ALTERNATIVES TO DISPOSAL OF HANFORD SITE LIQUID EFFLUENTS TO THE SOIL COLUMN

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ABSTRACT

A feasibility study was conducted to identify and evaluate available alternative waste disposal systems for liquid waste effluents discharged to the soil column at the U.S. Department of Energy (DOE) Hanford Site. Alternative systems were selected for 28 effluent streams, based on the use of available technology and ability to eliminate the contaminated effluent or reduce contaminant levels to meet specified effluent disposal criteria and standards derived from DOE Orders and environmental statutes. This study determined that technically feasible alternative waste disposal systems are available.

INTRODUCTION

Since 1944, when the first Hanford Site facilities began operating to produce plutonium for the Manhattan Project, large quantities of water have been used for reactor and chemical processing operations. Disposal of this water is accomplished by discharge to the environment via the soil column. Waste management programs at the Hanford Site have included a continuous, evolving program for environmental surveillance and assessment of these discharges and improvements in effluent controls for over 40 yr.

The radiation dose resulting to the offsite maximally exposed individual from Hanford Site operations, including discharges to the soil column, was calculated to be 0.03 mSv in 1985 compared to an estimated 0.5 to 1 mSv in the early 1960s. The current offsite dose limits are 5 mSv for occasional exposure and 1 mSv for prolonged exposure. The principle environmental impact from effluent disposal practices is the accumulation of radioactivity in the onsite soils and unconfined aquifer. A potential for significant nonoccupational dose to humans results only from an assumption that at some unspecified future time government control of the Hanford Site ceases and is followed by extensive human habitation.

Current U.S. Department of Energy (DOE) policy on the disposal of contaminated effluents (1) requires that disposal operations involving discharges of contaminated liquids directly to the environment or natural soil column be replaced by other techniques. A feasibility study was conducted to evaluate the implementation of current DOE policy at the Hanford Site. The specific objectives of this study included:

- Identification and evaluation of available, demonstrated technology for the elimination, recycle, or treatment of contaminated effluents
- Preliminary selection of specific, applicable technology for application and evaluation of cost
- Establishment of priorities for implementation of alternative systems to replace disposal of contaminated liquids to the soil column.

EFFLUENT IDENTIFICATION AND DESCRIPTION

Present activities at the Hanford Site include operation of nuclear reactors, chemical processing of nuclear materials, management of radioactive and chemical wastes, facility support, and a broad range of research and development activities. The following facilities (2,3) support these activities and discharge liquids to the soil column:

- N Reactor (100 Area)
  - N Reactor
- Chemical separations and waste management operations (200 Areas)
  - Fuel reprocessing (Plutonium-Uranium Extraction Plant (PUREX))
  - Cesium and strontium waste fractionation (B Plant)
  - Uranium calcination (UO_3 Plant)
  - Plutonium recovery and reclamation (Plutonium Finishing Plant)
  - Waste concentration and storage
  - Decontamination, laundry, and laboratory
  - Steam generation (2 plants)
- Fuels fabrication and laboratory operations (300 Area)
- Fast Flux Test Facility (FFTF) (400 Area)
  - Heating, ventilation, and air conditioning (nonradioactive).

The scope of the feasibility study included liquid waste effluents currently discharged to the soil on the Hanford Site that are routinely or potentially contaminated with radionuclide or regulated chemical constituents. Sanitary sewer systems, small volume nonprocess-related discharges, and discharges with National Pollution Discharge Elimination System permits were not addressed. A total of 32 effluents were evaluated for alternative disposal systems.

Based on similarities in the processes that generate the waste streams and in waste stream characteristics, the effluents were grouped into six categories. The number of effluents in each category and the volume discharged are summarized in Figure 1.

During 1985, the Hanford site effluent streams discharged 28 million m^3 of waste water (4). Streams defined as cooling water accounted for over 74% of the total volume discharged, the largest fraction of discharges. The production reactor and laboratory and chemical sewer streams amounted to an additional 22%. The remaining streams accounted for less than 6%.

The liquid effluents released to the soil in 1985 contained 414 TBq of tritium, 117 TBq of beta/gamma activity (half-life less than 45 days), and 0.23 TBq of alpha activity (4). Figure 2 illustrates how the alpha and beta/gamma activity (tritium excluded) were distributed between the categories of wastes. The N Reactor effluent released approximately 115 TBq in 1985, accounting for over 98% of the total activity released. The process condensates released approximately 2.1 TBq, which accounted for about 2% of the total effluent activity released.

The measured concentrations of selected chemical and radionuclide constituents in the waste streams are summarized in Tables I and II.

N Reactor Effluent

The N Reactor effluent consists of streams from several sources, including the reactor cooling system, spent fuel storage basin, periphery cooling system, and various drains. These sources contribute demineralized, filtered, and raw water contaminated with trace radionuclides and trace chemical constituents.

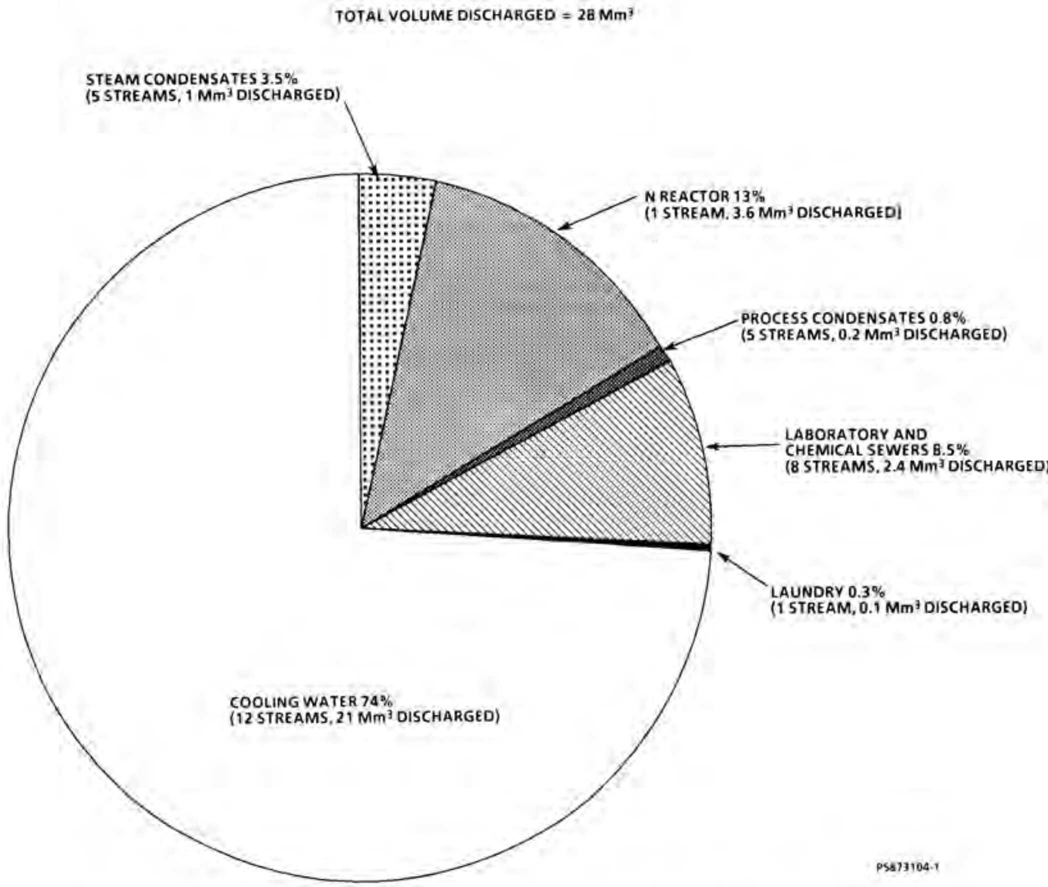

Fig. 1. Hanford Site Liquid Effluent Types and Volumes Discharged (1985).

TABLE I

Hanford Site Liquid Effluents Chemical Constituents Concentrations.

Effluents	Ba (mg/m^3)	Cd (mg/m^3)	Cr (mg/m^3)	Hg (mg/m^3)	NO3 (g/m^3)
N Reactor effluents (1)a	30	<2	<10	<0.1	<0.5
Laboratory and chemical sewers (8)	39 - 85	13 - 14	20 - 29	0.2 - 3.1	1.0 - 2.4
Process condensates (5)	16	10 - 18	13 - 120	1 - 13	0.7 - 14,000
Laundry (1)	67	9	16	0.3	3.1
Cooling water (12)	26 - 38	2 - 11	13 - 14	0.1	1.5 - 6.9
Steam condensates (5)	31 - 45	8 - 10	8 - 29	b	1.0

NOTE: Values and ranges shown are for positive analytical results only; many individual streams in the various categories are below detection limits for specific constituents.

[a]Number in parentheses denotes number of streams in each category.

[b]Below detection limits.

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TABLE II

Hanford Site Liquid Effluent Radionuclide Constituents.

Effluents	$^{80,90}Sr$ (kBq/m^3)	^{137}Cs (kBq/m^3)	$^{239,240}Pu$ (kBq/m^3)	U (kBq/m^3)
N Reactor effluent (1)[a]	4,070	890	35	b
Laboratory and chemical sewers (8)	<2	<3	b	b
Process condensates (5)	<2 - 15,000	<2 - 2,600	<2 - 370	<0.03-41
Laundry (1)	7	b	b	b
Cooling water (12)	<1	<1.9	<1 - 37	1.5
Steam condensates (5)	15 - 220	11 - 3,700	<1	0.4 - 4

[a]Number in parentheses denotes number of streams in each category.

[b]Specific nuclide data not available for any streams (streams monitored for total alpha and total beta/gamma).

[c]Assumes 0.4 MSv/yr contributions for single constituent.

[d]Based on gross alpha.

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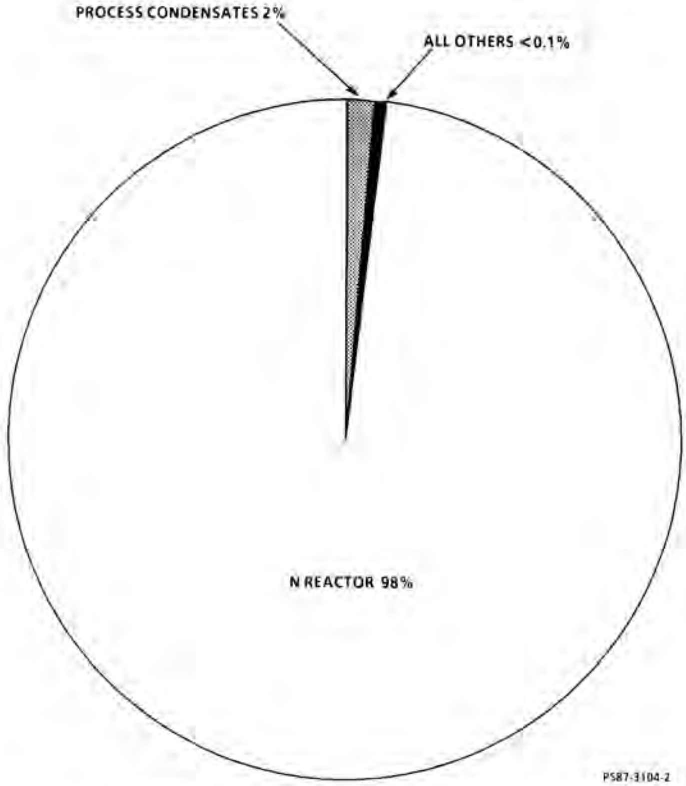

Fig. 2. Distribution of Total Activity Among Effluent Categories in 1985 (Excluding Tritium).

Laboratory and Chemical Sewers

Chemical sewers and laboratory drains were designed to collect and dispose of wastes from chemical makeup and operating area floor drains; water demineralizer regeneration; various heating, ventilation, and air conditioning steam condensates; and cooling water streams. Release of contaminants has been intermittent or nonroutine. Procedural controls are in place to prevent the release of regulated chemicals to these streams. Until engineered barriers are fully in place, a small potential still exists for the nonroutine release of contaminants due to spills.

Process Condensates

The process condensate streams contain the condensed overheads from process waste concentrators, which reduce the volume of waste routed to underground double-wall storage tanks. The process condensates may be acidic or alkaline depending on the specific plant and type of waste being concentrated. The principal constituents may include dilute HNO_3, dilute NH_4OH, low levels of uranium, various fission products and transuranics, and a range of trace chemical components.

Steam Condensate

The steam condensate streams result from the use of steam for process heating throughout the Hanford Site chemical processing and waste management facilities. Single-pass systems are used; steam is condensed and discharged following use. Contamination occurs from equipment failure, leaks in tube bundles or vessel coils, and the release of corrosion products in older pipe systems.

Cooling Waters

The cooling waters, which represent the largest volume of water discharged, result from the use of single-pass process and nonprocess cooling systems. Cooling water is pumped directly from the Columbia River and used untreated in most applications. Therefore, the cooling water waste streams contain trace chemical constituents found in the raw water. Introduced contaminants result from equipment failures, tube and bundle leaks, and release of corrosion products.

Laundry

The laundry waste stream results from operation of a conventional laundry facility used to decontaminate slightly contaminated protective clothing. This stream contains a variety of dissolved and suspended solids. Both biological oxygen demand and suspended solids range from about 0.05 to over 0.3 kg/m^3; ammonia and phosphate levels average 0.03 and 0.05 kg/m^3, respectively. The stream contains a wide variety of trace chemical and radionuclide contaminants resulting from various operations where protective clothing is used.

ALTERNATIVE WASTE DISPOSAL SYSTEMS

The replacement of soil column disposal practices for contaminated effluents on the Hanford Site requires the selection and implementation of alternative treatment and disposal technologies. A primary objective of the feasibility study was to select a specific alternate disposal system for each candidate effluent stream and evaluate the cost of implementing the selected system. General treatment and disposal strategies for each effluent category had to be defined. Specific technologies were then selected and the cost of application for each stream in the category was estimated.

Liquid Effluent Disposal Criteria

Selection of the strategy and specific technology required definition of effluent disposal criteria. The specific design criteria and standards applied to liquid effluent disposal and the corresponding environmental regulations included the following:

- Resource Conservation and Recovery Act: Liquid discharges to the soil or environment shall be nonhazardous
- Comprehensive Environmental Response, Compensation and Liability Act: Control and containment systems shall be used to prevent the release of chemical and radioactive substances
- Washington State Water Pollution Control Laws (WPCA): All known, available, and reasonable methods of prevention, control and treatment for pollutant shall be provided and; conditions necessary to preserve or protect beneficial uses for groundwater will be utilized.

Implementation of the WPCA criteria will utilize guidance established for Best Available Technology (BAT) economically achievable under the Clean Water Act and associated regulations.

Four general areas of technology were considered for the treatment and disposal of the liquid discharges:

- Facility and process modifications
- Closed-loop systems
- End-of-pipe treatment systems
- Solidification.

Facility and Process Modifications

Facility and process modifications upgrade older plant systems to prevent or minimize the introduction of radioactive and chemical contaminants to the stream. All Hanford Site reactor and chemical processing facilities were built using design standards and technologies that were in effect at the time of construction. These standards and technologies were different than would be applied today to the design of a new facility. In many cases, existing facilities may not easily accommodate the upgrades.

The following is a list of process and facility modifications that are available and being considered for application at the Hanford Site:

- Waste minimization and chemical substitutions
- Process control improvements
- Process equipment upgrades
- Process flow sheet modifications
- Process operation administrative controls and procedural modifications
- Process upset and spill control and containment upgrades.

Closed-Loop Systems

Closed-loop systems are designed to recycle water and chemicals back into the process. Closed-loop systems greatly reduce the quantity of liquid discharged and prevent the release of small quantities of contaminants that occasionally enter the steam or cooling water systems. Waste water treatment systems are used to remove contaminants that may accumulate in the closed loop. While this type of system may be applicable to Hanford Site facilities that were designed with single-pass and once-through cooling water and steam systems, the design of many of these facilities will not easily accommodate recycle systems without significant process equipment and facility upgrades and some increase in operational personnel exposure to ionizing radiation.

End-of-Pipe Treatment Systems

End-of-pipe treatment systems are designed to collect, separate, and concentrate radioactive and chemical contaminants once they have been introduced into the waste stream. This approach will be required for any Hanford Site facility in which the process flow sheets or facility designs will not readily accommodate additional in-plant controls and recycle systems.

The treatment operations currently being considered include the following:

- Pretreatment (e.g., flow equalization, filtration, neutralization)
- Evaporation
- Chemical treatment (e.g., precipitation, flocculation)
- Ion exchange and adsorption
- Membrane processes (e.g., reverse osmosis, ultrafiltration).

Additional technologies may be identified during the detailed engineering and design studies required for final technology selections.

Disposal of Concentrates Separated from Liquid Effluents

Work is currently underway at the Hanford Site to develop and implement a waste disposal technology for low-level radioactive and chemical wastes. This technology utilizes solidification of contaminated waste with cement and other additives to produce a physically and chemically stable waste form that is suitable for near-surface disposal in high-integrity vaults (5). Vault design includes double liners and leachate collection, groundwater monitoring, and an engineered surface barrier. Application of this technology is the most viable approach to disposal of the contaminants that are separated from the effluent streams. Two approaches are available: a decentralized solidification system for individual treatment systems and a centralized solidification system to collect wastes from several treatment systems.

TECHNOLOGY SELECTION

A preliminary technology selection has been completed for each of the six effluent categories. The selected technologies are state of the art, expected to meet or exceed BAT guidance, and are appropriate for site planning purposes. The selected technologies, however, are not necessarily the most cost-effective technology for a given stream nor has a BAT analysis been performed to determine whether the effluent reduction achieved justifies the cost involved or whether further treatment may be required. Stream-specific engineering and conceptual design studies, consultation with regulatory agencies, and the National Environmental Policy Act process will be required to make final technology selections, prepare project cost estimates, and determine cost effectiveness of the selected technology.

The selected treatment technologies include:

- An end-of-pipe treatment system for the production reactor effluent, which will include filtration, to remove the dissolved radioactivity
- In-plant and process modifications for the laboratory and chemical sewers. The type of modifications will be stream-specific but are expected to include neutralization, chemical reuse, spill control, and containment systems
- An end-of-pipe treatment system for the process condensates, which will include filtration, reverse osmosis, and ion exchange
- A closed-loop system for the steam condensates that will use a reboiler to recycle the condensates back to the facility
- A closed-loop system for the cooling water effluents, which will be composed of a primary loop with treatment to remove accumulating contaminants, a heat exchanger for heat transfer, and secondary loop and cooling tower for heat removal
- An end-of-pipe treatment system for the laundry effluent using filtration and ion exchange
- Solidification of separated effluent contaminants using the grout technology currently being developed at the Hanford Site.

PRIORITIZATION

A two-phased prioritization system is used to determine stream priority for implementation of alternative disposal methods. Phase I streams are considered higher priority and are identified based *on one* of the following criteria:

- A significant potential exists for the liquid effluent to receive reportable or regulated chemical spills
- The liquid effluent contains radioactive substances in excess of the derived concentration guides (DCG).[a]

Based on these criteria, 16 streams have been identified as Phase I priority. All eight laboratory and chemical sewer streams and the UO_3 Plant waste water, which has a chemical sewer component, are considered to have a potential for receipt of chemical spills. The other seven streams that currently exceed the DCG include:

- N Reactor effluent
- B Plant process condensate
- PUREX process condensate
- PUREX ammonia scrubber discharge
- UO_3 Plant process condensate
- Plutonium Finishing Plant waste water
- AY, AZ Tank Farm steam condensate.

IMPLEMENTATION COSTS

Implementation costs for alternative disposal of all 32 liquid effluents were evaluated. Complete implementation of the alternative systems identified in this study is estimated to cost from \$300 to \$410 million. Implementation of alternative systems for the Phase I streams and the waste concentration and solidification facilities is estimated to cost (including expense and capital costs) from \$150 to \$190 million. Implementation of alternative systems for the Phase II priority streams is estimated to cost (including capital and support costs) from \$150 to \$220 million.

CONCLUSIONS

From the evaluation conducted to date of the feasibility of eliminating disposal of contaminated liquid effluents to the soil column at the Hanford Site, the following conclusions can be made:

- Technically feasible systems for alternative waste disposal are available
- The magnitude of costs and other resource requirements for implementing alternative waste disposal systems require prioritization of implementation
- Engineering and design studies and coordination and consultation with regulatory agencies is required to select optimum and cost-effective technology
- Alternative waste disposal systems for those streams designated Phase I can be implemented by 1995.

Current plans call for implementation of alternative waste treatment and disposal methods for those streams designated as Phase I by 1995. Administrative controls are currently in place to prevent the discharge of regulated chemicals to the chemical and laboratory sewer streams, and engineered systems to control and contain spills are being implemented or being planned. Preliminary engineering and capital project planning have been initiated for the process condensate discharges. Final implementation and selected technology for these projects may be impacted by the long-term operating plans for current facilities.

[a]Draft concentrations of radionuclides in water that could be continuously consumed and not exceed an effective dose equivalent of 1 mSv were prepared by DOE (6).

REFERENCES

1. U.S. DEPARTMENT OF ENERGY, "Radioactive Waste Management," DOE Order 5820.2, Washington, D.C. (1984)

2. U.S. DEPARTMENT OF ENERGY-RICHLAND OPERATIONS OFFICE, "Draft Environmental Impact Statement: Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes," DOE/EIS-0113, Richland, Washington (1984).

3. U.S. ENERGY AND RESEARCH DEVELOPMENT ADMINISTRATION, "Final Environmental Impact Statement: Waste Management Operations," ERDA-1538, Washington, D.C. (1975).

4. R. C. ALDRICH, "Liquid Wastes Discharged to Ground in the 200 Areas During 1985," RHO-HS-SR-85-3 R Q Liquid P, Rockwell Hanford Operations, Richland, Washington (1986).

5. G. F. WILLIAMSON, R. L. TREAT, and E. L. McDANIEL, "Hanford Transportable Grout Facility: Technology and Design," *Transactions*, Vol. 52, ANS Annual Meeting, Reno, Nevada (1986).

6. K. R. PRICE, "Environmental Monitoring at Hanford for 1985," PNL-5817, Pacific Northwest Laboratory, Richland, Washington (1986).