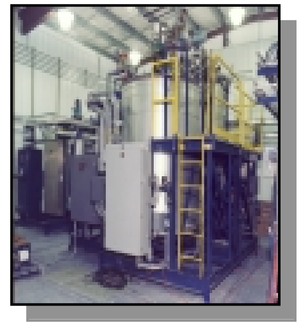
Perchlorate Treatment Technology Fact Sheet

Bioreactors

What Are Bioreactors?



Anaerobic Reduction of Perchlorate in a Bioreactor

Bioreactors are an *ex situ* form of biological treatment in which contaminated process wastewater or extracted groundwater is pumped into an above ground reactor vessel (*i.e.*, bioreactor), and placed into direct contact with microorganisms. These microorganisms remove perchlorate by consuming it as a food source. Careful control of environmental conditions (pH, temperature, oxygen content, nutrient sources, etc.), hydraulic flow, and residency time of the contaminated water supply in the bioreactor is necessary to support the growth of the microorganisms. Aerobic, or oxygen-based, bioreactors have been used for decades in the treatment of municipal and industrial wastewater. Common system designs include fluidized bed reactors (FBR), continuous-stirred tank or suspended growth reactors, and fixed film or packed bed reactors.

Despite widespread use of bioreactors in the treatment of municipal and industrial wastewater, only in the past decade have studies been performed to evaluate the effectiveness of bioreactors in treating contaminated groundwater. Studies focused on perchlorate have determined that it can be successfully biodegraded to the harmless chloride ion, but only in under anaerobic conditions (*i.e.*, in the absence of oxygen). Because the anaerobic reduction of perchlorate has been shown to be successful, initial research into using bioreactors to treat perchlorate-contaminated waters has focused on the development and optimization of anaerobic bioreactors.

Where Have Bioreactors Been Used to Treat Perchlorate?

The Air Force Research Laboratory (AFRL) Materials and Manufacturing Directorate (Tyndall Air Force Base, Florida) led the way in developing bioreactor systems to treat process wastewater containing very high levels of perchlorate. Since 1997, a bioreactor based on the AFRL design has been treating wastewater from rocket motor production and demilitarization operations at a defense contractor facility near Brigham City, Utah.

Private industry and academia are also investigating the use of bioreactors. A large, full-scale FBR system has been used since 1998 to remediate perchlorate-contaminated groundwater beneath a site in Rancho Cordova, California. Because other organic and chlorinated compounds also contaminate the Rancho Cordova site, the FBR system is integrated as a component into the site's overall groundwater extraction and treatment plant. Academic researchers have also conducted experiments with bioreactors. Environmental engineering faculty at the Pennsylvania State University and Northwestern University have developed prototype fixed or packed bed biological treatment systems.

The first DOD facility to install a functional bioreactor for treating perchlorate-contaminated groundwater was the former Longhorn Army Ammunition Plant (LHAAP) in Karnack, Texas. In the past, LHAAP manufactured solid propellant containing ammonium perchlorate for defense rocket and missile systems and was the site of demilitarization activities. These activities resulted in

Site Facts

Location: Longhorn Army Ammunition Plant (LHAAP), Karnack, Texas

Site Description: Former manufacturing and demilitarization facility of solid-propellant rocket motors. Closed in 1997 with plans to transfer majority of 8,493 acres to Fish and Wildlife Service.

Contaminated Media: Groundwater

Treatment Technology: Fluidized Bed Reactor.

Objective: Remove perchlorate from contaminated groundwater being discharged by treatment plant not originally designed to treat perchlorate.

Status: Full-scale FBR installation

Contacts:

Erica Becvar, AFCEE/ERT, 210-536-4314
Air Force Center for Environmental Excellence
erica.becvar@brooks.af.mil

Bryan Harre, NFESC, 805-982-1795
Naval Facilities Engineering Service Center
Harrebl@nfesc.navy.mil

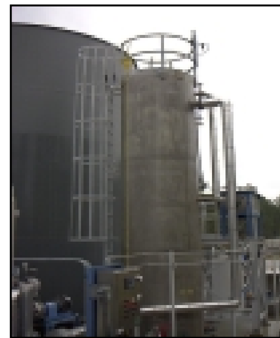
Jonna Polk, USACE, 918-669-7482
US Army Corps of Engineers, Tulsa District
jonna.Polk@usace.army.mil

Cyril Onewokae, 309-782-1350
US Army Operations Support Command
onewokaec@osc.army.mil

contamination of groundwater and led to the construction of a groundwater pump-and-treat system for the production and disposal areas. However, the groundwater treatment plant, which began treatment in 1997, was designed to extract and treat metals and volatile organic compounds, not perchlorate. After assessing the cost and technical feasibility of alternative technologies, LHAAP opted for a bioreactor, specifically an FBR, as an add-on device to the existing groundwater treatment system.

Perchlorate Contamination at LHAAP

Perchlorate was identified as a concern at LHAAP in 1998 when it was found in an effluent from an existing groundwater treatment plant. Effluent was discharged into surface water approximately one mile upstream of the plant boundary at the edge of Caddo Lake, a drinking water source and recreation area for several communities in Texas and Louisiana. Subsequent site investigations in 1999 discovered several locations in which soil and groundwater had been contaminated by perchlorate. In December 1999, the State of Texas directed the US Army to address the perchlorate discharge from the treatment plant by December 2002. In January 2001, the Army installed a full-scale biological FBR as an add-on device to the existing groundwater treatment system.



Fluidized Bed Reactor (FBR) at LHAAP

LHAAP Bioreactor Description and Performance

The LHAAP FBR uses acetic acid as an electron donor and nutrient for the microbes, which then reduce the perchlorate to harmless chloride ions. Operation of the FBR is completely automated, and all chemical feed rates, inflow, and outflow rates, pH, and control valves are viewable and adjustable from the computer console that controls the groundwater treatment plant. The reactor vessel itself is 5 ft in diameter, and 21 ft tall, and has an 8 ft X 20 ft total footprint. The system successfully reduces perchlorate in the treated water to below 4 ppb, the reporting limit of the EPA's approved analytical method for perchlorate.

Cost Effectiveness

The cost of the LHAAP FBR was determined to be much less expensive than other considered alternative treatment technologies. The total costs of planning the implementation, purchasing, and installing the single 50 gpm FBR unit, and one year of technical support totaled nearly $650,000. Operational costs, including electricity for the pumps, electron donor material, and other necessary nutrients, has been estimated at $25,000 to $30,000 for the first year of operation, with a significant portion of that cost attributable to analytical costs for effluent monitoring.

Advantages

- The system is relatively small and compact
- Can be easily inserted as an add-on treatment device into existing systems to treat perchlorate
- Simplicity of operation minimizes the amount of operator oversight needed
- Minimal biosludge production
- Appears to be relatively cost-effective, *e.g.*, low capital, operation, and maintenance costs

Disadvantages

- Bioreactors are a long-term pump and treat technology; when selected as a remedy, is typically operated for many years
- Requires careful control of reactor vessel environmental conditions, such as temperature, pH, oxygen content and nutrient loading
- Typically requires regular nutrient condition as the dilute nature of contaminated groundwater may not support an adequate microbial population density
- Discharge of treated water may still be regulated and require additional treatment
- System can be less effective if the wastewater to be treated contains elevated nitrate concentrations
- Access to an uninterrupted power supply is critical to the operation of a bioreactor system; ensuring access to electrical power can contribute to the capital costs of a bioreactor system, and may be problematic if the targeted water supply is in an undeveloped or remote area