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Wind Turbine Powers Ground-Water Circulation Well

Initial findings from a study conducted by the University of Missouri-Rolla (UMR) show that wind turbines provide technically effective and cost-efficient power for small remediation systems such as ground-water circulation wells (GCWs). Demonstration of this technology is underway at the former Nebraska Ordnance Plant Superfund site near Mead, NE. Analysis of data collected over the first five months of operation indicates that the technology is generating more energy than consumed by principal components of the GCW. The wind turbine operates in a utility grid "inter-tie" mode, whereby both utility and wind energy are used when wind energy is insufficient. When excess wind energy is produced, the surplus returns to the utility grid for other consumer use.

Data collected in 1995-1999 at a utility monitoring station near the demonstration site indicated an average wind speed of 6.4 m/s, a wind shear exponent of 0.27, and a turbulence intensity of 0.17-0.21. Performance modeling using these data indicated that a single 10-kW turbine installed on a 100-foot tower would meet the treatment system's anticipated energy demand. The turbine was installed in December 2003 (Figure 1) and connected to the facility's existing electrical power system the following month for preliminary testing.

The demonstration employs a 10-kW wind turbine system providing energy to power a single GCW. The well is equipped with an air stripper to remove trichloroethene (TCE) present in ground water at concentrations averaging 2,500 µg/L [see October 2001 issue of *Ground Water Currents*, available at www.cluin.org]. The site is underlain by an unconfined and relatively prolific sand and gravel aquifer with a saturated thickness of approximately 90 feet.

The treatment system includes a 12-inch, 108-foot deep circulation well with two hydraulically isolated screened intervals separated by a 19-foot unscreened interval. The well operates at an average flow rate of 50 gpm on a continuous basis, with the exception of occasional but temporary shutdowns. Primary electrical machinery of the system consists of a 1.5-hp submersible pump that extracts water from the aquifer and delivers it to a 5-hp air stripper, and a 1-hp centrifugal pump that returns treated water from the stripper sump to the well. Historical data for the GCW, which has operated since July 2000, show little correlation between the amount of purchased energy and the volume of treated ground water. This is a result of environmental control systems used to keep the principal GCW components from overheating in the summer or freezing in the winter.

Over the initial five months of the study, the average monthly electricity demand by principal components of the GCW was 767 kW-hr. On average, 817 kW-hr of electricity were generated by the wind turbine each month. More than 4 million gallons of water were treated by the system and an estimated 63 kg of TCE were removed from ground water during the same time period.

Data analysis shows that the treatment system is removing approximately 21 mg of TCE per kW-hr of energy generated by the turbine. Researchers estimate that the use of wind power, coupled with a well-designed climate control system, may result in a present-worth energy cost savings of more than $40,000 over the 20

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CLU-IN Resources

The Federal Remediation Technologies Roundtable (FRTR) is an interagency collaboration for actively sharing information on hazardous waste site clean-up technologies and the remediation marketplace. Updates on FRTR activities and recent publications issued by its member agencies are continuously added to the FRTR web site (http://www.frtr.gov). Currently, online access is available for 361 technology cost and performance reports, 144 site characterization and monitoring case studies, 73 remediation process optimization case studies, and 54 remediation technology assessment reports.

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years of ground-water treatment anticipated at this site.

Similarly sized off-grid wind turbine systems, including installation, cost approximately $45,000. The cost effectiveness of wind-powered remediation technology is expected to be higher in remote areas where installation of utility lines would incur additional expenses, on the order of $5,000-$10,000. Beneficial use of this technology is enhanced by its reliance on renewable resources, rather than non-renewable fossil fuel, and the absence of air emissions during deployment.

UMR researchers determined that the technology is applicable to areas with Class 3 or more wind resources, as classified by the U.S. Department of Energy scale of 1-7. Class 3 wind power density is defined as 150-200 W/m^2 at a height of 10 m and mean wind speeds of 5.1-5.6 m/s. Other limiting application factors may include the proximity of trees and buildings that could reduce effective wind speed at a turbine, and sensitive land use areas where sound generated by the rotating turbine blades may be intrusive.

Figure 1. *The 10-kW wind turbine system erected at the former Nebraska Ordnance Plant is possibly the technology's "first-ever" application for remediation purposes.*

This project was funded by the U.S. EPA's Office of Solid Waste and Emergency Response through its Innovation Work Group grant program, with additional support from UMR, the Kansas City District Corps of Engineers, Bergey Wind Systems, and Ohio Semitronics. Potential follow-on work involves operation of the GCW intermittently using a stand-alone wind turbine system that uses batteries to store energy for use during periods of low or no wind.

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EPA/ORD and Region 8 Evaluate In-Situ Treatment of Acidic Mine Pit Lake

Over the past three years, the Anchor Hill Pit at the Gilt Edge Mine NPL site near Deadwood, SD, has been the site of a joint effort by EPA's Region 8 Superfund Remedial Program and the Office of Research and Development's Mine Waste Technology Program (through an interagency agreement with the U.S. DOE). The project aimed to demonstrate and evaluate an innovative in-situ process for treating approximately 70 million gallons of acidic mine water containing high levels of dissolved metals, selenium, nitrate, and sulfate. EPA estimates that in-situ use of this technology avoided 20-50% of the operational costs associated with a conventional water treatment plant. Full-scale use is anticipated to help meet state standards for discharge of treated water to surface water.

The first step of this treatment process involved neutralizing the pit water to a pH of approximately 7. Neutralization was achieved by dispersing lime through a Neutra-Mill, a floating slaker similar to equipment commonly used to mix and disperse reagents at water treatment plants. The second step was to add nutrients such as methanol, feed-grade molasses, and phosphoric acid to the pit using Redox-Mediated Biotransformation (RMB™) technology. This process stimulated indigenous bacterial activity that electrochemically reduced nitrate to nitrogen gas and subsequently reduced selenium and sulfate. Reduction of sulfate to sulfide decreased dissolved-phase metal concentrations through formation of metal sulfide precipitates. The stability of metal sulfides that settled to the bottom of the pit was maintained in a permanent anoxic zone.

Neutralization of the pit occurred between March and May 2001. After several weeks of stabilization, four nutrient additions were made at 5- to 6-month intervals. Sodium hydroxide was included in the last two additions to address an unanticipated but significant reduction in pH (from 7 to 5) during the post-neutralization stabilization period.

Bacterial growth during redox treatment proceeded more slowly than expected due to below-optimum pH conditions at the process onset. Incorporation of wood chips in the final nutrient addition in September 2002 provided a successful substrate for increased bacterial growth. Raising the pH level also helped reduce the amount of dissolved aluminum in solution, which apparently inhibited denitrifying bacteria.

Nitrate concentrations continued to decrease through the winter of 2002-2003, with nondetectable levels observed by March 2003. Efforts were undertaken at that time to expedite sulfate reduction. Strings of porous bags filled with wood chips were suspended throughout the pit water column. In addition, porous bags of wood chips were placed on the

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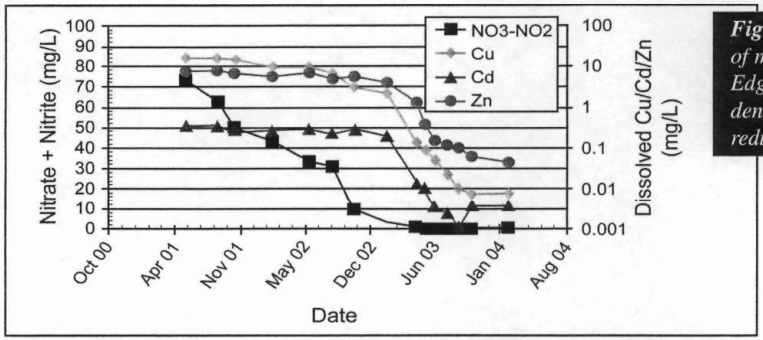

Figure 2. *Dissolved-phase concentrations of metals in acid mine water at the Gilt Edge Mine fell more than 99% following denitrification with the onset of sulfate reduction.*

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ice surface and allowed to sink to the bottom upon melting. Consideration was also given to developing an inoculum of sulfate-reducing bacteria in adjacent tanks. During installation of the porous bags of wood chips, however, observation of black precipitates and a slight hydrogen sulfide odor suggested that sulfate reduction had slowly begun prior to these efforts.

Chemical analysis confirmed sulfate reduction in the pit and significantly decreased concentrations of dissolved-phase metals in the treated water (Figure 2). Treatment effectively reduced dissolved-phase concentrations of copper from 43.3 to 0.008 mg/L, cadmium from 14.1 to 0. 0.003 mg/L, and zinc from 14.1 to 0.044 mg/L. Similarly, concentrations of selenium decreased from 26 to 12 mg/L, nitrate/nitrite dropped from 82.9 to 0.4 mg/L, and sulfate dropped from 3,270 to 2,175 mg/L. An alkalinity increase to approximately 400 mg/L in the deeper water provided indirect evidence that biological nitrate and sulfate reduction had occurred. Monitoring of the pit over the past year indicated continued, slow settling of the suspended metal sulfides.

Recent efforts have focused on transitioning to an operational mode involving possible use of the pit to treat acid mine water across the entire Gilt Edge site. Over the course of treatment, the pit lake has become permanently stratified whereby a strong density gradient (or "chemocline") at a depth of approximately 25-30 feet separates the upper layer from the lower layer. Acid rock drainage will be added with nutrients to the pit at depths below the chemocline, where the water column is expected to maintain anoxic conditions. Following treatment, water below the chemocline will be removed from the pit, filtered, and aerated to meet state ambient water quality requirements for discharge to surface water.

Modifications to this technology are required prior to beginning the operational mode. Fine suspended metal sulfide precipitates in the deep-pit water, for example, require improved methods for filtering. Similarly, improved methods are needed for aerating filtered water, which contained fine particles of elemental sulfur due to oxidation of excess dissolved sulfide. High concentrations of dissolved hydrogen sulfide in the deep water also will need resolution to ensure no health and safety issues exist during aeration. Future plans include development of a real-time monitoring system in the pit for continuous observation of water column hydrodynamics and geochemistry, particularly when feeding contaminated water to the deep portion of the pit.

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Defining a NAPL Source Zone Using Field Data

EPA's Region 1 and Office of Research and Development (ORD) are working with a group of PRPs to address dense nonaqueous phase liquid (DNAPL) at the Solvents Recovery Services (SRS) site in Southington, CT. Differences between the conceptual site models (CSMs) developed by the two organizations prompted an intensive field program in November 2003 to delineate the DNAPL source zone and refine the estimated volume of overburden contaminated with DNAPL. Earlier evaluations, which potentially supported a technical impracticability (TI) waiver based on drinking water standards, estimated that more than 200,000 yd^3 of DNAPL-contaminated soil existed in addition to 800,000 yd^3 of residual DNAPL zones in the overburden aquifer. Based on the results of a follow-on field investigation, however, the combined volume of residual and pooled DNAPL-contaminated overburden to be evaluated for treatment is now estimated at 45,000 yd^3.

Between 1955 and 1991, 60-100 million gallons of spent solvents were processed on a 4-acre parcel at the SRS site. Liquid waste was brought to the site in steel drums and tank trucks, and other wastes were managed in aboveground tanks. Still bottoms and sludge were placed in two unlined lagoons that occasionally overflowed and discharged into the nearby Quinnipiac River via an unlined drainage ditch. A 12-acre ground-water contaminant

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plume is present in the overburden, which consists of 15-50 feet of fluvio-glacial sediment and till. A slightly larger plume exists within the underlying fractured bedrock–a thickly-bedded, red, arkosic Triassic sandstone. The plume in the overburden ground water has affected two municipal water supply wells located 1,300 and 2,000 feet south of the site.

The initial estimate of 200,000 yd^3 was based on the visual observation of DNAPL, historical records, and indirect indicators, such as ground-water samples exceeding 1% of the DNAPL's effective solubility. The field program assessed whether a ground-water sample containing 10% of the effective solubility indicated that a DNAPL residual or free-phase mass was immediately upgradient or just "somewhere" upgradient.

The field program involved advancing 39 borings over a one-week period. Two direct-push rigs ran continuous cores to the point of refusal, which was commonly at the top of bedrock or till. Refusal was encountered about 15 feet below ground surface on the west side of the site, becoming progressively deeper (30-35 feet) to the east.

DNAPL was judged to be present in a core if it was directly observed or if a hydrophobic dye indicated its presence in soil samples. The plastic liners of each core were cut in half lengthwise, visually inspected, and screened with a photoinonization detector (PID). If the PID reading in any part of the core exceeded 100 ppm, the core was tested in a 40-mL vial containing equal portions of soil, water, and hydrophobic dye. The formation of a red "collar" around the top of the vial after vigorous shaking indicated the presence of residual DNAPL in soil.

DNAPL was not observed in areas where previously its presence was implied only by indirect indicators such as dissolved-phase concentrations. Data collected during the field program were integrated into an updated CSM that now reflects a much smaller source zone (Figure 3). Based on the results of this field investigation, which was estimated to cost less than $100K, a TI waiver for cleanup in the overburden is no longer probable.

Updates to the CSM will continue as remedial alternatives for the overburden are evaluated and implemented. A feasibility study is underway to evaluate the use of bioremediation, enhanced bioremediation, thermal treatment, chemical oxidation, and hydraulic flooding in treating the overburden. Pilot testing of phytotechnology began in 2002 with the planting of poplar trees.

A pump and treat system is in place to address contamination in the bedrock. In addition, the potential for natural attenuation is being evaluated through analysis of native microbial (*Dehalococcoides*) populations in Geoprobe® soil samples. Additional field tests will be conducted to evaluate the extent of DNAPL contamination in bedrock and to support any associated determination regarding a TI waiver.

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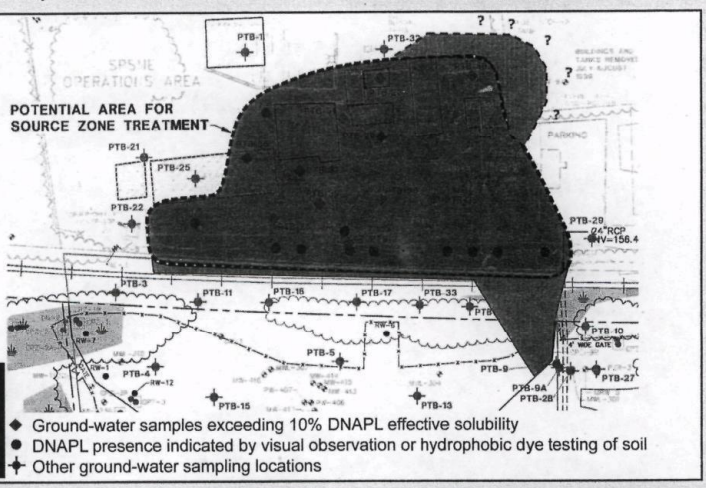

Figure 3. *Based on the results of field tests, EPA now estimates that 45,000 yd^3 of DNAPL-contaminated overburden at the SRS site require remediation.*

Superfund Document Management System Used in Columbia Space Shuttle Recovery

On February 1, 2003, the STS-107 space shuttle Columbia, traveling over 200,000 feet in altitude, broke apart over central Texas and eastern Louisiana. Response to the accident was shared by the U.S. Federal Emergency Management Agency (FEMA), the National Aeronautics and Space Administration (NASA), and EPA, which was given authority to run field recovery operations. EPA's Region 6 coordinated the effort, using in large part the Superfund Document Management System (SDMS) already employed by headquarters and regional offices.

Field work immediately began with four-member crews walking at arm's length to survey the ground for any material related to the crash. Vegetation at that time of year was relatively bare, but eastern Texas pine

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forests and western Louisiana swamps and lakes complicated the task. As spring approached, increasing vegetation, venomous snakes, insects, and wild havilina hogs added additional problems during the search and recovery work. Over 10,000 volunteers representing or supplementing more than 90 organizations, including EPA, the Texas Forest Service, and the U.S. Forest Service, joined the task of canvassing a debris field the size of West Virginia.

Each search team carried into the field a hand-held personal digital assistant (PDA) computer with pre-loaded data forms, a digital camera, and a geographic information system (GIS) transponder. When anything appearing to be related to the shuttle was found, the GIS position was documented on a PDA form. Digital photographs of the item were taken and other descriptive data were noted in the PDA.

Precautions were taken with each item of evidence. Worker protection was a concern due to the presence of hydrazine, a highly toxic rocket propellant coating much of the debris. Each item or container was affixed an identification tag and transferred to a collection facility where NASA and the Federal Aviation Administration worked to reconstruct a layout of the shuttle. Each evening as the search crews returned to one of five established field stations, the PDAs were placed in a bank of cradles and linked to a set of GIS servers. PDA data were transferred to an existing emergency-response computer application that was up-scaled to collate the large volume of information coming from the field. Debris points were plotted onto maps of the search areas and used by EPA's on-scene coordinators to plan the next day's search activities.

Region 6 information management personnel worked with emergency response staff to develop methods for documenting the diverse data produced in the field. Within one week of the accident, a commercially-developed mobile unit prototype called "SUREAIM" was delivered to a Lufkin, TX, command post to capture records. Contractors trained in its use and in Region 6 electronic records operations also arrived within days. In order to use minimal amounts of paper documentation, SUREAIM employed a paper scanning component, a high-speed workstation, and remote access software (AAA virtual private network extranet tokens under pilot in Region 6).

SUREAIM records typically were converted in the field to Adobe PDF files and transferred daily through the Agency firewall to a Region 6 automated Domino workflow tool called "ExpressLink." Key metadata were assigned to forms and associated documents and saved in ExpressLink, which triggered placement of the information in the SDMS.

Two years earlier Region 6 had re-engineered the client-server SDMS into a fully web-based form known as SDMS2 in order to receive electronic records and to provide a more textured information management environment for Superfund staff, records managers, and support contractors. The major procedural innovation made possible by SDMS2, in tandem with the PDA forms, was to move records management from a relatively passive "receipt of records" mode to one in which remediation staff was involved in the early lifecycle of data. This allowed record providers to immediately transmit items to the records program, while retaining unlimited access, and provided multiple parties joint and simultaneous record access.

During the high-pressure shuttle recovery, the ability of field staff to drop records off at the SUREAIM station with knowledge that the information would be rapidly processed and available for on-demand access was a great benefit. EPA currently is considering creation of documentation teams that could perform the same functions in emergency response centers and field settings. GIS data management during the recovery involved conversion of map layers to scalable vector graphics and export of a searchable database (with linked photos and documents) into a new SDMS2 component.

Subsequent assessment of the field recovery indicated that 99% of the documentation was captured at or just after lifecycle creation. It also was determined that field contractors had successful access to site-specific information and offsite discussions regularly. The effort demonstrated that records can be transformed from relatively restricted documentation of past events into front-line decision-making tools.

EPA concluded its field operations in May 2003, less than four months after the accident, with significantly more of the spacecraft recovered than expected. Within two weeks of closing the field stations, full documentation of the events was available in SDMS2 (with no paper backlog), and a hard drive containing the records was provided to NASA soon thereafter. SDMS2 and other tools used for the shuttle recovery have since emerged in Region 6 as instruments applicable to more routine field operations. With more than 50 million pages of national Superfund records, management of SDMS2 was transferred to EPA headquarters early this year.

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EPA/ORD/NRMRL Publishes Study on MNA Performance

EPA's ORD/National Risk Management Research Laboratory (NRMRL) recently completed a study on the performance monitoring of remedies that rely on natural attenuation of contaminants. The study's results are now available in the April 2004 report entitled *Performance Monitoring of MNA Remedies for VOCs in Ground Water*. As part of this effort, NRMRL developed technical recommendations regarding the types of monitoring parameters and analyses that are useful for evaluating monitored natural attenuation (MNA) during the design and implementation of MNA plans. NRMRL found that effective monitoring system designs need to be based on a thorough understanding of the migration and ultimate fate of contaminants in site-specific environments.

The study found that an effective monitoring program includes routine evaluations of institutional controls and measurements of contaminant, geochemical, and hydrologic parameters. These data are used to evaluate changes in three-dimensional plume boundaries, contaminant mass and concentration, and hydrological and geochemical changes that may indicate changes in remedy performance.

Continuation of an MNA program is appropriate when contaminant concentrations behave according to remedial expectations, and ground-water flow and geochemical parameters remain within acceptable ranges. Program modifications may include increases or decreases in monitoring parameters, frequency, or locations to reflect changing conditions or an improved understanding of natural attenuation processes at a site. Implementation of a contingency or alternative remedy may be triggered by:

- Increasing contaminant concentrations or unexpected trends;
- Contaminant migration beyond the established plume or compliance boundaries;
- Insufficient rates of contaminant reductions;
- Land or ground-water use changes with the potential to reduce protectiveness of the remedy; or
- Unacceptable risks to receptors.

The complete publication (EPA 600/R-04/027) is available online from CLU-IN at http://www.cluin.org/pub1.cfm.

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