Effects of organic amendments and plants on the chemistry of acid sulfate soils under aerobic and anaerobic conditions

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Abstract

Acid sulfate soils with sulfuric horizons (sulfuric soils) can exert a range of negative impacts on the ecology and productivity of soils. The primary treatment for these soils is to raise the pH using lime. Although often effective, this treatment can be expensive and not well suited to large areas. In this research, the possible use of plant organic matter to ameliorate sulfuric soils or to prevent acid sulfate soils with sulfidic materials (sulfidic soils) from acidifying was investigated. The advantage of this approach is that organic matter is readily available, inexpensive and environmentally friendly, especially in Ramsar listed wetlands where lime cannot be used. The experimental treatments used ground leaves of *Phragmites*, lucerne hay, pea straw and wheat straw as sources of organic matter with varying nitrogen, which were either incorporated into or overlaid on the surface of the soils. After 6 months of incubation under either aerobic or anaerobic soil conditions, pH, Eh and sulfate content were measured. Incorporation of complex organic matter significantly increased the pH of both sulfuric and sulfidic soils. These changes were correlated with reductions in soil redox and sulfate content. The magnitude of the changes depended on the nitrogen content of the complex organic matter.

The relative importance of carbon and nitrogen in ameliorating acid sulfate soils was further investigated respectively using glucose, sodium acetate and molasses as simple carbon sources, and urea, nitrate and ammonium as simple nitrogen compounds. It was found that compounds containing inorganic nitrogen alone without carbon were ineffective, while urea significantly increased pH and reduced Eh, but did not affect the sulfate content of the soil. Glucose had no significant effect on sulfuric soils, either at low (catalytic) or high concentrations, while acetate significantly increased pH. Molasses (which may contain small amounts of nitrogen) caused moderate changes in pH, Eh and sulfate content. On sulfidic soils, acetate prevented oxidation but glucose strongly acidified the soil, most probably by fermentation to butyric acid.

The effects of live roots on sulfidic and sulfuric soil chemistry under either aerobic or anaerobic soil conditions were investigated using *Typha*, *Phragmites* and *Melaleuca*. *Typha* and *Melaleuca* are respectively common wetland and inland plants, whereas *Phragmites* grows under both wetland and inland soil conditions. The study was extended to investigate the combined effects of incorporated ground *Phragmites* leaves as organic matter and *Phragmites* plants together. Generally, a great deal of variability was found in

the changes in pH, redox and sulfate content, the overall effects being dependent on plant type, whether there was incorporated organic matter, the type of soil and the moisture conditions. However, in all cases the growth of the live plants resulted in greater acidity than in the unplanted control soils. In the case of *Typha* and *Phragmites,* which have aerenchymatous tissues, the acidification under anaerobic conditions was attributed to the transport of oxygen in these tissues into the soil. Under non-flooded conditions, the acidification was most likely due to increased oxygen penetration as a result of loosening of the soil by the plant roots.

Synopsis

Acid sulfate soils are naturally occurring soils formed under reducing soil conditions. These soils either contain sulfuric acid or have the potential to form it, in an amount that can have detrimental impacts on other soil characteristics and the environment (Melville and White, 2012). The principle strategy to manage sulfuric soil is to neutralize the actual acidity and minimize its by-product discharge by application of an alkaline or neutral material such as agricultural lime while for a sulfidic soil is to minimize oxidation. In some localities such as in the tropics, however, availability of mineral lime is an issue and in most situations considered impractical because of excessive costs and the need for large quantities (Hue, 1992). In addition, lime cannot be applied under certain sensitive soil conditions such as in Ramsar-listed wetland environments. As a result, other more feasible management strategies need to be studied and established to effectively manage acid sulfate soils.

What follows are studies on understanding the effects of organic amendments and plants on the chemistry of acid sulfate soils. Firstly, the effects of addition of complex organic matter on acid sulfate soil chemistry under aerobic and anaerobic soil conditions were assessed. In Chapter 4, the changes induced by organic matter in sulfuric soils are investigated and in Chapter 5 the ability of organic matter to prevent oxidation of sulfidic soils is examined. The relative importance of carbon and nitrogen for ameliorating acid soils is also studied in these chapters through the addition of simple carbon and nitrogen compounds.

The second major component of this research assessed the impacts of live plants on acid sulfate soil chemistry and this is presented in Chapter 6. Chapter 7 also describes effects of live plants on soil pH, but using "neutralised sulfuric soil" as the substrate.

The final Discussion in Chapter 8 brings together the results from the various studies to evaluate the benefits and drawbacks of plants in treating acid sulfate soils, and attempts to give some insight into the mechanisms that underlie the changes induced in soil chemistry by the addition of organic matter or by live plants.

As part of the description of changes in the chemistry of acid sulfate soils in response to addition of organic matter, it was originally intended to attempt to identify the types of bacteria that contributed to these changes, at least to confirm a major involvement of sulfur reducing bacteria (SRBs) in the changes. Some good progress was made in this area, but not sufficient to justify a chapter of its own in the thesis, so it has been included in a separate appendix (A1).

Publications arising from this thesis

The University of Adelaide encourages the publication of papers during candidature and permits theses to be presented as either a collection of published papers or a combination of papers and conventional chapters. This thesis incorporates two journal papers based on some of the data from Chapters 4 and 5. One of these papers is published and the other has been submitted. Additionally, a peer reviewed conference paper based on early data from Chapter 7 is appended to that chapter.

1. Michael, P. S., Fitzpatrick, R., Reid, R., 2015. The role of organic matter in ameliorating acid sulfate soils with sulfuric horizons. Geoderma 225, 42-49.

2. Michael, P. S., Fitzpatrick, R., Reid, R., 2015. The importance of soil carbon and nitrogen for amelioration of acid sulphate soils. Soil Use and Management (submitted).

3. Michael, P.S., Reid, R., Fitzpatrick, R.W., 2012. Amelioration of slowly permeable hypersaline peaty-clayey sulfuric and sulfidic materials in acid sulfate soils by mixing with friable sandy loam soil. In: L.L. Burkitt, L.A. Sparrow (Eds.), Proceedings of the 5th Joint Australian and New Zealand Soil Science Conference: Soil solutions for diverse landscapes, pp. 146-149.

Signed declaration for thesis submission

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Patrick S. Michael

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