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Spatial variability of the rate of organic carbon mineralization in a sewage-impacted mangrove forest, Mikindani, Kenya

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Abstract
Purpose Extensive amounts of untreated sewage are discharged in creeks lined by mangrove forests. This is a common occurrence in peri-urban coastal areas of the developing world. There is much evidence to suggest that mangroves filter discharged wastewater and prevent coastal pollution. The Mikindani mangrove system, Kenya has been exposed to sewage for more than a decade. The study seeks to investigate the ability of the Mikindani mangrove system to deal with the sewage carbon load.
Materials and methods The ability of the mangrove system to phytoremediate sewage was investigated using anaerobic incubation experiments of sediments collected at several locations along the length of the creek at the study site. Carbon dioxide production was used as a proxy to measure the rate of organic matter degradation.
Results and discussion The carbon dioxide production for the 0–1-cm sediment segment at site MKR 1 (the sewage input site) increased twofold after 8 days, implying that the natural system does not get enough time to stabilize since it is dosed continuously every tidal cycle. In situ CO_2 efflux at site MKR 3 (~6 km from the sewage input site) was about three times the $\sum CO_2$ production obtained after incubation for 8 days (anaerobic), which indicates that the easily degradable sediment organic carbon pool had degraded by about 67 % after 8 days. This suggests that this is sufficient time for the *Rhizophora* mangrove sediment system under anaerobic natural conditions to naturally degrade the system's sediment organic matter.
Conclusions The Mikindani mangrove system effectively spreads the discharged sewage over a distance of ~3 km. This effectively spreads the impact allowing the system to phytoremediate the artificially added organic matter.

Keywords Carbon dioxide production · Fe(II) production · Fe(III) reduction · Sewage · Sulfate reduction · Tudor creek

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1 Introduction

Peri-urban coastal areas of the developing world receive extensive amounts of untreated sewage, which is typically discharged into creeks lined by mangrove forests. There is much evidence to suggest that mangroves filter discharged wastewater and prevent coastal pollution. The Mombasa municipality has separate sewerage systems for domestic (17 %) and storm water runoff. The rest of the inhabitants utilize pit latrines (59 %) and septic tanks (24 %) for sewage disposal (Munga et al. 1994). A large amount of raw and semi-processed sewage is directed into the surrounding creeks. The Mikindani mangrove system has been exposed to sewage for more than a decade. The sewage runs through the mangrove forest in canals and is discharged into the Tudor creek waters. The mangroves are therefore dosed with sewage every tidal cycle, although the loading declines exponentially with distance from the source.

Mangrove swamps appear extremely effective at removing phosphate (89–98 % of high exposures) (Ye et al. 2001). Soil bacteria dissolve phosphate in oxygenated areas, such as near the mangrove roots, promoting phosphorus uptake by the