

**Sediment remediation as a technique for
restoring eutrophic wetlands and controlling
nuisance Chironomidae**

by

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I declare that this thesis is my own account of my research and contains as its main content work, which has not previously been submitted for a degree at any tertiary education institution.

Signed.....

Date

ABSTRACT

Eutrophication is a global problem affecting many inland and estuarine waters. Many wetlands on the Swan Coast Plain, in Western Australia, have undergone increasing nutrient enrichment since European settlement of the region in the 1850's. Problems such as algal blooms and nuisance swarms of non-biting midges (Diptera; Chironomidae) are the consequence of nutrient enrichment in many of these wetlands. The restoration of these degraded wetlands, especially with respect to reducing nutrient enrichment, requires a range of comprehensive and effective techniques including catchment management, diversion or treatment of surface inputs and treatment of enriched sediments. Nitrogen and phosphorus, especially phosphorus, are not the only factors controlling algal biomass in water bodies, but they are the only elements that can be removed efficiently and economically.

Internal P cycling from wetland sediments can initiate and sustain eutrophication and related algal blooms and nuisance midge problems even after external sources are diverted or reduced. The aim of this study was to identify an effective material to reduce sediment phosphorus release and thereby the phosphorus concentration of the water column. It was also important to determine the impact of the selected amendment material on phytoplankton and larval midge (chironomid) communities.

A range of experiments at increasing scales, from bench-top, to microcosm to outdoor mesocosm experiments were designed to test three hypotheses:

- 1) Materials which have a high P sorption capacity, over a wide range of P solution concentrations, and low P release rate, are potentially suitable agents to reduce P in wetlands with enriched sediments by inactivating sediment P;
- 2) A reduction in the abundance of cyanobacteria caused by increasing the N:P ratio of an aquatic ecosystem results in a reduction in the density of nuisance species of Chironomidae.

- 3) Successful amendment of enriched sediments reduces P in the water column thereby reducing the total phytoplankton biomass and the related density of nuisance species of Chironomidae.

The adsorption and desorption experiments were carried out under a range of pH values and P concentrations, with a number of materials including fly ash, red mud, precipitated calcium carbonate, crushed limestone and lime to determine the maximum adsorption capacity and affinity of these materials. A range of P concentrations (0-1000 $\mu\text{g/L}$) simulated the P concentration of the water column in a range of wetlands of differing trophic status. Poor fits to the Langmuir equation occurred with both red mud and fly ash due to their high P content. A good fit occurred with lime, with a high P removal rate (90%-96%) over the same range. Fly ash and red mud were eliminated from further investigation due to the possibility that they might release phosphorus rather than absorb when P concentrations in surrounding environment were less than 300 $\mu\text{g/L}$ or 200 $\mu\text{g/L}$ respectively (concentrations which can occur in eutrophic systems).

Among the three lime-based, redox-insensitive materials tested in the second mesocosm experiments, precipitated calcium carbonate (PCC) possessed the highest maximum adsorption capacity and lowest desorption rate under a range of pH values (6.2, 7.2 and 10) and P concentrations (0-12 000 $\mu\text{g/L}$), followed by crushed limestone and lime. The different maximum absorption capacities of the three materials appears to be mainly attributed to their particle size (surface area).

Lime was chosen as the amendment material for further investigation because it was the only one of the three available in sufficient quantities within the timeframe of this study.

Microcosm experiments showed that lime was effective in reducing sediment P release from intact sediment cores, and the ratio of TN:TP in the treatment cores increased over time compared to the control cores (in which TN: TP decreased slightly).

In the first mesocosm experiment a significantly higher density of larval midges was found in the treatments than in the controls. The treatments were aimed to increase N:P ratio in the systems to reduce cyanobacteria and, subsequently, larval midge densities. However even though cyanobacteria were eliminated from the treatments, the nitrogen addition appeared to result in higher phytoplankton biomass overall, which fuelled an increase in larval midge densities.

In the second mesocosm experiment, the addition of lime to enriched sediments resulted in a reduction in P in the water column. This reduction was accompanied by a reduction in total phytoplankton biomass, the absence of cyanobacteria, and a less abundant and more species - diverse chironomid fauna in the treatment mesocosms.

Sediment P fractionation undertaken for both the microcosm and mesocosm experiments showed that most of the phosphorus adsorbed by lime was in the labile fraction (NH₃Cl extractable P and NaOH extractable P). Phosphorus in the HCl extractable fraction was also found to be higher in the treatments due to the presence of inert mineral P in the lime than the formation of new hydroxyapatite from adsorbed P.

The two mesocosm experiments suggested that larval midges were non-selective feeders, responding to total phytoplankton biomass, rather than the presence of cyanobacteria. Dissolved oxygen and predation also influenced larval midge densities.

In summary, although lime appeared to be a useful material for reducing P release from enriched sediments under controlled laboratory conditions, the effect under field conditions was not as definitive. Further work is required to more fully determine the conditions under which sediment remediation may be used as a means of controlling sediment P release and associated high densities of larval chironomids.

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Table of Contents

Abstract	iii
Acknowledgements	vi
Chapter 1 Introduction	1
1.1 Wetlands of the Swan Coastal Plain.....	2
1.2 Issues of Wetland Degradation.....	3
1.3 Strategies for Restoration of Eutrophic Wetlands.....	4
1.4 Study Objectives and Hypotheses.....	5
Chapter 2 – Literature Review	7
2.1 Eutrophication.....	7
2.2 Limiting Nutrients.....	7
2.3 Identification of Limiting Nutrients.....	8
2.4 The Primary Role of Phosphorus in Eutrophication.....	9
2.5 The Role of Sediment in Phosphorus Dynamics in Wetlands.....	10
2.6 Factors Regulating P Release between the Water Column and Redox-sensitive Sediment.....	10
2.6.1 Influence of aerobic and anaerobic conditions on sediment P release.....	11
2.6.2 Influence of temperature on sediment P release.....	12
2.6.3 Influence of pH on sediment P release.....	12
2.7 Factors Regulating P Release between the Water Column and Redox-insensitive Sediment (calcareous aquatic systems)	14
2.8 Transformations of Nitrate and Ammonium.....	16
2.8.1 Nitrification.....	16
2.8.2 Denitrification.....	17
2.8.3 Role of nitrate in regulating sediment P mobility.....	18

2.9	The Response of Phytoplankton to Eutrophication.....	18
2.9.1	Changes in phytoplankton composition with changing trophic level.....	18
2.9.2	Factors affecting phytoplankton distribution along a trophic gradient.....	20
2.9.3	The relationship between phosphorus and phytoplankton biomass	20
2.10	Factors Influencing the Composition and Abundance of Populations of Larval Chironomids.....	25
2.10.1	Food quality and quantity.....	25
2.10.2	Temperature.....	26
2.10.3	Substratum.....	27
2.10.4	Water Depth.....	28
2.10.5	Value of pH.....	29
2.10.6	Dissolved Oxygen.....	29

Chapter 3 Phosphorus Sorption Experiment with Five Potential Sediment

	Amendment Materials	31
3.1	Introduction.....	31
3.2	Materials and Methods.....	32
3.2.1	Materials.....	32
3.2.2	Methods.....	32
3.3	Results.....	35
3.3.1	Phosphorus sorption experiments.....	36
3.3.2	Phosphorus desorption experiments.....	57
3.4	Discussion.....	63
3.4.1	Adsorption experiments with fly ash, red mud and lime.....	63
3.4.2	Adsorption and desorption experiments with PCC, lime and crushed limestone	63
3.5	Conclusion.....	67

Chapter 4 Microcosm Experiments-Investigation of the Effects of Lime in Reducing Sediment Phosphorus Release	68
4.1 Introduction.....	69
4.2 Materials and Methods.....	69
4.2.1 Experimental design.....	69
4.2.2 Sampling and Analytical Methods.....	70
4.3 Results.....	71
4.4 Discussion.....	79
4.4.1 The impact of the addition of lime on the physiochemical environment of the water column.....	79
4.4.2 The effectiveness of lime in sediment nutrient release.....	81
4.5 Conclusion.....	86
Chapter 5 Mesocosm Experiments –2002	87
5.1 Introduction.....	87
5.2 Materials and Methods.....	88
5.2.1 Experimental Design.....	88
5.2.2 Sampling and Analytical Methods	89
5.3 Results	93
5.4 Discussion.....	106
5.4.1 Nutrient availability.....	106
5.4.2 Diatoms.....	107
5.4.3 Cyanobacteria.....	108
5.4.4 Chironomidae	110
5.5 Conclusion.....	113
Chapter 6 Mesocosm Experiments – 2003	114
6.1 Introduction.....	114
6.2 Materials and Methods.....	114
6.2.1 Experimental Design.....	114

6.2.2	Sampling and Analytical Methods	115
6.3	Results.....	118
6.4	Discussion.....	141
6.4.1	The effectiveness of sediment capping on enriched sediments.....	141
6.4.2	The effectiveness of sediment capping on reducing sediment phosphorus release and nutrient limitation in the controls and treatments	143
6.4.3	The impact of sediment capping on phytoplankton and periphyton communities.....	145
6.4.4	The impact of sediment capping on larval midges (Chironomidae).....	150
6.5	Conclusion.....	153

Chapter 7 General Discussion and Implication for Management154

7.1	The selection of appropriate material for sediment remediation.....	154
7.2	Addition of lime reduces phosphorus release from enriched sediments.....	156
7.3	The impact of the relative abundance of blue-greens on the density of larval chironomids	157
7.4	The effectiveness of lime in reducing phosphorus release from enriched sediments and its impacts on the biota.....	159
7.5	Conceptual model of sediment remediation by lime.....	161
7.6	Guidance for restoring eutrophic wetlands using sediment remediation.....	163
7.6.1	Optimization of sediment capping.....	163

References.....167