THE EFFECTS OF PARTICLE SIZE DISTRIBUTION ON THE RATE OF MINE ACID FORMATION AND ITS MITIGATION BY BACTERIAL INHIBITORS[1]

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Abstract. Among other factors, inhibition of acid formation using bactericides is dependent on particle size distribution. A model has been developed to correlate acid inhibition with particle size on a high sulfur (4.56%) refuse and has been verified with a column leaching test representing natural particle size distribution.

INTRODUCTION

Bacterial catalysis of iron oxidizing reactions in natural coal wastes can be mitigated through the use of bactericides. Proper use of these chemical agents primarily requires a consideration of geochemistry and particle size distribution. Field applications additionally necessitate an understanding of site hydrologic variables (Shellhorn, 1985). Nonetheless, the basic interactions between bactericides and coal waste materials have been relatively unexplored.

On an individual material basis, it is necessary to establish what the relationship will be for a given concentration of a bactericide on not only individual particle sizes, but a blend of such sizes as well. A model explaining such a relationship would enable the prediction of effective bactericide concentrations for field applications. Presented are the procedures and results for determining the relationships between acidity, bactericide concentration and particle size to develop such a model.

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EXPERIMENTAL METHOD

A high pyritic sulfur refuse (4.56%) was washed thoroughly with distilled deionized water and sieved into twenty-four particle size ranges spanning 0.157 inches to 0.0029 inches in average diameter. Six five-gram aliquots of each particle size were placed in incubation jars for an incubation period of six weeks. Three samples out of each particle size range were designated as controls to establish a statistical assessment. The remaining three samples of each set were treated with the BFGoodrich PROMAC® 500[5] bactericide at levels of 100, 250 and 500ppm by weight of sample. Treatment of each sample was established by adding 3ml of water (controls) or water/bactericide solutions in appropriate concentrations. This procedure resulted in a moist but not saturated slug of material.

Samples were incubated in a humidity chamber at 31°C and approximately 98% humidity to optimize bacterial activity and reaction kinetics. At the conclusion of the incubation, designated controls and treated samples of each particle size were removed and leached using standard EPA methods. Leachates were subsequently filtered and analyzed for pH, Eh, specific conductance and acidity.

Column leach testing was conducted on a blend of particle sizes representing the natural size distribution for the materials as received. Using a method previously described

[5]PROMAC® is a BFGoodrich Company registered trademark. This name is used to protect the company's proprietary information.

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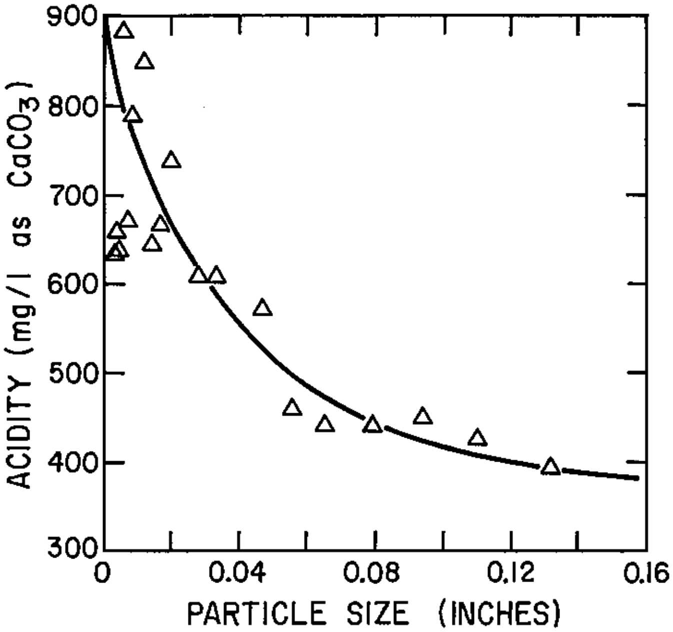

Figure 1. Acidity from 'control' samples as a function of particle size at six weeks of incubation. Data points represent averaged values of three samples for those analyses with a standard deviation of less than 5% of the mean value.

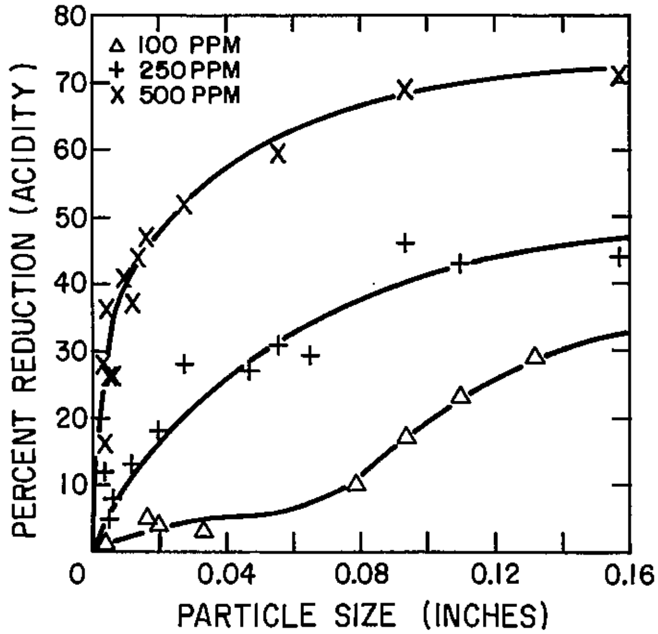

Figure 2. Percent reductions in acidity as a function of particle size for three levels of bactericide treatment. Data points represent those analyses with a standard deviation of less than 5% of their mean.

(Shellhorn, 1984), columns containing one kilogram of refuse were leached twice weekly for three weeks with water to establish equilibrated starting levels and to insure statistically valid data. Subsequent to initial leachings, designated columns were treated with a bactericide at 500ppm (by weight of sample material) to compare against control columns. All columns continued to be leached twice weekly using water, with the leachates being analyzed for pH, Eh, specific conductance and acidity.

For the purpose of this paper, only acidity measurements at the 500ppm bactericide concentration were used to develop and verify the correlation.

RESULTS

Six-week incubation analyses for control samples of each particle size were averaged and are presented in Figure 1. This curve shows an exponential increase in acidity with decreasing particle size or increased relative surface area.

Averaged acidity values for control samples of each size fraction were compared against treated samples to obtain a quantitative reduction in acidity. Figure 2 illustrates this relationship for all three treatment levels. All three treatment levels indicate a non-linear decrease in acidity reduction with decreasing particle size. In addition, increasing levels of acidity reduction for all particle sizes were obtained with increasing concentration of the bactericide.

Figure 3 shows results of column leach testing six weeks after treatment. In a graph of cumulative acidity as a function of time, linear trends established by the data show a 59% reduction in cumulative acidity at six weeks for the bactericide treated column.

DISCUSSION

Now that acid generation capacity of the site material and the acid reduction capacity of the bactericide as a function of particle size (Fig. 1 and 2) have been established, the results can be used to predict acid formation inhibition in a blend of particle sizes. This inhibition should be a composite of the relative effect on each particle size range. To assess this correlation, a model was developed to compare results from the particle size analyses with column leaching tests at the 500ppm treatment level.

A model for extrapolating individual particle size information to more natural distributions was established by fitting an equation to the 500ppm data. Figure 4 illustrates the linear trend created by graphing the percentage reduction in acidity

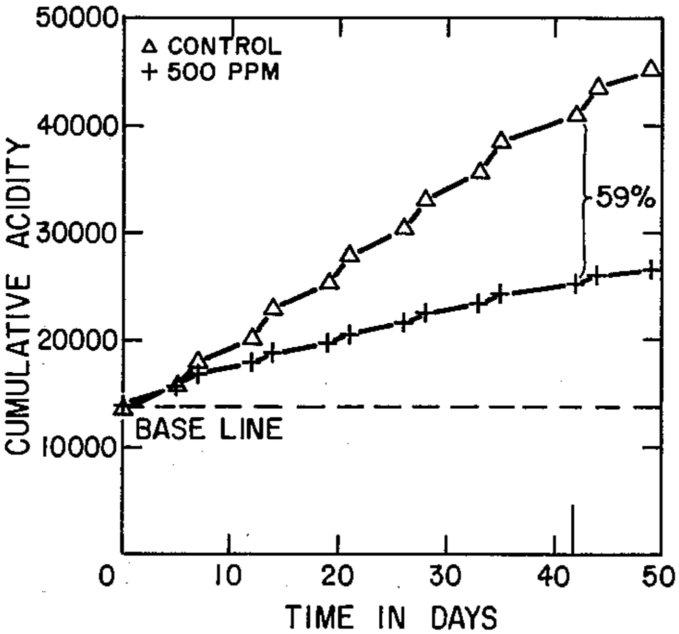

Figure 3. Cumulative acidity as a function of time for column leaching test. Control data represent the average of two columns with less than 1% internal deviation in slope. Base line indicates level of cumulative acidity established before treatment of test column and is deducted from both controls and treatment columns for percent reduction calculations. Percent reduction in cumulative acidity at the end of six weeks is 59%.

as a function of the $\log_{10}$ of the average particle size. A first order linear regression analysis yields the relation:

$$Y = 29.11x + 96.52$$

where

y = percent reduction in acidity

x = $\log_{10}$ of the average particle size in inches

and

$r^2 = 0.92$ (indicating good statistical correlation)

Using the particle size distribution in the column leach test, a predicted percentage reduction in cumulative acidity was made for comparison against actual data. Table 1 shows the estimated reduction percentage calculations for each particle size used.

Close agreement between the estimated 60% reduction and that actually determined at 59% supports the assumption that the acid inhibition in this material is a composite of the effect on each particle size. Replications of this experiment were used to verify the validity of this model. The model can be used to

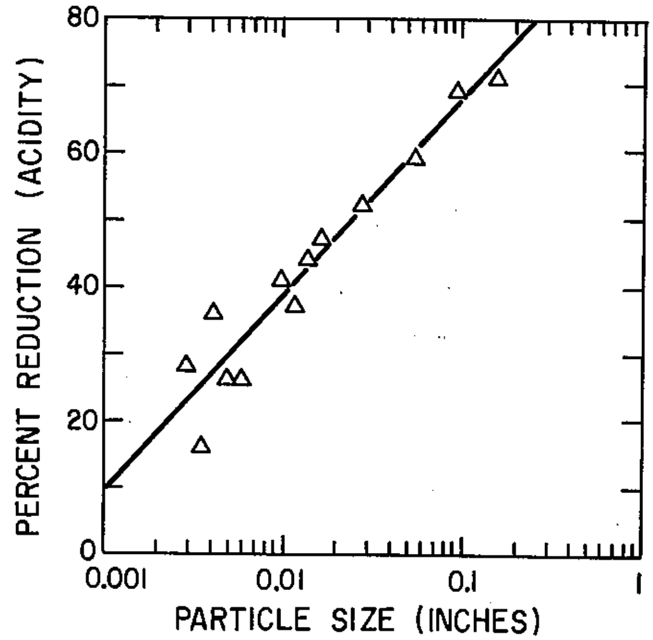

Figure 4. Percent reduction in acidity as a function of the $\log_{10}$ of the average particle size for incubation samples treated at 500ppm. Trend line represents the best fit equation from first order linear regression.

Table 1. Calculation of estimated percent reduction from equation (1) using column leach test particle size distribution.

Average Particle Diameter in Inches	Percent Total Size Distr.	Calculated Percent Reduction from Equation	Composite Percent Reduction
0.157	13.7	73	10.0
0.132	10.5	71	7.5
0.0937	19.0	67	12.7
0.0787	7.9	64	5.1
0.0555	13.1	60	7.9
0.0394	11.1	56	6.2
0.0232	10.2	49	5.0
0.0165	4.9	45	2.2
0.0098	4.9	38	1.9
0.0070	2.4	34	1.5
0.0059	0.8	32	0.3
0.0049	0.8	29	0.1
		Total	60.40%

extrapolate percentage reductions in natural field conditions when using bactericides to control acid drainage.

CONCLUSION

The effectiveness of a bactericide as a function of particle size is a non-linear relationship reflecting decreased effectiveness with decreasing particle size. Conversely, acidity as a function of particle size is a non-linear relationship with acidity increasing with decreasing particle size.

For a given site material, once the relative bactericide effectiveness has been established (Shellhorn, 1985) and an assessment made of the particle size distribution in the site, this model provides a useful tool for more accurately determining the effective bactericide dosage. This model is applicable to both reclamation and active mining operations.

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