EFFECTS OF TOPSOIL AND VEGETATION ON THE GENERATION OF ACID MINE DRAINAGE FROM COAL REFUSE

by

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Introduction

In May 1984 a study was implemented with the following objectives: (1) to determine the effects of a topsoil cover on the generation of acid mine drainage (AMD), (2) to compare the effects of two topsoil materials of widely differing characteristics on AMD generation, and (3) to determine the effects of vegetation on the generation of AMD. This paper is the second progress report for that study.

Materials and Methods

Facilities were constructed at the West Virginia University Agronomy Farm to accommodate 21 plastic barrels of 110-liter (30-gallon) capacity. The design of the barrels was presented in the first progress report (Thurman et al., 1985).

Three geologic materials were used in this study: acid producing coal refuse and two topsoiling materials consisting of crushed sandstone and native topsoil (mixture of A, B, and C horizons). The refuse was produced by mining the Upper Freeport coal seam in Grant County, WV. The crushed sandstone and the topsoil were obtained from stockpiles in Upshur County, WV. Methods used for analysis of these materials were presented in the first progress report (Thurman et al., 1985). Data are presented in Table 1.

Three replications of the following treatments were used in the study:

1. Coal Refuse (CR) only,
2. CR amended to 15 am (6 in.) depth with lime and fertilizer,
3. CR amended to 15 am (6 in.) depth with lime, fertilizer, mulch and seed,
4. CR covered with 30 am (12 in.) of crushed sandstone,
5. CR covered with 30 am (12 in.) of sandstone with fertilizer, mulch and seed.
6. CR covered with 30 am (12 in.) of topsoil

7. CR covered with 30 am (12 in.) of topsoil with lime, fertilizer, mulch and seed.

Table 1
Properties of Coal Refuse, Crushed Sandstone, and Topsoil Used in The Barrel Study.

Material	Particle[1] Size (mm)	Texture[2]	Moisture[3] Retention %	pH	Total S %	NP[4]	Exch. Acid	CEC meq/100g	Org.C %
Refuse	19	---	---	4.9	3.84	2.3	1.2	2.4	4.10
Sandstone	2	SL	7	8.2	0.08	16.6	0.0	2.0	0.19
Topsoil	2	L	15	5.4	0.01	-0.9	3.8	8.0	0.27

1. Particle size is the maximum particle diameter of materials placed in the barrels.

2. SL = sandy loam, L = loam

3. Moisture retention equals water held between 1/3 and 15 bars tension.

4. NP = neutralization potential as tons of $CaCO_3$ equivalent per 1000 tons of material.

Fertilizer was applied at a rate equivalent to 672 kg/ha (600 lb/A) 10-20-10. Agricultural limestone was applied to the topsoil at a rate of 6.72 Mg/ha (3 T/A) and to the CR at a rate of 168 Mg/ha (75 T/A). All vegetated treatments received 22.4 kg/ha (20 lb/A) KY-31 tall fescue (Festuca arundinacea) and 16.8 kg/ha (15 lb/A) Empire birdsfoot trefoil (Lotus corniculatus) and mulched with hay at a rate of 6.72 Mg/ha (3 T/A). Barrels were reseeded at the beginning of the second growing season because vegetation died during winter.

Vegetation evaluations were made at the end of two growing seasons (1984-1985). Percent ground cover was estimated by visual observations. In addition, the average vegetative height was determined, and the number of stems of each species greater than 10 cm (4 in.) tall were counted. Yields were determined at the end of the second growing season by clipping, drying, and weighing all vegetation in the barrels.

Leachate samples were collected after each major precipitation event, and volumes were measured in the field. Sub-samples of the leachate were analyzed by the West Virginia Geological Survey Laboratory for pH, acidity, SO_4, Fe, Al, Mn, Ca, Mg, K, and electrical conductivity. During the winter months (December through April) samples were collected after each melting event.

Results and Discussion

Statistical analyses of the data have not been completed at the time of this report. Therefore, only subjective inspections of mean data are presented. Conclusions can only emphasize obvious trends of the progress made to date.

To evaluate the effects of a given treatment on the generation of AMD this progress report will concentrate on the rate of accumulation of the reaction products of the oxidation of pyrite. The two variables to be examined are the load rate (concentration x volume/time) of the most mobile primary product of pyrite oxidation (sulfate) and the load rate of the chemical property best associated with both pyrite oxidation and in situ neutralization (acidity). These two variables will be referred to as sulfate load rate and acid load rate, respectively.

By experimental design, those treatments covered with a 30-cm thickness of topsoil or sandstone contained one-half as much reactive, acid producing material as the control and amended refuse treatments. One method of normalizing the load rate data with regard to different reactive masses was to express the load rate per unit mass of the reactive material in a given treatment. Because this method did not take into account progressive differences in unreacted pyrite among treatments of different reaction rates, a second method of normalizing the data was also performed. This second method expressed the load rate per unit mass of unreacted sulfur at each sampling point in time. Unreacted sulfur was calculated by subtracting the sulfate-sulfur accumulated in the leachate from the total mass of sulfur in the barrel at the start of the experiment.

Seasonal mean acid and sulfate load rates using both of the above normalization methods are presented in Tables 2 and 3 for inspection of treatment and seasonal influences on the rate of AMD generation. Graphic illustrations of acid load accumulation in the leachate and sulfur removal from the barrels are presented in Figures 1 and 2.

Table 2
Mean Seasonal Load Rates
Normalized to Mass of Reactive Material

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Treatment	Load Rate (g/kg/day)	Sum '84	Fall '84	Winter	Spr '85	Sum '85	Fall '85
Control	SO_4	0.325	0.206	0.029	0.106	0.189	0.968
	Acid	0.239	0.135	0.024	0.282	0.372	0.314
Amended Refuse	SO_4	0.244	0.194	0.015	0.090	0.122	0.075
	Acid	0.168	0.119	0.010	0.270	0.244	0.231
Vegetated Refuse	SO_4	0.310	0.168	0.014	0.071	0.125	0.074
	Acid	0.216	0.104	0.009	0.211	0.226	0.234
Sandstone	SO_4	0.475	0.244	0.149	0.093	0.166	0.101
	Acid	0.319	0.139	0.008	0.281	0.292	0.287
Vegetated Sandstone	SO_4	0.443	0.257	0.020	0.102	0.070	0.002
	Acid	0.273	0.143	0.012	0.298	0.140	0.005
Topsoil	SO_4	0.243	0.285	0.043	0.064	0.185	0.123
	Acid	0.148	0.165	0.030	0.155	0.342	0.319
Vegetated Topsoil	SO_4	0.172	0.243	0.051	0.164	0.103	0.011
	Acid	0.075	0.149	0.039	0.396	0.183	0.039

Table 3
Mean Seasonal Load Rates
Normalized to Mass of Unreacted Sulfur

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Mean Seasonal Load Rates
Normalized to Mass of Unreacted Sulfur

Treatment	Load Rate (g/kg/day)	Season: Sum '84	Fall '84	Winter	Spr '85	Sum '85	Fall '85
Control	SO_4	9.85	8.21	1.32	5.55	14.58	10.01
	Acid	7.28	5.41	1.11	14.92	28.31	32.48
Amended Refuse	SO_4	7.10	7.04	0.60	4.00	6.69	4.75
	Acid	4.90	4.35	0.39	11.94	13.25	14.54
Vegetated Refuse	SO_4	9.33	6.41	0.60	3.22	6.90	4.76
	Acid	6.49	3.95	0.36	9.55	12.33	15.02
Sandstone	SO_4	15.85	12.35	0.89	6.45	18.19	17.15
	Acid	10.62	6.98	0.49	19.42	31.28	48.80
Vegetated Sandstone	SO_4	14.45	12.67	1.14	7.12	6.20	0.15
	Acid	8.96	7.07	0.72	20.66	12.29	0.50
Topsoil	SO_4	7.08	11.14	2.02	3.31	13.24	12.10
	Acid	4.31	6.55	1.41	8.09	24.15	31.43
Vegetated Topsoil	SO_4	4.87	8.53	2.10	8.23	6.78	0.76
	Acid	2.12	5.32	1.59	20.29	11.84	2.80

FIGURE 1

CUMMULATIVE REACTIVE MASS NORMALIZED ACID LOAD

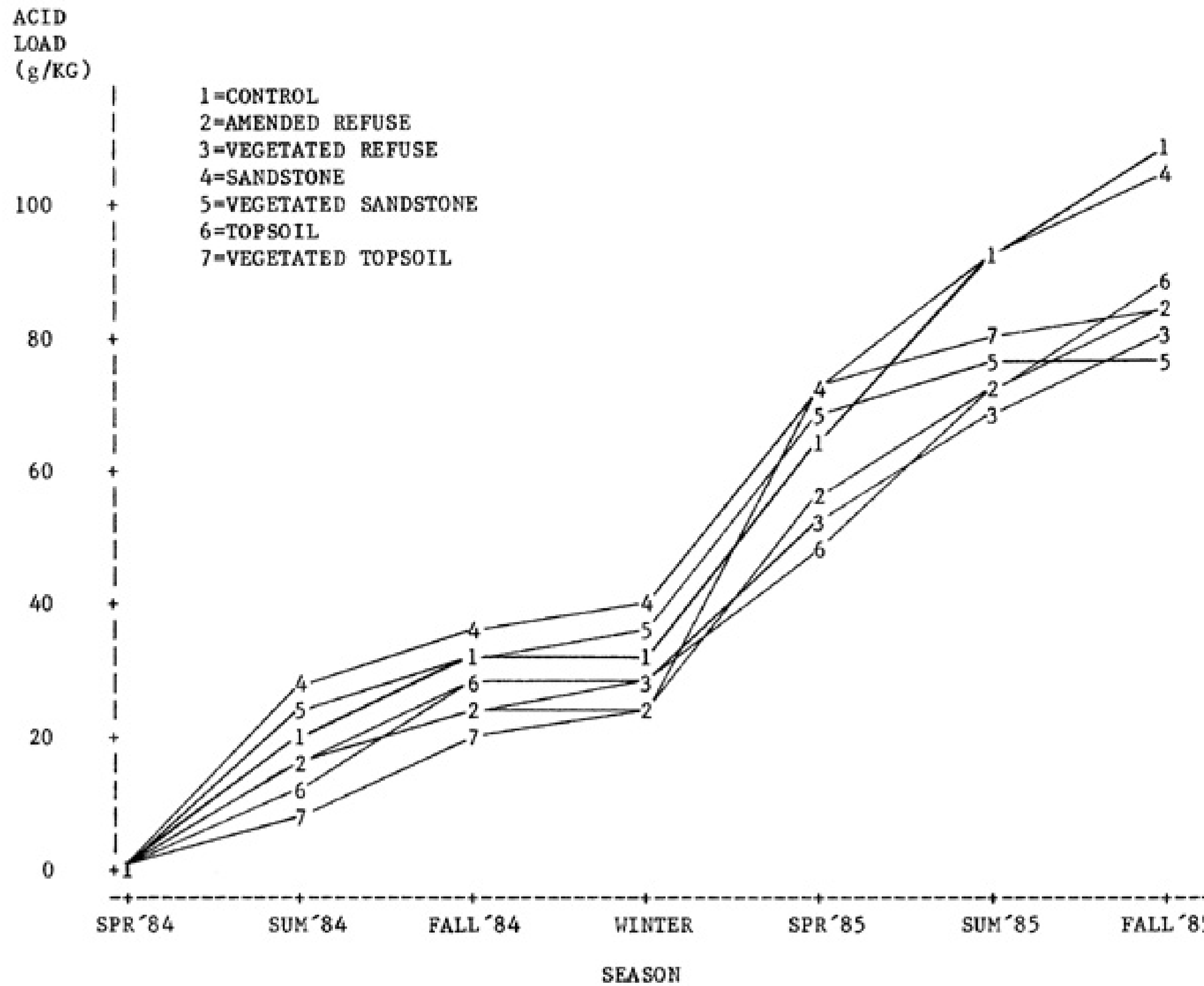
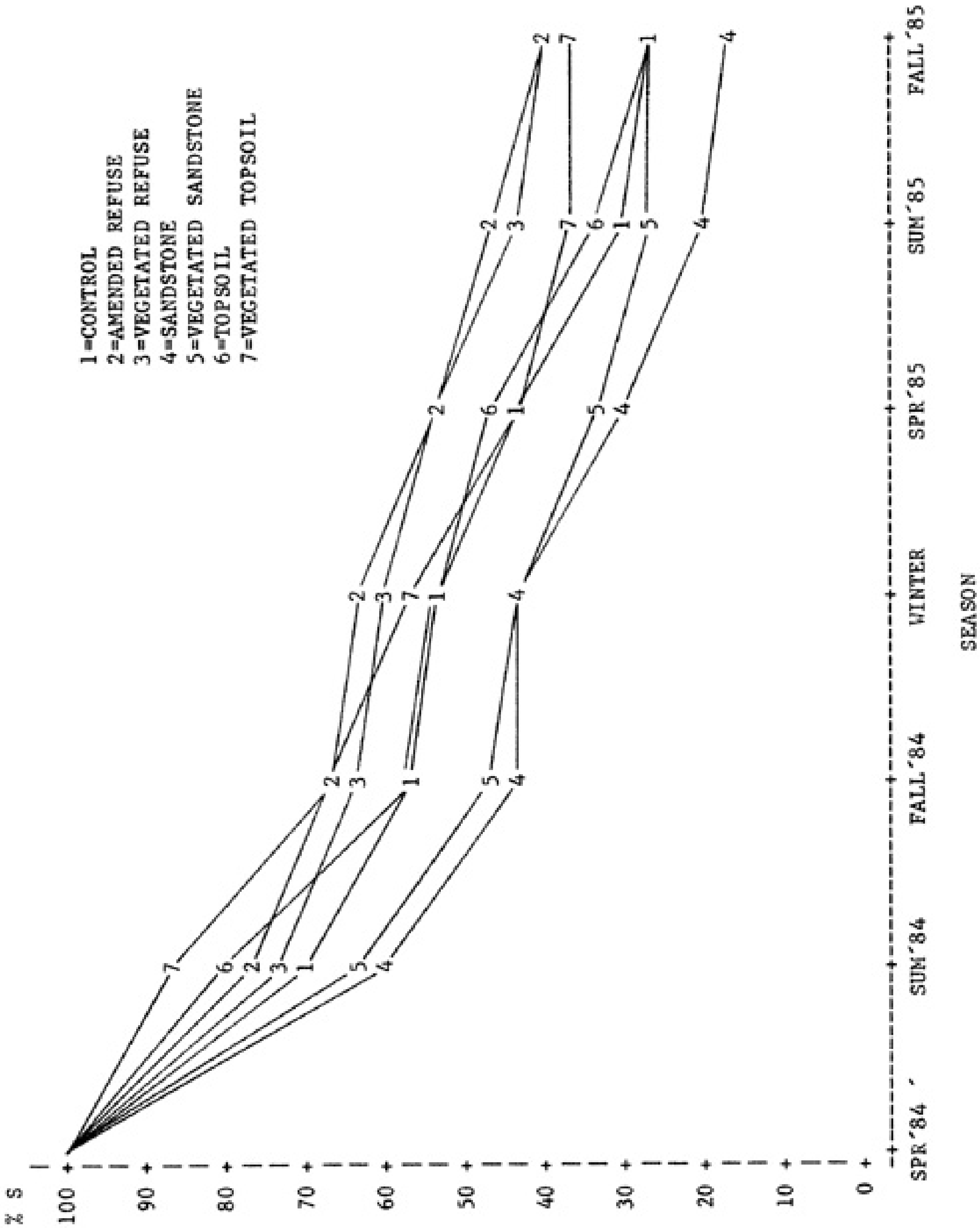


FIGURE 2
PERCENT UNREACTED SULFUR



Seasonal variation influenced reaction rates observed in this study more than any other factor. Reaction rates were very low in winter across all treatments (Tables 2 & 3). This seasonal variation was probably due to a very high fluctuation in temperature within the barrels caused by their exposed, above-ground position on the support structure. The apparent ameliorative effects due to treatments of incorporated lime and vegetation were most strongly manifested during summer and fall (Table 2).

The nonvegetated sandstone treatment seems to have accelerated the oxidation of pyrite as indicated by sulfate load rate. It would appear that by examining the sulfate load rates normalized to reactive mass that this phenomenon was restricted to the first nine months of the experiment (Table 2). Inspection of the sulfate load rate data normalized to the unreacted sulfur, however, suggests that the sandstone treatment was continuing to maintain a geochemical environment conducive to a higher rate of pyrite oxidation than the control throughout the experiment (Table 3). Partial neutralization of the leachate from the alkaline sandstone had apparently brought the total acid load of the nonvegetated sandstone treatment into parity with the control at the end of the experiment (Fig. 1).

The degree of apparent amelioration due to vegetated treatments appears to be strongly associated with vegetative vigor. Changes in vegetative growth in the sandstone and topsoil treatments between growing seasons tend to confirm this observation (Table 4).

Summary and Conclusions

Amended coal refuse, vegetated coal refuse, vegetated topsoil and vegetated sandstone treatments produced comparable total acid loads by the end of the experiment, whereas the nonvegetated topsoil produced somewhat more (Fig. 1). The control and the nonvegetated sandstone treatments produced comparable total acid loads which were higher than the other treatments by the end of the experiment. Acid load rates of vegetated sandstone and topsoil were suppressed during the summer and fall whereas those of the nonvegetated sandstone, topsoil and control were accelerated (Fig. 1).

Table 4
Vegetation Evaluation and Mean Growing Season
Acid Land Rates Normalized to Mass of Reactive Material

Material	Growing Season	---Stem Count[1]--- Tall Fescue #	Birdsfoot Trefoil #	Height (cm)	Live Cover (%)	Dry Weight (g)	-----Acid Load Rate------ Vegetated Material (g/kg/day)	Non-vegetated Material
Amended Coal Refuse	First	94	0	<10	43	---	0.172	0.146
	Second	23	0	<10	14	2.6	0.233	0.249
Sandstone	First	48	2	<10	23	---	0.229	0.257
	Second	4	131	13	85	41.0	0.108	0.294
Topsoil	First	263	0	18	90	---	0.068	0.138
	Second	25	27	<10	62	16.3	0.160	0.330

1. Number of stems greater than 10 cm (4 in.) tall

More pyrite oxidized in the nonvegetated sandstone barrels than any other treatment throughout the study, while the vegetated sandstone reached parity with the control by the end of the experiment. Less pyrite oxidized in the vegetated topsoil-covered refuse than the control by the end of the experiment whereas the nonvegetated topsoil was comparable to the control (Fig. 2). The lowest total sulfate loads were produced by the vegetated and amended coal refuse giving the appearance of the least pyrite oxidized across treatments (Fig. 2). These data may not be indicative of total pyrite oxidized by these treatments due to the probability of relic sulfate reaction products retained within the barrel material.

Reference

Thurman, N.C., R. Fugill, and J.C. Sencindiver. 1985. Effects of reclamation practices on soil and water quality. 22 p. In Surface Mining and Water Quality. Proceedings Sixth Annual West Virginia Surface Mine Drainage Task Force Symposium. West Virginia Mining and Reclamation Assoc. Charleston.