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Technical Communication

Passive Treatment of Acid Mine Drainage at the La Extranjera Mine (Puertollano, Spain)

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Abstract. In southern Spain, coal seams typically contain pyrite. The mines there are characteristically contaminated by the presence of diverse metals disolved in acidic water. An experimental passive system, containing an anoxic limestone drain, organic matter and wetlands, was constructed to assess how best to inprove the water chemistry. The procedure we used is reported on here so others can learn from what we did.

Key words: Acid mine drainage, wetlands, anoxic limestone drains (ALD), passive systems, sulphates

Background

Since June 1997, we have wrestled with the necessity of discharging a large volume of water from the La Extranjera Mine in Puertollano (Spain) to the river. The surface mine had to pump water from the pit to continue the extraction below the phreatic level. After being pumped, the water has been stored in an old abandonated pit, which works like a great sediment pond. Natural oxidation precipitates a great quantity of pollutants, so that the water has reasonably good quality, except for the concentration of sulphates, which remains above legal discharge criteria. An economic study was performed on treating the water using a conventional treatment system. Later, it was decided to determine if a less expensive passive system could be constructed to treat this water. An experimental system was constructed and tests were conducted for about a month.

Design of the experimental systems

An experimental system was designed to determine if it would be possible to adequately treat the La Extranjera mine water passively to allow discharge into the river. The fundamental problem were the sulphates dissolved in the water, although it was anticipted that the system would also improve the pH, reduce the concentration of dissolved and suspended metals. Given that objective, we knew we had to promote the bacterial reduction of sulphates. Sulphate reduction is a reaction catalyzed by some bacteria that also have the capacity to reduce the iron, and to precipitate both as iron sulphide. When other metals are present, it is possible that they will also form metallic sulphides. This reaction decreases the concentration of metals and sulphate, because the iron sulphide is insoluble and precipitates. The reaction also produces alkalinity, which counteracts the acidity of the water.

Sulphate reducing bacteria develop in anoxic environments if organic matter is present. This commonly occurs in wetland sediments. Meanwhile, near the surface of the ponds, elements can be oxidized, so that metals also precipitate as oxihydroxides.

Three parallel tests were conducted. The first simulated an anoxic limestone drain (ALD), to which a great quantity of organic matter had been added to promote the development of sulphate reducing bacteria, followed by a wetland with an anaerobic substrate to further promote precipitation of metals and sulphides. The second test system only contained an anaerobic wetland (without an ALD). The third test system was a conventional aerobic wetland, which was anticipated to have little effect on the concentration of sulphate, although it was also expected that it would perform the best relative to the precipitation of metals. The three test systems were constructed side-by-side (Figure 1), separated by plywood, with the idea that they could be united later on, if the evolution of the experiment suggested that this would be appropriate.

Construction of the wetlands

The ALD system was excavated about 2 m wide, 2 m deep, and about 6 m long (Figure 2). The bottom of the system had a relatively steep slope, dropping approximately a meter along the length of the channel. The water was piped into the higher end of the ALD using a 2 m lenth of entrance pipe to distribute the water evenly.

Figure 1. Experimental wetland in the final stage of construction the water

Figure 2. Calcareous stone being placed into the ALD system before it is enclosed in plastic

Calcareous stone (approximately 4 cm in diameter) was mixed with organic matter and foam rubber pieces (the size of an open hand, or smaller) and used to fill the bottom 60 cm of the trench. Next, a sheet of foam rubber about 3 cm thick was placed atop the mixture to hinder the passage of organic matter into the higher part of the ALD. Then another 60 cm of the same calcareous stone was added. A sheet of plastic was then used to cover the ALD, to restrict migration of oxygen into the system, and then the ALD was covered with the same soil that was excavated from the hole. It should be noted that the outflow of the ALD is located at a higher elevation than any point in it, ensuring that the system remains flooded.

A rectangular excavation 10 m x 10 m and approximately 1.5 m deep was dug for the wetland tests. It was slightly inclined to facilitate the flow of the water. The excavation was divided into three parts, using plywood to direct the flow of the water (Figure 3). In the two parts that have an anaerobic organic substrate, a PVC pipe was placed at the exit in such a manner as to force the water to flow through the organic substrate, with small overflows for when the flow peaks. These two components were covered with about 40 cm of organic matter amended with calcareous stone, and then this was covered with 40 cm of topsoil, in which *Typha* was planted.

Measures

In total, about 30 m^3 of calcareous stone, about 30 m^3 of organic matter, 6 x 2 m of foam rubber plus odd pieces of this, and the topsoil obtained when carrying out the excavations (about 50 m^3) were used in the construction of the test system. It had been expected that flow in each lane would be approximately 1 L/s initially, and that this flow would be increased if the results were positive.

Difficulties

When the system was put into operation, it was observed that the topsoil that covered the wetlands

Figure 3. Construction of the experimental wetland

was less permeable than expected, so that the water did not circulate through the anaerobic substratum, leaving the system by the overflows, instead of through the subdrains. It was also observed that the plywood did not completely isolate the different wetland lanes, although this was more or less expected. However, it was also observed than not a lot of water passed from one experimental lane to another, so it was considered acceptable for the test.

Analytical results

These systems were designed to work with a flow of approximately 1 L/s, although the intial flow was greater than that. Also, as mentioned above, before the modification, water did not pass through the anaerobic sustrate. In the first analysis (16 Sept 1997), water entered the system with nearly neutral pH, and after passing through the system, the pH was slightly higher. The pH change was most significant in the channel with the calcareous stone. Neither the iron nor the manganese ever exceded legal standards, even in the influent. The concentration of sulphate improved slightly, mainly in the aerobic wetland section, and in the channel of calcareous stone at the exit of the ALD. To verify these results, a second set of samples were collected 7 Oct 1997 under similar conditions, with similar results.

Ten days later, a third set of samples were collected and analyzed. However, shortly before the third sampling event, water from the working part of the mine was pumped into the large sediment pond, so that the water arriving into the passive system was much worse (more disolved metals and greater acidity) than previously observed. The influent concentration of sulphates was 1250 mg/L over regulatory limits.

At the exit of the treatment system, it was observed that the concentration of sulphates had decreased 400 mg/L, compared to initial values. Surprisingly, the aerobic wetland proved to be most effective in lowering the concentration of sulphates, improving water quality by more than 600 mg/L. As a result, we manipulated the plumbing in the anaerobic wetlands, as described above. Also, the flow was reduced to the original design level of 1 L/sec.

With these modifications, additional samples were colected 20 Oct 1997. The influent pH was 5.92, the dissolved iron was 129 mg/L, the manganese concentration was 10 mg/L and sulphate concentration was 2,900 mg/L. After the aerobic wetland, the pH rose to 6.1, the iron was decreased to 30.6 mg/L, and the manganese was lowered to 7.8 mg/L. Only a slight decrease was observed in sulphate concentrations.

Conclusions

Everything seems to indicate that the calcareous stone improves the quality of this mine water. The aerobic wetland was effective in lowering metal concentrations. However, because the effluent levels were normally lowered to effluent limits by just the sediment pond, this was not viewed as significant.

Wetlands with anaerobic sustrates seem to be the appropriate means to improve the sulphate concentrations, but this was not observed to be effective in the systems we tested. We decided to rebuild the anaerobic cells, this time without topsoil and without plants. The idea was to construct an irregular basin, adapted to the land, softly sloped and with a dense network of pipes beneath the sustrate. This system was built in 1998, but the La Extranjera Mine was closed a few months later, just as the systems began to work correctly. Now, it is not working, because no water is being pumped from the mine, and so there is no discharge to the river.