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Chemical Properties and Particle-Size Distribution of 39 SURFACE-MINE SPOILS in Southern West Virginia

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Chemical Properties and Particle-Size Distribution of **39 SURFACE-MINE SPOILS** in Southern West Virginia

ABSTRACT

A survey of 39 surface-mine sites in southern West Virginia showed that most of the spoils from current mining operations had a pH of 5.0 or higher. Soil-size material averaged 37 percent of the weight of the spoils sampled. A major problem for the establishment of vegetation was a deficiency of nitrogen and phosphorus. This can be corrected with additions of fertilizer at appropriate rates.

THE CHEMICAL COMPOSITION of the geologic materials blended together in surface-mine spoils affects vegetation establishment and growth. It may also alter the chemistry of surface and subsurface waters flowing from disturbed areas. Success of revegetation and water quality may also be influenced by the particle-size distribution of the spoil material.

An examination of spoils associated with some of the more important southern West Virginia coal seams permits an assessment of the opportunities for successful vegetation establishment and the probability of surface mining affecting the chemistry of associated streams.

It is assumed that wide variation does exist among spoil materials. The West Virginia Geologic and Economic Survey has identified 62 minable coal beds within the state. These are distributed through a stratigraphic column that may be as much as 6,750 feet thick. In all probability, there were wide variations in the paleo-environment when each of these coal seams was laid down. Even greater environmental variations could have occurred as the various rock strata above the coal seam were formed. Therefore, when these widely differing geologic materials are disturbed, mixed, and exposed by mining to weathering processes, we can expect variations in the chemical composition and particle-size distribution of spoil material from different coal seams.

In this study, we collected sample material from 39 locations in the southern West Virginia coal field. These were analyzed in a laboratory and greenhouse to identify properties that may affect establishment of vegetation.

Table 1.—Original reserves of coal seams selected for study

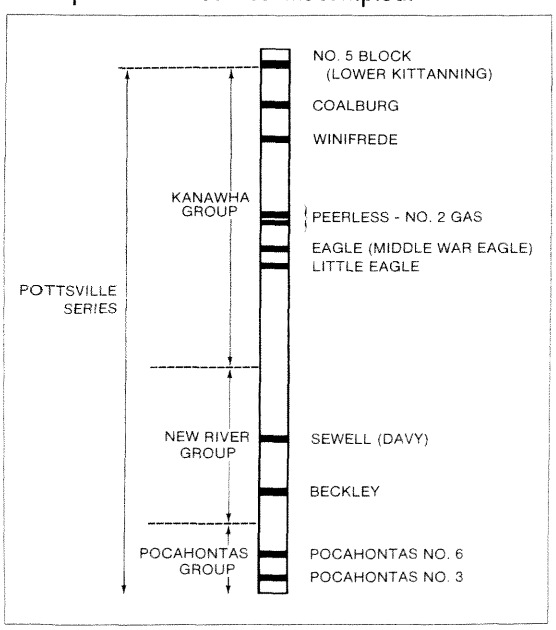
Coal seam	Original reserves
	Million tons
No. 5 Block	10.3
Coalburg	3.4
Winifrede	3.5
Peerless and No. 2 Gas	9.9
Eagle	4.2
Little Eagle	.9
Sewell	6.3
Beckley	2.0
Pocahontas No. 6	.9
Pocahontas No. 3	2.9
Total	44.3

THE STUDY

In cooperation with the West Virginia Department of Natural Resources, the West Virginia Surface Mining and Reclamation Association, and others, we selected 10 coal seams for study (fig. 1). All are believed to have extensive acreage of disturbance and large reserves that could be recovered by surface mining methods. The Peerless and No. 2 Gas seams were considered as one seam because the interval between them is small, and the spoils often mix.

The sample included coal seams from the base of the Pennsylvanian period through the entire Pottsville series to the No. 5 Block or Lower Kittanning coal bed at the base of the Allegheny series (table 1). Forty-four coal seams are recognized within this geologic section. The original reserves for these beds were estimated to be 79.5 billion tons.[1] More than 50 percent of this total is accounted for in reserves in the coal seams selected for this study.

Figure 1.—Stratigraphic section, showing relative positions of coal seams sampled.



Field Sampling

Four sample locations, widely separated geographically, were selected for all coal seams except the combined Peerless and No. 2 Gas, for which three locations were used. The spoil at each location was 6 months or less in age, regraded but not seeded or fertilized, and mined by a different operator. Sampling began in the fall of 1969 and was completed in November 1970.

At each location we selected a sampling point that appeared to be representative of most of the spoil. This decision was based on surface characteristics such as color, the proportion of sandstone and shale, and the size of the rock fragments.

All samples were collected along a 100-foot base line located on the outside edge of the bench at the crest of the outslope. The following samples were collected from the surface 6 inches at points evenly spaced along this base line:

[1]Tucker, R. C. BITUMINOUS COAL BEDS IN WEST VIRGINIA. West Virginia Geological Survey, Columnar Section. 1939.

1. Ten samples weighing 1 pound each. Rock fragments larger than ½ inch were removed from this material.
2. Three samples weighing 5 pounds each. These samples included rock fragments weighing a pound or less as they occurred on the spoil surface. We did not attempt to measure the percentage of the total spoil volume or weight of rock fragments heavier than a pound.
3. Approximately 60 pounds of material from one point at 25 of the locations. This material, passed through a screen with a ½-inch mesh, was used for the greenhouse tests. These collections were made at three locations on the Pocahontas No. 3, Pocahontas No. 6, Beckley, Winifrede, and Coalburg coal seams; and at two locations on the Little Eagle, No. 5 Block, Sewell, Eagle and Peerless—No. 2 Gas coal seams.

Laboratory Procedures

We determined pH and available phosphorus for each of the ten 1-pound samples. Available phosphorus was determind with the Bray No. 1 extractant solution. The pH was determined with a pH meter on a 1:2 mixture of spoil and distilled water.

Material from the three 5-pound samples was screened to obtain the percentage by weight of various sizes of rock and soil. This material was air-dried, then sieved through screens with ¾-inch, ½-inch, ¼-inch, and 2 mm. mesh. Chemical analyses of the material passing the 2 mm. mesh were made to determine exchangeable acidity, exchangeable aluminum, and exchangeable hydrogen. The titration method developed by Yuan[2] was used for these determinations.

Laboratory analyses showed that the spoil collected for greenhouse use was chemically and physically similar to the 1- and 5-pound samples of spoil.

Greenhouse Tests

The relative productivity of the spoils collected from the 25 locations was compared by growing Kentucky-31 tall fescue *(Festuca arundinacea)* and sericea lespedeza *(Lespedeza cuneata)* in pots of the spoil in the greenhouse. The following fertility treatments were applied to the spoils:

Kentucky-31 fescue:

1. Check (no fertilizer).
2. Nitrogen: 50 p.p.m. or 100 pounds N per acre.
3. Phosphate: 22 p.p.m. P or 100 pounds P_2O_5 per acre.
4. Nitrogen plus phosphate: at rates used in (2) and (3).
5. Nitrogen, phosphate, and potassium: nitrogen and phosphate at rates used in treatments (2) and (3), and potassium at a rate of 42 p.p.m. K or 100 pounds K_2O per acre.

Sericea lespedeza:

1. Check (no fertilizer).
2. Phosphate: 22 p.p.m. P or 100 pounds P_2O_5 per acre.
3. Nitrogen plus phosphate: nitrogen at a rate of 20 p.p.m. or 40 pounds per acre, and phosphate at rates used in treatment (2).
4. Nitrogen, phosphate, and potassium: nitrogen and phosphate at rates used in treatments (2) and (3), and potassium at a rate of 42 p.p.m. K or 100 pounds K_2O per acre.

The fertilizer materials used for supplying the N, P, and K were respectively ammonium nitrate, monobasic calcium phosphate, and potassium chloride. Treatments were not replicated within each spoil collection.

An error in procedure eliminated the intended nitrogen treatment for sericea lespedeza.

Each treatment was applied to two pots containing 2,000 grams of air-dried spoil. Fescue was seeded in one pot, and sericea lespedeza in the other. Distilled water was added to bring the spoil moisture content up to field capacity and maintain it there. The fescue was grown for 44 days from seeding to harvest; and the lespedeza 77 days. At the termination of each test, the plants were clipped at ground line, oven-dried, and weighed to determine yield.

[2]Yuan, T. L. Determination of exchangeable hydrogen in soils by a titration method. Soil Science 88: 164-167. 1959.

RESULTS

Particle-Size Distribution

The primary interest in this analysis was the percentage, by weight, of particles 2 mm. or less in size—the soil-size fraction. This portion affects water retention and availability, which in turn relates to plant establishment and growth. The potential for chemical pollution through weathering and soil erodibility are also related to the percentage of soil-size material on the spoil surface.

We found no significant statistical differences among coal seams in the percentage of soil-size particles per sample (table 2). The wide variation among samples for each coal seam apparently obscures any significant differences among coal seams.

The soil-size fraction for all spoils averaged 37 percent of the total air-dried weight. Material passing a 1/4-inch mesh screen accounted for 60 percent of the sample weight.

Apparently spoils in the southern West Virginia coal field have sufficient soil-size material to retain adequate amounts of water during normal weather conditions. The percentage of material passing a 2-mm sieve is less for the essentially unweathered spoil material than for the intensively weathered natural soils occurring above and below the mining disturbance. As an example, the percentage of material less than 2 mm. in size in three natural soils that occur over large acreages in southern West Virginia are as follows: Dekalb soils, 65-95 percent; Gilpin soils, 35-80 percent; and Muskingum soils, 65-95 percent.[3] By comparison, the material 2 mm. or less in the spoils sampled ranged from 17 to 64 percent. This percentage is expected to increase rapidly as weathering breaks down the large particles.

The proportion of soil-size material indicates that these spoils may be more vulnerable to the forces of erosion than coarser spoils. These small particles also provide a large surface area for chemical reaction and weathering.

Spoil pH and Available Phosphorus

The ten 1-pound samples collected at each site were analyzed for pH and available phos-

[3]Soil Survey, Fayette and Raleigh Counties, West Virginia. Unpublished manuscript, Soil Conservation Service.

Table 2.—Particle size distribution by coal seam in percent

Coal seam		Particle size				
		<2mm.	<1/4 inch >2 mm.	<1/2 inch >1/4 inch	<3/4 inch >1/2 inch	>3/4 inch
Pocahontas No. 3	Mean	33.5	21.8	14.3	9.3	21.1
	Standard Deviation	7.8	2.6	2.7	1.9	8.4
Pocahontas No. 6	Mean	33.6	24.0	14.8	10.9	16.7
	Standard Deviation	5.0	4.3	5.3	2.0	7.4
Beckley	Mean	41.8	21.7	12.1	8.5	15.9
	Standard Deviation	6.6	4.9	2.0	1.8	9.0
Sewell	Mean	40.1	22.9	12.6	8.7	15.7
	Standard Deviation	9.4	3.7	2.7	2.9	6.6
Little Eagle	Mean	36.7	24.0	15.7	9.3	14.3
	Standard Deviation	10.2	3.5	3.8	3.1	8.1
Eagle	Mean	35.9	24.3	14.1	9.6	16.1
	Standard Deviation	8.4	3.5	4.9	2.0	6.0
Peerless-No. 2 Gas	Mean	41.8	23.5	14.6	8.6	11.5
	Standard Deviation	9.5	5.4	3.8	2.1	6.1
Winifrede	Mean	32.9	23.4	13.7	10.1	19.9
	Standard Deviation	13.0	6.4	4.3	3.8	14.7
Coalburg	Mean	37.0	20.3	14.7	12.4	15.6
	Standard Deviation	5.9	4.0	5.1	4.5	6.0
No. 5 Block	Mean	40.9	19.9	14.5	8.3	16.4
	Standard Deviation	11.3	1.9	2.8	2.7	7.5
Mean, all samples	—	37.2	22.6	14.1	9.6	16.5

Table 3.—Spoil pH by coal seam

Coal seam	Median	Standard Deviation	Distribution			
			pH 6.1+	pH 5.1–6.0	pH 4.1–5.0	pH 4.0 or less
			Percent of samples			
Pocahontas No. 6	5.7	0.30	13	87	0	0
Pocahontas No. 3	5.6	.32	3	94	3	0
Beckley	5.3	.77	33	42	22	3
Little Eagle	5.2	.68	27	53	20	0
Winifrede	5.1	1.24	33	37	30	0
No. 5 Block	5.1	.76	33	32	35	0
Coalburg	5.0	.39	3	45	52	0
Sewell	5.0	.64	27	36	32	5
Eagle	4.5	1.14	27	33	10	30
Peerless-No. 2 Gas	4.5	.44	0	7	80	13
Mean, all samples	—	—	20	48	27	5

phorus. These data showed significant differences among coal seams for both variables (table 3). All seams except the Eagle and Peerless-No. 2 Gas had a median pH of 5.0 or more, indicating that most of the plant species commonly used for reclaiming strip mines can be grown successfully. By comparison, natural soils commonly occurring above or below the mining disturbance are often classified as very strongly acid or strongly acid. This means that the pH of the natural soils may vary from 4.5 to 5.5

Very low phosphorus (<3.0 p.p.m. P) occurred in spoils of the No. 5 Block, Little Eagle, Winifrede, and Coalburg seams. Spoils of all of the other seams except Pocahontas No. 6 were low (3.1 to 7.0 p.p.m. P) in available phosphorus (table 4). This indicates that most of the spoils in southern West Virginia will probably have insufficient phosphorus for the rapid establishment and good growth of seeded vegetation.

The data indicate that spoil acidity is not a major problem in the southern West Virginia coal field. Samples with a pH of 4.0 or less (extremely acid) occurred on only four coal seams, and they were a relatively small portion of the total samples. Extremely acid spoil was most common on the Eagle seam, but also occurred on the Peerless-No. 2 Gas, Sewell, and Beckley seams. Acid pollution from spoils may occur where these seams were mined. Care must be exercised in mining and regrading operations on these coal seams to insure that acid-forming materials are segregated and buried.

Table 4.—Available phosphorus by coal seam

Coal seam	Mean	Distribution		
		Very low 0.1–3.0 p.p.m.	Low 3.1–7.0 p.p.m.	Medium 7.1–20.0 p.p.m.
	p.p.m.	*Percent*		
Pocahontas No. 6	8.0	3	34	63
Peerless-No. 2 Gas	5.0	33	37	30
Sewell	4.9	55	25	20
Pocahontas No. 3	3.6	23	74	3
Eagle	3.2	53	42	5
Beckley	3.2	55	35	10
No. 5 Block	2.8	60	37	3
Little Eagle	2.5	63	37	0
Winifrede	2.4	80	20	0
Coalburg	1.8	92	8	0
Mean, all samples	—	52	35	13

Sixty-eight percent of the samples had a pH above 5.0, but 87 percent of the samples tested below a medium level (7p.p.m.) of phosphorus. Therefore deficiencies in plant nutrients, especially plant-available phosphorus, probably contribute to the failure and slow growth of seeded grasses and legumes more than does high acidity. Fortunately this condition can be corrected easily with phosphate fertilizers.

Exchangeable Acidity, Aluminum, and Hydrogen

Three samples of the soil-size fraction from each location were used for this analysis. Each sample was analyzed to determine exchangeable acidity, exchangeable aluminum, and exhangeable hydrogen. The latter two elements account for most of the exchangeable acidity that was present in these spoils. Our objective was to use these measures to identify spoils that may be difficult to revegetate. Exchangeable acidity is also used for determining rates of lime that are required to neutralize the acidity present in spoils.

Values for exchangeable acidity ranged from 0.05 to 14.35 meq./100 g. There were significant differences among spoils of the various coal seams. There was also much variation in acidity among samples of individual coal seams. The Sewell and Eagle spoils had the highest level of exchangeable acidity. Means for these spoils were 3.45 and 3.40 meq./100 g. The lowest values occurred on the Pocahontas No. 3 and No. 6 spoils (table 5).

Exchangeable aluminum ranged from 0 to 7.25 meq./100 g. There were significant differences among spoils. High values occurred in the No. 5 Block and Sewell spoils. Low values occurred in the Pocahontas No. 3 and No. 6 spoils.

From these analyses, spoils from the Pocahontas No. 3, Pocahontas No. 6, Beckley, and Little Eagle coal seams could be expected to have low exchangeable acidity and aluminum, and generally would present few or no problems in establishing vegetation. The Sewell, Eagle, Peerless-No. 2 Gas, Coalburg, and No. 5 Block coal seams have spoils with the highest exchangeable acidity and aluminum. The higher levels of acidity and aluminum in these spoils can cause problems in establishing seeded grasses and legumes.

Evidence from other research indicates that wide variation can occur in the properties of the various rock strata in the overburden above the coal seam. If the strata contributing excessive acidity and aluminum could be identified, then mining and regrading methods could be modified so that this acid material would be buried. The material most suitable for plant growth would be exposed on the spoil surface.

The chemical composition of the Eagle spoils was the most variable. The pH ranged from 2.9 to 6.5, available phosphorus from 1.4 to 17.5 p.p.m., exchangeable acidity from 0.05 to 14.35 meq./100 g., and exchangeable aluminum from 0 to 7.25 meq./100 g. This reflects the differences in the chemical composition of the various rock strata above the coal seam. It also shows the revegetation problems that can

Table 5.—Mean values for pH and for exchangeable acidity, aluminum, and hydrogen

Coal seam	Median pH	Exchangeable Acidity	Exchangeable Aluminum	Exchangeable Hydrogen
		------	*meq./100g.*	------
Pocahontas No. 6	5.7	0.44	0.29	0.15
Pocahontas No. 3	5.6	.51	.34	.17
Beckley	5.3	1.03	.73	.30
Little Eagle	5.2	.88	.63	.25
No. 5 Block	5.1	2.91	2.44	.47
Winifrede	5.1	1.41	1.16	.25
Coalburg	5.0	2.22	1.77	.45
Sewell	5.0	3.45	2.44	1.01
Eagle	4.5	3.40	1.92	1.48
Peerless-No. 2 Gas	4.5	2.48	2.04	.44

be caused on spoils derived from overburden of such composition.

Vegetation Response to Fertilizer

In the greenhouse evaluation of vegetation response to fertilization, the yields of plants in each fertilizer treatment were compared with yields of plants without fertilizer. The 25 spoils used in this test included two or three samples from each of the ten coal seams. However, the results presented here emphasize the overall response of plants to fertilizer treatments and spoil chemical properties. Relating plant response to individual coal seams is less meaningful because of the wide variation in spoil properties that can occur even on one seam.

Highest yields of both K-31 fescue and sericea lespedeza occurred on the spoils fertilized with nitrogen plus phosphorus. The addition of potassium did not increase yields (table 6). In fact, the addition of potassium fertilizer caused more reductions than increases in yield, especially with the sericea lespedeza. This indicates that potassium is not deficient in these spoils, and application of potassium fertilizer normally would not be required.

Fertilizing with both nitrogen and phosphorus is essential for acceptable establishment and growth of K-31 fescue (fig. 2). This requirement also applies to other cool-season grasses normally used for vegetating mine spoils.

Fertilizing with both nitrogen and phosphorus also gave best yields of sericea lespedeza. However, fertilizing with phosphorus alone also gave substantial increases in yield (table 6 and fig. 3). This is because legumes such as sericea lespedeza, when inoculated with the proper nitrogen-fixing bacteria (*Rhizobia*) are capable of providing their own nitrogen. It is also the reason why legumes are considered as an important constituent of a plant mixture for vegetating strip-mine spoils.

The greenhouse tests also showed that yields of fertilized K-31 fescue were much lower on spoils that had a pH below 5.0 than

Table 6.—Average herbage yields of K-31 fescue and sericea lespedeza grown on spoils with several fertilizer treatments

Spoil pH	Control	Fertilizer treatment N	P	NP	NPK
		- - - - - *grams/pot* - - - - -			
	K-31 FESCUE				
3.9—4.5	0.2	0.6	0.4	1.3	1.1
4.6—5.0	.2	.4	.5	1.6	1.2
5.1 and above	.4	.9	.8	3.9	3.6
	SERICEA LESPEDEZA				
3.9—4.5	.4	—	.9	2.3	.7
4.6—5.0	3.0	—	6.9	9.2	7.2
5.1 and above	1.7	—	11.0	13.8	9.8

Figure 2.—A typical response of Kentucky-31 fescue to the fertilization treatments on spoil with pH above 5.0. This is a Coalburg spoil.

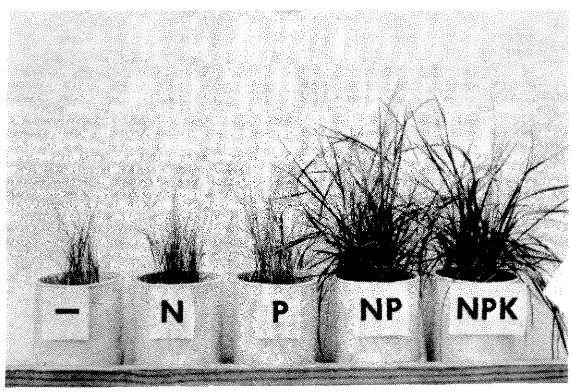
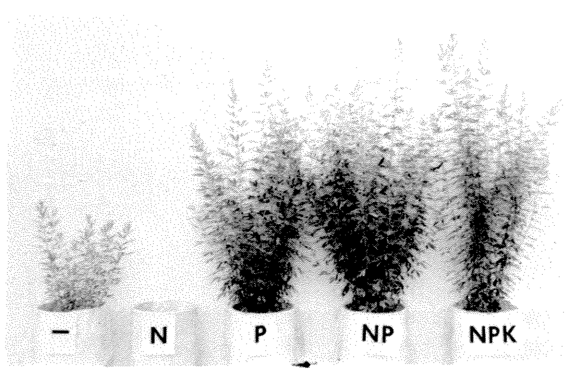


Figure 3.—A typical response of sericea lespedeza to the fertilizer treatments on spoil with pH above 5.0. This is a Pocahontas No. 6 spoil.



on spoils with a pH above 5.0 (table 6). If applied directly to field conditions, these results indicate that some problems may be encountered in establishing an adequate cover of fescue on spoils with a pH below 5.0. However, follow-up field trials should be made to determine the validity of these results for field conditions.

Yields of sericea lespedeza were much lower on spoils that had a pH below 4.5 than on spoils with pH above 4.5. Yields on spoils in the pH range 4.6 to 5.0 were only slightly lower than on spoils with pH above 5.0. These results suggest that sericea lespedeza can tolerate slightly more acid conditions than can K-31 fescue.

CONCLUSIONS

This survey provided a reasonably optimistic outlook for the opportunities to successfully establish vegetation on surface-mine spoils in southern West Virginia. The pH of a majority of the spoils sampled is 5.0 or higher, and there seems to be enough soil-size material to retain sufficient moisture for satisfactory plant growth during normal weather conditions.

A major problem is a deficiency of essential plant nutrients. In greenhouse tests, the addition of nitrogen and phosphorus resulted in dramatic increases in plant growth on a majority of the sample spoils. Low pH and high exchangeable acidity and aluminum could have a detrimental effect on vegetation establishment on some spoils associated with the Sewell, Beckley, Peerless-No. 2 Gas, and No. 5 Block coal seams.

It is recognized that these results apply to spoils resulting from present-day mining and regrading methods. In some cases, the systematic placement during mining of certain strata in the overburden could result in a more productive spoil. To accomplish this, acidity tests would have to be made of each major strata in the overburden. Those strata identified as high in acidity could, where possible, be segregated and buried under better spoil, thus reducing the percentage of vegetation failures.

■