EPA United States Environmental Protection Agency

Site Technology Capsule

EcoMat Inc.'s Biological Denitrification Process

Abstract

EcoMat, Inc. of Hayward, California (EcoMat) has developed an *ex situ* anoxic biofilter biodenitrification (BDN) process. The process uses specific biocarriers and bacteria to treat nitrate-contaminated water and employs a patented reactor that retains biocarrier within the system, thus minimizing solids carryover. Methanol is added to the system as a carbon source for cell growth and for inducing metabolic processes that remove free oxygen and encourages the bacteria to consume nitrate. Methanol is also important to assure that the nitrate conversion results in the production of nitrogen gas rather than the intermediate (and more toxic) nitrite.

EcoMat's BDN and post-treatment systems were evaluated under the SITE Program at a former public water supply well in Bendena, Kansas. Nitrate concentrations in the well groundwater have historically been measured from approximately 20 to 130 ppm, well above the regulatory limit of 10 mg/l. Low concentrations of VOCs, particularly carbon tetrachloride (CCl_4), are a secondary problem. The overall goal of EcoMat (the developer) was to demonstrate the ability of their process to reduce the levels of nitrate in the groundwater and restore the well as a drinking water source.

The SITE demonstration occurred between May and December of 1999 and was conducted in cooperation with the Kansas Department of Health and Environment (KDHE). The study consisted of four separate sampling events over 7½ months. During these events EcoMat operated their system to flow between three and eight gallons per minute. During that same time period nitrate-Nitrogen (nitrate-N) concentrations in the well water varied from greater than 70 mg/l to approximately 30 mg/l.

Since the post-treatment system implemented by EcoMat varied for each of the four events, data from the four events were analyzed separately. Formal statistical analyses were used to address specific test objectives using a significance level of 0.10. Events 1 and 2 were found to be successful in meeting performance goals for significantly reducing levels of nitrate-N and nitrite-N after BDN and after post treatment. Events 3 and 4 were not shown to be successful in significantly reducing levels of nitrate-N and nitrite-N after BDN and after post treatment.

Dissolved oxygen (DO) measurements indicated that the deoxygenating step of EcoMat's BDN process was not optimized throughout the demonstration. The desired DO levels of < 1 mg/l following the deoxygenating step in the process were measured only during the first two events.

The effectiveness of the post-treatment systems was variable for different parameters. None of the post treatment system combinations used during the demonstration was effective in removing residual methanol to the demonstration objective of $\leq$ 1 mg/l. However, the increased level of filtration incorporated following the first two events appear to have had a substantial beneficial impact on solids carryover.

Introduction

In 1980, the U.S. Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund. The Act is committed to protecting human health and the environment from uncontrolled hazardous waste sites. In 1986, CERCLA was amended by the Superfund Amendments and Reauthorization Act (SARA). These amendments emphasize the achievement of long-term effectiveness and permanence of remedies at Superfund sites. SARA mandates the use of permanent solutions, alternative treatment technologies, or resource recovery technologies, to the maximum extent possible, to clean up hazardous waste sites.

State and federal agencies, as well as private parties, have for several years now been exploring the growing number of innovative technologies for treating hazardous wastes. The sites on the National Priorities List comprise a broad spectrum of physical, chemical, and environmental conditions requiring varying types of remediation. The U.S. Environmental Protection Agency (EPA) has focused on policy, technical, and informational issues related to exploring and applying new remediation technologies applicable to Superfund sites.

One such initiative is EPA's Superfund Innovative Technology Evaluation (SITE) program, which was established to accelerate the development, demonstration, and use of innovative technologies for site cleanups. EPA SITE Technology Capsules summarize the latest information available on selected innovative treatment, site remediation technologies, and related issues. These capsules are designed to help EPA remedial project managers and on-scene coordinators, contractors, and other site cleanup managers understand the types of data and site characteristics needed to evaluate effectively a technology's applicability for cleaning up Superfund sites.

This Capsule provides information on a specific type of biological denitrification process owned and implemented by EcoMat, Inc. (EcoMat) primarily to treat water contaminated with high levels of nitrate (e.g., > 20 mg/l). This capsule presents the following information:

- Abstract
- Technology description
- Technology applicability
- Technology limitations
- Process residuals
- Site requirements
- Performance data
- Technology status
- Sources of further information

Technology Description

EcoMat's process is a type of fixed film bioremediation in which specific biocarriers and bacteria are used to treat nitrate-contaminated water. Unique to EcoMat's process is a patented mixed reactor that retains the biocarrier within the system, thus minimizing solids carryover. A 50% aqueous methanol solution is added to the system as a source of carbon for cell growth and for inducing metabolic processes that remove free oxygen. The resulting anaerobic environment encourages the bacteria to consume nitrate. Methanol is also important to assure that conversion of nitrate proceeds to the production of nitrogen gas rather than terminating at the intermediate nitrite, which is considered to be more toxic.

The mechanism for anoxic biodegradation of nitrate consists of an initial reaction for removal of excess oxygen followed by two sequential denitrification reactions (expressed in the equations below). The subsequent discussion refers to nitrate- and nitrite-nitrogen values (nitrate-N and nitrite-N, respectively), in which each mg/l of nitrate-N is equivalent to 4.4 mg/l of nitrate and each mg/l of nitrite-N is equivalent to 3.2 mg/l of nitrite.

Oxygen Removal:

$$CH_3OH + 1.5O_2 \text{ -------> } CO_2 + 2H_2O \quad (1)$$

Denitrification Step 1:

$$CH_3OH + 3NO_3 \text{ -------> } 3NO_2 + CO_2 + 2H_2O \quad (2)$$

Denitrification Step 2:

$$CH_3OH + 2NO_2 \text{ -------> } N_2 + CO_2 + 2OH + H_2O \quad (3)$$

Overall Denitrification Reaction:

$$5CH_3OH + 6NO_3 \text{ -------> } 3N_2 + 5CO_2 + 6OH + 7H_2O \quad (4)$$

In the first step, available oxygen must be consumed to a dissolved oxygen (DO) concentration of < 1 mg/l. Then the bacteria are forced to substitute nitrate as the electron acceptor and the nitrate is reduced to nitrite (equation 2). In the third equation, nitrite is further reduced to nitrogen gas. Nitrite production is an intermediate step and there is no *a priori* reason to assume that the second reaction is at least as fast and/or favored as the first reaction in the presence of a specific bacterial population. Consequently, any evaluation scheme must establish that there is no buildup of nitrite, particularly since the nitrite-N maximum contaminant level (MCL) for drinking water sources is only 1 mg/l, one tenth that of nitrate-N. High concentrations of nitrate and high nitrate/methanol ratios may also affect the concentration of residual nitrite-N.

Figure 1 is a simplified process diagram of the EcoMat treatment system used during the demonstration. As illustrated, the system is comprised of two major components; a BDN component and a post-treatment or polishing component. The BDN component is intended to convert nitrates in the groundwater to nitrogen, thus reducing nitrate-N concentrations to acceptable levels. The post-treatment system is used for destroying or removing any trace organics and intermediate compounds potentially generated during the biological breakdown of nitrate, and removing small amounts of bacteria and suspended solids that are not attached to the biocarrier. The post-treatment system can also incorporate traditional methods for treating other contaminants, such as VOCs, that may be present in the influent.

Biodenitrification (BDN) is conducted in two reactors, identified as R1 and R2 on Figure 1. The majority of the oxygen removal step (Equation 1) occurs within R1, which EcoMat also refers to as the "Deoxygenating Tank." Inside R1 are bioballs (a standard type of biocarrier) which have been loaded with denitrifying bacteria purchased from a commercial vendor. These aerobic bacteria initially reduce DO levels of the contaminated influent. A 50 percent aqueous methanol solution is metered to the tank to encourage the bacteria to begin consuming nitrate in the resulting oxygen deficient water.

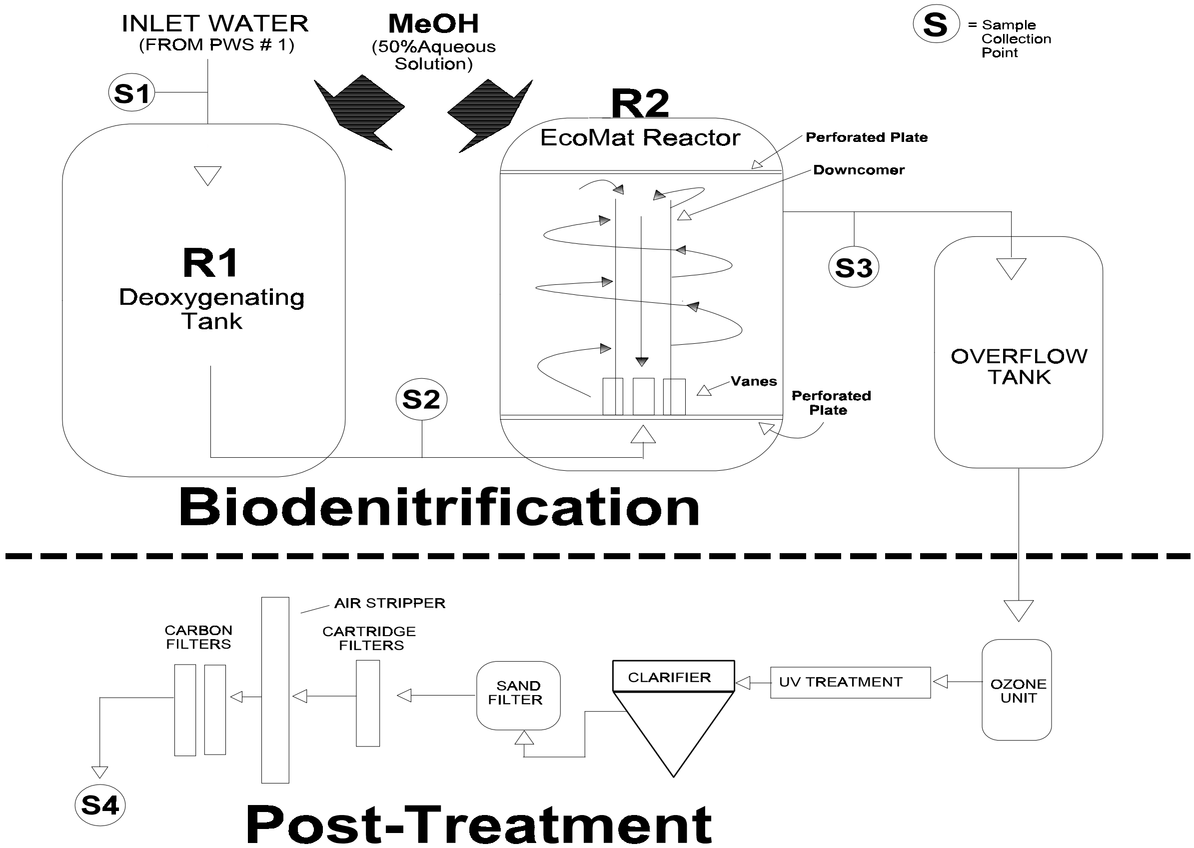

Figure 1. Biodenitrification and Post-Treatment Systems Flow Diagram**.**

The deoxygenated water is pumped from the bottom of R1 to the bottom of R2, referred to by the developer as "the EcoMat Reactor". R2 is densely packed with a synthetic polyurethane biocarrier called "EcoLink", which serve as the biocarrier for a colony of specialized bacteria cultured for degrading nitrate. The EcoLink media is in essence small cubes of sponge-like material, one centimeter on a side, that provide a large surface area for growing and sustaining an active bacteria colony. The cubes have contiguous holes so that bacteria can propagate within them and nitrogen gas can exit. A special additive to the polyurethane makes the surface more hospitable to the bacteria.

A specially designed mixing apparatus within R2 directs incoming water into a circular motion, which keeps the suspended media circulating and enables the water to have intimate contact with the media. Perforated plates within R2 retain the EcoLink biocarrier within the reactor, while permitting passage of the water. The specific gravity of EcoLink is slightly greater than that of water before nitrogen production starts. Within R2, the majority of denitrification (Equations 2 and 3) is conducted by the established anaerobic bacteria that are continually fed methanol as a carbon source. After a sufficient retention time the denitrified water drains by gravity to an overflow tank, which allows for a continuous and smooth transfer to the post-treatment system.

EcoMat's post-treatment system can be subdivided into two primary treatment parts: one part for oxidation and a second part for filtration. The oxidation treatment is intended to oxidize residual nitrite back to nitrate, oxidize any residual methanol, and destroy bacterial matter exiting the EcoMat Reactor (R2). The oxidation treatment may consist of ozonation or ultraviolet (UV) treatment, or a combination of both. Filtration usually consists of a clarifying tank and one or more filters designed to remove suspended solids generated from the BDN process. During the demonstration, a variety of filter combinations were used, including a sand filter and a series of variable-sized cartridge filters. The cartridge filters used included "rough filters" (20µm), "high efficiency filters" (5µm), and "polishing filters" (1µm). Carbon cartridge filters were also used on occasion for removing small amounts of CCl_4.

During the demonstration,EcoMat experimented with different levels and types of post-treatment. During Event 1 post-treatment consisted solely of chlorination without filtration. During Event 2, post-treatment consisted of an initial separation of suspended solids in a clarifying tank ("clarification"), followed by sand and cartridge filtration, and finally by UV oxidation. Event 3 post-treatment consisted initially of both ozone and UV oxidation, followed by clarification, rough filtration, high efficiency filtration, carbon adsorption, and polishing filtration. Event 4 post-treatment consisted of chlorination, clarification, high efficiency filtration, air stripping for removing VOCs, and finally, polishing filtration.

Technology Applicability

The EcoMat BDN process was evaluated based on nine criteria used for decision making in the Superfund feasibility study (FS) process. Results of the evaluation are summarized in Table 1.

The BDN process used during the demonstration was specifically targeted to the destruction/removal of nitrates in groundwater. However, the developer views the EcoMat reactor as an optimization vessel for growing different bacteria that can degrade different contaminants. Thus, the developer's process may have the potential to treat other contaminants, such as perchlorate.

Table 1. FS Criteria Evaluation for the EcoMat, Inc. Biological Denitrification Treatment Process

Criteria	Technology Performance
Overall Protection of Human Health and the Environment	Potentially provides protection of human health by reducing nitrate concentrations to below the regulatory drinking water standards. improvement of the overall mechanical operation of the process and improvement in the post-treatment portion of the process appear to be required for producing a more consistent treated effluent with respect to nitrate-N, nitrite-N, methanol, and solids concentrations.
Compliance with Federal ARARs	Requires compliance with RCRA and Safe Drinking Water Act treatment regulations. The post-treatment system appears to need refinement for attainment of certain drinking water criteria (e.g., turbidity).
Long-term Effectiveness and Performance	The technology is ex situ and is designed to treat nitrate-contaminated groundwater within a very short time period after the water is pumped from a well or holding tank. The areas of the country where this technology is most applicable are in agricultural regions where substantial amounts of fertilizers are used seasonally. Thus, the technology would not have a long term utility for the permanent restoration of an aquifer, but instead would be capable of supplying potable water from perennially degraded aquifers.
Reduction of Toxicity, Mobility, or Volume thru Treatment	Has the potential to reduce the toxicity of groundwater to an extent that would render the water a viable drinking source. Does not pertain to reduction in mobility of groundwater. If applied to wastewater, the technology has a significant potential for reducing the volume of wastewater that could potentially be released to the environment.
Short-term Effectiveness	The short-term effectiveness of the technology is immediate. The biologicval processes used to treat nitrate-contaminated waters have relatively short retention times. Presents minor short-term risks to workers from air releases of ozone (if used) during post-treatment process activities.
Implementation	Involves a testing or shakedown period. There is little to no environmental disturbance. Maintenance can delay or prolong implementation.
Cost	An estimated $.50-2.50/1,000 gallons (excluding profits) with groundwater contaminated with 20-40 mg/l nitrate, using a flow rate of 100-1,000 gpm, with an online factor of 95%, over a one year period. Actual costs of the remedial technology are site-specific and dependent on factors such as the local drinking water standards, the influent nitrate concentrations, the presence of other contaminants in the groundwater, the well recharge capacity, the level of post-treatment necessary, etc.
Community Acceptance	Presents minimal to not short term risk to community since all system components and treatment occur within a secured building (the only exception being an air stripper, if used). If an ozone generator is incorporated into the post-treatment system, monitoring for ozone emissions may be required. An air stripper, incorporated as a post-treatment system for VOCs, would be the only exterior treatment and air emission source. The equipment is relatively simple, easy to understand, and aesthetically acceptable to the public. There are minimal environmental disturbances. No appreciable noise is generated.
State Acceptance	State permits may be required if remediation is part of a RCRA corrective action. The permit may cover both the biodenitrification and post-treatment processes as a whole, or may be required for specific proceses along the treatment train (i.e., ozone, air stripping, etc.)

Technology Limitations

The presence of additional contaminants in the water, other than nitrate, can play a significant role in the effectiveness and viability of the overall treatment system. The post-treatment components that are required for treating these other contaminants can complicate the system and increase the potential for system irregularities.

Although the EcoMat BDN treatment system is designed to operate unattended, several problems were encountered during the demonstration which disrupted the system and led to system shutdown. Examples of the types of problems encountered included malfunctioning pressure switches used for controlling tank levels, clogging a perforated plate withintheEcoMat reactor, and air leaks in piping that allowed higher than desired DO levels in the bioreactor tanks. The post-treatment system also required excessive maintenance which necessitated shutting down the treatment system for short periods of time (i.e., flushing and/or replacement of fil ters to prevent microbial buildup, cleaning out of the clarifying tank, etc.).

Process Residuals

There are essentially little to no process residuals associated with the BDN component of EcoMat's process. The bioballs used in the Deoxygenating Tank are durable and can be reused indefinitely. The EcoLink biocarrier, used in the mixed reactor, is replaced only if they become overloaded to the point where they sink out of suspension. (During the demonstration, the EcoLink biocarrier was changed out once.) According to the developer, other treatment units have operated well over a year without the need for changing out the EcoLink biocarrier.

Process residuals associated with post-treatment were evaluated. For example, the clarifying tank generates sludge and the cartridge filters periodically need replacing. If carbon filtration is used for removing any VOCs from the water, the carbon ultimately needs to be disposed of.

Site Requirements

Depending on the size and location of the treatment system, a heated building may be required at a minimum to house the system components. At the Bendena site the entire EcoMat treatment system was contained inside a twelve foot wide, twenty foot long, and twelve foot high shed. This provided ample room for the Deoxygenating Tank and EcoMat Reactor (both of which were two cubic yards in size with a total water capacity of about 1,100 gallons), a small overflow tank, an ozone generator, UV system, sand filter, cartridge filters, and associated piping and pumps. The shed also provided work space and enough storage space for equipment and reagents.

The main utility requirement is electricity, which is used to operate the pumps and to provide heat during cold weather conditions. The system used at Bendena required between 5 and 10 kW of electricity. Other utilities that may be required include a telephone and facsimile hookup. If an on-line nitrate analyzer is utilized, a phone modem can be installed to access real-time data from a remote site.

Performance Data

The demonstration of the EcoMat BDN system was conducted from May until December of 1999 at the location of a former public water supply well in Bendena, Kansas. The study was conducted in cooperation with the Kansas Department of Health and Environment (KDHE), who provided for the construction of a small building and the necessary utilities (electric, heat, and telephone services) to house and operate EcoMat's systems. The KDHE also collected and analyzed water samples independent of the SITE Program.

The demonstration focused on treating contaminated water from the Bendena Rural Water District No. 2 Public Water Supply (PWS) Well # 1. This former railroad well, constructed in the early 1900s, was at one time the sole source of water for the town of Bendena. Nitrate is the primary contaminant. Nitrate-N levels in the well water have been historically measured at 20-130 ppm. Low levels of VOCs in the groundwater are a secondary problem. CCl_4 was the only VOC detected during 1998 pre-demonstration sampling, at concentrations ranging from 2-31 µg/l. During the demonstration, influent CCl_4 concentrations were too low to evaluate.

The central goal of EcoMat was to demonstrate that its system could produce water that would be in compliance with the drinking water MCLs for both nitrate-N and nitrite-N, and at the same time meet requirements for other parameters such as turbidity, pH, residual methanol, suspended solids, and biological material. With respect to both of their BDN and post-treatment components EcoMat proposed the following performance estimates:

I. With incoming groundwater from Well #1 having nitrate-N of 20 mg/l or greater, and operating at a flow rate of 3-15 gpm, the BDN unit would reduce the combined nitrate-N and nitrite-N to a combined concentration (total-N) of 10 mg/l or less.

II. The post treatment or polishing unit will produce treated groundwater that will meet applicable drinking water standards with respect to nitrate-N (<10 mg/l), nitrite-N(<1mg/l), and total-N (<10 mg/l).

III. Coupled with the planned or alternative post-treatment, the product water will consistently meet drinking water requirements, except for residual chlorine. Specifically it will not contain turbidity of greater than 1 NTU, detectable levels of methanol (1 mg/l), or increased levels of biological material or suspended solids, and will have a pH in the acceptable 6.5-8.5 range.

The first two performance estimates formed the basis for the statistically-based primary objective. The number of samples needed for each event was calculated based on assumptions about the variability of the final effluent. With the level of significance set at 0.10 (i.e., statistical decisions were made with 90% confidence), 29 samples were required for each sampling event. In actuality 28 were collected for Event 1, 31 for Event 2, and 30 each for Events 3 and 4. So the 28-31 samples collected during the four events satisfied the desired parameters for the hypothesis tests used for the demonstration.

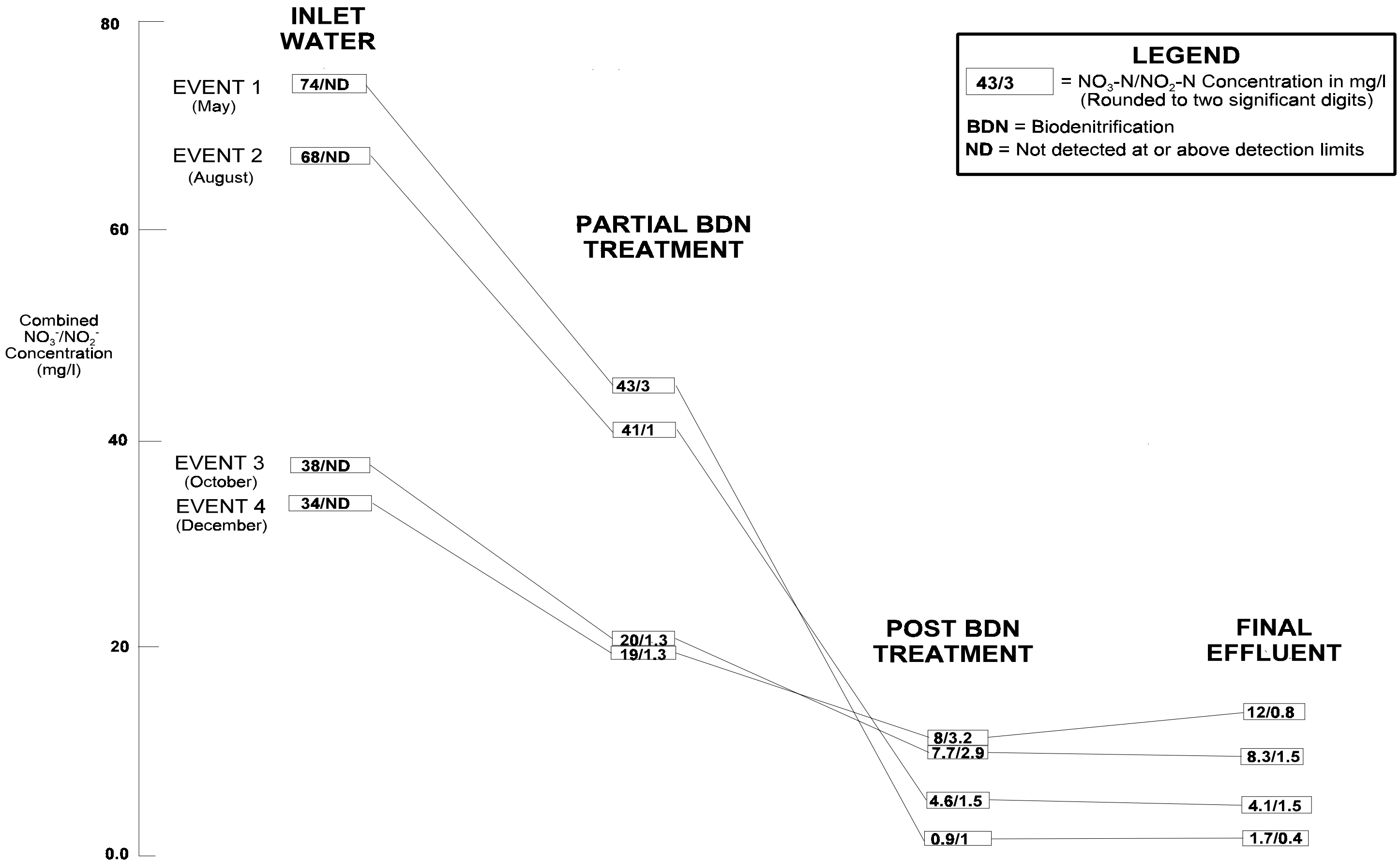

Figure 2. Treatment Effectiveness for Nitrate-N and Nitrite-N for Each Event.

For each test conducted during the four sampling events, water samples were collected from four specific sample taps along EcoMat's process (shown on Figure 1). These sample location points included the following:

1. An <u>untreated (**"Inlet Water"**) sample point</u> located between PWS Well # 1 and the Deoxygenating Tank (S1);

2. A <u>**"Partial BDN Treatment"**sample point</u> located between the Deoxygenating Tank and EcoMat Reactor (S2);

3. A <u>**"Post BDN"** sample point</u> located between the EcoMat Reactor and post-treatment system (S3);

4. A <u>**"Final Effluent"** sample point</u> located downstream of the post-treatment system (S4).

To qualitatively illustrate the relative performance of the four EcoMat sampling events, demonstration data were plotted on Figure 2. Each of the sampling events is graphed separately, with the four sample points represented on the x-axis. Values within the boxes are the average nitrate-N concentration and the average nitrite-N concentrations, presented as a data pair. These data pairs indicate how the process operated during the demonstration with respect to the simultaneous destruction of nitrate-N and production of nitrite-N. The plots also indicate the effectiveness of post-treatment for destruction of residual nitrite-N. Several interesting observations can be made from the inter-event comparison shown in Figure 2 by tracing the levels of nitrate-N and nitrite-N across the four sample points.

At the inlet water sample point, the levels of nitrate-N in the untreated inlet water from PWS Well # 1 were well in excess of the 10 mg/l MCL and the 20 mg/l threshold set for the demonstration for all four sampling events. At this point, the levels of nitrite-N are a For each test conducted during the four sampling events. At this point, the levels of nitrite-N are all reported as non-detects.

At the partial BDN treatment sample point, nitrate-N levels were reduced by a similar percentage (52-60%) for all four sampling events. However, small amounts of nitrite-N were being generated from the reduction of nitrate, causing nitrite-N levels to rise slightly as expected. (See the Technology Description section for technical discussion.) This pattern held for all four sampling events.

At the post BDN treatment sampling point, the nitrate-N levels were further reduced for all four sampling events. It is interesting to note, however, that at this point the nitrate-N levels for Events 1 and 2 fall below those for Events 3 and 4, even though they were higher at the beginning of the demonstration. The nitrite-N levels for all sampling events are generally higher here, as expected. At the final effluent sample point, the levels of nitrite-N remain essentially the same, while levels of nitrite-N are generally reduced.

Table 2 presents the summary statistics for the critical data, which is used to evaluate the effectiveness of EcoMat's BDN and post-treatment systems with respect to nitrate-N, nitrite-N, and total-N. To evaluate the post BDN and final effluent data against regulatory limits, the following analytical strategy was used. For each event separately, an Exploratory Data Analysis (EDA) was conducted for the post BDN total-N, the final effluent nitrate-N, the final effluent nitrite-N, and the final effluent total-N. The EDA consisted of graphing the data in several formats and calculating summary statistics. These graphs and summary statistics were used to make preliminary assumptions about the shape of the distributions of the variables (i.e., in order to identify possible appropriate statistical hypothesis tests for the data).

After reviewing the graphs and summary statistics, Shapiro-Wilk tests of Normality were performed. Based on the results of these tests, either the Wilcoxon Signed Rank test or the Student's t-test was chosen as the appropriate hypothesis test. The mean or median of the variable (depending on which hypothesis test was chosen) was evaluated against the appropriate demonstration criterion, which was the regulatory limit when rounded to a whole number. The post BDN total-N data was tested against the demonstration criterion of 10.5

Table 2. Summary Statistics for the Demonstration (mg/l).

CRITICAL MEASUREMENT				
Statistical Value	Post BDN Total-N	Final Effluent Nitrate-N	Final Effluent Nitrite-N	Final Effluent Total-N
Event 1				
Mean Median Std. Dev.	1.917 1.270 1.474	1.654 1.600 1.509	0.410 0.113 0.424	2.064 1.676 1.445
Statistical Hypothesis Tests Results	Part I: Post BDN mediun total-N of 1.27 mg/l was significantly below the criterion of 10.5 mg/l. Part II: Final Effluent met combined criterion. The median total-N of 1.68 mg/l is significantly below the criterion of 10.5 mg/l.			
Event 2				
Mean Median Std. Dev	6.145 4.600 3.781	4.132 2.220 4.237	1.459 1.200 1.155	5.590 3.610 4.898
Statistical Hypothesis Test Results	Part I: Post BDN mediun total-N of 4.60 mg/l was significantly below the criterion of 10.5 mg/l. Part II: Final Effluent met combined criterion. The median total-N of 3.61 mg/l is significantly below the criterion of 10.5 mg/l.			
Event 3				
Mean Median Std. Dev.	10.613 10.950 3.706	8.347 8.350 2.854	1.550 1.400 0.851	9.897 9.825 2.978
Statistical Hypothesis Test Results	Part I: Post BDN mediun total-Ndata, both the mean of 10.61 mg/l and the median of 10.95 mg/l were above the criterion of 10.5 mg/l. Thus, no statistical test was needed to determine that the Post BDN data did not meet the criterion. Part II: Final Effluent did not meet the combined criterion. since the nitrite-N mean was > 1.5 mg/l.			
Event 4				
Mean Median Std. Dev	11.197 10.550 5.079	10.63 11.750 5.023	0.870 0.076 1.523	11.993 12.076 5.324
Statistical Hypothesis Test Results	Part I: For the Post BDN total-N data, both the mean and mediuan were above 10 mg/l, so no statistical test was needed to determine that the Post BDN data did not meet the regulatory limit. Part II: Final Effluent did not meet combined criteria since both the nitrate-N mean and median was > 10.5 mg/l.			

mg/l, using an   error rate of 0.10. The results of this test are referenced on the line entitled “Part I” in Table 2.
The final effluent had to meet a 3-part criterion:

- The mean or median nitrate-N was tested against the demonstration criterion of 10.5 mg/l.
- The mean or median nitrite-N was tested against the demonstration criterion of 1.5 mg/l.
- The mean or median total-N was tested against the demonstration criterion of 10.5 mg/l.

All three of these criteria had to be met in order for the technology to be considered successful. Therefore, a family-wise error rate was set at 0.10 for these three tests. The results of this test are referenced on the line entitled “Part II” in Table 2.

As indicated in the “Statistical Hypothesis Test Results” rows of the Table 2 summary statistics, Events 1 and 2 were found to be successful in meeting performance goals for significantly reducing levels of nitrate-N and nitrite-N after BDN and after post treatment. However, Events 3 and 4 were not shown to be successful in significantly reducing levels of nitrate-N and nitrite-N after BDN and after post treatment.

Table 3 presents an overall summary of relevant criteria-oriented data collected for key parameters during the demonstration as averages per event. As shown, neither the carbon filtration employed during Event 3 nor the air stripping employed during Event 4 appears to have significantly impacted methanol levels in the final effluent (methanol was not detected above 1 mg/l in the untreated well water). Although total suspended solids and turbidity parameters improved to acceptable or near acceptable levels when filtration was employed, carryover of biological material from the EcoMat reactor to the final effluent remained considerable. The overall EcoMat process appears to have little impact on pH.

Technology Status

The treatment system operated at Bendena, Kansas is EcoMat’s first application of their BDN process to nitrate-con-

Table 3. Summary of Averaged Results for the EcoMat SITE Demonstration[1].

PARAMETER	CRITERION	SAMPLING EVENT			
		Event 1 (5/6-15)	Event 2 (8/3-12)	Event 3 (10/20-28)	Event 4 (12/7-14)
Process Parameters					
Flow (gpm)	3-15	3.0	3.5	4.2	6.2
Total Gallons Treated	--	42,000	45,000	49,000	61,000
DO in Partial BDN Effluent (mg/l)	--	1.1	1.0	2.1	2.8
Biodenitrification Parameters					
Nitrate-N (mg/l)	≤10	*1.7J*	**4.1**	**8.3**	11
Nitrite-N (mg/l)	≤1	*0.4*	1.5	1.5	0.8
Total-N (mg/l)[2]	≤10	*2.1*	**5.6**	**9.9**	12
Post-Treatment Parameters					
Post-Treatment System	--	Chlorination	Clarification Sand Filtration Rough Filtration UV Oxidation	Ozone UV Oxidation Clarification Rough filtration High EFF. Filtration Carbon Filtration Polishing Filtration	Chlorination Clarification High Eff. Filtration Air Stripping Polishing Filtration
Residual Methanol (mg/l)	≤1 mg/l	*15*	98	41	37
Turbidity (NTU)	≤1 NTU	4.4	1.8	1.2	*0.96*
Total Suspended Solids[3]	≤ inlet water	<5/10	*<5/<5*	*<5/<5*	*<5/<5*
pH Range (min-max)	6.5-8.5	7.5-8.6	7.6-8.4	*7.9-8.2*	6.8-8.9
Total Heterotrophs (% change)	≤ inlet water	+19,000	+18,000	+1,100	*+460*
Fac. Anaerobes (% change)	≤ inlet water	+7,300	+170,000	*+3,300*	+5,100
Fecal Coliform (% change)	≤ inlet water	NC	**-75**	*-91*	**-89**

[1]Values are averages that have been rounded to a maximum two significant digits. Values in italics are the best result of the four events. Bolded values are those meeting criteria on an average basis.
[2]Total-N is equal to the combined nitrate-N + nitrite-N concentration.
[3]Two values are presented for Total Suspended Solids, the first is for inlet water and the second is for final effluent.
NC - Not calculated (i.e., no growth in either inlet water of final effluent).
J = Estimated value.

taminated groundwater. Prior to this, their systems have been installed in-line with commercial size aquarium filtration systems for removing nitrate in saltwater.

EcoMat has indicated they also have the ability to cultivate different microbes in their mixed reactor to treat other types of inorganic pollutants. Recently, the company has designed and delivered a biological reactor to treat perchlorate at a DoD facility in California.

Sources of Further Information

An Innovative Technology Evaluation Report (ITER) for the EcoMat technology has been prepared in unison with this Capsule report. The ITER is anticipated to be available in the summer of 2003. The ITER provides more detailed information on the EcoMat technology, a categorical cost estimate, and a more thorough discussion of the SITE demonstration results.

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References

SAIC. May 2001. EcoMat Inc.'s Biological Denitrification Process. Draft Innovative Technology Evaluation Report.

SAIC. April 1999. Quality Assurance Project Plan for EcoMat Inc.'s Biological Denitrification and Removal of Carbon Tetrachloride at the Bendena Site, Doniphan County, Kansas.

Shapiro, JL., P. Hall, and R. Bean, "Ground Water Denitrification at a Kansas Well." Presented at the Technology Expo and International Symposium on Small Drinking Water and Wastewater Systems, Phoenix, Arizona, January, 2000.

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