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Project Summary

Cost Comparisons of Treatment and Disposal Alternatives for Hazardous Materials Volumes I and II

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Life cycle cost information is an important element in selecting hazardous waste treatment and disposal technologies. This project evaluates the technologies and costs of wastes from the organic/inorganic chemicals, and the electroplating and metal finishing industries for 16 alternative treatment and 5 alternative disposal methods. Capital and operation/maintenance costs were calculated for each process by using computer models. Final cost comparisons of treatment/disposal technologies for similar waste streams were then made. Risks associated with each technology were qualitatively assessed in terms of susceptibility to catastrophic events, unexpected downtime, and adverse environmental impacts.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This study details hazardous waste treatment and disposal technologies and costs. Guidance is provided for making conceptual cost estimates for selected technologies and making comparisons among alternative processes when more then one option is available. Specific project objectives were to:

- Assemble available data on the costs of technologies for treatment and disposal of hazardous wastes.
- Upgrade existing information from literature sources and equipment manufacturers.
- Rank treatment and disposal processes according to their cost effectiveness for environmental protection.
- Provide assessments and comparisons of the risk for adverse environmental impacts and complexity of implementing each technological process.

Comparisons of effectiveness are based on criteria developed by the U.S. Environmental Protection Agency, Office of Solid Waste, for controlling hazardous wastes as promulgated under Subtitle C of RCRA (P.L. 94-580).

Treatment and Disposal Technologies

The treatment and disposal of aqueous hazardous wastes produced by organic and inorganic chemicals in the electroplating and metal finishing industries are addressed. The types of chemicals contained in the waste streams of these three industries are listed in Table 1. Considerable attention must be given to selecting treatment and disposal technologies compatible with the chemical constituents of various waste streams.

Initial work on the cost-effectiveness models involved identifying the technologies and waste streams. Each treatment and disposal process was rated according to these criteria:

- Applicability within industry categories.
- Presence in typical off-site or municipal treatment processes.
- Availability of cost and performance data.
- Determination of whether the technique is destructive or involves indefinite fixation/storage.

Sixteen treatment and five disposal technologies were selected for study (Table 2). Detailed analyses of each of these technologies yielded descriptions and process flow schematics. In Table 2, the 21 treatment and disposal technologies are related to the equipment/process needed to achieve treatment/disposal.

Table 1. Chemicals Contained in Waste Streams of Three Industries

	Industry		
Hazardous Waste Category	*Organic Chemicals*	*Inorganic Chemicals*	*Electroplating/ Metal Finishing*
Organic Chemicals	*Phenols and cresols, ethers, halogenated aliphatics, polycyclic aromatic hydrocarbons, monocyclic aromatics, nitrosamines, PCBs, phthalate esters*	*Chlorinated hydrocarbons*	*Degreasing solvents, chlorinated hydrocarbons*
Metals, Metal Salts, Complexes, etc.	*Misc. (used in catalysts)*	*Hg, HgC1, HgS, Pb, Cr, Cu, Ni, Sb, chromates, sodium-calcium, calcium-fluoride, ferric ferrocyanide, ferric arsenate, arsenic chlorides, nickel hydroxide, lead salts, arsenic trisulfide*	*Pb, Cr, Cu, Ni, An, Cd, Pd*
Non-Metal Inorganics	*Various*	*Asbestos Phosphorus sulfide Phosphorus trichloride*	*Cyanides Fluorides*
Acids Caustics	*Misc. acids Misc. caustics (used in production reactions)*	*Hydrofluoric acid Sulfuric acid Hydrochloric acid Caustics*	*Sulfuric acid Hydrochloric acid Caustics*
Pesticides	*Certain halogenated aliphatics*	*Inorganic pesticide manufacture (mainly metals; Cu, Pb, Zn)*	*Chlorinated hydrocarbons*

Costs

Additional data collections and assessments produced (1) a compilation of comprehensive cost files for each technology and individual component, and (2) cost and performance equations that relate the cost of components to scaling factors and system variables. This information along with the *executive programs* (described in full in the report) were then coded and entered in a modified Fortran IV format for analysis. Cost data are sufficiently detailed so that equipment and size of the operation can be modified, and a specific cost estimate can be derived. Table 3 summarizes the life cycle costs for the 16 treatment and the 5 disposal technologies addressed in this study. These cost estimates consider:

Capital Costs:

- Costs of purchased equipment required for the processes, including contingencies and contractor's profit.
- Cost of equipment delivery, field erection, installation, piping, concrete, steel, instrumentation, electrical insulation, and all appurtenances required for proper operation of the processes.
- Prime contractor engineering for the technology.
- Licenses and fees.
- Construction overhead.
- Costs of buildings when required for proper process function or protection from weather.
- Land costs.
- Working capital.
- Allowance for funds during construction.

Operating and Maintenance Costs:

- Utility costs.
- Labor.
- Chemical costs (transported to site and prepared for use).
- Maintenance.
- Product or residuals (salable commodities as well as further disposal costs).
- Administrative overhead.
- Debt service and amortization.
- Real estate taxes and insurance.

The risk assessment process considers the probability of catastrophic events occuring (this can be related to geographical location); downtime risks associated with system reliability, unexpected equipment damage, and in some cases, problems independent of the technology selected (e.g., chemical supply or labor problems); and adverse environmental

Table 2. Unit Process Modules Comprising the Hazardous Waste Treatment and Disposal Technologies

Treatment and Disposal \ Equipment/Modules Process	Flocculator	Flash Mixer	Jacketed Flash Mixer	Aerated Lagoon	Aerated Basin	Sludge Digestor	Trickling Filter	Waste Stab. Pond	Chemical Fixation	Incinerator	Sedimentation Basin	Clarifier	Rotary Drum Vacuum Filter	Air Flotation	Oil/Water Separator	Multi-media Filter	Distillation	Evaporator	Reverse Osmosis	Ultrafiltration	Carbon Adsorption	Decanter	Chemical Storage: Gas	Chemical Storage: Liquid	Chemical Storage: Solid	Sludge Equalization	Haz. Waste Land Disposal Site	Encapsulation	Deaerator	Evaporation Pond	Steam Generator	Sludge Digestor
Precipitation Coagulation/Flocculation/ Sedimentation	X	X									X		X										X	X								
Filtration													X			X								X								
Evaporation																		X													X	
Distillation																	X							X							X	
Flotation				X									X	X																		
Oil/Water Separator															X									X								
Reverse Osmosis																			X					X								
Ultrafiltration																				X				X								
Chemical Oxidation/Reduction			X																				X	X	X							
Hydrolysis			X																			X		X					X			
Aerated Lagoon				X							X	X	X											X								
Trickling Filter							X				X	X	X											X								
Waste Stab. Pond								X			X																					
Anaerobic Digestion														X											X		X					X
Carbon Adsorption																					X										X	
Activated Sludge					X						X	X	X											X								
Evaporation Pond																														X		
Incineration										X														X								
Land Disposal																											X					
Chemical Fixation									X																							
Encapsulation																												X				

factors (emphasizing the existence or absence of potential causes of such impacts).

Evaluations of each of the 21 treatment/disposal technologies included the following engineering/design information:

- Technology description processes, flow diagram, design detail.
- Changes in technology configuration with scale.
- Application (hazardous waste streams treated and/or disposed of according to industry and waste type).
- Cost:
  - Summary of capital cost.
  - Changes in capital costs with scale.
  - Summary of first year operating costs.
  - Changes in operation and maintenance costs with scale.
  - Life cycle average costs.
  - Life cycle average costs according to scale.

Computed costs were typical of waste discharge rates from the three industries studied. Costs given are for mid-1978 and are based on unit costs as they apply in Chicago, Illinois.

Example

An example evaluation procedure for one of the selected treatment technologies (reverse osmosis) follows; the report includes similar assessments for the remaining 20 alternative treatment and disposal technologies.

Technology Description

The basic unit for an industrial waste treatment process that uses a reverse osmosis plant is the reverse osmosis process. The modules are assembled in a racklike configuration to accommodate the desired waste flow rate. Theoretically, reverse osmosis is induced by applying high pressure to a suitable membrane that, at the same time, rejects the salt molecules and produces a relatively salt-free water stream. The remaining salt solution is concentrated and removed from the system.

Care must be exercised with reverse osmosis systems to ensure that waste does not contain certain colloidal substances or heterogeneous matter; otherwise, these may, in time, reduce the permeability of the membrane and subsequently reduce the quantity of effluent produced.

Table 3. Cost Comparisons Among Treatment and Disposal Technologies: Standard Units

Technology	Life	Simple Average Cost ($ per 1,000 gal.)[a] at gpm					Life Cycle Average Cost ($ per 1,000 gal.)[a] at gpm				
		1,000	2,000	3,000	4,000	5,000	1,000	2,000	3,000	4,000	5,000
Precipitation/Flocculation/ Sedimentation	10	2.65	2.16	1.94	1.85	1.79	1.72	1.40	1.26	1.20	1.16
Filtration	10	3.66	3.12	2.75	2.54	2.43	2.31	1.97	1.74	1.61	1.54
Evaporation	5	10.33	9.43	9.12	8.98	8.89	8.48	7.74	7.49	7.37	7.30
Distillation	5	15.86	16.36	16.37	16.36	16.40	13.02	13.39	13.41	13.40	13.43
Flotation	10	1.98	1.62	1.43	1.33	1.27	1.26	1.04	0.92	0.85	0.81
Oil/Water Separator	10	0.76	0.51	0.44	0.44	0.48	0.48	0.32	0.28	0.28	0.30
Reverse Osmosis	7	9.05	9.40	9.61	9.62	9.79	6.71	6.97	7.12	7.13	7.25
Ultrafiltration	7	4.04	3.36	3.61	3.61	3.76	3.02	2.51	2.70	2.70	2.81
Chemical Oxidation/Reduction	5	5.31	4.56	4.52	5.23	6.22	4.36	3.74	3.71	4.29	5.10
Hydrolysis	5	0.99	0.83	0.75	0.74	0.76	0.82	0.69	0.62	0.62	0.63
Aerated Lagoon	15	5.30	3.81	3.31	3.89	4.35	2.62	1.89	1.64	1.93	2.15
Trickling Filter	15	4.70	3.82	3.63	3.30	3.19	2.37	1.93	1.84	1.68	1.63
Waste Stab. Pond	5	4.45	3.94	3.71	3.63	3.54	3.70	3.28	3.09	3.02	2.95
Anaerobic Digestion	10	7.88	6.91	6.53	6.41	6.28	5.14	4.53	4.29	4.21	4.13
Carbon Adsorption	7	27.43	16.43	12.69	10.96	9.89	20.26	12.14	9.38	8.10	7.31
Activated Sludge	10	4.84	3.54	3.11	4.02	4.84	3.08	2.28	2.00	2.57	3.10
Evaporation Pond	20	8.99	8.20	7.90	7.75	7.75	4.01	3.71	3.60	3.54	3.54
		Simple Average Cost ($ per 1,000 lbs.)[a] at lbs/hr					Life Cycle Average Cost ($ per 1,000 lbs.)[b] at lbs/hr				
		1,000	2,000	3,000	4,000	5,000	1,000	2,000	3,000	4,000	5,000
Incineration	5	309.90	298.23	295.10	293.34	293.64	256.55	246.91	244.34	242.88	243.15
Land Disposal	20	389.94	235.14	178.08	149.40	132.36	154.34	91.26	68.37	56.86	50.01
Chemical Fixation With Solids	NA	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
Chemical Fixation Without Solids	NA	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
Encapsulation	7	61.99	56.90				46.62	42.87			

[a] $/1,000 gal. = $/m^3$

[b] $/1,000 lbs. = $/t × 0.453

Changes in Configuration with Scale

Additional banks of modules are used to accommodate increased flow rates.

Applications

The following applications are documented for reverse osmosis:

- Separation of plating salts.
- Reclamation of rinse waters for reuse.
- Reclamation of metals from plating.
- Removal of residual total dissolved solids.
- Removal of certain trace organic compounds (e.g., pesticides).

Costs

The capital and first-year operating costs for the example facility are calculated with the use of the capital and operating/maintenance cost files and the computer model cost equations. First year operating costs for a 1,000 gpm Chicago-based facility (including administrative overhead, debt service and amortization, real estate taxes, and insurance) are approximately $871,000.

The life cycle average costs for the example facility (assuming a life cycle of 7 years) are calculated to be $6.71 per 1,000 gallons of waste treated. No economy of scale was observed over the range of design flows that were studied. In fact, for reverse osmosis treatment, the average life cycle cost increases. This increase is attributed to the need for larger and more complex module arrangements, support facilities, and increased chemical costs.

Volume II

Volume II contains the following: Appendix A, Section 250.45 of the Resource Conservation Act; Appendix B, Capital Unit Cost File; Appendix C, Operation and Maintenance Unit Cost File; Appendix D, Curve Fitting for Cost Files; Appendix E, Module Descriptions; and Appendix F, System Variable Equations.

Risk Assessment

The risk assessment concludes that some potential loss may occur from (1) catastrophic events (e.g., earthquakes, floods, tornadoes, or fires), and (2) unexpected downtime (e.g., membrane clogging). Potential adverse environmental impacts are assessed, and, in most instances, it is determined that only minimal impacts are likely.

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The complete reports, entitled "Cost Comparisons of Treatment and Disposal Alternatives for Hazardous Wastes: Volume I and Volume II," (Order Nos. PB 81-125 814; Cost: $20.00 and PB 81-128 522; Cost: $9.50, subject to change) will be available only from:
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