Novel Biological Treatment Removes Nitrate Contamination

By Mark Reinsel, Ph.D., P.E.

A process called the Anoxic Biotreatment Cell (ABC) now appears promising for treating a wide range of industrial wastewaters and groundwater. Initially developed to help Stillwater Mining Company meet its discharge limit for nitrate, the ABC process has been successful in bench-, pilot- and production-scale tests for removal of nitrate, selenium, perchlorate, sulfate, metals and acidity.

The patented ABC is a "semi-passive" bioreactor which uses pressurized flow and nutrient addition, yet has few moving parts and requires little maintenance. It is a packed-bed reactor with the addition of an external carbon source, usually methanol. Features distinguishing the process include the use of a natural reactor media, which may be available on-site; low-temperature operation (as low as 2°C); a simple yet flexible reactor configuration (typically in-ground, upflow, and insulated); and a low excess phosphate concentration to enhance microbial activity.

The ABC was developed to provide an engineered treatment system more reliable than passive treatment, yet simpler and less expensive than conventional biological or physical/chemical options. It combines the low cost of passive biological treatment with the consistent, long-term effectiveness of commercial mechanical systems.

The full-scale system has been operating at the Montana metal mine since early 1996 and has consistently removed over 90 percent of the incoming nitrate. Nitrate also has been biologically removed in another full-scale ABC, and in bench-scale and pilot-scale evaluations. Selenium, perchlorate, sulfate, metals and acidity have been treated successfully in ABC bench-scale column tests.

The ABC has lower capital and operating costs than alternative technologies for nitrate removal, including conventional biotreatment, ion exchange and reverse osmosis. The estimated installed cost for a 100-gpm system is $100,000 to $200,000; this cost will vary depending on the concentration of nitrate or other parameters to be removed. Operating costs (including operator labor, chemical reagents, electricity and maintenance) are typically $0.30 to $0.70 per 1000 gallons. Reagent costs are approximately 20 percent of this total.

The Anoxic Biotreatment Cell (ABC) process support building houses pumps, flowmeters, filters, valving, an on-line nitrogen analyzer and other controls.

Perchlorate Removal

The ABC process recently was evaluated in bench-scale tests for removal of nitrate and perchlorate (ClO_4^-) from groundwater. Located underneath an operating explosives plant, the groundwater contained approximately 280 mg/L of nitrate

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Outsourcing Avoids Capital Outlay

For industry, wastewater treatment and spent resource recovery are activities not typically associated with the core business. One company is helping industrial managers focus on manufacturing and production, relieving them from daily business disruptions, by offering its specialized services in wastewater and resource recovery.

"When operations managers outsource these responsibilities, it frees up human and capital resources from wastewater treatment responsibilities. Outsourcing is a way to remain up to date with the best technologies available," said Frank Craft, President of Mobile Process Technology.

sludge, maintaining equipment, and spending management time to run the wastewater operation.

Outsourced, state-of-the-art wastewater purification technologies and equipment can cost half as much as the problematic precipitation approach. Outsourcing may require roughly only 20 percent of the physical footprint. It reduces the risk of discharging wastewater with high levels of metals, and mini-

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(as N) and 40 mg/L of perchlorate.

Perchlorate is used as an oxidizer in solid missile and rocket fuel, in automobile air bag inflation systems, and may be present in lawn fertilizers in low concentrations. Perchlorate functions as an electron acceptor for a number of bacterial strains under anoxic conditions. Its removal was anticipated in the ABC along with nitrate.

Biological removal of nitrate and perchlorate was evaluated in two column tests operated in parallel, using acetic acid and molasses as the respective carbon sources. Denitrification was effective in both column tests.

Only the column test using molasses showed effective perchlorate removal. The influent contained 40 mg/L perchlorate and the effluent perchlorate level of <0.008 mg/L met the perchlorate standard of 0.018 mg/L.

Denitrification was effective in both column tests. Influent nitrate levels of 282 mg/L were reduced to < 0.05 mg/L, well below the standard discharge limit of 10 mg/L.

Nitrate Removal

Nitrate normally is present in minimeters from wastewater to meet discharge limits is often problematic and costly. Dissolved nitrate may be removed from water through the action of denitrifying bacteria, which convert nitrate to nitrogen gas. This action, called denitrification, can occur only in environments that are anaerobic (no oxygen) or anoxic (low oxygen concentration).

Traditional approaches to nitrate removal include biological treatment and physical/chemical processes. Wetlands or passive bioreactors are low-cost biological approaches but require a large amount of land and their effectiveness is often short-lived.

A production-scale ABC was designed by Hydrometrics, Inc. and the Stillwater Mining Company, and installed at the mine near Nye, MT. The design treatment objective for the production-scale ABC was 50 to 80 percent nitrate removal at a flow rate of 100 gallons per minute (gpm).

The system was sized to provide a hydraulic residence time of two hours (in contrast, wetlands or passive bioreactors are typically designed for a residence time of several days). Typical influent water contained 12 to 20 mg/L of nitrate (as N) at a temperature of approximately 10°C.

Typical daily results fom Stillwater ABC

Date	Flow	Influent			Effluent			% NO_3
	(gpm)	NO_3 (mg/L)	T (°C)	pH	NO_3 (mg/L)	T (°C)	pH	Removal
10/04/96	130	13.3	13.0	7.6	0.16	13.0	7.6	99
10/08/96	131	13.7	14.4	7.7	0.25	13.5	8.0	98
11/05/96	129	13.0	6.0	7.8	3.0	7.5	7.8	77
11/07/96	130	12.5	7.2	7.8	0.6	4.0	7.8	95
11/08/96	130	12.5	5.5	7.8	1.0	4.0	7.8	92

The system currently has a treatment capacity of 1100 gpm. According to Bruce Gilbert, environmental affairs manager for Stillwater Mining, they selected the system because it offers the advantages of low capital and operating costs; a relatively small footprint; minimal sludge generation; and flexibility in the use of either natural or artificial media.

A second Anoxic Biotreatment Cell was designed by Hydrometrics and constructed at an operating gold mine in South Dakota in 1997.

By February 1998, nitrate removal had increased to approximately 80 percent. The water at the gold mine initially contained approximately 110 mg/L of nitrate (as N); this reactor was designed for a six-hour residence time to remove the nitrate required. Both design objectives were met soon after start-up of the ABC.

Selenium Removal

Several conventional treatment technologies can be used for selenium removal—reverse osmosis, which produces a concentrated reject stream, and ion exchange, which produces a

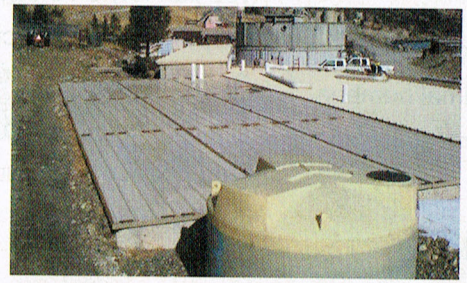
ing waters as a result of blasting activities using ammonium nitrate or dynamite. It also may be present in groundwater and surface water in agricultural areas from fertilizer use, or in municipal and industrial waste streams after the aerobic degradation of ammonia.

Removal of nitrate and other para-

Conventional bioreactors are fully engineered and effective, but are relatively costly. Physical/chemical methods such as reverse osmosis or ion exchange can be quite effective but have high capital and operating costs, and have the additional disadvantage of a waste stream.

The reactor was inoculated with bacteria from a municipal denitrification unit. A specialized psychrophilic (low-temperature) bacterial consortium developed naturally in the reactor and effectively removes nitrate at the low temperatures experienced at the site.

The ABC and its process support building were placed next to an existing clarifier, which removes suspended solids prior to the ABC and the ultimate discharge to existing infiltration ponds.



The full-scale Anoxic Biotreatment Cell (ABC) consistently has removed over 90 percent of the incoming nitrate and has a treatment capacity of 1100 gpm.

The table above shows nitrate removal rates for the system. The results show representative periods in October and November 1996, shortly after start-up. Flow rates during these two months averaged approximately 130 gpm.

The data for these two time periods correlate the system's nitrate removal efficiency with temperature. In November 1996, the temperature was significantly below the design tempera-

regeneration brine. Ferrous iron addition reduces dissolved selenium to elemental selenium, however, large amounts of iron must be added to remove even trace amounts of selenium.

In the ABC, bacteria reduce dissolved selenium to elemental selenium, resulting in a dense, low-volume precipitate. The same bacterial consortium that reduces nitrate also reduces selenium. Selenium removal is less efficient and requires longer hydraulic residence times than nitrate removal.

Groundwater from a large copper mine was treated in an ABC bench test (a continuous-flow column) in 1998. This water had a low nitrate concentration (less than 1.0 mg/L), with an initial selenium concentration of approximately 1.2 mg/L. Up to 97 percent of the selenium was removed with a six hour residence time. IWW

About the author: Mark Reinsel is a project engineer at Hydrometrics, Inc., a consulting firm headquartered in Helena, MT. He holds bachelor's and doctorate degrees in chemical engineering from Montana State University. Dr. Reinsel has 17 years of experience in manufacturing, research, consulting and teaching.