Coal Acid Mine Drainage – Passive Treatment Lime Compost Drains – Three abandoned coal mined sites in Southern Illinois

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Abstract

Coal mining has been occurring in the United States, in earnest, for well over two hundred years. It has been estimated that 5.5 billion tonnes of coal have been mined in Illinois from 1883 to 2004. As a result of this historic industry, legacy coal mining environmental impacts continue to afflict Illinois' communities and landscape. This is evidenced by the three different abandoned coal mine sites significantly affected by acid mine drainage presented below. The aim of this paper is to provide an overview of the implemented passive treatments at these three project sites. These constructed passive treatments should simply be considered practical case studies, where legacy acid mine drainage needed abatement, but due several constraints, no other type of treatment was to be considered. These case studies present some long-term positive results of the implemented passive treatment systems. Recommendations for future construction, modelling of these systems to offer improvements in sizing, based on flow and acid mine discharge chemical characteristics, as well as additional research on the use of different construction materials are proposed.

Introduction

A 1668 map from Father Louis Hennepin's expedition, down the Illinois River, mentions a "cole mine" (Coal Report 1954). Coal has been instrumental in the overall growth of the state of Illinois, with initial coal mining beginning in the early 1800s. Until the mid-1950s, Illinois was ranked third in the United States, in all time bituminous coal production, behind only Pennsylvania and West Virginia (Kolata 2010). Prior to the passage of the 1977 Surface Mining Control and Reclamation Act (SMCRA), by the United States Congress, there was no federal regulatory oversight over coal mining activities and what happened to those mine sites once mining stopped. Since the passage of SMCRA, states and tribes, with current or historic coal mining, are eligible to apply for abandoned mined land reclamation grants, funded primarily by fees generated by active mining production.

Marshall Equipment, Richardson Coal Company, and Beecher Williams No. 1, are three different abandoned coal mined sites, located in Saline County, in southeastern Illinois. These three legacy coal mine sites were eligible for reclamation, under SMCRA, by the Abandoned Mined Land Reclamation Division (AMLRD), in the state of Illinois.

These three sites mined the Davis and Dekoven coal seams. The Davis and Dekoven coal seams are frequently 3 to 7,6 meters apart and are most often surface mined, in tandem, in Saline and Gallatin counties, in southeastern Illinois. These two coal seams represent an estimated 3,7 billion tonnes of coal resources remaining in these two Illinois counties (Jacobson 1993). The Davis and Dekoven coal seams vary in thickness between 1 to 1,5 meters each, with ash content ranging from 8 to 13%, sulfur content in the range of 3 to 5%, and heating values from 12.500 to 13.500 kilojoules. (Jacobson 1993)

All three of these abandoned mined sites were contour surface mined, with some auger and deep mining also occurring, to remove the Davis and Dekoven coal seams, at a depth varying from 1,5 to 35 meters. These three coal mine sites were in operation from the early 1950s to the early 1960s.

Legacy coal mining at these three locations resulted in acid mine drainage seeps, with average flows of less than 37,9 Liters per minute. While the seeps had low water flows, the water chemistry of the Davis and Dekoven coal seams has proven to be extremely destructive.

Both coal seams produce highly acidic seepage, with high iron, aluminium and sulfate concentrations associated with the inter-burden material separating the two coal seams. The acid forming material associated with these coal seams had proven to be challenging to treat with traditional passive treatment methods and required a slightly different approach.

Methods

These abandoned coal mine sites present very similar post mining conditions, because of all different types of mining, surface, auger, and underground coal extraction occurred at all three sites. These locales all include dangerous vertical highwalls, averaging in height between 6 and 25 meters, often with shallow acid water filled pits and acid seeps along the highwall toe.

The abandoned coal mine sites presented acid mine drainage seeps with similar water chemistry produced by the Davis and Dekoven coal seam and its inter and overburden. An overview of the pre-reclamation acid mine drainage characteristics at each site, are presented in Table 1 below. Due to the Illinois AMLRD program funding and personnel limitations, only some form of passive treatment system was deemed possible to abate the acid mine drainage at the above-mentioned sites. After a careful review of the coal mine acid seepage data, with very low pH, overall high concentrations of iron, and aluminum, well above the recommended limits, less than 1 mg/L, designing a traditional passive treatment drain system was dismissed. Traditional passive drains systems do not remain anoxic and allow for oxidation, as pH increases along the treatment system. The oxidation process allows most iron, in ferrous form (Fe^{+2}), to precipitate out of solution, as ferric hydroxide ($Fe(OH)_3$), forming a rust coloured gelatinous solid, that coats alkaline rock material, eventually clogging the system, and rendering the passive drain network as ineffective. Aluminum (Al^{+3}), when present at higher concentrations, and low pH, such as is present at these three sites, can undergo hydrolysis and precipitation of the aluminum, to form aluminum hydroxide (Al(OH)3), which can also contribute to clogging of traditional passive drain systems. To prevent iron oxidation and aluminum hydrolysis, and avoid any solid precipitate clogging the system, a modified passive system for treatment of the acid seepage produced at these sites was needed. A Lime Compost Drain (LCD) was proposed as the passive treatment system on these three legacy coal mines sites, which was incorporated as part of the overall reclamation design at each project location.

The main proposed concept of the LCD chemical processes is to create a very low oxygen, high alkaline and high pH environment, within the drain, through which acid seepage is directed, with any oxygen present being consumed by the slow degradation of organic matter. Keeping the drain composition as anoxic as possible, would prevent iron (Fe^{+2}) from oxidizing and precipitating out, minimizing coating of the high alkalinity treatment material. Within the LCD, aluminum (Al^{+3}) would travel through a highly alkaline, high pH environment, maintaining the metal in

***Table 1** Pre-Reclamation Coal Acid Mine Drainage Data*

Site Name (date)	Acidity mg/L	pH	Aluminum mg/L	Iron mg/L
Marshall Equipment (2005)	784,0	2,68	41,00	154,00
Richardson Coal Company (2013)	122,3	3,38	12,51	42,98
Beecher Williams No. 1 (2021)	460,0	3,04	42,33	29,32

solution. Both metals, iron and aluminum would undergo oxidation and/or hydrolysis, when the pH drops to ranges 6.5 to 7.5, as treated water exits the LCD anoxic treatment system into the newly constructed open air sediment basins. Traditionally iron hydroxide ($Fe(OH)_3$), would settle out first, as a reddish-brown solid, followed by aluminum hydroxide ($Al(OH)_3$).

A Lime Compost Drain (LCD) consists of a two-layer system, wrapped by a permeable material, such as filter fabric. The bottom most layer contains 75mm, high alkalinity coarse aggregate, with 90% or greater calcium carbonate ($CaCO_3$) content and minimum thickness of 0,3 meters. The top layer, also 0,3 meters in thickness, consists of a well-blended mixture of 50% compost material, such as mulch, and 50% of 25mm high alkalinity coarse aggregate, with 90% or greater calcium carbonate ($CaCO_3$) content.

Mixing of these materials is done on site. Backfilling over the LCD is completed in such manner as not to compromise the integrity of the newly constructed drain. During construction, if possible, it is best to keep the LCD construction area free from water during the placement of the limestone, compost, filter fabric and cover soil. Both layers are then draped by an impermeable polyethylene liner, with a minimum thickness of 0,75 mm, to reduce surface runoff infiltration into the passive treatment. This is then, followed by carefully placed backfill material.

The LCD flow is then routed to an outlet basin/s where oxidation and hydrolysis occurs, precipitated solids are settled, and water is discharged to a nearby waterway and/or existing stream. To keep the LCD, drain anoxic at the basin outlet, the discharge elevation of the basin is kept a minimum 0,3 meters above of the LCD outlet elevation. Both drain layers vary in width and length, depending on existing highwall conditions, flow, and slight variations of the acid mine water chemistry at each location.

These drains are usually placed as close as possible to the exposed highwall face and on the pit floor. The trench bottom is excavated to the rock layer of the mined pit floor. Prior to any backfill activities, the trench floor, sides slopes, and adjacent highwall are made as clear as possible of any sediment, debris, or vegetation. Detail drawings for the drain construction are shown on Fig. 1. This LCD system was constructed on all three sites with great improvement to chemistry of the coal acid mine drainage discharging from the passive LCD system.

During implementation of the first LCD design, at the Marshall Equipment project, construction challenges arose. The original design included a 50mm perforated pipe system throughout the drain. This pipe system included vertical sampling ports to the surface. Pipe sampling ports were kept anoxic by using a 180˚ pipe elbow at the surface. The large amount of compacted backfill material that needed to be placed in and around these vertical pipe sampling ports, to abate the existing vertical highwall, made it nearly impossible to ensure proper construction. This piping for sampling ports proved to be very hard to maintain completely vertical

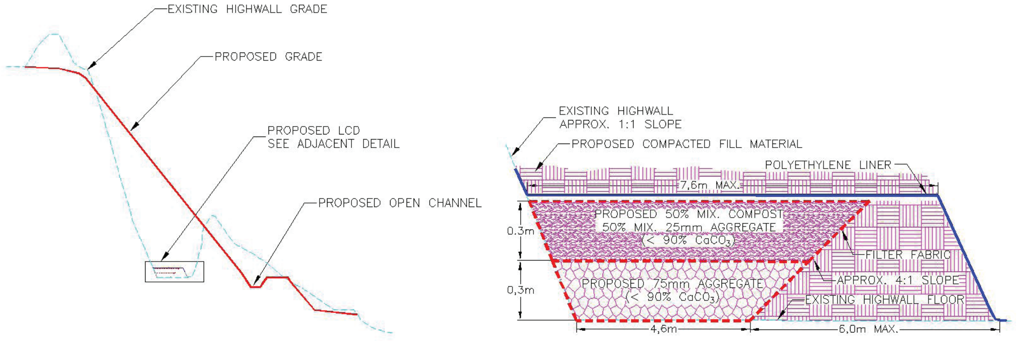

Figure 1 *Lime Compost Drain (LCD), Typical Cross Section and Profile, Not to Scale (image: Olga Moya Aranzubia).*

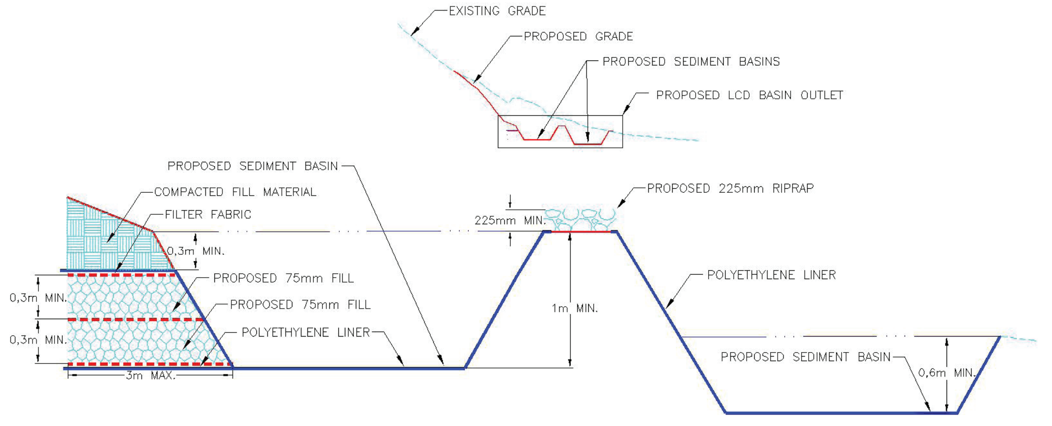

Figure 2 *Lime Cost Drain Basin (LCD), Typical Cross Section and Profile, Not to Scale (image: Olga Moya Aranzubia).*

to the surface. It was also very difficult to ensure the connection between the vertical pipes for these sampling ports and the main pipe network, running within the drain, remained in place and functioning, once backfill material was placed and compacted. The entire pipe system was removed from subsequent designs.

Another challenging aspect identified, post-construction of the LCD system, was the removal of settled solids. While riprap lined settling basins were very practical and easy to construct, they became difficult to maintain. These three LCD systems were built without any type of modelling for sizing, making it difficult to estimate the amount of precipitate that would be dropping out of solution at the outlet basins. While the original system at the Marshall Equipment site remains functional and precipitate sediment is being adequately handled, the Richardson Coal Company LCD system basins reached capacity after six years. A remedial project was completed to remove existing sediment from the basins at the Richardson Coal Company site. The clean out proved to be time consuming, due to the riprap lining of the basins, making it costly. The most recently designed and constructed LCD passive treatment included the lining of the outlet basins with high density polyethylene, instead of the previously used 225mm riprap. This new lining material was introduced in an effort to ease the maintenance removal of precipitated solids settled, from the basin, as it will accumulate over time.

The following figures illustrate pre-reclamation conditions, Figs. 1 and 2, construction activities, Fig. 3, and post reclamation results, Fig. 4.

Conclusions

These three constructed LCD passive treatments should simply be considered practical case studies, where legacy acid mine drainage needed abatement. Due to several constraints, such as program budget and lack of field and maintenance budget and personnel, only a passive treatment, with little or no maintenance, was to be considered. Research modelling of this passive treatment system would allow for the study of a method to properly size the

Table 2 *Post-Reclamation LCD Discharge Drainage Data.*

Site Name (date)	Acidity mg/L	pH	Aluminum mg/L	Iron mg/L
Marshall Equipment (2024)	0,0	6,44	0,05	25,70
Richardson Coal Company (2024)	0,0	6,05	0,40	29,90
Beecher Williams No. 1 (2024)	0,0	7,87	0,05	0,10

Figure 3 Marshall Equipment Acid Mine Drainage Seep 2007 (image: Olga Moya Aranzubia).

Figure 4 Marshall Equipment Phase Acid Mine Drainage Seep 2007 (image: Olga Moya Aranzubia).

Figure 5 Richardson Coal Company LCD Construction (image: Olga Moya Aranzubia).

Figure 6 Marshall Equipment Reclaimed Highwall and LDC Sediment Basin 2010 (image: Olga Moya Aranzubia).

width of the drain and the thickness of the treatment layers. Investigating the rate of decay of the organic matter, that keeps the system anoxic and functional would also be very beneficial. A study based on different parameters, such as flow, acid mine water chemistry and organic content, could lead to a better way to calculate the optimal mixture ratio of the organic material and alkaline rock material, while maintaining the integrity of this layer within the drain, and still be able to receive large amounts of backfill material. Additional examination of the drain system discharge would allow for more appropriate sizing of the outlet basins, to accommodate settling precipitate, based on the drain outlet water chemistry. Further investigation on the use of different lining material, for the sediment basins, to optimize the ease of precipitate removal, would also improve the overall design of the system. The introduction of a viable sampling system would provide measured parameters in the field, that could prove instrumental in estimating organic matter decay and the estimated life of a fully functional LCD.

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