Using a Passive Treatment System on Effluent Waters from the Smolnik Mine

Project Title: Feasibility Test for Water Quality Improvement Using Passive Treatment System on Effluent Waters from the Smolnik Mine in Slovakia
Leader: Aquipur, Smolnik, Slovakia
Partner: Knight Piesold Consulting, Colorado, USA
Location: Smolnik, Slovakia
Project Duration: August, 1999-September, 2000
EcoLinks Project Investment: Total EcoLinks Project Investment: $ 54,822
EcoLinks Grant Support: $36,310; Project Team Cost Share Contribution: $18,512.

Best Practice: Transferable Solution

Through this EcoLinks funded project, project members demonstrated that passive water treatment technology is an effective, feasible, low cost solution for treating mine effluent water at the Smolnik Mine in Slovakia. This Best Practice is a transferable methodology for improving water quality at other mines throughout Central and Eastern Europe. Full-scale effluent treatment systems can be successfully implemented based on this approach. The materials used in this project are easily attainable and low cost making this an especially attractive and feasible solution to water pollution problems from mining.

Project Summary

An important consideration in improving water quality in Central and Eastern Europe is minimizing wastewater effluent from inactive or abandoned mines. These waters can be highly acidic and contain heavy metals that are detrimental to human health and aquatic ecological vitality. The treatment of effluent mine water, however, can be costly and complicated to implement and maintain. To address water quality problems associated with mine effluent in Central and Eastern Europe, creative and economically efficient ways to minimize and treat contaminated mine waters must be explored.

This project tests the feasibility of a passive, low cost, low maintenance technique for treating mine water effluent. The Smolnik Mine in Smolnik, Slovakia is used as a test site. The Smolnik Mine, once a notable source of pyrite, became inactive in 1991 due to economic constraints. The mine eventually flooded with water leading to acid rock drainage. From eight to twenty five liters per second of acidic water contaminated with heavy metals now flows in the form of underground seepage from the mine into tributaries of the Ruzin Basin eventually crossing the international border into Hungary. The metal content of the Smolnik mine effluent far exceeds allowable pollution levels and has diminished ecological conditions in the Smolnik stream, the Hornad River, and transboundary waters. The amount of water that infiltrates the mine, however, has already been significantly reduced. This reduction was achieved by diverting the surface water from the most intensive infiltration points. Treating the mine water effluent would further help to improve water quality in the surrounding basin while providing an opportunity to explore new treatment techniques.

AQUIPUR, a consulting firm in Slovakia and Knight Piesold, a consulting company based in the United States, collaborated to develop a strategy for reducing water pollution associated with the Smolnik Mine. An EcoLinks Challenge Grant provided support to explore the feasibility of using passive treatment technology to improve the water quality of mine effluent. The project consisted of two phases: 1) a bench-scale study, and 2) a pilot-scale study. The first phase of the project, the bench-scale study, focused on determining the most effective mixture of sulfate-reducing agents for reducing acidity and removing metal contaminants. The second phase of the project, the pilot-scale study, involved the construction of a pilot cell to test the most favorable mixture under continuous flow conditions.

This project demonstrated the usefulness and applicability of passive treatment technology for reducing water pollution. The bench-scale and pilot studies revealed that heavy metal pollutants such as aluminum, copper, and zinc are reduced by almost 70% and acid levels are significantly improved. The bench-scale and pilot studies also demonstrated that the materials needed to build a passive treatment system are attainable and inexpensive compared to active water treatment systems. Passive treatment is also low maintenance compared to active water treatment that requires ongoing, costly maintenance. Given the effectiveness, applicability, and economic efficiency of this approach, it can be usefully applied to improve other mine waters throughout Central and Eastern Europe.

The scientific community has shown much concern over the environmental destruction associated with the inactive mine that is owned by the Slovak government. The Slovak government, while concerned for water quality, has not yet been able to dedicate the economic and political resources necessary for attacking the environmental problems associated with the closed mine. Demonstrating a feasible and inexpensive way to improve water quality as this project does, however, may attract more resources and support.

Project Activities

The purpose of this project was to develop an effective, full-scale, passive water treatment system for reducing water pollution associated with the inactive Smolnik Mine. Passive methods can be aerobic or anaerobic. For this particular case, it was decided that the anaerobic method would be tested due to the chemical composition of the water pollutants. The anaerobic method utilizes a filtration cell composed of sulfate reducing bacteria and organic matter to raise the pH and to form sulfide ions, which combine with the metals to form insoluble sulfides.

A bench scale study of different bioreactors was conducted to determine the most effective sulfate reducing mixture. Then, a pilot scale study was conducted that involved installing and activating the filtration system using the most effective bioreactor materials.

1. Prepared four different bioreactors

Action: The bench-scale study involved preparing four different sulfate-reducing bioreactors. The bioreactors were each made with different combinations of crushed limestone, aged sawdust, moldy hay, and aged cow manure.

Product(s): Four different bioreactors.

2. Studied bioreactor flow and filtration capacity; Determined most effective sulfate reducing mixture

Action: The flow from each bioreactor was tested to determine which of the four cell mixtures was most effective at improving the pH and reducing the amount of heavy metals. This test was performed under discontinuous flow conditions. Once the appropriate mixture was determined, it needed to be tested under continuous flow conditions. The most sulfate reducing mixture was identified based upon the results taken from each bioreactor.

Product(s): 1) Flow and filtration measurements 2) Identification of most sulfate reducing mixture.

3. Constructed and installed an anaerobic sulfate reducing cell

Action: The pilot-scale study involved the construction of an anaerobic sulfate-reducing cell (12m x 6m x 1m) using the most effective sulfate-reducing mixture as determined by the bench-scale study. The location of the cell was selected to allow gravity flow from the mine to the cell. The cell was filled with 14,700 kg of limestone, 19,000 kg of old sawdust, 4,250 kg of hay, and 5,600 kg of manure.

Product(s): Anaerobic sulfate-reducing cell 2) Cell location and installation.

4. Assessed cell functioning

Action: The cell was tested under constant flow conditions and the output was periodically monitored for five months. Output data were collected on pH levels, temperature, conductivity, and concentrations of iron, aluminum, copper, zinc, sulfate, magnesium, and calcium.

Product(s): Data on cell filtration capacity.

5. Developed full-scale treatment system plan

Action: Based on the results of the pilot-cell experiments, a plan including design parameters was developed for a full-scale treatment system.

Product(s): Full-scale treatment system plan.

6. Conducted outreach activities

Action: Upon completion of the pilot studies, the project results were compiled for presentation to the Slovak Ministry of Environment and the Slovak Ministry of Economy in hopes of achieving future support for the construction of a final passive water treatment system. AQUIPUR and Knight Piesold plan to seek local and international funds for a full-scale treatment system from the Slovak Ministry of Economy and US Trade and Development Agency and US Environmental Protection Agency. Research results obtained from the project were shared at conferences and published in conference proceedings.

Product(s): 1) Project report 2) Paper on project results presented at International Environmental Symposium in Prague and published in conference proceedings 3) Paper titled "Bench Scale Passive Treatment of Heavy Metals, Smolnik Mine, Slovakia" was presented at the American Society for Surface Mining and Reclamation" in June, 2000 in Tampa, Florida.

Project Benefits

This project promotes capacity building, environmental, and economic benefits. Partnerships were established that enhanced information sharing and technology transfer that can now be used to solve mine wastewater effluent problems throughout Slovakia and other countries in Central and Eastern Europe. The project established a workable methodology for reducing water pollution at a low cost compared to active treatment systems.

Capacity Building Benefits

This project built social capital in the form of network formation and information exchange. This project engaged a partnership between the Slovak consulting firm, AQUIPUR, the Faculty of Sciences at Comenius University in Slovakia, and a US firm, Knight Piesold. This network allowed for the exchange of information and established the implementation capacity to develop a plan for a full-scale passive water treatment system. Valuable knowledge was also obtained on how to collaborate effectively to improve the success of the project.

Due to the experience gained through testing the passive water treatment technology at the Smolnik Mine, AQUIPUR now has the knowledge and experience to implement passive treatment systems for other mines in the region as well as train others in applying the passive water treatment technique for its application throughout Central and Eastern Europe.

Environmental Benefits

The environmental benefits of this project are derived from the technological capacity to construct a full-scale passive water treatment system to reduce mine water pollution. The potential for water quality improvement using the developed system was demonstrated by the pilot study. The project demonstrated that the pilot cell effectively and consistently reduced heavy metals and improved the pH of the water even when the cleansing cell was overloaded. The test revealed that the sulfate-reducing cell could eliminate metals in loading conditions that are much higher than anticipated. The last data set gathered for metals discharged from the pilot cell is presented in Table 1.

Table1. Results of pilot scale tests

Component	Concentration before treatment [ppm]	Concentration after treatment [ppm]
Aluminum	165	3.25
Copper	6.29	0.08
Zinc	21.7	0.36
Manganese	44.9	37.4
Total iron	617	322

Altogether 70 % of metals were removed. Sulfate flow was reduced from 18.7 moles/day/m3 to 1.38 moles/day/m3. Note that while these readings were taken in September, the readings were also just as impressive at the beginning of spring in May when flow rates can be much higher (by 50 %). The pilot test also revealed that the pH level increased by one to two units reducing the acidity of the water.

Economic Benefits

The passive treatment system developed in this project is less costly than an active treatment system. The materials for a passive treatment system are less expensive, easily accessible, and system maintenance and monitoring are less demanding. A chemical treatment option was considered for improving the Smolnik Mine effluent but due to costs it was dismissed. Further, an active treatment system produces a sludge by-product requiring further investment. The passive treatment system, however, generates an insignificant amount of solid waste as the content of the cells is operational typically around twenty years. The technology was demonstrated as easily workable in poor conditions.

Table 2. provides a comparative financial analysis of passive and active wastewater treatment approaches for the Smolnik mine. The results show that the annual costs of using passive treatment are $ 0.42 million, almost two times lower than the annual costs of active treatment.

Table. 2: Comparative financial analysis of active and passive wastewater treatment systems for the Smolnik mine

	Active treatment	Passive treatment
Investment outlays [$ million]	2.0	4.1
Operation costs [$ million/year]	0.5	0.0
Annualized cost (over 15 years, 6 % discount rate) [$million/year]	0.71	0.42

Lessons Learned

Several lessons were learned through this project. A key lesson was learned regarding the importance of running bench scale and pilot studies. By running the bench-scale and pilot tests, the challenges and opportunities of using the passive treatment system were identified. The problems identified in the pilot cell test could be corrected for the final full-scale design of the treatment system. The multiple lessons learned from the bench scale and pilot studies are:

- The trial test cell showed that feed pipes can become clogged with iron hydroxide precipitates. To remedy this in the final design of the full-scale treatment system, it is indicated that feed pipes should have smooth walls and be easily accessible for cleaning purposes.
- The system can handle an influx six times larger than originally predicted by the bench-scale tests. Since the cells can handle a larger flow, fewer cells are needed reducing the amount of land needed to build the system. Note, however, that this decreases the longevity of the cells by half.
- Acquiring sufficient land to locate the system can be difficult. Multiple sites may be needed to have sufficient space for the entire treatment system, or fewer cells can be used.
- If the cell is built on an incline, water enters the cell via gravity and there is no need for a pump.
- There can be problems with vandalism and materials being taken from the site.

In addition to understanding the importance of the preliminary studies, other key lessons were learned including:

- A clear work plan and regular site visits by the key project participants improves project implementation. A clear work plan should outline not only a time schedule but also a communication schedule. More collaboration (e.g., more communication) and more site visits are needed to secure consistent data collection and reporting of results.

- The technology verification was very satisfying, especially as regional geo-chemical differences were overcome.
- The timing of project financing should correspond with construction needs.
- This project affirmed a low-cost solution to water pollution associated with inactive mines. Many other water treatment approaches require more costly and less accessible materials and sustained maintenance and monitoring. The passive water treatment system, however, employs inexpensive materials that are more readily available and requires only minimal, periodic maintenance.

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