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Cost Effectiveness of Detritiating Water with Resin Columns

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Author: *Robert H. Drake, TSA-4
Donna S. Williams, TSA-4*

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Summary

- There are technologies in use for cleaning up concentrated tritiated process water (Table 1). These are not cost effective for tritiated water with low concentrations of tritium. There are currently no cost-effective technologies for cleaning up low-tritium-concentration tritiated water such as most tritiated groundwater, spent fuel storage basin water, or underground storage tank water.
- Resin removal of tritium from tritiated water at low concentrations (near the order of magnitude of drinking water standard maximums) is being tested on TA-50 (Los Alamos National Laboratory's Liquid Radioactive Waste Treatment Facility) waste streams. There are good theoretical and test indications that this may be a technologically effective means of removing tritium from tritiated water.
- Because of likely engineering design similarity, it is reasonable to anticipate that a resin column system's costs will be similar to some common commercial water treatment systems. Thus, the potential cost effectiveness of a resin treatment system offers hope for treating tritiated water at affordable costs.
- The TA-50 resin treatment cost projection of \$18 per 1,000 gallons is within the same order of magnitude as cost data for typical commercial groundwater cleanup projects.
- The prospective Los Alamos National Laboratory (LANL) resin treatment system at \$18 per 1,000 gallons appears to have a likely cost advantage of at least an order of magnitude over the competing, developmental, water detritiation technologies.

Table 1. Summary of unit costs.

Type of Technology	Cost (\$ per thousand gallons)
Resin Column System (Tritiated Water)	Estimate: \$18
Typical Commercial Water Treatment (VOCs, Metallics)	Range: \$1 - \$100
Low Concentration Tritiated Water (10 SRS Studies)	Cheapest - Direct Heat Evaporation: \$66 Girdler Sulfide: \$162 Most Others: >\$1,000
High Concentration Tritiated Water (Mg Bed, PMR-ISS, Cement/Burial)	> \$3,000,000

1. Background

There are currently no cost-effective technologies for cleaning up low-tritium-concentration tritiated water such as most tritiated groundwater, spent fuel storage basin water, or underground storage tank water. This report briefly examines the potential cost effectiveness of a resin treatment system that plausibly may offer an opportunity to treat tritiated water at costs in the range of typical environmental water treatment systems already in use for other, more common contaminants.

There are technologies in use for cleaning up concentrated tritiated process water. These are not cost effective for tritiated water with low concentrations of tritium. These technologies include the magnesium bed system, palladium membrane reactor with cryogenic distillation, and simple cementation and burial. All have costs of the order of more than \$1,000 per liter of water treated. This cost translates to more than \$3 million per 1,000 gallons of water treated. In contrast, typical environmental water treatment systems for metallic or volatile organic compound contaminants (VOCs) have costs in the \$1 to \$100 per 1,000 gallons range.

Public perception, imaginable future public health concerns, and potential regulatory changes hint at the need for possible future action to enable DOE to clean up low-concentration tritiated water. There are no technologies that can be considered cost effective for this type of environmental cleanup at present.

2. Developmental Technologies

At the required scale of tritiated water treatment, all potential tritiated water treatment technologies are at the "exploratory development" or earlier stages of the technology development process. These technologies include the subject of this report, detritiation by passing tritiated water through a resin column where tritium is deposited. They also include processes such as evaporation, stripping and sparging, the Girdler Sulfide system, dual-temperature liquid-phase catalytic exchange, storage tanks, infiltration reduction, ground freezing, and electrolysis.

DOE/EM-50 guidelines indicate that costs should only be considered estimable to a within a factor of 5-10 at this stage of exploratory development. The 1996 Savannah River Site (SRS) study, Status and Practicality of Detritiation and Tritium Reduction Strategies for Environmental Remediation, WSRC-RP-96-0075 made detailed cost projections for 10 detritiation technologies applicable to groundwater or other low-concentration tritiated water sources. None of these technologies came in at projected costs of less than \$60 per 1,000 gallons and most were much higher. This report develops such a cost estimate for a resin column system, where projected costs are likely to be below \$60 per 1,000 gallons.

The subject resin column system resembles some types of commercial water treatment systems currently in use to remove VOCs or metallic contaminants. This is in contrast to the specialized tritiated water treatment technologies discussed in the SRS study, which all have infeasibly high costs in their current design conceptions. These high costs

result from the inherent difficulty of dealing with extraordinarily small fractions of the tritium contaminant within the volume of treated water. The concept of simply flowing the water through a resin column has the prospect (as with other more common contaminants) of removing the tiny, tiny fraction of tritium contaminant without huge, new energy requirements or having to deal with extraordinarily low isotope separation factors demanding costly multiple stages of treatment.

3. Resin Treatment

Resin removal of tritium from tritiated water at low concentrations (near the order of magnitude of drinking water standard maximums) is being tested on TA-50 (LANL's Liquid Radioactive Waste Treatment Facility) waste streams. There are good theoretical and test indications that this may be a technologically effective means of removing tritium from tritiated water. Tritium would selectively attach to resin sites and be tied up in the resin leaving detritiated water to pass on. Small-scale batch tests are currently being carried out on several different resins using actual effluent waste water. The follow-on engineered application would involve a continuous pass of effluent water through resin columns with discharge to the environment as cleaned water. The tritium would be retained in the resin which could be disposed of directly as low level radioactive waste (LLW), or possibly back-flushed with the capture of the concentrated tritium through ancillary processes and the potential recovery of the tritium in some scenarios.

3.1 LANL TA-50 Cost Projection for a Resin Treatment System

The following is an exploratory development cost projection for resin detritiation of TA-50 effluent water. It is only a very rough, preliminary projection. It takes as its starting analog a proposed ion exchange system for nitrate removal from the TA-50 effluent stream. Prospective cost information exists for this proposed nitrate removal system. The basic flow-through columns with nitrate ion exchange would be similar in engineering principles to what might be designed in using columns of resin to detritiate water. The flow rates, administrative requirements, space, manpower loading, and other capacities should be similar. But all of the realistic engineering awaits clarification of resin performance and operational requirements.

- Research and development costs are not included.
- Permitting and regulatory approval are assumed to be a part of R&D and/or engineering and supervision costs.
- Typical cost estimating accuracy at this stage of development is normally expected to be only accurate to within a factor of 5-10.
- The projection is for treating a current TA-50 annual flow of about 20 million liters per year (6 million gallons per year).
- Decontamination and Decommissioning (D&D) cost at the end of the project (if required) is relatively small and subsumed in annual operations and maintenance charges. D&D involves dismantling or replacement of columns/pipes and burial as LLW if required.

Figure 1. LANL's Liquid Radioactive Waste Treatment Facility (TA-50).

Table 2. Capital costs.	
Equipment	
Initial resin	\$10,000
2 resin containing columns	\$10,000
Piping	\$5,000
2 pumps (25 gpm)	\$10,000
Instrument and control systems	\$20,000
Electrical supply	\$2,000
Installation (30% of Equipment)	\$17,000
Building modifications (\$400 per square foot)	\$40,000
Total Equipment Cost	\$114,000
Engineering and Supervision (30% of Total Equipment Cost)	\$34,000
Contingency (15% of Total Equipment Cost)	\$17,000
Total Capital Costs	\$165,000
Annual capital cost charges assuming a 7-year-life @ OMB real interest rate of 3.4% and spreading the \$165,000 over the life of the project is \$27,000 per year.	

Table 3. Annual project costs.

		Annual Capital Charges	\$27,000
Operations			
Resin			\$10,000
Electric power			\$1,000
200 man-hours (\$50 per hour)			\$10,000
Maintenance			
Materials (10% of Equipment)			\$11,000
200 man-hours (\$50 per hour)			\$10,000
LLW Disposal (100 cubic feet @ \$30 per cubic foot)			\$3,000
Total Annual O & M and Disposal Costs			\$45,000
Overhead (50% of Annual O & M + Annual Capital)			\$36,000
Total Annual Project Costs			\$108,000
Unit Cost per gallon of water treated is \$18 per 1,000 gallons.			

4. Cost Drivers and Sensitivities

In this particular projection, the major cost drivers can be classified into three roughly equal shares:

- capital equipment 33%
- labor 28%
- resin plus other materials 33%

(Overhead is uniformly applied to all three.)

The resin itself is about 18% of the total, so there is no single dominant cost factor. Even a major error in one of the three main cost driver estimates will not make for nearly as big a percentage error in the overall estimate.

The resin cost and detritiation efficiency has not yet been evaluated for a production plant, and is thus the largest source of cost uncertainty. Because the resin contributes 18% of the cost in our example, its performance will be important to the veracity of the cost estimate, particularly if it works less well than in the example's projection.

If plant treatment capacity in the example is doubled, resin and materials costs would also roughly

double, capital costs would increase by something like 50%, and labor costs would barely be affected. Thus overall costs would only increase by about 50%, yielding a unit cost about one quarter less or about \$13 per 1,000 gallons. Similar, compounded economies-of-scale should be expected as the overall plant or project size changes by even larger amounts.

4.1 A Fanciful Cost Projection for a Similar Mobile System

If the example treatment system were to be made into a mobile setup for transfer to differing DOE sites and limited-term operations, additional costs would be incurred. Building modifications of \$40K would no longer be required. Instead, a mobile transporter (truck) of perhaps \$100K would be substituted. The TA-50 scenario projected only 10 total man-weeks of operating and maintenance time per year. A mobile operation would probably demand a full-time, 3-person crew increasing direct labor costs from \$20K to \$300K. This labor requirement would be the most significant change to overall costs. The TA-50 projected capacity factor

was 55% which is probably a decent guess for the mobile setup as well, so 6 million gallons would still be treated. The unit cost would rise to about \$90 per 1,000 gallons. (In this fanciful case, because of the huge share of virtually fixed labor costs, now becoming about 80% of the annual cost, increases in capacity would have very strong and immediate effects in reducing unit treatment costs for each increment of plant size increase and water throughput.)

5. Conclusions --- Comparison to Other Technology Costs

5.1 Conclusion #1

The above TA-50 resin treatment cost projection of \$18 per 1,000 gallons is within the same order of magnitude as the Compendium cost data for typical groundwater cleanup projects.

The DOE/ETCAP Compendium of Cost Data for Environmental Remediation Technologies, LA-UR-96-2205, (available at: <http://lib-www.lanl.gov/la-pubs/00326055.pdf>), pages 76-107, has a wide range of groundwater and surface water treatment costs. Case studies of costs for 56 water treatment projects are listed. Many results are in the \$1 per 1,000 gallons range, but lots of the studies range up to \$100s per 1,000 gallons. The Compendium generally deals with volatile organic compounds and/or various metallic contaminants. The compiled studies do not represent a scientific sample, but indicate that in many real cases the cost of groundwater cleanup is in the range of \$1 - \$100 per 1,000 gallons.

5.2 Conclusion #2

The prospective LANL resin treatment system at \$18 per 1,000 gallons appears to have a likely cost advantage of at least an order of magnitude over the competing, developmental, detritiation technologies.

The 1996 Savannah River Site study, Status and Practicality of Detritiation and Tritium Reduction Strategies for Environmental Remediation, WSRC-RP-96-0075 made detailed cost projections for 10 detritiation technologies applicable to groundwater or other low-concentration tritiated water sources. None of these technologies were found to be technologically ready for application or cost effective. However, the LANL resin technological development is a new, competing technology in this family. Our TA-50 projection for resin treatment costs is significantly more cost effective than any of the technologies in the SRS report. The SRS includes cost results for a tritiated water flow rate of 25 gpm - the same as our TA-50 projection.

The lowest cost technology reported by SRS was simple evaporation by direct heating with a cost of \$66 per 1,000 gallons. The Girdler Sulfide system with a cost of \$162 per 1,000 gallons was the next best, but has serious safety problems. Most other projected costs exceeded \$1,000 per 1,000 gallons -- greatly exceeding the potential resin treatment costs.

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