Physical and Chemical Characteristics of Small Coal Refuse Piles[1]

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ABSTRACT: Numerous small coal refuse piles dot the landscape in the eastern coal producing areas. These refuse piles most often are aesthetic eyesores and contribute to water quality degradation due to AMD and excessive sediment discharged to receiving streams. These refuse piles generally constitute priority 3 problems under OSM Title IV abandoned mine lands (AML) program. Due to the low priority and limited funding of the AML program, there is little likelihood for their reclamation. Local stakeholders favor corrective action regarding these wastes due to their contribution to the pollution of surface and ground water, to a degrading esthetic effect and to the loss of land values occupied by the piles.

This study reviews chemical and physical characteristics of selected refuse piles and the environmental problems that they cause. It presents data showing size and location of these features. The study covers six states in Appalachia (Alabama, Kentucky, Ohio, Pennsylvania, Virginia, and West Virginia). It also reviews past and current approaches to reclamation and remediation of the environmental problems associated with the piles.

Identification of small refuse piles and their physical and chemical characteristics will greatly aid their cleanup and subsequent reclamation by the economical removal of the coal contained within the piles. These piles constitute a viable resource. Data presented in this report indicate that it is economically feasible to remine many of these piles - they still contain burnable coal and thus can be burned directly in small cogeneration facilities or cleaned at modern facilities to recover the coal. Other uses for coal refuse may include: surface and subsurface fill, road base, light weight aggregate, cement, mineral-chemical recovery, and mixing with a cohesive material to form a low cost briquette fuel.

Additional Key Words: bony piles, coal tailings, gob piles.

Introduction

The large deposits of coal in the eastern United States have been the foundation for the industrialization of the area. The coal fields extend from northern Pennsylvania south to Alabama and as far west as the Great Plains. These deposits were originally developed by underground mining, but since World War II, surface mining has also been used to extract the resource. Unfortunately, most of the coal found in this region has a high sulfur content and must be cleaned prior to being used as a fuel. The sulfur occurs as organic sulfur (sulfur bound to the coal) and as inorganic sulfur (found as pyrite or iron sulfide).

Beginning with 1977 the disposal of coal refuse has been regulated under the Surface Mining Control and Reclamation Act of 1977 (SMCRA). Physical coal cleaning removes the ash-forming impurities along with pyrite. The current process includes crushing the coal to a size where mineral and coal particles can be separated by using the differences in density or surface properties. Older techniques used a visual separation of the coal from the impurities (referred to as binder, bony, or slate) at the mine site. This method rejected some coal with the impurities. One of the resulting by-products of cleaning coal is coal refuse. Prior to SMCRA, the refuse was normally piled near the mine entry, or dumped over a hill as a valley fill material. This practice exposed the minerals to oxidation and leaching by precipitation or surface runoff infiltration into the dump. This results in acid mine drainage (AMD) which enters and degrades the groundwater or streams of the area.

The problems associated with coal refuse piles have long been recognized and various activities have been developed to reclaim and utilize them. According to the U. S. Bureau of Mines (undated) local stakeholders favor: 1) solutions to the surface and ground water pollution originating within the refuse piles, 2) removal of the piles to prevent fire and air pollution hazards, 3) removal of the piles for esthetic improvements and 4) beneficial use of the land

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occupied and associated areas where value has been depreciated through refuse disposal.

Through the decades, thousands of acres of land were disturbed in surface mining operations and miles of underground workings in deep mines were abandoned as the coal was mined out. Thousands of miles of streams were contaminated with sediment and mine drainage. The acres of abandoned surface mined lands and refuse piles presented an ugly scar on the landscape. Some refuse piles occupy areas within municipal boundaries and are located on potentially valuable land. As the industry of the region changes, the presence of these piles represents a deterrent to community progress (Ziemkiewicz and Skousen, 1996).

The refuse piles are highly variable in content, ranging from high grade coal and clays to silica rock. Even as the material placed in the piles varied, the material in place is undergoing change. Thus, the piles represent a variable, unstable material ranging in size from fines to boulders in different stages of oxidation and change. The environmental problems associated with the refuse piles include sedimentation of stream channels, acid mine drainage production that degrades surface and ground waters. The piles may also spontaneously combust or be intentionally burned causing air pollution for neighbors (US Bureau of Mines, undated).

Conventional reclamation of coal refuse piles includes leveling and grading the pile to a mild slope. Clay and soil or an alkaline amendment is placed on top of the pile to act as a growth media for grasses to prevent erosion and reduce infiltration of precipitation. Unpublished data from the Somerset County, Pennsylvania Office of the United States Department of Agriculture Natural Resource Conservation Service indicate an average of $11,956 per acre to reclaim by this technique based on 12 refuse sites in Pennsylvania. (Most of the sites were reclaimed under the Rural Abandoned Mine Program). The range for these examples was $5,250 to $20,740 per acre. The problem with this technique is that precipitation will continue to infiltrate the pile, and leach the oxidized iron sulfide minerals to produce AMD, although the flows are typically reduced by 1 or 2 orders of magnitude.

Alternate reclamation strategies include the removal of the pile. The potential beneficial uses of coal refuse vary widely depending on the location of the waste. The most promising use is to burn the refuse in a fluidized bed combustion (FBC) or cogeneration process. Other uses for coal refuse include: re-cleaned for coal extraction, surface and subsurface fill, road base, light weight aggregate, cement, mineral-chemical recovery, and mixing with a cohesive material to form a low cost briquette fuel.

The U.S. Environmental Protection Agency and U.S. Office of Surface Mining requested this refuse pile characterization study to determine the economic potential and assorted environmental improvements possible by refuse pile removal. The objectives of the study are:

1. Estimate the total number of coal refuse sites in Alabama, Kentucky, Illinois, Ohio, Pennsylvania, Virginia, and West Virginia as well as the number of small coal refuse sites (25 acres or less in size).

2. Determine the number of these refuse piles that can be removed and burned in cogeneration plants, re-cleaned for coal extraction, or otherwise used.

3. Identify the physical and chemical characteristics of small refuse sites. The chemical analysis will include moisture, ash, sulfur, BTU, and washability (sulfur and ash will be tested on the washability product). A minimum of five sites will be sampled in each state for this study.

4. Identify the environmental problems that exist and to what extent they can be mitigated or eliminated by the removal of the refuse pile.

5. Document the differences observed between total refuse pile removal operations and coal mining operations on previously undisturbed land.

Abandoned Mine Lands

Approximately 1.4 million acres of land had been disturbed by coal mining and inadequately reclaimed prior to 1977 (based on data compiled and synthesized from the Abandoned Mine Land Inventory System maintained by the US Office of Surface Mining and discussions with AML administrators for the states covered by this study). Of this total approximately 26,000 acres exists as 1,893 refuse piles containing a total 963 million tons of coal refuse. The Surface Mining Control and Reclamation Act (SMCRA) of 1977 defined abandoned mine lands (AML) as lands that were mined, and left in an inadequate reclamation status and abandoned before August 3, 1977, with no continuing reclamation responsibility by any individual or company. Environmental problems associated with abandoned mine lands and coal refuse piles include unvegetated areas, extensive erosion and sedimentation, acid soils, acid mine drainage, and other water quality problems. SMCRA provides for an abandoned mine land reclamation fund, to be used for reclamation of areas affected by past mining. This fund is generated by taxing current coal operations on every ton of coal mined. Sites with the greatest risks to the health and safety of the public receive the highest priority for funding. Many of the environmental sites that need reclamation may not receive funding because the amount of money required to reclaim all AMLs far exceeds the amount that may be collected (Ziemkiewicz and Skousen, 1996) and (Growitz, 1998).

Coal Refuse

Inventory of coal refuse sites

Interviews with regulatory authorities and a review of existing data for all refuse sites from state and federal AML inventories yielded the following: Alabama has 2,780 acres of coal refuse in 97 piles, Kentucky has 4,000 acres of coal refuse in 330 piles, Ohio has 6,780 acres of coal refuse in 437 piles, Pennsylvania has 7,800 acres of coal refuse in 385 piles, Virginia has 440 acres of coal refuse in 150 piles, and West Virginia has 4,200 acres of coal refuse in 494 piles. Illinois has 9,107 total acres of coal refuse in 67 piles and 2,307 total acres in 43 slurry ponds. This study focused on smaller sites - less than 25 acres in size.

Potential uses of coal refuse

Electricity production

Coal today supplies more than 56% of the electricity in the United States. Even with major advances in alternative energy technologies, energy conservation, and increased natural gas use, coal will be needed as the Nation's primary source of electricity for well into the 21st century. Advanced technologies like fluidized bed combustion (FBC) will be essential if the U.S. is to meet future needs to generate economic growth.

Instead of requiring a utility to add expensive pollution controls to a plant (which drain power generating efficiency), fluidized bed combustion incorporates pollution control into the combustion process. It actually boosts overall efficiency. This translates into lower costs for consumers and cleaner air for the community.

In a fluidized bed, more than 90% of the sulfur dioxide emissions are captured inside the boiler by sulfur absorbing limestone. Nitrogen pollutants are prevented from forming by the relatively low combustion temperatures made possible by the advanced boiler design. More than 98% of the tiny fly ash particles are captured before they are exhausted to the atmosphere. Another advantage to fluidized bed combustion is that the system can cogenerate steam for heating and cooling nearby buildings, while turning a turbine to produce electric power. This will allow older inefficient and higher polluting steam plants to be taken off-line.

The lower temperature requirements and the ability to capture pollutants allow a wide variety of fuels to be used in fluidized bed combustion, including coal refuse. The minimum BTU requirement for the fuel is 6,000 BTUs per pound. The sulfur limit can be as high as 7% and the ash content should be less than 60%. A major benefit to this type of power generation, is that it produces an alkaline ash. The FBC ash can be back hauled to help reclaim refuse sites which have a highly acidic soil from the years of acid leaching into the ground.

Coal refuse fuels that do not meet the quality requirements for fluidized bed combustion can be processed at a preparation plant to recover a higher quality fuel. Three options are available for the processed coal. The first is to sell it to a conventional power plant if the quality meets the stricter requirements (12,000 BTUs/pound, less than 1% sulfur, and less than 25% ash). Secondly, the refuse could also be processed to meet the minimum requirements for FBC plants. The last option is a new process that would involve reducing the cleaned refuse to fines and combining it with high quality coal fines by adding a binder to produce briquettes for fuel.

Fill material and road base

The particle size and relative stability of coal refuse, both burned (reddog) and unburned, make it an ideal material for roadbed construction and fill material to prevent subsidence. The refuse material usually contains clay with the mixed sized particles and provides packing and compression properties similar to conventional road base materials. The problem of acid mine drainage production could be reduced by sealing the roadbed in an oxygen and water impermeable environment. This can be accomplished by placing clay under and on the sides of the base. The road surface will seal the top of the base. Other options would include mixing limestone (another roadbed material) with the refuse to treat any AMD produced.

The refuse material has also been used as fill material and as underground stowage material to prevent mine subsidence. The mixture of sizes and materials offer greater stability than conventional materials. The key to using the refuse as fill or stowage would be to add an alkaline amendment to prevent AMD formation.

Expanded refuse - aggregate

The utilization of refuse material as aggregate for road base or general construction was first studied in 1932. This research recommended expanding the refuse by firing in a rotary kiln to provide a lightweight aggregate. Expanded material is useful in general construction, manufacture of lightweight blocks, and road and bridge construction. The purpose of the expanding process is to form a material of lower specific gravity with nearly the same strength of the raw material. The process involves grinding the raw material to 1 ½ - ½ inch and firing in a rotary kiln or sintering machine to 2,000 degrees F. The refuse may also be pulverized and combined with an organic binder before firing to 2,100 degrees C. This process produces a material that typically weighs less than 100 pounds / cubic foot and can withstand forces of 2,000 - 2,500 pounds / square inch.

Chemical recovery

Rare chemicals have been found in coal and coal refuse in previous studies. Germanium seems to be the chemical that receives the most attention, probably because it is used in the semi-conductor industry. Other trace metals found in coal and coal refuse are: titanium, vanadium, gallium, copper, chromium, lithium, beryllium, cobalt, molybdenum, tin, zinc, bismuth, cadmium, and silver. Current market conditions for recovery of these metals are not favorable, but there is research being conducted to make metal recovery from mine wastes economical.

Sampling methods and analysis for small refuse sites

Eight to ten randomly selected refuse piles of 25 acres or less were sampled in each of the project states using American Society for Testing and Materials (ASTM) method D 2234 protocols. We believe these small sites may be the most amenable to removal under regulations that could be developed by OSM to implement the coal refuse provisions of the Surface Mining Control and Reclamation Act as amended by the Energy Policy Act of 1992. The study emphasized the smaller refuse piles as these sites may have more of a potential to facilitate their removal and achieve environmental gains.

The samples were analyzed for the following parameters: moisture (ASTM D 3173) (used to calculate the total BTUs of the sample), ash (ASTM D 3174) (used to determine the percent of unburnable material in the coal sample), sulfur (ASTM D 3177) (used to determine if the coal will meet emissions standards), BTU (ASTM D 2015) (used to determine the heat content of the coal) MAF (moisture and ash free BTU) is calculated by dividing the BTU by the percent moisture and the percent ash in the coal sample. The MAF is used to estimate the quality of the coal produced after it is cleaned. Five samples from each state had a washability analysis performed (ASTM D 4371) (used to estimate the amount of coal that can be recovered by a preparation plant).

Water samples were collected from piles that were discharging and analyzed using American Public Health Association Standard Methods for the Examination of Water and Wastewater 1060 protocols (Standard Methods). The water samples were analyzed for the typical acid mine drainage parameters. The first parameter is pH (EPA 600/150.1) which measures hydrogen ion concentration used to approximate acid content. The second parameter is specific conductance (EPA 600/120.1), this parameter is a directly proportional indicator of contaminants. Alkalinity (EPA 600/310.1) measures the samples ability to neutralize acidity. Acidity (EPA 600/305.1) is used to determine the water's ability to neutralize base solutions. Iron (EPA 600/236.1), manganese (EPA 600/243.1), aluminum (EPA 600/202.1), and sulfate (EPA 600/375.4) are all constituents of acid mine drainage, and are good indicators of the amount of AMD preent.

Geohydrologic settings

The settings of the refuse piles studied were mixed about evenly between head of hollow fills located high in the watershed and piles just sitting on relatively flat ground. The head of hollow fills were the piles that consistently discharged more water than the piles located on flat terrain. One possible reason for this uneven discharge is that they may be located over a spring or that surface water following the terrain is infiltrating the piles. The piles located on flat terrain would not pick up as much surface water as the head of hollow piles but may retain precipitation longer and would have a tendency to allow a discharge into the ground water. This is indicated from past removal operations that required a substantial amount of lime (45 tons/acre at the Vintondale site in Pennsylvania) to neutralize the soil under the pile. About one third of the piles were vegetated and stable. The vegetation ranged from grasses to large trees (1 site in Alabama had trees growing in excess of 15 inches in diameter). Sites like this would probably cause more environmental harm by removing them than if they were left in place (due to increased erosion sedimentation during logging operations).

Environmental problems

Many coal refuse piles are located high in the watershed at the head of the hollow or they were placed directly along a stream. This placement allows the passage of water over and through the refuse. Once the water contacts the refuse, soluble minerals and acid are leached from the waste material to produce acid mine drainage that can contaminate both surface and groundwater supplies. Large amounts of runoff also carry the smaller sized refuse into streams causing sedimentation problems as the particles settle in the stream bottoms. Fourteen of the 57 sites studied were discharging AMD and all nearby streams exhibited some type of sedimentation problems.

Air pollution can occur from fines being blown by strong winds to adjacent communities, creating dust on exposed property. Fires are another air pollution problem associated with coal refuse piles. They can be ignited spontaneously, accidentally, and some have been deliberately started. Two of our study sites were burning, but about half of the 57 sites studied exhibited signs of past fires.

Physical and chemical characteristics of coal refuse, by State

Alabama study sites

Eight sites were studied in Alabama. The BTUs ranged from a low of 2,034 to a high of 8,730. Four sites or 50% of the piles studied had a BTU content of 6,000 (or within five percent of this value) and thus could be burned directly in a FBC plant if there were any in the state.

The coal that could be recovered from the piles ranged from 27.5% - 64.5% based on washability analyses. One site or 20% of the five sites on which a coal recovery washability analysis was performed contained at least 60% coal (or within five percent of this percentage) which indicates the refuse at the site could be removed and processed off site for recovery of the coal. The washability at 1.7 specific gravity gives a very conservative coal recovery estimate. The coal recoveries could be increased by using a higher density fluid, up to a specific gravity of 2.0, to wash the refuse.

The inventory compiled for the 25-acre or smaller refuse sites indicates 86 sites comprise a total of 400 acres. In summary, we estimate that about 50% of these small refuse sites contain material that could be removed in total and burned in a FBC plant and that about 25% of these small refuse sites contain enough coal so that the material could be removed and the coal processed off site. Thus on the basis of these estimates it is reasonable to expect the following:

1. Sites that qualify for FBC use

- about 43 sites that
  - contain about 8,098,360 tons of refuse (200 x 12.2 x 3319)
  - contain about 200 mineable acres that would be removed and reclaimed
  - eliminate 161,967 tons of maximum potential acidity (200 x 12.2 x 3319 x .0064 x 3.125) at a cost savings of $4,859,010 (MPA/.8 x $24) as well as contribute to environmental water quality improvement

2. Sites that qualify for off-site processing

- about 22 sites that
  - contain about 1,305,860 tons of coal (50 acres x 12.2 x 3319 x .645)
  - contain about 50 mineable acres that would be removed and reclaimed
  - eliminate 40,491 tons of maximum potential acidity (50 x 12.2 x 3319 x .0064 x 3.125) at a cost savings of $ 1,214,730 (MPA/.8 x $24) as well as contribute to environmental water quality environmental improvement.

Note that the data for mineable acreage, tons, maximum potential acidity, and dollar cost savings summarized above for the two coal refuse categories, FBC and off-site processing, are not additive. This is due to the fact that the same refuse material in the sites that qualify for off-site processing (based on the washability analysis and 60% coal recovery) also qualifies for direct burning in an FBC plant (based on the BTU analysis of the pile).

Kentucky study sites

Nine sites were studied in Kentucky. The BTUs ranged from a low of 2,064 to a high of 9,299. Four sites or 44% of the piles studied had a BTU content of 6,000 (or within five percent of this value) and thus could be burned directly in a FBC plant if there were any in the state.

The coal that could be recovered after processing ranged from 22.9% - 66% based on washability analyses. Three sites or 60% of the sites on which a coal recovery washability analysis was performed contained at least 60% coal (or within five percent of this percentage) which indicates the refuse at the site could be removed and processed off-site for recovery of the coal. The washability at 1.7 specific gravity gives a very conservative coal recovery estimate. The coal recoveries could be increased by using a higher density fluid, up to a specific gravity of 2.0, to wash the refuse.

The inventory compiled for the 25-acre or smaller refuse sites indicates 72 sites comprise a total of 400 acres. In summary, we estimate that about 44% of these small refuse sites contain material that could be removed in total and burned in a FBC plant and that about 60% of these small refuse sites contain enough coal so that the material could be removed and the coal processed off site. Thus on the basis of these estimates it is reasonable to expect the following:

1. Sites that qualify for FBC use

- about 30 sites that
    - contain about 7,126,556 tons of refuse (176 x 12.2 x 3319)
    - contain about 176 mineable acres that would be removed and reclaimed
    - eliminate 102,444 tons of maximum potential acidity (176 x 12.2 x 3319 x .0046 x 3.125) at a cost savings of $3,073,327 (MPA/.8 x $24) as well as contribute to environmental water quality improvement

2. Sites that qualify for off-site processing

- about 43 sites that
    - contain about 5,927,999 tons of coal (240 acres x 12.2 x 3319 x .61)
    - contain about 240 mineable acres that would be removed and reclaimed
    - eliminate 139,696 tons of maximum potential acidity (240 x 12.2 x 3319 x .0046 x 3.125) at a cost savings of $ 4,190,900 (MPA/.8 x $24) as well as contribute to environmental water quality improvement

Note that the data for mineable acreage, tons, maximum potential acidity, and dollar cost savings summarized above for the two coal refuse categories, FBC and off-site processing, are not additive. This is due to the fact that the same refuse material in the sites that qualify for off-site processing (based on the washability analysis and 60% coal recovery) also qualifies for direct burning in an FBC plant (based on the BTU analysis of the pile).

Ohio study sites

Ten sites were studied in Ohio. The BTUs ranged from a low of 3,931 to a high of 11,588. Six sites or 60% of the piles studied had a BTU content of 6,000 (or within five percent of this value) and thus could be burned directly in a FBC plant if there were any in the state.

The coal that could be recovered after processing ranged from 40.7% - 84.9% based on washability analyses. Four sites or 80% of the five sites on which a coal recovery washability analysis was performed contained at least 60% coal (or within five percent of this percentage) which indicates the refuse at the site could be removed and processed at off-site for recovery of the coal. The washability at 1.7 specific gravity gives a very conservative coal recovery estimate. The coal recoveries could be increased by using a higher density fluid, up to a specific gravity of 2.0, to wash the refuse.

The inventory compiled for the 25-acre or smaller refuse sites indicates 381 sites comprise a total of 2520 acres. In summary, we estimate that about 60% of these small refuse sites contain material that could be removed in total and burned in a FBC plant and that about 80% of these small refuse sites contain enough coal so that the material could be removed and the coal processed off site. Thus on the basis of these estimates it is reasonable to expect the following:

1. Sites that qualify for FBC use

- about 228 sites that
  - contain about 61,223,601 tons of refuse (1512 x 12.2 x 3319)
  - contain about 1512 mineable acres that would be removed and reclaimed
  - eliminate 3,118,577 tons of maximum potential acidity (1512 x 12.2 x 3319 x .0163 x 3.125) at a cost savings of $93,346,874 (MPA/.8 x $24) as well as contribute to environmental water quality improvement

2. Sites that qualify for off-site processing

- about 305 sites that
  - contain about 61,060,338 tons of coal (2016 acres x 12.2 x 3319 x .748)
  - contain about 2016 mineable acres that would be removed and reclaimed
  - eliminate 4,158,102 tons of maximum potential acidity (2016 x 12.2 x 3319 x .0163 x 3.125) at a cost savings of $ 124,743,048 (MPA/.8 x $24) as well as improving environmental water quality.

Note that the data for mineable acreage, tons, maximum potential acidity, and dollar cost savings summarized above for the two coal refuse categories, FBC and off-site processing, are not additive. This is due to the fact that the same refuse material in the sites that qualify for off-site processing (based on the washability analysis and 60% coal recovery) also qualifies for direct burning in an FBC plant (based on the BTU analysis of the pile).

Pennsylvania study sites

Ten sites were studied in Pennsylvania. The BTUs ranged from a low of 1,451 to a high of 9084. Four sites or 40% of the piles studied had a BTU content of 6,000 (or within five percent of this value) and thus could be burned directly in a FBC plant if there were any in the state.

The coal that could be recovered after processing ranged from 32.7% - 68.9% based on washability analyses. Two sites or 40% of the five sites on which a coal recovery washability analysis was performed contained at least 60% coal (or within five percent of this percentage) which indicates the refuse at the site could be removed and processed off-site for recovery of the coal. The washability at 1.7 specific gravity gives a very conservative coal recovery estimate. The coal recoveries could be increased by using a higher density fluid, up to a specific gravity of 2.0, to wash the refuse.

The inventory compiled for the 25-acre or smaller refuse sites indicates 203 sites comprise a total of 1920 acres. In summary, we estimate that about 40% of these small refuse sites contain material that could be removed in total and burned in a FBC plant and that about 40% of these small refuse sites contain enough coal so that the material could be removed and the coal processed off site. Thus on the basis of these estimates it is reasonable to expect the following:

1. Sites that qualify for FBC use

- about 81 sites that
  - contain about 31,097,702 tons of refuse (768 x 12.2 x 3319)
  - contain about 768 mineable acres that would be removed and reclaimed
  - eliminate 544,209 tons of maximum potential acidity (768 x 12.2 x 3319 x .0056 x 3.125) at a cost savings of $16,326,293 (MPA/.8 x $24) as well as contribute to environmental water quality improvement

2. Sites that qualify for off-site processing

- about 81 sites that
  - contain about 19,498,259 tons of coal (768 acres x 12.2 x 3319 x .627)
  - contain about 768 mineable acres that would be removed and reclaimed
  - eliminate 341,219 tons of maximum potential acidity (768 x 12.2 x 3319 x .0056 x 3.125) at a cost savings of $10,236,585 (MPA/.8 x $24) as well as contribute to environmental water quality improvement

Note that the data for mineable acreage, tons, maximum potential acidity, and dollar cost savings summarized above for the two coal refuse categories, FBC and off-site processing, are not additive. This is due to the fact that the same refuse material in the sites that qualify for off-site processing (based on the washability analysis and 60% coal recovery) also qualifies for direct burning in an FBC plant (based on the BTU analysis of the pile).

Virginia study sites

Ten sites were studied in Virginia. The BTUs ranged from a low of 1,595 to a high of 10,802. Three sites or 30% of the piles studied had a BTU content of 6,000 (or within five percent of this value) and thus could be burned directly in a FBC plant if there were any in the state.

The coal that could be recovered after processing ranged from 39.4% - 98.9% based on washability analyses. One sites or 20% of the five sites on which a coal recovery washability analysis was performed contained at least 60% coal (or within five percent of this percentage) which indicates the refuse at the site could be removed and processed off-site for recovery of the coal. The washability at 1.7 specific gravity gives a very conservative coal recovery estimate. The coal recoveries could be increased by using a higher density fluid, up to a specific gravity of 2.0, to wash the refuse.

The inventory compiled for the 25-acre or smaller refuse sites indicates 150 sites comprise a total of 440 acres. In summary, we estimate that about 30% of these small refuse sites contain material that could be removed in total and burned in a FBC plant and that about 20% of these small refuse sites contain enough coal so that the material could be removed and the coal processed off site. Thus on the basis of these estimates it is reasonable to expect the following:

1. Sites that qualify for FBC use

- about 45 sites that
  - contain about 5,344,917 tons of refuse (132 x 12.2 x 3319)
  - contain about 132 mineable acres that would be removed and reclaimed
  - eliminate 70,152 tons of maximum potential acidity (132 x 12.2 x 3319 x .0042 x 3.125) at a cost savings of $2,104,561 (MPA/.8 x $24) as well as contribute to environmental water quality improvement

2. Sites that qualify for off-site processing

- about 30 sites that
  - contain about 3,452,817 tons of coal (88 acres x 12.2 x 3319 x .989)
  - contain about 88 mineable acres that would be removed and reclaimed
  - eliminate 46,768 tons of maximum potential acidity (88 x 12.2 x 3319 x .0042 x 3.125) at a cost savings of $1,403,040 (MPA/.8 x $24) as well as contribute to environmental water quality improvement

Note that the data for mineable acreage, tons, maximum potential acidity, and dollar cost savings summarized above for the two coal refuse categories, FBC and off-site processing, are not additive. This is due to the fact that the same refuse material in the sites that qualify for off-site processing (based on the washability analysis and 60% coal recovery) also qualifies for direct burning in an FBC plant (based on the BTU analysis of the pile).

West Virginia study sites

Ten sites were studied in West Virginia. The BTUs ranged from a low of 4,041 to a high of 12,380. Six sites or 60% of the piles studied had a BTU content of 6,000 (or within five percent of this value) and thus could be burned directly in a FBC plant if there were any in the state.

The coal that could be recovered after processing ranged from 32.2% - 62.6% based on washability analyses. Three sites or 60% of the five sites on which a coal recovery washability analysis was performed contained at least 60% coal (or within five percent of this percentage) which indicates the refuse at the site could be removed and processed off-site for recovery of the coal. The washability at 1.7 specific gravity gives a very conservative coal recovery estimate. The coal recoveries could be increased by using a higher density fluid, up to a specific gravity of 2.0, to wash the refuse.

The inventory compiled for the 25-acre or smaller refuse sites indicates 444 sites comprise a total of 2460 acres. In summary, we estimate that about 60% of these small refuse sites contain material that could be removed in total and burned in a FBC plant and that about 60% of these small refuse sites contain enough coal so that the material could be removed and the coal processed off site. Thus on the basis of these estimates it is reasonable to expect the following:

1. Sites that qualify for FBC use

- about 266 sites that
  - contain about 59,401,470 tons of refuse (1467 x 12.2 x 3319)
  - contain about 1467 mineable acres that would be removed and reclaimed
  - eliminate 2,283,244 tons of maximum potential acidity (1467 x 12.2 x 3319 x .0123 x 3.125) at a cost savings of $68,497,320 (MPA/.8 x $24) as well as contribute to environmental water quality improvement

2. Sites that qualify for off-site processing

- about 266 sites that
  - contain about 35,403,276 tons of coal (1467 acres x 12.2 x 3319 x .596)
  - contain about 1467 mineable acres that would be removed and reclaimed
  - eliminate 2,283,244 tons of maximum potential acidity (1467 x 12.2 x 3319 x .0123 x 3.125) at a cost savings of $68,497,320 (MPA/.8 x $24) as well as contribute to environmental water quality improvement

Note that the data for mineable acreage, tons, maximum potential acidity, and dollar cost savings summarized above for the two coal refuse categories, FBC and off-site processing, are not additive. This is due to the fact that the same refuse material in the sites that qualify for off-site processing (based on the washability analysis and 60% coal recovery) also qualifies for direct burning in an FBC plant (based on the BTU analysis of the pile).

Summary of coal resources and potential environmental gains through remining

Small refuse sites

Characteristics of small refuse piles related to economically recoverable coal resources and potential environmental gains are summarized in tables 1 and 2. The data indicate that significant coal refuse or coal can be economically removed. For example, table 19 shows a total of 693 sites comprise more than 4200 mineable acres and over 170 million tons of refuse that is suitable for burning in an FBC plant. The potential environmental gains consist of reclamation of more than 4200 acres and removal of about 6.2 million tons of acidity present in the piles that over time will infiltrate the ground water and discharge to local streams. Further, the data show:

- more than 80% of the sites are found in West Virginia, Ohio and Pennsylvania
- almost 90%of the FBC-burnable tonnage and mineable acreage is found in Ohio, West Virginia and Pennsylvania.

Table 2 shows a total of 727 sites comprise more than 4600 mineable acres and over 126 million tons of coal that is suitable for off-site processing. The potential environmental gains consist of reclamation of more than 4600 acres and removal of about 7 million tons of acidity present in the piles. Like the data above, this table shows that most of the sites, available coal and mineable acreage is found in Ohio, West Virginia and Ohio.

All refuse sites

Use/extraction of available coal and associated environmental gains from small refuse piles constitute only one resource - albeit a resource we focused on in this study as it may be possible to facilitate remining at these sites. Review of refuse piles as a whole, i. e., without regard to size, indicates significant coal resources are present and their removal would result in significant environmental gains. The data show a total of 2002 sites, including Illinois sites. These refuse sites cover a total of 37,414 acres. Using the kind of analysis we discussed earlier in the report for small refuse sites we estimate about 20,000 acres of the refuse material could be utilized directly in FBC plants or otherwise removed and processed off site for the existing coal. This refuse would contain about 172 million tons of material that could be used directly in an FBC or would contain about 126 million tons of coal that could be processed off site. In addition removal of these piles for the coal would result in the reclamation of more than 20,000 acres and the removal of more than 30 million tons of acidity estimated to be present in the piles.

Conclusions

This study identified the following information about coal refuse piles in Appalachia:

1. The refuse piles constitute an economic resource - many piles can yield coal for FBC operations, off-site processing or other uses.
2. Significant environmental improvement is possible through removal of the refuse piles and thus removal of the problem that is directly attributable to the pile.
3. There are significant differences between coal refuse removal Title V remining and surface mining operations on previously undisturbed sites.
4. It appears that the environment can be protected and improved through an expedited permit under SMCRA that would also serve as an incentive for coal refuse pile removal.

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Table 1. Summary State Estimates of Coal Refuse Tonnage and Environmental Gains through Remining of Small Refuse Sites that Qualify for FBC Use

State	Number of piles < 25 acres	Coal Refuse, in tons	Mineable/reclaimed land, in acres	Estimated Acidity to be removed, in tons
Alabama	43	8098360	200	161967
Kentucky	30	7126556	176	102444
Ohio	228	61223601	1512	3118577
Pennsylvania	81	31097702	768	544291
Virginia	45	5344917	132	70152
West Virginia	266	59401470	1476	2283244
TOTALS	693	172292606	4255	6280593

Table 2. Summary State Estimates of Coal Tonnage and Environmental Gains through Remining of Small Refuse Sites that Qualify for Off-site Processing

State	Number of piles < 25 acres	Coal, in tons	Mineable/reclaimed land, in acres	Estimated Acidity to be removed, in tons
Alabama	22	1305860	50	40491
Kentucky	43	5927999	240	139696
Ohio	305	61060338	2016	4158102
Pennsylvania	81	19498259	768	341219
Virginia	30	3452817	88	46768
West Virginia	266	35403276	1476	2283244
TOTALS	727	126648549	4629	7009520