TECHNOLOGY OVERVIEW

ANOXIC LIMESTONE DRAINS

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ANOXIC LIMESTONE DRAINS

1. INTRODUCTION

Anoxic limestone drains (ALDs) are passive treatment systems that can be an effective and established technology used to treat the acidity of mine-influenced water (MIW) under specific geochemical conditions. ALDs consist of a buried bed of limestone ($CaCO_3$) engineered to intercept anoxic, acidic MIW and add alkalinity through dissolution of the limestone (Watzlaf, Schroeder, and Kairies 2000). Metals dissolved in the MIW can be precipitated within the ALD (copper, lead, zinc) or, when oxidizing conditions are encountered, at or downstream of the discharge point of the drain (ferrous iron, manganese). ALDs can be used to treat MIW flows of various rates, alone or in combination with other treatment systems, and can be installed in a wide variety of locations with the use of commonly available construction equipment. They can be a temporary or permanent solution; however, experience indicates that most ALD systems exhibit reduced effectiveness over time and eventually require maintenance or replacement.

The construction of an ALD consists of a trench containing limestone (typically 90% calcium carbonate equivalent minimum) encapsulated in a plastic liner and covered with clay or compacted soil to maintain anoxic conditions, as well as to prevent water infiltration and to keep CO_2 from escaping. The width and length of the trench are based on the levels of dissolved metals present in the mine drainage, the retention time needed to raise the pH, as well as the amount of area that is available for construction. The ALD may be capped with topsoil and vegetation to control erosion. Figure 1-1 illustrates a typical cross section of an ALD (flow is directly towards or away from the viewer, not left or right).

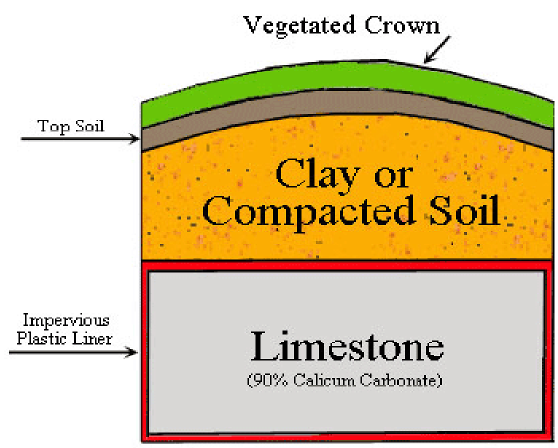

Figure 1-1. Cross section of an anoxic limestone drain.

It is also important that the discharge remain in an anoxic state prior to entering the ALD to prevent metals from precipitating out of the mine drainage and causing premature failure of the ALD. This condition is achieved by constructing the ALD directly on top of the discharge, allowing the acidic water to flow through the limestone, adding calcium carbonate to the water and increasing the alkalinity and pH while maintaining anoxic conditions. Maintaining low oxygen levels in the ALD is necessary to prevent ferric iron and aluminum hydroxide precipitation, which armors the limestone, reducing the treatment effectiveness and ultimately clogging pore spaces within the drain.

2. APPLICABILITY

ALD technology is applicable to the following situations:

- ALDs are designed to treat acidic water discharges by raising the pH and alkalinity of the MIW. MIW entering the drain must have little or no Fe^{3+} or Al^{3+} and a low concentration of dissolved oxygen. Because many MIW solutions contain dissolved oxygen and have a mixed ferric and ferrous iron content, it may be necessary to pretreat the MIW entering the drain by passing it through an organic substrate to reduce oxygen content and reduce Fe^{3+} to Fe^{2+} (Skousen 1998).

- ALDs may be used to treat a wide range of MIW flow rates. Field tests indicate that the highest rates of limestone dissolution occur during the first 15 hours of contact with the MIW. Therefore, ALD systems are commonly sized to allow for a minimum 15-hour detention time throughout the life of the system (Watzlaf, Schroeder, and Kairies 2000).

- ALDs can be used as a stand-alone technology but are more commonly used in combination with other treatment technologies, such as wetlands. The ALDs documented in the case studies were all used in combination with other forms of mine drainage treatment systems.

- Given their passive nature, ALDs can be installed in remote areas. Utilities are not required for implementation. As long as there is access to the site so that a trench can be dug and an imported liner and limestone can be installed, an ALD can be constructed.

3. ADVANTAGES

Passive ALD systems have the following advantages:

- low cost and easy to construct and maintain
- limited visual impacts
- immediate results
- wide range of climate tolerance

Passive ALD systems can be reliably implemented as a single permanent solution for many types of MIW at a much lower cost than active treatment. ALD systems involve readily implementable and proven construction methods. Equipment and materials needed to construct the systems are commonly available in mining areas. Routine maintenance is typically limited to inspection of the surface for evidence of leakage in the anoxic cover material, and periodic cleaning of the discharge point to remove accumulated iron oxides (www.AMRClearinghouse.org). The systems are generally designed for limestone replenishment every 15–25 years, depending on the characteristic of the drainage flow.

Because the systems are subsurface and commonly covered with soil and vegetation, there is typically little visual evidence of the drain at the surface once construction is complete. Once the ALD is placed in service, results are often seen in a short period of time. MIW treatment with ALDs can take place in most climates. The combination of exothermic acid mine drainage reactions and the insulating properties of the plastic liner and soil cover typically prevent freezing, although in extreme cold climates additional insulation may be required.

4. LIMITATIONS

- Limited range of acceptable geochemical conditions
- Limited long-term reliability

Relative to chemical treatment, passive systems require longer retention times and greater space, provide less certain treatment efficiency, and are subject to failure in the long term.

ALDs are suitable to treat MIW that has low concentrations of ferric iron, dissolved oxygen, and aluminum. When any of these three parameters are elevated, armoring of limestone can occur and slow the dissolution rate of limestone. When the dissolution rate slows, there is a higher buildup of ferric iron and aluminum on the limestone, which eventually clogs the open pore spaces, resulting in abnormal flow paths that can reduce both the retention time of MIW within the ALD and the reactive surface area of the limestone. Although ALDs are documented to have success in raising pH, the differing chemical characteristics of the influent mine water can cause variations in alkalinity generation and retention of metals.

Longevity of treatment is a concern for ALDs, especially in terms of water flow through the limestone. If appreciable dissolved Fe^{3+} and Al^{3+} are present, clogging of limestone pores with precipitated Al and Fe hydroxides has been observed. For waters with high sulfate (>1,500 mg/L), gypsum ($CaSO_4$) may also precipitate.

5. PERFORMANCE

The effluent quality generated from use of an ALD depends on several factors, especially influent chemistry. The concentrations of inorganic compounds and metals, along with their oxidation states and water pH, affect the removal efficiency. The maximum alkalinity that ALDs may generate is about 300 mg/L as $CaCO_3$, although the specific level varies with water chemistry and contact time.

The success of an ALD relies upon site-specific conditions, primarily on low dissolved oxygen and minimal ferric iron and aluminum concentrations in the drainage. Where these conditions exist and the drains are properly constructed and maintained, a service life of 25–30 years is possible. For those that do not perform as expected, failure is not sudden, but rather occurs as a progressive decline in treatment efficiency due to armoring and clogging.

Several case studies—Copper Basin Mining [Lower North Potato Creek Watershed]) site, the Tennessee Valley Authority Abandoned Mine Site, the Valzinco Mine, and the Hartshorne/Whitlock-Jones site—report that ALDs are still functioning as expected over operating periods ranging from several years to more than 10 years. The system at the Copper Basin of Tennessee site is still in use after 20 years but has not functioned as expected due to the elevated levels of dissolved oxygen and aluminum in the mine drainage. The ALD at the

Tecumesh, AML Site 262 in Indiana failed after one year of operation due to high concentrations of aluminum and gypsum.

Watzlaf, Schroeder, and Kairies (2000) assessed the long-term performance of 10 ALDs used for treating coal mine drainage. Influent and effluent water qualities were analyzed for a decade. Alkalinity concentrations in the effluent ranged 80–320 mg/L as $CaCO_3$ with near maximum levels being reached after approximately 15 hours of detention in the ALD. Where influent mine water contained less than 1 mg/L of both ferric iron and aluminum, the ALDs produced consistent concentrations of alkalinity for over 10 years. An ALD receiving influent mine water containing 21 mg/L of aluminum experienced rapid failure due to permeability reduction within 8 months.

6. COSTS

Relative to active treatment technologies, ALDs can be an inexpensive way to add alkalinity to acidic discharges. Costs factors to be considered include mobilization and use of heavy equipment at remote and or steep sites, the local availability of the limestone and the materials required to cover and seal the trench, the potential need for insulation to address extreme cold conditions, and the possible need for pretreatment to reduce oxygen, aluminum, or iron levels in the influent MIW.

The cost of installing ALDs can vary from site to site, depending largely on location and chemical makeup of the MIW. Operators of the Tennessee Valley Authority abandoned mine site in Alabama reported that their capital cost was approximately $0.25/1000 gal of water and their operation and maintenance costs were approximately $0.10/1000 gal of treated water.

7. REGULATORY CONSIDERATIONS

Constructed ALDs may require approvals and/or permits from one or more regulatory authorities (federal, state, and/or local) depending on the site location and the applications being proposed. It should also be noted that if any surface water is being impacted, a National Pollutant Discharge Elimination System permit may be required at the final point of discharge.

Review of laws or agencies that may be involved in implementation of an ALD include the following:

- Clean Water Act
- Comprehensive Environmental Response Compensation, and Liability Act
- Surface Mining Control and Reclamation Act
- U.S. Environmental Protection Agency
- state agencies
- local governments

8. STAKEHOLDER CONSIDERATIONS

Because of their simple construction, low capital costs, limited operation and maintenance requirements, and generally minor post-construction surface visual impacts, ALDs do not suffer from some of the stakeholder issues that may apply to other MIW treatment technologies.

9. LESSONS LEARNED

Watzlaf, Schroeder, and Kairies (2000) suggest the ideal influent water quality for an ALD is net acidic water with a pH above 5.0. At this pH level, ferrous iron, manganese, and low levels of ferric iron and aluminum remain soluble, preventing precipitation of metals into the voids of the limestone and ensuring effectiveness and permeability of the ALD. If there are elevated levels of ferric iron and aluminum in the AMD, other treatment technologies should be considered. It has also been recognized that low oxygen levels and CO_2 levels above atmospheric concentration favor development of high alkalinity concentrations.

A complete analysis of the MIW (including pH, alkalinity, acidity, total iron, dissolved oxygen, ferric iron, and aluminum), including seasonal variations, must be completed before selecting an ALD as the appropriate treatment method. This analysis will assist in determining whether or not an ALD is suitable for the site.

10. CASE STUDIES

Table 10-1. Case studies including anoxic limestone drains

Copper Basin Mining Site, TN
Hartshorne/Whitlock-Jones: Hartshorne, OK
Ohio Abandoned Bituminous Coal, SE OH
Tecumseh - AML Site 262, IN
Tennessee Valley Authority, AL
Valzinco Mine, VA

11. REFERENCES

Brodie, G. A., C. R. Britt, and H. N. Taylor. 1991. "Use of Passive Anoxic Limestone Drains to Enhance Performance of Acid Drainage Treatment Wetlands," in *Proceedings, 1991 Annual Meeting of the American Society for Surface Mining and Reclamation*, Durango, CO.

Faulkner, B. B., and J. G. Skousen. 1996. "Treatment of Acid Mine Drainage by Passive Treatment Systems," pp. 267–74 in *Acid Mine Drainage: Control and Treatment*, J. G. Skousen, and P. F. Ziemkiewicz, eds. Morgantown, WV: West Virginia University and the National Mine Land Reclamation Center.

Hedin, R. S., and G. R. Watzlaf. 1994. "The Effects of Anoxic Limestone Drains on Mine Water Chemistry," pp. 185–94 in *Proceedings, 3rd International Conference on the Abatement of Acidic Drainage*, Vol. 1. SP 06B-94. Pittsburgh: U.S. Bureau of Mines.

ITRC (Interstate Technology & Regulatory Council). 2003. *Technical and Regulatory Guidance Document for Constructed Treatment Wetlands.* WTLND-1. Washington, D.C.: Interstate Technology & Regulatory Council, Wetlands Team. www.itrcweb.org.

MEND (Mine Environmental Neutral Drainage). 1996. *Review of Passive Systems for Treatment of Acid Mine Drainage.* MEND Report 3.14.1 Canada: Mine Environmental Neutral Drainage.

Nairn, R. W., R. S. Hedin, and G. R. Watzlaf. 1991. "A Preliminary Review of the Use of Anoxic Limestone Drains in the Passive Treatment of Acid Mine Drainage," in *Proceedings, 12th Annual West Virginia Surface Mine Drainage Task Force Symposium*, Morgantown, WV.

Parker, G., and A. Robertson. 1999. *Acid Drainage.* Occasional Paper Number 11. Melbourne: Australian Minerals and Energy Environment Foundation.

Skousen, J. 1996. "Anoxic Limestone Drains for Acid Mine Drainage Treatment," pp. 261–66 in *Acid Mine Drainage: Control and Treatment*, J. G. Skousen, and P. F. Ziemkiewicz, eds. Morgantown, WV: West Virginia University and the National Mine Land Reclamation Center.

Skousen, J. 1998. *Overview of Passive Systems for Treating Acid Mine Drainage.* West Virginia Extension Service. www.wvu.edu/~agexten/landrec/passtrt/passtrt.htm.

Tremblay, G. A., and C. M. Hogan, eds. 2000. *Treatment, Mine Environmental Neutral Drainage (MEND) Manual*, vol. 5. MEND 5.4.2e. Energy, Mines, and Resources Canada.

Watzlaf, G. R., K. T. Schroeder, and C. L. Kairies. 2000. *Long-Term Performance of Anoxic Limestone Drains*. U.S. Department of Energy, National Energy Technology Laboratory. www.imwa.info/bibliographie/19_2_098-110.pdf.