United States Environmental Protection Agency

Municipal Environmental Research Laboratory Cincinnati OH 45268

Research and Development

EPA-600/S2-81-019 Mar. 1981

EPA

Project Summary

Concentration Technologies for Hazardous Aqueous Waste Treatment

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Data were compiled on the performance of unit processes for concentrating hazardous constituents of aqueous waste streams. During the course of this study, information was also collected on known ground and surface water contamination problems.

After the data were gathered evaluations were made of the applicability of each technology to the identified contamination problems Selected technologies were then carried forward for more detailed review. Compounds identified in the waste streams fell into one of 12 chemical classes: alcohol, aliphatic, amine, aromatic, halocarbon, metal, miscellaneous, PCB, pesticide, phenol, phthalate, or polynuclear aromatic.

Next, an extensive literature review was conducted to focus on the selected technologies and on the 12 types of chemical compounds. Six processes were concluded to have the greatest potential range and immediate applicability: biological treatment, chemical coagulation, carbon adsorption, resin adsorption, membrane processes, and stripping.

Since it was evident that in most cases no single unit process would be sufficient to adequately treat the diverse contamination problems likely to be encountered, five process trains were selected as being most broadly applicable to the types of known contamination. An analysis was then performed of the ability of each process train to treat each of three selected contamination problems. The resulting evaluations can help determine the applicability of a given technology to specific situations in the absence of experimental data. Results were also used to set priorities for further study of the technologies in the on-going phase of the project.

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

Contamination from unsecured industrial waste storage and disposal sites is widespread. Often this contamination manifests itself in the form of hazardous leachates and contaminated ground and surface waters. These contaminant streams are diverse in terms of composition and concentration, varying between and within sites, or over time at any given location. Some contaminant streams contain a broad spectrum of organic and inorganic constituents, while others have only a few compounds.

Regardless of whether contaminant streams are associated with active or abandoned sites, there is often the need to detoxify or decontaminate these hazardous aqueous wastes. Very limited data and experience exist for the treatment of hazardous aqueous wastes. In order to fill this information gap, the Solid and Hazardous Wastes Research Division of the Municipal Environmental Research Laboratory (MERL) initiated a project to evaluate and verify selected concentration techniques for hazardous constituents of aqueous waste streams. This project involves literature search and data acquisition, technology evaluations, and experimental investigations to evaluate and adapt appropriate technologies.

Project activities that preceded the experimental investigations are included.

Process Evaluation

Technologies were first characterized and screened for potential applicability on the basis of available data. The initial step in the evaluation was to identify technologies potentially applicable to the concentration of hazardous constituents of aqueous wastes. Thus, early in the project, the following list of candidate technologies was developed:

- Biological treatment
- Carbon Adsorption
- Catalysis
- Centrifugation
- Chemical precipitation
- Crystallization
- Density separation
- Dialysis/electrodialysis
- Distillation
- Evaporation
- Filtration
- Flocculation
- Ion exchange
- Resin adsorption
- Reverse osmosis
- Solvent extraction
- Stripping
- Ultrafiltration

Technology profiles were then prepared for each of these unit processes without regard to specific waste streams to be treated. These profiles were used to screen each technology for its ability to concentrate specific hazardous constituents of aqueous wastes. At this point, certain technologies were eliminated from further consideration and others were carried forward for more detailed scrutiny.

Next an extensive literature review was conducted to focus on the technologies that survived the initial screening and on chemical compounds in the contaminant classes listed below:

- Alcohol
- Aliphatic
- Amine
- Aromatic
- Halocarbon
- Metal
- Miscellaneous
- PCB
- Pesticide
- Phenol
- Phthalate
- Polynuclear aromatic

Chemicals in these classes have previously been identified as occurring at various hazardous waste sites. Chemical treatability information on more than 500 compounds was reviewed and summarized, and the information was assembled in an appendix to the project report. To provide a quick reference on the treatability of the 505 different chemical compounds listed in the report appendix, a concise summary was included in the body of the report.

As a result of the literature review, the following unit processes were determined to have the potentially broadest range of applicability to the treatment of hazardous leachates and contaminated groundwater:

- Biological treatment
- Chemical coagulation
- Carbon adsorption
- Membrane processes
- Resin adsorption
- Stripping

These processes must be supplemente with ancillary processes such a sedimentation and filtration, however.

Formulation of Process Trains

Since hazardous aqueous wast streams vary widely in composition an often contain diverse constituents, n single unit process is capable o providing optimum treatment. Rathe individual processes must be arrange in trains to achieve high levels o treatment in the most cost-effectiv manner. The objective was to identif process trains that would produc quality effluents when applied to th wide range of waste strean compositions likely to be encountered Five such process trains, incorporatin the selected concentration technologies, were formulated. Each of thes process trains has particular strength and weaknesses. One or more of thes trains should be applicable to mos situations dictating concentratio treatment of hazardous leachate o contaminated groundwater.

Process Train 1

Biological treatment followed b granular carbon sorption (Figure 1) i applicable to the treatment o wastewaters that are high in TOC, ar low in toxic (to a biomass) organics, an contain refractory organics. Chemica coagulation and pH adjustment ar provided for heavy metal removal an protection of the subsequent biologica system. This step may not be necessar if heavy metal concentrations are belov toxicity thresholds and if the moderat removal efficiencies typical of biologica treatment are sufficient. The furthe removal of metals by activate carbon may also make chemical coagulation unnecessary.

Biological treatment such as activated sludge, rotating biologica contactors, or anaerobic filters is included to reduce BOD as well as biodegradable toxic organics. This treatment reduces the organic load to subsequent sorption processes. To prevent rapid heat loss caused by the accumulation of solids in the sorption columns, clarification and multimedia filtration are provided. The intent is to reduce suspended solids to 25 to 50 mg/L.

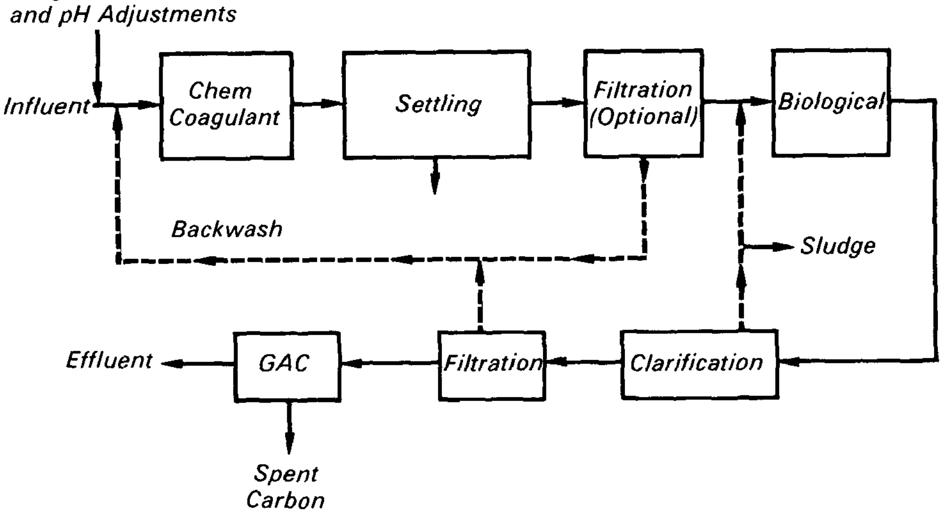

Figure 1. *Biological treatment/carbon sorption process train.*

Granular carbon adsorption is included to remove refractory organic residuals and toxic organics. Activated carbon rather than polymeric or carbonaceous resins has been specified because more full-scale experience exists, and performance as well as design and operating criteria have been reported.

This process train is expected to be highly effective and economical. Its success, however, depends on biological system performance. A potentially major impediment to the use of this process train is the possible stripping of volatile compounds from the waste stream during aeration and the resulting air pollution.

Because the process is intended to handle multicomponent waste streams, pollutant recovery for reuse is unlikely. Three by-product wastes are produced: chemical sludge, biological sludge, and spent carbon. Spent carbon can be regenerated, but the sludges must be disposed of in an environmentally acceptable manner.

Process Train 2

The second process train uses the same unit processes but places granular carbon ahead of biological treatment (Figure 2). This train, which is also applicable to high TOC wastewaters, was designed to respond to situations in which waste-stream components may be toxic to biological cultures. The rationale is to use the activated carbon to protect the biological system from toxicity problems. The carbon would thus be allowed to leak relatively high concentrations of TOC (organics) rather than to be operated to achieve maximum reduction of organic compounds. Allowable leakage would be based on the point at which the carbon-treated effluent becomes toxic to the subsequent biological process. Thus, selection of the allowable TOC or organic leakage (i.e., breakthrough) from the carbon contactors is crucial to the performance and cost effectiveness of this process train. If biologically toxic organics are present, treatability studies must be conducted for several reasons; one of the primary reasons would be to establish the acceptable breakthrough level. Higher organic loads handled by the biological system result in greater service life of the granular carbon and, consequently, lower costs related to the carbon treatment phase.

In this configuration, the chemical coagulation step (including settling and filtration) plays a role in organics removal and particulate removal to minimize head losses in contact columns.

As with the process train in Figure 1, there is little potential for recovery of pollutants. But, volatile organic compounds present in the waste stream may pose less of a problem in this process configuration since they may be sorbed onto the carbon before an aeration step.

Process Train 3

The third process train (Figure 3) uses biophysical treatment, which is a combination of biological and powdered activated carbon treatments conducted simultaneously. This approach is simpler than the sequential carbon/biological treatments, and it has the potential of achieving comparable effluent quality. Potential advantages include the use of less costly carbon (powdered versus

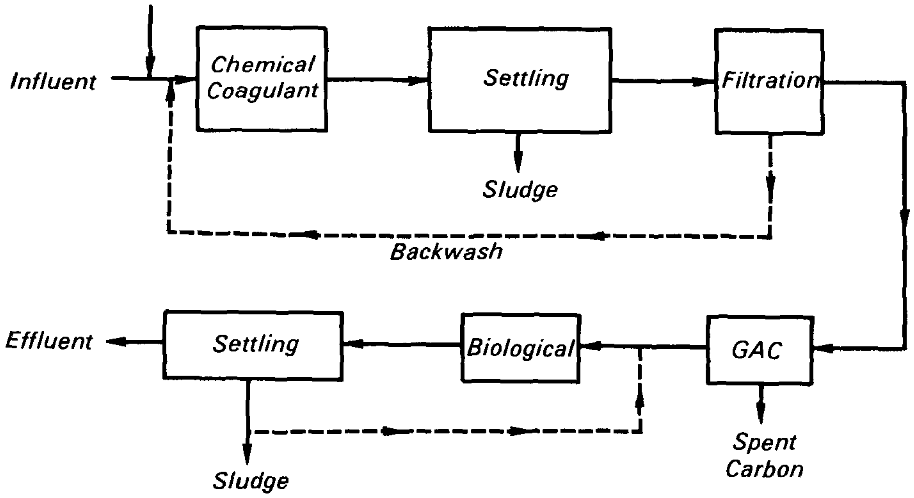

Figure 2. *Carbon sorption/biological process train.*

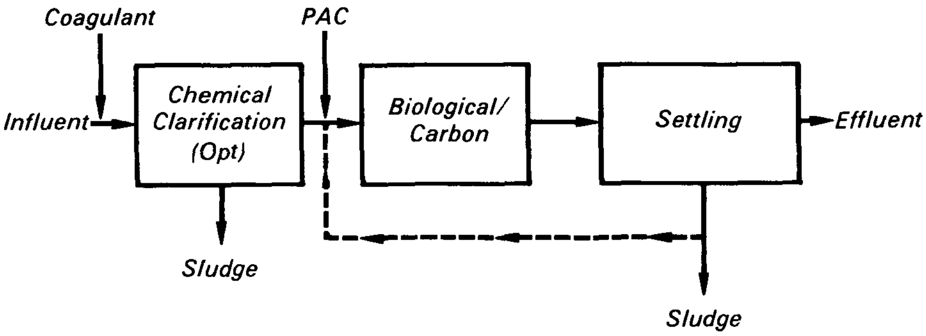

Figure 3. *Biophysical process train.*

granular) and minimal physical facilities. Spent carbon/biological sludge can be regenerated or dewatered and disposed of directly. If the latter approach is considered, economic comparisons must include cost for disposal of toxic-laden carbon sludge.

Complete mix activated sludge or contact stabilization are the two biological processes most frequently used. Recent reports suggest operating at long solids retention times, concentrations of 20,000 to 25,000 mg/L (60% PAC and 40% biomass).

Process Train 4

Train 4 consists of a membrane process preceding biological treatment (Figure 4). This configuration would be applicable to wastewaters containing organic and inorganic pollutants. Selection of the appropriate membrane process, ultrafiltration, and/or reverse osmosis would depend on wastewater composition and treatment goals. Ultrafiltration is a membrane process capable of separating high molecular weight (mw > ~ 1000) species from a liquid stream on the basis of size. Reverse osmosis uses a semipermeable membrane to concentrate numerous dissolved species, both organic and inorganic. Salinity is an important factor to be considered, since ultrafiltration will allow dissolved salts to enter the permeate stream, and reverse osmosis will not. The use of reverse osmosis on high salinity waste streams is therefore questionable because large volumes of concentrate are generated. Numerous reverse osmosis membrane materials and configurations are available. Different configurations provide different surface areas, flux rates, flow velocities, and other process variables. Care must be exercised in selecting membrane materials and configurations. Organic removals of 20% to 70% have been reported for reverse osmosis, but some membranes (e.g., cellulose acetate) tend to concentrate some organics (e.g., phenol and aniline) in the permeate stream.

A biological process was paired with the membrane process to address low molecular weight organics. As an alternative, stripping processes could be paired with membranes. Sorption processes were not considered in conjunction with membranes because of the likelihood that the lower molecular weight readily soluble organics would pass through the system.

A major disadvantage of the fourth process train is that membrane processes generate concentrate streams that require additional handling and disposal. The concentrate stream flow may be 10% to 20% of the feed flow.

Process Train 5

A processing system consisting of stripping and carbon adsorption is illustrated in Figure 5. This configuration will be applicable primarily to wastewaters containing organics, although chemical coagulation for inorganics and particulate removal is provided. This process flow may be suited to situations involving volatile and refractory or toxic organics. The method is essentially pertinent in the presence of a single or small number of volatile compounds that can be recovered from the overhead gas stream. Even though the wastewater may contain air-strippable compounds, air stripping may not be the best selection if air pollution is a potential concern (unless off-gases can be contained and collected). Stripping probably will remove biodegradable rather than refractory TOC, and it has therefore been paired with activated carbon adsorption rather than a biological process.

Aside from pH adjustment before stripping, little pretreatment is necessary. If the wastewater contains

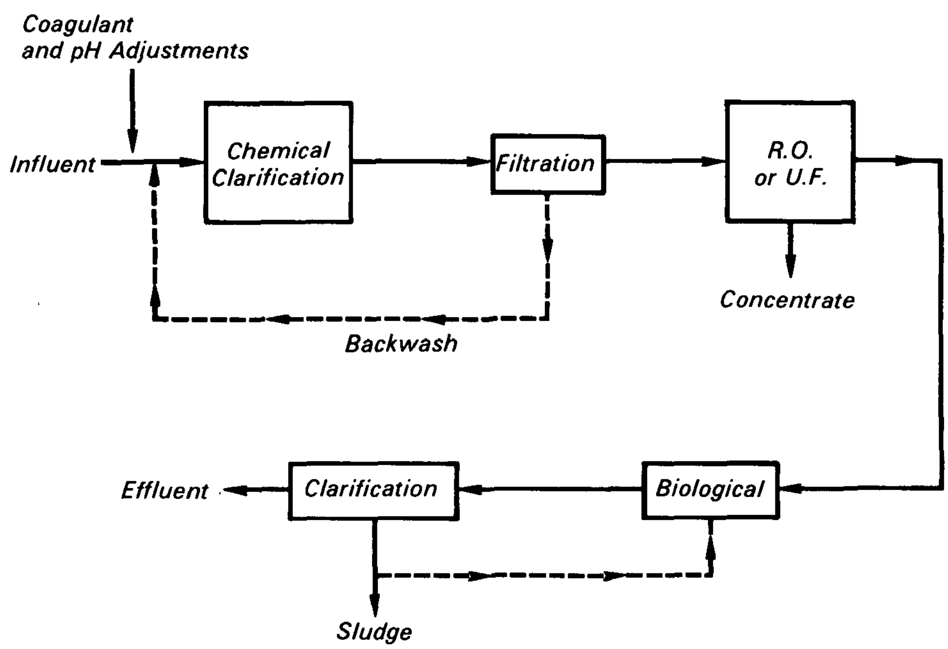

Figure 4. *Membrane/biological process train.*

readily settleable suspended solids, removal before packed column or tray tower steam stripping will prevent solids buildup in the stripping unit.

The steam stripping process train generates three waste streams: overhead condensate, chemical sludge, and spent carbon. Assuming that carbon will be regenerated, either on-site or by a commercial service, the two remaining streams require additional treatment and/or disposal. Preferably, the organic phase of the overhead condensate can be recovered and reused, with the water phase returned to the treatment system. If recovery is not possible, however, incineration is the best method for condensate disposal. Chemical sludge should be dewatered and disposed by a method compatible with the materials contained in the sludge.

Evaluation of Process Trains

Process trains illustrated in Figures 1 through 5 do not represent the only possible configurations. They do, however, encompass the concentration technologies that are expected to have the greatest broad-range applicability and effectiveness. They are the processes that have been demonstrated for the treatment of hazardous aqueous wastewaters.

Before experimental studies were initiated, it was decided to evaluate the five process trains to predict performance potential on actual hazardous waste streams. Based on unit process performance data compiled from the literature, the performance potential of each of the five process trains was calculated for each of the three actual waste streams. These calculations indicated that all of the process trains were potentially capable of producing effluents suitable for direct stream discharge. But because much of the available data were generated from single-compound, laboratory-scale studies, actual treatability of a multicomponent wastewater cannot be accurately assessed. Treatability studies using the actual wastewaters are needed to verify performance expectations and to select the optimum process train for a particular situation.

The full report was submitted in fulfillment of Contract No. 68-03-2766 by Touhill, Shuckrow and Associates, Inc., under the sponsorship of the U.S. Environmental Protection Agency.

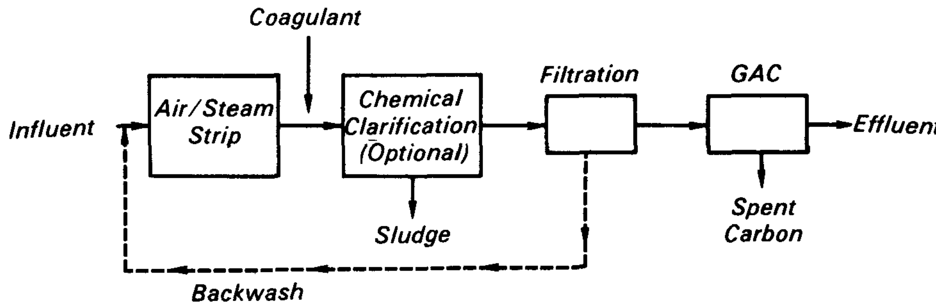

Figure 5. *Stripping/carbon sorption process train.*

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***Stephen C. James** is the EPA Project Officer (see below).*
The complete report, entitled "Concentration Technologies for Hazardous Aqueous Waste Treatment," (Order No. PB 81-150583; Cost: $26.00, subject to change) will be available only from:
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