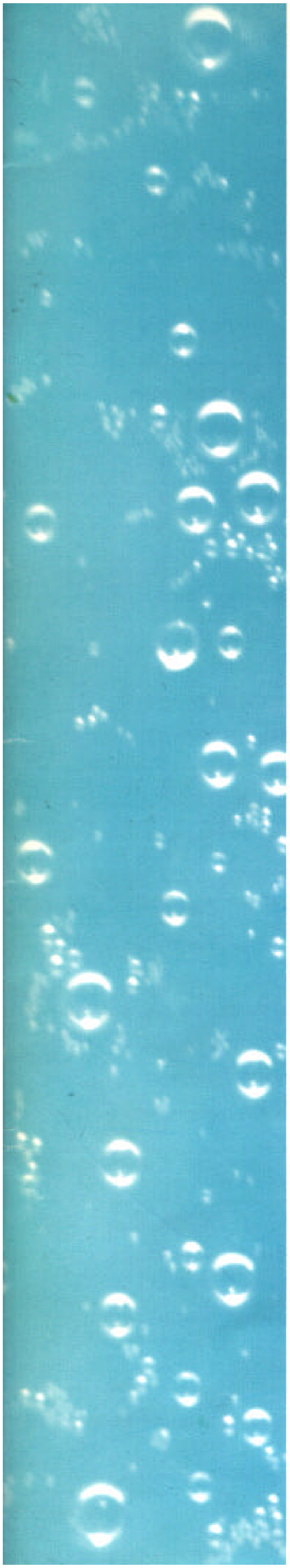


Cost and Performance Report

PerVapTM Membrane Separation Ground Water Treatment

Pinellas Northeast Site

Innovative Treatment Remediation Demonstration

U.S. Department of Energy

October 1997

1. SUMMARY

From July 1995 through March 1996, the Innovative Treatment Remediation Demonstration (ITRD) Program conducted a pilot demonstration of a membrane separation (also known as pervaporation) technology for the treatment of volatile organic compound (VOC)-contaminated ground water at the U.S. Department of Energy's (DOE) Pinellas Plant in Largo, Florida. This technology has often been used for separation of organic contaminants from air and industrial process water streams. These systems have been proposed for the treatment of VOC contaminated groundwater. The pilot system used during this demonstration was developed by Membrane Technology Research, Inc. of Menlo Park, California. The purpose of this evaluation report is to document the demonstration activities, present demonstration data, and provide evaluation results on the cost and performance of the MTR pilot-scale pervaporation system. The system was evaluated for analytical and operational performance relative to defined performance goals needed for full-scale implementation of this technology at the Pinellas Plant.

The membrane separation or pervaporation process uses an organic permeable but hydrophobic membrane to remove organic contaminants from the water to be treated. Bench-scale testing has suggested that removal efficiencies of 99% could be obtained. If the system could operate without fouling the membrane from the high iron and dissolved solids in the ground water at this site, the system would significantly reduce water pretreatment costs over the proposed baseline air stripper. Additionally, because the separated organics are condensed and concentrated in the process, they can be recycled, significantly reducing air emissions and waste disposal over the baseline air stripper.

The demonstration provided adequate analytical and operations data with which to evaluate the performance of the MTR PerVap™ Pilot System. Initial operational tests indicated that organic contaminant (TCE, DCE, and methylene chloride) removal efficiencies of 90–99% could be accomplished with the membrane system. Batch mode operation allowed groundwater at contamination levels as high as 1000 ppm to be reduced to 2–3 ppm in as little as 1-2 hours of treatment. The major problems associated with continuous batch operation of the system was fouling of the membranes by precipitated iron. Attempts to reduce this fouling through the modification of system operation and chemical additives met with some success. During continuous batch operation, contaminants generally could not be reduced below the 4-5 ppm total contaminant concentration. Concentration of the contaminants in an organic condensate was demonstrated. A limited analysis of field operational costs for the PerVap™ system shows that use of the system may provide cost-effective ground water treatment and direct operating costs of $.01/gal for treated ground water can be obtained.

Application of the system to ground water treatment seems feasible as long as compatibility with the chemistry of the ground water to be treated is fully considered before application. Because of the high levels of iron and dissolved solids in the ground water, this system was unable to meet the performance goals required for full-scale implementation at the Pinellas Plant.

2. SITE INFORMATION

Identifying Information

Facility:	DOE Pinellas Plant
OUS/WMU:	Northeast Site
Location:	Largo, Pinellas County, Florida
Regulatory Driver:	RCRA
Type of Action:	ITRD Technology Demonstration
Technology:	Groundwater pump-and-treat with membrane separation
Period of operation:	June 14, 1995 - March 12, 1996
Quantity of groundwater treated:	125 batches or 6,200 gallons

Site Background

The DOE Pinellas Plant occupies approximately 100 acres in Pinellas County, Florida, which is situated along the west central coastline of Florida (Figure 1). The plant site is centrally located within the county; it is bordered on the north by a light industrial area, to the south and east by arterial roads, and to the west by railroad tracks. The topographic elevation of the Pinellas Plant site varies only slightly, ranging from 16 feet MSL in the southeast corner to 20 feet MSL in the western portion of the site. Pinellas County has a subtropical climate with abundant rainfall, particularly during the summer months.

The Northeast Site includes the East Pond and is located in the northeast portion of the Pinellas Plant site (Figure 2). The Northeast Site is covered with introduced landscaping grass and contains no permanent buildings. The site contains approximately six acres and is generally flat, with slight elevation changes near the pond. Access to the Northeast Site is restricted and protected by fencing.

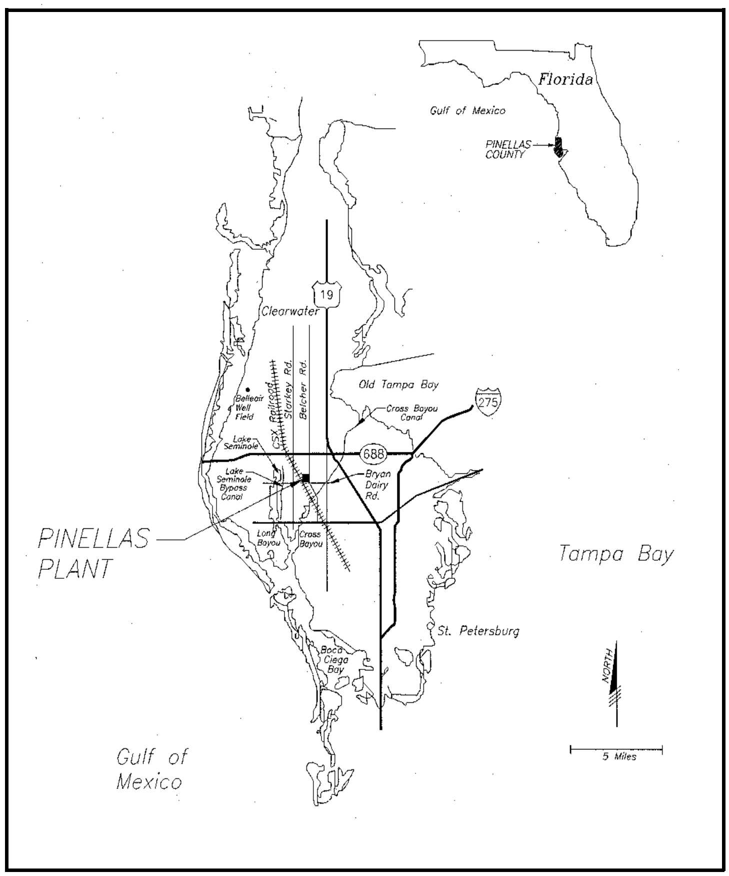


Figure 1. Pinellas Plant Location.

Site History

The DOE Pinellas Plant operated from 1956 to 1994 manufacturing neutron generators and other electronic and mechanical components fro nuclear weapons (SIC Code 9631A-Department of Energy Activities).

The Northeast Site is associated with the location of a former waste solvent staging and storage area. From the late 1950s to the late 1960s, before construction of the East Pond, an existing swampy area at the site was used to dispose of drums of waste and construction debris. The East Pond was excavated

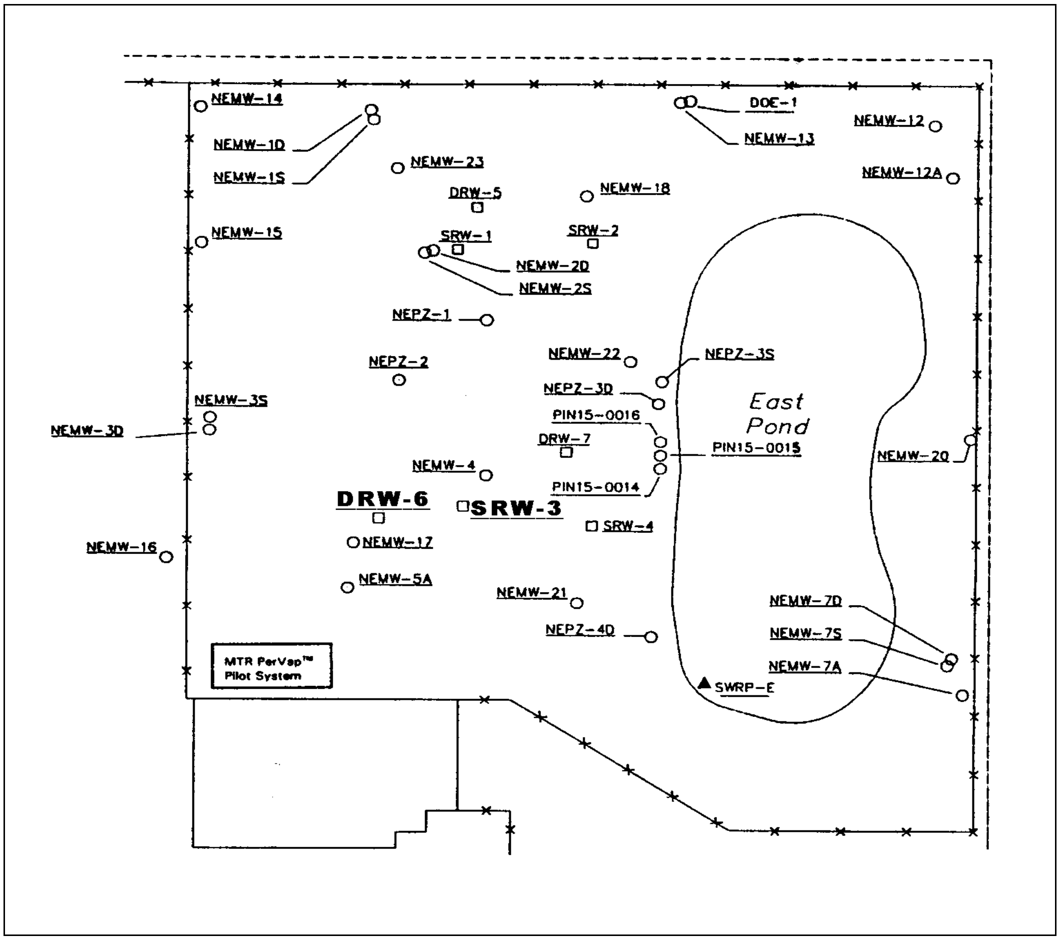


Figure 2. Pinellas Plant Northeast Site.

in 1968 as a borrow pit. In 1986, an expansion of the East Pond was initiated to create additional stormwater retention capacity. Excavation activities ceased when contamination was detected directly west of the East Pond.

The Northeast Site was identified as a Solid Waste Management Unit (SWMU) in a RCRA Facility Assessment (RFA)[1] conducted by the EPA Region IV. Subsequently, a RCRA Facility Investigation (RFI)[2] was completed and approved in compliance with the facility's Hazardous and Solid Waste Amendments of 1984 (HSWA) Permit.[3]

An Interim Corrective Measures (ICM) Study [4] was developed and submitted to EPA for approval. EPA issued final approval of the ICMS in October 1991, and an interim groundwater recovery system for the Northeast Site was installed and commenced operation in January 1992. The ICM system now consists of seven groundwater recovery wells equipped with pneumatic recovery pumps that transfer ground water for temporary storage in a holding tank prior to being pumped to a groundwater treatment system. Final disposition of the treated ground water is disposal in the Publicly Owned Treatment Works (POTW). The POTW discharge limit is 850 micrograms per liter (µg/l) total toxic organics (TTO).[5]

Release Characteristics

The Pinellas Northeast Site consists of a shallow groundwater aquifer contaminated with a variety of VOCs, including chlorinated solvents such as trichloroethene, methylene chloride, dichloroethene, and vinyl chloride. Because the site was used in the 1950s and 1960s for staging and burial of construction debris and drums, some of which contained solvents, contamination at the Northeast Site is believe to be the result of leakage of solvents or resins from these drums. A recent debris removal activity at the site confirmed the presence of multiple buried drums, many of which were empty, but had solvent residue. The ongoing ICM system (pump and treat with air stripping) continues to recover contaminants from the site and has been successful in preventing offsite migration of VOCs.

Site Contacts

Site management is provided by the DOE Pinellas Area Office (DOE/PAO). The DOE/PAO Environmental Restoration Program Manager is David Ingle [(813)-541-8943]. The Managing and Operating contractor for the Pinellas Plant is Lockheed Martin Specialty Components, Inc. (LMSC). The LMSC technical contact for the Pinellas Plant pervaporation pilot study is Barry Rice [(813)-545-6036].

3. MATRIX AND CONTAMINANT DESCRIPTION

The primary environmental contamination pathway at the Northeast Site is ground water. The CMS[6] at the site determined that the soil was not a credible exposure pathway. The type of matrix processed by the remediation system during this application was groundwater (ex situ).

Site Geology/Hydrology

Based on analysis of soil borings, details of well construction, and environmental studies at the Pinellas Plant, the thickness of the surficial deposit below the site ranges from 25 to 35 feet and is primarily composed of silty sand. The top of the Hawthorn Group (composed primarily of clay) at the Pinellas Plant is encountered at depths approximately 30 feet or greater below ground surface. The thickness of the Hawthorn Group ranges from 60 to 70 feet. The water table at the Pinellas Plant is generally 3 to 4 feet below the ground surface. Figure 3 shows the primary geologic units at the site.

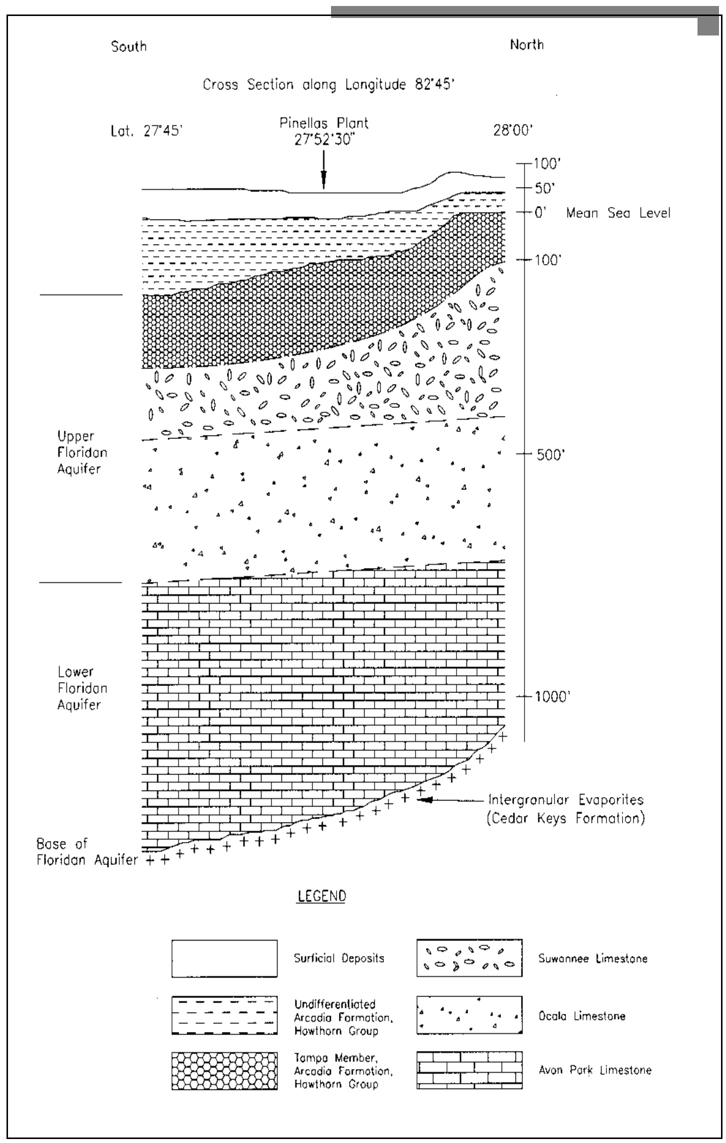


Figure 3. Geologic Section at the Pinellas Plant.

The groundwater system at the Pinellas Plant is composed of three primary units: (1) an upper unit, the surficial aquifer, (2) an intermediate confining unit, the undifferentiated portion of the Hawthorn Group, and (3) a lower unit, the Floridan aquifer. Undifferentiated sediments lie below the surficial aquifer and above the Floridan aquifer in Pinellas County. Because of the low permeability of these sediments in this region, these upper sediments are not considered part of the intermediate aquifer system and are generally considered to be a confining unit in the area of the Pinellas Plant.

Nature and Extent of Contamination

The primary contaminant group that this technology was designed to treat in this application was halogenated volatile organic compounds. Contamination at the Northeast Site is limited to groundwater in the surficial aquifer. Contaminants of concern detected in Northeast Site groundwater include 1,1-dichloroethane, 1,1-dichloroethene, benzene, ethylbenzene, 1,2-dichloroethene (cis and trans isomers), methylene chloride, toluene, trichloroethene, tetrachloroethene, methyl tert-butyl ether, vinyl chloride, total xylenes, and chloromethane. The predominant contaminants detected at the site during performance of the demonstration were methylene chloride, 1,2-dichloroethene, and trichloroethene. Other VOCs which are detected in relatively high concentrations are toluene and vinyl chloride.

At various times, limited VOC contamination has been detected at most of the surficial aquifer monitoring wells within the fenced portion of the site. However, the bulk of the contaminant mass is located in the central portion of the site, especially in the vicinity of recovery wells SRW-3 and DRW-6 which were used to provide water for the pilot study. Table 1 summarizes the concentrations of important parameters detected in these two wells.

Table 1. Typical Pervaporation Influent Contaminants
(concentrations in µg/l)

Analyte	SRW-3	DRW-6
Total 1,2-Dichloroethene	26,000	58,000
Trichloroethene	13,000	360,000
Methylene Chloride	82,000	1,200,000
Vinyl Chloride	9,700	5,000
Toluene	16,000	140,000
Iron	20,800	19,300
Manganese	52.2	101

Matrix Characteristics Affecting Treatment Cost or Performance

The site includes seven operating ground water recovery wells that are connected to an air stripper for water treatment before discharge to a public owned treatment works (POTW). The ground water at this site has naturally high dissolved solids and high iron content. Because the aquifer is anaerobic, the pumped ground water at this site requires pretreatment before air treatment in the air stripper. The potential benefit of the pervaporation system would be its ability to treat the ground water directly without costly pretreatment and to concentrate the contaminants in a condensate that could be recycled, reducing waste-disposal costs and significantly reducing air emissions. Surficial aquifer ground water iron concentrations at the site during the demonstration performance period ranged from 5,000 µg/L to 50,000 µg/L.

4. PERVAPORATION TECHNOLOGY DESCRIPTION

The technology evaluated in this field demonstration is membrane separation of multicomponent liquid streams or pervaporation. In the pervaporation process (Figure 4), a multicomponent liquid stream is passed across a membrane that preferentially permeates one or more of the components. The process can be applied to the dehydration of organic liquids, removal of dissolved organic compounds from water, and to the separation of mixed organic compounds.

Technology Description

Figure 4 shows the basic pervaporation process is shown schematically. As the feed liquid flows across a membrane surface, the preferentially permeated organic components pass through the membrane as a vapor. Transport through the membrane is induced by maintaining a vapor pressure on the permeate side of the membrane that is lower than the vapor pressure of the feed liquid. The pressure difference is achieved by vacuum pump. The permeate vapor is condensed and then removed as a concentrated permeate fraction. The treated liquid exits on the feed side of the membrane. The residue, depleted of the permeating component, exits on the feed side of the membrane.

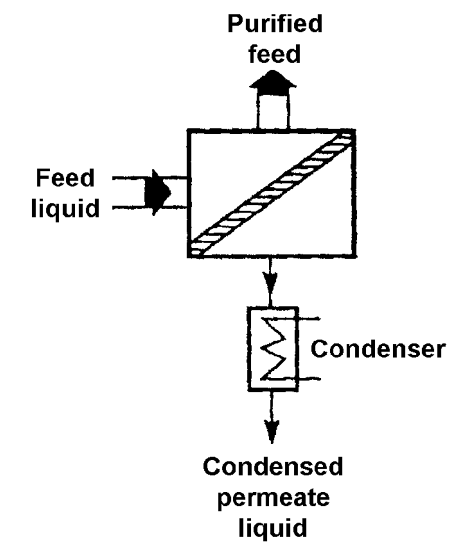


Figure 4. Basic pervaporation process.

Pervaporation is especially effective for handling aqueous streams containing VOCs in the concentration range of 100 ppm to 50000 ppm. Membranes are available to remove a broad range of VOCs from highly hydrophobic (toluene and TCE) to hydrophilic (ethyl acetate and acetone) organics. The technology has application to industries that generate VOC-containing process or waste water streams including chemical, petrochemical, pharmaceutical, pulp and paper, and food processing operations.

The technology also has application to the treatment of contaminated surface or ground waters, as demonstrated in this application. As the ground water flows across the membrane surface, the preferentially permeated organics pass through the membrane as a vapor. Transport through the membrane is induced by maintaining a vacuum on the permeate side of the membrane. The concentrated permeate or condensate containing the recovered organics can then be recycled. The purified ground water can then be discharged or recycled. The overall system separation effectiveness depends on the volatility of the organic contaminants, their relative permeabilities, and the organic concentration of the ground water. The system can provide removal efficiencies for many common organic contaminants of 90-99% for concentration ranges of 100-1000 ppm.

The effectiveness of the pervaporation technology for separation of organics from water is dependent on the design of the multilayer composite membranes. The membranes consist of a tough, open, microporous polymer layer that provides strength and an ultrathin, dense polymer coating that is responsible for the separation properties. This selective layer is very thin, typically 0.1 to 5 µm. Some components of a fluid in contact with the membrane surface permeate the membrane faster than others, the difference in permeation rate depending on the relative solubility and mobility of the component in the membrane material. This difference enables separation of the feed components. Membranes can be made of different selective polymers to meet specific separation needs. The membranes are packaged in spiral wound modules as shown in Figure 5. During treatment, the feed fluid enters the module and flows between the membrane leaves. The fraction of the feed that permeates the membrane spirals inward to a central collection pipe. The rest of the feed flows across the membrane surface and exits as the residue. To meet the capacity and separation requirements of specific applications, membrane modules may be connected in a serial or parallel arrangement. The residue flow can also be recycled through the membrane modules until the desired level of organic removal is attained.

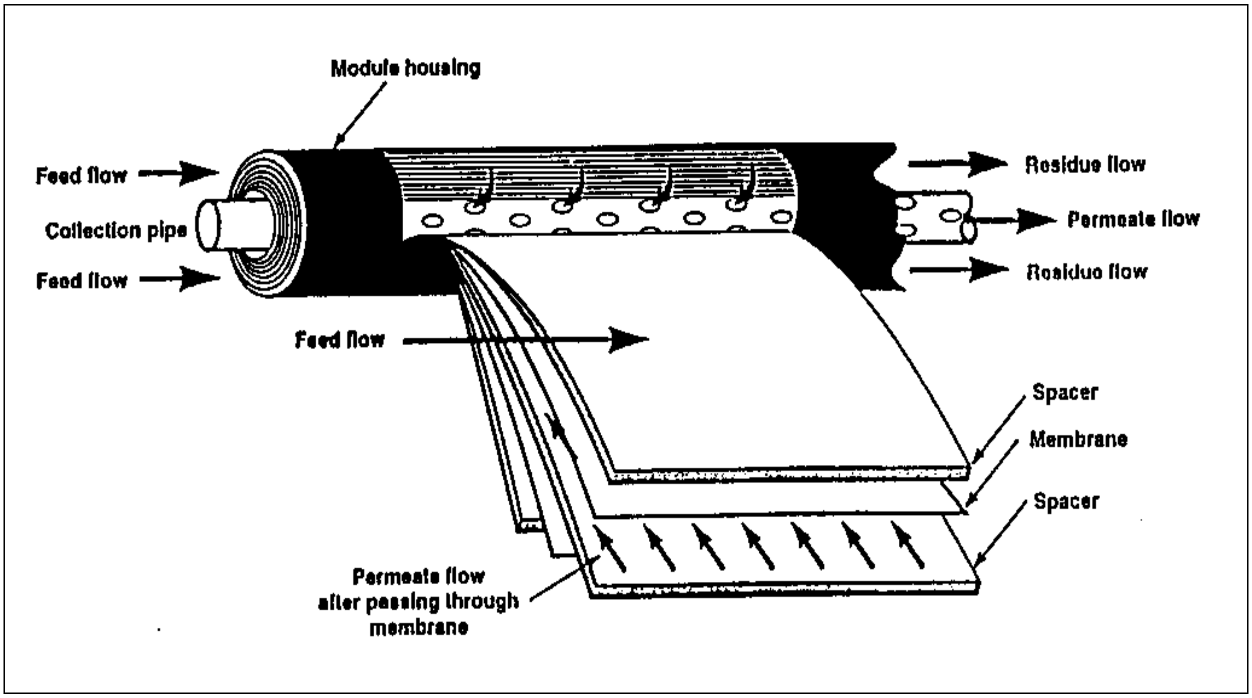


Figure 5. Typical spiral-wound membrane module.

PerVap™ Pilot System Description

Membrane Technology and Research, Inc. (MTR) and the Advanced Technology Group of Hoechst Celanese Corporation, who provides the membrane material, have formed an alliance to market the PerVap™ organic/water separation technology. MTR has developed a PerVap™ Pilot system that was used for this demonstration. The MTR PerVap™ pilot system is a self-contained, field-transportable pervaporation system which has been adapted for use in removing organics from aqueous liquid streams. Table 2 identifies the overall system capabilities. Figure 6 is a process flow diagram of the pilot system. Figure 7 is a photograph of the system in use at the Pinellas Plant..

Table 2. PerVap™ Pilot System Specification

Parameter	Developer’s specification
Capacity	1–2 gal/min.
Operation mode	Batch
Batch size	50 gal
Operation	Continuous batches
Power requirement	480 V, 60Hz. 100 amp, 3-phase
Support equipment	Permeate collection system
Controller	Siemens

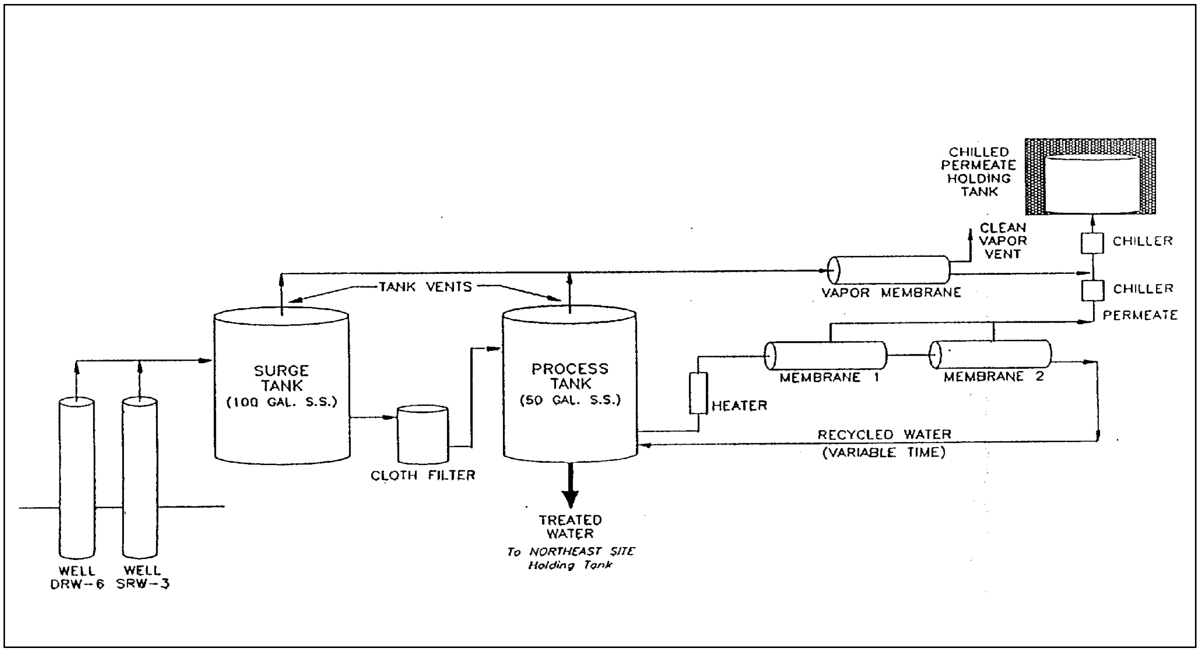


Figure 6. PerVap™ pilot system process flow diagram.

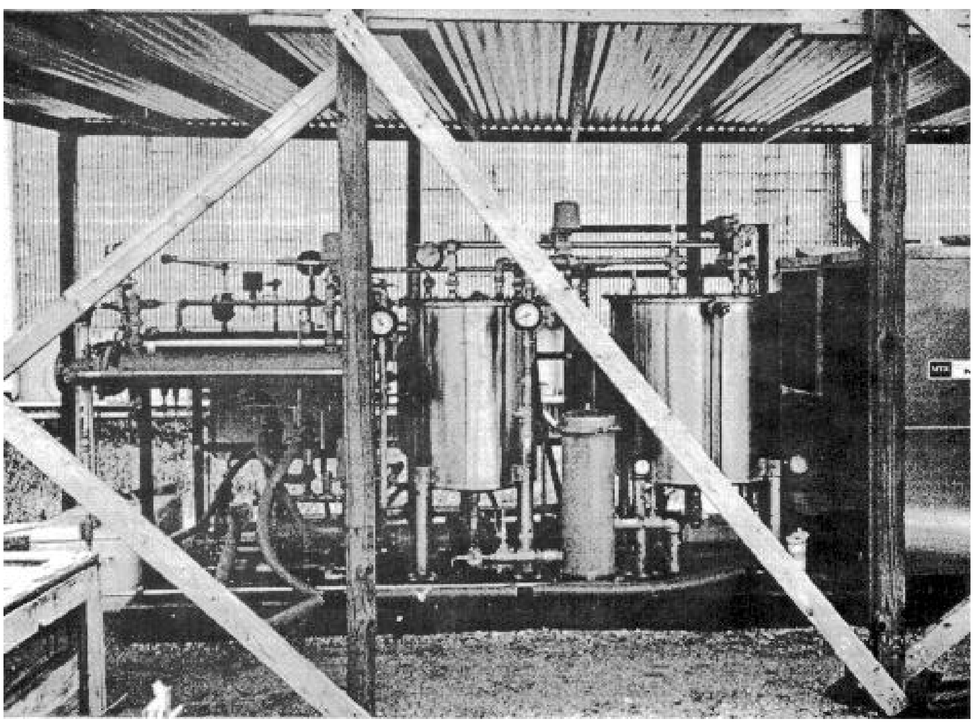


Figure 7. PerVap™ pilot system as used at the Pinellas Plant.

Technology Advantages

Treatment of VOC contaminated wastewater is practiced for several reasons: to recover valuable organic compounds, to minimize disposal costs of hazardous wastes, and to meet regulatory requirements. The advantages of the technology include:

- pervaporation is a low-temperature, non-destructive technology;
- VOCs are recovered in a concentrated liquid form, allowing recycling;
- no secondary wastes or air emissions requiring disposal or permitting;
- no expendable chemicals needed, and
- modular design allows easy modification to meet treatment requirements of streams with high or low VOC concentrations and flow rates.

Technology Limitations

The technology has the following limitations:

- potential membrane fouling from particulates or precipitation of dissolved solids (if the membranes foul, organic removal efficiency and cost effectiveness are reduced significantly);
- potential need pretreat for some ground water,
- diminished removal efficiencies at low organic concentration levels,
- high cost of membrane modules, and
- high initial capital costs.

Treatment System Schematic and Operation

Figure 6 is a schematic of the MTR Pervap™ pilot system.

Pilot system operation was controlled by a Siemens program logic controller that operated the pumps and solenoid-operated valves to process groundwater through the system in 50-gallon batches. The treatment system process flow was as follows:

- Groundwater was pumped to the 100-gal stainless steel surge tank.
- The groundwater was then transferred through a filter to the 55-gal stainless steel feed tank.
- When the feed tank was full, the pervaporation cycle started.
- The pervaporation cycle involved pumping a 50-gallon batch across the heater (elevating the water temperature to 50 degrees C) across the surface of each membrane module, and back into the feed tank.
- The pervaporation cycle timer controlled how long this process continued (typically 1 to 2 hrs). When the timer ended the pervaporation cycle, the treated groundwater was discharged through the effluent line.
- During the pervaporation cycle, a vacuum pump applied a pressure gradient across the membrane modules to assist in the transfer of VOCs across the membranes. The resultant vapor stream, called permeate, was then cooled to a concentrated liquid through a series of condensers and discharged to a chilled permeate storage container.
- All pilot system vents were routed through an MTR vapor separation membrane that functioned similar to the pervaporation modules by removing any VOC vapors from the air and releasing only treated air to the atmosphere.

Health and Safety requirements for the pilot system were limited to safety glasses during routine operations. The tanks emitted an objectional odor during pilot system operations; however, monitoring of the breathing zone around the pilot system with a photoionization detector did not detect any VOCs.

In continuous operating mode, system operation was automated. In this mode, personnel attendance was not required, though system operation was checked daily.

Key Design Criteria

- The MTR Pervap™ Pilot System was supplied as a complete skid-mounted system. It required only an electrical source, a groundwater supply, and a permeate collection container to become operational. As supplied, it was capable of treating the equivalent of 1 gal/min of ground water in a continuous batch mode.
- The pilot system was constructed for use in a hazardous atmosphere. All metal components in the system were corrosion resistant (mainly stainless steel) and the electrical system was contained in explosion-proof housings. MTR chose this construction for universal application; not specifically for the Pinellas Plant.
- The only residuals produced by the pilot system were permeate, spent filters, and used membranes. The filters and permeate were disposed of as hazardous waste. The used membranes were returned to MTR.

Operating Parameters

System throughput and temperatures are adjustable, depending on the desired effluent concentration and contaminants being treated. For this application the following operating conditions were used:

- Average total VOC influent concentration was 1000 parts per million (ppm).
- Nominal system throughput is approximately 1 gpm (50 gal treated for 60 minutes).
- Nominal flow rate through the membrane modules was 13 to 15 gpm.
- System operating temperature used at Pinellas was 50 degrees C.
- The chiller temperature used at Pinellas was 5 degrees C.
- Permeate discharge for the Pinellas ground water was approximately 1,500 mL/batch. (30 L/day assuming continuous 24-hr operation, relatively constant influent VOC concentration, and 1-hr pervaporation cycle.)
- Electrical consumption was approximately 200 kWh/day.

5. REMEDIATION SYSTEM PERFORMANCE

To evaluate the performance and cost effectiveness of the pervaporation process, the MTR PerVap™ pilot-scale field system was operated at the site from July 1995 through February 1996. The following sections of this report present the details of the technology demonstration as they relate to cost and performance results of the PerVap™ pilot system for the treatment of VOC-contaminated ground water at the Pinellas Northeast Site.

Demonstration Objectives and Approach

The primary objectives of this demonstration were as follows:

1. to evaluate overall system performance in treating VOC contaminated ground water;
2. to evaluate environmental factors on system performance; and,
3. to determine expected full-scale ground water treatment costs.

The demonstration was coordinated by LMSC, the DOE site contractor for the Pinellas Plant, in cooperation with the ITRD Program and was designed to evaluate the overall cost and performance of the PerVap™ system. The PerVap™ Pilot System was connected to two ground water recovery wells, each producing 1 to 2 gpm of contaminated ground water. The two wells provided ground water contaminated with approximately 1000 ppm and 100 ppm volatile organics respectively. These wells represented the nominal range of ground water contamination levels at the Pinellas Northeast Site. The PerVap™ system was operated in batch mode with approximately 125 50-gal batches.

Performance Evaluation Criteria

Performance criteria considered in the approach for evaluating membrane separation technology included the following:

1. removal of VOCs from groundwater without the need for pretreatment;
2. removal of VOCs to concentrations low enough to permit discharge to the POTW (a permit requirement);
3. system operation without air emissions in excess of accepted standards; and
4. removal of ground water contaminants as a recyclable product.

The pilot system's performance was evaluated against the original anticipated pervaporation technology benefits:

1. greater than 99% removal of contaminants from the groundwater.
2. no pretreatment of groundwater required.
3. no air emissions were observed in excess of accepted standards.
4. contaminants recovered as a recyclable product.

The approach used to operate the pilot system was based on the goal of evaluating the system for application at the Pinellas Plant Northeast Site. The following three types of evaluations were conducted.

- The first was an initial check of efficiency to verify performance of the membranes. This check included verification of proper system operations, membrane performance, and determination of the appropriate automatic operation cycle

- The second evaluation was a mechanical evaluation that focused on the actual design and construction of the pilot system. Previous experience with treatment systems at the Pinellas Plant has shown that precipitation will occur in an aerobic environment and will eventually result in fouling or flow restriction in a treatment system. Based on this experience, the pilot system was evaluated to determine capability of sustained performance without reduction from clogging or precipitation of dissolved metals from the groundwater.

- The third evaluation focused on the pilot system's ability to remove VOCs during continuous (24 hrs/day) operation. MTR supplied new membrane modules for the performance evaluation.

Performance Summary

Before operating the pervaporation treatment system in a continuous batch mode, LMSC and MTR performed a series of evaluations, included a filter evaluation and re-evaluation, a backwash evaluation, and an efficiency evaluation. Filter and backwash evaluations concentrated on varying the mesh size of the cloth filter between the surge tank and the feed/process tank. Flow pressure was measured both before and after the cloth filter. Initially, a 1-µm mesh was used. Very early in the evaluation, a pressure differential across the filter and a reddish brown sediment were recognized in the water, fouling the filter MTR suggested that the aeration involved in the filtration process was oxidizing the dissolved iron in the process ground water, resulting in precipitate or increased suspended solids. Because 80% of suspended particles in the Pinellas ground water are in the 10- to 15-µm range, the 1-µm mesh filter was replaced with a 10-µm mesh filter in order to improve the system flow. The initial efficiency evaluation of process water across the membranes consisted of a 20-hour batch test with sampling every 10 min. The greatest VOC reductions occurred in the first 60 min. Typical results are shown in Figures 8 and 9.

Subsequent performance evaluations designed to mimic full-scale operations were then conducted on a more or less continuous batch mode. The system operated in automatic mode for 1-hour pervaporation cycles. These evaluations included the addition of a hydrocyclone filter in front of the 10-µm cloth filter, and a cartridge filter was inserted between the heater and the first membrane. Initial VOC removal efficiency was very good, but it decreased with time.

A significant degree of membrane clogging occurred, likely the result of the oxidation of aqueous iron. The system shut down after 13 batches because of pressure buildup. The premembrane filter was replaced with coarser (20 to 100 µm) filters and the system was restarted. Over pressure shutdowns occurred again after 56 batches, then after 2 batches. Various acid washes and backflushes failed to solve the problems. The system was then operated with just the premembrane filter, but it rapidly shut down again because of pressure buildup.

Removal efficiencies during this phase were initially at a 90%+ level until the filters and membranes became clogged. Efficiency decreased to nearly zero as clogging of the membranes reduced the flow rate to as low as 5 gpm. During the tests, aqueous iron concentrations were measured. As much as 3 to 18 mg/L of iron were being removed from the ground water during each batch treatment. It became obvious that the system operation was oxidizing the iron in the ground water and causing the membranes to foul.

Several ground water pretreatment alternatives were identified and evaluated to eliminate the iron fouling problem. These included:

- replacing the air in the headspace of the surge and process tanks with nitrogen, thereby decreasing the oxidation of the water while it is in the tanks;
- adding muriatic acid to lower the pH of the process ground water to 3.5 to reduce precipitation;
- adding tetrapotassium pyrophosphate as a precipitate inhibitor;
- adding citric acid as a chelator to keep the iron in solution; and
- adding Nalco 8356-D as a dispersant to prevent precipitate deposition.

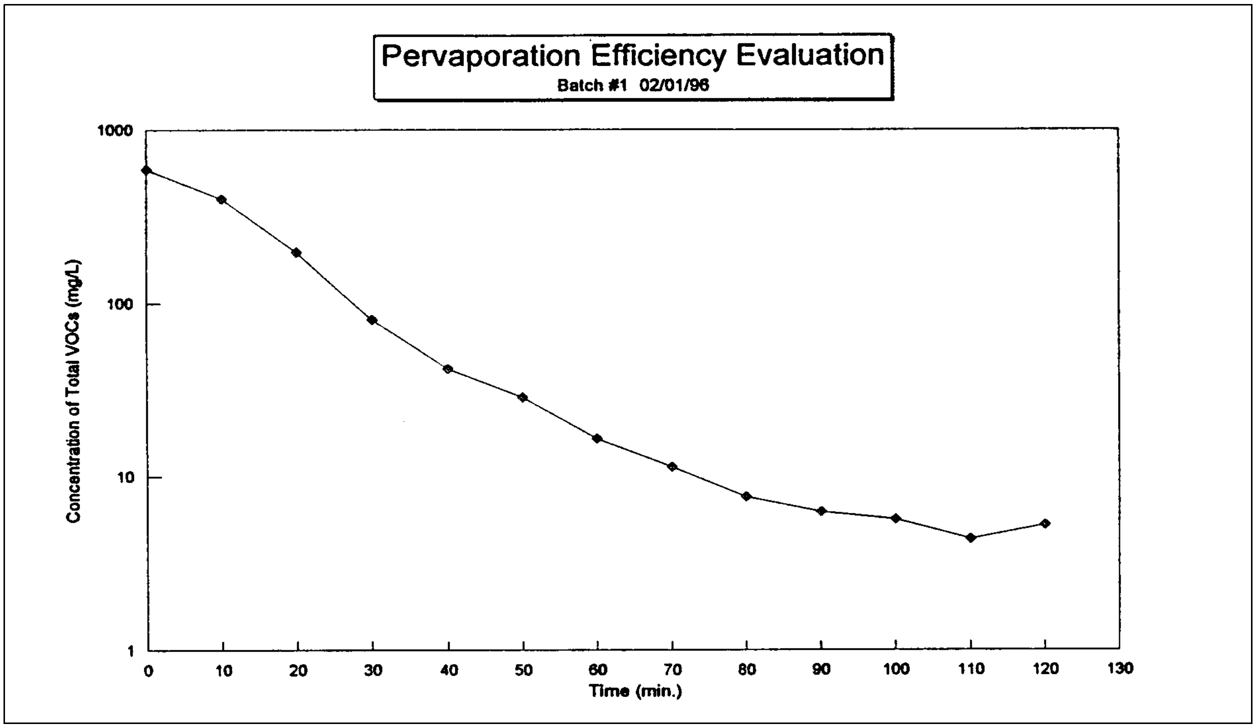


Figure 8. VOC Removal Batch #1.

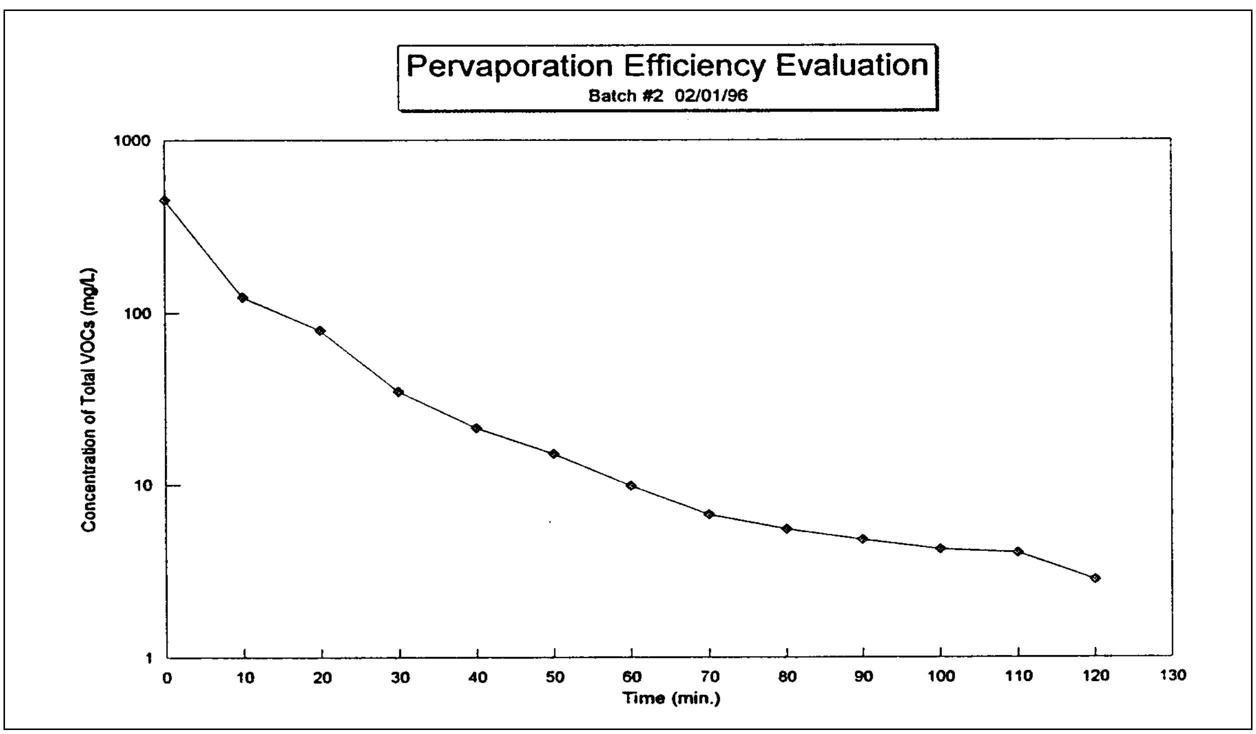


Figure 9. VOC Removal Batch #2.

Several batch operations were conducted to evaluate the alternatives, attempting to maintain high VOC removal rates but reduce the amount of iron being removed. In preliminary tests, nitrogen blanketing resulted in 83% removal of VOCs and 50% less removal of iron. Blanketing plus pH adjustment yielded similar results, but significant quantities of acid were required because of the buffering capacity of the Pinellas ground water. With precipitation inhibition, the results were 78% VOC removal and 88% less iron precipitation.

Efficiency evaluation testing using nitrogen blanketing and Nalco dispersant had the best results, with over 90% VOC removal and over 90% less iron precipitation. Unfortunately, the application of this dispersant and chelator at Pinellas was not compatible with existing ground water treatment systems at the plant. Therefore, it was decided to use nitrogen blanketing to see how well fouling could be reduced in continuous operations.

A mechanical evaluation was conducted to evaluate system performance for fouling/plugging of filters and membranes during continual, 24-hr/day operation, using nitrogen blanketing of the surge and feed tanks, 10-um filters between the tanks and before the first membrane, 70 degree C operating temperature, and a 2-hr pervaporation cycle time. After operating continously for 6.5 days and processing a total of 60 batches, the system continued to have filter fouling problems and showed less efficient overall VOC removal.

Table 3 summarizes design and operational performance data resulting from continuous system operation. The results show that pervaporation can remove VOCs from ground water at high efficiencies andconcentrate the contaminants in a permeate. However, the membranes are susceptible to fouling in certain geochemical conditions. Cost effective methods exist to reduce the fouling problems, but their applicability is subject to site specific requirements and constraints. The chemistry of the ground water to be treated must be fully evaluated before application of this technology can be considered at a site.

Table 3. Pervaporation pilot system performance summary

Performance goals	Values/results
Theoretical Pilot System Benefits • Greater than 99% removal of volatile organic compounds (VOCs from the ground water • No pretreatment of ground water • No air emissions	• Removal efficiencywas highly variable and did not maintain > 99% efficiency. • The POTW discharge limit was never achieved. (All effluent from the pilot system was treated by the existing ground water treatment system.). • Pretreatment of ground water was necessary because of membrane clogging from ground water percipitants. • No detectable air emissions occurred, although a very strong odor prevailed during operations. • Optimal operating parameters could not be established because of the highly variable removal efficiencies.
Compliance levels • Publicly Owned Treatment Works (POTW) discharge limit 850 ug/L total toxic organics (TTO)	• Influent concentrations ranged from approximately 500 to 1,000 mg/L total VOCs. • Effluent concentrations ranged from approximately 1 to 750 mg/L. During optimal conditions, the effluent concentrations were approximately 1 to 10mg/L. (Refer to Figs. 8 and 9 for typical VOC removal data.).
Quantity of ground water treated	• Approximately 125 batches or 6,250 gal.
Residuals	• Spent filters, clogged membranes, VOC permeate.
Quantity of material disposed	• Two 55-gal drums of spent filters, two 55-gal drums of permeate.

6. REMEDIATION SYSTEM COSTS

The pilot system supplied by MTR for evaluation at the Pinellas Plant was subcontracted by LMSC on a monthly fixed price basis. Under this subcontract, MTR agreed to supply the pilot system and engineering services at the following rates:

Cost for first month:	$ 5,000
Monthly cost thereafter:	$ 3,000/month for 8 months
Total cost:	$29,000

MTR provided the following engineering services, (1) during the first month, an engineer at the site to provide start-up assistance and training on the pilot system for 5 days, and (2) during the rest of the evaluation period, an engineer at the site 2 days per month to monitor the equipment and provide technical support.

The costs for the demonstration of the PerVap^{TM} pilot system are shown in Table 4. The costs provided are based on accepted Federal Remediation Technologies Roundtable cost elements.

Table 4. Pinellas pervaporation system cost by interagency work breakdown structure

Cost element (with Interagency WBS Level 2 code)	Description	Costs ($)	Subtotals ($)
Pre-demo consultation	MTR visit & system inspection	1,500	1,500
Mobilization and preparatory work (33 01)	Shipping to Pinellas	1,500	22,478
	Site preparation (utilities, materials, etc.)	12,260	
	System installation and startup	8,718	
Monitoring, sampling, testing, and analysis (33 02)[a]	Sampling and analysis	30,000	30,000
Physical treatment (33 13)	Daily operations (50 days)	3,250	32,250
	Membranes	unknown	
	Subcontract costs	29,000	
Disposal (other than commercial) (33 18)	Spent filters	1,000	1,000
Demobilization (33 21)	Return shipment	1,500	1,500
Total cost			88,728

[a]Monitoring and sample analysis costs for this evaluation were very extensive. This cost is highly variable and depend on the number and frequency of contaminants analyzed.

The most important cost information in this evaluation are the expected capital and operating costs for a full-scale implementation. These costs will vary depending on the desired treatment volume and level. MTR submitted the cost of a full-scale as part of the pilot system evaluation. The specifications for this system are as follows:

- design feed flow: 20 gpm
- design organics concentration in: 400 ppm total VOCs of which 250 ppm is methylene chloride
- design organics concentration out: <850 µg/L TTO, and
- capital costs: $250,000 ±20%, operating costs: $.01/gal.

The maximum site discharge to the POTW is 850 µg/L TTO. This price does not include a 2,000 gal surge tank, a 1,000-gal feed tank, local site setup, or utility connection costs; they would be supplied locally.

During the evaluation of the pilot system the unit operating costs for the ground water treated varied between $.01-$.015/gal during continuous operations. These values suggest that during full scale operations the projected operating costs suggested by MTR will indeed be attainable, provided fouling of the membranes is controlled.

7. REGULATORY/INSTITUTIONAL ISSUES

In July 1993, the DOE, EPA, the Florida Department of Environmental Protection (FDEP), and LMSC entered into an agreement with the ITRD Program to evaluate innovative technologies to remediate ground water contamination at the Pinellas Plant Northeast Site effectively and expeditiously.

Because the membrane separation demonstration was performed at an existing SWMU, no additional permitting or regulatory requirements were applicable. Ground water monitoring reports for the Northeast Site are submitted quarterly to FDEP and EPA Region IV. For each quarterly report submitted during the performance period of the demonstration, a description of the membrane separation demonstration activities was provided thus agencies were made aware of the progress of the demonstration.

Effluent from the membrane separation demonstration was expected to meet the requirements of the Pinellas Plant's Industrial Wastewater Discharge Permit. According to this permit, the limit for TTO is 0.850 mg/l for disposal in the Pinellas County Sewer System (PCSS). (Because it was not initially known if the effluent from the membrane separation demonstration would exceeded this limit, the effluent was disposed with ground water that is normally treated in the plant's ground water treatment system.

No air permitting or air permit modifications were necessary to support this demonstration. Cleanup criteria for groundwater at the Northeast Site are the FDEP maximum contaminant levels and are listed in Table 6.

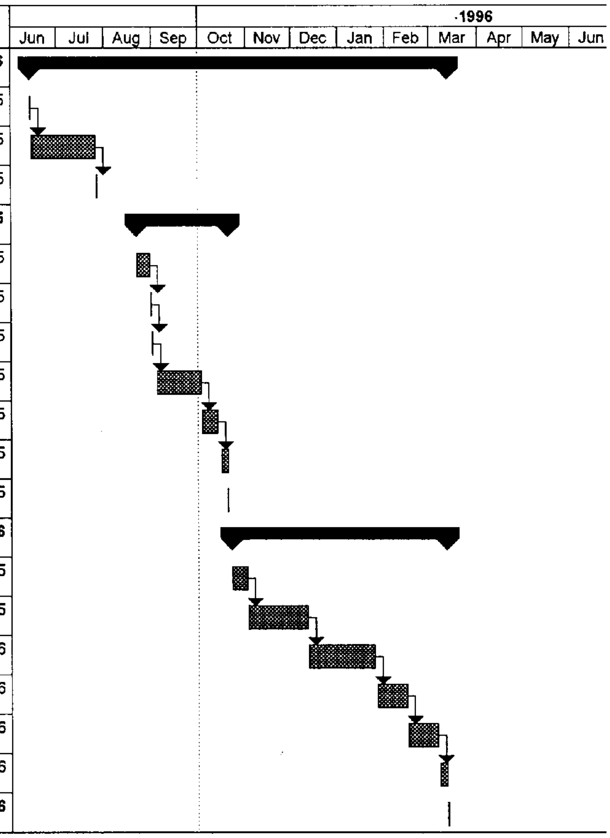
No air permitting or air permit modifications were necessary to support this demonstration.

8. SCHEDULE

The demonstration an devaluation of the pervaporation pilot system at the Pinellas Plant, the associated tasks, and schedule for each task are provided below.

Pinellas Plant Pervaporation Pilot Study

ID	Task Name	Start	Finish
1	**Pervaporation Pilot Study**	**6/14/95**	**3/12/96**
2	System arrival	6/14/95	6/14/95
3	System setup & initial operation	6/15/95	7/26/95
4	Initial Efficiency Evaluation	7/27/95	7/27/95
5	**Mechanical Evaluation**	**8/22/95**	**10/20/95**
6	Filter Evaluation	8/22/95	8/30/95
7	Front End Plumbing Mod.s	8/31/95	8/31/95
8	Filter Re-evaluation	9/1/95	9/1/95
9	Plumbing Modifications	9/4/95	10/2/95
10	Backwash Evaluation	10/3/95	10/13/95
11	Back End Plumbing Mod.s	10/16/95	10/20/95
12	Membrane Changeout	10/20/95	10/20/95
13	**Performance Evaluation**	**10/23/95**	**3/11/96**
14	Auto-mode Operation	10/23/95	11/1/95
15	Progress Evaluation by ITRD	11/2/95	12/11/95
16	Pretreatment Evaluation	12/12/95	1/24/96
17	Auto-mode Operation	1/26/96	2/14/96
18	Nitrogen Blanketing addition	2/15/96	3/5/96
19	Auto-mode Operation	3/7/96	3/11/96
20	**System Shut-off & Decon.**	**3/12/96**	**3/12/96**



9. OBSERVATIONS AND LESSONS LEARNED

Cost Observations and Lessons Learned

The major cost item for the pilot system was sampling and analysis, particularly the laboratory analytical cost, which was reflective of (1) the need to have an accelerated analysis time (3–5 days) to stay abreast of system efficiency, and (2) the number of analytes monitored (EPA 8240A suite). If problems with clogging and efficiency had not occurred, it might have been possible to relax the accelerated analysis time. In addition, less contaminants of concern would have lowered analytical costs.

A limited analysis of direct operating costs for this technology shows that the system can provide cost-effective ground water treatment provided the chemistry of the water is compatible with the system.

Performance Observations and Lessons Learned

The demonstration provided adequate analytical and operations data with which to evaluate the applicability of the MTR PerVap™ Pilot System for remediation of VOC contaminated ground water. Initial operational tests indicated that organic removal efficiencies of 90–99% could be achieved with the pilot system. Batch mode operation allowed 50 gal of ground water at contamination levels as high as 1,000 ppm total VOCs to be reduced to 2 to 3 ppm total VOCs in as little as two hours of treatment.

However, major problems developed during continuous batch operation of the system at the Pinellas Northeast Site because of fouling of the membranes by precipitated iron. Attempts to reduce this fouling through the modification of system operation and some chemical additives met with limited success at the Northeast Site. During continuous batch operation, contaminant concentrations could generally be reduced below 4 to 5 ppm total VOCs.

Summary

Base on the results of the demonstration, the MTR PerVap™ system is an innovative technology capable of providing ex-situ treatment of VOC-contaminated ground water, assuming there is no compatibility problems between the system and the ground water. At the Pinellas Plant, the PerVap™ system was incompatible with the ground water and the results were a major impact on system operations and performance. Because of these impacts, the PerVap™ system failed to meet the theoretical benefits and objectives of the technology demonstration for the Pinellas Plant.

10. REFERENCES

1. *Installation Assessment, Pinellas Plant*, U. S. Department of Energy, Comprehensive Environmental Assessment and Response Program, Albuquerque Operations Office, Albuquerque, N.M., 1987.

2. *RCRA Facility Investigation Report, Pinellas Plant*, Vol. 1-Text, U.S. Department of Energy, Environmental Restoration Program, Albuquerque Operations Office, Albuquerque, N. M., 1991.

3. *RCRA Hazardous and Solid Waste Amendments Permit*, U. S. Department of Energy Pinellas Plant, Largo, Florida, EPA ID No. FL6-890-090-008, U. S. Environmental Protection Agency, February 9, 1990.

4. *Interim Corrective Measures Study, Northeast Site*, TPA2 6350.80.01, prepared by CH2M Hill for the U. S. Department of Energy and General Electric Company, Neutron Devices Department, Largo, Florida, May 1991.

5. *Industrial Wastewater Discharge Permit*, U. S. Department of Energy Pinellas Plant, Pinellas County Sewer System, Pinellas County, Florida, 1994.

6. *Corrective Measures Study Report, Northeast Site, Pinellas Plant, Largo, Florida,* U. S. Department of Energy, Environmental Restoration Program, Albuquerque Field Office, Albuquerque, N. M. 1993.

7. 11. VALIDATION

"This analysis accurately reflects the performance and costs of the remediation."

10-22-97

David S. Ingle, Pinellas Area Office
U.S. Department of Energy

Mike Hightower, Technical Coordinator
Innovative Treatment Remediation Demonstration Program
Sandia National Laboratories

Department of Environmental Protection

Lawton Chiles
Governor

Twin Towers Building
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Virginia B. Wetherell
Secretary

June 2, 1997

Mr. David S. Ingle
Albuquerque Operations Office
Pinellass Area Office
Post Office Box 2900
Largo, Florida 34649

Dear Mr. Ingle:

Jim Crane, John Armstrong and I have reviewed the "Cost and Performance Report, Innovative Treatment Remediation Demonstration, PerVap Membrane Separation Ground Water Treatment, Pinellas Plant Northeast Site" final draft dated April 15, 1997. We concur with the purpose of the report. Unless the EPA or other parties desire modifications, we recommend that the report proceed to "final" designation.

If I can be of any further assistance with this matter, please do not hesitate to contact me at 904/921-9999.

Sincerely,

Eric S. Nuzie
Federal Facilities Coordinator

ESN/sr

cc: Jim Crane, FDEP Technical Review Section
John Armstrong, FDEP Technical Review Section
Bill Kutash, FDEP Southwest District
Carl Froede, US EPA Region 4

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CERTIFIED MAIL
RETURN RECEIPT REQUESTED

The United States Department of Energy
Pinellas Plant
Attn: Mr. David Ingle
P.O. Box 2900
Largo, FL 34649

SUBJ: Cost and Performance Reports for the:
1) Dual Auger Rotary Steam Stripping Technology, and
2) Pervap Membrane Separation Technology
Demonstrations at the Northeast Site
DOE Pinellas Plant, FL
EPA I.D. Number FL6 890 090 008

Dear Mr. Ingle:

The Environmental Protection Agency (EPA), Region 4, has completed our review of the above referenced documents. Both of these reports appear to accurately convey information gathered by the Innovative Treatment Remediation Demonstration (ITRD) Team for the two different technologies that were demonstrated on the small scale at the Northeast site.

The activities associated with the Northeast Site under the direction of the ITRD have been very important to the Agency because the successful demonstration of the various technologies would ultimately lead to a remedy selection for this solid waste management unit. Additionally, the information gained from these activities is valuable in determining the cost/benefit of using these innovative technologies at other sites. EPA remains committed to working with the Department of Energy (DOE) at the former Pinellas Plant to document the success of these technology demonstrations, for a final remedy selection at this site, and eventually facility restoration.

If you have any questions regarding the ITRD at the Northeast Site then please contact me at (404) 562-8550.

Sincerely,

Carl R. Froede Jr.

Carl R. Froede Jr., P.G.
DOE Remedial Section
Federal Facilities Branch
Waste Management Division

cc: Eric Nuzie, FDEP
Jim Crane, FDEP

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