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……………………….

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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 rang of P concentrations (0-1000 μg/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 μg/L or 200 μg/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 μg/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 (NH_3Cl 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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