

REMEDICATION OF ACID SULFATE SOILS BY ORGANIC MATTER ADDITION

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Contents

Abstract	I
Declaration	V
Acknowledgement	VII
List of abbreviations	IX
CHAPTER 1 Introduction and literature review	1
CHAPTER 2 Sulfate reduction in sulfuric material after re-flooding: Effectiveness of organic carbon addition and pH increase depends on soil properties	23
CHAPTER 3 Amount of organic matter required to induce sulfate reduction in sulfuric material after re-flooding is affected by soil nitrate concentration	39
CHAPTER 4 Organic matter addition reduces acidification during oxidation of sulfidic material: effect of application form and rate	55
CHAPTER 5 Conclusion and future research	81
APPENDIX Descriptions of soil profiles mentioned in Chapters 2 and 3	93

Abstract

Acid sulfate soils (ASS) are soils containing iron sulfide minerals (predominantly pyrite) and/or their oxidation products. ASS have a large distribution in the world (10^7 – 10^8 ha coastal ASS) and in Australia (215,000 km²). Sulfide in ASS is formed from sulfate in sea water or fresh water under anaerobic conditions by sulfate-reducing bacteria, which need organic matter (OM) as the energy source. Sulfide then reacts with dissolved Fe(II) to form pyrite. Sulfuric material (containing sulfuric acid) is formed during oxidation of ASS with sulfidic material (containing sulfide minerals), resulting in significant release of acid and dissolved metals that can have detrimental effects on soil and water quality and thus ecosystem services. Remediation of sulfuric material and prevention of oxidization of sulfidic material are therefore of great environmental concern. Conventional remedial strategies, such as liming sulfuric material and covering sulfidic material with water or non-ASS soil, can be costly or not practically feasible due to the large amount of lime, water or soil required.

Organic matter (OM) is the energy source for sulfate reducers, which play a critical role in the formation of sulfidic material and generate alkalinity during sulfate reduction. OM could influence the oxidation of pyrite through oxygen consumption by OM decomposers, complexation of ferric iron, and coating of pyrite. OM can also buffer acid generated from pyrite oxidation. However, the availability of native OM in ASS can be low due to binding to clay particles, occlusion in aggregates, or complexation by dissolved metals. Therefore application of OM may be an economical and environmentally friendly option to remediate ASS. But systematic studies are required on the effectiveness of OM application for the management of ASS.

Ten ASS with sulfuric material, with pH increased to 5.5 and OM (finely ground mature wheat straw) added at 2% (w/w) separately or combined, were incubated submerged for 36 weeks. Unamended soils served as controls. Only the combined treatment (pH increased and OM added) increased the concentration of reduced inorganic sulfur significantly compared to the control and had higher soil pore water pH than the treatment with only pH increased. But the stimulation of sulfate reduction compared to the control of the combined treatment differed among soils which could be attributed to the initial soil properties. Stimulation of sulfate reduction in the combined treatment was negatively correlated with soil clay content and initial nitrate concentration. Clay can limit the availability of the added OM by binding and nitrate is a competing electron acceptor for sulfur reduction. In a subsequent experiment, ASS with smaller increase in sulfate reduction compared with other soils in the previous study were incubated with up to 6% (w/w) OM added for 36 weeks. The concentration of reduced inorganic sulfur increased with OM addition rate, with the increase between 4% and 6% being smaller than that between 2% and 4%, suggesting that besides OM other factors influenced sulfate reduction. Further, the impact of nitrate (competing electron acceptor) at different OM addition rates on sulfate reduction was examined. Nitrate addition inhibited sulfate reduction but the extent was smaller with OM added at 4% compared to 2%, indicating that the inhibition by nitrate was overcome by higher OM addition.

In the two following experiments, the effect of OM addition on oxidation and acidification of sulfidic material was investigated by laboratory incubation under oxidizing conditions for 6 weeks. In the first experiment, OM (finely ground mature wheat straw) was added to a sulfidic material at 3% (w/w) as a layer on the soil surface or by mixing into soil. Soil pH decreased by 0.9 unit in the unamended control, increased by 0.2 unit in

the treatment with OM as a layer, and increased by 0.8 unit in the treatment with OM mixed into the soil. In the second experiment, 1, 2, 3, and 4% (w/w) OM was mixed into the sulfidic material. The pH decrease was strongest in the unamended control and was smaller with 1% and 2% OM. Only 3% and 4% OM addition prevented acidification. However, the increase in soil sulfate concentration was similar in all the amended treatments. Prevention of acidification of sulfidic material by OM addition can be explained by consumption of oxygen by OM decomposers and pH buffer capacity of OM.

Declaration

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Acknowledgment

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I will also tell my parents and sister. They don't know English, they don't know what Adelaide looks like, and they don't even know what I currently look like. They haven't seen me since I came here. They must miss me.

Chaolei Yuan

List of abbreviations

ANOVA analysis of variance

ASS acid sulfate soils

AVS acid volatile sulfide

DO₂ dissolved oxygen

ICP-AES inductively coupled plasma atomic emission spectroscopy

MaOC mineral-associated organic carbon

OM organic matter

PCA principal component analysis

pH(1:1) pH measured in a 1:1 soil to water ratio

pH(1:5) pH measured in a 1:5 soil to water ratio

POC particulate organic carbon

RIS reduced inorganic sulfur

Scr chromium reducible sulfur

S_{HCl} 4 M HCl extractable sulfur

S_{KCl} 1 M KCl extractable sulfur