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Heavy metals distribution in sediments along the Killindini and Makupa creeks, Kenya

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Abstract

Makupa creek is connected to the Indian Ocean via the Killindini creek; the study deals with the distribution of heavy metals in the Makupa and Killindini creeks.

Concentrations of Cu, Cd, Fe and Zn, in sediments at the inner sections of the creeks were high compared to those measured at Likoni (ocean). Considering trace metal levels at the inner sections relative to Likoni the ratios obtained, were Cd 7:1, Cu 13:1, Fe 5:1 and Zn 21:1.

The results obtained point at Makupa creek as the main source of heavy metals into the creek system, however iron behaved differently, it was significantly higher at the Killindini Habour $P<0.05$ (at 95% confidence level).

There was a decline in concentrations of, copper and zinc from the inner stations to the frontwater zone at Makupa creek. Spatial variations of cadmium were not significant between inner and frontwater zones of the Makupa creek $P>0.05$ (at 95% confidence level), and also between Makupa and Harbour. There was however a significant difference $P<0.05$ (at 95% confidence level) between Likoni and Makupa.

Introduction

Studies on the distribution of trace metals in sediments and other media are of great importance in the context of environmental pollution (Garrels, 1975). As pointed out by the United Nations Center for Human Settlement (1991), the main sources of pollution of the seas are the result of human activities on land related to the increasing degree of urbanization along coastal areas and their adjacent watersheds.

It is widely accepted that sediments can be used to monitor metal pollution in the biosphere and the effects of anthropogenic events in the environment. It is also widely believed that sediments provide the main sink for heavy metals in the aquatic environment.

By virtue of their composition, sediments conserve heavy metal contamination and "express the state of a water body" (Zulleg, 1956). Vertical sediment profiles (cores) often uniquely preserve the historical sequence of pollution intensities; lateral distributions (quality profiles) are used to determine and evaluate local sources of pollution (Forstner & Muller, 1974).

Mangrove forests are efficient barriers of heavy metals transport in tropical coastal areas (Carlos Augusta et al., 1990). Reducing conditions in Mangrove sediments will favor metal precipitation and immobilization as sulphides (Lacerda & Abrao, 1984).

Areas such as peripheral lagoons which are sheltered from strong tidal currents are subject to lesser amounts of erosion, and are liable to be storage areas, or sinks for contaminated sediments (Rees et al., 1996).

The Mombasa local authority operates a refuse collection service, which manages to dispose off approximately 50% of the domestic waste at an uncontrolled dumpsite known as Kibarani (Munga et al., 1994). The site is located on the west mainland next to the shores of the Makupa creek.

A large proportion of the wastes find their way into the sea. They are swept by rainwater runoff, and by wet or dry deposition of suspended particles in the air.

The 1988 oil spill at Kipevu power station destroyed the mangrove forests surrounding Makupa creek, exposing the creek to direct contamination from the dumpsite. Makupa creek is connected to the Ocean

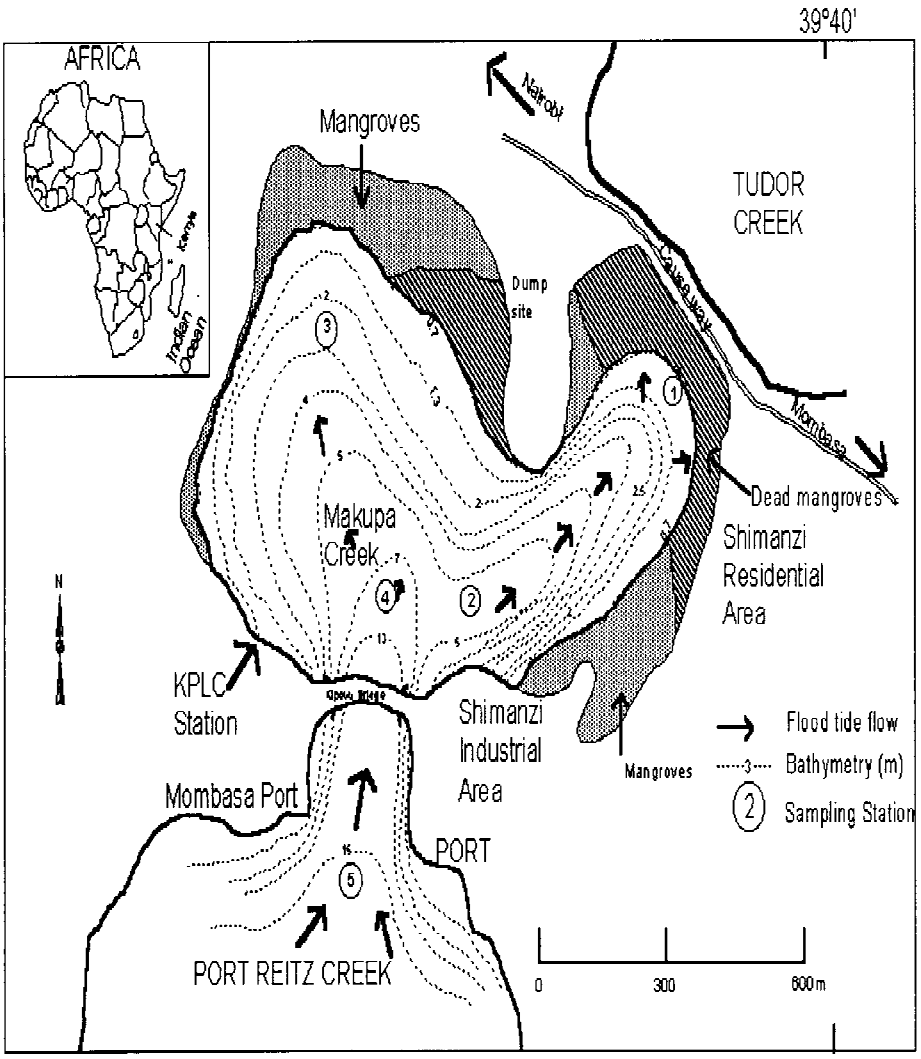

Figure 1. The bathymetry and location of sampling stations in Makupa creek.

via the Killindini creek. This study is a survey of trace metals distribution in sediments along the two creeks.

Materials and methods

Study area and sampling stations

Makupa creek (39° 38′ E, 4° 02′ S) is located in Mombasa District, Kenya (Fig. 1). The total creek area is presumed to be 1.1 km^2. At high spring tide, the entire creek is usually covered with flood tide water flowing from Killindini channel through the Kipevu Bridge. Most parts of the creek with the exception of the zone near the frontwater section next to the Kipevu Bridge are shallow with depths often less than 3.0 m. The deepest zone is the frontwater section next to the Kipevu Bridge where depths in spring tide reach 13 m.

The country's main harbour is located at the Killindini creek, which borders the Makupa creek connecting it to the ocean. In this study, seven stations were identified (Figs 1 and 2).

Sample collection and storage

Sediments were collected using a gravity corer with P.V.C core-liner, 4 cm of the suficial sediment was extracted from the P.V.C core-liner and placed in labelled polythene bags. In the laboratory, the sediments were air dried to a constant weight and homogenised with a

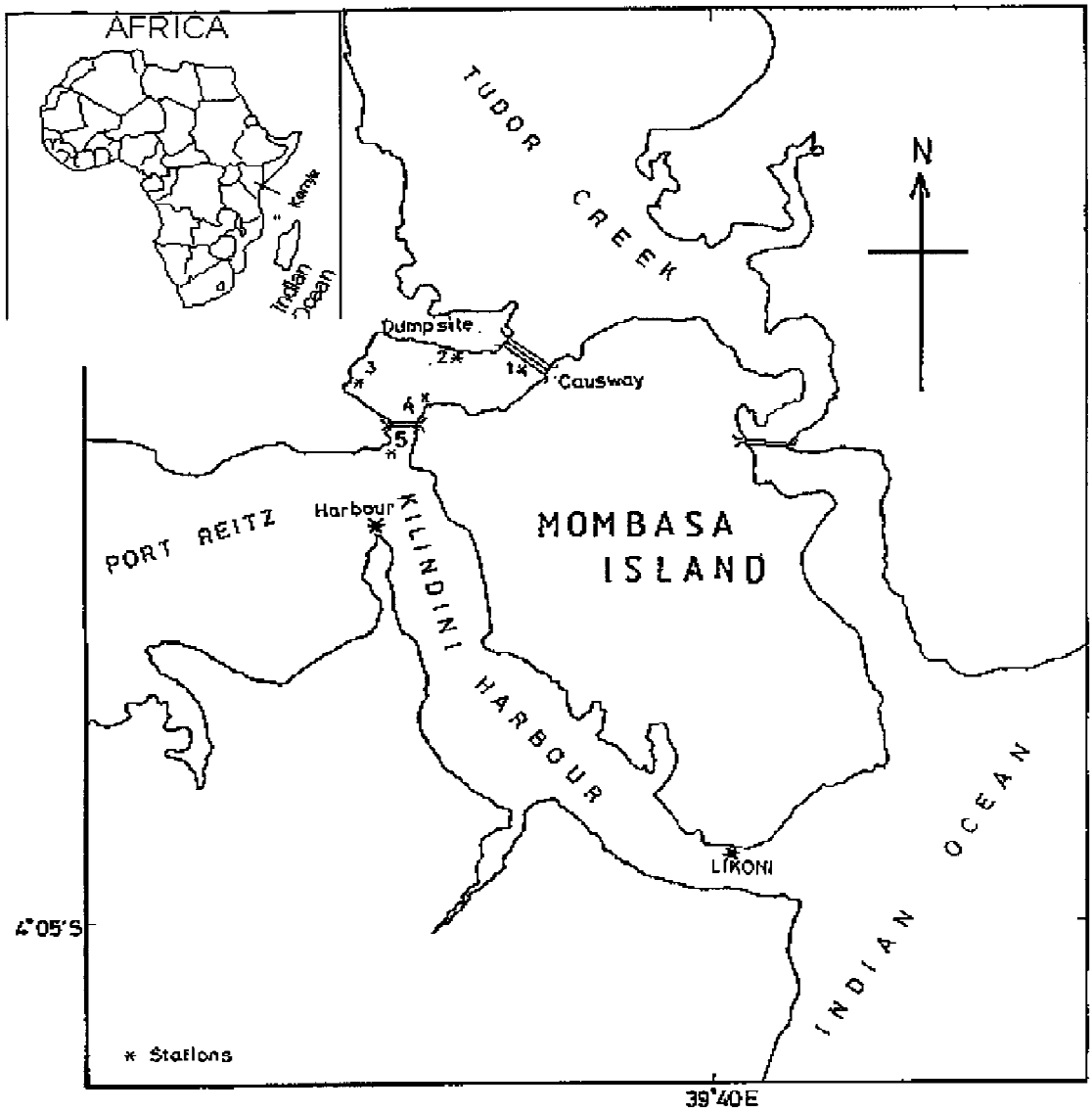

Figure 2. Map showing all the sampling stations.

pestle and mortar, in order to normalise for variation in grain size distribution.

Analytical methods

0.2 g of dried sample was placed in a teflon lined pressure container, one drop each of hydrochloric acid and nitric acid was added, followed by 4 mls of hydrofluoric acid. The containers were then sealed and placed in an oven at 125 °C for 2 h.

The containers were then removed from the oven, cooled and the contents transferred to teflon beakers. Also, 5 mls each, of perchloroic, and hydrofloric acid was added and the mixture heated to white fumes of perchloric acid, it was then cooled and 2 mls of hydrochloric acid added to dissolve the salts. The resultant mixture was made to volume in a 50 ml volumetric flask with distilled water. Instrumental analysis was by atomic absorption spectrometry (Varian spectra AA10).

Analytical and instrumental accuracy were tested in reference to IAEA standard 140, though the digestion process was different, relative to the experiment. Differences between certified and measured results were always less than 10%.

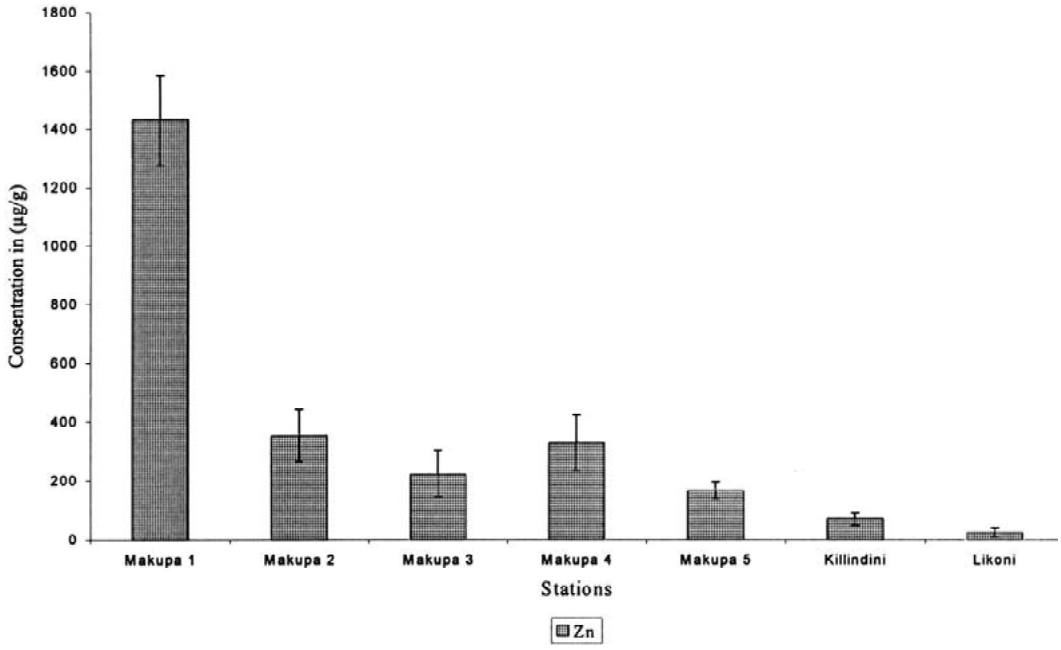

Figure 3. Zinc distribution in sediments at Makupa and Kilindini creeks (n=4, 1997).

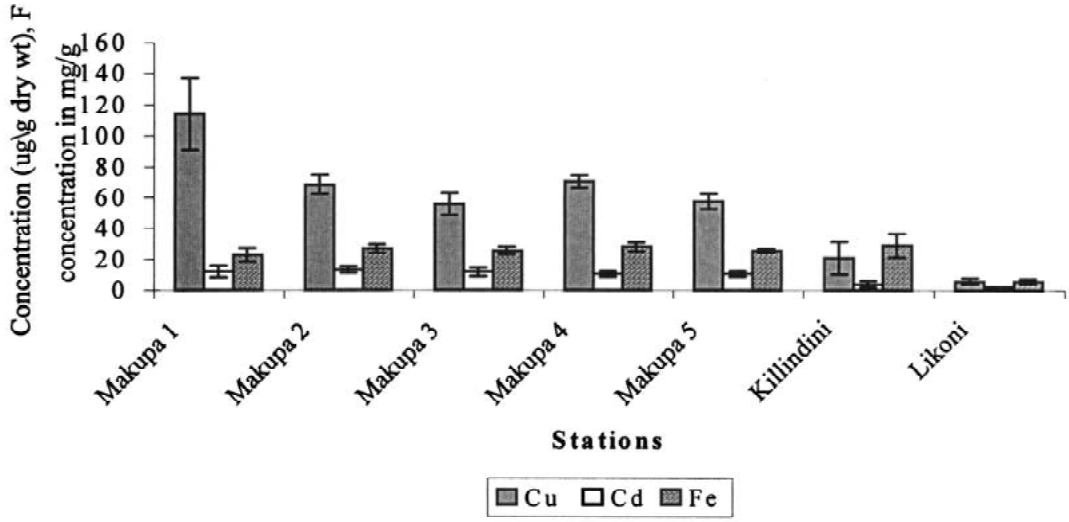

Figure 4. Cadmium, Copper and Iron distribution in sediments at Makupa and Kilindini creeks (n=4, 1997).

Results and discussion

Figures 3 and 4 presents the spatial variation in the concentration of trace metals at Makupa and Kilindini creek sediments. The magnitude of trace metal concentrations in sediments at Makupa creek generally exhibit the following order: Fe > Zn > Cu > Cd.

Concentrations of Cu, Cd and Zn, in sediments at Makupa creek were high as compared to those measured at the Killindini creek. Considering trace metal levels at Makupa creek and the relatively unpolluted Likoni station, the following ratios were obtained: Cu 13:1, Fe 5:1 and Zn: 21:1.

The high ratios of concentration at Makupa creek relative to Likoni station give an indication of the degree of anthropogenic stress on the Makupa creek. This would include, the construction of the Makupa Causeway, reclamation of inter tidal areas through the

dumping of Municipal wastes. These anthropogenic pressures have to a certain extent contributed in altering the water circulation dynamics, thus interfering with the flushing of the creek. Makupa creek being a peripheral lagoon further affects the dynamics of sediment hosted contaminants.

Copper levels ranged between 56 μg/g dry weight and 114 μg/g dry weight. Makupa station 1 registered the highest level of Copper, 114 μg/g dry weight, while the rest of the stations in Makupa creek ranged between 70 μg/g dry weight and 57 μg/g dry weight. Kilindini Harbour and Likoni posted 20.5 μg/g and 5.5 μg/g dry weight of Copper, respectively.

Makupa station 2 and 4 posted high Fe levels 26 577 μg/g and 27 718 μg/g dry weight, respectively, while Makupa station 1 (22 680 μg/g dry weight) had the least relative to the other stations in Makupa creek, deviating from the trend observed with Cu and Zn. It was observed that raw domestic sewage sludge is dumped at a site next to Makupa station 1, the sewage sludge flows by gradient into Makupa station 1, increasing nutrient levels cause a change in the redox condition of the sediments, leading to oxygen deficiency. Oxygen deficiency in the sediment leads to an initial dissolution of hydrated manganese oxide, followed by that of iron compounds (Förstner & Patchineelam, 1976b). The effect of dumping of raw domestic sewage sludge explains the low iron values obtained at station 1. The Harbour posted higher levels relative to Makupa ($p<0.05$), this can probably be attributed to chipping of ships while docking.

Cadmium levels in the Makupa creek ranged between 12 μg/g dry weight and 13 μg/g dry wt, lower levels were detected at Makupa station 4 and 5 of 10.3 μg/g dry weight, Cadmium levels did not show a distinct trend. There was also no significant difference in the variation of cadmium between Makupa creek and the Harbour ($p>0.05$), However, a significant difference was observed between Likoni and Harbour indicating cadmium input at Makupa creek.

Zinc levels were very high in Makupa station 1 a mean of 1429 μg/g dry weight, Makupa station 2 and station 4 (353 μg/g dry weight and 329 μg/g dry weight, respectively) posted similar values. Makupa station 3 was slightly lower 223 μg/g dry weight while Makupa station 5 had the least, compared to the other station in Makupa creek.

There was a decline in concentrations of copper and zinc from the inner stations to the frontwater zone. While the spatial variations of cadmium was not significant $p>0.05$), between inner and frontwater zones of Makupa creek.

Poorly flushed backwater zone promotes trapping of pollutants, this is clearly illustrated in the results where we have high levels of trace metals in Makupa station 1 for Cu and Zn. A visual observation of the sediments in all the stations show that sediments in Makupa station 1 are fluidy.

Makupa station 2 and 4 registered similar values of Cu, Fe and Zn, despite station 2 being next to the dumping site this is an indication that the front waters are better flushed. Makupa station 2 and 4 have the same bathymetry, and are also the deepest stations in the creek, as such they interact more with the Killindini creek, which is the point of exit for pollutants in the Makupa creek. Except for Fe that registered a high mean value of 28 657 μg/g dry weight at Killindini Harbour, the rest of the elements were highest at Makupa creek, indicating that the dumpsite is the main source of Cd, Cu and Zn contamination.

Pearson's correlation analysis on the spatial variation of trace metals at Makupa creek were performed, relating Zn to the rest of the metals, Zn and Cu, correlated very well (r=0.987), the same was recorded for Zn and Fe (r=0.76) an indication that Zn; Cu and Fe follow a similar trend of distribution at Makupa creek. The correlation coefficient for the relationship between Zn and Cd was however low being r=0.243, Cadmium showed no definite trend.

Despite the high metal concentrations, the levels of potentially toxic elements remains substantially lower than those reported for many perturbed coastal setting, for which Fergusson (1994) has documented concentrations of cadmium frequently exceeding 10 μg/g (e.g. Derwent estuary, Corpus Christi). It should, however, not be viewed as a green light to continue dumping, as it has been observed in the results that the creek acts as a pollution sink. Formal sediment quality criteria remain to be finalised by most national and international regulatory authorities. However the mean Cu, Zn and Cd concentrations recorded in Makupa and Kilindini creeks did not exceed the 'limit' proposed in a draft criteria document at an international sediment quality forum in 1982 (Van Veen & Strotelder, 1988). 'Limit' values proposed in this document are substantially higher (Cu, 400 μg/g, Zn 2500 μg/g Cd 30 μg/g). This should, however, not be a consolation since heavy metals that are 'immobilised' in the sediments, constitute a potential hazard to water quality as they can be released by chemical changes in the aquatic system. Makupa station 1 is exposed

during low tide, resulting to high salinities in the interstitial waters. Increased salinity of the interstitial waters leads to competition between dissolved cations and adsorbed heavy metal ions and results in partial replacement of the latter (Förstner & Patchineelam, 1976b).

Conclusion

Lack of proper flushing and high energy events have caused Makupa creek to act as a heavy metal sink, Makupa station 1 being the most affected, an indication that there is better flushing at the front waters as opposed to the backwaters. Kibarani dumpsite is the main trace metal source at Makupa creek, since stations next to it posted high values.

Chipping exercises conducted on the ships while docking is significant, indicated by the high iron levels at the Kilindini Harbour.

Trace metal levels have not exceeded the 'limit' (Cu 400 μg/g, Cd 30 μg/g, and Zn 2500 μg/g) proposed in a draft criteria document at an international sediment quality forum in 1982 (Van Veen & Strotelder, 1988).

Recommendations

Causeways interfere with water circulation dynamics; they should, therefore, be planed carefully.

Reclamation of inter-tidal areas at Makupa creek, by dumping activities should stop.

Mangroves should be re-forested along the Kibarani dumpsite, so as to act as buffer zones.

Casurina trees should be planted along dumpsite to minimise dry deposition.

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