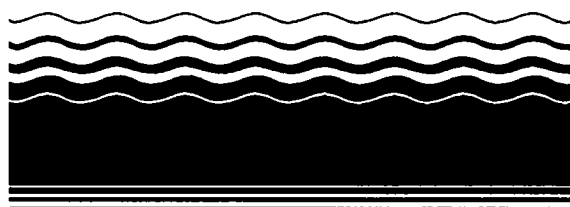




# SITE

SUPERFUND INNOVATIVE  
TECHNOLOGY EVALUATION



## Demonstration Bulletin

### Zenon Cross-Flow Pervaporation Technology

ZENON Environmental, Inc.

**Technology Description:** Pervaporation is a process that employs a membrane to remove volatile organic compounds (VOC) from aqueous matrices. Figure 1 displays a schematic diagram of the ZENON cross-flow pervaporation system in a typical field application. Contaminated water is pumped from an equalization tank through a prefilter and silt particles, and then into a heat exchanger that raises the water temperature to about 165 °F (75 °C). The heated contaminated water then flows into a pervaporation module containing dense polymeric membranes.

The membrane material is a nonporous organophilic polymer, such as silicone rubber, formed into capillary fibers measuring less than 1 mm in diameter. Silicone rubber is highly permeable to organic compounds and resistant to degradation. The capillary fibers are aligned parallel on a plane and spaced slightly apart. This arrangement of capillary fibers forms one membrane layer.

Separate membrane layers are aligned in series, with the interior of the capillary fibers exposed to a vacuum (about 1 lb/in<sup>2</sup>, absolute). The number of membranes used in a particular system depends on expected flow rates, contaminant concentrations in the untreated water, and target concentrations for contaminants in the treated water.

The organophilic composition of the membrane causes organics to adsorb to the membrane (capillary fibers). The organics migrate to the interior of the capillary fibers and are then extracted from the membrane by the vacuum. This organic migration into the fibers

creates a concentration gradient that tends to facilitate transport. Contaminated water passing through the pervaporation module is depleted of organics and exits the ZENON system for reuse or discharge.

Organic vapor and small amounts of water extracted from the contaminated water through the membranes is called permeate. As the permeate exits the membranes, it is drawn into a condenser by the vacuum, where the organics and any water vapor are condensed. Because emissions are vented from the system downstream of the permeate condenser, organics are kept in solution, thus minimizing air releases.

The liquid permeate contains highly concentrated organic compounds and has a significantly reduced volume compared to the untreated water. Because of this high concentration, the liquid permeate generally separates into aqueous and organic phases, rendering the organic fraction potentially recoverable. The organic phase permeate is pumped from the containment vessel to storage while aqueous phase permeate can either be returned to the pervaporation module for further treatment or removed for disposal.

**Waste Applicability:** Cross-flow pervaporation can be applied to aqueous matrices contaminated with liquids containing VOCs such as solvents, degreasers, and gasoline. Pervaporation provides an alternative approach to treating organic-contaminated water at sites where conventional air stripping or carbon adsorption are currently used. Unlike air stripping, pervaporation releases

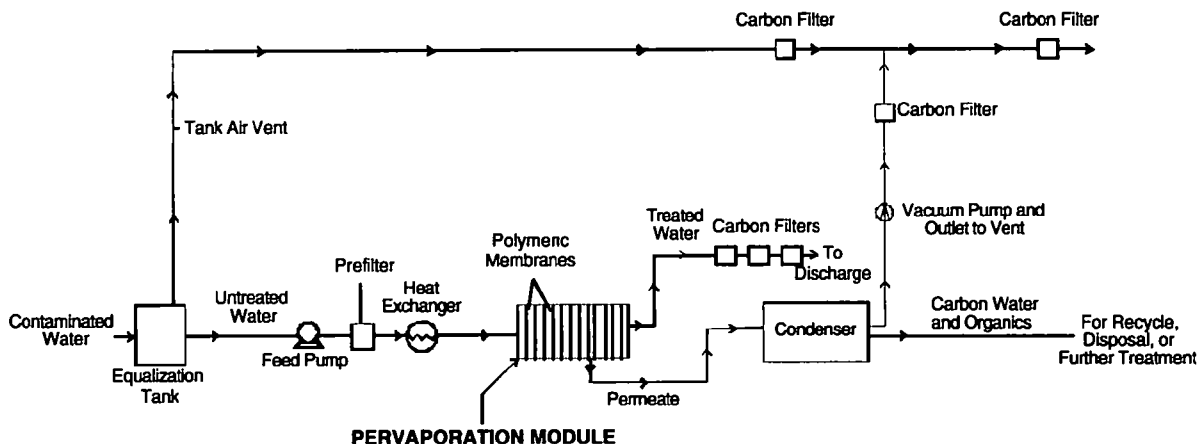


Figure 1. Zenon Cross-Flow Pervaporation System

negligible amounts of VOCs to the outside air. Unlike activated carbon, the treatment medium does not require replacement and disposal. Periodic cleaning of the membranes is necessary to enhance treatment.

A full-scale ZENON pervaporation system can be easily transported and requires only an electrical source. For large applications, a pervaporation unit containing multiple modules can be used.

**Considerations When Using Pervaporation:** As noted, the prefilter prevents solids from reaching the pervaporation module and inhibiting the movement of organics through the membrane. Water containing high concentrations of solids can clog the prefilter, requiring it to be cleaned frequently.

VOCs with water solubilities of less than 20,000 parts per million (ppm) are generally suited for removal by pervaporation. Highly soluble organics, such as alcohols, are not effectively removed by a single-stage pervaporation process. Low-boiling volatile compounds, such as vinyl chloride, tend to remain in the vapor phase after moving through the condenser. For conditions involving elevated concentrations of low-boiling VOCs, a carbon filter placed on the vacuum vent ensures that contaminants are not released to the outside air. Influent with a high alkalinity or high amounts of calcium or iron can cause scaling of the system. In these cases, anti-scalents can be added to the untreated water as a preventive measure.

**Technology Demonstration:** In 1991, under EPA's Emerging Technology Program, bench-scale testing of the ZENON pervaporation process was performed in Burlington, ON. In late 1993, under EPA's SITE Program, a pilot-scale pervaporation unit was successfully evaluated at a hydrocarbon-contaminated groundwater site just south of Burlington.

In February 1995, a full-scale ZENON pervaporation system was evaluated during a SITE demonstration at a former waste disposal area at Naval Air Station North Island in San Diego, CA. Groundwater in the area contains elevated concentrations of trichloroethylene (TCE), as well as other contaminants. The demonstration was conducted as a cooperative effort among EPA, ZENON, the Naval Environmental Leadership Program, Environment Canada, and the Ontario Ministry of Environment and Energy.

The focus of the demonstration was to determine the system's effectiveness in removing TCE from contaminated groundwater. The removal of other VOCs, semivolatile organic compounds, and total recoverable petroleum hydrocarbons was also monitored. To determine the removal efficiency of the pervaporation system, EPA collected samples of untreated groundwater, treated groundwater, and vapor emissions over 8-hr sampling runs. The system was operated at influent flow rates ranging from 2 to 11 gallons per minute (gpm) with TCE concentrations up to 250 ppm. A portable gas chromatograph (GC) unit was used to provide field data and identify the pervaporation system's optimal operating conditions. The GC unit was also used to ensure that treated groundwater to be discharged to the sanitary sewer was within assigned contaminant limits.

Preliminary demonstration results, based on field GC data, indicate that the ZENON pervaporation system was about 98% efficient in removing TCE from groundwater. The system achieved this removal efficiency with TCE influent concentrations up to 250 ppm at a flow rate of 10 gpm or less. Treatment efficiency of the system remained fairly consistent throughout the demonstration; however, at a flow rate near 2 gpm, the treatment efficiency decreased during the 8-hr sampling run due to mineral scaling problems.

Detailed information on the technology's capabilities and the results of the ZENON SITE demonstration will be discussed in the forthcoming SITE Technology Capsule and the Innovative Technology Evaluation Report.

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