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The Technical Support Times is an online newsletter highlighting EPA's field activities, research, and new documents on current topics. This issue is the fourth in a series of periodic publications from the Hazardous Substances Technical Liaison (HSTL) program and is available on the intranet at http://intranet.epa.gov/ospintra/scienceportal/.

Brian Caruso, HSTL for Region 8, compiled this article from various EPA resources.

FOCUS ON: MINE WASTE CHARACTERIZATION AND REMEDIATION

Mine waste and acid mine drainage (AMD) associated with operational and historic abandoned hardrock metal mines are significant environmental problems in many regions of the United States, particularly in the western part of the country, as well as world-wide. Problems include waste rock and tailings left in place; erosion of these materials; AMD and other mining-influenced waters; increased loads of acidity, metals, and solids to streams; discharges to groundwater; exceedances of water quality standards; toxicity to humans and aquatic and terrestrial biota; and other ecological and socioeconomic impacts. EPA and many other organizations recognize the scope of the problem and have been taking steps to address these issues. A range or EPA programs address these problems, including Superfund, Brownfields through the Mine-Scarred Lands initiative, the Clean Water Act, National Environmental Policy Act, and other abandoned mine lands and watershed programs.

Several recent high-profile studies and reports highlight the significant issues associated with mine waste problems in the United States. As part of its evaluation of Superfund mega-sites (sites that may cost $50 million or more to clean

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up) in 2004, the EPA Office of Inspector General identified and evaluated hardrock mining sites across the nation, including financial impacts (*Nationwide Identification of Hardrock Mining Sites* — http://www.epa.gov/oig/reports/2004/20040331-2004-p-00005.pdf). The report identified 156 sites nationwide that have the potential to cost between $7 and $24 billion to clean up, and recommended continued evaluation of promising new remediation technologies as well as prioritizing clean-up efforts. In addition, the Toxics Release Inventory has identified the metal mining industry as the largest toxic polluter in the country with almost 50% of the total released by U.S. industry. A 2005 EPA-sponsored National Academy of Sciences (NAS) study and report entitled *Superfund and Mining Megasites: Lessons from the Coeur d'Alene River Basin* (http://www.epa.gov/superfund/reports/coeur.htm) found that application of models would have benefited from greater collection and use of additional site-specific information. The report also concluded that there was significant uncertainty associated with metal contaminant sources and the effectiveness and long-term environmental protection of the selected remedial actions, particularly those associated with groundwater and sediment from flood events.

EPA recognizes that inorganic metals and metal compounds, from mine waste as well as many other sources, present unique issues and the added challenge of addressing the complexity of these issues in a consistent manner across the Agency's programs. The recent *Framework for Inorganic Metals Risk Assessment (External Review Draft)* (http://cfpub2.epa.gov/ncea/raf/recordisplay.cfm?deid=88903) reflects an EPA effort to develop cross-Agency internal guidance for assessing metals. The primary goals of the framework are to outline key metal-specific scientific principles and consistent approaches for conducting metals risk assessment, based on the best currently available science.

The Office of Research and Development (ORD), in partnership with the regions, Office of Solid Waste and Emergency Response (OSWER), Office of Superfund Remediation and Technology Innovation (OSRTI), and many other organizations, is taking a lead role in performing applied research on these issues and providing the technical support and sound science and technology needed to help solve these problems. ORD and the technical support centers are working on a wide range of projects involving mine waste characterization and remediation using innovative technologies and providing site-specific technical support to the regions.

CHARACTERIZATION

Metals fate and transport modeling is needed for characterization, as well as remedial planning and design, in mining-impacted watersheds. Due to complex biogeochemical processes, however, modeling metals can be difficult and there are few models in use capable of modeling metals fate and transport incorporating the most important processes. The EPA Water Quality Analysis Simulation Program (WASP7) can be used for relatively simple metals modeling, while WASP in conjunction with the Metals Transformation and Assessment (META4) model (also developed by EPA) can be used for more complex modeling. The U.S. Geological Survey (USGS) One-Dimensional Transport with Equilibrium Chemistry (OTEQ) model has been used more widely for metals in recent years, and EPA funded Colorado State University and the Rocky Mountain Regional Hazardous Substances Research Center (RMRHSRC) to develop an advanced watershed contaminant transport model (Two-Dimensional Runoff with Erosion and Export [TREX]) that has been used for metals associated with sediment. An EPA Council on Regulatory Environmental Modeling (CREM) Region 8 seminar on *Metals Fate and Transport Modeling for Contaminated Sites and Mercury TMDLs*, focusing on using WASP

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CASE STUDY NUMBER 1

Modeling Effects of Natural Flow Restoration on Metals Fate and Transport in the Upper Tenmile Creek Mining Area Superfund Site, Montana

ORD's HSTL in Region 8, Dr. Brian Caruso, provided technical support to the region on a mine waste site by modeling the effects of natural flow restoration on metals fate and transport at the Upper Tenmile Creek Mining Area Superfund Site in the Rimini Mining District, southwest of Helena, Montana. This watershed consists of abandoned and inactive hard rock mines that produced gold, lead, zinc, and copper from before 1870 through the 1920s. The watershed is the primary municipal drinking water supply for the City of Helena, and has more than 150 mines with tailings, waste rock, and draining adits. Although the Record of Decision (ROD) has been completed and some priority remedial actions implemented, additional alternatives involving restoration of natural flows in Tenmile Creek are being evaluated. A WASP model was developed and used for steady-state conditions based on simple metals modeling using the equilibrium partitioning approach and a June 2000 data set for calibration under baseflow conditions. Total and dissolved arsenic, cadmium, copper, lead, and zinc were originally modeled in the mainstem to help evaluate and select eight remedial alternatives and whether Applicable or Relevant and Appropriate Requirements (ARARs) could be met. An improved model now is being used to evaluate metals under both natural low-flow conditions in August and high flows/snowmelt in June. Because so much flow is diverted by the city for water supply during these months, natural flow estimates were provided by the USGS. Modeling has shown that under natural low-flow conditions most metals loads and concentrations decrease, but some still may not meet ARARs due to continuing sources and relatively high concentrations or loads in some tributaries and from nonpoint groundwater sources. Under high flows, some metals such as Cd and Zn become diluted and are reduced to near ARARs. Other metals that are more highly adsorbed to sediment, such as Cu and Pb, can be mobilized with increased loads and concentrations if no further remediation is implemented. A dynamic version of the model may be developed in the future to provide more detailed estimates of metals fate and transport under high-flow conditions. ■

REMEDIATION

Remediation of mine waste sites across the country, many of which are Superfund and/or mega-sites, requires good site characterization, careful planning, and sometimes tens or hundreds of millions of dollars for effective clean up and perpetual treatment of AMD using conventional lime or soda ash plants. There is a great need for innovative and effective semi-passive treatment technologies that can help reduce costs and reliance on perpetual treatment. The National Risk Management Research Laboratory's (NRMRL) Mine Waste Technology Program is investigating and testing many innovative remediation technologies, and has annual funding opportunities for innovative technology research projects. NRMRL's Engineering Technical Support Center (ETSC) also has been providing support to the regions on a wide range of mine waste innovative remediation technology projects throughout the United States. One of the most prominent semi-passive technologies for acid rock drainage (ARD) is the use of sulfate-reducing bacteria bioreactors (SRBs) for precipitation of metal sulfides and subsequent settling out of solution. The ETSC has been a leader in developing this technology, and has implemented successful demonstrations in several regions. The ETSC also is studying the microbiological aspects of these bioreactors, working with researchers at the Colorado School of Mines, Colorado State University, and the RMRHSRC to understand issues regarding what makes them fail, the rate limiting reactions inside the cells, how to make them smaller and more efficient, etc. Dr. Brian Caruso, ORD's Region 8 HSTL, has been working with the ETSC and researchers with the RMRHSRC to evaluate current and future best practices for design and operation of these innovative technologies, including the following two case studies. ■

CASE STUDY NUMBER 2

Sulfate-Reducing Bacteria Bioreactor – Upper Tenmile Creek Mining Area and Basin Mining Area Superfund Sites, Montana

The ETSC has been testing compost reactors and a combination geochemical serpentine bioreactor with pre- and post-treatment wetlands at the Upper Tenmile Creek Mining Area Superfund Site. In 1991, the site Remedial Project Manager (RPM) contacted the ETSC requesting assistance for the consideration of passive treatment. After a meeting and site visits by ETSC staff and contracted experts, two areas of the site were selected for testing. Both areas are above 7,800 feet in elevation, have no electric power and are difficult to access between November and June. The first area is Peerless Jenny King Mine, and ETSC staff assisted by their contractor, Golder Associates, and the site contractor, Envirocon, constructed the wetlands and bioreactor in September 2002. The unique design can handle flows up to approximately 50 gallons per minute of AMD water with a pH greater than 5. The system still is functioning going into Fisical Year 2006, and meeting EPA and State of Montana water quality standards. The system is totally passive, requiring no power and almost no maintenance.

The second area in the adjacent Basin Mining Area Superfund Site is the Luttrell Repository, which was the old mine pit. This is a 1,000,000 cubic yard joint repository designed to accept mine wastes from both government and private landowners in the region. A leachate collection system was constructed so that when the repository was filled and capped, the leachate would be sent to the geochemical bioreactor for treatment and then discharged. The ETSC has been testing the bioreactor and collecting data for 2 years, and will continue this into the future. The results have been exceptional, with the discharge from the reactor meeting most, but not all standards. Because the system is new, improvement is expected over time. There also is strong collaboration with the U.S. Forest Service and Bureau of Land Management, the primary land owners in the watersheds.

FIGURE 1. Sulfate-reducing bioreactor at the Luttrell Repository at the Basin Mining Area Superfund Site, Montana.

CHARACTERIZATION

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and META4 for mine waste issues, was presented in May 2005 by experts from ORD and the National Exposure Research Laboratory (NERL) Watershed and Water Quality Technical Support Center. The seminar was well received by a national audience of EPA and state model users. The Engineering Technical Support Center (ETSC) has been working on validating the WASP/META4 model for new water quality data sets and to aid in remedial planning at the Clear Creek/Central City Superfund Site near Denver, Colorado. In conjunction with modeling, innovative characterization of mine site surface and subsurface hydrology and metals transport using tracer/isotope studies is being performed in several mountain watersheds by EPA Region 8 and ORD in collaboration with the USGS and the University of Colorado. The NRMRL Site Characterization and Groundwater Technical Support Centers also provide support to a number of regions on monitoring and quantitative evaluation of metals from mine waste in surface and ground water, sediment, and soils.

CASE STUDY NUMBER 3

Sulfate-Reducing Bacteria Bioreactor – Leviathan Mine Superfund Site, California

The ETSC joined with the Superfund Innovative Technology Evaluation (SITE) Program to test some of these SRB technologies at the Leviathan Mine Superfund Site in California. This is an abandoned open-pit sulfur mine high on the eastern slope of the Sierra Nevada, 24 miles southeast of Lake Tahoe in Alpine County. The mine has been contaminating mountain streams draining to Nevada about 5 miles from the mine and entering the picturesque Carson Valley 9 miles downstream from the mine. The Toiyabe National Forest surrounds the site, and there are no permanent residents within several miles. Although there had been some mining activities for copper minerals since the 1860s, major environmental problems originated during the open-pit sulfur mining that occurred from 1951 through 1962. During this period, Anaconda used Leviathan Mine as a source of sulfur to dissolve copper from relatively low-grade ore at a mine near Yerington, Nevada. In 1962, Anaconda ceased operations and sold the property to a local interest. No significant mining activities have taken place since. By 1997, the Washoe Tribe of Nevada and California asked EPA to get involved to fully address the contamination from the mine. Local governments in California and Nevada also voiced their support for intervention. After a number of voluntary measures in 1997 and 1998 proved inadequate, the Leviathan Mine was listed on the National Priorities List (NPL) in 2000.

There has been significant progress during the last 3 years in implementation of several treatment approaches. An innovative two-phase (biphasic) lime treatment developed by the State of California with the University of California–Davis has been very successful in eliminating the worst acid discharge, capturing millions of gallons throughout the year and treating it during the summer months. Atlantic Richfield, the successor to Anaconda, is capturing and neutralizing most of the remaining AMD. So far, this system has only operated during the summer months. The full-scale biological treatment system designed by the University of Nevada–Reno with help from the ETSC has gained international attention for its remarkable success in treating one of the seeps year-round, and has been expanded and re-designed with the aid of ETSC staff. The bioreactor is compost-free and uses alcohol to feed the bacteria, thus getting the moniker "bugs on booze." In addition, EPA researchers tested a series of new mine treatment technologies (e.g., recycling treatment water to reduce chemical use) at the Leviathan Site. During the summers of 2001, 2002, and 2003, the water quality of Leviathan and Bryant Creeks made remarkable improvements while the treatment systems were operating. In addition to careful monitoring of the treatment system operations, critical environmental data have been gathered to help characterize the site, including streamflow, water quality, sediment chemistry, meteorological data, and stream biological measurements. These field-scale tests will provide the data needed to design long-term water remediation plans.

FIGURE 2. Compost-free "bugs on booze" sulfate-reducing bioreactor at the Leviathan Mine Superfund Site, California.

AVAILABLE RESOURCES

Publications

EPA National Hardrock Mining Framework (http://www.epa.gov/superfund/programs/aml/policy/hardrock.pdf)

EPA Abandoned Mine Site Characterization and Cleanup Handbook (http://www.epa.gov/superfund/resources/remedy/pdf/amscch.pdf)

EPA Framework for Inorganic Metals Risk Assessment (External Review Draft) (http://cfpub2.epa.gov/ncea/raf/recordisplay.cfm?deid=88903)

EPA Office of Inspector General Nationwide Identification of Hardrock Mining Sites (http://www.epa.gov/oig/reports/2004/20040331-2004-p-00005.pdf)

National Academy of Sciences Report on Superfund and Mining Megasites: Lessons from the Coeur d'Alene River Basin, 2005 (http://www.epa.gov/superfund/reports/coeur.htm)

Online Links

EPA Mine Waste Technology Program
http://www.epa.gov/ORD/NRMRL/std/mtb/mwt/index.html

EPA Abandoned Mine Lands
http://www.epa.gov/super-fund/programs/aml/

EPA Region 8 Mining
http://www.epa.gov/region8/land_waste/mining/mining.html

International Network for Acid Prevention
http://www.inap.com.au/

The Acid Drainage Technology Initiative (ADTI) Metal Mining Initiative
http://www.unr.edu/mines/adti/

Enviromine
http://www.infomine.com/technology/enviromine

USGS Toxic Substances Hydrology Program, Hard-Rock Mining Contamination
http://www.epa.gov/region8/land_waste/mining/mining.html

Conferences/Workshops

An Abandoned Mine Lands Treatment Workshop sponsored by EPA ORD and OSRTI was held in May 2005 in Denver, Colorado. This workshop featured more than 100 invited participants discussing innovative AMD treatment and related technology development and application throughout the United States and overseas. This was the first in a series of planned EPA workshops on special issues, with the next two being planned for 2007.

The next International Conference on Acid Rock Drainage (ICARD 7) will be hosted by the Society for Mining, Metallurgy, and Exploration (SME). It will take place in St. Louis, Missouri in conjunction with the SME annual meeting March 27-30, 2006. The ICARD is the largest international acid drainage event and is held every 3 years. More information about ICARD 7 will be provided when it becomes available at http://www.inap.com.au/Icard7.htm, but information also can be obtained from the SME Website at http://www.smenet.org/meetings/AnnualMeeting2006/index.cfm.

ORD and OSRTI also are planning the third in a series of national conferences on environmental issues associated with hardrock mining—Hardrock Mining 2006. This conference will focus on sustainability issues and will be held in Tucson, Arizona in November 2006. A call for papers was issued recently and can be found at http://www.epa.gov/hardrock-mining/hardrock/hardrock2006.htm.

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