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Innovative Method to Reduce Land Area and Cost in the Treatment of Acid mine Drainage

by

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ABSTRACT

High metals loading from acid mine drainage requires more area for treatment than is often available. When available, sizing requirements make effective treatment prohibitively costly. This paper will detail the installation of a currently operating innovative system at the Penn Allegh Mine located near Tarentum, Pa. that reduces the land area requirement for acid mine drainage treatment. Although the influent water at this site is alkaline and has a pH of 6.5, this system may be combined with an anoxic limestone drain to treat acidic abandoned mine discharges more effectively and with lower total cost than current methods. The system uses low-pressure air to transfer mass quantities of oxygen to oxidize and precipitate iron. More than 285,000 grams per day total iron is removed from 2,721,000 liters per day utilizing considerably less than half the land area of current systems. Influent water contains 105-mg/l iron all in the ferrous form. Effluent water has less than 0.6 mg/l total iron. More than 90 % of total iron is removed in two ponds with combined total area of 940 square meters and the balance in a final pond. Removal rate in these two ponds is 273 grams per day per square meter. This area is 13 to 26 times smaller than the area recommended for current systems that remove 10 to 20 grams per day per square meter. No chemicals are used at this site for any purpose. Existing ponds were modified to eliminate laminar flow, increase detention time and consolidate sludge to facilitate removal and potential recovery of the iron hydrate sludge.

INTRODUCTION

Maelstrom Oxidizer

The Maelstrom Oxidizer is an apparatus and method for single pass mass transfer of oxygen into a liquid. The apparatus comprises individual aeration modules contiguously aligned to allow continuous gravity flow liquid to be permeated with oxygen repetitively as it passes through a successive series of reaction chambers. Maelstrom Oxidizer modules contain an air cell that distributes high volume low pressure air equally to each of the individual Maelstrom Oxidizers contained within the separate reaction chambers. Air injected through the apertures of individual Maelstrom Oxidizers induce a swirling motion in the liquid in a predetermined direction and plane. The Maelstrom Oxidizers are in close proximity and create separate maelstroms with the same rotation and which collide with maelstroms created by adjoining Maelstrom Oxidizers. The turbulent action, within the modules, strips carbon dioxide, transfers oxygen and oxidizes and precipitates metals.

Innovative Apparatus and Method

The author of this paper conducted on site tests of water from the mine pool of a non-operating coal company that was the point source of a breakout of acid mine drainage. A small-scale version of the Maelstrom Oxidizer treatment system developed and patented by the author was used for these on site tests. Results of the testing confirmed that the apparatus and method could treat this acid mine drainage to meet National Pollutant Discharge Elimination System and Pennsylvania Department of Environmental Protection limitations, and could do so without the use of any chemical reagents or flocculent.

BACKGROUND

Penn Allegh Coal Company is located in Allegheny County, Pennsylvania approximately five miles north of Tarentum, Pennsylvania. Coal from the Freeport seem was mined at this site until 1992 when operations ceased. In mid 1999, an acid mine drainage seep on property adjacent to the mine was reported to the Pennsylvania Department of Environmental Protection. It was determined that the Penn Allegh mine was the point source of the discharge. The mine pool elevation was more than 13 feet above the elevation of the seep. Plans were formulated to pump water from the mine to reduce and maintain the mine pool level to a point lower than the breakout elevation. Elevations are shown in Table 1.

Table 1. Elevations

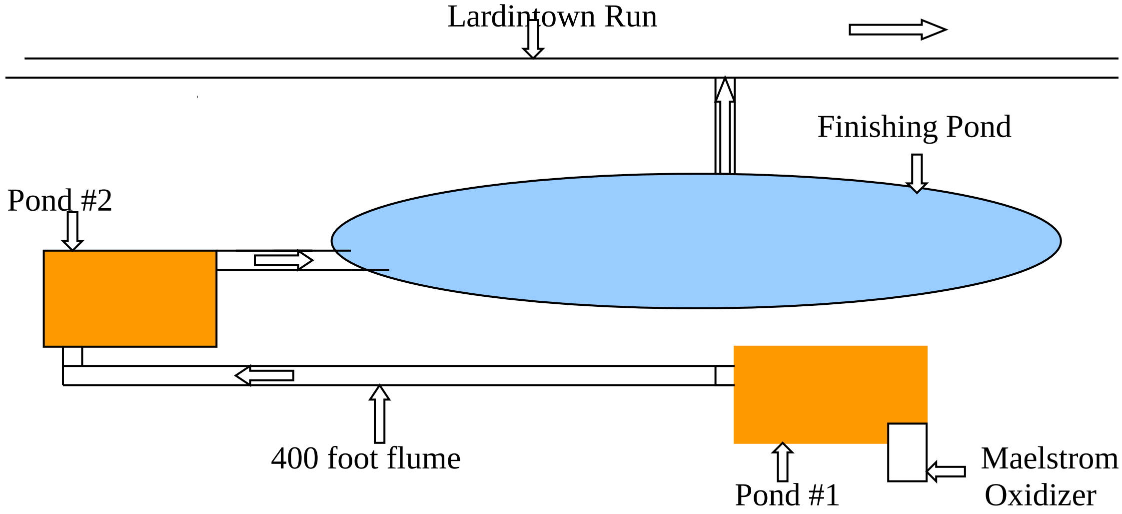
Penn Allegh Mine Pool	843.907 feet
Wetland seep	832.855 feet
Bull Creek Bank Seep	830.695 feet
Bull Creek	828.355 feet

This paper will document the installation of an innovative apparatus and method to treat the acid mine drainage from the mine pool. Although the installation was made for a responsible point source mine owner, the apparatus and method can be used in conjunction with passive methods to reduce cost and land area requirements at abandoned mine lands sites.

TREATMENT SITE

A site that was currently being used to treat runoff from the refuse pile was selected as the location to treat water from the mine pool. Figure 1 is a drawing of the Penn Allegh treatment site. The site had two small existing ponds. Each pond was 40 feet wide, one hundred feet long and ten feet deep. Sidewalls were tiered eight-inch by eight-inch planks and pond bottoms were concrete. Pond #2 was located four hundred feet downstream from Pond #1 and received Pond #1 water through a fifteen-inch diameter enclosed pipe. The site also contained a finishing pond to receive water after it flowed from Pond #2. Discharge from the finishing pond was at the far side of the pond and at the mid point of its length. A forty two-inch diameter steel pipe that contained a series of threaded portholes was the means to vary the level of the finishing pond. This vertical steel pipe was connected to a forty two-inch diameter horizontal pipe that discharged effluent into Lardintown Run that then flows into Bull Creek.

Figure 1. Penn Allegh Treatment Site



PENN ALLEGH MAELSTROM OXIDIZER INSTALLATION

A full scale Maelstrom Oxidizer was designed and constructed to treat up to one thousand gallons per minute of acid mine drainage containing in excess of 130 mg/l iron in the ferrous state. Acid mine drainage is extracted from the mine pool using a submersible pump. A variable frequency drive is used to control the flow rate. Influent water enters the apparatus and gravity flows through the system. Turbulence created by the injection of high volume low-pressure air and subsequent transfer of oxygen combine to outgas carbon dioxide and oxidize and precipitate the iron dissolved in the water. The treatment module is at ground level abutting the front of Pond #1 at a ninety-degree angle. Effluent water from the module falls directly into Pond #1. The existing pond was modified by building three walls that created four chambers within the pond. This was done to eliminate laminar flow and to increase retention time. Pond #1 is shown in Photo #2. Water flows through a series of openings at the base of the first wall to enter chamber #2. It then flows over the second wall to enter chamber #3. A series of openings at the base of the third wall pass the flow into chamber #4. The water spills over the pond downstream wall into an eight-foot wide four hundred-foot long channel. This channel replaces the original fifteen-inch diameter enclosed pipe. At the end of the four hundred-foot channel, flow is split into two streams that straddle Pond #2 and spill water into Pond #2 from both sides. Each of these two streams are shallow ponds sloped to the front end to facilitate the removal of iron by a submersible pump. Pond #2 contains five interior walls for maximum retention time and is shown in Photo #3. Water flows through Pond #2 in the same under and over pattern as in Pond #1 and enters the finishing pond from a small spillway connecting the two. Photo #4 is titled "Spillway and Finishing Pond".   A floating baffle is installed at the front end of the finishing pond to remove the final amount of iron and retain it at this end of the pond. Photo #5 is "Finishing Pond" The existing forty -two inch diameter outflow pipe at the mid-point of this pond was modified. A slit was cut into the top of the horizontal section of this pipe. All water effluent entering the pipe is from the surface of the pond. The effluent location is at the shoreline on the far side. An eight-foot three-sided baffle is erected around the effluent pipe. During winter months, the finishing pond is frozen over with the exception of the baffled area at the front of this pond and this effluent baffled area. Final effluent water flows directly into Lardintown Run, which flows into Bull Creek.

Photo # 1. Maelstrom Oxidizer

Photo # 2. Pond # 1.

Photo # 3. Pond # 2.

Photo # 4. Spillway and Finishing Pond

Photo # 5. Finishing Pond

EFFLUENT LIMITATIONS

The Penn Allegh treatment site, operated by a responsible point source coal company, must meet National Pollutant Discharge Elimination System (NPDES) and the more stringent Pennsylvania Department of Environmental Protection effluent discharge limitations. Table 2. Shows the discharge limitations set by the National Pollutant Discharge Elimination System and Table 3 Shows the limitations set by the Pennsylvania Department of Environmental Protection.

Table 2. National Pollutant Discharge Elimination System (NPDES)

pH	Maximum Daily Total Iron	Monthly Average Total Iron	Manganese
6-9	6 mg/l	3 mg/l	<2 mg/l

Table 3. Pennsylvania Department of Environmental Protection

pH	Maximum Daily Total Iron	Monthly Average Total Iron	Manganese
6-9	3.8 mg/l	1.9 mg/l	<2 mg/l

RAW WATER CHEMISTRY

Initially, the raw water in the mine pool contained 130 mg/l total iron. Now that the mine pool has been lowered by more than ten feet, the total iron has decreased to 105 mg/l. Current chemical analysis of the raw water is shown in Table 4.

Table 4. Analysis Mine Pool Water

pH	Total Iron	Total Manganese	Alkalinity	Acidity	Sulfate
6.5	105 mg/l	1.63 mg/l	238 mg/l	0 mg/l	2080 mg/l

RESULTS OF MAELSTROM OXIDIZER TREATMENT

Table 5. Penn Allegh Treatment Progression

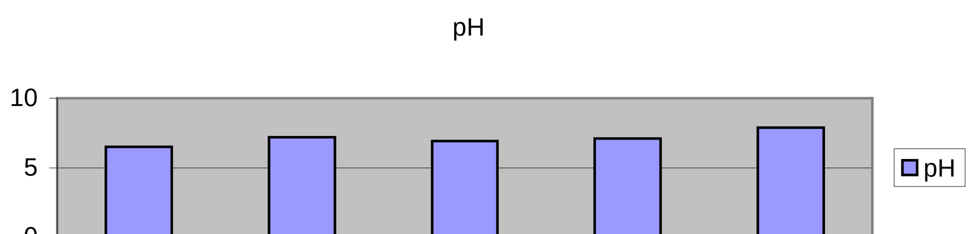
	Raw Water	Oxidizer	Pond 1	Pond 2	Effluent
pH	6.5	7.2	6.93 mg/l	7.09 mg/l	7.86 mg/l
Dissolved O2	0.92 mg/l	9.15 mg/l	4.55 mg/l	5.93 mg/l	9.21 mg/l
Dissolved Fe	105 mg/l	73.5 mg/l	24.70 mg/l	2.84 mg/l	<0.05 mg/l
Total Iron	105 mg/l	105 mg/l	51.45 mg/l	9.81 mg/l	0.45 mg/l

The Penn Allegh treatment progression shown in Table 5 are results of single day testing but are representative of treatment for more than a year. Chemical analysis of total iron, dissolved iron (Fe^{2+}) and pH are made on a daily basis of the raw water, effluent from pond 1, pond 2, and the final discharge. Median final effluent total iron is less than 0.6 mg/l with high of 0.79 mg/l and low of 0.13 mg/l. Effluent pH is always in the range of 7.8 and dissolved oxygen always near saturation at 9.2 mg/l. The Pennsylvania Department of Environmental Protection monitors the site monthly with analysis from their own laboratory. Samples were collected twice by the National Energy and Technology Center and processed in the National Energy Center Laboratory.

pH Progression

Figure 2 charts the change in pH as ferrous iron is oxidized, precipitated and settled out as ferric hydroxide. The increase in pH in the Maelstrom Oxidizer is due to the striping of carbon dioxide from the mine water. Variation in pH in Pond 1 and Pond 2 is much less than would normally be expected from acidity created by the oxidation of iron in the ponds. The excess of alkalinity in the raw water is neutralizing this acidity causing a decrease in net alkalinity without decreasing pH appreciably. The increase in pH in Pond 2 and the final effluent is most likely due to a continued release of carbon dioxide combined with the increase in dissolved oxygen.

Figure 2. pH Progression

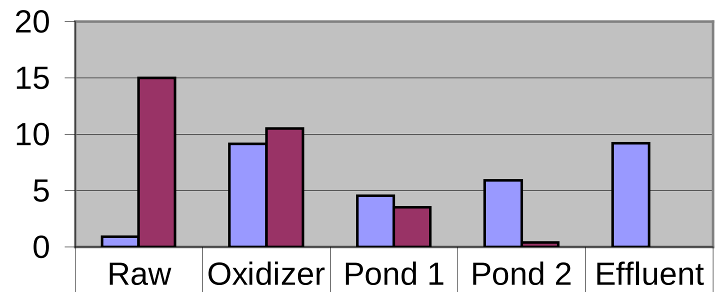


	Raw Water	Oxidizer	Pond 1	Pond 2	Effluent
pH	6.5	7.2	6.93	7.09	7.86

Oxygen Demand Vs Dissolved Oxygen (mg/l)

Figure 3. is a chart showing the amount of oxygen required to oxidize the amount of dissolved iron (Fe^{2+}) in the water as it passes through the treatment cycle. It was computed by dividing the amount of ferrous iron (Fe^{2+}) remaining at each testing point by a factor of 7. The apparent excess of demand above available oxygen as the water leaves the Maelstrom Oxidizer may be due to the slow oxidation rate at this pH. Ferrous iron may have absorbed sufficient oxygen at this point and be in the process of oxidation. In any event, additional oxygen being absorbed from the atmosphere is adequate for complete oxidation of all the iron contained in the water.

Figure 3. Oxygen Demand Vs Dissolved Oxygen Mg/l

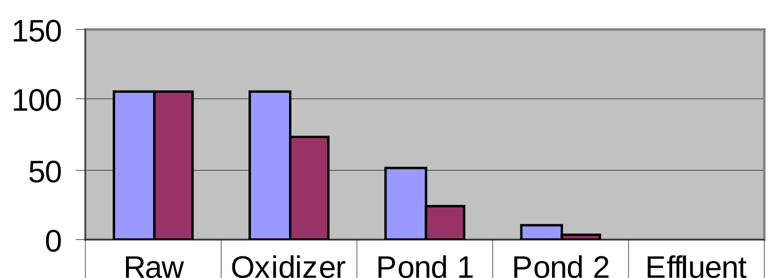


	Raw	Oxidizer	Pond 1	Pond 2	Effluent
Dissolved 02	0.92	9.15	4.55	5.93	9.21
O2 Demand	15	10.5	3.53	0.41	0

Treatment progression

Figure 4. is a chart of the progression of treatment. The amount of total iron and the portion of the total that is dissolved iron (Fe^{2+}) are shown at each stage of the treatment cycle. Approximately 28% of the water leaving the Maelstrom Oxidizer has been oxidized and precipitated but is suspended in the water. This is the reason total iron is the same amount in the raw water column as in the Oxidizer column. Approximately 50% of total iron has been precipitated and settled in Pond 1. 90% has been precipitated and settled in Ponds 1. and 2. The balance of total iron is settled within the baffled area of the finishing pond. Effluent with total iron of less than 0.6 mg/l flows from the finishing pond to Lardintown Run that flows into Bull Creek

Figure 4. Treatment Progression



	Raw	Oxidizer	Pond 1	Pond 2	Effluent
Total Iron	105	105	51.45	9.81	0.46
Dissolved Fe	105	73.5	24.7	2.84	0.05

The Penn Allegh effluent water has averaged 0.6 mg/l total iron for the past twelve months. Winter weather has not affected effluent quality. The effluent meets National Pollutant Discharge Elimination System and the more stringent Pennsylvania Department of Environmental Protection limitations for discharge into clean streams.

REDUCTION OF LAND AREA

The following calculations were made using 2,721,000 liters per day flow containing 105 mg/l iron all in the ferrous state.

More than 285,000 grams per day total iron is removed in two ponds with combined total area of 940 square meters. Removal rate in these two ponds is 273 grams per day per square meter. This is 13 to 26 times smaller than the area recommended for passive systems that remove 10 to 20 grams per day per square meter. (Hedin et al, 1994). Total iron removed at this site is more than 115 tons annually with more than 103 tons removed within the 940 square meter area.

SLUDGE REMOVAL AND METALS RECOVERY

The removal of sludge for metals recovery or disposal is facilitated by the compact area within which the iron is precipitated and settled out. Sludge is removed from the two ponds to a holding pond or bore hole by means of a submersible pump and piping. Treatment and sludge removal can be accomplished simultaneously. Removal may take six to eight hours every two to six months.

DISCUSSION

The apparatus and method employed at this site enabled the mine owner to save several hundred thousand dollars in capital costs for a chemical treatment system. Savings in chemical costs over a twenty-five year period may also amount to several hundred thousand dollars.

All of the data in this paper is based on a 500 gallon per minute flow twenty-four hours per day.

The iron removed at this site is similar to iron produced from other net alkaline mine drainage which has been found to contain up to 95% iron oxide. (Kairies et al, 2001)

No Chemicals are used in the treatment. Means have been provided at the site to remove the iron from the treatment ponds. Income from the sale of the iron may be able to reduce the operators cost. (Hedin, 2001)

The site is self-operating. Fail safe controls are in place to prevent untreated water from being discharged to a receiving stream. The pump automatically shuts down if the blower on the system shuts down. Effluent water is continuously monitored for total iron and an out of range reading will trigger controls to shut down the operation.

CONCLUSION

1. The Maelstrom Oxidizer system effectively treats Acid Mine Drainage to State and Federal mandated limitations.
2. The oxidation rate of 273 grams per day per square meter is thirteen to twenty-six times faster than the ten to twenty grams per day per square meter of current passive systems.
3. The system may be used at abandoned mine lands sites with alkaline gravity flow discharges to reduce land area and cost.
4. The system may be used at abandoned mine lands acidic discharges down stream of an anoxic limestone drain.
5. Removal of sludge from a compact area is cost effective and maintains the integrity of the system.

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