In Situ Removal of Perchlorate from Groundwater

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ABSTRACT: Laboratory column studies suggest that *in situ* barriers might be used to remove perchlorate from groundwater. Water containing perchlorate was pumped through columns containing sand. After 14 days operation soybean oil was injected onto one group of columns, the treatment group, while a second group of columns, the control group, received no oil. Samples of the effluent water were collected at intervals and analyzed for chloride and perchlorate. In the control columns, perchlorate was present in the column effluents throughout the study. In the treatment columns, perchlorate in the effluent decreased by ~ 99 %. Permeable barriers containing innocuous vegetable oils, other carbon substrates, or other electron donors, might be used *in situ* to remove perchlorate from contaminated groundwater.

INTRODUCTION: Perchlorate, used in a number of industrial and agricultural applications, is highly soluble in water, highly mobile, and remarkably persistent as a groundwater contaminant. It has been identified as a water contaminant in over a dozen states. The presence of perchlorate in drinking water is a health concern because it resembles iodine in both charge and ionic radius and, as a result, it interferes with the proper functioning of the thyroid gland by acting as a competitive inhibitor of iodine.

Ion exchange, reverse osmosis, and nanofiltration can remove perchlorate from water but these processes do not destroy the anion. Biological treatment destroys the perchlorate anion by converting it to chloride and oxygen

Objective. Glass chromatography columns packed with sand were used to evaluate the use of vegetable oil as a carbon substrate for the *in situ* treatment of groundwater contaminated with perchlorate. Previously, we demonstrated that vegetable oil could be used to form a stationary organic zone or wall that was high in organic matter and permeable to water that could be to remove nitrate from flowing water. The present study evaluated the same process with perchlorate rather than nitrate as the electron acceptor. In addition, a simple survey was conducted to determine the distribution of perchlorate reducing microorganisms in the environment.

MATERIALS AND METHODS:

Soil Survey. For the survey soil samples were collected from a number of different sites in northeastern Colorado and evaluated for the ability of these indigenous microorganisms to reduce perchlorate during two weeks incubation under anaerobic conditions with soybean oil as a substrate.

Soil Columns. Columns were 1.5 by 30 cm glass chromatography columns filled with sand. Columns were inoculated with a soil extract and water supplemented with iron, phosphate, NH_4^+ -N, and 0.20 mM (20 mg/L) perchlorate was pumped through the columns at a rate of ~25 ml/day. After 14 days of operation soybean oil was injected as an emulsion onto two of the columns, the treatment group, while two other columns, the control group, received no oil. Water containing perchlorate was pumped through both groups of columns for another 16 weeks. Effluent water was collected at regular intervals and analyzed for perchlorate with an HPLC.

RESULTS AND DISCUSSION:

Soil survey. All soil samples were found to contain microorganisms capable of reducing perchlorate to chloride under anaerobic conditions. These results suggest that perchlorate-reducing organisms are ubiquitous or nearly ubiquitous in surface soils and that indigenous microorganisms can serve as the inoculum for the *in situ* remediation of perchlorate at most sites.

Column studies. Over an 18-week period water containing 0.2 mM (20 mg/L) perchlorate was pumped through the treatment and control columns. During the first 2 weeks of the study, before oil was applied to the treatment columns, no perchlorate was removed from the water pumped through any of the columns. However, after the addition of the oil emulsion to the treatment columns the amount of perchlorate in the effluents of these columns dropped rapidly and averaged 0.0007 mM (0.070 mg/L) between the 5th and 18th week of the study. This represents a decrease in the amount of perchlorate in the treated water of more than 99 % in the period following the addition of the vegetable oil (Figure 1). In the control columns the amount of perchlorate in the effluent fractions remained high, averaging 0.14 mM (14 mg/L) over the study.

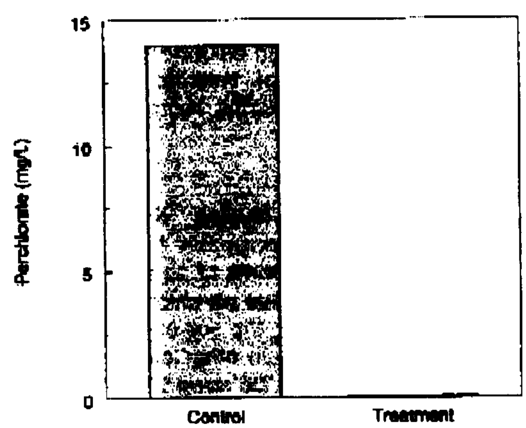

FIGURE 1. Perchlorate in control and treatment column effluents between week 5 and 18.

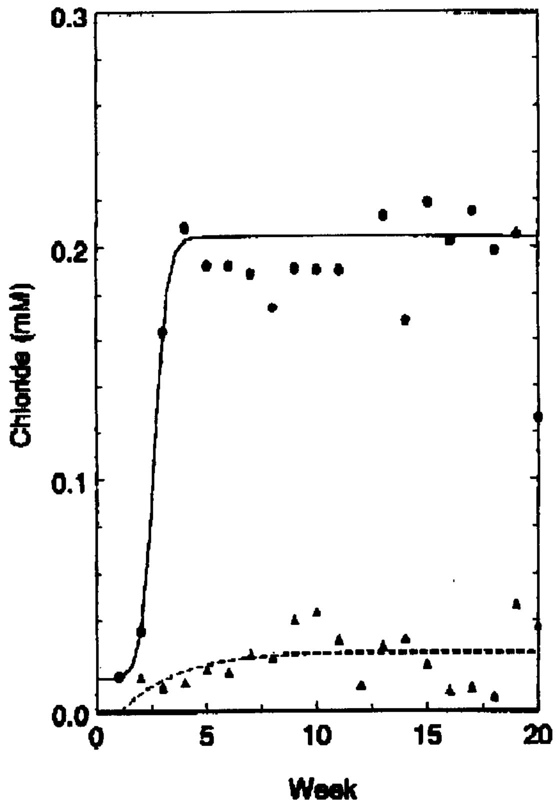

FIGURE 2. Chloride in treatment (•) and control (Δ) column effluent fractions over the course of the study.

The amount of chloride in the column fractions from the treatment columns increased rapidly indicating the conversion of perchlorate to chloride by the treatment columns while the amount of chloride present in the effluents from the control columns remained low during the study (Figure 2).

CONCLUSIONS: These studies demonstrate the principles whereby a simple permeable barrier composed of sand, gravel and small amounts of an insoluble carbon substrate can be used to remove perchlorate from flowing ground water. In these studies the soil columns contained innocuous vegetable oils though other carbon substrates or electron donors might also be used *in situ* to remove perchlorate from contaminated groundwater.

Applications. Shallow permeable *in situ* barriers might be constructed by digging a trench and backfilling the trench with sand coated with vegetable oil or with a mixture of sand and an insoluble carbon substrate such as saw dust, crop residues, waste papers, etc. Such barriers can be quickly and cheaply constructed to remediate shallow aquifers or to protect an aquifer from runoff. However, the construction of deep trenches for deep barriers is much more difficult and expensive. A simpler and less expensive approach for forming deeper barriers might involve the injection of vegetable oil emulsions across a section of a sand and gravel aquifer. Injection could reduce the cost of constructing deep barriers but additional research is needed to develop the methods and evaluate injection technologies.