A computerized automated rapid weathering apparatus for determining total lime requirements for acid minesoils
by Kevin Christopher Harvey

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Land Rehabilitation
Montana State University

Abstract:
Acid minesoil problems, similar to those in the eastern coal mining states, are common at western coal and hardrock mine operations. Traditional analytical methods for predicting lime requirements are inadequate for evaluating on-going acid production from the oxidation of sulfides. Manual laboratory weathering methods attempt to rapidly simulate the natural chemical weathering of acid producing minesoils and overburden. These methods can circumvent the problems associated with acid-base account interpretations. However, the manual laboratory weathering method is extremely laborious and time consuming. The primary objective of this study was to develop a computer-ized automated rapid weathering apparatus (CARWA) that could determine a sample's characteristic acid production curve and subsequent lime requirement in 24 hours instead of 6 to 12 weeks. CARWA prototype development was accomplished in association with total lime requirement determinations for acid minesoil sites at the Dave Johnston Mine in Wyoming.

Twelve acid minesoil samples were weathered and logarithmic curve fitting was used to project one-time application lime requirements. Calculations were based on the assumption that three CARWA weathering cycles represent one year of natural chemical weathering in the field.

CARWA acid production curve characteristics were similar to those determined by the more established manual laboratory weathering method. In addition, CARWA determined lime requirement projections were statistically similar to or greater than those determined by manual weathering..

Acid-base account lime recommendations were consistently much higher than CARWA determined lime rates. This may be due to the measurement of non-reactive sulfides and/or the inclusion of organic sulfur in the calculation of the acid producing potential. A linear regression equation (r=.95) was found to predict CARWA type lime rates from standard acid-base account data of acid minesoil samples from the Dave Johnston Mine.

CARWA lime rates were put to the ultimate test by implementing them into field plot tests at the Dave Johnston Mine. Vegetation performance results after one growing season suggest that substantial perennial grass establishment has occurred on non-topsoiled acid spoils amended with CARWA determined lime requirements.

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APPROVAL

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Kevin Christopher Harvey

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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TABLE OF CONTENTS

TABLE OF CONTENTS--Continued

LIST OF TABLES

LIST OF TABLES--Continued

LIST OF FIGURES

ABSTRACT

Acid minesoil problems, similar to those in the eastern coal mining states, are common at western coal and hardrock mine operations. Traditional analytical methods for predicting lime requirements are inadequate for evaluating on-going acid production from the oxidation of sulfides. Manual laboratory weathering methods attempt to rapidly simulate the natural chemical weathering of acid producing minesoils and overburden. These methods can circumvent the problems associated with acid-base account interpretations. However, the manual laboratory weathering method is extremely laborious and time consuming. The primary objective of this study was to develop a computerized automated rapid weathering apparatus (CARWA) that could determine a sample's characteristic acid production curve and subsequent lime requirement in 24 hours instead of 6 to 12 weeks. CARWA prototype development was accomplished in association with total lime requirement determinations for acid minesoil sites at the Dave Johnston Mine in Wyoming.

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Acid-base account lime recommendations were consistently much higher than CARWA determined lime rates. This may be due to the measurement of non-reactive sulfides and/or the inclusion of organic sulfur in the calculation of the acid producing potential. A linear regression equation ($r=.95$) was found to predict CARWA type lime rates from standard acid-base account data of acid minesoil samples from the Dave Johnston Mine.

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INTRODUCTION

Numerous coal and hardrock mine sites throughout the western United States are experiencing acid minesoil problems parallel to those in the eastern states. Acid production from the oxidation of iron sulfides (e.g. pyrite) in overburden materials often inhibit revegetation of minesoils. The reactions involved in pyrite oxidation are complex but can be summarized by the equation:

$$2\ FeS_2 + 7\ O_2 + 2\ H_2O = 2\ Fe^{+2} + 4\ SO_4^{-2} + 4\ H^+$$

Lime application to neutralize minesoil pH seems necessary to provide a suitable growing medium. However, a reliable methodology to determine a one-time total lime requirement for the life of the material is not available.

Traditional agricultural lime requirement tests (Dunn 1943, Woodruff 1948, Shoemaker et al. 1961, Peech 1965, McLean et al. 1966) generally underestimate the total lime requirement for acid producing minesoils. These methods only evaluate exchangeable or soluble acidity and do not consider the total potential acidity generated from long term chemical weathering of sulfide minerals or organic sulfur compounds.

Acid-base accounting (Smith et al. 1974) is used extensively in the United States to assess the long term

acid production and base release in minesoil materials. The method can, with 90 percent accuracy (Russell 1984, Russell and Dollhopf 1984) indicate which geologic stratum in overburden will produce acid upon oxidation/hydrolysis and which will not (Caruccio 1980, Sturey et al. 1982).

The method is less reliable when the actual quantity of acid production must be known so that a lime requirement can be calculated. Variations in kinetics between acid and alkaline production indicate that a simple balance of the acid potential against the base potential, to determine the excess of one over the other, is incorrect (Geidel 1979, Caruccio and Geidel 1984). In addition, uncertainties associated with the yield of acid from organic sulfur in minesoils results in difficult interpretations of acid-base account data (Dollhopf 1984).

An alternative method to analytical approaches such as the acid-base account, is to simulate natural chemical weathering of spoil samples using humidity cells (Hanna and Brandt 1962, Caruccio 1968, Sobek et al. 1978). This empirical technique provides simple control over air, temperature, moisture and catalytic microbes to circumvent the problems associated with acid-base accounting and the uncertainties of acid production from organic sulfur.

Russell and Dollhopf (1984), Russell (1984) and Blanton and Dollhopf (1985) utilized a slightly modified laboratory humidity cell apparatus to weather minesoil

materials from ten abandoned hardrock and coal mining areas in Montana. Acid production curves, derived from weekly extractions to measure acid generation, were used to calculate one-time total lime requirements for these materials.

It appears that simulated weathering chambers can be used to determine the total lime requirement of minesoil materials. The technique was laborious and required from six to twelve weeks of time for results, making it impractical to process large numbers of samples or to attain rapid results. This was the impetus behind the development of a rapid and reliable method which will determine one-time total lime requirements for acid producing minesoils.

The primary objective of this study was to 1) develop a computerized automated rapid weathering apparatus (CARWA) that could weather a sample in days rather than weeks. Other objectives were to: 2) determine total lime requirements for acid minesoil sites at the Dave Johnston Mine near Glenrock, Wyoming; 3) compare CARWA lime recommendations to those from the manual laboratory weathering (humidity cell) method and acid-base accounting; 4) determine which sulfur components contribute to acidity liberated by CARWA; and 5) field test lime rates recommended by CARWA.