilities.

RADWASTE ACCEPTANCE CRITERIA

KNFC faces two important objectives in its responsibilities as far as low- and intermediate-level radioactive waste (radwaste) is concerned. One objective is to furnish the waste generators with technical guidelines regarding how to manage their radwaste for disposal. The other one is to construct and operate a disposal repository. The former objective is deemed to be a prequisite but is interrelated[2] with the disposal concept and the disposal method to be established.

In order to initiate performance of the two objectives, a working group within KAERI's Radwaste Division* formulated 25 criteria** for the acceptance of packaged radwaste at the disposal site (radwaste acceptance criteria)[3]. These criteria cover the desirable properties[4-9] of a radwaste package (the waste form plus container) which include:

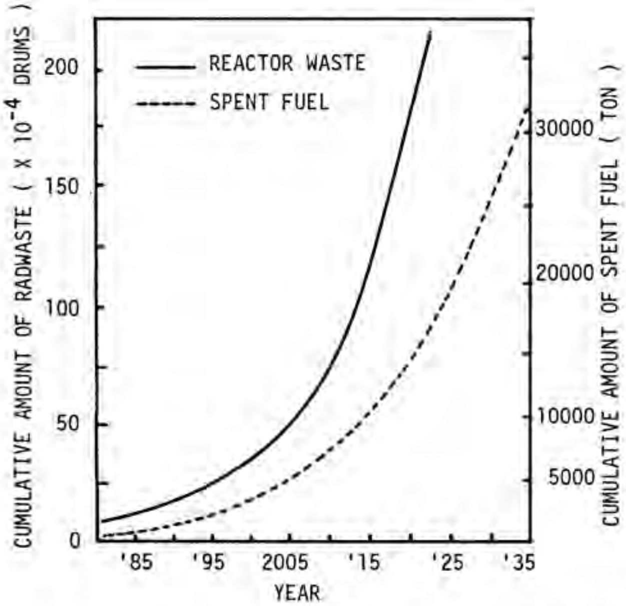

Fig. 1. Projection of Radwaste and Spent Fuel Arisings.

1. Sufficient chemical, mechanical, biological, thermal and radiation stability:

2. Sufficient compatibility with the disposal medium and environment:

3. Low specific surface area with a low leaching rate of the form, including the radionuclides;

4. Solid form with low dispersibility;

5. Low content of nondegradable toxic chemicals;

6. Non combustible; and

7. Appropriate packaging for ease of handling and transporting.

Not all of the foregoing desirable properties of a radwaste package necessarily need to be met if the characteristics of the disposal site or special engineered disposal methods can compensate for their absence. Nevertheless, it is felt that radwaste acceptance criteria should not be relaxed in the absence of such knowledge. However, the criteria can be adjusted later to suit the conditions of the disposal site and disposal methodology when they become known.

It recently has been recognized that, in many instances, radwaste may contain toxic, pathogenic, or mutagenic materials or chemicals that will remain in the disposal area, continuing to present a hazard to ecological systems and humans, long after the radiological hazard has ceased to exist. While, generally not included specifically in the radwaste acceptance criteria, such hazardous material and chemicals should be accounted for and be either removed or destroyed or rendered to a permanetly safe form in the packaged waste prior to its disposal.

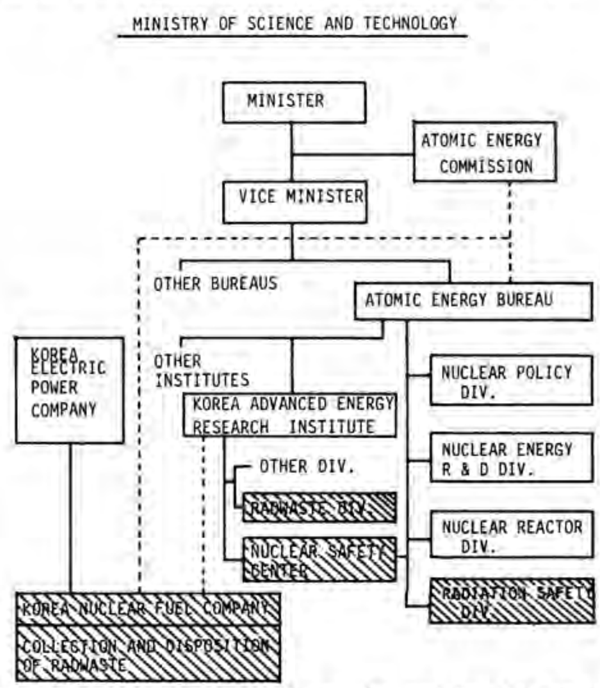

Fig. 2. Organization of Licensing and Regulation of Nuclear Energy in Korea.

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* Members of the Radwaste Division is to be transferred to KNFC.

** Refer to the Appendix.

The 25 radwaste acceptance criteria are being recommended for giving basic guidelines to the radwaste generators, as well as to the radwaste management organization in the absence of:

1. A selected disposal site;
2. A planned method of disposal; and
3. Knowledge of the radiological objectives for the long term.

FURTHER CONSIDERATIONS

In the course of drafting the radwaste acceptance criteria, several important subjects were encountered concerning radwaste disposal; namely, limitations on the content of certain radionuclides and waste classification, current waste packaging practices, quality control/quality assurance (QC/QA), disposal alternatives, and assessment of disposal safety.

Radionuclide Content and Waste Classification

After reviewing the radwaste acceptance criteria KEPCO people commented that they seemed to be reasonable and acceptable with the exception of the first criterion, to wit: "The radionuclide content, radioactivity and composition of the waste form should be known and identified with sufficient accuracy to ensure compliance with this radwaste acceptance criteria and/or authorized limits or exceptions." It was pointed out to KEPCO that the radwaste acceptance criteria, as proposed, did not require quantitative determination.

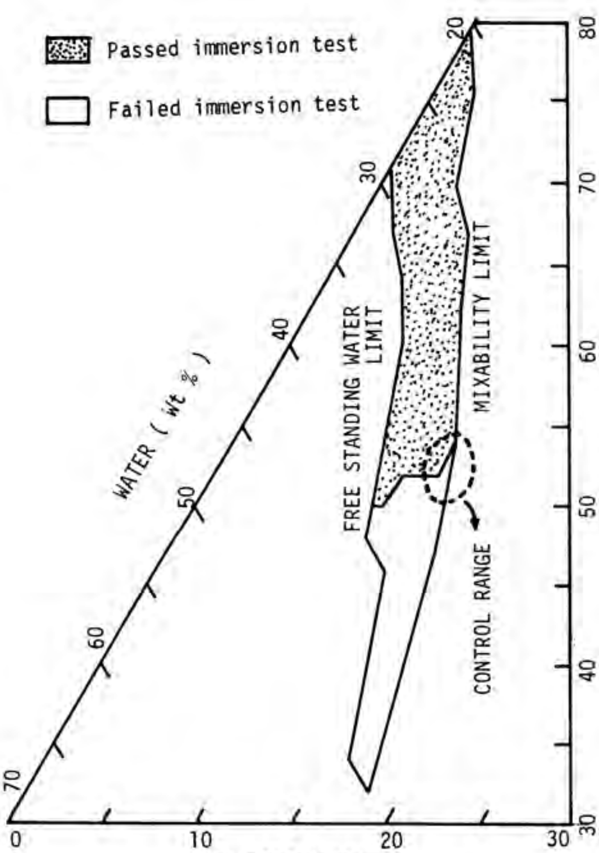

Fig. 3. Phase Diagram of Cement-Water-Resin Mixture.

It would be somewhat presumptrous to establish limitations on specific radionuclides without some idea of the disposal site, methodology, and objectives. On the other hand, if the disposal site and methodology are suitable, it may not be necessary to establish limitations on specific shorter half-life (less than a few decades) radionuclides having significant radioactivity. The disposal method could be adjusted to the radiation levels of the package (e.g., whether the package can be contact handled or must be handled remotely) which obviously is a much simpler approach, nor does it necessarily extend the period that the repository needs to remain under institutional controls.

Radiological limitations on packaged radwaste are usually based on the specific activities and total quantities of radionuclides that are contained in the package which can be accepted for disposal at a specific site of repository. The radwastes that are buried in shallow ground are, of course, more vulnerable to natural surface processes of dispersion and exposure and to human intrusion than if they were placed in deeper repositories. Under the circumstances, it would appear more workable at this time for radwaste acceptance criteria in Korea to be based on total radioactivity levels with maximum limitations on transuranics and certain other long half-life radionuclides rather than classifying the waste on the basis of volumetric concentrations of specific radionuclides.

Concerning the classification: It is planned to establish a criterion to define very low-level radwaste, possibly from applications and uses of radioisotopes and from decommissioning nuclear facilities, which may not necessarily have to be considered as radwaste. This criterion will have to be determined from safety and risk assessment, considering a specific disposal site and repository.

Current Packaging Practices and QC/QA

In PWR-type nuclear power units in Korea, concentrated liquid waste and spent resin beads are solidified (or immobilized) by cementation. The solidified wastes are packaged in carbon steel, 200 L drums. A few of the drums apparently have been

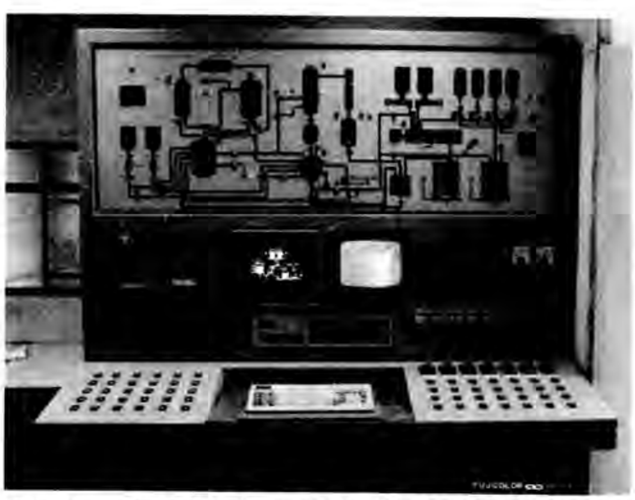

Fig. 4. Control Scheme of the Testing Facility for the Reactor Waste Treatment System.

corroded by free liquid to the extent that they are leaking. This could be a violation of criterion 3 that recommends "Waste and/or waste forms containing free liquid are not acceptable for disposal." To cope with this problem, the Radwaste Division is carrying out R&D on cementation with the concentrate and the spent resin with the objective of improving the performance of the cementation process together with the mixing conditions. The conditions include knowledge of solid waste form and the ratio of the components. Figure 3 shows an example of the phase diagram that has been developed from batch experiments that are expected to result in predicting the optimum cementation conditions applicable to the nuclear power plants.

A pilot scale liquid waste treatment system, shown by Fig. 4, simulating a typical radwaste treatment process in PWRs has been fabricated for process performance testing. Primary attention is being given to the cementation process with which controllability is to be tested in order to know how to guarantee (QC) a uniform solid product using an optimum ratio of components, as depicted in Fig. 3. For this purpose, flow rates of cement and waste as well as weight of solidified product are measured continously in the process to evaluate the feasibility of adjusting material balance[10] by means of computerized feedback control. The permissible range of free or free-standing liquid and other properties in relation to radwaste disposal alternatives is to be determined also. In addition, testing methods for selected properties of the solid waste should be developed as a means of quality assurance.[11]

In the PHWR-type unit, all of the liquid is purified by resin powder to the extent that it can be released. After its usage, the loaded resin powder is stored in large concrete tanks for not less than 10 years which could be much longer. The loaded resin powder is to be immobilized for disposal, considering criterion 4: "Ash or ashes, ion exchange resin, powders, and other particulate radwaste material must be stabilized to a solid, monolithic form." Consequently, preliminary studies on bituminization, polymerization as well as the cementation for the resin powder are underway in the Radwaste Division.

Disposal Alternatives

The foregoing discussions emphasized that the disposal site and methodology should be determined in order to arrive at more specific radwaste acceptance criteria. In this regard, a preliminary study has characterized Korea's environment for radwaste disposal, followed by an evaluation of disposal alternatives that might be applicable.

The Republic of Korea has heavy rainfall (110 to 140 cm), with 50 to 60 percent of the total amount falling during the summer (3 months). The country has a high population density (200 to 300 persons/km^2 for the southern costal area) and is mountainous (75%). These statistics imply that the probability of public acceptance and human intrusion could be very important considerations for the location of a disposal site and the safety of disposal. With respect to geology, the groundwater table in the Republic is shallow (usually 4 to 5 m) and argillaceous formations are not abundant. Indeed, what clay deposits there are are being used and are considered a resource. On the other hand, stable granite formations can be found in many areas of the country.

In general, land disposal alternatives for packaged radwaste are shallow, land burial, engineered trench burial, and cavity disposal. At first sight, shallow, land burial in Korea is not thought to be suitable when considering the specific environment that should be used. A quantitative safety and economic analysis is to be made for the other two alternatives before one of them is definitely chosen. At this time, cavity in granite rock seems to be more applicable with respect to safety while preliminary cost estimates showed not much difference between the latter two alternatives (engineered trench versus cavity) in terms of disposal cost per unit volume of waste package. In addition, considerations are being given to locating a radwaste repository nearby the sea coast where the concentrations of any escaping radionuclides would be quickly diluted and dispersed.

Safety Assessment

In previous discussions, safety assessment has to be an essential fundamental factor that can assist in establishing quantitative guidelines for radwaste disposal, including acceptance criteria and in making definitive decision on disposal methodology.

The safety assessment can be realized essentially by an accident analysis and a consequence analysis as shown by Fig. 5. Disposal safety is guaranteed by three barriers; namely, packaged radwaste, repository and site. Groundwater permeates into the radwaste packages and leaches out radionuclides before it travels back through the barriers to human bodies. In the course of the flow, groundwater movement (accident analysis) and radionuclide transport (consequence analysis; leaching, migration and dose) can be minimized due to the resistance of the barriers. Here, each barrier shears the resistance and this explains how the acceptance criteria and the disposal performance are interrelated.

A complete safety assessment requires long time and various experiments. But, in practive, the use of computer codes[12-15] that are established for such a purpose have been suggested and each stage of

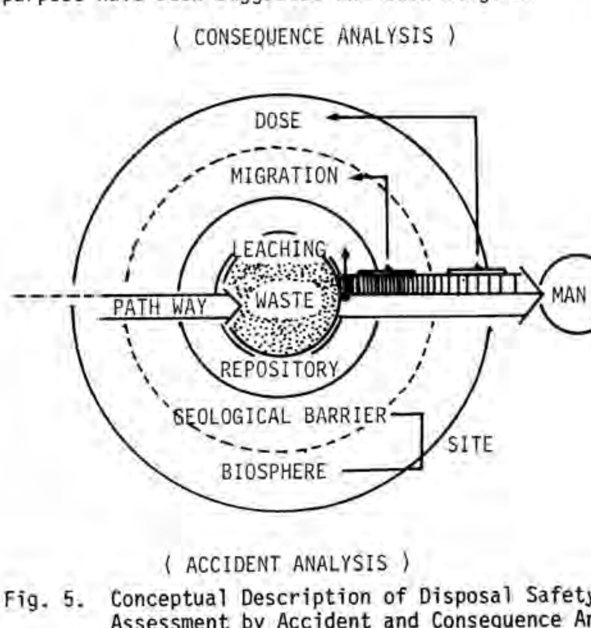

Fig. 5. Conceptual Description of Disposal Safety Assessment by Accident and Consequence Analysis along with Multiple Barriers: Waste Package, Repository and Site.

disposal selection and performance (site selection, design and construction, operation, transportation, etc.) necessitates different levels of analysis. A simplified code can be established primarily by compromising existing concepts and codes with specific regional perameters such as retardation factors and hydrolic permeability in soil and rock. The more sophisticated analysis will have to be done, as a second step, to meet the safety assessment requirements at the repository design stage by around 1989 in compliance with the national radwaste mangement plan that stipulates commissioning of the repository in the early 1990's. Laboratory experiments and field testing on the underground radionuclide movement now are planned to verify the feasibility of established methods of analysis.

CONCLUSIONS

In order to meet the management requirements for the increasing amount of radwastes, the Republic of Korea established a radwaste management policy that stipulated disposal in a terrestrial envioronment (land disposal) and the principle that the waste generator pays the costs and has designated KNFC as the responsible organization for radwaste management under the government control.

A packaged radwaste acceptance criteria has been conceived for initiating the execution of KNFC's responsibilities. Based on the criteria, several considerations are discussed which include limitations on radionuclide content and waste classification, current packaging practices and QC/QA, disposal alternatives, and safety assessment. These considerations result in basic guidelines on radwaste management not only to the responsible management organization but also to the waste producers.

Future R&D work is envisaged on radwaste packaging and safety assessment to provide more detailed guideance and technology within the necessary time.

REFERENCES

1. H. H. Park, K. W. Han, et.al. "Development of Radwaste Treatment and Disposal Technology," KAERI/RR-403/83, 1984.

2. "Characteristics of Radioactive Waste Forms Conditioned for Storage and Disposal - Guide for the Development of Waste Acceptance Criteria," IAEA TECDOC-285, 1983.

3. William L. Lenneman, "Nuclear Waste Management," A Final Report to the Div. of Technical Assistance and Cooperation, IAEA Under IAEA Project No. ROK/9/022-01, 1985.

4. "Criteria for Underground Disposal of Radioactive Waste," Section 5.3, IAEA Safety Series No. 60.

5. "Shallow Ground Disposal of Radioactive Waste: A Guide Book," Ch. 5, IAEA Safety Series No. 53.

6. "Underground Disposal of Radioactive Waste, Basic Guidance," Section 4.2, IAEA Safety Series No. 54.

7. W. L. Lennemann, "United States Atomic Energy Commission Interim Radioactive Waste Burial Program. Disposal of Radioactive Wastes into Ground," IAEA, Vienna, 1967, STI/PUB/156, pp. 261-300.

8. "Radioactive Waste Management," DOE Order 5820.2, 1984.

9. "Licensing Requirements for Land Disposal of Radioactive Waste," Ch. 61 of Title 10 of the U.S. Code of Federal Regulations (10 CFR 61).

10. "Low-Level Radwaste Solidification," EPRI NP-2900, Ch. 4, 1983.

11. E. Warnecke, P. Brennecke, et. al. "Quality Control of Radioactive Wastes," IAEA-SM-261/17.

12. W. V. DeMier, et. al. "GETOUT: A Computer Program for Predicting Radionuclide Decay Chain Transport Through Geological Media," PNL-2970, 1979.

13. Benjamin Ross, et. al. "NUTRAN: A Computer Model of Long-Term Hazards from Waste Repositories," UCRL 15150, The Analytic Science Corporation, 1979.

14. Craig A. Little, et. al. "Environmental Assessment Model for Shallow Land Disposal of Low-Level Radioactive Wastes," ORNL/TM-7943. 1981.

15. A. Alan Moghissi, Bernard Kahn, "Management of Low-Level Radioactive Waste," Vol. 2, PP1193-1212, Pergamon, 1979.

APPENDIX: ACCEPTANCE CRITERIA

1. The radionuclides content, radioactivity and composition of the waste form should be known and identified with sufficient accuracy to ensure compliance with these radwaste acceptance criteria and/or authorized limits or exceptions.

2. Waste accepted for disposal should be in a solid form. If the original waste is liquid, it should be absorbed or solidified (treated) in such a way that it is equivalent to a solid form with low leachability.

3. Waste and/or waste forms containging free liquid are not acceptable for disposal. Any free liquid in a waste package must be solidified or the waste be packaged with a sufficient quantity of an appropriate absorbent material which would absorb and immobilize twice the original volume of the free liquid.

4. Ash or ashes, ion exchange resin, powders, and other particulate radwaste material must be stabilized to a solid, monolithic form.

5. Aqueous and other liquid radwaste, slurries, sludges and dispersable particulate radwaste such as ion exchange resins, ash, powders and crystals must be solidified or stabilized by approved and licensed solidifying and/or stabilizing processes and agents. The following solidifying and/or stabilizing agents are accetable forms for disposal provided the other conditions of the waste acceptance criteria are met. (Acceptable agents can be listed.)

6. Gaseous radwaste is not acceptable for disposal unless it is absorbed on or within a solid form or rendered to a solid form. Gaseous waste asorbed on or in a solid form must not exert a vapor pressure in excess containing at least 3.0 atmospheres internal pressure.

7. The waste must not be readily capable of detonation or of explosive decomposition or reaction at normal pressures or temperatures or of an explosive reaction with water.

8. Waste containing corrosive materials must have the corrosiveness of such materials neutralized and/or be packaged in such a manner as to be rendered non-corrosive.

9. Waste containing hazardous toxic, biological, pathogenic or infectious material must be treated and packaged to reduce to the extent practicable the risk from these hazardous, nonradiological materials.

10. The radwaste form should not be capable of generating quantities of gases, vapors or liquids, e.g., by radiolysis, biological or chemical reactions, to the extent that one or more of these products could jeopardize the integrity of the waste package, the performance of the disposal site, or be harmful to persons handling and disposing of the waste.

11. Waste containing pyrophoric, flammable or explosive materials is not acceptable unless it is certified that such material(s) has been treated and/or packaged in such a manner as to be rendered safe along with a description of the treatment and/or packaging.

12. Waste containing significant quantities of complexing, chelating or solubilizing agents that would enhance the mobility of the radionuclides in ground or seepage waters is not acceptable unless it is certified that such agents are rendered immobile in the waste package and disposal environment along with a description of the treatment and/or packaging.

13. The waste form and its geometry should be such that criticality safety can be maintained in the disposal site.

14. The waste package and its transport shall be in conformance with Korea Regulations on Transportation and Packaging of Radioactive Materials.

15. The shape, volume and weight of the waste package should not exceed the receiving, handling and disposal capabilities of the disposal site, including available outside assistance.

16. The waste package can be received, handled and disposed of within the acceptable limits of radiation exposure to workers at the disposal site.

17. Solid combustible waste must be packaged and compacted to the extent practical in noncombustible containers.

18. All waste packages should be completely and tightly sealed with closures that will withstand the condition of a normal transport accident and handling at the disposal site, including the forces of disposition and disposal environment under the expected conditions of disposal.

19. The waste package must have structural stability such that it will generally maintain its physical dimensions and its shape and does not breech under the expected conditions of its disposal.

20. Void spaces within the waste or waste form and between the waste form and its container must be reduced to the extent practicable.

21. The waste form and its container should be sufficiently resistant to the radiation and thermal energy (heat) arising from the decay of the radionuclide content to avoid changes in the physical and chemical properties of the radwaste package which would unduly either compromise the ability of the package to contain or restrict the release of the radionuclide from the package or compromise the integrity and performance of the disposal site.

22. Each package of waste must be clearly labelled as radioactive material and clearly identified as to origin, shipment number, package number, contents and radiation levels.

23. The waste must not be packaged in plastic bags or cardboard, fiberboard or wooden containers for disposal. Experience and testing must indicate that any plastic containers that are used are strong and durable, conforming to the requirements of these "waste acceptance criteria."

24. Lifting devices and other handling aids and/or mechanisms for the package must be secured to the body of the container. Lifting devices and other handling aids on container lids and closures will not be used for handling the container at the disposal site and during disposal operations.

25. The surface of the container or package should be free of removable radioactive contamination and be clean.