

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, NV, estimates the waste quantities and characteristics, compares technologies 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 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; accidents that could result in large quantities of radioactive waste are expected to occur very infrequently and temporary, portable systems could be used for any necessary cleanup. The results of this study can be used to develop more definitive plans for managing the site-generated wastes and as a basis for the design of associated facilities at the proposed repository.

WASTE CHARACTERIZATION

The repository conceptual design for a single waste-handling building with no spent fuel consolidation facilities was used to estimate sources, quantities, and characteristics of site-generated wastes. Preliminary investigations of design alternatives identified this configuration as a preferred alternative to the reference Yucca Mountain Project configuration (SNL, 1987).

The following assumptions were used to estimate 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 spent fuel and DHLW. (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 (measured in MTU). 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 also not addressed; these quantities are not expected to affect the waste treatment system evaluations and selections.

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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 activities that generate most radioactive wastes in a repository include normal operations, decontamination, housekeeping, preventive and corrective maintenance, and health physics surveys. These activities generate liquid, solid, and gaseous radioactive wastes.

Liquid radioactive wastes, generated primarily by decontamination operations, include chemical liquid wastes such as decontamination solution, laboratory wastes, vehicle wash wastes, laundry drains, and spent resin slurries. Solid radioactive wastes, generated primarily by waste-handling operations, include both compactible wastes such as plastic, paper, cloth, rubber, and metal items, absorbent materials, and filters, and noncompactible wastes, such as wood, metal, and concrete items, filters, glass, lead, and dirt. During normal operation of the repository, there will be no gaseous or airborne radioactive wastes that require treatment other than high-efficiency particulate absolute (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 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

10 CFR Part 60.132 (d) (NRC, 1986b) specifies that "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." For near-surface burial, the requirements of 10 CFR Part 61 (NRC, 1986a) for the disposal of liquid and solid wastes 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 the liquid.
- Solid waste 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) (NRC, 1986b) must be met. Site-generated wastes emplaced in the underground excavations may be required to be noncombustible. 30 CFR Part 57.4104 (MSHA, 1985) requires 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. Potential interactions due to decay heat and bacterial and radiolytic decomposition 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 to prevent release of contaminated or potentially contaminated liquids to the environment. All such liquids are solidified for disposal or are treated for recycling, with no liquid discharge to the environment.

Waste treatment systems and facilities will be designed to maintain radiation exposures within applicable limits and as low as reasonably achievable. Waste treatment systems will be sufficiently flexible 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 those limits are exceeded, special gaseous collection and treatment systems will be installed.

Using the foregoing guidelines, treatment and disposal technologies for site-generated wastes were reviewed. 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 and operating costs for waste collection, treatment, packaging, transportation, and disposal.

The ten treatment options are described below.

1. The first option is the reference waste treatment case. Chemical liquids are solidified with cement. Spent resins are combined with chemical liquids for solidification. Liquids for recycling are filtered and purified using ion exchangers. Spent cartridge filters are packaged with absorbent in 55-gal drums. Compactible dry active waste (DAW) is compacted using a standard box compactor; 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 remotely handled canisters. Radiation doses to workers are expected to be low due to remote handling of the highly radioactive waste and the limited amount of waste volumes to be handled and disposed.
2. Option 2 limits the radioactivity buildup on cartridge filters so the filters may be contact handled. This eliminates equipment and operations associated with packaging the spent filters in canisters for remote handling. Many more cartridge filters are used in this option, so that radiation levels will be low enough to allow contact handling. Spent cartridge filters are packaged with absorbent in 55-gal drums 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. Option 3 packages the highly radioactive waste in concrete shield boxes with wall thickness of 18 inches to allow contact handling rather than remote handling. Shield boxes are used for packaging spent cartridge filters and hot cell air filters. This eliminates equipment and operations associated with remote handling and disposal of site-generated waste. 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 spent hot cell air filters are compacted prior to packaging in shield boxes. This reduces the number of shield boxes required, as well as eliminates the equipment and operations associated with remote handling. 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 with similar radiation levels are being handled.
5. Option 5 packages 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 increases 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 packages DAW with supercompaction, which 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; several supercompacted drums can 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 with similar radiation levels are being handled.
7. In Option 7, combustible DAW and hot cell air filter media (not frames) are loaded into wire baskets placed into 55-gal drums. Grout (cement, sand, and water) placed into each drum surrounds the basket of combustible material. Drums of highly radioactive hot cell air filter media (encased in grout) are placed in casks and 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 both to the additional handling requirements associated with segregating combustible and noncombustible wastes and loading combustible wastes into baskets for encasement in cement and 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 solidified ashes 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 for 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 solidifies all site-generated liquid wastes; no liquids are recycled. This eliminates equipment and operations associated with the purification of liquids for recycling; however, many more solidified waste packages are produced. Evaluation of this option will determine the cost-effectiveness of the recycling 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 evaporates all site-generated liquid wastes with recycling of the distillates. 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 for 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 described below:

1. On-Site Geologic Repository - This option transports site-generated waste to subsurface excavations for disposal, eliminating the need for off-site transportation and reliance on a separate organization or independent site for waste disposal.
2. Off-Site Disposal at Beatty - Packages of site-generated waste would be loaded onto a commercial shipping vehicle for off-site transportation to the commercial low-level waste disposal site at Beatty, NV, which is about 50 miles (80 km) by road from the repository site at Yucca Mountain. 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 shielded cask would be 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 a burial site to be developed for the Rocky Mountain Low-Level Waste Compact. The location of the site has not been selected; however, this study assumes that such a site would be developed at a distance of about 1,000 miles (1,600 km) from the repository location. It is assumed that the waste disposal fees at the Rocky Mountain Compact site are the same as those at Beatty. Repository site-generated waste would be shipped to this site using commercial transport vehicles as described for the Beatty option.

Because the life-cycle costs and technical merits of each 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 significantly more economical than off-site transport and disposal due to the additional transportation costs of off-site disposal.

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

- Filtration/ion exchange of liquids to allow recycling 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 described in Jardine, et al., 1987, can be used to develop more definitive plans for treating and disposing of the site-generated wastes and as a basis for the advanced conceptual design of associated facilities at the proposed repository.

References:

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