2005 National Abandoned Mine Land Reclamation Award Nomination

Linden Acid Mine Drainage Bioremediation System
Village of Mineral City
Rose Township, Carroll County, Ohio

Submitted on:	March 1, 2005
Submitted by:	Ohio Department of Natural Resources Division of Mineral Resources Management Abandoned Mine Land Program 1855 Fountain Square Court Columbus, OH 43224 614-265-6633
Construction dates:	Commenced August 15, 2002 and completed June 6, 2003.
Project Construction Cost:	$321,619.11
Inoculation Cost:	$96,000.00
Total Cost:	$417,619.11
Design and Construction Oversight by:	Ohio Department of Natural Resources Division of Mineral Resources Management Mike Sponsler, Chief Abandoned Mine Land Program Nancy Seger, PE James B. Gue, Environmental Specialist Cheryl Socotch, Hydrologist
Additional Design Assistance:	U. S. Department of the Interior Office of Surface Mining Louis Uranowski, PE Ray Mates, PE
Construction Contractors:	Tucson Excavating Inc. JH Water Systems, Inc. Gor-Con Concrete, Inc.
Bioremediation Consultant:	Allegheny Mineral Abatement, Inc.

Linden Acid Mine Drainage Bioremediation System

I. PROJECT PURPOSE

Ohio's Huff Run watershed has been adversely impacted by surface and underground coal and clay mining. The Linden site, located in the upper reaches of the watershed, includes mine-impacted discharges from a Lower Kittanning (#5) underground coal & clay mine, and other drainage associated with several acres of open pit impoundments and eroding spoil.

The Linden AMD Bioremediation Project is an experimental passive treatment alternative with potential for low maintenance, high metals reduction and the generation of alkalinity. The system consists of a large limestone-filled bed that has been inoculated with microorganisms cultured using the Pyrolusite® Process, developed by the Allegheny Mineral Abatement Company (AMA). This patented process uses highly selected groups of aerobic microorganisms that grow on limestone while oxidizing iron and manganese into insoluble metal oxides. Although similar Pyrolusite® treatment beds have been developed in Pennsylvania, Maryland, and West Virginia, the Linden Treatment Bed is the first of its kind in Ohio.

The process of passive manganese removal lacks understanding and consensus among the scientific community, and disputes exist related to the cause of performance problems found in some earlier projects. Previous systems were developed without the use of detailed project designs. The Ohio Department of Natural Resources and the Office of Surface Mining successfully cooperated in completing the first detailed design of its kind, including modifications to address previous failures.

The contractor, Tucson, Inc. of New Philadelphia, Ohio, performed exceptionally well in achieving construction goals while recommending and implementing beneficial changes. The contractor also provided extremely competent project supervision and work crew.

The system includes features that allow monitoring of each system component. Design criteria, project plans and specifications, and all aspects of construction are thoroughly documented. The Linden project provides the scientific community an opportunity for researching system performance while studying the underlying processes of passive manganese removal.

By generating alkalinity and decreasing metals loadings the system also aids in returning Huff Run to the Ohio Environmental Protection Agency designated aquatic life classification of warm water habitat.

II. BIOREMEDIATION

The bioremediation process consists of several separate but inter-related systems. Mine drainage passes sequentially through a flow control system, a wetland, to reduce metals concentrations and provide microbial nutrients, and finally through an inoculated

limestone treatment bed and/or attendant discharge structures and diversion ditches, before being discharged to a receiving stream. A bioremediation system utilizing the "Pyrolusite® Process" was selected.

The Allegheny Mineral Abatement Company (AMA) developed the Pyrolusite® treatment process. This process uses specific, cultured microorganisms that oxidize manganese and iron into their insoluble metal oxides in a limestone treatment bed. Although the system was initially designed for the removal of manganese (Mn) in mine contaminated waters, it proved effective in removing moderate levels of other metals, including iron. Manganese removal is extremely difficult and costly, as manganese does not precipitate as readily as iron and other metals. Alkaline additions (e.g. limestone) are helpful in raising pH, but aeration and oxidation are essential in the precipitation of manganese hydroxides (Rose, et al, 2003). The pH levels must be raised above pH of 9 to initiate manganese precipitation.

In the Pyrolusite® process, a flooded bed of limestone fragments is inoculated with specifically cultured microorganisms. These aerobic microbes oxidize iron and manganese in the water that is in contact with the limestone bed and yield alkalinity by etching the limestone that serves as a host for the organisms (Vail and Riley, 1997; 2000). In most systems, a small wetland is located up gradient of the treatment bed to provide nutrients for the microorganisms.

Data from systems installed in Pennsylvania revealed problems with several of the Pyrolusite® treatment beds. Many of those systems had greater flows than anticipated, higher concentrations of iron which caused plugging of the limestone bed, accumulation of debris and other materials in the system, ponding of water on the surface, and general problems with influent and outlet levels in the beds. Comments from the PADEP were strongly considered in the design of the Linden system to avoid some of the more recent problems experienced in several of their Pyrolusite ® systems (Milavec, 2000: Rose, et al, 2003).

The Pyrolusite® limestone treatment system seems well suited for treating moderate mine drainage at this site. The system should prove relatively low in maintenance, and provides alkalinity to the upper reaches of the watershed. The Linden site is the first application of the Pyrolusite® bioremediation process in Ohio.

III. SYSTEM DESIGN

An intensive twelve-month sampling investigation preceded the actual design start-up. This twelve-month period, including both chemical analyses and flow measurements, reflect seasonal variations. Ideally, AMA suggests that systems be designed based on peak flow, rather than average flow (Vail and Riley, 2000). The maximum peak flow was not used for design purposes due to limited available funds and massive land requirements. Design was instead based on the second highest recorded flow of 168 GPM. Flows greater than the design rate are diverted through a flow control structure to adjacent diversion ditches.

Flow Control Structure
Controlling inflow to the system was the first consideration of the design process. Disturbing the water filled pit and manipulating the entry could create serious flow problems. To prevent these problems, the area immediately surrounding the discharge would not be disturbed in any way. The discharge would need to pass through a flow control structure in order to ensure that only the design discharge of 168 GPM would flow into the treatment system.

Primary outflow is through a triangular sharp-crested V-notch weir made of ¼ inch thick plate of 304L stainless steel. AMD flows exceeding the design discharge overflow through a rectangular weir set at the east side of the box spillway. The rectangular weir is four feet in width and two foot deep. Flows through the rectangular weir will discharge to the east diversion channel in order to be routed around the treatment system. The flow control structure includes 15 cubic yards (CY) of concrete and 1,243 pounds of rebar.

Wetland
The Pyrolusite® process consists of select aerobic organisms that use dissolved oxygen to oxidize metals as their source of energy (Rose, et al, 2003). The purpose of the wetland in this treatment system is to add nutrients through the generation of dissolved organic matter to feed the inoculated microorganisms. The wetland system also adds alkalinity and oxygen to the system and removes some metals prior to inflow to the treatment bed. The wetland cell also collects silt, leaves and other organic matter, which have caused plugging problems in other systems.

Allegheny Mineral Abatement (AMA) recommends that the surface area of the wetland should be approximately 10% of the limestone treatment bed volume. The Linden treatment bed volume was 104,748 cubic feet, requiring a wetland of only 10,475 square feet. The overall footprint of the wetland was designed to be approximately 11,475 square feet. The proposed water depth for the wetland was 0.5 feet.

The wetland discharges to the treatment bed through a riffler channel composed of ODOT Type “D” rock channel protection over filter fabric. A minimum elevation difference from the wetland to the treatment bed of three feet was used to ensure that the discharge would aerate in the channel.

Treatment bed
The approximate recommended detention time recommended by AMA is two days (48 hours). In order to maximize detention time within the treatment bed and to limit the possibility of dead space, baffles were included. The overall bed was divided into five (5) cells.

Also incorporated are AMA recommends that a liner be utilized to allow for proper microbial development, and to increase the likelihood that the bed will remain wet during extended periods of dry weather. The liner system was installed, seamed and field tested on-site.

The initial cell (cell #1), which receives the highest metal loading, was filled with No. 1 stone (3 ½ to 1 ½ inch sieve opening) to provide greater void space and prevent clogging. The remaining cells were filled with smaller No. 57 stone (1 to ¼ inch sieve opening) to maximize limestone surface area exposure. All limestone used in the treatment bed was required to have a minimum calcium carbonate equivalency of 87%.

Since it was anticipated that cell #1 would receive the highest quantity of metal precipitation it was constructed with an underdrain system to facilitate removal of precipitated metals and prevent clogging, ponding and/or short-circuiting within the system. These problems have affected similar systems in Pennsylvania and Maryland, where regular excavation has been required to break-up clogged and/or cemented limestone.

Microorganisms to be used in the limestone treatment bed were selected and cultured by AMA based on water samples collected from the mine discharge at an earlier date. Inoculation ports for the liquid bacteria cultures were placed in the center of all the cells except the first cell. These ports were also designed to allow sampling from each cell to allow system evaluation.

System evaluation was enhanced by the addition of a large 60-degree trapezoidal flume. The flume, manufactured by Tracom, Inc., was installed at the limestone bed outlet channel.

IV. CONSTRUCTION

The engineer's estimate for the Linden AMD Bioremediation project was $313,590. The low bid received for the project was $257,629.10, which was awarded on July 30, 2002 to Tucson, Inc. of New Philadelphia, Ohio.

All construction requirements were met on June 6th 2003 at a final cost of $321,619.11. Under a separate contract Allegheny Mineral Abatement inoculated the bed on the same date at a cost of an additional $96,000.

V. PROJECT BENEFITS

Although several AMD bioremediation systems have been constructed, detailed information regarding their design and construction has not been readily available. The paper "Development of the Linden AMD Bioremediation System" (Gue, Socotch, Seger and Uranowski, 2004) documents site conditions, design criteria, design detail, construction related problems, modifications, project timing/sequencing, inoculation, as well as pre-construction and post-construction performance data. This in-depth analysis of the Linden system should be of great assistance in understanding and developing future AMD bioremediation and limestone leach-bed systems.

During the 12-month performance evaluation period, loading increases/reductions have occurred as follows: alkalinity + 49.71 lbs/day, acidity –9.9 lbs day, iron –2.45 lbs/day,

Manganese –4.03 lbs/day, Aluminum -.48 lbs/day. The Linden system is located in a relative upstream position. The system's net-alkaline, low-metals discharge greatly assists in the top-down restoration approach being implemented within the Huff Run Watershed.

Due to the low bid price in comparison with the project budget, the reclamation of an adjacent 4.5 acres of barren area and mine refuse east of the passive treatment system was included as part of the overall project. Excess resoiling material from the project excavation provides adequate covering of the material and was suitable for vegetative growth.

Photos

Attached are six photos that attest to the project's success. Captions for each photograph are noted below.

Photo #1:
Deep mine discharge from the Linden #3 Mine that was operated by the Davis Railroad Company to extract the Lower Kittanning (#5) coal seam until abandoned in 1898. This discharge is directed through the Linden AMD Bioremediation System.

Photo #2:
Plan view of the Linden AMD Bioremediation System, including mine discharge location, flow control structure, diversion and overflow channels, wetland, riffler and treatment bed.

Photo #3 (Cover Photo):
Post-construction photograph of the flow control structure and developed wetland, with the treatment bed (and inoculation ports) in distant view.

Photo #4:
Plan view of the treatment bed including baffles, cleanout schematic, inoculation ports and outlet channel.

Photo #5:
Construction photograph of the Linden treatment bed. Seen within the photograph are the liner system, underdrain/cleanout, #1 and #2 limestone backfill, #57 limestone backfill and inoculation ports.

Photo #6:
The completed treatment bed as seen in August of 2003.