Will sea-level rise solve our coastal acid sulfate soil issues?

Vanessa N.L. Wong[1,2] Scott G Johnston[2], Edward D Burton[2], Richard T Bush[2], Leigh A Sullivan[2], Peter G Slavich[3]

[1]School of Geography and Environmental Science, Monash University; Wellington Rd Clayton VIC 3800
[2]Southern Cross GeoScience, Southern Cross University; PO Box 157 Lismore NSW 2480
[3]New South Wales Department of Trade and Investment, Regional Infrastructure and Services

Rising sea-levels and coastal acid sulfate soils

Sea level has risen approximately 1.2 mm/year over the last 100 years (Hennessy et al., 2004) and is predicted to rise up to 80 cm by 2100 relative to 1990 sea levels (IPCC, 2007). The number of extreme events related to sea level such as higher sea levels and increased inter-annual variability have also increased in frequency in the same time period (Hennessy et al., 2004).

Coastal floodplains in eastern Australia are commonly characterised by large, low-elevation backswamp basins (0-1 m Australian Height Datum; AHD). These backswamp basins frequently contain coastal acid sulfate soils (CASS) and are underlain by estuarine sediments which contain high concentrations of acidity and trace metals. A significant portion of the stored acidity occurs in the form of exchangeable and hydrolysable acidic metal cations such as Al and Fe. Watertables in these environments are often close to the surface and intercepted by relatively shallow drains. The estuarine sediments are usually capped by a thin layer of fluvial sediments, and hence, can have a strong influence on surface water, groundwater and drainage water geochemistry. Due to their low elevation and locations, these backswamp basins are highly susceptible to pulses of saline water caused by saltwater intrusion, storm surge, king tides and rising sea levels. Construction of extensive drainage systems has further increased the susceptibility of the floodplain to seawater inundation by increasing connectivity to the estuarine channel. This risk is likely to increase in the future with predicted increases in sea level and extreme events due to climate change.

Previous studies have shown inundation of CASS can mobilise trace metals, which has implications for water quality in these floodplain wetland environments (Burton et al., 2008). However, controlled tidal exchange in degraded tropical floodplains can neutralise acidity and re-establish reductive environments to aid in reclamation of these areas (Johnston et al., 2009).

This study uses both batch experiments to determine the effects of increasing ionic strength on exchange processes and trace metal desorption in oxidised floodplain sediments and sulfidic drain sediments, and intact soil cores to determine the surface water-porewater interactions over the short term following seawater inundation in coastal floodplain backswamps.

It has been assumed that inundation of CASS with seawater and the alkalinity contained within will promote proton consuming processes, resulting in an increase in pH and decrease in acidity. In contrast, we found that a pulse-release of acidity and mobilisation of trace metals will occur in the shorter term (Wong et al., 2010). In a series of controlled experiments, flooding of soils from four CASS floodplain environments with waters of increasing seawater concentration resulted in greater mobilisation of trace metals from the sediments into the soil solution and surface waters (Figure 1). Importantly, high concentrations of metals such as Al, Fe, Ni and Zn were mobilised at relatively dilute salt concentrations, similar to those found in brackish waters of estuarine environments.

Increasing seawater concentration also resulted in decreases in pH in all sediments (Wong et al., 2010). This is attributed to the displacement of adsorbed protons on the exchange surface. The higher ionic strength solution displaces those ions adsorbed on the surface of the soil particles. We suggest that the desorption of some pH dependent species such as Al and Fe are also partially driven by the decline in pH in addition to increasing ionic strength of the treatment solution.

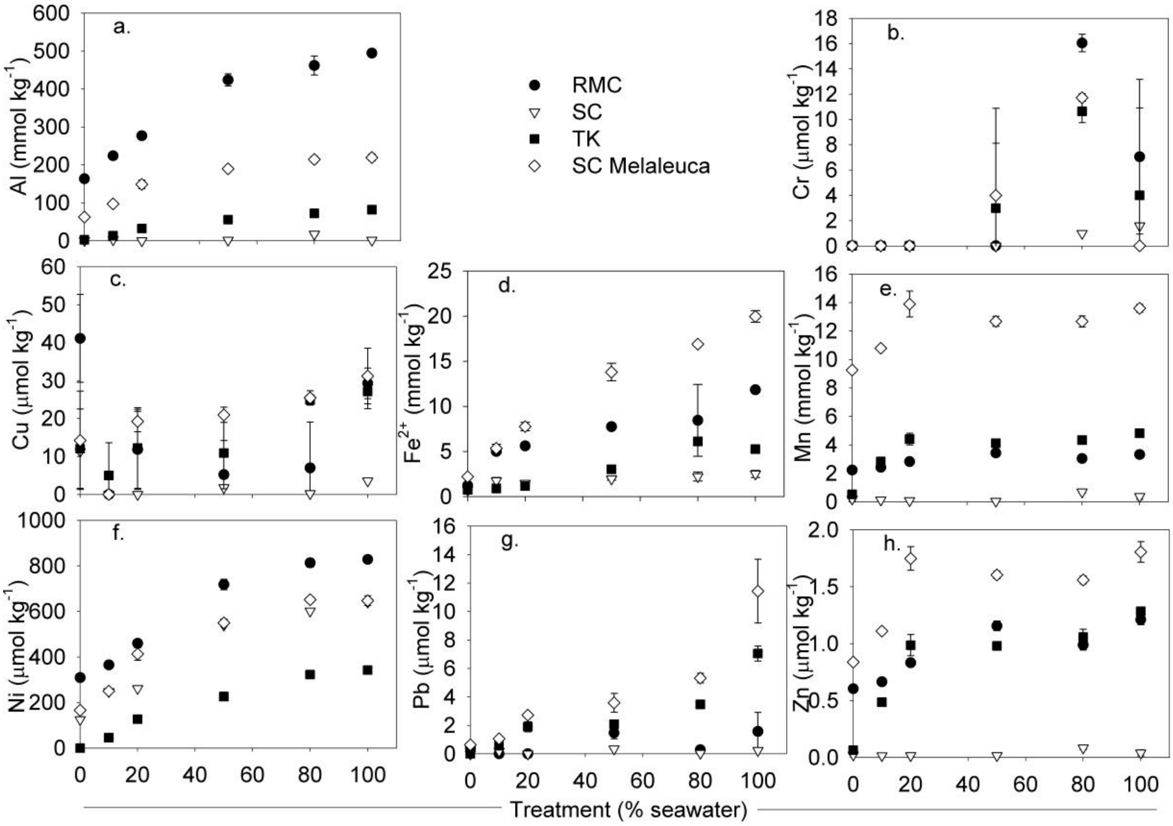

Figure 1: Mobilisation of a) Al, b) Cr, c) Cu, d) Fe^{2+}, e) Mn, f) Ni, g) Pb, and h) Zn with increasing seawater concentration from four CASS floodplain environments (RMC, SC, TK and SC Melaleuca) (Wong et al., 2010)

The biogeochemical processes which occur at the surface water-soil interface following seawater inundation of coastal floodplains are complex and will only increase in importance in the future with predicted increases in sea levels. We suggest that seawater inundation of floodplain backswamp basins initiates two distinct, sequential geochemical processes with different kinetics. Both of these processes influence acidity and trace metal behaviour in contrasting ways. Experimental results show that a pulse-release of acidity and mobilisation of trace metals will occur in the shorter term during the transition to reducing conditions. However, over longer time periods, prolonged seawater inundation will result in a shift to reducing conditions (eg. Johnston et al., 2009).

Benthic drain sediments are also highly vulnerable to rapid increases in ionic strength from seawater incursion due to their low elevation and connectivity of drains to estuarine channels. We also examined the effect of increasing seawater concentration on trace metal mobilization from sulfidic drain sediments collected along an estuarine salinity gradient. Similarly, mobilisation of some metals (Cu, Fe, Mn, Ni) increased markedly with increasing ionic strength under anoxic conditions at near-neutral pH (Wong et al. submitted). The largest proportion of metals mobilized from the labile metal pool occurred in sediments from relatively fresh upstream sites compared to sediments sourced from brackish downstream sites. Sediments sourced from environments with a greater marine influence are more likely to be in equilibrium with high ionic strength water, causing metal solubility to be partially controlled by stronger binding sites with labile metals having already been desorbed (Millward and Liu, 2003). Therefore, seawater inundation of sulfidic sediments formed in freshwater environments will more likely result in mobilisation of a greater proportion of metals compared to those formed in brackish or marine environments.

Summary

These exchange processes have implications for water quality in coastal floodplain environments. We found that that saline inundation of oxic CASS floodplain environments, even by relatively brackish water may cause rapid, shorter-term water quality changes and a pulse release of acidity due to desorption of acidic metal cations. We also found that trace metals can be mobilised from sulfidic estuarine drain sediments at near-neutral pH values without oxidation as a result of increased ionic strength and competitive desorption of metal cations. Rapid seawater incursion in CASS drainage networks is likely to adversely impact drain water quality by increasing trace metal mobilization. Drainage networks on CLASS floodplains are highly susceptible to rapid seawater inundation through storm surge, king tides, seasonal salt wedge migration, floodgate failure or floodgate opening. The experimental results show that the initial addition of marine derived salts will result in a decrease in pH and increase in trace metals, even at low salt concentrations such as that found in brackish waters in estuarine environments

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