Session II:

SITE CHARACTERIZATION

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COAL COMBUSTION BY-PRODUCTS
THE WESTERN U.S. PERSPECTIVE

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Abstract

Coal Combustion By-Products (CCBP) production and the subsequent use both on-site and off-site are currently environmental and economic concerns throughout the Western U.S. for electric utilities. Texas Utilities presents the Western U.S. perspective by providing local information on CCBP production and uses on-site at lignite mining operations and electric generation facilities.

Introduction to Texas Utilities

The Texas Utilities Company consists of six (6) principal subsidiary companies that include: TU Electric, TU Australia PTY. LTD., Southwestern Electric Service Company,TU Services, Texas Utilities Fuel Company and Texas Utilities Mining Company. The primary business of United States operations is to bring low cost and reliable electric service to approximately 2.4 million customers in 101 Texas counties with 89 billion kilowatt-hours of electricity. The customer base is composed of residential and large industrial facilities. Twenty-four generating facilities give the System 22 million kilowatts of power resources. Fuel sources range from fossil fuels such as natural gas, oil, lignite and western coal to nuclear fuels and renewable resources.

TU Electric provides, through various business units, generation, transmission, distribution, marketing and customer service to North Central, East and West Texas. Southwestern Electric Service Company, acquired in 1993, provides service to areas in North Central and East Texas.

Texas Utilities Fuel Company provides natural gas and fuel oil to TU Electric generating facilities through a 2,100-mile pipeline system and with 27 million cubic feet of underground storage. TU Electric, with this system and by direct connection to other suppliers, is the nation's largest consumer of natural gas, using about 15 percent of all natural gas consumed by electric utilities. Texas Utilities is also in the process of completing the acquisition of the ENSERCH Corporation which is the parent company to several natural gas related businesses including the Lone Star Gas Company, Texas' largest gas company.

Texas Utilities Mining Company (TUMCO) is the mining unit within the system and is the largest lignite producer in Texas. We are presently rated as the 5th largest mining company in the nation and the largest mining company in relation to overburden removed to obtain the mined product. Lignite is produced at mine-mouth operations for use in TU Electric generation facilities where 100% of the lignite produced is consumed.

TUMCO has three primary lignite mines with two of the mines containing satellite operations. Currently, more than 104,000 acres of land are regulated under permits issued by the Texas Railroad Commission. Mines range in size from 1,200 to more than 26,000 acres. Eleven mine permits are active plus other associated permits required for operation.

Mines operate as surface mines with a successive series of narrow, parallel pits. Equipment such as draglines, bucket wheel excavators and cross-pit spreaders provide overburden removal. Lignite transportation is accomplished by a combination of haul roads, service roads and rail transportation for movement of material from remote locations.

Other Electric Utilities in Texas

Other regions within Texas receive electric service from various public and private utilities. These utilities include small local cooperatives and large corporations with residential, rural and industrial customers. Major utility companies include Central & Southwest, Houston Lighting & Power and Entergy.

Regional Perspective & Characteristics

Texas Utilities Mining Company operates mines at locations within North CentraI and East Texas. The Big Brown Mine is in Freestone County approximately 90 miles south of Dallas. Directly east of Dallas in Titus County, is the Monticello Mine with a satellite operation in Hopkins County. Further to the southeast in Panola County, near the Louisiana border, are the Martin Lake Mine and the satellite Oak Hill Mine in Rusk County.

Terrestrial and aquatic wildlife, within the area surrounding these mines, is typical of species that inhabit the Texan and Austroriparian biotic provinces (Blair, 1950). The forested Austroriparian biotic province, as described by Blair (1950) is bordered on the west by the Texan province. It extends eastward from east Texas to the Atlantic coastal plain and as far north as the Dismal Swamp in southeast Virginia. Species range from forest dwellers to grassland inhabitants and transitional species between the two provinces. Many species are local inhabitants throughout much of East and North Central Texas.

Typical Wildlife Species in the Area

Mammals
- white-tailed deer *(Odocoileus virginiana)*
- Virginia opossum *(Didelphis virginiana)*
- fox squirrel *(Sciurus niger)*
- cotton mouse *(Peromyscus gossypinus)*
- gray squirrel *(Sciurus carolinensis)*
- common raccoon *(Procyon lotor)*
- beaver *(Castor canadensis)*
- coyote *(Canis latrans)*
- fulvous harvest mouse *(Reithrodontomys fulvescens)*
- nine-banded armadillo *(Dasypus novemcinctus)*

Birds
- northern mockingbird *(Mimus polyglottos)*
- mourning dove *(Zenaida macroura)*
- red-winged blackbird *(Agelaius phoeniceus)*
- great blue heron *(Ardea herodias)*
- red-eyed vireo *(Vireo olivaceus)*
- Carolina wren *(Thryothorus [udovicianus)*
- northern cardinal *(Cardinalis cardinalis)*
- blue jay *(Cyanocitta cristata)*

Reptiles
- ornate box turtle *(Terrapene ornata ornata)*
- western cottonmouth *(Agkistrodon piscivorus leucostoma)*
- east Texas toad *(Bufo woodhousii)*
- bullfrog *(Rana catesbeiana)*
- common snapping turtle *(Chelydra serpentina serpentina)*
- red-eared slider *(Trachemys scripta elegans)*

Texas Utilities Mining Company operations are found within three distinct vegetational regions in Texas including the Post Oak Savannah, Blackland Prairies and Pineywoods (Gould, 1975). Historically, between regions, vegetation is variable and ranges from: 1) open prairies with tall grass climax communities of little bluestem, 2) savannahs of oak, oak-hickory and tall grasses, and 3) extensive pine and pine-hardwood forests.

Land uses include the full spectrum of uses typical of East and North Central Texas. These include cropland, pastureland, grazingland, forestry, fish & wildlife habitat, developed water resources, undeveloped land, recreation areas, residential and industrial/commercial. Most of the area is rural in nature with scattered pockets of urbanization near major transportation routes. Rural areas are predominately agricultural in nature with primary land uses dictated by vegetational region. East Texas is dominated by land uses such as forestry and undeveloped areas intermixed with pastureland. Areas to the north and west are dominated by pastureland and grazingland areas intermixed with remnant bottomland forests that are vestiges of past forestland.

Generally, much of East and North Central Texas was affected by farming and forestry activities that occurred from the mid to late 1800's through the 1950's. Historic agricultural practice ranged from intensive cotton farming over large areas to truck farming of fruits and vegetables. The trend throughout the area has been from intensive land use for market crops to less intensive pastureland and grazingland for livestock production. Forestry activities, although controlled to some extent by regional vegetation, have ranged from intensive production of saw-logs to harvesting timber for pulpwood operations. Land uses associated with commercial/industrial activities include oil and gas operations and lignite mining.

The primary geologic features associated with Texas lignite include three geologic units - the Wilcox Group, Jackson Group, and YEGUA Formation (Kaiser, 1980). These tits are associated with three ancient depositional systems - fluvial, deltaic and strandplain/lagoonal. The Wilcox and Jackson Groups are the most important lignite bearing units with 90 percent of resources occurring north of the Colorado River. Texas Utilities Mining Company lignite mines are all in the Wilcox Group. Economically minable lignite seams range from 2 ft thick or thicker at depths ranging from 20 to 200 ft.

Soils associated with these mines are predominately of the soil orders Alfisols and Ultisols. Alfisols are characterized by gray to brown surface horizons with medium to high base supply, and with subsurface horizons of clay accumulation. They are usually moist but may be dry during the warm season and occur on gently or moderately sloping areas of rangeland, small grain and irrigated crops. Ultisols are characterized as usually moist soils on moderately sloping to steep areas in woodland and pasture with a horizon of clay accumulation and a low base supply. Soil and overburden material characteristics generally show pH and acid-base accounting values higher in the oxidized sediments than the reduced sediments.

Coal Combustion By-Products (CCBP)

The major fossil fuels used throughout Texas by electric utilities are natural gas, western coal from the Powder River Basin and Texas lignite. Texas Utilities uses a variety of fuel resources to diversify fuel use and to balance fuel cost. Fuel resources, in order of use, include lignite, natural gas and nuclear. Since the use of western coal is new at Texas Utilities, only CCBP from the combustion of lignite will be addressed in relation to Texas Utilities Mining Company and TU Electric operations.

On average. Texas Utilities produces 30,000,000 tons of lignite annually for use by generating facilities. From this production, approximately 5.7 million tons of CCBP are produced in the following categories.

Tons	Type of CCBP Produced
3,400,000 tons	fly ash
1,600,000 tons	bottom ash
726,000 tons	flue gas desulferization material

CCBP include fly ash, bottom ash and flue-gas desulfurization material. Each is defined as follows:

- Flv ash is the fine, light residue carried out of the boiler in the exhaust gases. It is removed from the air by an electrostatic precipitator or a baghouse.
- The larger, heavier material, bottom ash, falls to the bottom of the boiler/furnace system and is collected in a hopper.
- Flue-gas desulfurization material (FGD) results from exhaust gases passing through scrubbers, where pulverized limestone reacts with sulfur particulate and binds together forming these materials.

The volume of CCBP produced is related to the constituents within combusted material. Constituents within Texas lignite are variable between geologic groups and even within lignite seams at the same mine. Typically, lignite of the best quality occurs in the Wilcox Group north of the Colorado River and the poorest quality material is from the Jackson Group with YEGUA lignite intermediate between Wilcox and Jackson. Btu/lb values range from 7,500 to 4,500. Wilcox lignite on average has 33 percent moisture, 15 percent ash, 0.9 percent sulfur and a heat value of 6,000 Btu/lb.

Bottom Ash Use by Texas Utilities

Bottom ash is the primary CCBP used by Texas Utilities. Of the 1.6 million tons produced annually, approximately 230,000 tons of bottom ash are beneficially used each year at lignite mines and generating facilities.

Bottom ash is beneficially used by Texas Utilities Mining Company for various purposes related to transportation. These uses are beneficial due to economic benefits, material availability, product adaptability and Texas Utilities commitment to recycling and use of CCBP.

Bottom ash is used primarily as a cost-effective surfacing material for ramps and access roads in active mining and reclamation areas. All weather access is a critical component to the management of coal mining and reclamation activities. Lignite mining is a year round process that is done 24 hours a day. Access into mine pits is accomplished through the use of ramps. Ramps are constantly being moved or extended as the mine pits progress to keep up with the dynamics of the mining operation. Bottom ash is used to surface ramps to maintain suitable traction for 100 to 150 ton lignite haul trucks and service vehicles moving in and out of pits. As mine areas progress, reclamation activities immediately follow. A system of roadways is necessary to gain access for leveling and revegetation operations. Many of these roads are surfaced with bottom ash. Once reclamation is complete, the access road system may remain as a beneficial feature for future management of the land. The physical characteristics of bottom ash and its availability provide a durable and economical source of surfacing material for transportation uses at lignite mines.

Construction and maintenance of the transportation system for each mine operation are a major undertaking in relation to capital expense and size. Traction control is required on the curves of major haulage roads. for service roads and for infrequently used access roads, Use of bottom ash as construction material. primarily as road base and surfacing material, is a primary area of CCBP use. Approximately 110 miles of roads have been constructed using 100,000 tons of bottom ash since mine operations began in 1976.

At certain mine locations, railroad construction is a major area where bottom ash is used as a construction material. Rail lines are an integral part of some Texas Utilities Mining Company mines. They may be used to connect mine areas within a mine, mines to generating facilities or to connect generation facilities to CCBP disposal areas. It is estimated that a rail spur currently being constructed will use approximately 12,000 tons of bottom ash to set drainage culverts. The use of bottom ash instead of purchased material for this project alone will result in an estimated savings of $125,000. In another operation, temporary rail spurs at a CCBP disposal operation are constructed using bottom ash. To date, approximately five miles of rail spur using 9,000 tons of bottom ash have been constructed.

Lignite storage areas, parking lots and temporary 'lay down' yards are other examples of beneficial uses of bottom ash at mine facilities. In one application, 20,000 tons of bottom ash were used as base material for a lignite storage area.

TU Electric began using bottom ash at generating facilities as early as 1976 as light duty paving of temporary access roads, parking lots, drive ways and storage yards. Later, as generating facilities expanded, plant island piping and culverts are bedded with bottom ash due to its granular shape.

<u>Other CCBP</u>

Texas Utilities uses fly ash in other applications at lignite mines and generation facilities. Fly ash is used as an additive in concrete and as road base stabilization in conjunction with lime. These uses are infrequent and require only minimal amounts of fly ash compared to fly ash production.

No uses for FGD have been developed at lignite mines or generating facilities.

<u>Environmental Issues and Milestones</u>

Reclamation activities that prepare mine soils for planting are one area where Texas Utilities does not use CCBP. Stringent State regulations on postmine soil quality and the possibility of future liability are critical factors affecting the decision to use CCBP in reclaimed soils at Texas Utilities lignite mines. Fly ash and FGD, produced by Texas Utilities, contain trace elements (specifically heavy metals) which if added to reclaimed soils may elevate trace element concentrations above regulatory limits. Federal and State limits on trace elements in reclaimed minesoil make it difficult to justify the use of these by-products as amendments in reclaimed soils.

In 1993, after 20 years of study, the Environmental Protection Agency (EPA) affirmed that CCBP are nonhazardous solid waste and thus fall under the jurisdiction of the states. In Texas, the Texas Natural Resources Conservation Commission (TNRCC) regulates CCBP. The TNRCC, in a letter to the Texas Coal Ash Utilization Group, recognized that CCBP are not waste when used as road base, subbase and subgrade material when covered by a wear surface and used as road construction material. The Railroad Commission of Texas (RCT) has followed the lead of the TNRCC in accepting the use of bottom ash as a useful and environmentally safe material. CCBP are not considered, by the TNRCC, industrial wastes until they are to be disposed.

CCBP are typically either a Class 2 or Class 3 waste material. The definitions of solid waste classes as adopted by the TNRCC are as follows:

- Class 3 Waste - any industrial solid waste which is inert and essentially insoluble. A material's waste classification, among other things, is based on its leachable metals. The leachate must meet drinking water standards set forth by the US EPA.

- Class 2 Waste - any industrial solid waste which cannot be classified as **a** Class III waste.

- Class 1 Waste - this includes materials which are toxic or carcinogenic or bioaccumulative. Hazardous wastes are determined by the US EPA and are listed in CFR Title 40.

CCBP that are not beneficially used are disposed of according to TNRCC requirements. There are no requirements for the disposal of Class 3 Waste bottom ash from TUMCO's Monticello or Big Brown mines. Bottom ash produced at the Martin Lake mine is a Class 2 waste since its selenium leachate exceeds drinking water limits. Fly ash and FGD material are Class 2 Waste. Class 2 Waste must be disposed in a registered landfill that is typically lined with 3 feet of impermeable clay or a double layered synthetic liner containing a leachate collection system. At the Monticello mine, TU Electric demonstrated to the TNRCC that the soil stratum within mine pits is suitable for containing Class II waste and as a result, a traditional constructed landfill is not necessary.

Texas Utilities Off-site Use of CCBP

All forms of CCBP are marketed by Texas Utilities for off-site use in asphalt roofing shingles, concrete, wallboard, commercial carpet backing, plastics, oil field drilling cement and for soil stabilization material. Approximately 330,000 tons are marketed annually for off-site use and recycling. Other uses are being researched to increase beneficial use of these materials and reduce expensive disposal options.

Summary

CCBP can be used in economical and environmentally sound ways. Texas Utilities has demonstrated that on-site use is practical; although the volume of materials used at mines and generating facilities cannot meet the volumes produced. Excluding elevated trace element levels, fly ash incorporation into reclaimed soils may have potential for positive benefits. Benefits include improved texture and neutralization of natural soil acidity. Further study on this issue is warranted.

Initial impediments to development of beneficial uses were regulatory in nature. Acceptance by regulatory agencies has renewed interest in CCBP recycling opportunities and increased interest in legitimate. beneficial and economical uses. The groundwork for future development of CCBP uses will be continued study and further documentation showing that CCBP have no negative environmental impact.

Acknowledgments

I am grateful to the following people who provided information and editorial comments for this paper: Shawn Glacken. Jacob Gonzales, Eddie Bearden, Joel Palin, Sid Stroud, Larry Williford, Brian Craig and Bruce Lousberg.

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A SUMMARY OF SOIL ISSUES RELATED TO COAL COMBUSTION RESIDUES AND SURFACE MINES: SITE CEIARACTERIZATION FROM A MID-WESTERN PERSPECTIVE

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Abstract

The Midwest is blessed with highly productive soils and a landscape of relatively low relief that offers opportunities and challenges to the coal industry. While the coal itself is a product of an ancient warm landscape during the geologic age known as the Pennsylvanian, Midwestern soils and surficial geology are largely products of the glacial epoch, the Pleistocene. During the Pleistocene, continental glaciers repeatedly overrode the landscape, removing and burying preexisting soils and landscapes and depositing fresh geologic materials, till and outwash, while subduing the terrain. At the close of the last glaciation, the Wisconsinan, wind blown silts, called loess, were deposited over much of the area. Loess is what gives the Midwest productive soils, with its high water holding capacity and supply of nutrients, it is naturally fertile. The chemistry and productivity of Midwestern soils is related to their parent material, age, and initial calcium content. In general, there are abundant, high quality soils and geologic materials. Acid mine drainage is not as big a problem as in the Appalachian coal areas. Because of the very productive soils, reclamation of surface mines is held to a high standard. Where prime farmlands were mined, productivity of reclaimed surface mines must meet target yields set on nearby unmined areas. Coal combustion residues (CCR) may be disposed of in active mines or serve to increase productivity of reclaimed soils that are deficient in pH or the nutrients that it can supply. Residues may also be used as an aid to revegetate abandoned surface mines that have similar deficiencies. However, the application of CCR materials must be done with an achievable objective in mind and with both the site characteristics and the properties of the CCR materials carefully considered.

Introduction

The history of surficial geology and soils in the Midwest is the story of glaciation (Fehrenbacher et al. 1984). Several times in the Pleistocene, known as the Ice Age, much of the Midwest was overridden by continental glaciers. These glaciers served as giant bulldozers that reduced the relief and removed preexisting materials and deposited fresh materials, till and outwash, on the landscape. Till is material moved directly by a glacier. It is of variable texture and may be compacted due to the weight of the ice. Outwash is material washed away from a glacier by running water. It tends to be stratified and coarse textured.

During glaciation, older, infertile soils were removed or buried and replaced with younger, more fertile soils. At the end of the most recent glacial period, the Wisconsinan, vast deposits of wind blown silts, called loess, blanketed much of the Midwest, even beyond the glacial margins. Loess was an added bonus of glaciation. It is inherently fertility, rich in calcium to the point of being calcarious initially, and has a high water holding capacity. Soils that develop from loess parent materials are among the most productive in the world. This high productivity presents a challenge to reclamation specialists because of the high expectations for reclaimed mine soils,

Surface mining exposes buried geologic materials or overburden. Some of these materials are of reasonably good quality, and some are undesirable. Pleistocene deposits may be lacking or a minor portion of the overburden but are occasionally deep and also comprise most of the parent materials for Midwestern soils. Deep deposits of loess and till are usually calcareous, but buried paleosoils may be infertile. Outwash can be sandy and drouthy, or of a more desirable medium texture. The Pennsylvanian aged rocks below the Pleistocene materials include sandstones, limestones, and shales and the coal itself.

Pyrite may be associated with the coal. If allowed to oxidize, it will form sulfuric acid. Sandstones tend to be infertile and produce coarse fragments. Shales are often calcareous, as are unweathered Pleistocene materials and limestone, so acid mine drainage is generally not as significant an issue as in the Appalachian coal fields. The low relief of the Midwest also contributes to the rarity of acid mine drainage because acid generating materials are easily buried as part of reclamation and there are few high walls exposed which could allow acid seeps.

Coal combustion residues (CCR) can make a contribution to reclamation of surface mines in the Midwest. Despite the generally favorable nature of the soils and geological materials, there are areas with low pH and low contents of calcium and other nutrients that CCR might supply. In addition, in some situations, the moisture holding capacity of the soil may be improved by the addition of appropriate CCR materials. However, some characteristics of CCR materials may be undesirable under certain circumstances. The application of CCR materials must be done with an achievable objective in mind and with both the site characteristics and the properties of the CCR materials carefully considered.

Site Characterization

Post surface mining landscapes in the Midwest range from virtual "moonscapes" to areas where a casual observer could not detect evidence of mining. Most of this range in possibilities was driven by changing state and federal laws that required increasing amounts of reclamation over the years. Pre-law mined areas largely reflect nature's ability to recover from disturbance. Midwestern natural landscapes have generally low relief that is relatively easy to mimic in reclamation and the high natural fertility of many of our soils and geologic materials allows vegetative growth to cover the scars in many instances. Depending on local conditions, soil infertility due to the presence of acid generating material or to the lack of nutrients may be a problem. Soil erosion can also be a problem on steep or unvegetated sites. Plant productivity can also be a problem due to drouthy conditions caused by poor moisture holding conditions, or poor rooting depth due to soil compaction. Soil compaction is especially a problem where soil materials were placed with rubber tired vehicles. It is important to know the characteristics of the site in question before reclamation efforts are undertaken.

Physical Properties of Soils

Soils are a three-phase system, solids, gas, and liquid. The solids in soils include organic and inorganic material. Organic materials in soils include decomposed plant and animal remains and generally account for less than 5% of the total mass. Organic materials increase soil fertility but are generally lacking in mine soils. Inorganic material includes minerals formed in the soil and rock fragments inherited from the parent geologic material. As a rule of thumb. inorganic materials account for more than 95% of a soil's mass and 50% of a soil's volume. Materials <2mm in diameter are included in conventional soil analyses and material >2mm are considered coarse fragments and include material ranging in size from gravel to boulders, Inorganic materials provide mechanical support and serve as a water and nutrient reservoir. Soil fluids and gases occupy void spaces between the solids. The composition and relative abundance of air and water in soil is quite variable, depending on rainfall patterns. temperature, and other climatic and soil variables. The amount of void space in a soil depends on soil texture, structure, and compaction. Access to the appropriate amount of water and air by plant roots is necessary for plant productivity and survival.

Soils exist as part of a landscape. Topography, or relief, is the most obvious aspect of any landscape. Surface mining greatly alters topography because the very act of mining requires removal of all the materials above the coal. The post-mining landscape is largely dictated by the laws in place at the time of the mining. Pre-law surface mines are often composed of irregularly sloping piles of overburden or a series of sub-parallel. steep sided ridges, These piles and ridges are composed of a highly variable mixture of materials moved in the mining process. Soils in this situation tend to be erosive, high in coarse fragment content. low in fertility, and drouthy compared with the pre-mining, undisturbed soils. As reclamation regulations strengthened over the years, post-mining landscapes became more similar to the pre-mining conditions. Most recent law, the Surface Mining Control and Reclamation Act (SMCRA), requires grading to roughly the original topography and replacement of topsoil and rooting media of similar thickness and composition to the pre-mining soils. The resultant soils are not the same as the pre-mining soils. Removal, storage, transport, and placement of soils all influence the quality of the reclaimed soil. Soils tend to become compacted during handling, particularly if rubber tired scrapers are used. Much of the microbial population dies in storage. These problems can be corrected with careful soil handling and appropriate tillage and amendments.

Chemical Properties of Soils

Soil chemistry includes consideration of both the presence of adequate nutrients to support desired plant growth and the absence of undesirable or toxic materials. Soils have the capacity to store chemicals as cations or anions sorbed to mineral surfaces or as dissolved species in soil water or as a solid part of the soil matrix itself. Ions sorbed to soils can be released to plant roots or to the soil water. The capacity to sorb cations is called the cation exchange capacity (CEC) and is often included in soil fertility tests because most plant nutrients are cations. Soils with high CEC have the ability to store nutrients and resist changes in pH Soil pH, the measure of hydrogen ion activity, is the most common chemical measurement made in soils. Low pH indicates acid conditions, high pH indicates basic conditions. Most agricultural plants prefer a near neutral pH in the range of 6.0 - 6.5, and liming materials are routinely added to soils to maintain their proper pH (Illinois Agronomy Handbook, 1994). CCR materials may serve as liming agents if they contain calcium carbonate or other suitable alkaline materials. Along with pH and CEC, soil fertility tests can include primary, secondary, and micronutrients.

Major nutrients include N, K, and P. These nutrients, along with lime, are routinely added to agricultural soils. Nitrogen (N) is often not tested because the results are difficult to interpret. Potassium (K) is often abundant in mine soils. Phosphorus (P), may be low in mine soils. CCR materials would generally not be a source of these nutrients. Secondary nutrients include Ca, Mg, and S. Calcium generally is not limiting in soils with a pH above 5.5. Magnesium is generally not limiting in Midwestern soils except in acidic or sandy conditions. Mine soils with low pH could be deficient in these nutrients. CCR materials would be expected to be rich in these nutrients. Sulfur deficiency in agricultural soils is becoming an increasing concern because a major source was air pollution. The S that no longer contributes to air pollution is now contained in some CCR materials that could be applied to ameliorate S deficient soils.

Micronutrients are often not included in routine soil fertility tests because of costs and because they may not be limiting. The fresh geologic materials exposed by mining may be rich in micronutrients. An important micronutrient to test for when considering adding CCR to soils is boron (B), which may be plentiful in CCR materials, deficient in soils, but is toxic in large amounts.

A consideration of applying large amounts of CCR materials is the salt content. Depending on the drainage of the soil and its CEC, salt may be dissolved in the soil water, or accumulate in the soil. Salts and other chemicals in soil water may be flushed from the soil and move with the groundwater.

Solid materials generally do not play an important role in soil chemistry unless they dissolve or otherwise become water soluble. An important example of this is the mineral pyrite that can oxidize to form sulfuric acid, which creates serious consequences for reclamation. Alkaline materials in some CCR materials such as calcium carbonate can be used to counteract the potential acid generating materials in mine soils and wastes.

Summary

Soils found in areas that have been surface mined are a highly variable mixture of everything that was left near the surface after mining. In pre-law mines, it is called “overburden” and consists of a mix of Pennsylvanian bedrock fragments and Pleistocene materials. Landscapes are as the mining machines left them; sloping ridges or chaotic piles. Erosion, excessive coarse fragment contents, drouthiness, infertility, and acid generation can all be problems in these areas. Modem reclamation regulations essentially require replacement of the original soil and landscape. With modem reclamation, soil chemistry and other characteristics are reasonably similar to the pre-mining conditions, however soil compaction can be a problem. Coal combustion residues can be simply buried in active mines or serve as amendments to increase soil fertility, micronutrients, pH, or moisture holding capacity. However, they may also contribute excess salts or toxic materials to the soil or groundwater. In working with surface mined areas and coal combustion residues, the important thing to remember is to have a reasonable objective and to properly characterize the soils and coal combustion by-products or other soil amendments of interest.

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POTENTIAL USE OF COAL COMBUSTION BY-PRODUCT (CCB) IN THE EASTERN COAL REGION: SITE CHARACTERISTICS

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Abstract

The Eastern mining region presents numerous beneficial re-use environments for CCBs. Chief among these are use as an amendment for minespoil and coal refuse. These materials are difficult to reclaim due to low water holding capacities and in many cases high levels of acidity. In addition both spoil and refuse contain iron pyrite (FeS_2) and have the potential to produce acid mine drainage (AMD). The addition of alkaline CCB's would modify the coarse textures of spoil and refuse and add alkalinity needed to neutralize acidity. The mission of the American Coal Ash Association (ACAA) is to advance the use of coal combustion byproducts (CCBs) in ways that are technically sound, commercially competitive and environmentally safe. The use of CCBs is affected by local and regional factors including production rates; processing and handling costs; transportation costs; availability of competing engineering and manufacturing materials; seasonal factors; and the experience of materials specifiers, design engineers, purchasing agents, contractors, legislators, regulators and other professionals.

Introduction

The Eastern coal mining region stretches from northern Alabama to northern Pennsylvania, and includes the coalfields of Tennessee, eastern Kentucky, Virginia, West Virginia, Ohio, and Maryland. In 1993 the region produced 409 million tons of coal of which 45 % was extracted using surface methods with the remainder extracted by deep mining (EIA, 1996; Table 1). About 60% of the regions production comes from the coal fields of West Virginia and E. Kentucky. The region contains two large coal fields and the boundary between these fields is situated in West Virginia. The coal fields of Northern WV, PA, MD and OH, generally contain higher sulfur and than the coals of southern WV, KY, and VA. The coal bearing strata are mid-Mississippian to Pennsylvanian in age. Coal beds are interstratified with shales, siltstones and sandstones. The average seam thickness is 5.5 ft. and some seams may be as thick as 12 feet.

Within the region it has been estimated that > 1.2 million acres of surface mined lands need to be reclaimed (Sutton and Dick, 1987). This figure does not take into account the acreage of coal refuse piles which also need to be reclaimed. Minespoil, overburden material blasted and moved during the surface mining process, and coal refuse, the material cleaned from the coal at a coal preparation plant, are the two waste materials from coal mining in which the beneficial reuse of CCB's could take place. Both minesoils and coal refuse are being produced by active mining activities and are found on abandoned mined land (AML) sites. Active operations have an advantage in potential CCB reuse in that equipment for incorporation of CCB's is on site. On most AML sites CCB use would be limited to surface applications which may not effect the acid generation from the whole pile of material.

Minespoil

Minesoil (soils derived from minespoil) properties, like soil properties, vary due to differences in geology, topography, climate, vegetation, the actions of organisms. Minesoil properties also depend on the mining and reclamation methods, which could be considered the acts of organisms. During the mining process in the Midwest and West, the A, B, and C horizons are often separated, stockpiled and then replaced after mining. Often the soils in the eastern region are too thin to allow the separation of horizons and minesoils are formed from all material above hardrock that can be moved with a bulldozer. In other cases mines are granted a permit variance and the minesoil is formed from suitable crushed rock from the minesite itself. In either case the resultant minesoil bears little resemblance to the native soil. During the mining process soil structure is destroyed and flow paths are disrupted. Often the materials are severely compacted during placement. The large coarse fragments in the material may also bridge and create large voids in places. A network of these voids may give areas of a spoil pile a pseudo-karst hydrology in which water may move very rapidly.

Table 1. Coal Production from the Eastern Region for 1993 (EIA, 1996).

State	Tons Mined (Millions)	Tons Surface Mined (Million)	% Surface Mined
AL	24.8	9.6	38.7
E. KY	120.1	61.4	51.1
MD	3.3	0.8	25.1
OH	28.8	18.5	64.2
PA	59.6	24.5	41.1
TN	3.0	1.2	38.0
VA	39.3	12.2	31.3
N. WV	33.6	8.5	25.3
S. WV	96.9	47.6	49.2
Total	409.4	184.5	45.0

In modem mining, testing allows the operator to determine which strata will produce the best minesoils and strata which are high in iron pyrite are isolated from drainage and buried to avoid the placement of potentially toxic material at the surface. When oxidized iron pyrite produces acid mine drainage (AMD), and is the source of the high levels of acidity associated with these sites. In older sites and AML sites such technology was not used and unsuitable materials were placed at the surface. These sites often require the use of large amounts of liming agents for reclamation.

Coal Refuse

Coal refuse is known by other names such as minestone, coal mining wastes, colliery spoil, colliery discard, mine gob, and slate. Coal refuse is primarily waste rock material that is mined along with the coal and subsequently removed at a coal preparation plant. The source of this waste rock is portions of the mine roof and floor mined along with the coal, partings in the seams, and other geological waste in the coal seam. After separation, refuse is disposed in a pile or valley fill near the preparation plant. Depending upon the coal seam, the refuse may comprise from l0-50% of the mine run material. The passage of the federal Surface Mining Control and Reclamation Act (SMCRA) of 1977 set management guidelines and rigorous geotechnical standards for these areas. The SMCRA standards also apply to surface mined areas. Prior to SMCRA, refuse piles were more loosely constructed, and erosion and spontaneous combustion were common problems. After SMCRA, refuse piles were constructed differently. Coarse refuse (>0.5 mm) was commonly used to build an impoundment dam. behind which the finer material (slurry) was pumped and subsequently dewatered. These “zoned” fills are now commonly emplaced in valley heads throughout the Appalachian coalfields.

The federal SMCRA further required that these areas be reclaimed with a 1.2 m (4 ft.) lift of topsoil and a diverse. self-sustaining (5 yr) vigorous plant cover. Generating that much topsoil cover from the thin native soils of Appalachia was difficult, and interest in direct-seeding refuse led to varied research in the use of amendments and reduced topsoil thicknesses on coal refuse (Daniels et al., 1989;

Joost et al., 1987; Nickerson, 1984; Jastrow et al., 1981). Other research has examined refuse from the aspects of mineral recovery (Rob1 et al., 1976), soil characterization (Delp, 1975), material characterization (Buttermore et al., 1978; Stewart and Daniels, 1992), and engineering properties (Skarzynska, 1995; Albuquerque, 1994).

Coal Refuse Properties

Particle Size: Most modem coal preparation plants handle the coarse (> 0.5 mm) and fine (< 0.5 mm) coal refuse in different cleaning circuits. Coarse coal refuse initially contains very little fine material, which can change as weathering takes place. A study of refuse piles in West Virginia (Moulton et al., 1974) determined that fresh refuse contained 68-95% coarse material, while 18 month to 30 year-old material contained 47-80% coarse material. A decrease in coarse fragment content with increasing silt and clay were also reported. Coarse fragment content of 79 inactive bituminous refuse piles in Pennsylvania ranged from 56 to 69% (Davidson, 1974). The mean coarse fragment content of the piles sampled by Delp (1975) was 60%, which concurs with the findings of Stewart and Daniels (1992) who report a mean coarse fragment content of 60% for 27 refuse piles from Southwest Virginia. The <2 mm fraction had a mean soil texture of sandy loam with 19% clay (Stewart and Daniels, 1992). These coarse textures and high coarse fragment contents result in refuse having a very low water holding capacity, which was identified as the chief physical factor limiting plant growth on coal refuse.

pH: Low pH is likely to be the chemical factor most limiting to plant establishment and growth on coal refuse. Although many refuse materials have a near neutral pH when originally placed in the pile, the pH of refuse usually drops rapidly as pyritic materials weather and produce acidity. The detrimental effects of low pH on plant growth have been expounded on by different authors (Brady, 1990; Bohn et al., 1985; Thomas and Hargrove, 1974).

The reported pH values for weathered coal refuse are usually in the acid, to extremely acid range. A range of refuse pH values from 3.0 to 8.3 was reported for 27 refuse piles from southwest Virginia (Stewart and Daniels, 1992). A study of five refuse piles in Illinois produced a mean pH of 2.8 with a range of 2.4 to 3.0 (Haynes and Klimstra, 1975), and a study of four piles revealed pH values from 2.3 to 3.0 (Nawrot, et al., 1986). Refuse pH was found to range from 5 to 10 in Spain, 4 to 7.9 in Poland, and 2.8 to 9.6 in the United Kingdom (Skarzynska, 1995). Refuse with pH values >3.0 are commonly associated with S contents of >2% (Stewart, 1990) and low pH and associated toxic levels of Al, Fe, Mn, and other ions were found to be the chemical factor most limiting plant growth (Stewart and Daniels, 1992).

Electrical Conductivity: Coal refuse tends to have high electrical conductivity (EC) values indicating high levels of dissolved salts. These salts are produced during pyrite oxidation and subsequent acid attack on minerals. Electrical conductivity values of 0.4 S m^{-1} are considered to inhibit the growth of salt sensitive plants (Bower and Wilcox, 1965). In a study of five refuse piles in Illinois, Haynes and Klimsta (1975) reported EC values from 0.03 to 0.30 S m^{-1}. Medvic and Grandt (1976) studied two piles in Illinois. where EC values ranged from 0.2 to 0.62 S m^{-1}. A mean EC of 0.09 S m^{-1} with a range of 0.01 to 0.55 S m^{-1} was reported by Stewart and Daniels (1992). The EC of refuse undergoing active pyrite oxidation will be high, but once oxidation has run its course and salts are leached away, the EC values may decrease.

Elemental Content and Mineralogy: The elemental content of coal refuse has been examined by several researchers (Skarzynska, 1995: Stewart and Daniels, 1992; National Academy of Sciences, 1978; Rose et al., 1978). Coal refuse contains some unrecoverable coal; which can comprise up to 30% of the refuse (Skarzynska. 1995). The SiO2 content ranges between 19 and 78%. and the relative amounts of Al, Fe, K. Ca. and Mg oxides indicate a mineralogical suite that contains alumino-silicate clays such as muscovite and kaolinite along with quartz. In addition to these minerals, smectites, hydroxy-interlayered vermiculite. mixed layer illite montmorillonite, chlorite, feldspars, and iron pyrite have been identified in coal refuse (Skarzynska, 1995: Stewart. 1990; Bamhisel and Massey, 1969). Quartz is usually the dominant mineral with lesser amounts of the alumino-silicate clays. Again, this suite of minerals is relatively low in charge, and the high amount of coarse material in coal refuse further dilutes the charge on a mass basis.

The properties of spoils and refuse that restrict plant growth and limit thier productivity are acidity, compaction near the surface, and course texture. On outslope these problems are compounded by erosion, runoff and difficulty in operation machinery. Application of CCB's could remedy some of these problems. Many ashes are alkaline in nature and could neutralize acidity. Ashes are also fine in texture and water holding capacity may be improved through the application of ash.

Coal Combustion Byproducts (CCBs)

CCBs are manufacturing and engineering materials, and their uses are similar to the uses of competing virgin and processed materials. The most recent data published by ACAA shows that in calendar-year 1994, approximately 90 million tons of CCBs was produced in the USA. As shown in Table 2, the annual production of CCBs in the USA during calendar-year 1994 was greater than and on the same order of magnitude as portland cement and iron ore. The mineral resources that were produced in quantities greater than CCBs during this same period were crushed stone and sand and gravel, both of which exceeded CCB production by an order of magnitude.

Table 2. Comparison of CCBs to Other Mineral Resources (ACAA, 1994)

Mineral Resources: Annual Production in USA (million tons)	
Crushed Stone	1,200
Sand & Gravel	900
CCBs	90
Portland Cement	80
Iron Ore	60

Approximately twenty-five percent (25%) of the annual CCB production was used, and the remaining seventy-five percent (75 %) was disposed.

It is clear from survey data compiled by ACAA since 1966 that the annual use of CCBs has continued to increase both as a percentage of production; and in terms of the tonnage used (Figure 1). At the same time, there has been a generally steady upward trend in total CCB quantities produced. The overall amounts of fly ash, bottom ash and boiler slag used in the USA, for the years 1966 through 1994, are shown in Figure 1 as combined percentages of those three types of CCBs produced in those years. Also shown in Figure 1 are the similar combined percentages of fly ash, bottom ash, boiler slag and FGD material used in the USA, for the years 1987, the first year FGD material was included in ACAA's survey, through 1994.

In 1994, a total of 12.93 million tons of fly ash was used. This represented almost fifty-nine percent (59%) of the cumulative amount, 22.08 million tons, of all CCBs used in 1994. Clearly, the use of fly ash is greater than the use of other CCBs, both individually and combined. The leading applications of fly ash in 1994 are shown in Figure 2 as percentages of the total fly ash used in that year. The top five uses of fly ash in 1994 were as follows:

Fly Ash Applications

cement and concrete products million tons	57.4%	7.42
structural fills	9.4%	1.21
road base and subbase	5.5%	0.71
flowable fill	4.9%	0.64
waste stabilization1	0.8%	0.23
all other	21.0%	2.72
Total:	100%	12.93 million tons

Opportunities exist for at least a doubling of CCB use within the construction industry. For example, structural fill and flowable fill applications, which compete with traditional fill materials such as soil and construction rubble, provide major avenues for market development. In addition the use of CCBs as a reclamation amendment and as a material for mine sealing and grouting is a topic of great interest.

Currently, about 54 million tons of fly ash are produced each year in the U.S. (ACAA, 1996). Fly ash makes up about 80% of the wastes associated with the burning of coal. Presently only about 24% of the ash generated is utilized with the remaining material being deposited in landfills and surface impoundments (ACAA, 1996). Disposal of fly ash poses the greatest environmental impact of coal combustion waste at the present time. Recently, the environmental impacts of fly ash were reviewed by El-Mogazi et al. (1988) and Carlson and Adriano (1993).

Fly ash is mainly composed of silt sized glassy spheres (Fisher et al., 1976), some of the spheres are hollow, termed cenospheres, or spheres filled with smaller spheres termed plerospheres. During the combustion and subsequent cooling process many different metal oxides can precipitate and concentrate on the surfaces on these spheres. These oxides control the chemical properties of the ash, and tend to vary from ash to ash. The oxides may also affect the physico-chemical properties of some fly ashes, especially the pozzalonic (cementious) reactivity.

Physical Properties: The physical properties of fly ash depend upon a number of factors, including the type of coal burned, the boiler conditions, the type and efficiency of the emission controls, and the disposal method (Adriano et al., 1980). Certain characteristics tend to be similar in most ashes. Fly ash is mainly composed of silt-sized materials having a diameter from 0.01 - 100 μm (Chang et al., 1977). When compared with mineral soils, fly ash has lower values for bulk density, hydraulic conductivity, and specific gravity. Both crystalline (mullite) and amorphous (glass) phases have been identified by X-ray diffraction in fly ash (Mattigod et al., 1990).

Chemical Properties: The chemical properties of fly ash will largely be determined by the metal oxides that were surface adsorbed during particle formation. In the U. S., fly ash from eastern coals, which usually are higher sulfur coals, tend to be higher in Fe, Al, and S and lower in Ca and Mg when compared to western coals. Ashes from eastern coals also tend to be higher in the trace elements As, Cd, Cr, Pb, V and Zn (Roy et al., 1981). Most of these elements can substitute into the iron pyrite structure, and coals higher in pyrite therefore tend to produce fly ashes which contain higher levels of these elements. The element Se does not seem to be correlated with any particular coal property. Selenium is known to be a volatile element and its behavior may be highly dependent upon the burning conditions within the boiler.

One property of certain fly ashes which makes them attractive as reclamation amendments is their liming potential. In a study of 23 ashes from across the U.S., Furr et al. (1977) found that ash pH ranged from 4.2 to 11.8. Most low pH ashes came from eastern coal sources. Ash pH values of up to 12.5 have been reported (Chang et al., 1977) for western sub-bituminous coal derived ash. Fresh unweathered fly ashes can have pH values higher than 9 but it is rare to find pH values higher than 8.5

for weathered fly ash. Many ashes are high in Ca and Mg oxides and have a significant neutralizing capacity. Fly ashes with neutralizing capacities of up to 10 % calcium carbonate equivalent (CCE) have been reported, but CCE values of l-6% are more common (Aitken, et al., 1984). Thus, more than 20 tons of most fly ash would be required to replace 1 tonne of ground limestone. This indicates that ash would not be effective in raising a low pH, highly buffered system due to the large amount of ash needed, but may be more effective in poorly buffered, coarse textured systems, such as coal refuse. Water soluble Ca content was found to be the best indicator of ash potential to produce alkalinity (Theis and Wirth, 1977). Unweathered fly ash also contains high levels of soluble salts. Ash from lignite and sub-bituminous coals tend to have the highest salt levels (Adriano et al., 1980), and the application of 179 Mg ha^{-1} of unweathered fly ash was found to increase soil salinity 500 to 600% and causing significant increases in soluble B, Ca, and Mg (Page et al., 1979). Values for saturated paste conductivity for fly ash can be as high as 6 S m^{-1} (Page et al., 1979).

Fly Ash as a Soil Amendment on Agricultural Land : Fly ash has been proposed as a soil amendment due to its previously mentioned neutralizing capacity and potential to improve soil physical properties. The reported effects of fly ash application are summarized in Table 3 (Carlson and Adriano, 1993). This table is split into the effects of weathered and unweathered ash.

Since fly ash contains many silt-sized particles its addition at high rates to soils high in sand or clay can change the soil texture (Chang et al., 1977, 1989). When ash was added to five soils with sandy textures the bulk density decreased, while ash addition to three soils with clayey textures increased bulk density. This difference could be due to the structural position where the fly ash resides after incorporation. In sandy textured soils the ash is likely to reside between grains, pushing them apart. In a clayey soil, the fly ash likely would reside in voids between the peds (Chang et al., 1989). This would tend to increase the bulk density when ash is applied to clayey textured soils.

Ash additions have also been found to increase the water holding capacity of soils. Addition of I0 % ash to fine (0.2-0.5 mm) and coarse (1.4-2.0 mm) sand fractions increased the available water by 7.2 % and 13.5 %, respectively (Campbell et al., 1983). Ash alone was found to have > 40% available water in 11 of 13 Australian ashes tested (Aitken et al., 1984). Improvements in available water in ash amended soils have also been reported by other researchers (Salter et al., 1971; Chang et al., 1977; 1989). It is unclear whether the increases in water holding capacity also result in increases in plant available water; Chang et al. (1979) report that water in fly ash amended soils is less available. Other studies have noted a lack of yield response to the increase in water retention. This could be due to other growth limiting effects of the fly ash, such as B toxicity or high soluble salts. The yields of carrot ***(Daucus carota),*** beet ***(Beta vulgaris),*** radish ***(Raphanus sativus),*** and bean ***(Phaseolus vulgaris)*** showed no improvement in response to the application of fly ash to a sand and sandy loam soil, even though the water holding capacity had increased (Salter et al., 197 1). These researchers hypothesisized that water may not have been a growth limiting factor in this experiment and only one treatment showed a yield response when irrigation water was applied later in the experiment.

Some studies do report yield increases due to fly ash application. An ash that had been leached to remove soluble B content was found to increase the yield of Rhodes grass ***(Chloris gayana*** Kunth) and French bean ***(Phaseolus vulgaris*** L.) (Aitken and Bell, 1985). These researchers also report that the high levels of B in the ash caused a yield decrease, but the removal of B allowed a yield increase which was attributed to an increase in available water Improved corn ***(Zea mays*** L.) yields have also been attributed to ash addition (Plank et al., 1975). A study in which the ash was applied in bands on sandy Michigan soils produced some interesting results. Soil moisture was increased by 2570% during a droughty growing season (Jacobs et al., 1991), and plant roots were found to have grown into the ash bands, which were higher in moisture than the surrounding soils.

Table 3. Potential and observed effects of fly ash amendment on soil properties (Carlson and Adriano, 1993).

Soil property	Typical agricultural soil	Soil amended with weathered ash	Soil amended with unweathered ash
Aeration	high	higher	higher
Bulk density	1.3 (avg)	lower	lower
Cation Exchange Capacity	medium 12 cmol/kg	lower	lower
Cementation	low	low	may increase due to alkaline ash
Electrical Conductivity	low	moderate to higher	higher
Hydraulic conductivity	high	increased by low rates; decreased by high rates	increased by low rates; decreased by high rates
Modulus of rupture	high	lower	lower
Nutrient availability	balanced supply of nutrients	deficient in N, P, and potentially Cu, Mn, Zn; potential for food chain concern with Mo and Se	deficient in N, P, and potentially Cu, Mn, Zn; potential for food chain concern with Mo and Se
Nutrient content	all nutrients present.	very low N, potentially high B; others present	very low N, often excessive B; others present
Organic matter	high	lower	lower
pH	6.0 - 7.5	<6.0 to 8.0	<6.0 to 12.0
Plant available water	high	no effect to large increase	no effect to large increase
Salinity	low	moderate	high but decreases with time
Temperature	adequate	higher	higher
Toxic salts	none	may have enough B to toxic to sensitive plants	High B and soluble salts of Ca, K, Mg, and Na
Erosion	resistant	more susceptible	more susceptible
Water holding capacity	high	higher	higher

Elemental Uptake. Application of fly ash to soil can affect soil and plant chemical composition. **The** concentration of trace elements can be greatly effected. Wheat (*Triticum* spp.) seedlings grown on an ash amended soil showed decreases in some metals due to a high pH ash, while other ashes produced increases in seedling metal content due to metals in the ash (Petruzzelli et al., 1987). In research on a Virginia soil, Martens and Beahm (1976) reported that fresh ash added to a Tatum (Typic Hapludult) soil increased the Mo concentration in alfalfa. They were not able to isolate whether the increase was due to added Mo from the ash, or an increase in Mo availability from a pH increase.

Due to the relatively high concentrations of some trace elements in fly ash many researchers have investigated the use of fly ash as a trace element source, and in some cases as a macro-element fertilizer. For a review of these studies and which elements were examined. see Carlson and Adriano (1993). Ash application can also increase the plant content of the non phyto-essential element Se. Selenium is required by animals and is deficient in some forages grown on the soils of the southeastern U.S. When using ash as a trace element source, care must be taken because over-application can result in phytotoxic levels of B and sufficiently high levels of As, Mo, and Se to pose a potential threat to animal consumption (Doran and Martens, 1976; Tolle et al., 1983).

In a study of elemental uptake of grasses from fresh and weathered ash dumps, Nass et al. (1993) found that grasses grown on unweathered ash had Mo, Pb, and Se levels that exceed the maximum tolerable limits for domestic animal feed. In grasses grown on weathered ash the Mo, Pb and Se concentrations where below the maximum tolerable limits. They pointed out that Mo levels may be sufficiently high to induce a Cu-deficiency and suggested the necessity to monitor all animals feed grasses grown on ash.

Fly Ash as a Mine Reclamation Amendment: Disposal of coal fly ash in coal refuse piles and minespoil heaps is a common practice in other countries (Skarzynska, 1995; Twardoswska, 1990), but is not currently a widespread practice in the U.S. The USEPA recently excluded coal fly ash from regulation as a hazardous waste (USEPA, 1993) which has led to an increased interest in returning fly ash to the coalfields for disposal. Provisions that call for coal producers to accept back-haul and disposal of fly ash are now being written into many coal contracts. This presents an opportunity for this ash to be used in the reclamation of coal refuse. Use of ash in this manner would represent utilization of a coal combustion waste to reclaim wastes generated in coal extraction. The use of coal fly ash in reclamation of coal refuse has been the subject of several experiments (Adams et al., 1972; Jastrow et al., 1981), but has not become a widespread practice in the U. S., primarily due to regulatory constraints and the lack of ash sources within many mining districts. The addition of fly ash to coal refuse and minesoils has been shown to lower bulk density, increase water holding capacity, and neutralize acidity (Capp, 1978; Jastrow et al., 1981; Taylor and Schuman, 1988).

Nearly all coal refuse piles in the Appalachian coal basin are located on or near streams, and can be the source of significant stream pollution from sediment and AMD. The AMD results from iron pyrite oxidation, which may be native to the refuse material or was separated from the coal during the cleaning process. The addition of an alkaline fly ash would raise the pH of the coal refuse, lower its hydraulic conductivity, and lower the rate of gas exchange with the atmosphere. These principles are the basis of the mine and spoil grouting work that has been done by several researchers, (Kim and Ackman, 1995; Baker et. al. 1992;) Ash incorporation could greatly decrease or halt the oxidation of pyrite in a mixture of coal refuse and fly ash. The mixing rate must necessarily be fairly high due to the low neutralizing power of fly ash. Very high rates of fly ash application, up to 1600 ton a^{-1} (Capp, 1978) may be needed to raise the pH of the refuse above 7. The placement of layers of fly ash within a coal refuse pile has led to improved drainage quality from a pile in Poland (Twardowska, 1990). In most studies, the ash has been surface applied to coal refuse and minespoils (Bhumbla et al., 1993; Capp, 1978). While this practice affects the surface of the pile, the vast majority of the bulk of a waste pile are not affected. Blending fly ash with refuse in bulk would treat the entire refuse pile.

Work has also been done in Ohio (Stehouwer et al, 1995) and West Virginia on the use of some of FGD as amendments in reclamation. These materials offer higher liming capacities than fly ash but do not have the bulkiness and abundance of silt sized material. Some researchers have used mixtures of fly ash and FGD materials (Kim and Ackerman, 1995) as amendments in mine sealing.

Regulatory and Legislative Issues

In the Energy Policy Act of 1992 [Public Law No. 102-486, October 24, 1992] the U.S. Secretary of Energy was charged with the task of conducting a detailed and comprehensive study on the "institutional, legal and regulatory barriers to increased utilization of CCBs by potential governmental and commercial users" and reporting the findings to Congress. The U.S. Department of Energy (DOE) report was published in July 1994 [DOE, 1994].

The report has had a significant effect on the continuing efforts to advance the use of CCBs. The recommendations in the DOE report address a network of related barriers which can be overcome only through cooperative efforts among federal and state government agencies and industry. ACAA has addressed many of these issues in its activities and will continue to do so in the future.

Summary

Throughout ACAA's history, its goal has been to gain recognition and acceptance of CCBs as engineering and manufacturing materials that compete in an open market with virgin and processed materials. As we continue to advance the use of CCBs in ways that are technically sound, commercially competitive and environmentally safe, the number and quantity of CCB applications will grow as well. Minesoils and coal refuse are hard to reclaim and limited in their productivity due to coarse particle size, and high levels of acidity. Coal Combustion Byproducts, particularly those that are alkaline in nature, could be used as an amendment to ameliorate these problems. Application of alkaline CCBs and in particular alkaline fly ash would decrease particle size, and neutralize acidity if applied in large quantities. This would result in the beneficial reuse of ash and in improved reclamation results.

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Figure 1. Combined Percentages for CCBs Used: 1966-1994

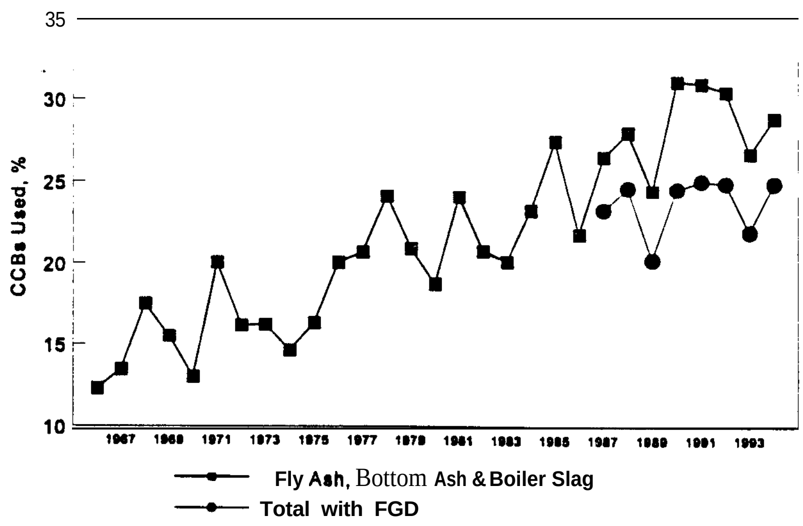

Figure 2. Leading Fly Ash Applications - 1994