GEOCHEMISTRY OF SEDIMENTS IN RESPONSE TO URBANIZATION IN MERIMBULA/PAMBULA ESTUARIES

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INTRODUCTION

Coastal regions are areas of significant and continued growth and development in Australia. With over 84% of the total population living along the eastern coastline (ABS, 2004) and with this population increasing during peak seasons, the impact on the environment is likely to be spatially and temporally variable, and significant. Estuaries are particularly important areas of urban and recreational growth and development, resulting in an increased pollutant load into the water and sediments through stormwater outflow, urban runoff, and increased sewage loads. Estuarine sediments can act as sinks of anthropogenic pollutants, where certain elements become immobilized and essentially "locked up" in the sediments. Future impacts on estuarine sediments driven by urbanization and increased geochemical forcing, have the potential to alter the physical and chemical characteristics of the sediment profiles, which could then cause significant environemental effects if previously immobile metals and other pollutants become remobilized and made bioavailable.

By examining the geochemical, hydrogeochemical and biogeochemical processes occurring in regolith and associated estuaries, the transformations and accumulations of elements can be determined for aquatic coastal systems. This, in turn, provides a rigorous scientific basis for developing future environmental monitoring schemes.

OBJECTIVES

The principal aim of this project is to show that regolith undergoes significant post-depositional geochemical changes that do not necessarily reflect the original source composition. This raises the following question: *Are human impacts on estuarine environments essentially creating anthropogenic heavy metal anomalies as a result of accumulation in recently deposited regolith?*

This project will identify the anthropogenic impacts on estuarine geochemistry at macro and micro scales and determine what potential effects these will have on the system in the future. The ultimate outcome for this project is to use regolith geochemistry to understand how "urban centres impact on environmental problems and how mitigation and remediation strategies can be developed, providing sound scientific advice to planners and aquatic industries" (CRC LEME Research theme 8: Regolith geoscience and urban Australia).

Specifically, this project will aim to:

- Determine the geochemical processes controlling the mobility and subsequent sequestration of elements in the sediments (trace elements and heavy metals such as Pb, Sn, Cu, Zn, and As).
- Determine the concentrations and distributions of trace elements and heavy metals within the sediments
- Determine the role of bacteria in transport and fixation of metals in clay-rich regolith materials
- Determine the order of addition of certain elements to recently deposited sediments to establish that the elements are actually added post-deposition to a recent sediment
- Determine whether certain anthropogenic contaminants interact within the sediments, or have the potential to do so in the future, remobilizing otherwise "inert" heavy metals back into the environment.

Furthermore, it is intended to establish the geochemical relationships between the original sediment composition and what has been added through anthropogenic processes to the regolith material, and determine the source of the regolith materials and the added pollutants. The results of these studies will link regolith geoscience with coastal aquatic geochemistry as a means of identifying the role that transported regolith plays in the concentration of certain potentially toxic elements in the depositional environment of an estuary.

STUDY SITE

The south-eastern coastline of Australia is a highly populated region, with the potential to expand even more in the future. Regional centres along the south-eastern coast are likely to undergo significant population growth, which will have a major effect on the environment. Merimbula Lake, New South Wales is an inlet/lake system, consisting of a natural entrance, an inlet channel, and a substantial marine delta depositing into a large, medium depth (3-4 metres) basin, and a much smaller southern shallow (0.3m) basin (DLWC, 2004) (Figure. 1). Merimbula Lake is a wave-dominated estuary, with high sediment trapping efficiency, naturally low turbidity and salt wedge/partially mixed circulation (OzEstuaries, 2005). Fresh water enters the back lake through two small creeks, Boggy Creek in the north, and Bald Hills Creek further south. Merimbula town centre (population 4,883; ABS Census, 2001) is north of the lake. A sewage treatment facility exists to the south of the small lake, and Merimbula airport runs along the edge of the shoreline from the small lake to the bridge. The Princes Highway crosses the inlet by a 250m long causeway and short bridge.

Figure 1: Merimbula Lake (BVSC, 2001).
Source: http://www.begavalley.nsw.gov.au/Environment/estuaries/estuaries.htm

Merimbula is an extremely popular tourist destination, with populations increasing threefold during peak seasons. Merimbula is also one of the most utilised recreational fishing and oyster farming estuaries of the region. Oysters are exceptional bio-indicators of water quality because, as filter feeders, they can accumulate pollutants and heavy metals in their flesh and shells, providing an indication of the level of pollutants present within estuarine systems. Thus the cultivation of oysters for human consumption in Merimbula requires the chemistry of the lake to be maintained at exceptional standards. In addition, due to the lack of industry, there are a limited number of major point sources of pollutants, which include stormwater outlets, the Sewage Treatment Plant (STP) and contaminated sites from earlier settlement. The contaminants and pollutants are largely derived from diffuse sources across the catchment in response to urbanization and rural residential development.

BACKGROUND

Estuarine sediments are important sinks and potential sources of heavy metals in the marine environment. The degree to which the heavy metal load in the sediment is harmful to the environment depends on the geochemical conditions existing in the sediment (Adamo, et al., 2005). Heavy metals become immobilized in the sediments due to adsorption, complexation and speciation processes, with the most dominant pathway in estuarine environments being adsorption of metals onto fine-grained, organic-rich particles. Changes in pH, Eh, EC, organic matter content, or redox potential of the sediment and pore waters, instigated by natural or anthropogenic processes such as bioturbation and dredging may affect the remobilization of these metals (Acevedo-Figueroa, et al., 2006). Although these geochemical processes are subject to natural variability due to seasonal and tidal cycles, the addition of anthropogenic contaminant fluxes into the sediments is also likely to cause significant geochemical changes in the sediment and water column. This has the potential to remobilize previously immobile sediments.

PREVIOUS WORK

Previous work undertaken at Merimbula Lake studied the addition of metals to recent clay-sand sediments (i.e. regolith materials), with a specific focus on lead in the form of fishing sinkers (Beavis et al., 2005). From this work, anomalous heavy metal concentrations were detected in the sediments and were recognized as either natural or anthropogenic. Through the examination of the alteration products on lead fishing sinkers, as well as an overall estimation of anthropogenic lead inputs into the estuarine sediments, it was evident that lead was being added to the sediment post-deposition (Figure 2).

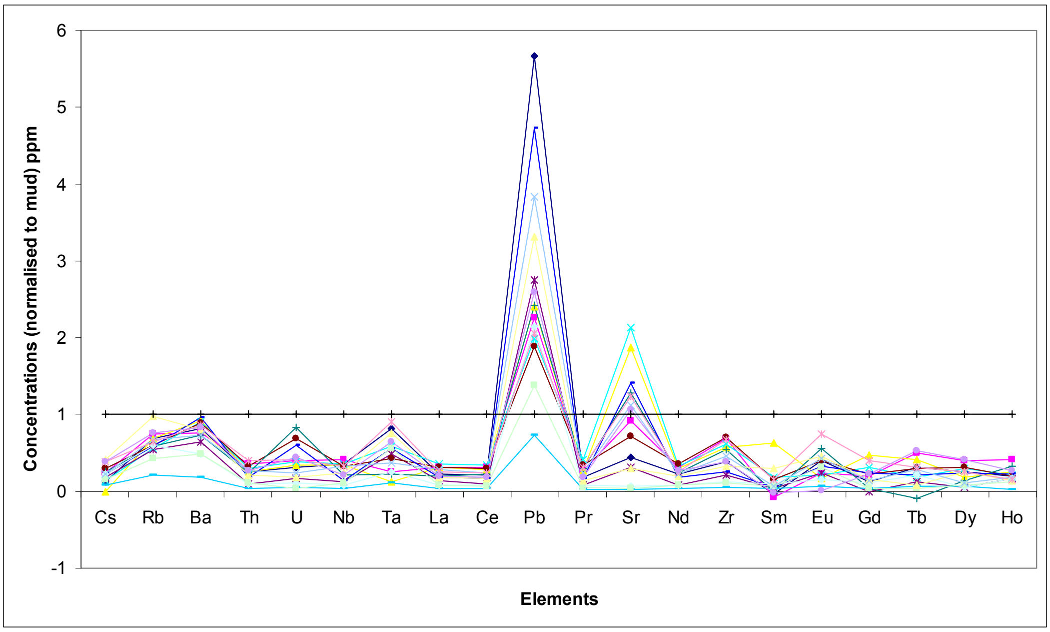

Figure 2. Relationships between the various elements to the normalized mud sample show a range of elements behaving anomalously from the mud. These elements all lie below the mud line because they are part of the original sediment. Sr has been added from shells present in the sediment. Lead has been added anthropogenically.

RESEARCH APPROACH

Previous sampling of Merimbula Lake sediments identified locations for the initial sampling for this project. The primary criteria for sample selection are sediment grain size, distance from shore, water depth and location with respect to creeks entering the lake. Initial samples from the study sites were collected within several days of a very large storm event on [date?], with surface sediment grab samples being collected over large areas of Pambula and Merimbula Lakes so as to obtain a preliminary indication of sediment and heavy metal distributions. Samples were also collected from tributaries feeding into Merimbula Lake. Future work will determine the geochemical processes that alter heavy metals in the sediment post-deposition. Sampling of the study sites will involve collection of a series of grab sediment samples and core sediment samples from the lake bed, which will follow a series of transects in order to optimise an understanding of the physical, chemical and biological characteristics of the sediment within the lake.

Analytical methods used to distinguish the heavy metal concentrations in the sediments will include XRF and LA-ICPMS. Characterisation of the mineralogy of the sediments will be through XRD, clay classifications and SEM analyses. In addition, selective sequential extraction experiments and column experiments will be undertaken to assess the rates and extent of metal immobilization in the sediments, as well as the rates at which metals are remobilized back into the water column with the addition of anthropogenic contaminants. This work will form the basis for predicting future anthropogenically induced remobilization of the contaminants, by modelling the post-depositional geochemical processes that concentrate metals in the sediments.

By identifying sources and sinks, and quantifying the fluxes, transformations and accumulation of heavy metals, this research will answer some key questions relevant to environmentally sensitive areas undergoing rapid and increasing change:

- Are anthropogenic impacts on estuaries causing disturbances to otherwise immobile quantities of metals?

- What changes sediments from a pollutant sink to a pollutant source?
- What geochemical processes occur after the deposition of a pollutant? Are these changing the compositions of what was originally added vs. what is present now?
- Do different pollutants interact with one another (e.g. from sewage treatment plant, runoff, etc) causing different concentrations/levels of toxicity/bioavailability in the estuary? For instance, is the sulphur and phosphorus from the sewage treatment plant affecting the distribution and concentration of other pollutants (i.e. metals) in the estuary?

The outputs of the research will represent significant baseline data against which change can be measured, but also can be used to inform planners and managers of risks and hazards within an estuary that have not been previously understood or identified.

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