NEUTRALIZATION AND STABILIZATION OF COMBINED REFUSE USING LIME KILN DUST AT HIGH POWER MOUNTAIN [1]

by

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and

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Abstract. High Power Mountain Corporation (HPM), a large coal surface mine in central West Virginia, disposes of filter cake and coarse refuse by means of "refuse cells". These cells are designed to encapsulate the combined refuse, isolating the material from the hydrological system, and provide an environmentally sound method of refuse disposal.

Lime kiln dust, a by-product of the lime industry, is admixed with the refuse to:

- Increase pH and alkalinity,
- Inhibit bacterial growth, and
- Limit formation of acid water.

- $Ca[OH]_2 \rightleftharpoons Ca^{++} + 2[OH]^-$
- $Ca^{++} + 2[OH]^- + SiO_2$ (clay silica) CSH
- $Ca^{++} + 2[OH]^- + Al_2O_3$ (clay alumina) CAH

In addition, the lime kiln dust has the added benefit of stabilizing the combined refuse. The requirement of "rock bridges" needed to support 85 ton refuse trucks in the cell is no longer necessary. Therefore, the volume of the refuse cell is totally utilized by refuse and not a combination of the refuse and the rock bridge material.

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[1] Paper presented at the 1990 Mining and Reclamation Conference and Exhibition, April 23-26, 1990, Charleston, West Virginia.

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Introduction

High Power Mountain (HPM) , located in the western portion of Nicholas County, is approximately sixty five miles east of Charleston, West Virginia. Summersville, the county seat of Nicholas County, is located approximately twelve miles east of the mine site.

HPM is a mountaintop removal operation mining seven seams. Also, a contour/highwall operation mines a lower seam for a total of eight seams. The mining is performed for HPM by a contract miner, High Power Energy (HPE) , and the preparation, shipment and sales are performed by HPM. In 1990 approximately 2.3 million tons of coal will be shipped from the property. At this shipment level, upwards of 900,000 tons of combined refuse will be generated.

Mining

Surface mining is performed by front-end loaders, shovel, and trucks. The overburden is removed by a 19 cubic yard Demag hydraulic shovel and 13.5 and 22 cubic yard front-end loaders. Trucks consist of 85 ton Caterpillars and 200 ton LeTourneaus. The majority of the overburden is a very fine to fine grain, buff colored, micaceous sandstone. A minor amount of shale is present. Cast blasting is performed in selected mining areas.

The seven coal seams mined by the mountaintop removal method are the:

- Upper Kittanning
- Middle Kittanning
- Lower Kittanning (5-Block)
- Clarion
- Stockton A
- Stockton
- Coalburg

The lowest seam mined at the HPM is the Winifrede seam. Mining of this seam is by the contour method followed by highwall mining using the Metec mining system.

The coal seams are in the upper portion of the Pottsville Series and the lower portion of the Allegheny Series of the Pennsylvanian Era. Most seams are multi-benched, ranging from two to five benches, with intercalated shale partings. Because the quality of the coal varies both horizontally and vertically, the coal is mined by split loading of the benches. Prior to coal loading, the shale partings are removed. Typically, the loading operations consist of twenty to twenty-five different loading sequences for all eight seams. Coal loading is accomplished by a 26 cubic yard coal bucket attached to a Caterpillar 992 front-end loader, loading into 85 ton Dart coal haulers.

Preparation

The coal is mined, weighed and delivered to the HPM preparation plant, crushed to minus eight inches, and transported via two 42 inch belts to one of three raw coal stockpiles. Under the stockpiles a 42 inch reclaim belt delivers the coal to the plant crushing and screening station. The coal is crushed to minus two inches (-2") before being washed.

The plant is computer controlled and consists of three parallel washing circuits. The heavy media cyclones clean the coarse size fraction (2" x 28 mesh) . The fine coal circuits consist of hydrocyclones and classifying cyclones for the 28 mesh x 0 inch material. During cleaning the minus 100 mesh material is not recovered. The fine reject material is pumped to the refuse thickener, combined with flocculants to enhance settling, and pumped to one of three belt filter presses. At the belt filter press, additional flocculant is added and the slurry is pressed and de-watered. The filter cake, approximately 28-30% moisture, falls on to the filter cake belt which transports the cake to the main refuse belt. At this point the filter cake is combined with the coarse refuse.

The clean coal is stored at the plant in one of three eight thousand clean coal stockpiles. From here, the coal is hauled to one of three stockpiles at the unit train loadout facility. Train loading is at a rate of 4,500 ton per hour using a computer batch-weighing, flood-loading system and a continuous railroad loop. Loading a 13,500 ton train typically takes 3 hours.

Methods and Materials

Refuse Cells

The refuse cell concept is new to the coal industry and is based on the idea of encapsulating the refuse material and isolating it from the environment. The refuse cells are placed in mined out areas on the tops of the mountains. Areas designated for future refuse cells are mined by mountaintop removal and the coal is removed to the pavement of the lowest seam. Construction of the cell begins by the placement of a berm around the cell area to contain water and divert it to the sediment control structures. Once the berm is constructed, an inner dike of impervious material is built to contain the refuse. A ten foot layer of large shot rock is placed on the floor of the cell, providing a french drain. This disrupts the capillary action by groundwater from the pavement to the cell property. on top of the shot rock, a three to five foot layer of shale is placed to make an impervious layer.

Once the initial work is complete, refuse is hauled into the cell and dumped by the 85 ton trucks. When a layer of refuse has been placed, the next higher level is constructed using a second inner dike structure. The process is repeated until design height is attained. When the cell is full, the top and sides of the cell are covered with shale in a dome shape. The entire cell is covered with two to four feet of soil and reclaimed with grasses. The shale, soil, and dome shape help divert rainfall to the outside berm and reduce infiltration of water into the cell. Thus, the refuse becomes encapsulated and, after interstitial moisture is squeezed out, the long term environmental impact is minimized or eliminated. If water from the cell becomes a problem, the outside berm structure captures and diverts the water to a central pond where treatment can occur.

Refuse Quality

The nature of the refuse varies and is a function of the particular coal seam or split being cleaned. The amount of fines in the static thickener determines the activity level of the three belt filter presses. Typically, the filter cake fraction is 20% to 35% of the refuse. However, there are times when the refuse is either all filter cake or all coarse material. The percentage of pyritic sulfur varies in the refuse. The vast majority of the coal seams at HPM are low sulfur (<1%) and thus the refuse generally contains less than 1% pyritic sulfur. However, the Stockton seam, representing about 5% of the reserve, is high in sulfur and when it is cleaned with the other coals the pyritic sulfur of the refuse climbs to over 1%.

When the project started, the refuse was tested to determine the quality and the acid producing potential of the material. Sturm Environmental Services, Inc. was contracted to do both laboratory bench testing and actual field testing. The lab testing consisted of acid-base accounting and column leaching. These tests showed the refuse to be 26 to 53 tons per 1000 tons of material $CaCO_3$ equivalent deficient. Thus, the refuse required neutralization treatment.

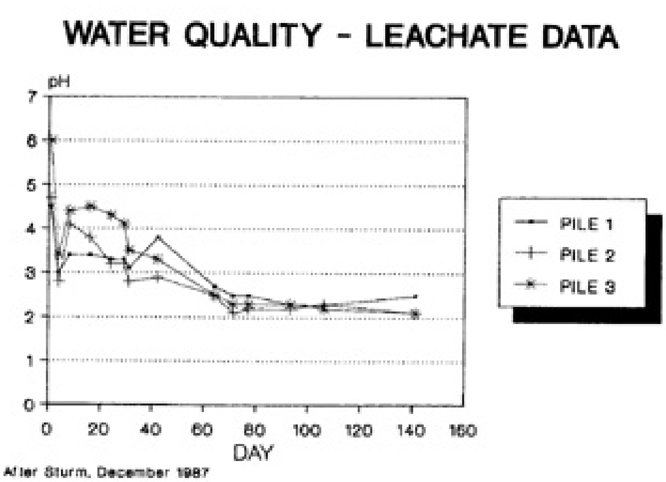
Field testing was developed by placing low (0.9%), medium (1.1%), and high (2.5%) sulfur refuse in three separate test areas. These areas were constructed by placing a small two foot berm around a 15 x 20 foot area lined with plastic. A discharge pipe was placed through the lower portion of the berm and water samples collected. The graph in Figure 1 delineates the change in pH over time. As shown, the water acidified very quickly.

The next step was to determine the method needed for neutralization and the associated economics. This portion of the study concentrated on applying five different neutralizing agents to a bulk sample (25-30 tons) of refuse and testing the effectiveness of each.

Agents tested include:

- Ag Lime
- Spent Lime
- Rock Dust
- Rock Phosphate
- Lime Kiln Dust

A second investigation concentrating on bacterial growth was conducted to establish the relative amounts of iron oxidizing bacteria and the effects of changing from an acidic to alkaline environment. With the exception of the rock phosphate, all the agents neutralized the refuse but required various rates of application. Also, the bacterial growth was inhibited by increasing the alkalinity of the interstitial moisture.



Results and Discussion

Initial Refuse Treatment

After internal discussions a decision was made to treat the refuse by use of limestone rock dust. The method employed was to treat the refuse after the trucks dumped the material into piles within the cell. The limestone rock dust was slurried and "hydroseeded" on top of the piles. This allowed water to be buffered prior to entering the underlying piles. This method worked with somewhat satisfactory results but did not allow for a good mix of the limestone rock dust in the internal portions of the piles.

Limestone rock dust was used during the construction of the first refuse cell and a portion of the second cell. As an added precaution, when the final layer of refuse was placed in the first cell, a bacterial inhibitor was applied to the top of the refuse to further reduce bacterial growth. Even at an added cost, it was felt the bacterial inhibitor would provide additional protection prior to covering the cell with the dome material. This cell, completed in September 1987, has been reclaimed and seeded. One small leak in the upper inner dike system occurred; however, it has since stopped. This leak was attributed to the weight of the overlying material squeezing the interstitial moisture out of the refuse. The water from the leak was somewhat acidic but was contained within the berm and pond system, neutralized and released.

Operational Problems

During the construction of the first cell and a portion of the second refuse cell, two problems existed which needed to be addressed:

1. Volume of rock between refuse layers required to support 85 ton trucks, and
2. Increase efficiency of neutralization.

First, to support the weight of fully loaded (gross weight approximately 190 tons) refuse trucks on top of the combined refuse, it was necessary to place a 5 to 7 foot rock "bridge" between the refuse layers. This rock "bridge" allowed the trucks to drive on top of the refuse but it also consumed over 50% of the volume within the cell. The active life of the cells and the ability to handle refuse was therefore substantially reduced. Besides the shortened life of the refuse cell, the required rock material added to the overall cost of cell construction.

The second problem was to evaluate and develop a better neutralization system so as to provide for greater admixing of the neutralizing agent and refuse constituents. This evaluation led to serious consideration of lime kiln dust. Also the decision was made to apply the dust directly to the refuse from a bin situated over the main refuse belt. Application was to be made prior to the refuse entering the refuse storage bin so as to take advantage of the mixing that occurs during movement of the material.

Lime Kiln Dust

Lime kiln dust, a product of the lime industry, is the by-product of calcining limestone in rotary kilns. The gasses and dust generated from this process are directed through a baghouse where the dust is collected and the gasses vented to the atmosphere. This dust material contains 15% to 18% calcium oxide (CaO) , 70% to 75% calcium carbonate ($CaCO_3$), and the remaining portion 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 neutralizing potential, lime kiln dust also acts as a drying agent, forming calcium hydroxide when it comes in contact with water.

The mechanism for the stabilization process is the pH increase which causes the calcium hydroxide to combine with the fly ash and clay minerals in the refuse. 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:

$Ca[OH]_2 + Ca^{++} + 2[OH]^-$

$Ca^{++} + 2[OH]^- + SiO_2$ (clay silica) CSH

$Ca^{++} + 2[OH]^- + A12O_3$ (clay alumina) CAH

J.L. Eades (1962) suggests that 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 reprecipitated as CSH and CAH. Stocker (1972) proposes the "diffuse cementation" theory in which lime reacts directly with clay crystal edges, generating accumulations of cementatious material. It appears that chemical reactions occur and new phases nucleate directly on the surfaces of the clay particles.

The reaction of the calcium hydroxide with the clay mineralogy of the refuse and fly ash not only produces the required neutralization but also the stabilizing effect. The calcium hydroxide has the added benefit of reacting with available sulfate radicals to produce the mineral gypsum (calcium sulfate).

Application of Kiln Dust

The lime industry is under environmental constraints as is the coal industry. Whereas coal refuse generally tends to be acidic, lime kiln dust produces alkaline conditions. By addressing the by-product problems (acidity and alkalinity) of both industries it appeared a symbiotic relationship existed. Besides the neutralization aspects, the use of lime kiln dust with its stabilizing properties appeared to offer HPM a solution to the volumetric and cost problems resulting from the rock bridges within the cells.

In the third quarter of 1988, HPM began the process of applying lime kiln dust to the refuse. The lime kiln dust, obtained from APG Lime Corp., located in Ripplemead, Virginia, is transported to HPM via trucks equipped with pneumatic transferring systems. After off-loading into the lime kiln dust bin, the dust is metered onto the belt by means of a variable rate screw conveyor. The application rate is approximately 2% by weight of the refuse being generated. At the computerized control panel located in the preparation plant, the rate of refuse generation is displayed on a video monitor. As the rate changes, the plant operator has the ability to adjust the screw conveyor.

Since the beginning of the application program, several key factors have been learned regarding the handling of the lime kiln dust. The first factor is that dust behaves both as a solid and as a fluid. When de-aerated, the dust has to be mechanically activated to flow. However, if the material is aerated, it flows as a fluid and, unless contained, will flow directly through the screw conveyor. When off-loading from the delivery truck it is necessary to ensure the positive pressure is minimized in the dust bin.

The second key factor is that the lime kiln dust is most effective when it is in contact with the high moisture filter cake. This cake, with its large surface area and associated chemical flocculant, does not dry easily. The lime kiln dust, if in contact with the cake, helps to dry the material and make it workable. The problem at HPM is that the coarse size fraction rests directly on top of the filter cake and not vise versa. Application of the dust is performed immediately after the refuse leaves the plant. To solve this problem, access to the filter cake was gained by installing belt plows. The first plow is situated prior to the dust application point and is used to open the coarse refuse. Once past the application point, a series of plows roll the coarse refuse back on top of the filter cake, trapping the dust between the coarse and fine material.

Refuse Disposal

As with the problems associated with the application of the kiln dust, the handling and placement of the treated refuse material in the refuse cell required rethinking of past practices. The original method was to dump pile against pile and, on a sporadic basis, push the refuse with a dozer or front-end loader. Prior to kiln dust treatment, the combined refuse material was difficult to handle and would not shed water in a reasonable timeframe (i.e., three to five days) . Once the refuse became treated on a somewhat regular basis, the handling problems were addressed. The first attempt to handle treated refuse in the cell was to push the refuse into high piles by a dozer. This method not only pushed up the refuse but also pushed water back into the refuse which had accumulated on the cell floor.

To solve the problem, a rock road was built in the middle of the refuse cell approximately 10 to 15 feet above the cell floor. The treated refuse was then end dumped from the rock road down into the cell. A dozer and operator were assigned full time to push and level the treated refuse. This enabled the dozer to push the refuse down and at the same time allowed the water being shed from the refuse to drain away from the piles.

A second standard operating procedure was also instituted. It was noticed that if the piles were contiguous to each other, the excess water was trapped between the piles. The procedure was modified so that the piles were dumped with a space between adjacent piles. This allowed water to be channeled away from the piles.

Once these handling problems were addressed, the effects of the lime kiln dust became apparent. The dust not only neutralized acidic waters but also, if dozed flat and left untouched for two to three days, the refuse began to stabilize. This stabilization process, driven by the pH and pozzolan nature of the calcium hydroxide, fly ash (with associated silica and alumina) , and clays began to firm the combined treated refuse material. Within a total of five days it was possible to drive a fully loaded refuse truck on top of the material with minimal (5 inches) indentation of the refuse material by the truck tires. The work of developing handling procedures and the successful results of stabilization and treatment occurred during a time of above normal precipitation (first half of 1989). Even with the high proportion of rainfall, the treated refuse stabilized to a point of being able to support the weight of the loaded trucks.

As experience was gained, it was determined that multiple end dump sites within the refuse cell were needed. This would allow the required time for the refuse to stabilize. To this end, three distinct dumping areas were developed. From these sites a sequential dumping pattern was used, giving the refuse time to stabilize. As time has progressed, the three dump sites have become progressively larger and spread out. This has given additional area for dumping and a proportional increase in refuse stabilization time.

Summary

Since the inception of HPM, the concern for the long term effects on the environment has been one of the factors in the planning process. The refuse cell concept is a "leading edge" technology which, to date, appears to be a very successful method for handling refuse. The addition of the lime kiln dust to the combined refuse has had the **anticipated** positive effects. Because calcium oxide has a higher degree of reactivity and the lime kiln dust is being mixed more intimately, the neutralization of the refuse is occurring with a higher degree of success. Secondly, and equally important to uninterrupted operations, is the stabilization resulting from the pozzolan nature of the materials. Volumetrically, a refuse cell which was designed to contain 20 million yards of material can now hold 20 million yards of refuse. Without the kiln dust, the rock bridges use over 50% of the volume. With the lime kiln dust the life of the refuse cell has been substantially increased.

Although proprietary in nature, several generalized comments can be made regarding the economic impact of using lime kiln dust in the refuse cells. First, the cost of neutralization by the combination of hydroseeded limestone rock dust and bacterial inhibitor approximates the cost of using the lime kiln dust. Secondly, because rock bridges are no longer required to support the refuse trucks, the cost of rock transport and placement is eliminated. And thirdly, with the extended life of the cells, fewer cells are required, saving permitting, construction, and monitoring costs.

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