RECLAMATION OF COAL MINE WASTES AND STRIP SPOIL WITH FLY ASH

By

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ABSTRACT

Strip mine scars, coal refuse piles and fly ash dumps are solid wastes resulting from the mining and combustion of coal. The total unreclaimed area resulting from these wastes is over 2 million acres. Disposition of these wastes is obviously a monumental problem. Large-scale field experiments in the reclamation of acid surface-mined coal lands and refuse piles with raw fly ash from bituminous-coal-fired powerplants were conducted at several sites in Northern West Virginia. Plots were treated with varying tonnages of fly ash from area powerplants and were planted with a variety of grasses, legumes, trees and shrubs. Greatest potential for growth and survival under harsh soil conditions was shown by Kentucky 31 fescue, rye and red top grasses and by birdsfoot trefoil, a legume. Application of fly ash to the acid materials increased the pH to a range tolerable to plant growth, improved the texture of the soil, increased the water-holding capacity of the resulting misture, and added trace nutrients to the soil.

INTRODUCTION

Solid wastes from the mining and combustion of coal are serious environmental problems of vital concern to the producers and users of coal as well as the general public. Establishment of vegetative cover on each of these areas through reclamation procedures is essential to maintain effective control over erosion and stream pollution.

Vegetation of areas where adverse conditions (steep slopes, highly acid soil material, etc.) prevail is not always possible. In such cases, it may be necessary to modify the sites with a soil amendment such as lime, mulch, additional nutrients in the form of fertilizer and even waste materials such as composted garbage, processed sewage, and bark may be employed. If fly ash can be used as a soil amendment on acid spoil and refuse, it might be possible to achieve a good balance of physical, chemical and biological factors essential to the success of the reclamation effort. An additional benefit is the disposal of large quantities of fly ash in a manner that is useful to the environment in coal mining areas.

Researchers at the Bureau's Morgantown (W. Va.) Energy Research Center are investigating the technical feasibility of utilizing power-plant fly ash to reclaim coal mine refuse and surface mine spoils. [1]

SCOPE OF FLY ASH DISPOSAL PROBLEM

Within 10 to 15 years, coal-fired power generating stations will be producing about 40 million tons of ash annually in the United States, and this could double if lime or limestone injection becomes widely used to control sulfur oxide emissions. Most of this ash will be entrained in the stack gases and trapped as fly ash. Although uses for about 10 percent of the fly ash have been developed, mainly in the construction industry, the bulk of it is transported either in slurry or dry form to disposal areas at considerable cost to the power companies and therefore to the public. The accompanying economic loss in terms of unused raw materials and displaced land is not as obvious but is just as significant.

SCOPE OF SURFACE MINE RECLAMATION PROBLEM

Another environmental problem of considerable magnitude in the United States and one that is closely related to the surface mining of coal is the reclamation of the disturbed spoil materials that remain after the mineral is recovered. According to D. M. Whitt[2], table 1, every state in the United States has land disturbed by strip mining of one kind or another.

The total area requiring reclamation (over 2 million acres) is almost as large as Yellowstone National Park. Whitt reviews a study[3] by several cooperating Federal agencies that reveals the following facts:

1. About 91 percent of the affected acreage is in private ownership, and nearly half of that is in small scattered ownerships.

2. More than 80 percent of the mined land surveyed was a mile or more from towns of 200 or more people. About 40 percent of the mined land was more than 5 miles from towns of this size. In other words, most disturbed land is in rural areas.

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[1] Adams, L. M., J. P. Capp and E. Eisentrout. Reclamation of Acidic Coal-Mine Spoil with Fly Ash, BuMines Rept. of Inv. 7504, April 1971, 29 pp.

[2] Whitt, D. M. Surface-mined land. Soil Conservation, v. 33, No. 6, January 1968, pp. 123-125.

[3] Udall, Stewart L. Study of strip and surface mining in Appalachia. An interim report of the Secretary of the Interior to the Appalachian Regional Commission, June 30, 1966, 78 pp.

3. About one-third of the land disturbed by surface mining has been rehabilitated. Some of this was restored by natural seedings, but more than half was treated through the efforts of private owners.

4. Restored surface-mined land can serve several useful purposes. A survey in 1966 by the Soil Conservation Service in 14 states showed that the greatest potential uses were woodland production and wildlife habitat.

The study recommended that the appropriate Federal agencies demonstrate leadership with technical and financial aid working through local conservation districts and that "research studies, and field demonstrations be expanded."

More than 50 minerals are produced by surface mining in the United States. About 95 percent of the acreage disturbed by 1965 was for seven commodities, as shown in figure 1.

SCOPE OF THE COAL REFUSE PROBLEM

For many years, burning coal refuse banks have blighted coal-producing areas of this country, posing a health hazard to local populations, producing local defoliation of vegetation and causing other losses in property damage. Further, there are hundreds of non-burning refuse piles which are potentially dangerous; moreover, additional annual accumulation of coal refuse amounts to approximately 70 million tons.

Recently much attention has been focused on this situation. Renewed efforts have been made by the coal industry, by state controlling agencies and by research organizations to prevent the spontaneous heating, ignition and burning of refuse banks, and even find uses for the hugh quantities of refuse material.

Currently, active dumps are leveled, covered with soil, and planted with grass and/or trees with varying degrees of success.

EXPERIMENTAL PROCEDURE

The surface mine reclamation field experiments were started by the Morgantown Energy Research Center in 1965 and have continued through 1971 on so-called orphaned strip mines that fall into the category of areas that require considerable treatment in order to support vegetation. Table 2 summarizes the Bureau's program and shows treatment at the various sites.

The coal refuse bank or "gob pile" reclamation effort was done on a leveled refuse dump that was owned by a large coal company. Both types of material (i.e., spoil and gob) were acidic due to the presence of pyritic minerals associated with the coal and the overburden with soil pH values mostly in the range of 2.5 to 3.5.

All the sites were droughty[4] and generally devoid of plant cover and nutrients. Routine soil textural classifications indicated that the materials were loams, sandy loams or clay loams. However, the surfaces of these areas were covered with scattered pieces or rock, shale or coal, ranging in size from pebbles to boulders. A chemical analysis of the spoil materials is given in table 3.

Although the fly ash for these experiments was obtained from several local powerplants, the largest tonnage used came from the Fort Martin power station because of the easy availability, the large daily production, and consistent quality. A typical analysis of this ash is given in table 4. This fly ash has a pH of 12 and an alkaline soil reaction when mixed with acid soils. Since limestone normally is used to neutralize acid soils, a comparison of the limestone requirement for a particular strip spoil and the fly ash to give the same effect shows that approximately 10 times more fly ash may be required.

The application rate of fly ash actually used in the field was determined in the laboratory by measuring the pH of equilibrated soil-water mixtures on a 1:1 by weight basis. The ratio of fly ash to spoil was adjusted empirically to obtain a near neutral condition. The ratio was then used to calculate the fly ash application rate based on a 6-inch plow layer depth of soil material. These applications varied between 150 and 800 tons per acre depending upon the fly ash used, the type of spoil and its buffering capacity, and the depth of mixing anticipated.

The type of machinery used for spreading and mixing fly ash with the spoil or refuse depended primarily upon the relative roughness of the surface. Conventional farm equipment was used at some sites while large earthmoving machines were required at others. After the area was prepared, fertilizer and seed were applied at the desired rates.

One typical seed mixture was used, as shown in table 5, at the rate of 43-47 lbs/acre. Kentucky 31 fescue was almost always included in the mixture because of the high degree of success experienced with this grass.

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[4] Gravimetric moisture determinations of spoil and refuse indicated that moisture content was generally at or near wilt point. See discussion of Chemical and Physical Benefits of fly ash, last paragraph.

Fertilizer (granular, 10-10-10-analysis) was applied at 1,000 lbs per acre in most cases but higher rates were occasionally employed for special purposes.

The Morgantown Energy Research Center presently has two large-scale demonstration sites under treatment. One is a surface mine spoil area (Strip Site No. 4) consisting of about 65 acres, half of which has been treated with fly ash. Approximately 12 acres have a vegetative cover consisting mostly of Kentucky 31 fescue and rye grass. Several varieties of trees, shrubs, various grasses and legumes have also been planted experimentally on small plots for survival and growth studies.

The other site is a one-acre area (Coal Mine Refuse Site No. 1) that was laid out in the middle of a level coal refuse dump. A successful grass cover has been established that consists of the first four grasses shown in the mixture in table 5.

Most of the data discussed in the next section was obtained at strip sites 1, 2 and 3, and represents accumulated experience since the start of the work in 1965. The collection and analysis of data at these sites is continuing and it is expected that similar information will be forthcoming from the two large-scale demonstration sites presently being reclaimed with fly ash.

RESULTS AND DISCUSSION

Dry Matter Yields

Dry matter (hay) yields are indicative of the beneficial effects of fly ash treatment. At site No. 1 an average yield of 1.09 tons/acre was obtained from the fly ash-treated areas; a limestone-treated control plot at the same site produced only 0.54 ton/acre. At site No. 2 the yields ranged from 1.6 to 2.3 tons per acre, as shown in table 6. Similar yields were obtained at site No. 3.

During the third year at site No. 2, fertilizer (N, P and K) rates were increased. Since nitrogen is the most easily lost by leaching, it was applied in equal portions of 70 pounds per acre as urea in the spring and after the first two cuttings. Spring applications of P and K were 90 pounds per acre of P (as P_2O_5) and 180 pounds of K (as K_2O) from 0-15-30 analysis granulated fertilizer. This treatment increased yields and permitted three cuttings instead of the usual one or two per year. Average dry matter yields from all the plots for each cutting are given in table 6. The overall average yields for the three cuttings are 44, 34 and 22 percent of the season total, which is comparable with those obtained at the West Virginia University Agronomy Farm, Reedsville, W. Va., in high-fertilization-rate experiments. Furthermore, the total average yield of about 4 tons per acre for the third year at site 2 was typical of the yields obtained during West Virginia University's pasture experiments with these same perennial tall grasses.

Chemical and Physical Benefits from Fly Ash

Periodic pH determinations were made for three consecutive years at two of the experimental sites and plotted to show long-range changes, figure 2. The untreated controls in both cases show a slight increase, but it would require many years before conditions would become favorable for plant survival. Fly ash-treated plots on the other hand show slight decreases indicating the need for additionaly fly ash application or the application of small quantities of lime periodically to maintain acceptable soil pH levels for long-range use.

Mixing large quantities of fly ash with spoil also produced physical changes that enhanced plant survival and growth. Bulk density of the mixtures was decreased by the large additions of the light-weight amendment. Decreased bulk density values resulted in greater pore volume, greater moisture availability, and higher air capacity, and hence better conditions for root penetration and growth.

Soils consist of sand, clay and silt-sized mineral fractions and the relative proportion of these various fractions defines a specific soil texture classification. For example, the plow layer (6 inches deep and weighing 1,000 tons per acre) of a typical clay loam has the following analysis per acre: Clay, 350 tons; sand, 350 tons; and silt, 300 tons. A typical silt loam has the following per acre analysis: Clay, 150 tons; sand, 200 tons; silt, 650 tons. (Obviously considerable changes in these amounts would be required to change from one classification to another.)

Although soil scientists consider alteration of texture virtually impossible under ordinary circumstances, this study showed that adding fly ash to surface mine spoil changed the textural classification. (See figure 3.)

Spoil texture influences the amount of moisture available for plant growth. In general, spoil composed largely of sand has good aeration but is apt to be droughty. Clay banks compact easily and crust over during dry periods. Loams and silty shales usually have enough fine material to hold moisture.

Figure 4, which compares the wilt point and field capacity of different textured soils, further illustrates this point. The capacity of the soil to hold water is related to surface area, pore-space volume, and continuity of the pore space. Water-holding capacity is therefore related to structure as well as to texture. It can be seen in figure 4 that fine-textured soils have the maximum total water holding capacity, but that maximum available water is held in medium-textured soils. Research has shown that available water in many soils is closely correlated with the content of silt and very fine sand.

Fly ash, which is mostly in the silt size range, was applied at rates of 150 to 800 tons per acre. This proved to be a sufficient quantity of ash (particularly at the higher rates) to produce a textural change by shifting the analysis toward the silt side of the textural triangle.[5]

Further evidence of the beneficial effect that the use of fly ash has on the water capacity of the spoil and the availability of this moisture is indicated by figure 5. This figure gives quantitative moisture values for the undisturbed control plot and a plot treated with 800 tons/acre of fly ash at strip site No. 2. Field capacity and wilt point values for these plots, indicated in the figure by dashed lines, show how the available water range corresponds to the actual moisture content under field conditions. Heavy spring rains built up a significant reservoir of moisture in the fly ash-treated plot and continued to be available even during the summer dry period, as the bar graph indicates. On the other hand, the control plot retained little moisture from the spring rains and during the dry period moisture was not in the available range for plants for several weeks. Since the actual moisture content of the control spoil remains at or near the wilt point value, most of the water that fell on this area as rain probably ran off and was not absorbed.

SUMMARY

These experiments demonstrate the feasibility of disposing of large quantities of power plant fly ash on acid surface mine spoil and coal refuse dumps. The benefits that result are:

1) Acid materials are partially neutralized and soil conditions improved to a tolerant level for some grasses and legumes.

2) The grasses and legumes establish an immediate cover that resists erosion and hence reduces stream pollution potential.

3) Soil texture changes increase moisture holding capacity, increase pore space and improve root growth conditions.

4) Yields of forage and hay from reclaimed lands are comparable to yields from undisturbed pastures and meadows as reported by the West Virginia Cooperative Crop Reporting Service.[6]

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[5] Textural changes discussed in this text refer to the "plow layer" or top 6 inches of material.

[6] West Virginia Department of Agriculture, Div. of Statistics, Charleston, W. Va., July 12, 1968, Monthly Farm Report.

Although reclamation of strip spoil with fly ash appears technically feasible, practical application and widespread acceptance depend on a number of other considerations. Economic justification will be a major factor, and esthetics and strip mining laws will also play important roles. Surface mining doubtless will continue to be a major factor in recovering minerals vital to the nation's economy, hence there is continued incentive to evolve better reclamation techniques and develop methods of recovering minerals with minimum damage to surface areas and streams.

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TABLE 1. - Condition of surface-mined land, by state, January 1, 1965

[In thousands of acres]

State	Land needing treatment [1]	Land not needing treatment [1]	Total land disturbed [2]
Alabama	83.0	50.9	133.9
Alaska	6.9	4.2	11.1
Arizona	4.7	27.7	32.4
Arkansas	16.6	5.8	22.4
California	107.9	66.1	174.0
Colorado	40.2	14.8	55.0
Connecticut	10.1	6.2	16.3
Delaware	3.5	2.2	5.7
Florida	143.5	45.3	188.8
Georgia	13.5	8.2	21.7
Hawaii [3]			
Idaho	30.7	10.3	41.0
Illinois	88.7	54.4	143.1
Indiana	27.6	97.7	125.3
Iowa	35.5	8.9	44.4
Kansas	50.0	9.5	59.5
Kentucky	79.2	48.5	127.7
Louisiana	17.2	13.6	30.8
Maine	21.6	13.2	34.8
Maryland	18.1	7.1	25.2
Massachusetts	25.0	15.3	40.3
Michigan	26.6	10.3	36.9
Minnesota	71.5	43.9	115.4
Mississippi	23.7	5.9	29.6
Missouri	43.7	15.4	59.1
Montana	19.6	7.3	26.9
Nebraska	16.8	12.1	28.9
Nevada	20.4	12.5	32.9
New Hampshire	5.1	3.2	8.3
New Jersey	21.0	12.8	33.8
New Mexico	2.0	4.5	6.5
New York	50.2	7.5	57.7
North Carolina	22.8	14.0	36.8
North Dakota	22.9	14.0	36.9
Ohio	171.6	105.1	276.7
Oklahoma	22.2	5.2	27.4
Oregon	5.8	3.6	9.4
Pennsylvania	229.5	140.7	370.2
Rhode Island	2.2	1.4	3.6
South Carolina	19.3	13.4	32.7
South Dakota	25.3	8.9	34.2
Tennessee	62.5	38.4	100.9
Texas	136.4	29.9	166.3
Utah	3.4	2.1	5.5
Vermont	4.2	2.5	6.7
Virginia	37.7	23.1	60.8
Washington	5.5	3.3	8.8
West Virginia	111.4	84.1	195.5
Wisconsin	27.4	8.2	35.6
Wyoming	6.4	4.0	10.4
Total	[4] 2,040.6	1,147.2	3,187.8

[1] Compiled from data supplied by Soil Conservation Service, U.S. Department of Agriculture.
[2] Compiled from data supplied by U.S. Department of the Interior; from Soil Conservation Service; and from study-group estimates.
[3] Less than 100 acres.
[4] Does not include 108,000 acres of National Forest land needing treatment.

TABLE 2. - Description of surface mine spoil sites treated with fly ash

Site No., name, year treated	Bituminous coal seam mined	Area, acres	Original pH	Fly ash rate, tons/acre	pH after treatment
1, Westover 1965	Sewickley	½	3.5	55-600	4-6
2, Albright 1966	Bakerstown	1	2.6-3.3	200-800	6-8
3, Fort Martin 1968	Sewickley	5	3.1-4.7	150	6-7
4, Stewartstown 1970	Pittsburgh	65	3.0	150	7-8

TABLE 3. - Chemical analysis of surface mine spoil at sites 1, 2 and 3[1]

Constituent	Weight-Percent		
	Site 1	Site 2	Site 3
Al_2O_3	18.0	24.0	21.4
SiO_2	69.3	59.7	62.1
Fe_2O_3	7.9	9.2	7.7
P_2O_5	.1	.1	.1
TiO_2	.7	.7	.8
CaO	.2	1.0	.5
MgO	.2	.5	.8
K_2O	2.4	3.5	3.1
Na_2O	.7	.5	.5
S	.3	.6	.1
H_2	.8	1.0	--
C	1.7	5.0	2.9
Bulk density, g/cc	1.4	1.6	--

[1] Sample cores were taken to depth of 6 inches and composited for analysis.

TABLE 4. - Typical analysis of Fort Martin fly ash

Constituent	Wt pct (ppm)
Major elements	
SiO_2	47.7
Al_2O_3	23.6
Fe_2O_3	15.6
CaO	3.5
MgO	1.5
Na_2O	1.9
K_2O	2.2
TiO_2	2.7
P_2O_5	.6
N.D.	.7
LOI	3.6
Trace elements	
B	450 ppm
Cu	40 ppm
Mn	200 ppm
Mo	20 ppm
Zn	90 ppm
Bulk density g/cc	1.15

TABLE 5. - Typical seed mixture of various grasses applied to fly ash--spoil or refuse areas

Seed mixture	Wt pct
Kentucky 31 fescue (Festuca arundinacea shrebe)	35
Red top grass (Agrostis alba)	14
Orchard grass (Dactylis glomertas)	18
Rye grass (Lolium perenne)	28
Birdsfoot trefoil (Lotus corniculatus)	5
	100

TABLE 6. - Average dry matter yields, site 2

Year	Dry weight, tons/acre						
	1st Cutting		2nd Cutting		3rd Cutting		Total
	Date	Yield	Date	Yield	Date	Yield	Yield
First (1967)	June 1	1.6	--	None	--	None	1.6
Second (1968)	June 5	1.4	Sept. 5	.9	--	None	2.3
Third (1969)	June 2	1.7	July 29	1.2	Sept. 30	.9	3.8

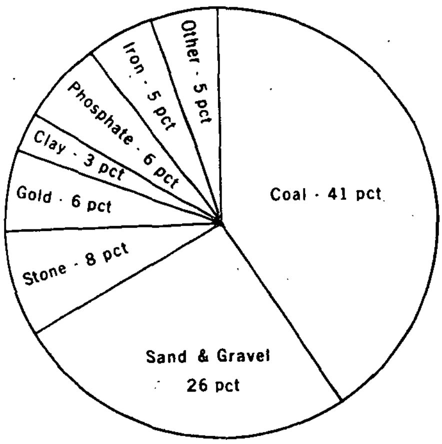

FIGURE 1. - Surface mining in USA by mineral

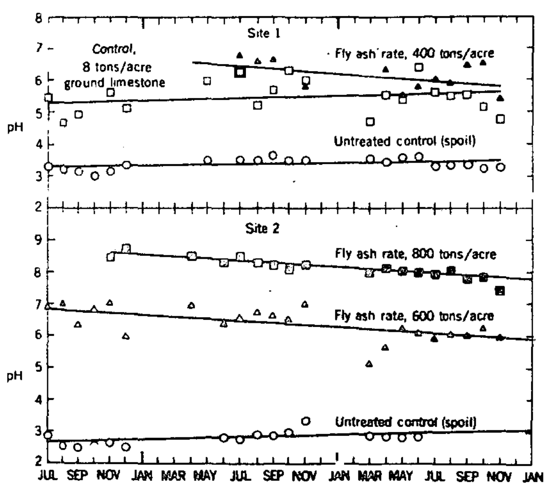

FIGURE 2. - Untreated spoil remains acidic, pH of spoil-
fly ash mixtures remain sufficiently high to
maintain plant life

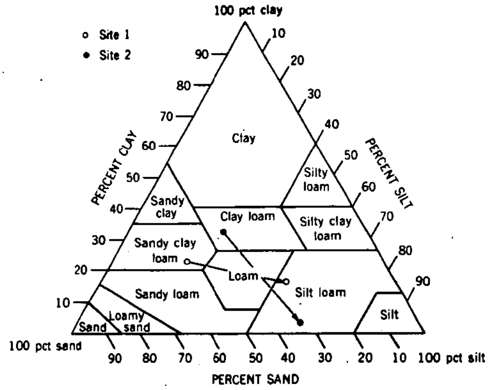

FIGURE 3. - Fly ash changes spoil to silt loam classification

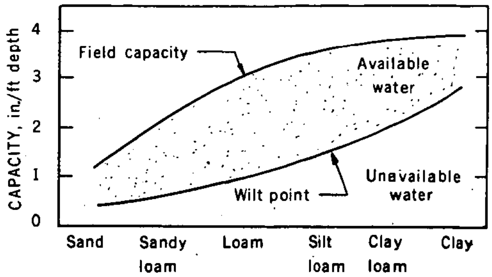

FIGURE 4. - Water-holding capacities of different textured soils

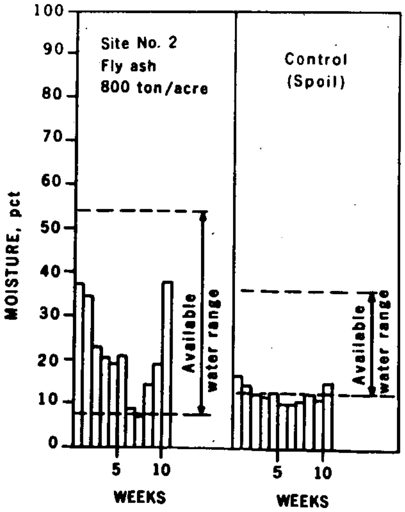

FIGURE 5. - Moisture availability of fly ash-modified soil