Passive Aluminum Treatment Successes

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Abstract

Aluminum remains perhaps the least understood acid mine drainage parameter of passive treatment system design, yet aluminum is often the most significant problem requiring address. Aluminum cannot be ignored or mishandled in a passive treatment design, or the system will be relegated to almost sure and relatively quick physical failure. These shortcomings have been well documented with Anoxic Limestone Drains (ALDs). Passive treatment application will not meet the compliance needs of industry or the restoration goals of watershed organizations if aluminum is not specifically managed within the treatment system. In that aluminum removal is a pH dependent function, independent of redox conditions, the physical integrity of aluminum treatment systems is of more concern than the actual chemical mechanisms of treatment. Damariscotta has modified their Successive Alkalinity Producing Systems (SAPS) design to treat aluminum. This system, known as an Aluminator©, is designed to operate under high iron and/or oxygen concentrations, can increase pH values and generate alkalinity, will retain aluminum within the treatment system, and will carry out these functions with a minimum of operation and maintenance concern. Mine drainage enters the Aluminator© on the surface of the treatment unit and flows downward through the treatment column of a standing pool of water above an organic compost layer above a bed of limestone. The limestone layer is the prime treatment area where aluminum is accumulated. The treated water is collected in a perforated piping system specifically sized and situated within the limestone to match the needs of both the total flow and the aluminum loading of the given discharge. Treatment effectiveness can be maintained by periodically flushing the collected aluminum from the limestone with minimal interruption of treatment. Aluminators© have several years worth of proven field application.

Introduction

The effectiveness of today's passive mine drainage treatment technologies can be attributed to the well-intentioned misapplication of their prototypes. It is imperative that we continue to misapply the prototypes; not in a deliberate or haphazard fashion, but in a calculated and logical manner. Passive mine drainage treatments have not always garnered widespread support because early results often fell short of expectations. Passive treatment technologies have since achieved a degree of favor because applications developed from failed expectations have achieved at least a modicum of success, by any measure. However, there is an ever increasing demand within this field to develop the perfect prototype; and an inexplicable willingness to dwell upon the perceived shortcomings of innovation.

There are various examples of ALDs "failing" because they plugged off with aluminum (Cliff, et. al. 1996, Watzlaf 1997a) ; and an awareness of this which has led to two rather unique circumstances. One school continues to build ALDs of varying design in an attempt to overcome system malfunctions exacerbated by aluminum, but to little avail. The other school assumes that since ALDs cannot be used to treat aluminum contaminated flows, that aluminum cannot be treated by passive means. (A third school wrongly assumes that aluminum is not a treatment concern.) For a variety of reasons, aluminum is perhaps the easiest of the mine drainage contaminants to treat by passive means. ALDs, while very effective under the proper circumstances, are simply an inappropriate technology where aluminum is a constituent of the mine drainage.

Understanding and treating for aluminum is critical to the implementation of a successful passive treatment strategy for several reasons; 1) effective passive treatments target iron, manganese, and aluminum, as well as alkalinity generation and pH adjustment, in specific and distinct ways, 2) the inappropriate use of even a proven technology will lead to the failure of the application, and 3) one unit of aluminum will generate roughly 5.6 units of acidity in the treatment process. Passive treatments must be capable of removing the contaminant(s) of concern from a given discharge and must be capable of neutralizing the acid load of the same discharge. Passive treatment by definition must be a low operation and maintenance effort that must also function for an extended period to prove cost-effective in comparison with other treatments. Passive treatment application will not meet the compliance needs of industry or the restoration goals of watershed organizations if aluminum is both present in the target mine drainage and ignored or mishandled during treatment design. Aluminum is the primary, and sometimes sole, acid producing mineral of many active and abandoned discharges.

This paper will describe the successful application of a passive aluminum treatment technology. Three case studies will be presented and discussed.

Project Site Descriptions

The treatment components as described are portions of larger, integrated treatment systems. Aluminum is a significant constituent of each of the mine discharges, and aluminum removal is the initial target process within each system. This initial treatment is the only aspect of the projects discussed in detail.

Buckeye Reclamation Landfill

The Buckeye site is located in Belmont County, Ohio, roughly 6 km southeast of St. Clairsville. Treatment was initiated as a pilot study utilizing an 11,355 L polyethylene tank (2.7 m [effective] height by 2.4 m diameter). The target drainage flows from valley fill mine refuse and was run through the tank at a rate of 3 l/min over the course of a 19 month study, spanning November of 1992 to June of 1994.

Little Mill Creek

The Little Mill Creek site is situated in Jefferson County, Pennsylvania, approximately 3.5 km northeast of Corsica. System construction was completed in August of 1995 with a design life of 25 years. The target drainage emanates from the toe of a surface mine and flows directly into the first treatment unit. The flow is relatively consistent at 120 l/min. Treatment area is roughly 225 M2.

Greendale

The Greendale site may be found roughly 7 kin northeast of Dixie, in Clay County, West Virginia. The treatment system was constructed in August of 1996 with a 25 year design life. The relatively low flow emanates from a rock fill associated with a surface mine, averaging about 25 I/min, but flows up to 100 I/min have been recorded. Treatment covers about 600 M2, with the source included directly within the initial treatment unit.

Treatment Approach

Treatment was achieved at the referenced sites utilizing a modified version of Damariscotta's Successive Alkalinity Producing Systems (SAPS) design (Kepler and McCleary 1994a), known as the Aluminator©. Aluminators© are designed to carry out several primary functions, including the ability to; 1) operate under virtually any field condition, including high iron and/or oxygen concentrations, 2) increase pH values and generate alkalinity, 3) retain aluminum within the treatment system, and 4) carry out these functions with a minimum of operation and maintenance concern.

A typical Aluminator© cross-section may be seen in Figure I on the next page. The approach to treatment follows. Mine drainage enters the Aluminator© on the surface of the treatment unit and flows downward through the treatment column. The standing pool of water provides a buffer from flow surges, allows for a relatively even distribution of flow across the entire treatment area, and provides a positive head; essentially forcing the water down, into, and through the underlying substrates. The compost may remove a limited amount of aluminum and will generate some alkalinity, but the main role of the compost is to remove dissolved oxygen from the flow and to reduce ferric iron to ferrous iron to prevent armoring of the limestone. The limestone layer increases the pH of the flow, generates alkalinity, and retains aluminum.

A key design factor in aluminum removal within the limestone bed is that retention of the aluminum does not prohibit, or effectively limit, the amount of alkalinity which can be generated (Kepler and McCleary 1994b and Watzlaf 1997b). The treated water is collected in a perforated piping system bedded within the stone, and is then conveyed to a receiving pond. The piping systems are specifically sized and situated within the limestone to match the needs of both the total flow and the aluminum loading of the given discharge, and are a key component of the treatment design. Treatment effectiveness can be maintained by periodically removing the collected aluminum from the limestone with minimal interruption of treatment. This is accomplished through a physical "flushing" of the system, using the natural head of the pooled water; and can be conducted by one individual over a period of a few hours and without a need for heavy equipment.

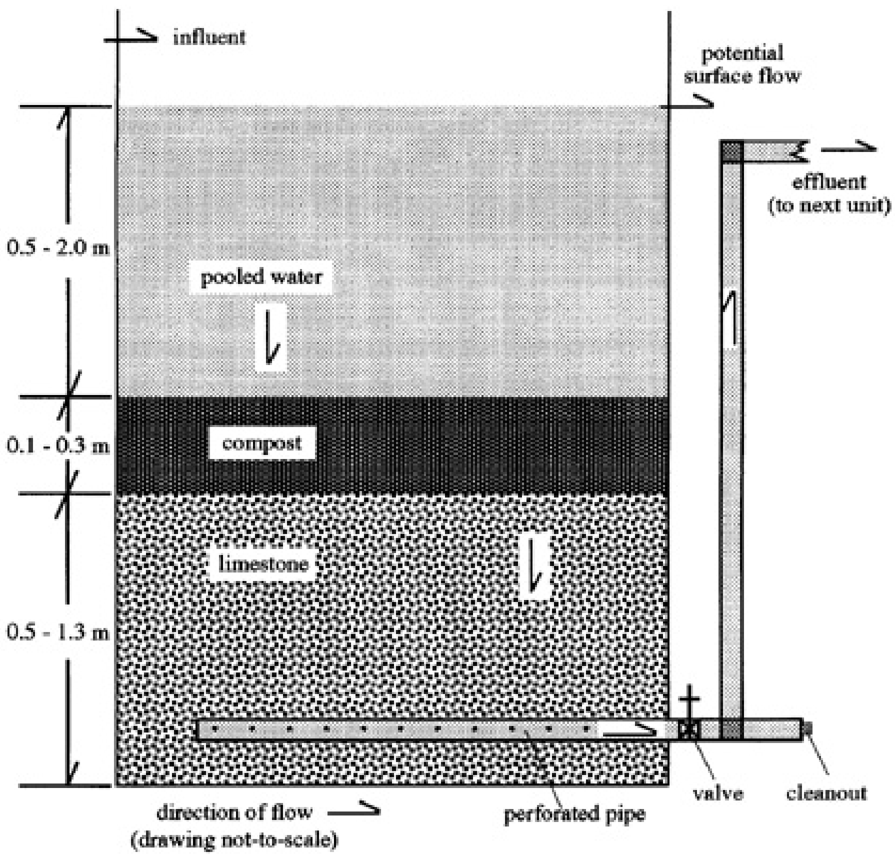
Materials and Methods

The general sizing and composition of the individual Aluminators© (D is provided below. Aluminum was the initial and primary design consideration with each of the treatment systems.

Buckeye Reclamation Landfill

The 11,355 L polyethylene tank was buried vertically with only the top of the tank exposed. A 7.62 cm diameter PVC pipe was fitted to a bulkhead at the bottom of the tank, turned 900 towards the surface and parallel with the tank for 2.7 in, and then turned 900 again to discharge on the ground surface. The tank was filled to a height of 2.5 in with 13 tons of 1.3 cm diameter limestone (67% CaC03 equivalent), which was then covered with 0.2 m of spent mushroom compost (0.6 tons). The flow was introduced above the compost, with the only exit being the described portal at the bottom of the tank.

Figure 1.
Typical Aluminator©
Cross-Section



Little Mill Creek

The Little Mill Creek system was constructed through excavation and the construction of a breastwork across an existing ravine. The system is roughly 9 m wide and 25 m long with a level bottom. Two hundred and fifty tons of 7.6 cm diameter limestone (88% $CaCO_3$ equivalent) were placed across the bottom of the excavation to a depth of 0.6 m. A perforated piping network was developed within the limestone and a solid section of pipe was extended through the breastwork to a receiving pond. The stone was covered with 20 tons of mushroom compost to a depth of 15 cm. Roughly 0.6 m of freestanding water was developed above the compost, with an additional 0.6 m of freeboard in the breastwork. A spillway was constructed 0.5 m above the normal pool elevation. The primary flow control for the

Aluminator© is a valve on the discharge end of the solid piping. The mine drainage enters the system at the surface of the pool at the toe of the existing backfill.

Greendale

The Greendale system consisted of upgrading an existing impoundment that was about 27 m in diameter. Approximately 800 tons of 7.6 cm diameter limestone (85+% $CaCO_3$ equivalent) were placed across the bottom of the excavation to a depth of 0.6 in. A perforated piping network was developed within the limestone and a solid section of pipe was extended through the breastwork to a rock-lined spillway. The limestone was covered with 60 tons of mushroom compost to a depth of 15 cm. One meter of freestanding water was developed above the compost, with an additional 0.5 in of freeboard in the breastwork. The referenced spillway was constructed 0.5 in above the normal pool elevation. A valve was installed at the discharge end of the pipe to control the flow as necessary, but was left in the full open position. The height of the pool is regulated by a standpipe connected to the hard piping. The mine drainage enters the system at or under the surface of the pool at the toe of the existing backfill.

Results

The influent and effluent values have been characterized below for each Aluminator© system. The data reflect steady state conditions since construction. These treatments produce stable and consistent results virtually immediately upon implementation. Typical results do not fluctuate with seasons or temperatures, although efficiency can decrease with sustained or uncontrolled high flow events (Kepler and McCleary 1994b).

It must be reemphasized that the effluent values are for the initial stages of treatment only, and do not reflect the success of the complete treatment systems.

Buckeye Reclamation Landfill

Flow was introduced to the pilot treatment system in November of 1992.

Buckeye Reclamation Landfill

Flow was introduced to the pilot treatment system in November of 1992.

	pH[1]	alkalinity[2]	acidity[2]	iron[3]	aluminum[3]	manganese[3]
Influent	3.98	0	1,989	1,005	**41**	4.2
Effluent	5.88	241	1,206	866	**0.2**	4.0

[1]s.u.; [2]mg/L $CaCO_3$ equivalent, net; [3]mg/L, total values

Little Mill Creek

The treatment system was put into service in August of 1995.

	pH[1]	alkalinity[2]	acidity[2]	iron[3]	aluminum[3]	manganese[3]
Influent	2.9	0	325	75	**20**	20
Effluent	6.1	54	167	68	**<0.1**	19

[1]s.u.; [2]mg/L $CaCO_3$ equivalent; [3]mg/L, total values

Greendale

The treatment system became operational in August of 1996.

	pH[1]	alkalinity[2]	acidity[2]	iron[3]	aluminum[3]	manganese[3]
Influent	2.8	0	925	40	**140**	10
Effluent	6.5	225	71	35	**0.5**	9

[1]s.u.; [2]mg/L $CaCO_3$ equivalent, net; [3]mg/L, total values

Discussions and Conclusions

Aluminum presents a serious treatment concern in developing passive treatment systems for acid mine drainage. Aluminum can account for the majority of acidity in a given discharge and must be managed effectively to maintain the physical functioning of the treatment system. As an example, the aluminum component of the Greendale discharge (including pH) accounts for 90 percent of the total acidity of the discharge. An earlier effort to treat this drainage with an ALD produced treatment results similar to those reported here, but the ALD showed significantly diminished flows within two months of implementation and essentially failed (WVDEP 1996). The Aluminator© treatments provided in the above examples have consistently removed the aluminum complement of the given discharges while generating alkalinity and remaining functional.

One of the more significant aspects of the Aluminator© treatment strategy is its ability to both accumulate aluminum and generate alkalinity in quantities comparable to "clean" limestone. This facet of treatment is apparent in the field examples and has also been demonstrated in laboratory experiments (Watzlaf 1997b). This aspect of aluminum treatment is in contrast with the finding that there is a decrease in dissolution efficiency and alkalinity generation with iron armored limestone (Ziemkiewicz, et. al. 1996).

Some aluminum treatment field applications have relied more heavily on compost than limestone as the aluminum "removal zone" because of the problems associated with aluminum and limestone in ALDs. Aluminum removal in (the commonly used) mushroom compost is a temporary phenomenon, resultant of the carbonate fraction of the compost (Kepler and McCleary, unpublished, Watzlaf 1997b). If treatment within the limestone portion of an Aluminator© is effective and consistent, then maintenance becomes the key concern of operation and longevity. This is where periodic flushing of the precipitates from within the limestone of an Aluminator©(D appears to have a functional advantage to treatments such as

ALDs. (Existing applications indicate that greater than 80 percent of Aluminator© accumulated aluminum can be removed from the system with a single flushing.) A downflow system operating under a positive head is inherently better suited to both accumulating and flushing precipitates than is a lateral flow treatment strategy.

Properly sized and "plumbed" Aluminators© have demonstrated the potential to passively treat aluminum contaminated discharges that have been problematic under other treatment approaches. This technology should prove beneficial to industry and watershed restoration efforts alike.

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