Removal of VOCs from Contaminated Groundwater and Soils by Pervaporation

Cleanup
CU-371

LEAD AGENCY: Environmental Protection Agency

LAB: National Risk Management Research Laboratory

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PROBLEM STATEMENT: Petroleum hydrocarbons, and other volatile organic compounds (VOCs), which are found to contaminate groundwater and soils, are usually treated by pump-and-treat methods, which are very time-consuming, expensive, and not very effective. We are proposing the use of pervaporation for effectively removing these hydrocarbons and VOCs from contaminated soil and groundwater (with or without using surfactants) and concentrating them by at least a thousand-fold, for economical disposal or recycle/reuse using specially designed hydrophobic membranes.

This project supports the DoD's Tri-Service Environmental Quality R&D Strategic Thrust Areas: 1.H Solvents Contaminated Groundwater, 1.I Fuels Contaminated Groundwater, and 1.L Solvents/Fuels Contaminated Soils, and will partially meet or substantially contribute to User Requirements:

- S Solvents in Groundwater
- S Alternatives to Pump and Treat
- S Improved Treatment of Water Contaminated with Chlorinated Hydrocarbons
- S Chlorinated Solvents in Groundwater Treatment
- S Dissolved Fuel in Groundwater (BTEX) Treatment
- S Improved Recovery of Free Petroleum, Oils, and Lubricants from Aquifers
- S Improved Remediation of Groundwater Contaminated with Nonchlorinated Hydrocarbons
- S Improved Remediation of Soils Contaminated with Chlorinated Solvents
- S Improved Remediation of Soils Contaminated with Nonchlorinated Hydrocarbons

PROJECT DESCRIPTION: Petroleum hydrocarbons and other volatile organic compounds (together described hereafter as VOCs) form various industrial activities in both civilian and military sectors are frequently found to contaminate groundwater and soils. These VOCs typically are transportation fuels, and solvents including chlorinated organic compounds such as trichloroethylene (TCE), carbon tetrachloride, tetrachloroethane (TCA). Many of these VOCs are potential carcinogens. In groundwater the VOCs exist as non-aqueous phase liquid pools (NAPLs), which are of two types, light NAPL (LNAPL) which floats on water, and dense NAPL (DNAPL) which sinks under water. The NAPL pools are a long-term source of contamination, as the organics slowly leaks into the aquifer water, which then is unusable for human use, and if the water discharges into a river or a lake, it poses danger to aquatic life. Soil contamination by VOC is a source for continuous air pollution and is also a source for groundwater pollution.

The technology of choice for remediating these environmental problems is the so-called pump- and-treat method, one variation of which is circulating water through the contamination area and pumping it out to a treatment stage, typically carbon adsorption, which needs to be subsequently regenerated, and the VOCs disposed of chemically. We propose to develop a simpler and more effective technology which will use the membrane pervaporation method. This method removes the VOCs from the water and concentrates it by at least a thousand-fold, which permits much more economical recovery for recycle/reuse.

In the "pump" part of the pump-and-treat process, the use of surfactants has been proposed for enhancing the removal of VOCs from the groundwater or soil matrix (surfactant flushing). While the VOCs will indeed be removed more efficiently by emulsification, the oil-water emulsion is harder to dispose of by ordinary means of bioremediation or carbon adsorption. We are proposing pervaporation as a means of breaking the emulsion while removing the VOCs from the contaminated water. The efficiency of pervaporation for VOC removal from water has already been demonstrated in several studies to be better than 99%. The use of pervaporation for breaking oil-water emulsions is protected by an invention disclosure at NRMRL-EPA.

Pervaporation works on the principle of solution diffusion, i.e. the organic compounds dissolves in the non-porous membrane, diffuses out to the permeation side, and evaporates. The energy for this evaporation is conveniently provided with the feed stream itself. In contrast to conventional membrane processes, which use porous membranes, pervaporation membranes are not akin to filtration, and are therefore less prone to mechanical fouling. For VOCs, which are hydrophobic, a hydrophobic membrane is appropriate. Either a vacuum or an inert sweep gas is employed on the permeate side of the membrane. Usually the VOCs permeate through a hydrophobic membrane, such as one made of polydimethylsiloxane or silicone, orders of magnitude faster than water, as a result of which the VOCs are highly concentrated. For instance, it is possible to concentrate a 100 ppm VOC-solution to over 10% VOC solution (or suspension).

The composition and morphology of the membranes are a key to effective use of pervaporation technology. It is best to use a thin film of the discriminating layer deposited on a highly porous support structure. In addition, NRMRL-EPA has invented specially doped membranes that enhance the selectivity by 40% or more. An invention disclosure has also been made on the use of these membranes for pervaporation.

The proposed research has four parts:

1. Use of special membranes: These membranes will be designed, fabricated and tested for their superior VOC-selectivity and transport rates. The results will be useful to predict the opportunity for improved efficiencies offered new membranes in comparison to conventional commercially available membranes.

2. Bench-scale test: Laboratory research will be conducted to investigate the removal of VOCs from simulated ground water and surfactant-flushed VOC-solutions. Transport rates, selectivity, and separation factors will be measured for one advanced membrane system of a baseline system comprised of a commercially available membrane.

3. Mathematical modeling will be conducted to predict the design features of a prototype for a designated removal efficiency. This is a mere extension of modeling currently being done at NRMRL.

4. We will conduct a pilot demonstration of a prototype for VOC-removal from contaminated water (with or without surfactant in it). We had originally proposed to demonstrate the technology at a defense facility; however, we are now developing a proposal to test in an existing EPA pilot facility to determine potential cost savings.

All work from proof-of-concept of the removal of VOCs from VOC-emulsion in water to pilot demonstration can be completed in two years from the inception of the study, which began in January of 1995.

EXPECTED PAYOFF: The proposed technology will make two specific advances: (1) provide a cost-effective way of dealing with surfactant-VOC solutions, and (2) provide a boost to the use of surfactants for groundwater and soil remediation. Large savings will accrue from this practical and efficient technology.

TRANSITION PLAN: The pilot demonstration was originally planned to take place at a defense site, constituting technology transfer to DoD. However, we are considering the possibility of conducting the pilot plant work at EPA's Test and Evaluation Facility of significant cost savings could be relieved. We are preparing a comparative feasibility study (in-house) on this possibility.