REVEGETATION POTENTIAL OF OVERBURDEN MATERIALS FROM KITTANNING COAL MINES[1]

by

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Abstract. Two independent revegetation studies were conducted on Kittanning overburden materials. Problems with acidity have often been encountered during reclamation of Kittanning coal mines in West Virginia, Maryland, and Pennsylvania. The first study was a field study in which part of a regraded area was covered with local topsoil, but the rest of the area was covered with a topsoil substitute obtained from sandstone in the overburden. This substitute had not been analyzed before use. In this study, the topsoil supported vegetation better than the substitute, since the substitute was acid-producing material. In the second study, minesoil profiles were constructed in 30-cm diameter, 100-cm deep PVC columns. Spoil was covered with topsoil, crushed alkaline sandstone, or a mixture of the topsoil and sandstone. In this study the sandstone, mixture, and spoil with no soil cover supported better vegetative growth than the topsoil. Although Kittanning overburden strata are generally thought to be potentially toxic, the strata should be thoroughly characterized. This study indicates that not all overburden strata above Kittanning coal is toxic and that some has the potential of serving as topsoil substitute.

Additional Key Words: minesoil properties, topsoil, topsoil substitute.

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Introduction

The Kittanning coal seams (Upper, Middle and Lower), which formed in the Allegheny geologic formation of the Pennsylvanian period, are very important to the coal industry of West Virginia. The estimated original minable reserve of these three seams was 15.2 billion tons (Barlow 1974).

Kittanning coals are generally located in the northern coal field of West Virginia but are found near the "hinge line" which separates the northern and southern coal fields (Barlow 1974). These coals generally have high-sulfur (> 1.5% S) contents, and overburden materials associated with these seams commonly have high sulfur levels. Sites which are mined for these coals have a propensity to produce acid mine drainage (AMD) and acidic minesoils which are difficult to vegetate. Although some sites have been reported to be successfully reclaimed (Smith et al. 1974), others present major challenges to reclamationists.

Because of revegetation and acid mine drainage problems associated with Kittanning coal mining, the Director of the West Virginia Department of Natural Resources (WVDNR) appointed a group of scientists, coal operators and WVDNR personnel to study the problem. This group, called the Acid Mine Drainage Technical Advisory Committee (AMDTAC), was appointed in 1981. AMDTAC has been dissolved but some of the studies initiated by that group are continuing.

The purpose of this paper is to report some results of two of the AMDTAC studies. The primary objective of both studies was to evaluate the revegetation potential of various Kittanning overburden materials. A secondary objective was to determine if revegetation potential could be predicted by acid-base accounting procedures. The studies were conducted on Kittanning surface mines in the Buckhannon River watershed in Upshur County, West Virginia.

Materials and Methods

Study #1

The study site was a mountaintop surface mine where a 0.5-mm thick PVC liner was placed over 18 ha of acid-producing spoil in an effort to control AMD (Nicholas and Foree 1982; Caruccio and Geidel 1983). The purpose of this paper is to discuss the properties of the soils and vegetation above the liner.

Two cover materials, varying from 35 to 100 cm thick, were placed on the liner. Since a limited amount of native topsoil was available, a substitute material was used to cover part of the liner. The topsoil was derived from a stockpile of native soils [Dystrochrepts, Fragiudults, Hapludults (Soil Survey Staff 1975)], and the substitute consisted of crushed acid sandstone overburden. After placement of the cover materials, slopes ranged from 1 to 8%, near the top of the hill and from 11-25% on the sides.

Minesoils were sampled in October 1982 and August 1984 along transects established perpendicular to the contour. Since soil properties were not significantly different between 1982 and 1984, only 1984 data are presented. Soil pits were excavated to the liner at 55-m intervals along the transects. Nine topsoil and 14 substitute pits were described. Bulk soil samples were taken at 0-12 cm, 12-25 cm, 25-50 cm, and 50-75 cm from alternate pits in each transect for laboratory analyses.

The areal extent of each cover material was mapped to identify the minesoil series. Fiveblock [loamy-skeletal, mixed, nonacid, mesic Typic Udorthents (Soil Survey Staff, 1975)] and Sewell (loamy-skeletal, mixed, acid, mesic Typic Udorthents) were mapped on the topsoil. An unnamed series in the same family as Sewell was mapped on the substitute.

Both cover materials were amended with 27 Mg/ha (12 T/A) of limestone, 150 kg/ha of N, 90 kg/ha of P, and 125 kg/ha of K (100 lb 0-40-0 and 700 lb 19-19-19 per acre). Amendments were incorporated to a depth of 12 cm. The seeding mixture included 'Ky-31' tall fescue (Festuca arundinacea Schreb.), annual ryegrass (Lolium multiflorum), 'Empire' birdsfoot trefoil (Lotus corniculatus L.), alsike clover (Trifolium hybridum), and red clover (Trifolium pratense). Reclamation on the site was completed in June 1982.

Study #2

Simulated minesoil profiles were constructed on a West Virginia University farm in Monongalia County. The subsoil was collected from a stockpile of fragmented sandstone spoil from the Middle and Lower Kittanning coals at an active mine in Upshur County. Topsoil and a topsoil substitute were collected from a nearby inactive mine. The topsoil, a mixture of A, B, and C horizons [Fragiudults and Hapludults (Soil Survey Staff 1975)], was sampled from a stockpile. The topsoil substitute was a crushed alkaline sandstone which had been quarried from the coal overburden.

Containers for the simulated minesoil profiles were constructed from 30-cm diameter white PVC pipe. The pipe was cut into 98-cm long sections, and each section was placed vertically into a 10-cm thick bed of mortar sand to allow free drainage of water from the columns.

The minesoil profiles constructed within the containers were designed to represent a loamy-skeletal subsoil covered with topsoil materials of different thicknesses. Fragments greater than 7.6 cm in diameter were removed from the subsoil before placement in the container. After placement, the subsoil was compacted to achieve a penetrometer reading similar to that observed on a graded site prior to topsoiling.

Each profile was 91 cm thick and consisted of one of the following:

1. Spoil only;

2. Spoil with a covering of crushed sandstone at thicknesses of 15 cm, 30 cm, or 45 cm;

3. Spoil with a covering of stockpiled topsoil at thicknesses of 15 cm, 30 cm, or 45 cm;

4. Spoil with a covering of a 1:1 mixture of crushed sandstone and topsoil at thicknesses of 15 cm, 30 cm, or 45 cm.

Each treatment was replicated three times and incorporated into a randomized complete block design. The blocks were arrayed as parallel north-south rows with 4.9 m between rows and 3.1 m between containers.

Soils in all columns were fertilized with ammonium nitrate, triple superphosphate, and potassium chloride at a rate equivalent to 672 kg/ha (600 lb/A) of 10-20-10 blended fertilizer. The native topsoil, the only material requiring lime, was limed at the rate (5.5 T/A) recommended by the WVU Soil Testing Laboratory to raise the pH to 6.5 (Ghazi et al. 1978). Both the fertilizer and limestone were incorporated to a depth of 15 cm.

In June 1983, all treatments were seeded at a rate equivalent to 22.4 kg/ha (20 lb/A) of tall fescue and 16.8 kg/ha (15 lb/A) of birdsfoot trefoil. Hay mulch was applied at a rate approximating 5.6 Mg/ha (2.5 T/A).

Laboratory Analyses

Minesoil properties for both studies were analyzed by the following procedures: pH (1:1), KCl exchangeable Al, ammonium acetate, exchangeable Ca, Mg, and K, cation exchange capacity (CEC) at pH 7.0 by ammonium saturation, organic carbon (OC) by acid-dichromate digestion, and electrical conductivity (EC) of the saturated paste extract (Soil Survey Staff 1972); total S, neutralization potential (NP), total N by Kjeldahl distillation, soil texture by the pipette method, and moisture retention at 33 and 1500 kPa pressures (Sobek et al. 1978); DTPA extractable Fe, Mn, Cu, and Zn (Lindsay and Norvel 1978); Bray I extractable P (Olsen and Sommers 1982); and liquid limit (LL) and plasticity index (PI) (American Society for Testing and Materials 1981).

Vegetation Evaluation

For study #1 the vegetative cover was estimated by a point frequency method (Raelson and McKee 1982) in September 1983 and 1984. A grid was superimposed over the site map and coordinate points were selected at random. The points were located in the field, and vegetation at these points was evaluated.

For study #2, vegetation establishment was evaluated by two methods. A stem count was made for each container for two growing seasons. The count was restricted to stems greater than 8 cm in height. At the end of the second growing season, an estimate of percent ground cover was included because all of the first season's vegetation died during the winter. Although vegetation returned to every container during the second season, much of the vegetation consisted of volunteer and weedy species, and the total number of stems was less than the first season.

Statistical Analyses

All statistics were performed using a SAS computer package containing ANOVA and Duncan's multiple range test (SAS Institute 1982). Kramer's adjustment was applied to those comparisons which had unequal group sizes.

Results

Study #1

Soil Properties. The topsoil and substitute had loam and sandy loam textures (Table 1). Rock fragments comprised 35 to 80% (avg 55%) of the volume of the substitute material and 25 to 60% (avg 35%) of the topsoil material. Sandstone was the dominant rock type, making up 90% or more of the rock fragments in both cover materials. While the substitute had a higher percentage of sand than the topsoil, both cover materials were similar in percent clay, moisture retention characteristics, LL, and PI (Table 1). Low MRD, LL, and PI values reflected the sandy nature of both soils.

Chemical properties of the topsoil and substitute sampled during the third year of the study are summarized in Table 2. Surface OC increased from 9 to 16 g/kg in the topsoil and from 8 to 11 g/kg in the substitute between the first and third years, respectively. Other chemical properties did not change significantly within the 3-yr period. In both materials, Ca, NP, and pH were

Table 1. Physical properties of the two materials used to cover the PVC liner.

Material	Clay	Sand	Moisture Retention 33 kPa	Moisture Retention 1500 kPa	MRD[1/]	LL	PI
	---------	---------	-------% by weight	-------	-------		
Topsoil	15.6	52.0	0.19	0.09	0.10	24	4
Substitute	13.1	60.1	0.16	0.08	0.08	20	2

[1/]MRD = 33 kPa - 1500 kPa.

Table 2. Chemical properties of the topsoil and substitute cover materials over the PVC liner three years after placement.

Depth	CEC	Extractable Ca	Extractable Al	EC	P	OC	S	NP $CaCO_3$ Equiv.	pH
cm	--cmol	(+)/kg--		ds/m	mg/kg	g/kg	%	kg/mg	
				Topsoil					
0-12	10.2a	13.0a	<0.1c	1.2cd	5.7ab	16a	0.05b	41.6a	6.8a
12-25	11.5a	4.4bc	0.7bc	1.5cd	5.4ab	13ab	0.06b	1.8b	5.0b
25-50	10.6a	4.9bc	0.4c	1.8bc	4.2ab	13ab	0.06b	2.1b	5.3b
50-75	9.0ab	2.3c	0.3c	0.8d	3.8ab	9cd	0.05b	1.1b	5.3b
				Substitute					
0-12	7.2bc	9.6ab	0.7bc	2.6b	11.0a	11bc	0.21a	26.2ab	5.2b
12-25	6.3c	3.3c	2.4a	3.8a	1.0b	7cd	0.24a	-1.6b	3.4c
25-50	6.0c	2.6c	2.6a	4.3a	1.4b	7cd	0.24a	-1.3b	3.4c
50-75	5.8c	2.1c	1.5b	3.7a	3.0b	6d	0.23a	-0.2b	3.9c

Column means followed by the same letter are not significantly different at the 0.05 level.

higher in the surface (0-12 cm) than in the subsurface (12-75 cm) because of lime additions. Liming resulted in lower Al, acidity, and EC levels in the surface than in the subsurface of the substitute. Both materials had a higher OC content in the surface than in the subsurface as a result of the accumulation of organic matter due to vegetation establishment, litter accumulation, and root growth. Cation exchange capacity, OC, and pH were higher in the topsoil, whereas Al, S, and EC were higher in the substitute. While both cover materials had low to very low agronomic levels of P, K, and Mg, the topsoil did not have the acid-related problems found in the substitute. The substitute had extremely-acid pH values, high levels of extractable Al, a deficiency of neutralizers, and high salt concentrations (as indicated by the EC). These data may be attributed to pyrite oxidation (Evangelou and Phillips 1984; Singh et al. 1982).

Vegetation and Root Growth. By the third growing season, the vegetative cover across the site was 69% (90% CI ± 6%). Vegetative cover was 30% greater on the topsoil than on the substitute (Table 3). Of the species present on the entire site, 50% were seeded grasses, 40% seeded legumes, and 10% volunteer species. The dominant species in the third growing season were tall fescue and birdsfoot trefoil. Legumes on the site increased in proportion to the grasses between the second and third growing seasons. The grass/legume ratio was 1:1 in the second growing season, compared to 1:3 in the third.

Table 3. Vegetative cover and root growth characteristics on the topsoil and substitute materials.

	Topsoil	Substitute
Vegetative cover (%)		
1984	93	61
90% CI[+]	6	7
Depth of major root zone, cm		
1982	8	4
1984	10	7
Depth of maximum root growth, cm		
1982	14	7
1984	52	12

Most roots were concentrated in a shallow zone at the surface (Table 3). By the third growing season, root growth extended below the depth of lime and fertilizer incorporation in all 9 topsoil pits but in only 3 of 14 substitute pits. The average depth of maximum root growth in the topsoil more than tripled between the first and third growing seasons, and was over four times greater than the substitute.

Study #2

Characterization of Materials. The spoil material used in this study had been segregated by the mine operator as an acid producing material containing about 0.5% sulfur. Analysis revealed that this material was moderately high in total sulfur (Table 4), but it also had a high pH, high Ca level, and high NP, indicating no potential to produce acid. In addition, the spoil effervesced when diluted HCl was added. The sandstone was segregated as an alkaline topsoil substitute, but it did not effervesce with HCl. The topsoil held more water than the other materials (Table 5), because it had more clay.

Extractions of available Fe, Mn, Cu and Zn indicated that neither toxicities nor deficiencies of these micronutrients existed in any of the materials at the beginning of the study. All of the materials were extremely low in total nitrogen ($\leq$ 0.05%) and soil organic matter ($\leq$ 0.6%).

Vegetation Evaluation. Three months after seeding, both seeded species (fescue and trefoil) were established in all containers. During the first growing season, topsoil treatments were less successful in producing a vegetative cover than the other three

Table 4. Chemical properties of topsoil and substitute materials before treatment.

Material	Ca	Mg	K	Al	CEC	S	N.P.	pH
	----------cmol (+)/kg----------					%	g/kg	
Spoil	12.50	0.96	0.12	0.0	2.92	0.302	30.90	7.4
Sandstone	2.56	0.80	0.90	0.0	2.08	0.056	11.44	7.5
Topsoil	0.28	0.20	0.09	3.3	6.79	0.002	0.28	4.4
1:1 Mix	2.62	0.72	0.11	0.1	4.50	0.088	7.23	5.1

Table 5. Physical properties of topsoil and substitute materials before treatment.

Material	Sand	Silt	Clay	Moisture Retention 33kPa	Moisture Retention 1500kPa	MRD[1/]
	-----------------% by weight-----------------					
Spoil	68.7	19.2	12.1	11	3	8
Sandstone	75.3	16.2	8.5	9	2	7
Topsoil	37.8	42.6	19.6	22	7	15
1:1 Mix	61.8	25.2	13.0	15	5	10

[1/]MRD = 33kPa - 1500kPa.

soil materials (Table 6).

The vegetation parameters analyzed during the second growing season generally followed the trends observed in the first season (Table 6). Since the vegetation could not survive the winter, it was decided to discontinue collecting vegetation data after the second growing season.

Soil pH. When analyzed three years after treatment, pH of the surface samples (0-15 cm) of the sandstone, topsoil, and the 1:1 mixture appear to have remained constant (Table 7). The spoil pH appears to be lower after three years. When the columns were sampled after the fifth year, roots were observed to be proliferating through the total thickness of the spoil in all columns. Therefore, after five years, the spoil properties (data to be reported at a later date) were still promoting root growth.

Discussion

Study No. 1

The substitute was inferior to the topsoil for revegetation because of its acidic properties. These results have been corrobated by literature reports of Lower Kittaning coal seam overburden analyses (Smith et al.

Table 6. Growth of vegetation on topsoil and substitute materials for two growing seasons.

Material	Stems First Season	Stems Second Season	Cover Second Season
	No./column	No./column	%
Spoil	105	36	67
Sandstone	117	57	74
Topsoil	54	39	57
1:1 Mix	114	56	67

Table 7. pH of topsoil and substitute materials for a three-year period.

Material	Before Treatment	After Treatment 1YR	After Treatment 3YRS
Spoil	7.4	7.3	7.0
Sandstone	7.5	7.8	7.7
Topsoil	4.5	6.6	6.6
1:1 Mix	5.1	7.2	7.3

1974). Vegetation after three growing seasons was substantially better on the topsoil than on the substitute. At the end of the third growing season, only the vegetative cover on the topsoil met the West Virginia regulatory requirements of 90 percent ground cover on mined lands.

Results of this study indicate that when reclaiming areas mined for the Lower Kittaning coal or other seams within the Allegheny Geologic Formation, care should be taken in selecting alternative topsoil materials. If non-acidic materials are not available, deep incorporation of limestone is recommended for revegetation. If possible, limestone should be incorporated to a depth of 60 to 90 cm so that roots will proliferate the minesoil for water and nutrients. Since incorporation of limestone to these depths will be very difficult after regrading has been completed, it is recommended that limestone be mixed with the alternative topsoil materials as they are being graded to final contour.

Study #2

The results indicate that all of the materials studied were capable of establishing a vegetative cover provided they were amended with the recommended rates of fertilizer and lime. Thickness of the topsoil cover did not affect plant establishment or growth in this study. This may be due to the fact that the underlying spoil did not restrict root growth as originally anticipated. At the end of the study when the columns were sampled, it was noted that roots had penetrated throughout the spoil material. The only experimental parameter which appeared to affect plant growth and species composition was the type of soil material. Vegetation establishment was poorer on native topsoil than on crushed sandstone, mixture or spoil. This difference was manifested most strongly by the limited establishment of the seeded legume in the native topsoil. The other three materials were equally successful in establishing vigorous vegetative stands with favorable grass-legume composition.

Examination of the soil data does not reveal any probable plant growth constraint in the native topsoil with the exception of low levels of exchangeable magnesium in comparison to sandstone, mixture and spoil.

Since vegetation establishment on the sandstone and the mixture of sandstone and topsoil were similar, it appears that the sandstone had an ameliorative effect exceeding that which might occur from a dilution effect alone. The sandstone proved to be an effective liming material by reacting quickly with the acid topsoil to reduce exchangeable acidity and raise soil pH. It was superior to the agricultural limestone used in this study in that it supplied enough available magnesium to overcome an apparent deficiency of that nutrient in the native topsoil.

Conclusions

Although Kittanning coal overburden materials in many areas of Appalachia will produce extreme acidity when mined, the overburden in some areas produces very little, if any, acidity. Therefore, it is important to analyze the overburden before mining, and then develop specific overburden handling plans for those materials. The overburden in study #1 was more acidic than the topsoil, but in study #2 sandstone from the overburden was alkaline while the topsoil was acid. Acid-base account analyses predicted these results.

Development of a topsoiling program for reclamation of drastically disturbed land should be an important part of the planning stage of the operation. Considerations are site specific and vary widely depending on post mining land use, regulatory compliance, costs, and the quality and quantity of overburden materials which are available. It is also important to monitor the overburden ahead of mining, because overburden properties may change. Given a situation where an operator wishes to reclaim a site to pasture or hayland and has access to materials with soil properties similar to the native topsoil and crushed sandstone used in this study, blending of the two materials offers promise for this land use. Either of these materials by themselves possess properties which could potentially restrict rapid revegetation and site stabilization. The crushed sandstone, like many sandy soils, had a low moisture retention capacity, low cation exchange capacity, and may be susceptible to erosion on slopes. The native topsoil is quite acid and deficient in available magnesium. Blending of these materials eliminates or ameliorates all of the potential problems associated with the properties of the individual parent materials. This blend would still require an amendment of N-P-K fertilizer because both parent materials are deficient in these essential nutrients.

When formulating a blend of alkaline sandstone and acid topsoil to be used as a topsoil substitute for grazing and hayland post-mining land uses, some conditions must be satisfied. It is important that enough alkaline material be present to neutralize the soil acidity. In this study, good results were produced by a blend which contained twice the excess neutralization potential required to satisfy the soil test lime requirement. In situations dealing with unweathered geologic materials rather than topsoil, it is recommended that blending rates supply neutralizers in excess of the maximum potential acidity predicted by the acid-base account.

Another condition which must be satisfied by a topsoiling program is the achievement of a minimum thickness of cover. If, during the planning stage, estimates of the volume of available native topsoil are less than required to achieve the desirable minimum thickness over the post mining area, then blending of an additional appropriate material should be considered. A cover thickness of 15 cm should be considered as a minimum for all sites. Where potentially toxic (by acid-base accounting) materials are directly below the topsoil, greater thicknesses are recommended.

In summary, the use of topsoil substitutes, such as crushed alkaline sandstone, have the potential to help create superior minesoils. It should be stressed that for effective reclamation, a good topsoiling program needs to be followed promptly by a good revegetation program. Success in rapidly establishing a vigorous vegetative cover on suitable topsoil is an integral part of nearly all aspects of reclamation and water quality control.

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