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Project Summary

Preliminary Assessment of Hazardous Waste Pretreatment as an Air Pollution Control Technique

James J. Spivey, C. Clark Allen, Robert L. Stallings, D. A. Green, J. P. Wood, and Benjamin L. Blaney

Many hazardous or potentially hazardous waste streams that contain volatile compounds can be emitted to the atmosphere during waste storage, treatment, and disposal. One way to minimize or eliminate these emissions is to pretreat wastes to remove these compounds.

The full report examines 72 waste streams containing volatile compounds and the technical applicability of 12 pretreatment techniques (e.g., steam stripping) for removing volatile compounds from them. Based on this analysis, conclusions are derived about the general applicability of these techniques to hazardous waste streams for volatile removal. In addition, a cost analysis is performed for each of the 12 pretreatment techniques to determine the unit costs of VOC removal.

This Project Summary was developed by EPA's Hazardous Waste Engineering 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

The purpose of this study was to conduct a preliminary assessment of the technical and economic feasibility of various pretreatment techniques for the removal of volatile constituents from hazardous waste streams. This study was conducted in response to increasing concern over the potentially adverse health and environmental consequences associated with emissions of volatile substances from hazardous waste treatment, storage, and disposal facilities (TSDFs).

According to U.S. Environmental Protection Agency (EPA) national survey of TSDFs conducted in 1981, there are about 4,820 TSDFs in this country managing a total of about 151 billion liters of hazardous waste annually. There are a number of sources within TSDFs from which volatile emissions can be emitted. These sources include aerated impoundments, landfills, land treatment, surface impoundments, cooling towers, storage tanks and general process operations. While in many cases these emissions can be controlled by add-on equipment (e.g., carbon canisters), another option is to remove volatile compounds from waste before the waste enters these TSDF processes.

Approach

The approach to this project was to:

1. Identify an appropriate hazardous waste stream data base for use in assessing the feasibility of VOC removal by waste treatment.
2. Identify general pretreatment unit processes (e.g., adsorption) that can be used to remove volatile constituents from physically and chemically different hazardous waste streams and to estimate volatile removal efficiency.

3. Calculate preliminary economics, using an example case, for each pretreatment unit operation.

Reasonably detailed data on stream composition and physical properties are required to evaluate pretreatment technology for removing volatile constituents. Available compilations of hazardous and potentially hazardous waste stream composition and generation rate information were evaluated to find the one most suitable for this study. The Waste Environmental Treatment (WET) Model* was judged to have the most pertinent information for an engineering assessment of this type. It is also the most comprehensive, and, in spite of some limitations (e.g., volatile constituents are not identified for some streams, and waste streams can vary in composition), the WET Model data were useful for assessing potential pretreatment techniques.

A thorough screening of current technology was conducted to determine which pretreatment techniques could be used for volatile constituent removal/recovery. Twelve engineering techniques were selected:

- Steam stripping
- Chemical oxidation
- Liquid phase carbon adsorption
- Liquid phase resin adsorption
- Air stripping/adsorption
- Evaporation/adsorption
- Biological treatment
- Ozonation/radiolysis
- Distillation
- Wet oxidation
- Solvent extraction
- Physical separation

Techniques that are used primarily for ultimate destruction, such as incineration and pyrolysis, were excluded. The individual compatibility of each of these techniques with the 72 WET Model waste streams that contained volatiles was evaluated.

For each pretreatment technique, there is a set of hazardous waste stream characteristics (or criteria) that determine if the technique is applicable to that stream. (For example, one criterion for using liquid phase carbon adsorption pretreatment to remove volatiles is that the waste stream in contact with the adsorbent must not contain excessive concentrations of metallic ions or solids.) Using such criteria, an appropriate WET Model stream was selected for each treatment technique and a detailed example was prepared to show how pretreatment might be used. In addition, an economic analysis was performed for each technique on one waste stream to obtain preliminary unit cost estimates.

Example Case—Liquid Phase Carbon Adsorption

As an example of the analysis of each of the 12 treatment techniques, summary of the applicability of liquid phase carbon adsorption to waste treatment for volatile removal is presented here.

The adsorption of organic compounds from both liquid and gaseous phases onto activated carbon is a mature process technology with widespread use as an integral unit operation in such industrial manufacturing processes as corn syrup and pharmaceuticals production and sugar refining, in industrial and municipal wastewater treatment, in drinking water purification, in the separation and recovery of organic compounds from vapor streams, and in pollution control of atmospheric emissions. Although activated carbon has been and continues to be the dominant adsorbent used, other adsorbents such as resin or polymeric materials and zeolite molecular sieves have found increasing use for a number of special applications in recent years.

Process Description

The liquid phase activated carbon adsorption process involves two basic steps as shown in Figure 1. In Step 1 (adsorption), the waste stream contacts the carbon, which selectively adsorbs the hazardous material(s) and allows the purified stream to pass through. Step 2 (disposition of contaminated or spent carbon) represents a number of process options. When the carbon reaches its maximum capacity or when the effluent is unacceptable for discharge, the carbon is removed from the adsorber for disposal, destruction, or regeneration as established by the option selected under Step 2. In some cases, the carbon can be regenerated in such a way that the adsorbate is recovered. This may be important in pretreatment of hazardous wastes because the recovered volatile material may have some economic value (e.g., as a solvent).

Process Operation

The technical suitability of a waste stream for carbon adsorption pretreat ment depends mainly on its physica form and the type and relative concen tration of constituents. However, othe factors that affect the treatment eco nomics often dictate which streams ar actually feasible for carbon treatment such factors include the required de gree of solute removal, waste through put rate, and carbon utilization.

The following characteristics may b used as guidelines to identify wast streams that are likely candidates fo carbon treatment:

- Aqueous waste streams with o ganic solute concentrations th are less than 15 percent, althoug in practice the most concentrate influent to be treated contains les than 10,000 ppm total organic ca bon.
- Waste streams in which the aggr gate concentration of high molec lar weight nonvolatile organics i substantially lower than the co centration of the volatile organics
- Waste streams in which suspende solids are less than 50 ppm if th stream is not prefiltered and les than 2.5 percent if prefiltered.
- Waste streams in which oil an grease concentrations are less tha 10 ppm.
- Waste streams in which the co centration of dissolved inorgani is low (less than 100 ppm), unle waste stream preconditioning an spent carbon washing before rea tivation operations are included.

The removal efficiency of carbo treatment can be controlled to prac cally any level through the design of t carbon contractor. Typical carbon trea ment efficiencies are better than 99 pe cent with influent concentrations belo 1,000 ppm. At higher influent conce trations, removal efficiencies can e ceed 99.99 percent removal to yield e fluent concentrations at several pp As with most alternative treatme processes, carbon treatment remov efficiencies must be compared to ca tal and operating costs which increa dramatically as efficiencies approa 100 percent.

Process Economics

Several variables and/or alternativ in the design and operation of a carb treatment system can have a major i pact on the economics of the proce These factors include:

- type of carbon (GAC or PAC),
- flow rate,

*The 1983 version of the WET model was used in this study. The model is being updated and expanded.

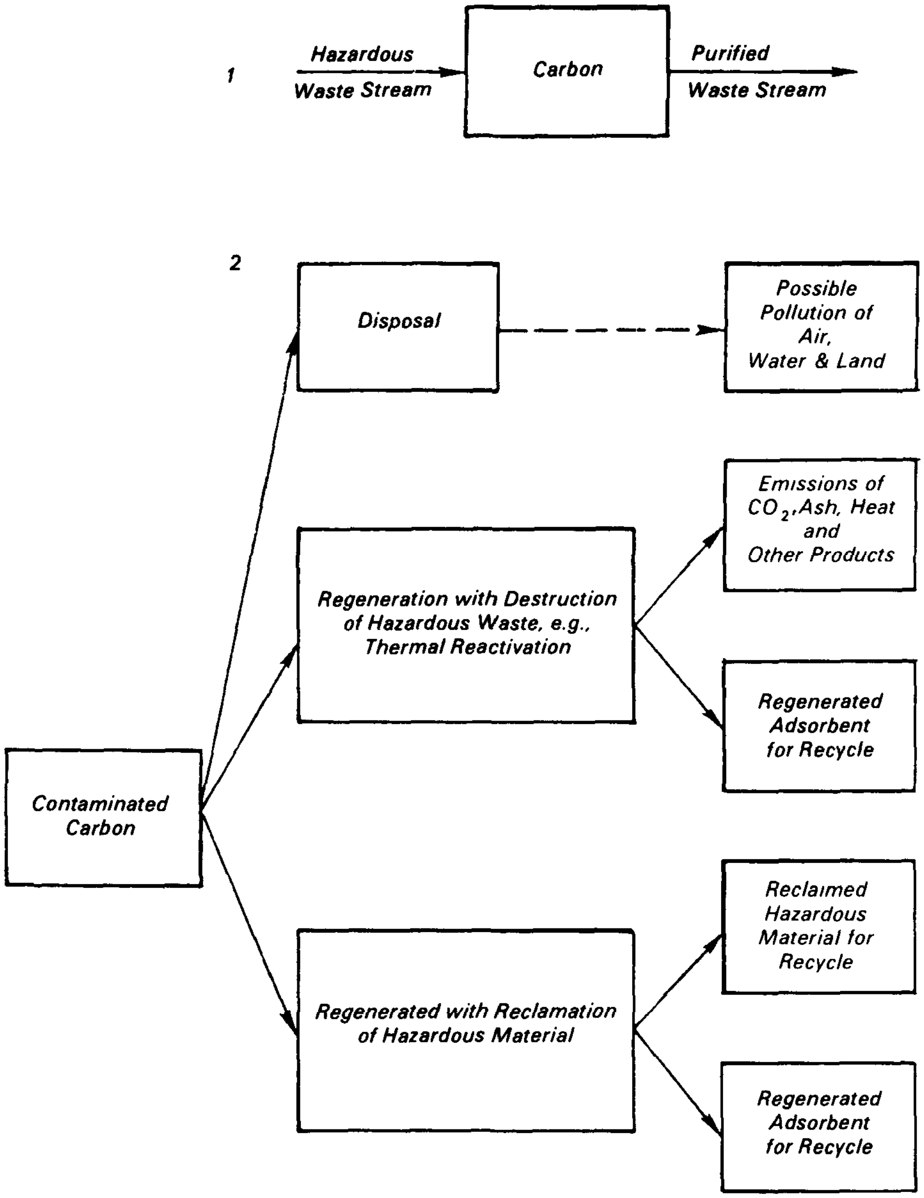

Figure 1. *Steps in carbon adsorption.*

- contact time,
- process configuration (series, parallel, or moving bed)
- number of stages, and
- flow direction (packed or expanded; upflow or downflow).

Wet Model Example

Waste stream 02.02.14 from the WET Model was selected as an example to show a typical carbon adsorption system design, associated material balances, and treatment economics.

This stream, with a nominal rate of 426,000 kg/day (17,750 kg/h, based on 365 day/yr operation) contains benzene, toluene, and phenol at concentrations ranging from 3,000 to 5,000 ppm. Although these concentrations are on the upper range of the concentrations currently being treated in commercial practice, GAC has been effective for these constituents at these levels. The composition of WET stream 02.02.14 is given in Table 1.

The major process uncertainties in the design of this carbon adsorption system are: (1) the equilibrium capacity of the carbon for the three organics in a multicomponent aqueous solution of this particular composition, (2) the adsorber residence (retention) time, and (3) the carbon recirculation rate. For this case, a carbon loading of 0.3 kg adsorbate/kg carbon and a minimum adsorber residence time of 30 min. was assumed. Also, to size the reactivation furnace, a furnace residence time of 30 min. was assumed. These assumptions are consistent with the ranges used in current practice.

Table 1. *Composition of Wet Stream 02.02.14, Quench Blowdown from Ethylene Production by Thermal Cracking of Heavy Liquids*

Component	Mass fraction	Flow rate, kg/h
Benzene	0.005	88.8
Phenol	0.003	53.3
Toluene	0.004	71.0
Solids	0.010	177.5
Water	0.980	17,359.5
Total	1.002	17,750.1

The capital and operating costs for the above example case were based on 24 h/day, 330 day/yr operation, an adsorber design capacity of 200,000 gal/day (126 percent of waste stream rate including recycle streams to the adsorber), and reactivation furnace throughput rate of 25,500 kg carbon/day. The capital costs of the major components of the carbon treatment system including support equipment, installation, engineering, legal, financing, and administrative costs are presented in Table 2.

The annual operating costs for the system are also included in Table 2. The major operating costs include: labor, electricity, fuel (natural gas), maintenance materials, and carbon makeup.

Advantages and Disadvantages

The major advantages of carbon pretreatment are:

- It is a mature technology in commercial use for waste treatment applications.
- Carbon adsorption can handle a broad range of organic constituents and concentrations.

The disadvantages of carbon pretreatment include:

- Carbon adsorption treatment, especially with thermal reactivation, is a complex and labor-intensive operation.

Table 2. *Capital and Operating Costs for Carbon Adsorption Pretreatment With Thermal Reactivation of the Carbon for WET Model Stream 02.02.14*

Capital Costs	
Influent pump station	*21,000*
Carbon adsorption system (2 pulsed-bed contactors)	*181,000*
Carbon regeneration system (fluidized-bed furnace)	*1,925,000*
Carbon inventory (150,000 lb @ $0.85/lb)	*128,000*
Construction costs[a]	*925,000*
Total Installed Cost	*$3,180,000*
Annualized Operating Cost	
Operating labor (36,000 man-hours @ $15/m-h)	*540,000*
Maintenance (5% of capital cost)	*159,000*
Electricity (824,000 kWh @ $0.05/kWh)	*41,200*
Steam (13,680,000 lb @ $4/1,000 lb)	*54,700*
Fuel (1,430,000 therms @ $0.59/therm)	*840,000*
Water (20,800,000 gal @ $0.40/1,000 gal)	*8,300*
Carbon makeup (829,000 lb @ $0.85/lb)	*704,700*
Taxes, insurance, administration (4% of capital cost)	*127,200*
Capital recovery (16.3%; 10% over 10 years)	*518,300*
Total Operating Costs	*$2,993,400*
Product Recovery Credit	*0*
Net Operating Costs	*$2,993,400*
Waste treated (kg/yr)	*155,490,000*
Total volatiles removed (kg/yr)	*1,865,880*
Unit treatment cost ($/kg waste treated)	*0.019 $/kg*
($/kg volatiles removed)	*1.60 $/kg*

[a]Construction fee (10%), contingency (15%), engineering (15%), startup (1%).

- Carbon adsorption has substantial operating costs.

Study Findings

Table 3 shows the results of the analysis of other types of pretreatment processes. Applicable pretreatment processes are shown for some typical waste types that may contain volatile constituents. This table shows that air stripping or evaporation (coupled with carbon adsorption of the off gases), steam stripping, and distillation are the most widely applicable techniques for volatile removal.

The full report draws conclusions based on engineering judgment regarding the most applicable pretreatment technique(s) for all streams covered in the preliminary version of the WET Model. In the final report for this project a matrix is presented that matches the 12 pretreatment techniques considered which were studied with all 72 WET Model streams that contain volatile constituents. Based on this matrix, the following pretreatment techniques are considered most applicable for removing volatile constituents from the WET Model waste streams:

- Air stripping or evaporation/carbon adsorption
- Steam stripping
- Batch distillation

Table 3. *Appropriate Pretreatment Process by Waste Type*

Waste type	*Applicable pretreatment process(es)*
Organic liquids	*Distillation*
Aqueous, up to 20% organic	*Steam stripping* *Solvent extraction*
Aqueous, less than 2% organic	*Steam stripping* *Carbon adsorption* *Resin adsorption* *Air stripping with carbon adsorption* *Ozonation/radiolysis* *Wet oxidation* *Biological treatment*
Sludge with organics	*Air stripping with carbon adsorption* *Evaporation with carbon adsorption* *Ozonation/radiolysis* *Wet oxidation* *Chemical oxidation* *Evaporation with carbon adsorption*
Some sludge in organic or aqueous stream	*Physical separation*

A distinction can be made betwee pretreatment processes that are appli cable at the site of generation and proc esses that could be used at a TSDF tha accepts waste materials from a variet of sources. At a commercial TSDF, th waste streams are generally not segre gated by source. Thus, pretreatmer using carbon adsorption, steam strip ping, or batch distillation, which has th capability of handling a variety of wast types, is likely to be most applicable a such TSDFs. Streams treated at th point of generation are likely to be mor uniform in composition and flow. I such situations, continuous distillatior solvent extraction or biodegradatio may be applicable.

Insofar as the hazardous wast streams analyzed in this summary ar typical of the application of each pre treatment technique, the reporte volatile removal efficiency (kg volatil removed/kg volatile in the stream), un cost ($/kg stream treated), and cos effectiveness ($/kg of volatile remove are typical of what may be expected the pretreatment technique were use on other streams of a similar natur The cost-effectiveness of pretreatin specific waste streams ranged from $5 to over $1800/mg volatiles removed.

Conclusions

This project is a preliminary enginee ing assessment of various pretreatme techniques for the removal of volati compounds from hazardous was streams identified in one data base. Th conclusions and analyses herein a preliminary; at the time of this study l tle data were available on hazardo waste stream treatment and many the conclusions are based on other i dustrial applications of the 12 prc esses. However, this study does provi insight into the potential applicability pretreatment to reduce emissions volatile compounds from TSDFs.

The conclusions of this investigati are:

- Pretreatment of these hazardo waste streams could remove m (90 to 99 percent) of the volatile m terials. A number of alternati processes are available for p treatment for most of the wa streams.
- The cost-effectiveness of pretre ing specific waste strea varies greatly. The actual co

effectiveness depends on the chemical and physical characteristics of the waste stream(s), the design capacity of the pretreatment system, and the degree of volatile removal required.

- Pretreatment techniques using carbon adsorption, steam stripping, or batch distillation are the most applicable ones for the waste streams evaluated. This judgment considers cost, the range of applicability, and the extent to which the technology has been demonstrated.

*James J. Spivey, C. Clark Allen, Robert L Stallings, David A. Green, and John P. Wood are with Research Triangle Institute, Research Triangle Park, NC 27709; and the EPA author, **Benjamin L. Blaney** (also the EPA Project Officer, see below), is with Hazardous Waste Engineering Research Laboratory, Cincinnati, OH 45268.*

The complete report, entitled "Preliminary Assessment of Hazardous Waste Pretreatment as an Air Pollution Control Technique," (Order No. PB 86-172 095/AS; Cost: $22.95, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

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