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Studies on Toxic Heavy Metals in Sediment Ecosystem of Mahim Creek near Mumbai, India

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Abstract

The present study was performed for the period of one year from June 2012 to May 2013 in order to understand the level of toxic heavy metals in the sediments of Mahim Creek near Mumbai. The annual average concentration of heavy metals like *Pb*, *Cd*, *Cr*, *Zn*, *Cu*, *Ni* and *Hg* was found to be 9.88, 2.33, 1.41, 33.31, 22.07, 32.21 and 32.06 ppm respectively. It is feared that this heavy metals accumulated in the creek sediments might affect the benthic macro invertebrates whose metabolic activities contribute to aquatic productivity. The results of present study indicates that the existing situation if mishandled can cause toxic effect on sediment dwelling organisms and fish, resulting in decrease survival, reduced growth, or impaired reproduction and lowered species diversity.

Key words: heavy metals; toxic metals; creek sediments; Mahim Creek; Bandra ki Khadi; Mumbai.

1. Introduction

Mahim Creek (locally known as *Bandra ki Khadi*) is a creek in Mumbai, India. The famous Mithi River which is one of the most polluted river of Mumbai [1-6] drains into the creek which further drains into the Mahim Bay. It is the only Creek which balances the water level of Mumbai during heavy rainfall and during Mumbai monsoon time. The creek is the biggest sink for most of the waste generated by residential complexes and small scale industries. The waters of the creek are foul smelling due to the dumping of untreated industrial effluents further upstream. The creek is swamped by mangroves and has a mini-ecosystem within it. It is a less known fact that the Mahim bay area, where Mahim creek meets Arabian Sea, is a nominated bird sanctuary called "Salim Ali Bird Sanctuary" where migratory birds come for nesting. In recent years, the mushrooming of slums around the creek has caused concern for the mangrove ecosystem, vital to the ecosystem of Mumbai. The mangrove along the creek area plays an important role in the survival of many coastal communities and harbors a unique biodiversity [7]. The mangrove forests are important because of their role in harbouring a variety of biotic communities, protecting the coastal areas from cyclonic storms and functioning as lungs in the case of Mumbai. The increase in number of contaminated sediment sites around the world has resulted in increasing awareness that sediments act as a major pollution reservoir [8-19], which has further prompted us to investigate pollution load due to accumulation of toxic heavy metals in sediments of Mahim Creek. It is well known that the sediment strata serve as an important habitat for the benthic macro invertebrates whose metabolic activities contribute to aquatic productivity [20]. It is observed that continuous

accumulation of toxic heavy metal pollutants due to biological and geochemical mechanisms can cause toxic effect on sediment dwelling organisms and fish, resulting in decrease survival, reduced growth, or impaired reproduction and lowered species diversity [21, 22].
The present day by day increasing pollution level along most of the creeks and rivers in Mumbai have prompted us to conduct the systematic study of pollution along the Mahim creek of Mumbai which receives heavy pollution load from the adjoining Mithi River and also from the surrounding slum areas.

2. Experimental

2.1 Study Area

The Mahim Creek is located along western Arabian cost of India from 19^{o}2'52.84'' north and from 72^{o}50'17.56'' east. The depth of the creek is 15 feet (4.6 m). The area experiences tropical savanna climate. It receives heavy south west monsoon rainfall, measuring 2166 mm on an average every year. The temperature ranges from 16 ^{o}C to 39 ^{o}C with marginal changes between summer and winter months. The relative humidity ranges between 54.5 to 85.5% [23].

2.2 Requirements

All the glassware, casserole and other pipettes were first cleaned with tape water thoroughly and finally with de-ionised distilled water. The pipettes and standard flasks were rinsed with solution before final use. The chemicals and reagent were used for analysis were of Analytical Reagent *(A.R.)* grade. The procedure for calculating the different parameters were conducted in the laboratory.

2.3 Sediment Sampling

The study on pollution status along the Mahim creek of Mumbai was performed for the period of one year from June 2012 to May 2013. The grab sediment samples were collected every month along different locations of the creek. The sampling was done by hand-pushing plastic core tubes with an intention to avoid metallic contamination. Samples so collected were kept in polythene bags which were free from heavy metals and organic contaminants. The samples thus collected were mixed to give gross sample. The gross samples were air dried, ground using agate mortar and sieved with a 0.5 mm mesh size sieve to uniform particle size. The thoroughly mixed sediment samples were packed in polythene bags and kept in a dry place until analysis. Such samples were drawn and analysed monthly for their toxic heavy metal content, so as to get the seasonal variation in pollution level along the Mahim Creek.

2.4 Sample Preparation

For analysis of heavy metal content in sediment samples, well mixed sample weighing 2 g was digested with 8 mL of aqua regia on a sand bath for 2 h. After evaporation to near dryness, the sample was dissolved in 2% nitric acid, filtered through Whatman's No.1 filter paper and then diluted with deionized water to give final volumes depending on the suspected level of the metals **[24]**.

2.5 Quality control/assurance

Sediment samples were collected with plastic-made implements to avoid contamination. Samples were kept in polythene bags that were free from heavy metals and organics and well covered while transporting from field to the laboratory to avoid contamination from the environment. All glassware used were soaked in appropriate dilute acids overnight and washed with teepol and rinsed with deionised water before use. All instruments used were calibrated before use. Tools and work surfaces were carefully cleaned for each sample during grinding to avoid cross contamination. Triplicate samples were analysed to check precision of the analytical method and instrument.

2.6 Analysis of Heavy Metals

The sediment samples collected were analyzed for the heavy metal content. The analysis for the majority of the trace metals like lead (*Pb*), cadmium (*Cd*), chromium (*Cr*), zinc (*Zn*), copper (*Cu*) and nickel (*Ni*) in sediment samples was done by Flame Atomic Absorption spectrophotometer (*AAS*) technique, while analysis of mercury (*Hg*) was performed by cold-vapour techniques **[25]** using Perkin Elmer Analyst 200 Flame Atomic Absorption Spectrophotometer (2003 model). The calibration curves were prepared separately for all the metals by running different concentrations of standard solutions. A reagent blank sample was run throughout the method, and the blank readings were subtracted from the samples to correct for reagent impurities and other sources of errors from the environment. Average values of three replicate measurements were calculated for each determination.

3. Results and Discussion

Although there is no clear definition of what a heavy metal is, density is in most cases taken to be the defining factor. Heavy metals are thus generally defined as those having a specific density of more than 5 g/cm^3. Heavy metals are among the most common environmental pollutants, and their occurrence in waters and biota indicate the presence of natural or anthropogenic sources. Although adverse health effects of heavy metals have been known for a long time, discharge of heavy metals continues and is even increasing in some areas, in particular in less developed countries. The main threats to human health from heavy metals are associated with exposure to lead, cadmium and mercury. Their accumulation and distribution in soil, sediments and aquatic environment are increasing at an alarming rate thereby affecting marine life **[26-28]**. The experimental data on concentration (*ppm*) of toxic heavy metals like *Pb*, *Cd*, *Cr*, *Zn*, *Cu*, *Ni* and *Hg* in the sediment samples collected along the Mahim Creek of Mumbai is presented in Table 1. The annual average concentration of these metals is graphically represented in Figure 1.

Table 1: Heavy metals in the sediments of Mahim Creek near Mumbai

Heavy Metals ➡ (ppm) / Sampling Months/Year ⬇	Pb	Cd	Cr	Zn	Cu	Ni	Hg
June 2012	5.10	2.30	2.50	15.50	14.10	42.50	15.50
July 2012	6.10	0.90	1.00	55.50	10.50	12.50	ND
August 2012	6.45	ND	ND	61.30	15.50	6.80	ND
September 2012	7.33	ND	ND	71.18	18.16	ND	0.02
October 2012	8.12	0.10	ND	55.50	19.10	8.50	7.90

November 2012	8.63	0.30	0.50	43.50	19.80	15.50	19.80
December 2012	9.70	1.20	1.00	22.50	21.50	32.50	22.20
January 2013	10.00	2.20	1.50	16.30	23.50	44.50	44.60
February 2013	11.00	4.00	2.00	10.80	25.40	52.74	51.13
March 2013	12.80	5.10	2.30	10.50	27.50	57.60	61.50
April 2013	13.50	5.80	3.20	9.80	29.30	59.80	70.50
May 2013	15.00	6.00	4.00	9.50	32.50	63.85	75.05

ND= Not Detected

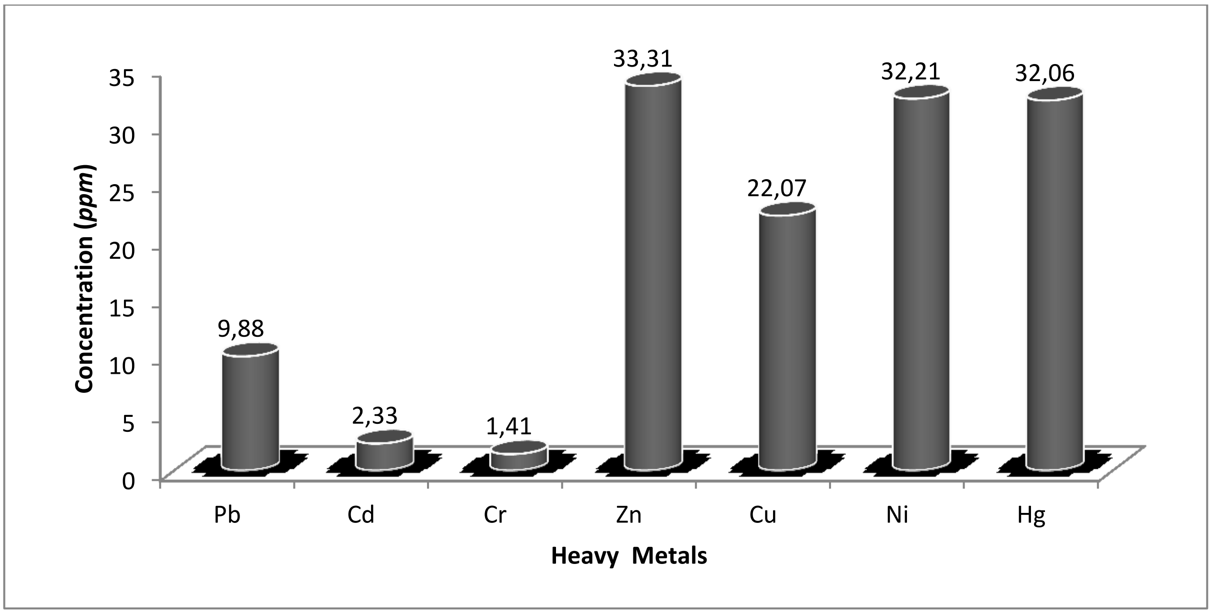

Figure 1: Annual average concentrations of heavy metals in the sediments of Mahim Creek near Mumbai.

From the results of our study, it was observed that the concentration of *Pb* in the creek sediment was found to vary in the range of 6.10-15.00 *ppm* with an annual average concentration of 9.88 *ppm*. It is feared that the *Pb* which is accumulated in the sediments might enter the creek water thereby increasing its concentration in aquatic environment. Such high concentration of *Pb* might create adverse metabolic effects and might also affects hematopoietic, vascular, nervous, renal, and reproductive systems **[29-34]**. *Cd* is typically a metal of the 20^{th} century, and is mainly used in rechargeable batteries and for the production of special alloys. It was the outbreak of the *Itai-Itai* bone disease in Japan in the 1960s that really drew the attention of the public and regulatory bodies to this heavy metal that had been discharged in the environment at an uncontrolled rate for more than one century. From the results of our study, the highest concentration of *Cd* was recorded as 6.00 ppm in the month of May having an annual average concentration of 2.33 *ppm*. *Cd* dispersed in the environment can persist in soils and sediments for decades. When taken up by plants, *Cd* concentrates along the food chain and ultimately accumulates in the body of people eating contaminated foods. By far, the most salient toxicological property of *Cd* is its exceptionally long half-life in the human body. Once absorbed, *Cd* irreversibly accumulates in the human body, in particularly in kidneys, the bone, the respiratory tract and other vital organs such the lungs or the liver **[35]**. In addition to its extraordinary cumulative properties, *Cd* is also a highly toxic metal that can disrupt a number of biological systems, usually at doses that are much lower than most toxic metals **[36-38]**. *Cr* is one of the most common skin sensitizers and often causes skin sensitizing effect in the general public. A possible source of chromium exposure is waste dumps for chromate-producing plants causing local air or water pollution. Penetration of the skin will cause painless erosive ulceration ("chrome holes") with delayed healing. These commonly occur on the fingers, knuckles, and forearms. The characteristic chrome sore begins as a papule, forming an ulcer with raised hard edges. Besides the lungs and intestinal tract, the liver and kidney are often target organs for chromate toxicity **[39]**. The results of our study indicate that the *Cr* concentration in the sediment samples was recorded maximum of 4.00 ppm in the month of May having the average concentration of 1.41 *ppm*. The concentration of *Zn* in the creek sediments was found to vary in the range of 9.50 ppm (minimum) in the month of May to maximum of 71.18 *ppm* in the month of September having an annual average concentration of 33.31 *ppm*. *Cu* is highly toxic to most fishes, invertebrates and aquatic plants than any other heavy metal except mercury. It reduces growth and rate of reproduction in plants and animals. The chronic level of *Cu* is 0.02–0.2 *ppm* **[40]**. It was reported that the aquatic plants absorb three times more *Cu* than plants on dry lands **[41]**. Excessive *Cu* content can cause damage to roots, by attacking the cell membrane and destroying the normal membrane structure, inhibited root growth and formation of numerous short, brownish secondary roots **[40]**. Copper is highly toxic in aquatic environments and has effects in fish, invertebrates, and amphibians, with all three groups equally sensitive to chronic toxicity **[42, 43]**. Copper will bio concentrate in many different organs in fish and molluscs. Copper also causes reduced sperm and egg production in many species of fish, such as fathead minnows, as well as early hatching of eggs, smaller fry (newly hatched fish) and increased incidence of abnormalities and reduced survival in the fry **[44]**. The results also indicates that the *Cu* concentration in the sediment samples was found to be minimum of 10.50 *ppm* in the month of July and maximum of 32.50 ppm in the month of May. The annual average concentration of *Cu* was found to be 22.07 *ppm*. Nickel (*Ni*) and nickel compounds have many industrial and commercial uses, and the progress of industrialization has resulted in increased emission of pollutants into ecosystems. In the present study it was observed that the concentration of *Ni* in the sediment samples was found to be maximum of 63.85 *ppm* in the month of May, having annual average concentration of 32.21 *ppm*. Although *Ni* is omnipresent and is vital for the function of many organisms, concentrations in some areas from both anthropogenic release and naturally varying levels may be toxic to living organisms **[45, 46]**. Nickel compounds have been well established as carcinogenic in many animal species and by many modes of human exposure but their underlying mechanisms are still not fully understood **[47]**. *Hg* poisoning has become a problem of current interest as a result of environmental pollution on a global scale. High concentration of mercury, which could pose an ecological hazard, leading to contamination of plants, aquatic resources and bioaccumulation in the food chain **[48]**. The results of present investigation indicates that the concentration of *Hg* in the sediments was maximum of 75.05 ppm in the month of May having the annual average concentration of 32.06 *ppm*.

4. Conclusion

The ecological and human health safety due to discharge of heavily polluted effluents are undoubtedly under threat. From the results of the present investigation it seems that the time has come to move towards ecosystem specific discharge standards to maintain the health and productivity of natural resources on which the human beings are dependent. This is possible by proper treatment of domestic waste water and enforcement of pollution control by the regulatory authority on the indiscriminate discharge of industrial wastewater into water bodies. Educating the urban as well as the rural mass is another major step to put a check on such industrial pollution. Masses should be made aware of the drastic consequences of such industrial pollution on their lives, both directly and indirectly. The existing situation if mishandled can cause irreparable ecological harm in the long term well masked by short term economic prosperity due to extensive urbanisation and industrial growth.

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Biography

Pravin U. Singare completed his Masters in Inorganic Chemistry (1997) and his PhD in Chemistry (1999), both from University of Mumbai, India. He has worked at Sikkim Mining Corporation, Sikkim, India, on a project related to the concentration of Cu/Pb/Zn sulfide ores. He is currently an Assistant Professor in Chemistry at Bhavan's College, Andheri, Mumbai. His research areas of interest are radioanalytical nuclear chemistry, ion exchange techniques and environmental analysis. He is a member of several scientific societies such as ISAS, NAARI and INS all from BARC, Mumbai, and the Indian Council of Chemists, Agra, India.

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