Influence of roots and climate on mineral and trace element storage and flux in tropical mangrove soils

D.M. ALONGI1,*, G. WATTAYAKORN2, S. BOYLE1, F. TIRENDI1, C. PAYN1 and P. DIXON1

1Australian Institute of Marine Science, PMB 3, Townsville M.C., Qld. 4810, Australia; 2Department of Marine Science, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand; *Author for correspondence (e-mail: d.alongi@aims.gov.au; phone: +61-7-47534444; fax: +61-7-47725852

Abstract. The storage and flux of various mineral and trace elements in soils (0–30 cm depth) were examined in relation to monsoonal rains and fine root biomass in four mangrove forests of different age and type in southern Thailand. The onset of the wet SW monsoon resulted in the percolation and dilution of porewater solutes by rainwater and by less saline tidal water, as indicated by shifts in Eh, pH and porewater SO4/Cl ratios. This is contrary to temperate intertidal environments where seasonal patterns of porewater constituents, and biological and biogeochemical activities, are strongly cued to temperature. Fluxes across the soil–water interface were most often not statistically significant. Concentration of dissolved porewater metals were dominated by Fe, Mn, Al, Mo and Zn. The decreasing order of solid-phase element inventories in these soils, on average, was: Al, S, Fe, Na, Mg, Ca, N, P, Mn, V, Zn, Cr, Ni, As, Co, Cu, Pb, Mo, Cd and Hg. There were no gradients in concentrations of dissolved or solid-phase elements with increasing soil depth. This phenomenon was attributed to physical and biological processes, including the presence and activities of roots and tidal recharge of soil water. Fine dead roots were storage sites for most mineral and trace elements, as some elements in roots composed a significant fraction (%/C) of the total soil pool. Analysis of S and Fe concentration differences between live and dead roots suggested extensive formation of pyrite associated with dead roots; correlation analysis suggested that trace metals coprecipitated with pyrite. An analysis of inventories and release/uptake rates indicate turnover of the N, P, Na and Ca soil pools equivalent to other tropical forests; turnover was slow (decades to centuries) for S, Fe, K and trace elements. Our results indicate that mineral and trace element cycling in these soils are characterized by net storage, with net accumulation of most elements much greater than uptake and release by tree roots.

Introduction

The composition, flux and storage of mineral and trace elements in soils of wetland ecosystems are influenced by rates of sediment accumulation, the origin of inorganic and organic material, primary productivity, bioturbation, and physical disturbance. In intertidal environments where physical processes and atmospheric exposure are dominant, the accumulation and diagenesis of mineral and trace elements is also greatly influenced by the degree of tidal action and microbial activity (Rae 1997).

In wetlands, the presence of extensive below-ground roots and rhizomes are also thought to play an important role in regulating the geochemical composition of soils, mainly by active uptake and release of various solutes, and by oxidation of surrounding microenvironments, including development of metal coatings on root...
surfaces (St-Cyr and Campbell 1996; Dykyjova and Ulehlova 1998; Sundby et al. 1998). These processes are much better documented for freshwater marshes and swamps and salt marshes than for mangroves. Like other forested ecosystems, mangrove forests have extensive below-ground root systems that often extend to >50 cm beneath the forest floor (Komiyama et al. 1987; Alongi and Dixon 2000). Recent studies have found that most (80–90%) fine roots in mangrove deposits are dead (Robertson and Dixon 1993; Alongi and Dixon 2000; Alongi et al. 2002a). How (and whether or not) dead and live mangrove roots influence the economy of mineral nutrients, trace elements and heavy metals in soils, is not well known. Most studies of metals and trace elements in mangrove soils have focused on their composition and geochemical behavior, rather than on how they effect, or are affected by, below-ground biological processes (Lacerda et al. 1993). Laboratory and field studies have found that some mangroves directly and indirectly trap and retain some heavy metals, functioning as sinks for metals by modifying environmental conditions that promote metal storage (Tam and Wong 1995).

Another factor often overlooked is the role that climate plays on the biogeochemistry of intertidal deposits (Eisma 1998). Ice scouring, storm surges and freezing temperatures are important factors in high latitudes, but in the wet tropics where mangrove forests attain peak abundance, heavy monsoonal rains dominate seasonal climate patterns. The pattern of seasonal monsoons is well understood for southeast Asia, but what impact such periodic heavy floods and precipitation has on element cycling in mangrove sediments is unknown.

As part of a larger study of the role of mangroves in the cycling of carbon and other elements in southeast Asia (Alongi et al. 2001), we examined how biomass of live and dead fine roots (data from Alongi and Dixon 2000) and monsoonal rainfall, influenced dissolved and solid-phase element pools and fluxes in sediments of four different mangrove forests in southern Thailand. We compare these data with co-incident measurements of microbial activity and other edaphic characteristics to develop an understanding of factors regulating the cycling, storage and turnover of mineral and trace elements within tropical mangrove ecosystems.

Methods

Site characteristics

Four mangrove habitats were sampled during the dry northeast (April 1999) and the wet southwest (October 1999) monsoons in Sawi Bay, located on the southwestern coast of the Gulf of Thailand. The climate of southern Thailand is dominated by the two monsoon seasons. Water temperatures varied within a narrow range of 27–30°C; rainfall was much greater in the wet season (8–34 mm day⁻¹) than in the dry season (0–3 mm day⁻¹) with an annual average of 1800 mm (Wattayakorn et al. 2000). Sawi Bay has mixed semi-diurnal tides with a tidal range of 1.5 m (Wattayakorn et al. 2000). These sites differed in stand age, sediment type and tidal inundation frequency (Table 1).