USE OF BACTERICIDES TO CONTROL ACID MINE DRAINAGE FROM SURFACE OPERATIONS[1]

Dan Parisi[2], Jeffrey Horneman[3], and Vijay Rastogi[4]

Abstract: Anionic surfactants such as sodium dodecylbenzene sulfonate, sodium laurel sulfate, and others are effective in controlling acid production from sulfidic materials such as overburden, coal, coal refuse, ores, waste rock, and tailings. Their use in practical mining and reclamation applications, however, is only being recently documented since longer term field data are only now becoming available. This paper describes three applications of bacterial inhibitors. The first is at a surface coal mine where special handling and bacterial inhibition have prevented acid drainage from highly pyritic (more than 0.5% pyrite, neutralization potential less than 30 st per 1,000 st of $CaCO_3$ equivalent, and net deficiency of neutralizers of 15 st per 1,000 st of $CaCO_3$ equivalent) dark shale overburden for over 2 yr. The second application is at an active refuse disposal area where alkaline addition at more than three times that indicated by acid-base accounting failed to control acid production in refuse with 13% pyritic sulfur and neutralization deficiency of 444 st per 1,000 st of $CaCO_3$ equivalent. Bacterial inhibitors were successful in reducing acidity and metals in site underdrain effluent by 88% to 90%. The third application was at a silver mine where waste rock containing up to 0.37% pyrite was treated with surfactant bactericides to reduce leachate acidity by 93% and sulfates by 70%.

Additional Key Words: acid mine drainage, bactericides, coal refuse, pyritic overburden, silver waste rock, surface operations, selective handling.

Introduction

Acid is generated in soils and minerals containing pyrite or other sulfidic materials when they are exposed to the elements. The *Thiobacillus ferrooxidans* bacteria catalyze the oxidation of pyrite to acid and increase the rate of acid formation by over 1 million times (Kleinmann et al 1981). Once acid forms, it solubilizes metals, most predominant of which are iron, manganese, and aluminum. As metal content in the effluent increases, the cost of water treatment and neutralization increases exponentially. Presence of manganese is of special significance since it is so difficult to precipitate out, requiring pH above 11 or aeration or both.

Bactericides effectively control acid production (Watzlaf 1986) since the kinetics of inorganic oxidation of pyrite are extremely slow. When bacterial inhibitors reduce acid production by 80% to 95%, the effluent is unable to solubilize metals. A reduction of iron, therefore, by over 80% can produce correspondingly high savings in water treatment and in sludge removal and disposal. Similar improvements in manganese concentration lead to much greater water treatment cost reductions, often by an order of magnitude.

Application to Pyritic Overburden at a Surface Mine

This application is being made at Action Mining, Inc., of Meyersdale, PA, to mine on top of the Cover Hill summit approximately 3 miles northwest of Berlin, PA. The permit area consists of 108 acres with 56 acres

[1]Paper presented at the International Land Reclamation and Mine Drainage Conference and the Third International Conference on the Abatement of Acidic Drainage, Pittsburgh, PA, April 24-29, 1994.

[2]Dan Parisi, Chief Engineer, Action Mining, Inc., Meyersdale, PA, USA.

[3]Jeffrey Horneman, Project Engineer, Adobe Mining Company, Kittanning, PA, USA.

[4]Vijay Rastogi, President, MVTechnologies, Inc., Akron, OH, USA.

Proceedings America Society of Mining and Reclamation, 1994 pp 319-325

DOI: 10.21000/JASMR94020309

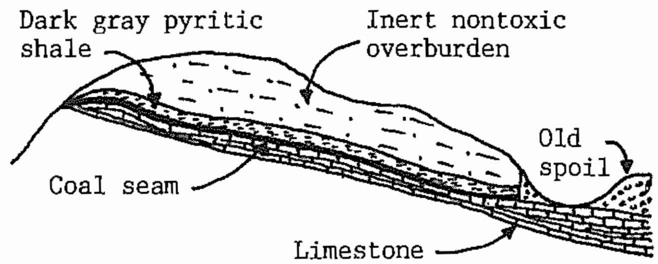
https://doi.org/10.21000/JASMR94020319

of Lower Bakerstown coal to be mined. Overburden analysis was requested by the Pennsylvania Department of Environmental Resources because an acid mine water discharge exists as a result of previous mining in the 1960's. Overburden analysis at the site identified two chemically and lithologically distinct and separate areas. The first area is the gray shale above the coal (fig. 1A), which the analysis showed to contain sulfur above 0.6% and neutralization potential generally well below 30. To the Pennsylvania Department of Environmental Resources, this is a potentially dangerous acid-producing zone (Smith and Brady 1990) and was of critical concern.

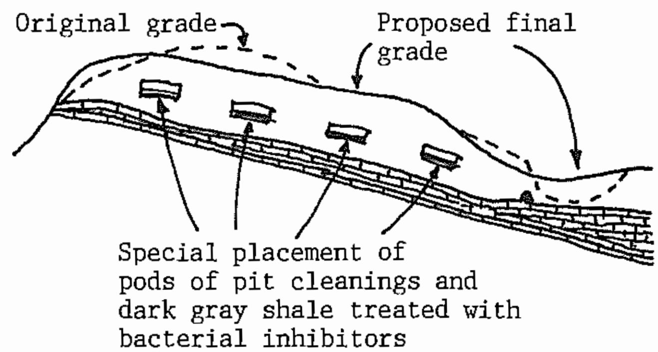
Table 1 shows the overburden analysis data. The second area is the brown sandstone, shale, and clay that comprise the remainder of the overburden from the top of the gray shale to the surface. This layer is mostly void of sulfur with all units less than 0.3% and all but one less than 0.01% and with positive net alkalinity.

The only significant alkaline unit on the site is the pit floor, which is a limestone as shown in table 1 and figure 1A. The mining and backfilling plan is designed to place some brown sandstone, shale, and clay spoil on the bottom. The gray shale is stripped by the drag and cast on top of the brown shale. Bacterial inhibitors are used to treat the gray shale to keep it from acidification. The concept is to keep pods of gray shale far enough above the pit floor so that it is not flushed by ground water which may flow over the pit floor after reclamation. Any rain water percolation will not acidify because the bactericide treatment will not let acid develop in the shale while it is exposed. The pods of gray shale are covered by clay and overburden well below the surface to prevent future contact with air. The operating plan is as follows:

1. The first cut is stripped utilizing a dozer and a dragline. The dozer pushes the top brown shale layer off and below the outcrop. The dragline casts the remaining spoil to the lowwall side. The last spoil removed from the pit is the dark gray shale (fig. 1B). As the spoil lies on the lowwall spoil pile, it is treated with surfactant bactericide applied as a water-based spray to keep it from producing acid while it is exposed to the elements.



A, Premining cross section



B, Postmining cross section

Figure 1. A, premining cross section of Cover Hill showing locations of coal seam, dark gray pyritic shale, and limestone; B, Postmining cross section showing selective placement of pods containing pit cleanings and pyritic shale after treatment with bactericide.

2. The coal is removed from the pit, and the pit floor is scrupulously cleaned of all coal waste. The impermeable limestone is left in place but is scarified with a dozer ripper blade to increase surface area and alkaline reactivity with any groundwater. All coal waste is special-handled by hauling it with a loader to disposal pods, which are constructed at least 10 ft above the pit floor. The pods are treated with bactericide surfactant spray.

Table 1. Overburden analysis data for Cover Hill.

Depth, ft	Thickness, ft	Graphic log	Lithologic description	Total sulfur,%	Fizz	$CaCO_3$ equivalent, st per 1,000 st of material: Neutralization Potential	Net Alkalinity
3	3		Topsoil, clay	0.007	0	0.96	0.74
6	3		Brown clay	0.008	0	2.60	2.35
15	9		Brown clay with sandstone	0.002	0	3.05	2.99
				0.002	0	2.75	2.69
				0.002	0	2.29	2.23
18	3		SS, shale stk	0.003	0	2.57	2.48
21	3		SS, clay	0.001	0	4.41	4.37
24	3		Hard clay	0.001	0	2.42	2.39
48	24		Soft brown sandstone and clay	0.002	0	2.93	2.86
				0.003	0	3.31	3.22
				0.009	0	3.95	3.67
				0.004	0	4.87	4.74
				0.002	0	5.22	5.16
				0.002	0	4.66	4.60
				0.008	0	6.09	5.84
				0.226	0	9.20	2.14
51	3		Soft gray ss	0.667	0	10.07	-10.78
60	9		Dark gray shale	0.647	0	12.18	-8.04
				0.687	0	10.91	-10.56
				1.180	0	22.28	-14.59
64	4		Dark gray shale	0.805	0	24.50	-0.66
				0.747	1	27.13	3.78
66	2		L. Bakerstown	3.670	0	1.37	-113.32
69	3		Limestone	1.070	3	192.19	158.75

3. The next pit is started by the dozer pushing brown shale into the previous pit. The spoil from the previous cut is partly backfilled into the previous pit. The remaining spoil from the next cut is cast into the previous pit. The dark gray shale is the last spoil removed from the pit. After it is cast on the spoil pile, it is treated with surfactant bacterial inhibitors in the form of spray. After removal of the coal, the pit is cleaned and any coal waste is handled as described previously.

4. As the pits progress, the regrading of the spoil is done concurrent with the removal of overburden from the pit being mined. The dark gray shale is always treated with bacterial inhibitor spray shortly after it is exposed. After the spoil is regraded, an application of bactericide controlled-release pellets is made. Subsoil and topsoil are applied to the surface, and the area is revegetated at the first available planting date.

The bacterial inhibitor spray solution used 280 lb of 88% active surfactant in 1,000 gal of water per acre of material to be treated, or the equivalent of 0.3 lb of active ingredient per ton of material treated. The controlled-release pellets are applied at the rate of 700 lb per surface acre and contain an average of 28% surfactant. Mining at this site commenced in February 1991. In more than 2 yr no acid seeps have developed at the site.

Application at an Active Refuse Disposal Area

In September 1991, a review of the Branchton Refuse Disposal Area, located in Butler County and operated by Adobe Mining Company, Kittanning, PA, showed that the alkaline addition plan for this site was not neutralizing all the acid generated. Discharge from the underdrain due to the refuse moisture content in the active disposal area was acidic and had high levels of manganese that the treatment ponds were inadequate for handling further neutralization without additional additives and maintenance. The entire proposed refuse disposal area is 39 acres in size. It was started in the summer of 1991, and thus far an estimated 900,000 st of refuse had been deposited over a 13.5-acre area.

The pyritic sulfur content of the combined coarse and fine refuse is as high as 14.2% with a neutralization deficiency in excess of 444 st per 1,000 st of $CaCO_3$ equivalent. Table 2 shows the sulfur forms analysis and the acid base account (Sobek et al 1978) for the refuse. The permit called for a 4-ft lift of combined coarse and fine refuse followed by a 1-ft layer of lime reject (approximately 3,000 st/acre), which has a $CaCO_3$ equivalence of 40% to 60%. The lime reject application was followed by a 2-ft layer of alkaline overburden. Additional measures to control the discharge quality included treating the refuse at the cleaning plant with caustic soda.

A new treatment plan consisting of spraying surfactant bacterial inhibitors was developed. The plan called for spray applications to be made four times a year, followed by controlled-release pellet applications prior to overburden cover. The spray used was 200 lb of 88% active sodium dodecylbenzene sulfonate per acre in 800 gal of water. Water used was taken from a nearby stream with a pH above 5 and iron content less than 7 ppm. The controlled-release pellets were applied at the rate of 600 lb per acre and had surfactant active ingredient ranging from 16.4% to 27.9%.

Bactericide spray applications were made the weeks of December 9, 1991, January 13, 1992, March 16, 1992, and August 10, 1992. The effect on underdrain water quality is shown in figure 2. Acidity (fig. 2A) dropped 88% from highs of 2,600 ppm to average around 300 ppm. Iron (fig. 2B) dropped 82% from highs of 1,000 ppm to average about 180 ppm. Most importantly, manganese (fig. 2C) dropped 90% from 50 ppm to 5 ppm. Without bactericides, manganese was extremely difficult to purge and was primarily responsible for the difficulties this site was experiencing in meeting permit requirements.

The Branchton site has since been able to meet water discharge criteria with the present treatment ponds.

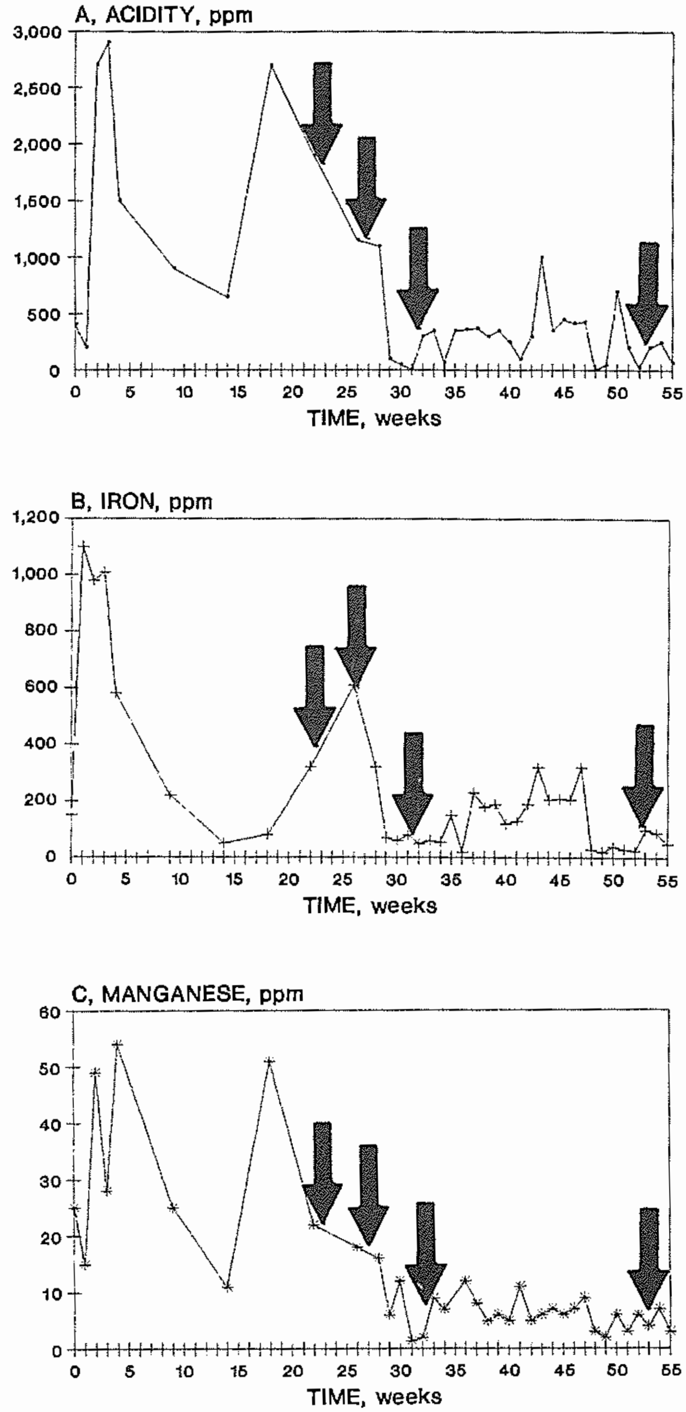


Figure 2. Underdrain water quality at the Branchton refuse disposal area before and after bactericide treatments. Black arrows indicate dates of bactericide applications.

Table 2. Analysis of refuse from the Branchton refuse disposal area.

Sulfur forms, percent				Paste pH	Acid-base account		
					$CaCO_3$ equivalent, st per 1,000 st of material		
Pyritic	Sulfate	Organic	Total		Acid potential from % sulfur	Neutralization potential	Net alkalinity
13.1	0.26	0.81	14.17	3.2	443.75	-0.65	-444.4

Application to Silver Mine Waste Rock

At a silver mine in Idaho, waste rock is placed into previously mined pits as backfil. In order to make an informed decision to use bacterial inhibitors at the site, laboratory column leaching tests were run to compare effectiveness of bactericide treatment with lime addition. These tests were run as described by Shellhorn and Rastogi (1984). Results of waste rock sulfur forms and acid-base account are given in table 3.

Table 3. Analysis of silver waste rock from Idaho mine site.

Sulfur forms, percent				Paste pH	Acid-base account		
					$CaCO_3$ equivalent, st per 1,000 st of material		
Pyritic	Sulfate	Organic	Total		Acid potential from % sulfur	Neutralization potential	Net alkalinity
0.365	0.119	0.002	0.486	4.8	15.19	0.19	-14.28

The control columns received no treatment, the bactericide columns received the equivalent of 0.1 lb of active surfactant to 1 st of material, and the lime-treated column received the equivalent of 14.28 st per 1,000 st of material as determined by the acid-base account. Results of the column tests, which were run for a period of 9 weeks, are shown in figure 3 for pH, acidity, sulfates, and T. ferrooxidans population control. In all cases, the bactericide treatment showed the best results, which are summarized in table 4.

As a result of the laboratory success, bactericide applications were made on site at a rate of 180 lb of active surfactant per surface acre applied with 800 gal of water. Each 60-ft lift was treated. Figure 4 shows results from lysimeters installed in the treated area and in an adjacent untreated area. The average improvement in water quality was 92.7% in acidity and 70.3% in sulfates. The water from the treated area averaged a pH of 5.6 over a 15-month period.

Table 4. Summary of column leach tests in 9 weeks.

Parameter	Control (no treatment)	Lime treated	Bactericide treated	% improvement bactericide over- Lime	% improvement bactericide over- Control
pH	3.33	3.7	4.3	16.2	30.3
Acidity, ppm	503	265	78	70.6	84.5
Sulfates, ppm	708	467	193	58.7	72.7
Bacteria, log MPN[1]	5	4.3	0	100.0	100.0
Iron, ppm	32.7	8.9	1.8	79.8	94.5
Manganese, ppm	2.05	2.49	1.57	36.9	23.4
Aluminum, ppm	59.9	33.8	1.8	79.8	94.5
Copper, ppm	2.61	1.96	0.48	75.5	81.6
Zinc, ppm	5.74	4.14	1.84	55.6	67.9

[1]Most probable number.

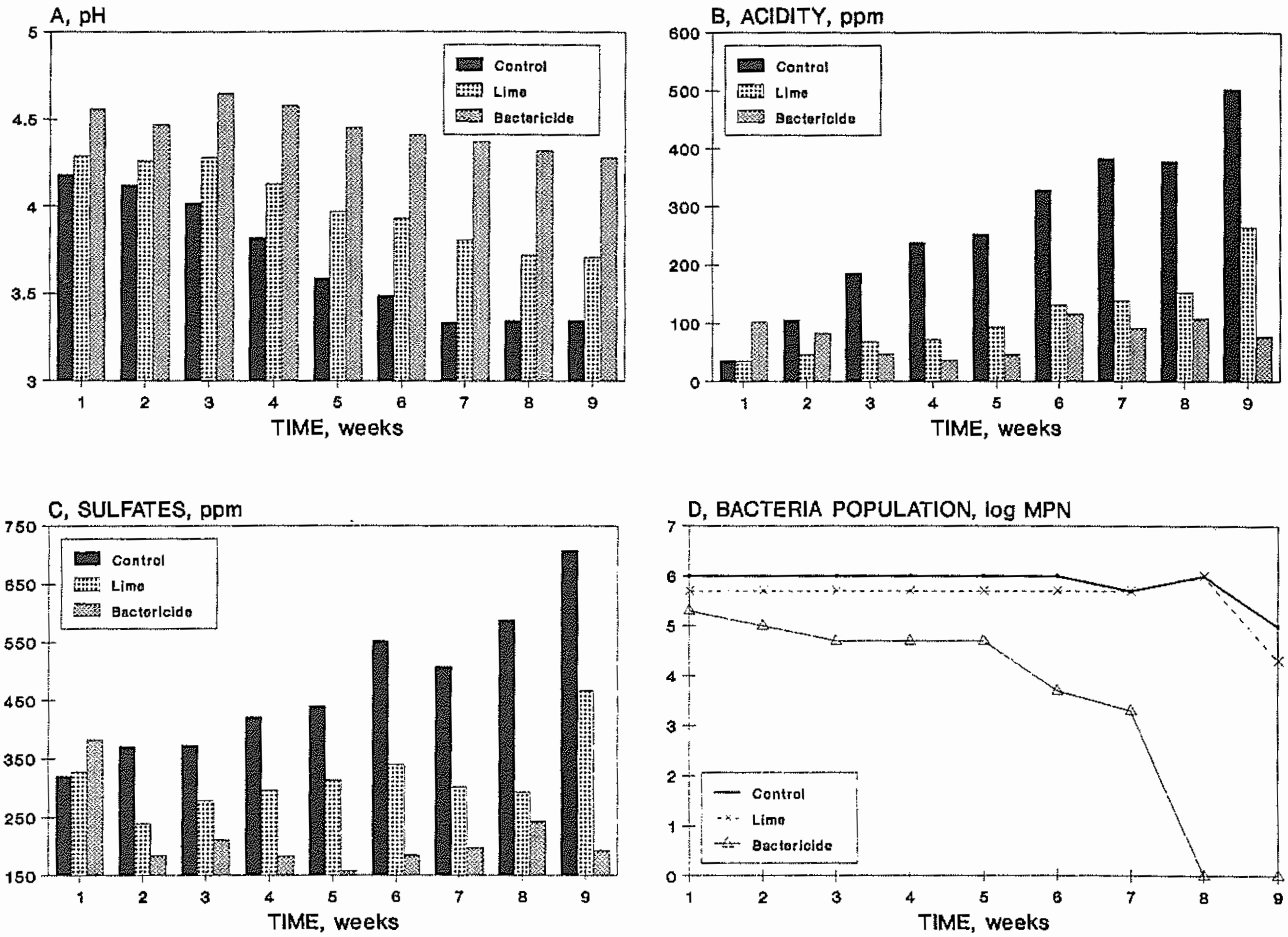


Figure 3. Results from column leaching tests on silver mine waste rock samples showing comparison between no treatment (control), lime treatment, and bactericide treatment in controlling (A) pH, (B) acidity, (C) sulfates, and (D) bacteria populations.

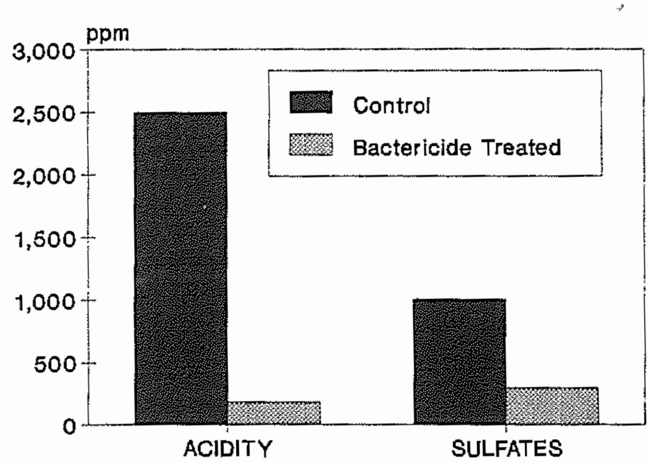


Figure 4. Actual water quality from lysimeters at mine site waste rock dump with and without (control) bactericide treatment.

Conclusions

The following conclusions can be drawn from these cases:

1. Bacterial inhibitors control acid generation and the subsequent solubilization of metals from diverse materials such as overburden, coal refuse, and metal mine waste rock.

2. Through proper planning, and utilizing a combination of technologies such as special handling, a systems approach to solving acid mine drainage can be successfully applied to resolve different problems.

3. Bactericide treatments achieve long term control through the use of controlled release systems and disciplined operations.

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