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TECHNOLOGY EVALUATION

Emerging Technology Summary

Cross-Flow Pervaporation for Removal of VOCs from Contaminated Wastewater

Pervaporation is a membrane technology using a dense, nonporous polymeric film to separate contaminated water from a vacuum source. The membrane preferentially partitions the volatile organic compounds (VOC) organic phase used in this test. This process has proven to be an alternative to conventional technologies because it removes VOCs without requiring any pre- or post-treatments and is cost-effective.

This Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the SITE Emerging Technology program that are fully documented in a separate report (see ordering information at back).

Background

Water contaminated with VOCs is encountered throughout industry and in many groundwater and site remediation situations. VOCs are common contaminants found in groundwater, leachate, and wastewater. Approximately 50% of the U.S. Environmental Protection Agency's (EPA's) list of priority pollutants is composed of VOCs—compounds known to be toxic, or carcinogenic, or both.

Conventional technologies such as air stripping and activated carbon treatment are the current methods used to remove low concentrations of organic contaminants from various water sources. Previous work has demonstrated that pervaporation is a potentially suitable remediation method for wastewater applications. The primary objectives of this project were to develop an improved membrane and module design to make pervaporation a more cost-effective method for removing VOCs from contaminated water and to compare the improved pervaporation module and membrane design with conventional remediation technologies as well as other pervaporation module and membrane designs.

Technology Description

Pervaporation is a membrane process for removing VOCs from wastewater, leachate, and contaminated groundwater (Figure 1). For water treatment applications, the membrane is made of an organophilic polymer such as modified silicone rubber, which exhibits high selectivity for organic compounds while allowing very little passage of water. Only the minor component (organic compounds) of the feed goes through the membrane, which reduces the potential for membrane fouling. One side of the membrane is in

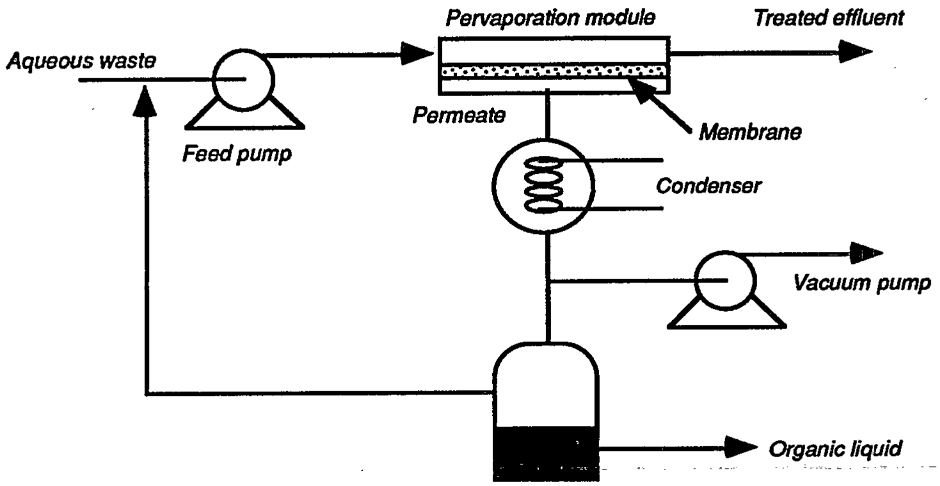

Figure 1. Schematic of pervaporation process for removing VOCs from wastewater.

contact with the VOC-contaminated water; the other side is exposed to a vacuum. VOCs are absorbed in the membrane and diffuse through to the other side where they are drawn off by vacuum. The treated water is depleted of VOCs and exits the pervaporation system for collection or discharge. VOCs passing through the membrane, now called permeate, are condensed and flow to a permeate collection tank where gravity separation of water and VOCs occurs. The VOC phase is pumped from the base of the collection tank to storage. Collected water is returned to the pervaporation system for further treatment.

Project Accomplishments

During the project, membranes and modules were developed, and several module cartridges were produced to evaluate their performance. Testing was carried out at bench scale with separate synthetic wastewaters containing trichloroethylene (TCE), toluene, or ethylene dichloride. These components vary significantly in volatility (as defined by Henry's Law Constant) and other secondary properties. To identify key operating parameters, these components were tested at various temperatures and vacuum pressures. Bench testing was followed with pilot testing. A 5-ft^2 membrane area was used to treat water contaminated with toluene. Testing with the 5-ft^2 module verified the results of the bench testing. A computer model, developed from the bench-test results, was used to predict and optimize pervaporation conditions for effective removal of VOCs from wastewater.

Results To Date

The results of this project have shown that pervaporation performance depended greatly on both the membrane and module design. The module, composed of hollow fibers, was designed to allow liquid to flow orthogonal to the fiber direction. This high mass transfer allowed the membrane surface area requirements to be minimized. The effective combination of membrane and module allowed the waste VOC to be concentrated by 5,000 to 50,000 times as it was removed from the wastewater. The permeate always separated into an aqueous and organic phase. In practice, this would offer the possibility of recovering the organic fraction for industrial applications.

Pervaporation performance for VOC removal depends on (1) VOC type, (2) membrane type, (3) liquid turbulence in the module, (4) operating temperature, and (5) vacuum pressure. Pervaporation performance is optimal for VOCs with a solubility of less than 1%. High solubility VOCs, such as ethyl acetate, methylene chloride, and ethylene dichloride can, however, be considered but require higher operating temperatures to enhance VOC removal. Higher operating temperatures marginally increase operating costs. Membranes should be organophilic to minimize water passage. In this study, a modified silicone rubber membrane was used, and the pervaporation module demonstrated mass transfer coefficients above 100 μm/s. This represents a performance enhancement of 2 to 4 times that of previous work. Furthermore, this enhancement reduces the membrane area requirement by 2 to 4 times for any given application. Membrane thickness and type reduce the passage of water and, thereby, increase separation factors. This reduces operating costs significantly. Operating temperature and vacuum pressure are interrelated. Since the ultimate vacuum pressure depends on the condenser temperature (minimum 0°C) and the VOC present in the condenser, the operating temperature of the feed must be sufficient (typically greater than 60°C) to provide a vapor pressure gradient (chemical potential) from the membrane to the condenser.

Pervaporation also has the following advantages over conventional technologies:

- No chemicals or air is added to the wastewater, therefore fouling and scaling problems are avoided.
- Pervaporation does not require sorbents or chemicals.
- Monitoring for breakthrough is not required.
- Recovered solvents may be reused in industrial applications.
- Degree of VOC removal is independent of concentration and type of VOC.

A cost comparison of pervaporation with conventional technologies was conducted for a 44-gpm application with 10 ppm TCE to be reduced to 0.1 ppm TCE. Cost analysis indicates that pervaporation was more cost-effective than air stripping and activated carbon.

Field testing through the SITE program will be carried out through 1994 to verify these pervaporation results.

The full report was submitted in fulfillment of cooperative agreement CR-815788 by the Wastewater Technology Center and Zenon Environmental Inc. under the sponsorship of the U.S. Environmental Protection Agency.

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The complete report, entitled "Cross-Flow Pervaporation System for Removal of VOCs from Contaminated Wastewater," (Order No. PB94-170230; Cost: $19.50, subject to change) will be available only from

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