ASSESSING THE ALKALINE AND ACID LOADS OF COAL MINE OVERBURDEN AND THE PREDICTION OF MINE DRAINAGE QUALITY

by

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Background

During surface mining operations, as the overburden is disturbed and backfilled, strata are exposed to the atmosphere and changes in water movement. The resulting ground water and effluent quality depend, to some extent, on the physical and chemical characteristics of the various strata comprising the backfill. Whole rock analyses, including pyrite and carbonate contents, provide information on the mineralogy of the rock which can be used to predict leachate quality. Leaching tests are used to obtain kinetic components. While whole rock analyses and leaching tests are conducted on specific size fractions to provide uniform and consistent data, field situations involve numerous size fractions and in order to enhance the interpretation of the data derived from laboratory tests, the variations in sizes and their affects must be considered.

Whole rock analyses generally express the composition of the material in terms of weight percent; which is related to the volume of the material (volume = mass/density). However, the mineral components exposed on the surface of the particle are the ones that weather most rapidly and have the greatest affect on leachate quality. As a result, the particle size distribution and the porosity of the backfill material determine the amount of acid material that will come in contact with water. The intrinsic permeability of the rock material is assumed to be small and negligible when compared to the permeability of the backfill mass; i.e., water will flow around the particle more readily than through it. However, the chemical diffusion of ions from the water into the rock particles may be significant and although not penetrating the entire rock mass may have radical affects on the minerals contained in the near surface layer of the rock material. Thus the determination of the acid load from a particular site should be based on the physical characteristics (which include particle size, sorting and rock type) as well as the chemical characteristics of the rock mass.

In order to test the validity of these assumptions and determine the affect of the physical characteristics on acid loads, this study was designed to evaluate these various factors. Two rock types, each of which would be expected to break into two distinct shaves, yet having shapes common to a particular rock type were chosen. An acid producing sandstone was selected as the rock type which would break into angular and massive blocks. Due to the angular nature of the fracturing the sandstone would not provide sufficient opportunity for capillary water to adhere to the rock surface.

In comparison, an acid producing shale was selected because of its tendency to fracture along planar features and produce slabs. Further, this rock would be expected, because of the laminated nature of the bedding, to retain significant quantities of capillary water, maintaining the rock in a moisture-rich environment which would accelerate oxidation reactions, when compared to the sandstone.

Methodology

Sample Preparation: The two rock types selected for the initial study were 1) an acidic sandstone layer found above the Kittanning coal seam, and 2) a binder (siliceous, organic rich shale) found between the Middle and Lower Kittanning coal seams in an active coal stip mine in north-central West Virginia. Approximately, 10 tons of each rock type were crushed and sieved through a series of screens. The five size fractions included: less than one inch, one to two inches, two to four inches, four to six inches and greater than six inches.

During July and August, 1982 the samples of sandstone and binder were placed in large (8 feet x 4 feet x 2 feet) plastic lined containers which are open to precipitation events. Each container is connected by plastic pipe to 30 gallon plastic collection barrels and following each significant rain event, the drainage collected in each of the ten barrels is measured for total volume. A sample is collected and analyzed for a variety of chemical parameters which include temperature, pH, specific conductance, acidity, alkalinity and sulfate. To monitor rainwater background quality, samples of rainwater are collected and analyzed for the same parameters as the leachates. The volume of the sample, coupled with the acid concentration, is used to calculate the acid loads produced by each size fraction of the two rock types.

At the present time the response of these samples to precipitation events continues to be monitored and the laboratory and field results continue to be evaluated and analyzed. We are currently adjusting the study to evaluate the affect of various ameliorants on the acid production potential.

Representative portions of the various size fractions of the two rock types used in this study were collected and each portion was crushed to pass 4 mm. The crushed sample was riffled into three representative, but unequal weight portions. One portion of approximately 350 to 500 g was used in simulated weathering tests located within the laboratory complex, one portion of approximately 50 g was cast into pellets, polished and examined with a reflected light microscope to determine the petrography of the sample and the mineral characteristics. The third portion (approximately 50 g) was pulverized to pass 125 microns and analyzed for total and pyritic sulfur and alkaline production potential (APP) or cabonate content. The results of the whole rock analyses are presented in Table 1.

Acid Production and Loads: The concentration of acid produced for a particular leaching event (field or laboratory) will depend on the weight of the sample (the greater the weight the greater the acid levels for a specified aliquot of leachate) as well as the pyritic sulfur content. In addition, the time between flushing will also have an affect on the amount of acidity produced. To afford accurate comparisons of all samples, all values are adjusted to cumulative acid loads per kg of sample per 1% pyritic sulfur (Sp). The acid loads (mg) produced by the various size fractions of the samples can be calculated by multiplying the volume of the effluent collected (L) at one leaching event by the concentration of acidity (mg/L). In turn, the acid loads can be normalized by converting the acid loads (mg) to loads of acid produced per kilogram of sample per 1% pyritic sulfur; simply by adjusting the acid loads by the weight of the sample and the pyritic sulfur content. In turn, the cumulative acid loads produced through time for the various sample size fractions, factor out the variations in the leaching intervals. The resulting curves can be used to discern the affect of particle size on acid loads.

Table I - Pyritic sulfur and calcareous content of samples used in this study

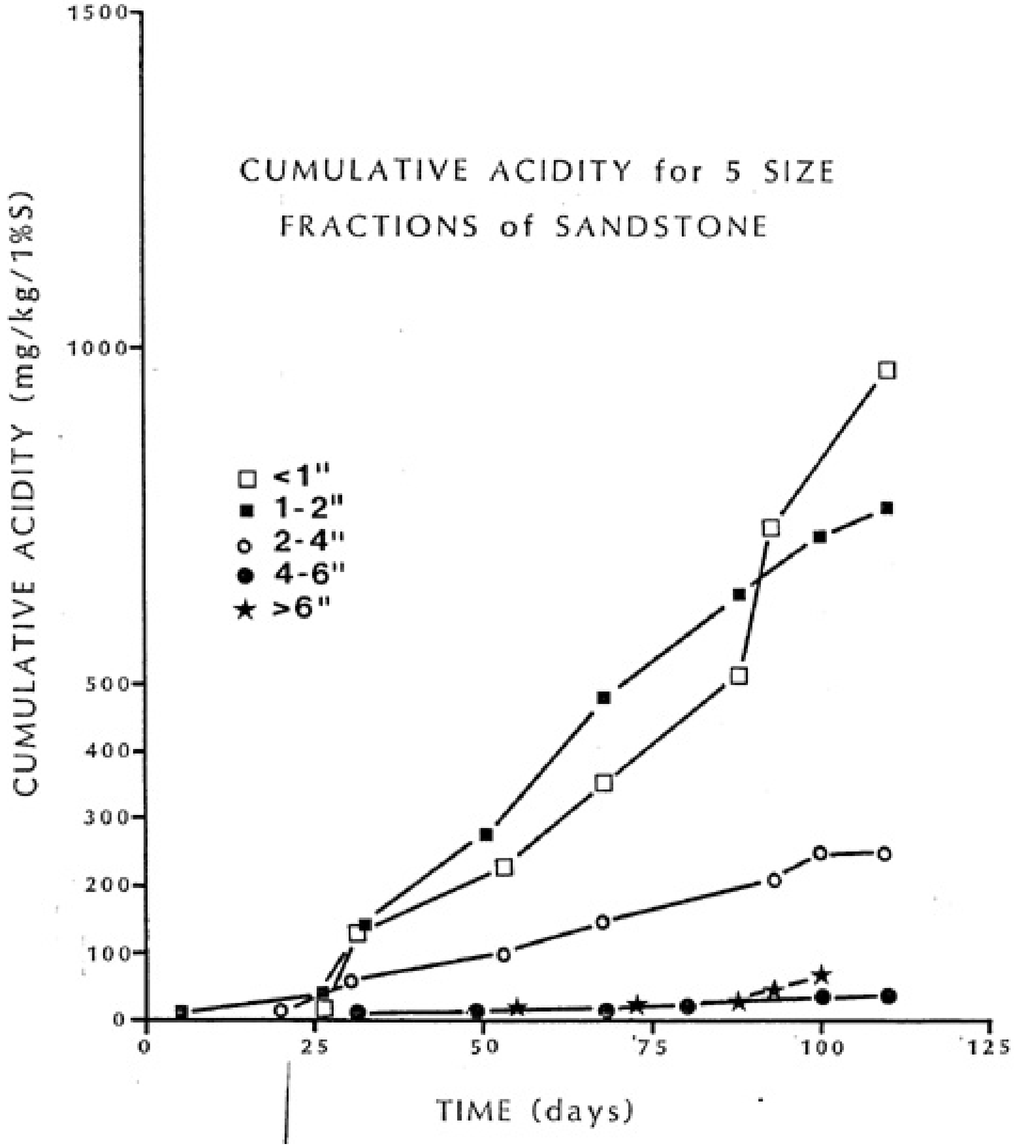
Sample	Pyritic Sulfur (%)	APP* (mg/500 mg)
Sandstone		
Less than 1"	0.15	1.15
1-2 inches	0.14	0.65
2-4 inches	0.18	1.15
4-6 inches	0.26	1.10
Greater 6"	0.23	0.49
Binder		
Less than 1"	0.74	0.80
1-2 inches	0.45	1.20
2-4 inches	0.51	1.00
4-6 inches	0.34	0.60
Greater 6"	0.28	0.89

*All values indicate a paucity of calcareous material

Results and Discussion

Sandstone: Cumulative acid loads (expressed as mg of acidity produced per kg per 1% Sp) plotted against time for the various size fractions of sandstone are shown in Figure 1. As would be expected the finer size fractions of sandstone produce more acid than the coarser sizes. Obviously, the smaller particles have greater surface areas of reactivity whereby more pyrite grains are made available for oxidation. It appears, that for this sample, most of the weathering processes represent near particle surface phenomena and that the rock undergoes little, if any, physical decomposition. In general, the rates of acid production for

Figure 1



each size fraction remains relatively constant, with respect to each other, through time.

Binder: The cumulative acid loads plotted through time for the various size fractions of binder material are shown in Figure 2. In contrast to the sandstones, all particle sizes greater than one inch produce acid loads of around 300 to 600 mg/kg/1%Sp over a 125 day period. For this same time interval, the sandstone showed acid production rates which differed with the various size fractions; sample size had to be less than two inches to generate equivalent amounts of acid.

The clustering of acid trends for the binder samples greater than the one inch size, suggests that the weathering process has penetrated deeper into the rock particle and/or the chemical weathering is accompanied by some physical decomposition. Significantly, binder material samples less than one inch in size produce almost four times more acid than the equivalent size of sandstone. The results shown in Figures I and 2 have been adjusted to a common base and variations in pyritic sulfur content, volume of leachate, frequency between flushings and grain size have been taken into consideration. Thus, for equivalent amounts of pyritic sulfur, binders produce greater amounts of acidity than equal portions of sandstone.

Conclusions

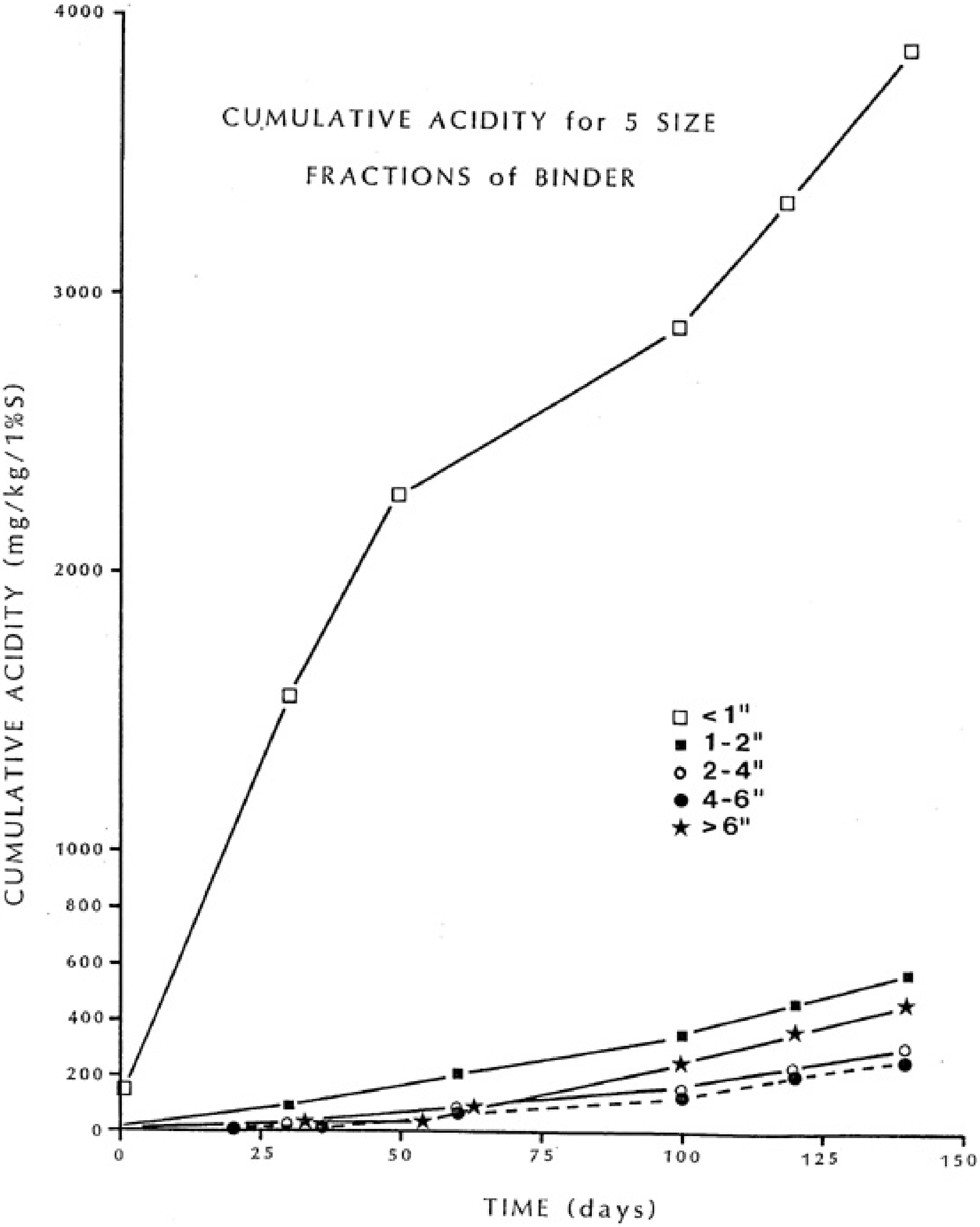
This study showed, as expected, that smaller sized rock particles produced greater amounts of acidity (loads) than the larger sizes. Because all samples were adjusted to a common base (cumulative mgs of acid/kg/1%Sp) we were in a position to compare sample response to chemical weathering as a function of rock type. These comparisons showed surprising results. Binder material (organic, siliceous rich shales) produced almost four times more acid than equivalent sized sandstones. We conclude therefore, that the permeability and/or the nature of the physical decomposition of the rock controls to a large extent the amount of acidity produced by a sample.

In these processes, we must consider rocks which have the capability of producing acid loads as a function of particle size, hence the surface areas of reactivity (as with the sandstones). In contrast, rocks with high chemical permeabilities, which allow penetration of oxidation processes into deeper zones, produce acidity independent of particle size; up to a critical dimension (as with binder materials, and presumably even more so with shales). This may explain why, in some cases, the observed drainage qualities may be inconsistent with the quality predicted solely on whole rock analyses. It appears that the physical characteristics of the rock play a significant role in controlling drainage quality and must be considered in an integrated fashion.

While this study continues to evaluate the physical dimensions of the rock samples, the results presented suggest that shale-like rocks have the capability of producing four times more acid than other rocks of similar chemical composition.

Figure 2

Figure 2



CUMULATIVE ACIDITY for 5 SIZE FRACTIONS of BINDER
CUMULATIVE ACIDITY (mg/kg/1%S)
TIME (days)
< 1"
1-2"
2-4"
4-6"
> 6"
4000
3000
2000
1000
800
600
400
200
0
0
25
50
75
100
125
150