



Project Summary

Nitrate for Bioremediation of an Aquifer Contaminated with Jet Fuel

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There is little information available in the open literature on the performance of bioremediation at field scale. This report documents the rate and extent of treatment of a spill of JP-4 in a drinking-water aquifer, using nitrate as the primary electron acceptor for microbial respiration of the contaminant hydrocarbons. Nitrate has theoretical advantages over the more traditional electron acceptors used in the United States. It is much more soluble than oxygen, and less costly and less toxic than hydrogen peroxide. Ground water amended with nitrate and mineral nutrients was recirculated through a 10 m by 10 m study area. After 165 days the individual concentrations of benzene, toluene, ethylbenzene, and xylenes were below 5 $\mu\text{m}/\text{l}$ in monitoring wells under the study area. The concentration of benzene was below 0.1 $\mu\text{g}/\text{l}$. Some of the removal of alkylbenzenes may have been due to low concentrations of oxygen (0.5 mg/l) in the recirculation water.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, 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).

Background

A field demonstration project on nitrate-mediated bioremediation of a fuel-contaminated aquifer was conducted at a U.S. Coast Guard facility in Traverse City, MI.

Several leaks from an underground storage facility containing JP-4 jet fuel have resulted in contamination of ground water at the site. The focus of the field demonstration project is a 10 m x 10 m infiltration area located within the larger area contaminated by the JP-4 spill. An infiltration gallery was installed above the study area; it is part of a closed-loop system designed to perfuse the study area with ground water supplemented with nitrate and nutrients. The 10 m x 10 m section of the site was instrumented with monitoring wells and piezometers. A series of recirculation wells was installed down gradient to intercept contaminants, nutrients, and nitrate and provide hydraulic recirculation back through the infiltration gallery. In addition, four purge wells are in place to provide a net discharge from the site and prevent escape of nitrate or contaminants to regional flow in the aquifer.

The design of the system was facilitated by hydraulic modeling to evaluate the infiltration rate necessary to raise the piezometric surface above the contaminated zone, the withdrawal rates necessary to retain the contaminants and nutrients on-site, and the nutrient contact time important to biological treatment. A tracer study was conducted to confirm estimated breakthrough times and give a preliminary evaluation of the performance of the in-situ bioreactor.

The effects of recirculation, purging to waste, and biodegradation on the decrease in solution concentration of BTEX compounds within the treatment zone were examined. The aquifer was cored and analyzed for total petroleum hydrocarbons and



for the quantity of selected fuel hydrocarbons. Water was recirculated through the system for 41 days to bring the system to hydraulic and chemical equilibrium. Then nitrate and mineral nutrients were added for an additional 160 days. Biological processes supported on the ambient concentrations of oxygen and nitrate removed benzene from the fuel spill and the recirculated water before nitrate was added. Benzene concentrations were below 0.1 µg/l. After addition of nitrate, toluene was rapidly removed in the fuel spill. Ethylbenzene and m+p-xylene were also removed during denitrification; however, there was little evidence for biodegradation of o-xylene until the end of the demonstration. As expected, minor amounts of the alkane fraction were removed.

Conclusions

The technology produced excellent results. Concentrations of BTEX in monitoring wells were below the appropriate State of Michigan and Federal Drinking Water Standards within 165 days. Unit costs for remediation were calculated by dividing the cost of construction, labor, chemicals and electrical service by (1) the volume of JP-4 beneath the infiltration gallery, (2) the volume of aquifer material contaminated with JP-4 under the infiltration gallery, and (3) the volume of aquifer between the infiltration gallery and the confining unit beneath the aquifer. The unit costs for the remediation were \$22 per liter JP-4, \$200 per m³ of aquifer material contaminated with JP-4, and \$17 per m³

of aquifer material down to the confining layer.

Computer simulation was very useful in determining reasonable injection and withdrawal rates of water before construction of the gallery. It allowed a prediction of the areal extent of the hydraulically affected zones and an estimate of the vertical mounding of the water surface at the injection gallery and drawdown at the withdrawal wells. This information was also required to size pumping and piping apparatus, to estimate electrical power requirements, to size mixing tanks, and to estimate bulk chemical purchases.

Proper hydraulic control of an infiltration gallery to maintain saturated conditions throughout the contaminated zone is absolutely necessary.

In this study, the calculated effect of dilution using partitioning theory on the equilibrium solution concentration of BTEX compounds does not explain their continued disappearance. Including the effect of steady purging of a certain percentage of the recirculated water better explains the trends in the observed data, but does not explain the sharp drops seen in the solution concentrations of benzene, toluene, and m-xylene. After taking these physical processes into account, biological processes provide a reasonable explanation for benzene, toluene, and m+p-xylene removal. The decrease in solution concentrations of o-xylene was observed to follow that predicted by dilution and wasting, indicating that it may be less sensitive to degradation processes. Concentrations decreased significantly in the monitoring wells only towards the end of the demon-

stration when the other compounds were depleted.

The laboratory work has shown that aromatic hydrocarbons, with the possible exception of benzene, can be degraded under strictly anaerobic conditions by native subsurface bacteria using nitrate as the terminal electron acceptor. Toluene is most easily degraded with the xylenes being more recalcitrant. The project has demonstrated, through extensive core analyses, that simple hydraulic flooding will remove a significant amount of the lower molecular weight aromatic hydrocarbons in far greater proportion than the residual fuel hydrocarbons.

Addition of nitrate and nutrients results in denitrification occurring within the contaminated zone, as shown by decreases in nitrate concentrations through the infiltration gallery along with transient nitrite production. Core analyses revealed that BTEX was removed to very low concentrations after two months of nitrate addition. There was a general decrease in all constituents of the jet fuel, although detectable concentrations of the higher molecular weight alkylbenzenes still remain.

It was impossible to determine the extent to which a particular BTEX compound was removed through denitrification. Aerobic biodegradation was feasible in the system. Over the course of the demonstration, 7.4 kilomoles of electrons were accepted by oxygen, and 178 kilomoles of electrons were accepted by nitrate.

The actual amount of nitrate consumed was ten times greater than the theoretical nitrate demand for oxidation of the BTEX compounds alone.

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The complete report, entitled "Nitrate for Bioremediation of an Aquifer Contaminated with Jet Fuel," (Order No. PB91-164 285/AS; Cost: \$ 17.00, subject to change) will be available only from:

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