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EVALUATION OF SITE-GENERATED RADIOACTIVE WASTE TREATMENT AND DISPOSAL METHODS FOR THE YUCCA MOUNTAIN REPOSITORY

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OBJECTIVE

This study identifies the sources of radioactive wastes that may be generated at the proposed high level waste (HLW) repository at Yucca Mountain, Nevada, estimates the waste quantities and characteristics, compares various technologies that are available for waste treatment and disposal, and develops recommended concepts for site-generated waste treatment and disposal. The scope of this study is limited to the repository operations during the emplacement phase, in which 70,000 MTU* of high-level waste will be received and emplaced at the proposed repository. The evaluations consider all radioactive wastes generated during normal operations in surface and underground facilities. Wastes generated as a result of accidents are not addressed because accidents that could result in large quantities of radioactive waste are expected to occur very infrequently so that temporary, portable systems could be used for cleanup, if necessary. The results of this study can be used to develop more definitive plans for managing the site-generated wastes and to serve as a basis for the design of associated facilities at the proposed repository.

WASTE CHARACTERIZATION

The conceptual design of a repository consisting of a single waste-handling building with no spent fuel consolidation facilities was used as the basis for estimating sources, quantities, and characteristics of site-generated wastes. Preliminary investigations have led to this configuration being identified as a preferred alternative to the reference NNWSI Project configuration presented in SAND84-2641, (MacDougall, 1987). This configuration is subject to further studies in future design activities.

The following assumptions were used in estimating the quantities of radioactive wastes generated at the repository facilities.

1. The repository will accept spent fuel at an annual rate of up to 3,000 MTU and will accept defense high level waste (DHLW) canisters at an annual rate equivalent to 400 MTU.

2. No spent fuel will be consolidated at the repository, and there will be only one waste-handling building to receive and package the

*An MTU of waste is that produced from one metric ton of uranium initially loaded in a reactor core.

spent fuel and DHLW. (It is noted that at-repository consolidation would result in substantially larger quantities of site-generated waste than those reported here).

3. Spent fuel transportation from reactors will be 70 percent by truck and 30 percent by rail on the basis of MTU. This study assumes that each spent fuel rail cask will contain about 4 ounces of crud (activated corrosion products) and each spent fuel truck cask will contain about 4/7 of an ounce of crud dislodged from the fuel assemblies.

4. Estimates of site-generated waste characteristics are based on the average rates of handling and processing spent fuel and DHLW during the emplacement phase. (Variations in throughput rates during the first few years of operation are not addressed.) Radioactive wastes that may be generated at the repository during caretaking, retrieval, or decommissioning are not addressed, because these quantities are not expected to affect the waste treatment system evaluations and selections.

5. Site-generated wastes are not expected to contain concentrations of transuranic or other radionuclides that would preclude near-surface disposal as specified in 10 CFR Part 61 (NRC, 1986a).

The types of activities that generate the majority of site-generated wastes in a repository include normal operations, decontamination, housekeeping, preventive and corrective maintenance, and health physics surveys. These operations generate liquid, solid and gaseous wastes.

The liquid wastes are generated primarily by decontamination operations, and include chemical wastes like decontamination solution, laboratory wastes, vehicle wash wastes, laundry drains and spent resin slurries.

The solid radioactive wastes are generated primarily by waste-handling operations, and include both compactible wastes (like items made of plastic, paper, cloth, rubber and metal, absorbant materials, filters, etc.) and noncompactible wastes (like items made of wood, metal and concrete, filters, glass, lead, dirt, etc.)

During normal operation of the repository, there will be no gaseous or airborne radioactive wastes that require treatment beyond HEPA filtration.

Table 1 summarizes the estimates of the site-generated waste volumes and concentrations of radioactivity for the repository facilities. The sources of each of the waste types are discussed in detail in SAND86-7136 (Jardine, et al., 1987).

Table 1

Estimates of Site-Generated Waste

Waste Type	Annual Quantity	Activity	Annual Activity (Ci)
Chemical liquids	48,000 gal	7.5×10^{-5} Ci/gal	4
Spent resin slurry	4,000 gal	1.1×10^{-2} Ci/gal	45
Recycle liquids	417,000 gal	6.3×10^{-4} Ci/gal	261
Waste-handling building cartridge filters	182 filters	12 Ci/filter	2,200
Recycle purification cartridge filters	18 filters	12 Ci/filter	216
Noncombustible/ Noncompactible dry active waste	14,400 ft^3	3.5×10^{-3} Ci/ft^3	51
Combustible/ Compactible dry active waste	36,800 ft^3	3.0×10^{-3} Ci/ft^3	112
Hot cell air filters	1,200 ft^3	3.3×10^{-1} Ci/ft^3	400

WASTE TREATMENT METHODS

In accordance with 10 CFR part 60.132 (d), "radioactive waste treatment facilities shall be designed to process any radioactive wastes generated at the geologic repository operations area into a form suitable to permit safe disposal at the geologic repository operations area or to permit safe transportation and conversion to a form suitable for disposal at an alternative site in accordance with any regulations that are applicable..." (NRC, 1986b).

Waste treatment techniques must convert the waste into a form that meets the requirements associated with the particular disposal technique used. For near-surface burial, the requirements of 10 CFR Part 61 (NRC, 1986a) must be met. Major requirements of this regulation include the following:

- Liquid waste must be solidified or packaged in sufficient absorbent material to absorb twice the volume of liquid.

- Solid waste containing liquid shall contain as little freestanding and noncorrosive liquid as is reasonably achievable, but in no case shall the liquid exceed 1 percent of the volume.

- Waste must not be packaged for disposal in cardboard or fiberboard boxes.

If waste is transported off-site for disposal, the requirements of 49 CFR Part 173 (DOT, 1986) and 10 CFR Part 71 (NRC, 1986c) must be met. These regulations provide criteria for packaging and labeling the waste.

If on-site subsurface excavations are used for disposal of site-generated waste, the requirements of 10 CFR Part 60.135(d) must be met. The regulation states that criteria for such wastes "will be addressed on an individual basis if and when they are proposed for disposal in a geologic repository" (NRC, 1986b).

Site-generated wastes emplaced in the underground excavations may be required to be reduced to a noncombustible form. Regulations in 30 CFR Part 57.4104 (MSHA, 1985) require that combustible material in the subsurface excavations "shall not accumulate in quantities that could create a fire hazard." In addition, 30 CFR Part 57.4500 requires that "heat sources capable of producing combustion shall be separated from combustible materials if a fire hazard could be created."

For disposal in subsurface excavations, site-generated wastes should be located sufficiently far from the spent fuel and DHLW emplacement to prevent potential interactions due to decay heat, bacterial and radiolytic decomposition that could compromise postclosure performance issues such as radionuclide migration. This study assumes that subsurface excavations can be designed to prevent such interactions.

Waste treatment systems shall be designed so that no contaminated or potentially contaminated liquids are released to the environment. All such liquids are solidified for disposal or are treated for recycle, with no liquid discharge to the environment.

Waste treatment systems and facilities will be designed so that radiation exposures are maintained within applicable limits and as low as reasonably achievable. Also, waste treatment systems will have sufficient flexibility to accommodate unforeseen waste processing demands, such as might result from off-normal operations or equipment maintenance.

Gaseous radioactive wastes may not be released to the environment in quantities that exceed the 10 CFR Part 20 Appendix B (NRC, 1986d) limits. If it is found that those limits are exceeded, special gaseous collection and treatment systems will be installed.

Using the foregoing guidelines, treatment and disposal technologies that would be suitable for site-generated wastes were reviewed, and the technical and economic aspects of the most feasible options were evaluated. Ten treatment options and three disposal options were compared to determine the recommended methods. The comparisons involved qualitative evaluations of relative radiation doses to workers and development of relative life-cycle cost estimates that included capital costs for treatment and disposal facilities for each alternative, as well as operating costs for waste collection, treatment, packaging, transportation, and disposal.

The ten treatment options are:

1. This is the reference waste treatment case in which chemical liquids are solidified with cement. Spent resins are combined with chemical liquids for solidification. Recycle liquids are filtered and purified using ion exchangers. Spent cartridge filters are packaged in 55-gal drums with absorbent. Compactible dry active waste (DAW) is compacted using a standard box compactor, and noncompactible DAW is packaged in metal boxes without compaction. Hot cell air filters are processed by separating the frames from the media, shredding the frames, and compacting the media. Drums of highly radioactive wastes (spent cartridge filters and hot cell air filters) are packaged in canisters remotely handled.

   Radiation doses to workers are expected to be low due to remote handling features for the highly radioactive waste and the limited amount of waste volumes to be handled and disposed of.

2. In this option, the radioactivity buildup on cartridge filters is limited so that they may be contact handled. This eliminates equipment and operations associated with packaging the spent filters in canisters for remote handling.

   Much larger numbers of cartridge filters are used in this option, so that associated radiation levels will be low enough to allow contact handling. Spent cartridge filters are packaged in 55-gal drums with absorbent and are prepared for disposal without packaging in canisters. Treatment methods for other site-generated wastes are the same as those in the reference case.

   In Option 2, radiation doses to waste treatment workers are expected to be much greater than those in the reference case due to the much larger number of drums requiring handling, transporting, and disposal.

3. In this option, the highly radioactive waste is to be packaged in concrete shield boxes with wall thickness of 18 in. to allow contact handling rather than remote handling. This option eliminates equipment and operations associated with remote handling and disposal of site-generated waste.

   Shield boxes are used for packaging spent cartridge filters and hot cell air filters, so that the associated radiation levels will be low enough to allow contact handling.

   In Option 3, radiation doses to waste treatment workers are expected to be about the same as for the reference case, because approximately the same number of waste packages with similar radiation levels are being handled.

4. This Option is similar to Option 3, except that spent hot cell air filters are compacted prior to packaging in shield boxes. This reduces the number of shield boxes needed annually and also

eliminates the equipment and operations associated with remote handling (as in Option 3).

In Option 4, radiation doses to workers are expected to be about the same as in the reference case, because approximately the same number and type of waste packages are being handled.

5. Option 5 involves packaging DAW without compaction. Evaluation of this option will determine the cost-effectiveness of using the compactor in the reference case. In Option 5, the DAW compactor is eliminated; however, the number of boxes of DAW requiring disposal is increased significantly.

   In Option 5, radiation doses to waste treatment workers are expected to be slightly greater than in the reference case due to the greater number of DAW boxes requiring handling, transporting, and disposal.

6. Option 6 involves supercompaction of DAW, which further reduces the volume of waste below that of standard compaction. All DAW is initially packaged in 55-gal drums, with a standard compactor used for compactible DAW. The drums of DAW are then supercompacted, and several supercompacted drums can then be placed in an 85-gal drum.

   In Option 6, radiation doses to waste treatment workers are expected to be about the same as in the reference case, because approximately the same number of waste packages are being handled with similar radiation levels.

7. In Option 7, combustible DAW and hot cell air filter media (not frames) are loaded into wire baskets that are placed into 55-gal drums. Grout (cement, sand, and water) is then placed into each drum to surround the basket of combustible material. Drums of highly radioactive hot cell air filter media (encased in grout) are placed in casks and then returned to the waste-handling building, where they are loaded into canisters for remote handling and disposal.

   In Option 7, radiation doses to waste treatment workers are expected to be greater than in the reference case due to the additional handling requirements associated with segregating combustible and noncombustible wastes and loading combustible wastes into baskets for encasement in cement, and due to the much larger number of waste drums requiring handling, transporting, and disposal.

8. In Option 8, combustible DAW and hot cell air filter media (not frames) are shredded and transferred into an incinerator. The resulting ash is then immobilized in concrete in 55-gal drums. Drums of highly radioactive hot cell air filter ashes (solidified) are transferred (in a shielded cask) to the waste-handling building and loaded into canisters for remote handling.

In Option 8, radiation doses to waste treatment workers are expected to be about the same as those in the reference case. Slight decreases in exposures associated with the reduced number of waste packages requiring disposal are offset by additional maintenance of incineration system components contaminated with radioactivity.

9. Option 9 involves solidification of all site-generated liquid wastes with no recycle of liquids. This eliminates equipment and operations associated with the purification of recycle liquids; however, a much greater quantity of solidified waste packages is produced. Evaluation of this option will determine the cost-effectiveness of the recycle purification system.

   Radiation doses to workers are expected to be greater than those in the reference case due to the larger number of waste drums requiring handling, transporting, and disposal.

10. Option 10 involves evaporation of all site-generated liquid wastes, with recycle of the distillate. This option replaces the filtration and ion exchange system with an evaporation system. Evaporator bottoms are solidified with cement in the same manner as chemical liquids in the reference case.

    Radiation doses to workers are expected to be about the same as those in the reference case, because approximately the same number of waste packages, with similar radiation levels are being handled.

The three waste disposal options considered are:

1. On-Site Geologic Repository - This waste disposal option involves transport of site-generated waste to subsurface excavations for disposal. This approach eliminates the need for off-site transportation and reliance on a separate organization or independent site for waste disposal.

2. Off-Site Disposal at Beatty - The commercial low-level waste disposal site at Beatty, Nevada, is about 50 mi (80 km) by road from the repository site at Yucca Mountain.

   Packages of site-generated waste would be loaded onto a commercial shipping vehicle for off-site transportation to the disposal site. Shielded casks would be used as necessary to meet radiation dose limits for transportation. For highly radioactive site-generated wastes, such as spent cartridge filters and hot cell air filters, a shield cask is used for on-site transfer of drummed waste from the waste-handling building to the waste treatment building and to the commercial shipping cask.

3. Off-Site Rocky Mountain Compact - Another option for off-site disposal of site-generated waste may be use of a burial site to be developed for the Rocky Mountain Low-Level Waste Compact. The location of the site has not been selected yet; however, this study

assumes that such a site would be developed at a distance of about 1,000 miles (1600 km) from the repository location. It is assumed that the waste disposal charges at the Rocky Mountain Compact site are the same as those at Beatty. Repository site-generated waste is shipped to this site using commercial transport vehicles in a manner similar to that described in 2.

Because the life-cycle costs and technical merits of each type of treatment method depend on the disposal alternative being considered, all combinations of the above treatment and disposal methods were evaluated to determine the preferred approach.

RESULTS

This study indicated that on-site disposal of site-generated waste in special subsurface excavations would be much more economical than off-site transport and disposal because of the difference in transportation costs.

For on-site disposal, the following waste treatment methods were recommended based on their combined technical merits and life-cycle costs:

- Filtration/ion exchange of liquids to allow recycle and solidification of chemicals and spent resins
- Standard compaction of solid wastes
- Compaction and packaging of highly radioactive solid wastes in disposable concrete shield boxes

CONCLUSIONS

The results of this study can be used to develop more definitive plans for treating and disposing of the site-generated wastes, and to serve as a basis for the advanced conceptual design of associated facilities at the proposed repository.

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