Contribution of Sewer Discharge and River Msimbazi on Heavy Metals Loading in the Indian Ocean along the Dar Es Salaam Coast, Tanzania

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Abstract: ***The concentrations of heavy metals; lead (Pb), Zinc (Zn) and Cadmium (Cd) were studied in water and sediments at Ocean Road and Kigamboni sites at Dar es Salaam Coastal area. The project aimed to assess the contribution of the sewer pipe and Msimbazi River to heavy metals loading in the Indian Ocean. Samples were collected from the Ocean Road and Kigamboni stations, standard procedures for sample extraction were employed, sediments were prepared by wet digestion and metals were determined by atomic absorption spectrophotometer (AAS). Higher levels of lead (Pb) and zinc (Zn) were found at Ocean road compared to Kigamboni, suggesting possible contribution of the sewer pipe and the River Msimbazi. The concentrations of lead (Pb) and zinc (Zn) were found to be higher in sediment than in water for the two stations. Mean levels of the metals in water were 0.371mg/L (at Kigamboni) and 1.037mg/L (at Ocean Road) for lead while zinc and cadmium in water were below the method detection limit (MDL) at the two sites. Further study is recommended to study the actual load contributed by the River Msimbazi and the sewer pipe by taking into account the variation of physical parameters between the two sites.***

Keywords: Heavy metals, sewer pipe, wet digestion, partitioning, method detection limit.

1. Introduction

Contamination of water bodies by heavy metals has attracted global attention owing to their persistence and environmental toxicity that endangers the aquatic life (Khalid et al., 2016). The increasing anthropogenic activities that effortlessly generate heavy metals in the households and the entire environment may cause a significant adverse health effects for invertebrates, fish, and humans at the discharge point (Martin *et al*., 2015). Several human activities can contribute to heavy metal pollution in the marine environment, for example, seafloor and bedrock dredging, shipping activities, industrial and urban effluents, mining, agricultural fertilizer use, and burning of fossil fuels (Machiwa, 1992; UNEP, 1997; Lionetto et al., 2003). In the marine environment, heavy metals may occur as dissolved free metal ions or as complex ions, chelated with certain inorganic ligands such as Cl^-, OH^-, CO_3^-, and NO_3^-; and sometimes heavy metals can form complexes with organic ligands such as fulvic acid, amines, humic acids, and proteins (Beijer and Jerenlöv, 1979; Batley et al., 2004). The principal model of effluent entering an open water system like sea and ocean comprises of factors like speed of the effluent at the entrance, solubility of the metals, suspended solids and water tides available. All these determine the frequent changes of the load due to dissolution, precipitation and sorption phenomena (Abdel-Ghani and Elchaghaby, 2007). Precipitation of metals into the sediment is subject to the flow rate of the water as it enters the open water body (Islam et al., 2015c). In the aquatic environment, sediments have been widely used as environmental indicators for the assessment of natural water pollution by metals (Islam et al., 2015c). The investigation of heavy metals in water and sediments may be used to assess the anthropogenic and industrial impacts and risks posed by waste discharges on the marine ecosystems ((Machiwa, 1992; Engdahl et al., 1998; Machiwa, 2000). Therefore, it is important to measure the concentrations of heavy metals in water and sediments of any contaminated aquatic ecosystem to form a baseline before estimation of the actual load of metals entering the ecosystem.

In many countries sewer pipes are used to transport sewage effluents from point sources to the discharge or disposal points. In the Eastern Coastal zone of Tanzania it is a common practice that most sewage disposal pipes are directed to the Indian Ocean indicating that metals are directly introduced into the Ocean. Ocean road is a sewer disposal site collecting sewage through the sewer pipe and River Msimbazi. The composition of the sewer discharge includes among others metals like copper, iron, lead, chromium and zinc. The extent to which the sewer discharge contributes to heavy metals loading to the Ocean is not well understood. Assessment of the concentrations of metals at the two stations may give baseline information to study the contribution of sewer pipe and River Msimbazi to the loading of metals to the Indian Ocean. The study aimed at assessing the extent to which the sewers may contribute to the heavy metal loading to the Indian Ocean.

2. Materials and Methods

2.1 Study Area and Sampling

The study was conducted at two stations along the Indian Ocean in Dar es Salaam namely Ocean Road and Kigamboni shores (Figure 1). Ocean Road is located on the mainland side, a site where the sewer pipe and Msimbazi River discharge directly from the mainland. Kigamboni station is located at the opposite side to Ocean Road with no direct sewer discharge. Three sites were located at both stations with increasing distances from the shore into the Ocean (K1, K2 and K3 at Kigamboni and R1, R2 and R3 at Ocean Road, respectively) from which duplicate composite samples of water and sediments were collected. The sites 1, 2 and 3 were at 10, 30 and 60m from the shores at both stations.

Sampling was done early in the morning when the water turbulences were few, so as to give uniform partition between water and sediment.

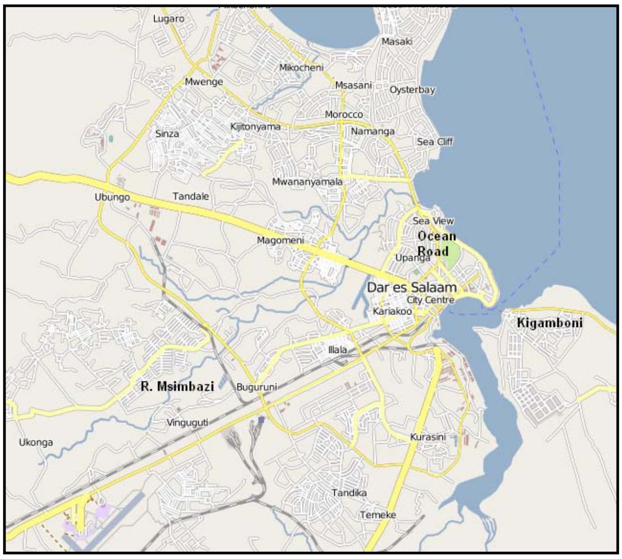

Figure 1: Physical Map of Dar es Salaam showing the River Msimbazi, Kigamboni and Ocean Road areas

2.2. Sample digestion and analysis

Ultra-pure HNO_3 from Merck Germany was used for sample digestion. Other acids and chemicals were either supra pure or ultra-pure received form Merck Germany. After collection, water samples were filtered through Millipore Filtration Assembly, using 0.45 mm membrane filter. The filtrate was then acidified with concentrated HNO_3 to make a pH of <2. Measured volume (50 mL) of well mixed, acidified sample was taken in a beaker. About 5 mL of concentrated HNO_3 was added and boiled at 130 °C on hot plate till the volume came to about 25–30 mL and light color. Addition of HNO_3 and boiling were repeated till solution became light colored or clear. After cooling, the volume was made to desired level with distilled water passing through the Whatman no. 41 filter paper. About 2.0 g portion of dried sediment was taken in 100 mL beaker and 15 mL of concentrated HNO_3 was added. The content was heated at 130°C for 5 h until 2–3 mL remained in the beaker. After digestion materials were passed through *Whatman* no. 41 filter paper, washed with 0.1 M HNO_3 solution and made up to 100 mL volume with distilled water. Sample Analysis was attained by atomic absorption spectroscopy (AAS).

3. Results and Discussion

3.1 Levels of heavy metals in sediment and water at Kigamboni

Lead (Pb) and Zinc (Zn) were detected in sediments in all the three points at Kigamboni where as only lead was detected in the water. Cadmium (Cd) was not detected in any samples.

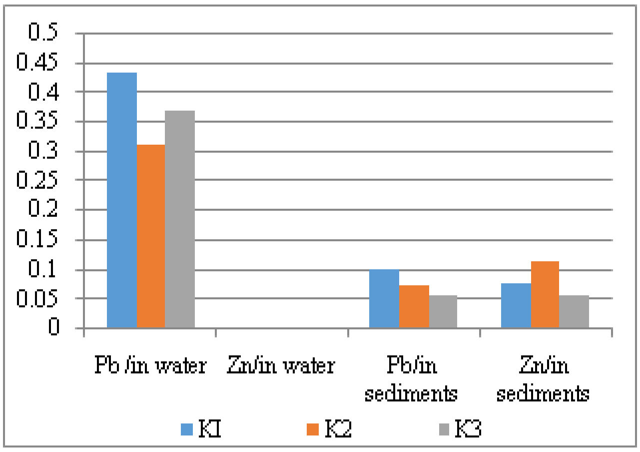

Figure 2: Levels of heavy metals in water (mg/L) and sediments (mg/kg) at Kigamboni

Lead and Zinc were equally detected in sediments at Kigamboni. The general trend showed decreasing concentrations from the shore into the ocean suggesting higher level on the mainland side that is diluted or washed away as it enters the water mass(Figure 2).

3.2 Levels of heavy metals in sediment and water at Ocean Road

At Ocean Road similar trend was displayed that Cd was not detected in all the samples. The observed trend at Ocean Road was generally similar to that at Kigamboni for both lead (Pb) and Zinc (Zn) (Figure 3). Likewise zinc was not detected in water at both Ocean Road and Kigamboni.

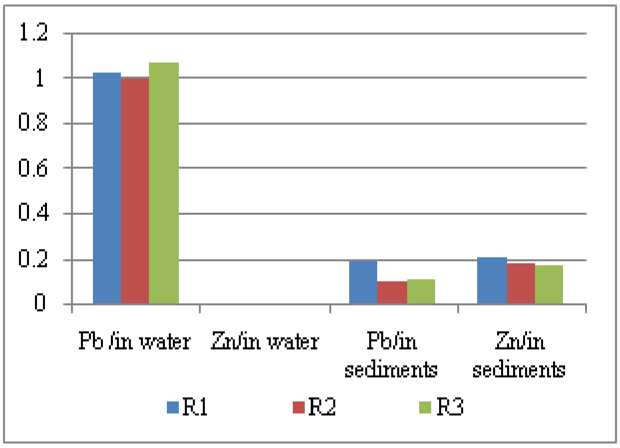

Figure 3: Levels of heavy metals in water (mg/L) and sediments (mg/kg) at Ocean Road

3.3 Comparison of heavy metals in sediments and Water at Ocean Road and Kigamboni

The levels in water and sediments were relatively higher at Ocean Road than at Kigamboni. Lead concentration of up to 1.05 mg/L and 0.43 mg/L in water were detected at Ocean Road and Kigamboni, respectively. In sediments, about the same levels of lead and zinc were detected with relatively higher concentrations at Ocean Road (0.2 mg/kg) than Kigamboni (0.1 mg/kg) (Figures 2 and 3). The higher levels of the metals at Ocean Road than those at Kigamboni support the argument that the sewer pipe and River

Msimbazi at Ocean Road contribute to the metal loading to the ocean.

Table 1: Mean values of Lead (Pb), Zinc (Zn) and Cadmium (Cd) in water and sediments at Kigamboni and Ocean Road

Metal	Concentration in water(mg/L)	Concentration in sediments(mg/kg)	Partition coefficient(α)
KIGAMBONI			
Lead	0.3706	0.07904	0.21
Zinc	BDL	0.0829	∝
Cadmium	BDL	BDL	BDL
OCEAN ROAD			
Lead	1.0368	0.1395	0.13
Zinc	BDL	0.1916	∝
Cadmium	BDL	BDL	BDL

∝ : Infinite value (very large number) BDL: Below Method Detection Limit

Generally, higher levels of lead were found in the water column compared to the sediments. The levels of zinc were non-detectable (BDL) in the water column while in the sediments the two were nearly at the same concentrations. Furthermore, higher levels of lead in the water column than zinc may suggest the lower solubility of lead with respect to zinc that may also be reflected on their differences in their atomic mass of 207 and 66, for lead and zinc, respectively. Detection of lead in water column is common (Ali et al, 2016, Gupta et al., 2009). The higher solubility of zinc with respect to lead may result to more of the later (zinc) being dissolved into the water immediately as it enters the water column. Based on the factors like pH, solubility and the speed of the effluent some metals are easily washed away by the water while others are normally adsorbed into suspended particles and eventually settle to sediments. The calculated sediment: water partition coefficient of lead gave higher value at Kigamboni (α=0.21) compared to Ocean Road (α=0.13) showing that at Kigamboni more lead is found in the sediments than in the water column compared to Ocean Road. Interpretation of this may be that lead is more soluble at Ocean Road than at Kigamboni based on the differences like pH, suspended solids, and water mass and water tides.

4. Conclusion

Higher levels of the metals at Ocean Road compared to Kigamboni supports the possible contribution of the sewage pipe and Msimbazi River to the heavy metal pollution of the Indian Ocean. Partition of the metals between water column and sediments could hardly reveal the actual load entering the ocean through the sewer pipe and the river Msimbazi. This may only indicate that there is a significant load that is left to sink to the bottom after the potential transfer of the metals to the ocean water. Lead (^{207}Pb) is less soluble in water than Zinc (^{66}Zn) hence found to be more available in the water. The metals in the ionic form can easily dissolve in water and hence easily transferred to deep waters from the shore. A number of factors that may affect the availability of metals at the discharge point of the river and the sewer include location of the sampling sites, speed of the discharges, ocean tides and the pH of the water. Apparently, the study of concentrations in water cannot give the correct picture since the partition of the metals depends on their solubility in water as well as the speed of the turbulence.

5. Recommendations

Thorough analysis of the effluent direct from the sewer pipe and River Msimbazi before discharging to the ocean is necessary. Tracing of other possible sources of the metals at the two stations should be studied to build a baseline on the pollution sources of the ocean. Variation of pH, ocean tides at different times of the day is also important to enable the assessment of the actual load entering the ocean due to the sewer pipe and the Msimbazi River.

References

[1] El-Moselhy, K.M., Saad, E.M., El-Shaarway, R.F., Mohamadein, L.I. and Mahmoud, S.A. (2016), Assessment of Heavy Metals Pollution using Sediments and Bivalve *Brachidontes variabilis*as Bioindicator in the Gulf of Suez, Egypt, *International Journal of Marine Science*, Vol.6, (26), pp. 1-13

[2] Martin, J.A.R., Arana, C.D., Ramos-Miras, J.J., Gil, C. and Boluda, C.R (2015), Impact of 70 years urban growth associated with heavy metal pollution, *Environ. Pollut*., 196 (2015), pp. 156–163

[3] Machiwa, J.F. (1992), The Anthropogenic Pollution in the Dar es Salaam Harbour Area. *Tanz.Mar. Pollut. Bullet*. 24: pp.562−567

[4] UNEP, (1997), Assessment of Land-Based Sources and Activities Affecting the Marine Sediment in the Red Sea and Gulf of Aden. UNEP Regional Seas Reports Studies, No. 166.

[5] Lionetto M. G., Caricato R., Giordano M. E., Pascariello M. F., Marinosci, L., Schettino T., (2003), Integrated use of biomarkers (acetylcholinesterase and antioxidant enzymes activities) in Mytilus Galloprovincialis and Mullusbarbatus in an Italian Coastal Marine area , *Mar. Pollut. Bull*. 46 (3), pp. 324–330

[6] Beijer, K. and A. Jerenlöv (1979), Sources, Transport and Transformation of Metals in the Environment, In: Friberg, L., Nordberg, G.F. and Vouk, V.B. (Eds.), Handbook on Toxicology of Heavy Metals. Amsterdam: Elsevier, pp. 47−63.

[7] Batley, G.E., S.C. Apte and GJ.L. Stauber (2004), Speciation and Bioavailability of trace metals in water: progress since 1982. *Aust. J. Chem*. 57: pp. 903–19.

[8] Abdel-Ghani, N.T. and Elchaghaby, G.A. (2007), Influence of operating conditions on the removal of Cu, Zn, Cd and Pb ions from wastewater by adsorption, *Int. J. Environ. Sci. Technol*., 4, pp. 451–456

[9] Islam, M.S., Ahmed, M.K, Raknuzzaman, M., Habibullah-Al-Mamun, M., Islam, M.K. (2015), Heavy Metal Pollution in Surface Water and Sediment: A Preliminary Assessment of an Urban River in a Developing Country, *Ecol. Indic*., 48, pp. 282–291

[10] Engdahl, S., F.A. Mamboya, M. Mtolera, A.K. Semesi and M. Björk (1998), The Brown Macroalgae Padina Boergesenii As An Indicator Of Heavy Metal Contamination in The Zanzibar Channel, *Ambio,* 27 (8), pp. 694–700.

[11] Machiwa, J.F. (2000), Heavy Metals and Organic Pollutants in Sediments of Dar Es Salaam Harbour Prior to Dredging in 1999. *Tanz. J. Sci*., 26: pp. 29–46.

[12] Ali, M.M., Ali, M.L., Islam, M.S., Rahman, M.Z. (2016), Preliminary Assessment of Heavy Metals in Water and Sediment of Karnaphuli River, Bangladesh, *Environmental Nanotechnology, Monitoring & Management*, Volume 5, pp. 27–35

[13] Gupta, A., Rai, D.K., Pandey, R.S. and Sharma, B. (2009) Analysis of Some Heavy Metals in the Riverine Water: Sediments and Fish from River Ganges at Allahabad, *Environ. Monit. Assess*, 157, pp. 449–458.