# APPENDIX L

# MINE WASTE TECHNOLOGY PROGRAM

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# Appendix L
# Mine Waste Technology Program (MWTP)

## *L.1 Introduction*

The purpose of this appendix is to provide the user with information and contacts for the Mine Waste Technology Program (MWTP). This program was created to provide engineering solutions to national environmental issues resulting from the past practices of mining and smelting of metallic ores. The MWTP has developed and implemented a program that emphasizes treatment technology development, testing and evaluation at bench- and pilot-scale, and an education program emphasizing training and technology transfer. Evaluation of the treatment technologies focuses on reducing the mobility, toxicity, and volume of waste; implementability; short- and long-term effectiveness; protection of human health and the environment; community acceptance; and cost reduction.

This program was formed through an interagency agreement between the United States Environmental Protection Agency (EPA) and the Department of Energy (DOE). The program is being implemented by MSE Technology Applications, Inc. (MSE) of Butte, Montana. Montana Tech of the University of Montana (Montana Tech) also located in Butte, Montana, currently provides analytical and computer support to MSE.

## *L.2 Information Management*

As part of MWTP, Montana Tech is documenting mine waste technical issues and innovative treatment technologies. These issues and technologies are then screened and prioritized in categories related to a specific mine waste problem. Technical issues of primary interests are:

Mobile toxic constituents in water, including acid generation issues;
Mobile toxic constituents in air;
Cyanide;
Nitrate;
Arsenic; and
Pyrite.

Waste forms related to these issues include point- and nonpoint-source acid drainage, abandoned mine acid drainage, stream-side tailings, impounded tailings, priority soils, and heap leach-cyanide/acid tailings.

In conjunction with the data collection, Montana Tech has prepared a generic quality assurance project plan that provides specific instructions on how data will be gathered, analyzed, and reported for all activities of the MWTP. Features of both the EPA and DOE quality requirements are incorporated into this plan. Project-specific quality assurance project plans are developed by MSE; in addition, MSE provides oversight for all quality assurance activities performed by Montana Tech.

## *L.3 Demonstration Projects*

As of 1996, MSE had undertaken seven pilot-scale demonstrations of innovative technologies for remediation of mining waste. Brief descriptions of six of the seven pilot projects follow this introduction; Project 6, the Pollution Magnet project, was dropped from the MWTP for reasons related to its similarity with competing technologies that were more developed and had a use that was non-mining-specific. The demonstrations were chosen after a thorough investigation of the technical issue is performed, the specific waste form to be tested is identified, and a sound engineering and cost determination of the innovative technology is formulated.

In addition to the pilot scale programs conducted by MSE, Montana Tech is conducting bench- or small pilot-scale research on several innovative techniques that show promise for cost-effective remediation of mine waste. One major criteria for these projects is the potential for scaling to demonstration pilot plants. One example, the Berkeley Pit Innovative Technologies Project, was initiated to focus on bench-scale testing of remediation technologies to help assist in defining alternative remediation strategies for EPA's future cleanup objectives for the Berkeley Pit waters. The Berkeley Pit is an inactive, open-pit copper mine that has been filling with acidic water since pump dewatering of adjacent underground mines ceased in 1982.

### *Project 1: Remote Mine Site Demonstration*

EPA asked MSE to develop a treatment facility to treat acidic metal-laden water. Due to the remote nature of some mine sites, this facility must operate for extended periods of time on water power alone, without operator assistance.

An example of a remote mine site with a point-source aqueous discharge is the Crystal Mine. Located seven miles north of Basin, Montana, the Crystal Mine was an ideal site for this demonstration. In addition, the site has been identified by the Montana State Water Quality Bureau as a significant contributor of both acid and metal pollution to Uncle Sam Creek, Cataract Creek, and the Boulder River.

The Remote Site Demonstration Project at the Crystal Mine was to be conducted in the field for a minimum of 1 year under all weather conditions. Acid mine drainage from the lower portal of the Crystal Mine began passing through the system on a full-time basis in early September 1994. Initial analytical data from the project showed a greater than 90% removal of toxic metals from the mine drainage. The system was operated and data was collected for 2 years.

### *Project 2: Clay-Based Grouting Demonstration*

Surface and groundwater inflow into underground mine workings becomes a significant environmental problem when water contacts sulfide ores, forming acid drainage. Clay-based grouting has the ability to reduce or eliminate water inflow into mine workings by establishing an impervious clay curtain in the formation. Groundwater flow is the movement of water through fissures and cracks or intergranular spaces in the earth. With proper application, grout can inhibit or eliminate this flow. Grouting is accomplished by injecting fine-grained slurries or solutions into underground pathways where they form a groundwater barrier. The Ukrainian clay-based grouting technology was selected for testing and evaluation because it offered a potentially long-term solution to acid mine drainage problems.

The project was finalized at the Mike Horse Mine near Lincoln, Montana. This site was selected because of its geologic characteristics. A major factor in the selection was an identified point-source inflow from Mike Horse Creek into the mine causing acid drainage that could potentially be controlled using a grouting technology. Grout injection began September 20, 1994, and was completed November 1, 1994.

Approximately 1,600 cubic yards of grout were injected during the initial phase. A second phase of grout injection was planned for the summer of 1995; however, high water damned up within the mine caused extensive damage to the mine and to the monitoring stations for the demonstration. As a result, Phase Two was discontinued.

### *Project 3: Sulfate-Reducing Bacteria Demonstration*

Acid generation typically accompanies sulfide-related mining activities and is a widespread problem. Acid is produced chemically, through pyritic mineral oxidation, and biologically, through bacterial metabolism. This project focuses on a source-control technology that has the potential to retard or prevent acid generation at affected mine sites. Biological sulfate reduction is being demonstrated at an abandoned hard-rock mine site where acid production is occurring with associated metal mobility.

For aqueous waste, the biological process is generally limited to the reduction of dissolved sulfate to hydrogen sulfide and the concomitant oxidation of organic nutrients to bicarbonate. The particular group of bacteria chosen for this demonstration, sulfate-reducing bacteria (SRB), require a reducing environment and cannot tolerate aerobic conditions for extended periods. These bacteria require a simple organic nutrient.

At the acid-generating mine site chosen for the technology demonstration, the Lilly/Orphan Boy Mine near Elliston, Montana, the aqueous waste contained in the shaft is being treated by using the mine as an in situ reactor. An organic nutrient comprised mainly of cow manure was added to promote growth of the organisms. This technology will also act as a source control by slowing or reversing acid production. Biological sulfate reduction is an anaerobic process that will reduce the quantity of dissolved oxygen in the mine water and increase the pH, thereby slowing or stopping acid production.

The shaft of the Lilly/Orphan Boy Mine was developed to a depth of 250 feet and is flooded to the 74-foot level. Acid mine water historically discharged from the portal associated with this level. Pilot-scale work at the Western Environmental Technology Office (WETO) in Butte was performed in 1994. The objective of these tests was to determine how well bacterial sulfate reduction lowers the concentration of metals in mine water at the shaft temperature (8°C) and pH (3.0).

During 1996, the field demonstration was again monitored on a regular basis. The data generally demonstrated a decrease in metals concentrations. An increase in metals was observed during spring runoff; however, the levels decreased when flow rates returned to normal. Monitoring of the field demonstration will continue for an additional year.

### *Project 4: Nitrate Removal Demonstration*

The presence of nitrates in water can have detrimental effects on human health and the environment. As a result, regulatory agencies have limited the allowable concentration of nitrates in effluent water. Nitrates may be present in mine discharge water as a result of the following mining activities: residuals from ammonium nitrate and fuel oil (ANFO) used in blasting; cyanide breakdown from leaching; and leaching of ANFO contamination from waste rock. To comply with Federal and State water quality standards, mining companies have typically used ion exchange or reverse osmosis to remove nitrates from discharge water. Both, however, are expensive and generate a concentrated wastestream requiring disposal.

Of the 20 technologies screened, the following 3 showed the most promise in making nitrate removal more cost effective and environmentally responsible: ion exchange with nitrate-selective resin; biological denitrification; and electrochemical ion exchange (EIX).

The best solution to the nitrate problem may be some combination of the three technologies that balances capital costs with operating costs, reliability, and minimization of wastestreams requiring disposal. Each combination has advantages and disadvantages that will be addressed during the project. A test process train was developed that is flexible and optimizes equipment capital while acquiring value-added test data. The demonstration included the following innovative technologies: ion exchange combined with biological denitrification for destruction of the concentrated brine; ion exchange combined with EIX for destruction of the concentrated brine; biological denitrification as a stand-alone process; and EIX as a stand-alone process.

The Nitrate Removal Demonstration Project was conducted at the TVX Mineral Hill Mine near Gardiner, Montana, where a building to house the equipment was constructed. Conventional ion exchange was used to remove nitrates from the mine water and produce a concentrated brine for additional testing. Biological denitrification units and an EIX unit were used to process both mine water and concentrated nitrate brine. Of all the technology combinations tested, biological denitrification of concentrated nitrate brine was the most successful at meeting these goals.

Biological denitrification was performed on both mine water and concentrated brine. This removal rate met the project goals and was typically greater than 99%. Biological denitrification of the raw mine was less successful. A removal rate of approximately 50% was typically achieved.

Electrochemical ion exchange was able to remove nitrate from the raw mine water more effectively than from the brine. Nitrate was removed at first, however, fouling of the resin by dirty water occurred quickly and the process was rendered ineffective after one batch. Filters were installed to alleviate the problem, but the size and nature of the particles made filtration difficult.

### *Project 5: Biocyanide Demonstration*

The primary use of cyanide in the mining industry is to extract precious metals from ores, and the use of cyanide has expanded in recent years due to increased recovery of gold using heap leach technologies. Most processes use chemicals to oxidize the cyanide and produce nontoxic levels of carbon dioxide and nitrogen compounds. These are relatively expensive to operate.

Biological destruction of cyanide compounds is a natural process that occurs in soils and dilute solutions. To take advantage of this natural destruction, a strain of bacteria was isolated by researchers at Pintail Systems, Inc. The bacteria has been tested on cyanide-contaminated mine waters and has shown degradation rates of over 50% in 15 minutes. The main goal of this project is to use a strain of bacteria to destroy cyanide associated with precious metal mining operations. Another project goal is to develop a reactor design that will best use the cyanide-degrading effects of the bacteria to destroy cyanide from mining wastewater.

The field demonstration portion of the project is located at the Echo Bay McCoy/Cove Mine, southwest of Battle Mountain, Nevada. The mining rate at the mine exceeds 160,000 tons of ore per day. Milling of high-grade and sulfide ores occurs simultaneously with the cyanide solution heap leaching of lower grade ores.

Actual cyanide mine water was processed through the reactors to study the kinetics of cyanide degradation. The results from the tests were then used to design the pilot-scale reactors to be used at the mine. The final process train consists of tanks where both aerobic and anaerobic cyanide-degrading organisms are grown in large quantities. The bacteria are then pumped to the reactors for reinoculation. The cyanide solution enters the aerobic first where aerobic organisms degrade a large portion of the cyanide. The solution then moves through a series of anaerobic units for further degradation. Finally, an aerobic polishing step removes the last traces. Since cyanide is known to degrade by mechanisms other than biological, a series of control reactors was installed to run concurrently with the biological reactors.

### *Project 6: Arsenic Oxidation*

The Arsenic Oxidation Project was proposed to demonstrate and evaluate arsenic oxidation and removal technologies. The technology being demonstrated during this project was developed jointly by the Cooperative Research Center for Waste Management and Pollution Control Limited (CRC-WMPC) and the Australian Nuclear Science & Technology Organization (ANSTO) from Lucas Heights, New South Wales, Australia.

Arsenic contamination in water is often a by-product of mining and the extraction of metals such as copper, gold, lead, zinc, silver, and nickel. In most cases, it is not economical to recover the arsenic contained in process streams because there is little demand worldwide for arsenic.

The small-scale pilot project demonstrated a two-step process for removing arsenic from contaminated mine water. The first step and primary objective of this project was to evaluate the effectiveness of a photochemical oxidation process to convert dissolved arsenic(III) to arsenic(V) using dissolved oxygen as the oxidant. The technology provides a method for the oxidation of arsenic(III) in solution by supplying an oxidant, such as air or oxygen, and a nontoxic photo-absorber, which is capable of absorbing photons and increasing the rate of arsenic(III) oxidation to the solution. The photo-absorber used is economical and readily available. Ultraviolet oxidation using high-pressure mercury lamps and solar energy was tested. The second step of this project resulted in the removal of arsenic(V) from the solution by using an accepted EPA method, adsorption using ferric iron.

The photochemical oxidation process was very effective at oxidating arsenite to arsenate at optimum conditions in the batch mode for both the solar tests and the photoreactor tests. Design problems with the photoreactor unit in the continuous mode, however, would not allow ANSTO to achieve their claim of 90% oxidation of arsenite in solution. Channeling of the process waters in the photoreactor unit was the reason for poor oxidation of arsenite, and steps

to correct the problem during the field demonstration were unsuccessful. Modifications to the baffle system are necessary to prevent further channeling.

For further information on any of these demonstration projects, contact:

MSE TECHNOLOGY APPLICATIONS, INC.
200 Technology Way
P.O. Box 4078
Butte, MT 59702
(406)494-7268
E-mail: mseta@buttenet.com