# LIME TREATMENT OF COAL REFUSE AT HPM A CONTINUING SUCCESS

by

## Douglas H. Rich

## INTRODUCTION

High Power Mountain (HPM) is a large surface mine located in the central portion of West Virginia. The mine began production in 1985 and has produce over 16 million raw tons. Production is by the mountaintop removal mining method using hydraulic shovels, front end loaders, and trucks (both 85 and 190 ton capacity). In addition, mining of a lower seam is by contour and highwall methods. Annual maximum production has reached 3.0 million run of mine tons and shipments have been upwards of 2.3 million clean tons.

The coal seams are in the upper portion of the Pottsville Series and lower portion of the Allegheny Series of the Pennsylvania Era. Seven seams are mined by the mountaintop removal method:

- Upper Kittanning
- Middle Kittanning
- Lower Kittanning (Five Block)
- Clarion
- Stockton "A"
- StocktonCoalburg

The seam mined by contour and highwall mining methods is the underlying Winifrede seam.

Each of the seams have multiple splits, with each split having varying coal quality. As a result the coals must be blended to meet customer specifications. This necessitates multiple coal pits being available for mining and thus multiple mining areas being in varying degrees of production. Typically, twenty to twenty five (20-25) different splits of coal are mined from the eight seams.

Coal processing is accomplished in a computer controlled preparation plant built in 1985. The plant circuitry consists of three heavy media cyclones to process the coarse size fraction (2in. x 28 mesh). Hydrocyclones and classifying cyclones are used to process the 28 mesh x 0in. material. The minus 100 mesh material, being higher in ash and moisture, is not recovered.

The minus 100 mesh material is combined with flocculant in the static thickener to enhance settling. The slurry material is pumped to the belt filter presses where the slurry is de-watered between two porous belts. The end product of this process is filter cake, a high clay content material having a moisture of approximately 28 to 30 percent.

The filter cake is carried by conveyor to the main refuse belt. Within ten feet of travel the coarse refuse is transferred onto the main refuse belt by means of chutes thereby making a combined refuse material. The combined refuse, having a moisture of 15 to 20 percent is conveyed to the 500 ton refuse bin. Transportation from the bin to the disposal site is by 85 ton capacity haul trucks.

## REFUSE DISPOSAL

The production of refuse varies between 600,000 to 700,000 tons annually. Thus, refuse at HPM is a major part of the total material handling system. In the initial design of the mine, refuse disposal was planned as part of the reclamation process. To this end the concept of the "refuse cell" was developed.

As initially conceived, the refuse cell was to be an integral part of the mine development process. The first phase of construction begins once the lowest coal seam is removed by mountaintop removal methods. The coal pavement is thoroughly cleaned to remove any potential acid producing material. Once completed the next step is to place an eight to ten foot layer of large shot rock (sandstone) on the pavement, forming the base. In practice, this layer acts as a french drain and is the under drain. As a benefit, the upward capillary action of groundwater is broken by the large interstitial space between rock fragments.

Construction continues with the placement of the outer dike structure. This berm consists of compacted soil and shale material. Water from the refuse cell is contained by this dike system and directed to the refuse cell sediment control structure. If needed, water can be treated at this point prior to release.

Once the outer dike is complete, a three to four foot layer of soil and shale is place to form an "impervious" barrier. The first level of the inner dike system is now ready to be constructed. This dike also consists of compacted soil and shale. Once a layer of refuse is placed, the next higher inner dike is constructed and that layer is filled with refuse. The process continues until design height is obtained. At this point, the cell is capped in a dome shape using soil and shale and grasses are planted.

The refuse is isolated from the environment, groundwater cannot enter by capillary action and the dome shape diverts rainfall to the outside dike, thereby reducing infiltration. Thus after interstitial water is squeezed out by weight of compaction the long term environmental impact is minimized or eliminated. If water quality does not meet standards, the outer dike system diverts the water to a central sediment control structure where it can be treated prior to release.

## REFUSE QUALITY

The sulfur content of the various coals vary by seam and therefore the acid producing potential of the refuse also varies. Table I illustrates the sulfur content of the seams at different float/sink gravities.

TABLE I

PERCENT SULFUR
BY SEAM

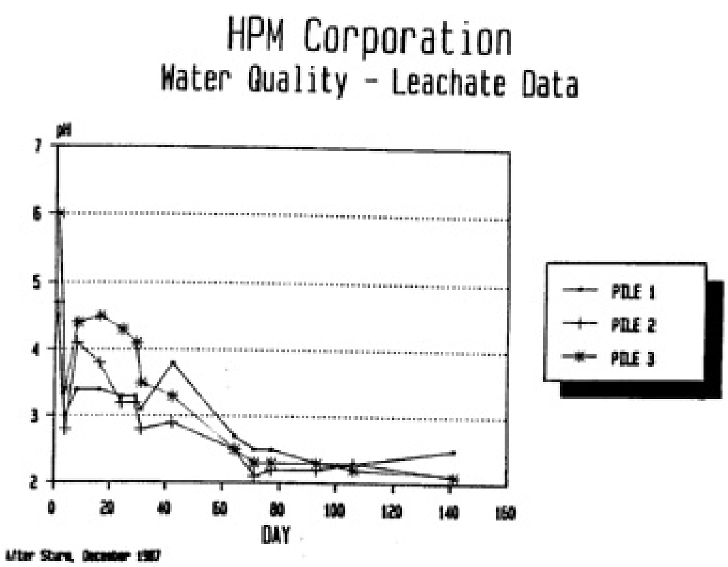
| Seam | Raw | Float 1.60 | Float 1.45 |
|---|---|---|---|
| Upper Kittanning | 1.32 | 0.98 | 0.92 |
| Middle Kittanning | 0.95 | 0.85 | 0.85 |
| Lower Kittanning | 0.66 | 0.68 | 0.69 |
| Clarion | 0.83 | 0.84 | 0.83 |
| Stockton "A" | 0.71 | 0.71 | 0.76 |
| Stockton | 4.97 | 3.53 | 3.13 |
| Coalburg | 1.11 | 0.93 | 0.93 |
| Winifrede | 0.65 | 0.68 | 0.68 |

Overall the sulfur content is generally less than one percent. However, the Stockton seam is the notable exception. The sulfur in the run of mine Stockton coal varies from 4% to 6% and remains high (3%) even after the coal is cleaned. The Stockton refuse also contains an elevated level of pyritic sulfur.

Initial laboratory testing of the HPM refuse consisted of acid base accounting and column leaching. These tests showed the refuse to be 26 to 53 tons for every 1,000 tons of material CaC03 equivalent deficient.

Once the plant began operation, field tests were conducted by placing low sulfur (0.9 per cent), medium sulfur (1.1 per cent) and high sulfur (2.5 per cent) refuse in three separate test sites. These sites were exposed to rainfall and weathering. Water samples were collected on a regular basis. Figure 1 delineates the change in pH over time. As shown, the water acidified very quickly.

Figure 1




From laboratory and field testing the data indicated the refuse at HPM generates acidic waters. If this problem was not addressed these waters would be a continuing source of environmental problems, not only in pH but also in the mobilization of metals (i.e., iron and manganese).

## NEUTRALIZATION

Acid generation is the result of the oxidation of pyrite. In the presence of water this reaction generates iron hydroxide (Fe(OH)) and sulfuric acid ($H_2SO_4$). Studies have shown that, in the presence of iron consuming bacteria (Ferrobacillus and Thiobacillus), the oxidation rate of pyrite is-greatly enhance. Thus the generation of sulfuric acid is also enhanced. In the absence of bacteria, the natural oxidation of pyrite and thus generation of sulfuric acid occurs at a reduced level.

It was evident from the testing that neutralization of the refuse was required. Five neutralizing agent were applied to bulk samples of 25-30 tons. These agents included:

- Ag lime
- Spent lime
- Limestone rock dust
- Phosphate
- Lime kiln dust

With the exception of the phosphate, all agents neutralized the refuse but to varying degrees.

The method first used by HPM to treat refuse consisted of slurrying limestone rock dust and spraying it over the top of the refuse piles. This occurred after the combined refuse was back-dumped into the cell. The intent **was to add** alkalinity. Rainfall, buffered by the limestone, would permeate through the back-dumped pile and neutralize the acidic waters. In practice however, the low reactivity of limestone rock dust did not allow for a sufficient increase in alkalinity nor did the rainfall permeate uniformly throughout the piles. Thus acidic waters continued to generate. These waters were treated in the refuse sediment control structure prior to release.

Concurrently, operational problems were encountered in the refuse cell. In order to place the next layer of combined refuse into the cell a rock bridge was required to be placed on top of the back-dumped piles. This rock bridge, overlying the non-stable combined refuse, needed to be of such thickness so as to support the fully loaded refuse trucks. This situation required over fifty percent of the refuse cell being filled with rock bridge material thereby dramatically reducing the active life of the cell.

Therefore, two problems needed to be addressed. A more efficient method of neutralization was required and a way to stabilize the combine refuse was needed.

## APPLICATION OF LIME CHEMISTRY

The initial neutralization data suggested that the use of calcium oxide provided greater neutralization potential than the use of limestone rock dust. Also, lime use for soil stabilization of clayey material has been use in the construction industry for years. It was decided to modify the operating procedure and use lime kiln dust as the neutralizing agent instead of limestone rock dust.

Lime kiln dust is a by product of the lime industry, being generated during the calcining process. Crushed limestone is heated in a rotary kiln, driving off the carbon dioxide and producing calcium oxide. In the process of calcining, the heated air stream picks up dust consisting of calcium oxide and un-calcined calcium carbonate. In addition, the coal fly ash is also carried in the stream. The air is passed through a bag house to remove particulate matter prior to being released to the atmosphere. The dust contains approximately 15 percent calcium oxide, 75 percent calcium carbonate, and the remaining percentage is fly ash (high in silica and alumina).

Lime kiln dust is alkaline, producing a pH of 12.4 in a saturated solution. In addition to its obvious neutralization potential, it also acts as a drying agent forming calcium hydroxide when the calcium oxide comes in contact with water.

The mechanism for the soil stabilization process is facilitated in a high pH environment and occurs during the ionic substitution of calcium into the clay mineral lattice crystal structure. The soil-lime reactions are complex and not completely understood. According to Chou (1987), an oversimplified qualitative view of some typical soil-lime reactions are:

- $Ca(OH)_2$ > $Ca^{++}$ + $2(OH)^-$
- $Ca^{++}$ + $2(OH)^-$ + $SiO_2$ > Calcium Silicate Hydrate (CSH)
- $Ca^{++}$ + $2(OH)^-$ + $Al_2O_3$ > Calcium Alumina Hydrate (CAH)

J.L. Eades (1962) suggests the high pH causes silica from the clay minerals to dissolve and, in combination with $Ca^{++}$ form calcium silicate. Diamond, et al. (1964) theorized that lime molecules are absorbed by clay surfaces and react with other clay surfaces to precipitate reaction products. These studies suggest the clay lattice components are dissolved from the clay structure and are precipitated as CSH and CAH. Stoker (1972) proposes the diffuse cementation theory in which lime reacts directly with clay crystal edges, generating accumulations of cementatious material.

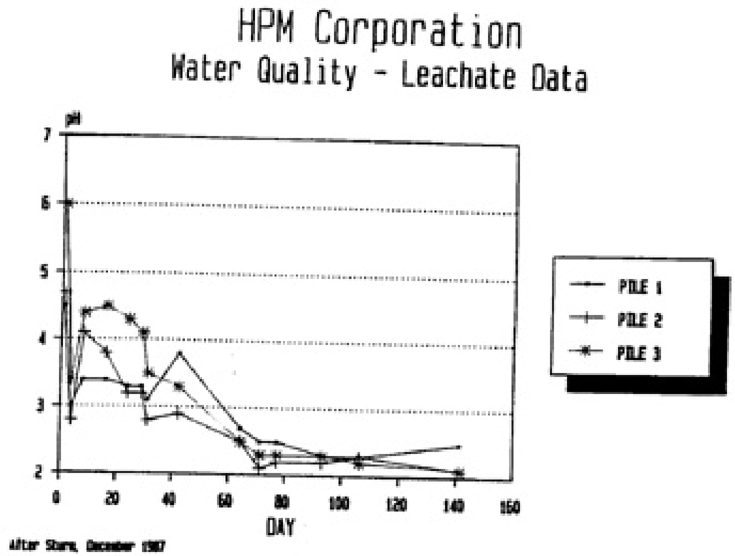
## DISCUSSION

Regardless of the theoretical reactions, application of lime kiln dust at HPM appeared to offer the solution to the operational problems of combined refuse disposal in the refuse cells.

In 1989 a bin was erected directly over the preparation plant refuse belt and the lime kiln dust application process begun. This placement increased the contact of the kiln dust with the refuse thereby providing greater mixing potential. The refuse moisture, combining with the calcium oxide component, drys the refuse and generates an alkaline environment. This is immediately noticeable in that the refuse is able to maintain a sharp angle of repose.

The generation of calcium hydroxide is the key chemical reaction to the treatment of the refuse. The high pH environment facilitates:

Figure 1

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## NEUTRALIZATION

Acid generation is the result of the oxidation of pyrite. In the presence of water this reaction generates iron hydroxide (Fe(OH)) and sulfuric acid ($H_2SO_4$). Studies have shown that, in the presence of iron consuming bacteria (Ferrobacillus and Thiobacillus), the oxidation rate of pyrite is greatly enhance. Thus the generation of sulfuric acid is also enhanced. In the absence of bacteria, the natural oxidation of pyrite and thus generation of sulfuric acid occurs at a reduced level.

It was evident from the testing that neutralization of the refuse was required. Five neutralizing agent were applied to bulk samples of 25-30 tons. These agents included:

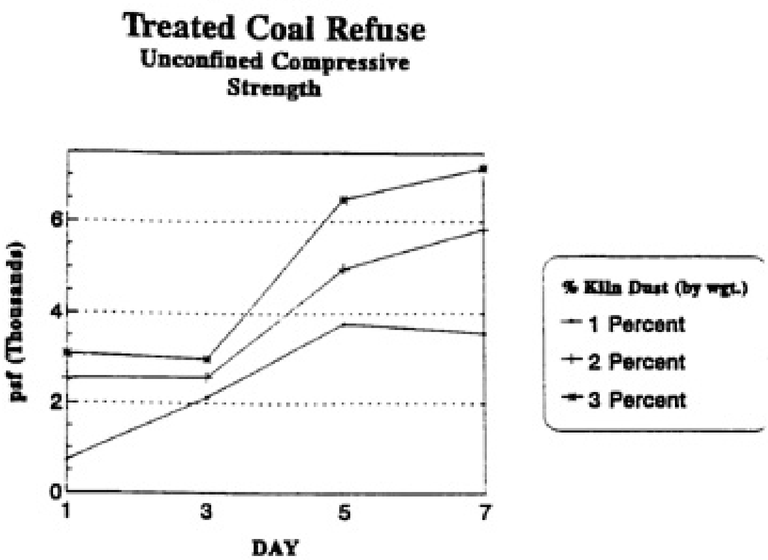
- Ag lime
- Spent lime
- Limestone rock dust
- Phosphate
- Lime kiln dust
- The elimination of Ferrobacillus and Thiobacillus bacterium.
- Provides the pH environment required for soil stabilization.

By elimination of the bacterium the rate of pyrite oxidation is substantially lower and thus the generation of sulfuric acid is decreased. The acid generation is now dependant on the slow, natural oxidation of pyrite. The long term control of acid generation is controlled by the calcium carbonate component of the kiln dust. With its lower reactivity rate, the dissociation of calcium carbonate keeps pace with the slow oxidation of pyrite. Thus an alkaline environment is maintained and acid generation in controlled.

The high pH environment drives the complex soil-lime soil stabilization reactions. These reactions, noticeable in the refuse cell three to five days after refuse placement, stabilizes the refuse. By allowing the refuse to stabilize the rock bridge construction technique is no longer needed. Fully loaded refuse trucks (85 tons back-dump trucks) are able to drive directly on top of the stabilized combined refuse for lift placement.

Proprietary studies have shown strength is gained over time. Samples of refuse mixed with varying percentages of kiln dust were tested. Figure 2 shows the unconfined compressive strength obtained over time using 1%, 2%, and 3% kiln dust (by weight) additive. These data are site specific and are presented only as an example of the effect of the soil-lime stabilization reactions.

Figure 2




## CONCLUSIONS

The refuse cell concept is a leading edge technology for the handling of coal refuse in an environmentally safe manner. Since 1989 HPM has been using lime kiln dust as an additive to its combined refuse. From the experience which has been gained, a successful method of treating acid mine drainage has been developed, not only for the near term but also over the long haul. Treatment of water associated with the refuse disposal system has not been required since the application of lime kiln dust began. Water quality, both pH and metals, has remained within NDPES limits for the last four years and indications are that the refuse will not become an environmental problem in the future. By use of the refuse cell concept, including treatment with lime kiln dust, the long term environmental liability appears to be minimized.

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