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A survey on heavy metal pollution in Shing Mun River, Hong Kong

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Abstract

The Shing Mun River is a major river in the northeastern part of Hong Kong. In this study, the extent of heavy metal pollution in the river system has been evaluated. Six heavy metal cations, namely copper, lead, zinc, chromium, aluminum, and cadmium from the sediment taken at different points along the river were analyzed. The results showed that the highest concentrations of copper, lead, zinc and chromium were found in the Fo Tan Nullah, a major tributary of the Shing Mun River, while the highest concentrations of aluminum and cadmium were found in the Shing Mun Main River Channel. These contaminated sediments, accumulated over the years on the river bed, could act as secondary sources of heavy metal pollution to the water body.

1 Introduction

The Shing Mun River is a major river in the northeastern part of Hong Kong. It flows through the heart of Sha Tin New Town areas and drains into Tolo Harbor. The length of the river is about 50 km, which covers a catchment area of 37 km^2 and three main tributaries, including the Tin Sum Nullah, Fo Tan Nullah and Siu Lek Yuen Nullah (Fig. 1). During the past two decades, large amounts of pollutants from various industries, namely electroplating, dyeing, printing, metal finishing and chemical industries were discharged into the Shing Mun River [1]. Consequently, the Shing Mun River and its tributaries were heavily polluted with such illegal industrial discharges [2]. This area has been classified as a 'hot spot' of pollution. The river has possessed an unpleasant smell over the years and has received many complaints from residents and users of the river. The sediment

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has been identified as the main sources of the river's unpleasant smell, resulting from the contamination by industrial discharges over the past decade. A number of studies were carried out to study the water pollution problems in the Shing Mun River [3], [4].

With the implementation of Water Pollution Control Ordinances (WPCO) since 1987, major pollutants such as COD, BOD and ammonia-nitrogen are under control [5]. However, the progress towards fully achieving the water quality objectives for heavy metals remains slow. This may be due to the pollution from unauthorized discharges around the Shing Mun River and contaminated sediments accumulated over the years on the river bed. Such heavy metal pollution problem has drawn much attention due to its toxicity, abundance and persistence in the environment, and subsequent accumulation in aquatic habitats. Moreover, heavy metal residues in contaminated habitats may accumulate in microorganisms, aquatic flora and fauna, which, in turn, may enter into the human food chain and result in health problems [6], [7].

Numerous papers reported the extent of metal contamination in the rivers. Raised concentrations of lead (Pb), copper (Cu), cadmium (Cd) and zinc (Zn) have been documented in the literature. Bertin and Bourg [8] assessed the extent of Cd, Pb and Zn contamination in the Lot River basin in the areas of southwest France. Cahill and Unger [9] reported high levels of Cu, Pb, Zn, chromium (Cr) and Cd in sediments collected from the west branch of the Grand Calumet River, USA. Chen and Hung [10] found that the sediments from the lower stream of the Kaohsiung River were heavily contaminated with Cu, Pb and Zn.

In the river system, sediments are regarded as the ultimate sinks for heavy metals [11]. Hart *et al.* [12] demonstrated that the major amount of heavy metals was transported in particulate form (Pb, Zn, Sn ca. 60%, Cu ca. 60%) during major flood event in the Annan River, Australia. Sediments, not only act as the carrier of contaminants, but also the potential secondary sources of contaminants in aquatic system [13], [14]. The analysis of river sediments is a useful method to study the metal pollution in an area [15]. Changing environmental conditions in the system may render the remobilization of metals from sediments [16]. Malo [17], Chester and Voutsinou [18], reported that metals in the surface of bottom sediments would be released into the water body by physiochemical processes. In fact, the higher the metal concentrations in the sediments, the greater the quantity of metals that could be desorbed from the sediments [19].

The objective of this study is to evaluate the extent of heavy metal pollution in the Shing Mun River, Hong Kong. Six heavy metal cations, namely copper, lead, zinc, chromium, aluminum, and cadmium from the sediment taken at eight locations along the river system were analyzed. The concentrations of different heavy metals in the sediments were then compared with published data of river sediments from other countries.

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2 Materials and methods

2.1 Samples collection

The sediment samples were collected from eight sampling locations along the Shing Mun River and its tributaries (Fig.1). Station SM-1 was located in the upstream of the main channel of the river system, which received metal contaminants from the cottage type industries in the vicinity. Station SM-2 was located at the mouth of the Tin Sum Nullah, which was polluted by the alum sludge discharged from the Sha Tin Water Treatment Works. Stations FT-1 and FT-2 were located in the Fo Tan Nullah, which was heavily polluted by unauthorized discharges of industrial effluents. Stations LY-1 and LY-2 were located in the Siu Lek Yuen Nullah, which was polluted heavily by livestock waste in the past. Some cottage-type industries such as metal works and car-repairing workshops were found adjacent to the nullah. Station SM-4 was located at the river mouth and its degree of metal pollution would reveal the quality of river water entering the Tolo Harbor. The top portion (3cm) of the sediment samples was collected by a Birge-Ekman grab. After sampling, the sediment samples were washed with 10% nitric acid, and refrigerated at 4°C before analysis.

2.2 Analytical methods

The sediment samples were wet-sieved through a 63-mm sieve with distilled water, dried at 105°C, and then homogenized with an agate mortar. The homogenized samples were then digested according to de Groot [20] and Muller *et al.* [21]. After digestion, the samples were cooled and filtered with Whatman (no. 541) paper. The filtrate was made up to 100 ml with distilled-deionized water. Cu, Pb, Zn and Cr were analyzed by a flame atomic absorption spectrophotometer (Perkin-Elmer Model 3030) using air-acetylene flame with deuterium lamp background correction. Cd and Al were analyzed by an atomic absorption spectrophotometer Perkin-Elmer Model 3030 equipped with a graphite furnace (Perkin-Elmer Model HGA-600 Fraphite Furnace and AS-60 autosampler).

3 Results and discussion

Figure 1 shows the heavy metal concentrations in surface sediments from the Shing Mun River system. Compared with different river systems in other countries, the Shing Mun River is severely polluted with heavy metals, especially its two main tributaries, Fo Tan Nullah and Siu Lek Yuen Nullah. The extent of metal pollution in the Shing Mun River is no better than that in the Grand Calumet River, and much worse than the Tigris River, Brantasand River and Linggi River (Table 1).

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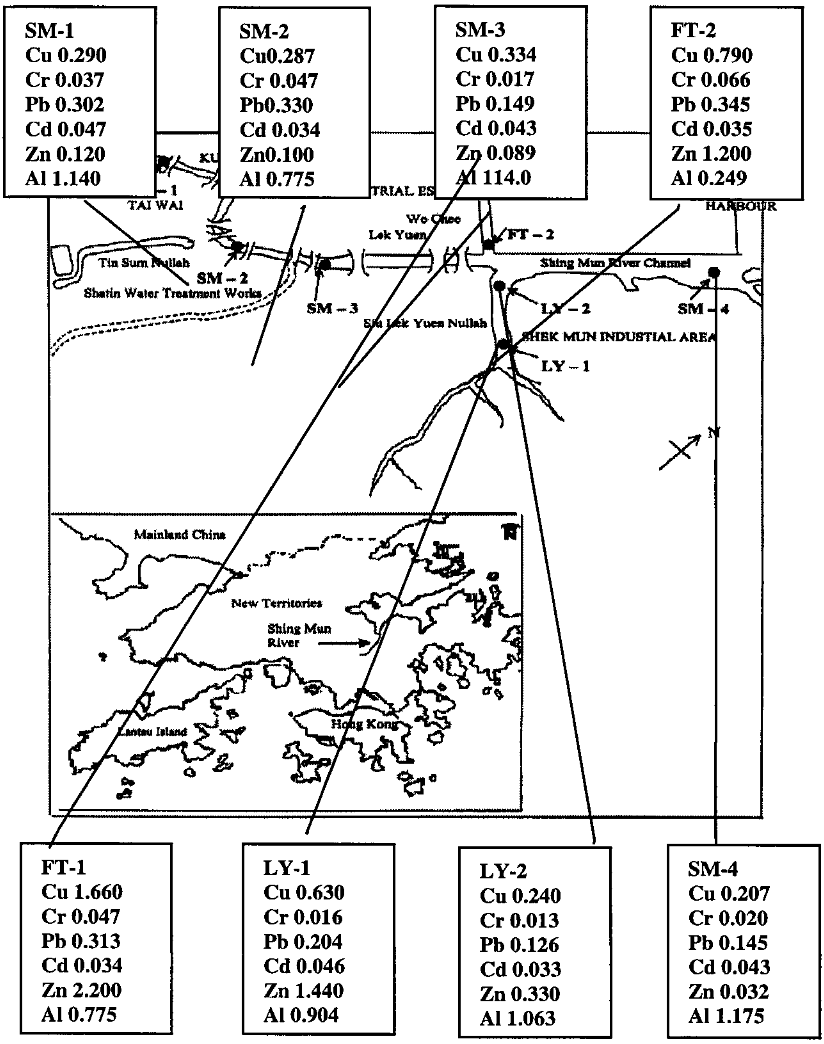

Figure 1: The heavy metal concentrations (mg/g) in sediments (fine fraction <63µm) from different sampling locations along the Shing Mun River System (FT = Fu Tan Nullah; LY = Siu Lek Yuen Nullah; SM = Shing Mun Main River Channel).

Table 1: Heavy metal concentrations in sediments from river of different countries.

River	Heavy Metal Concentrations (mg/g dry weight)						Extent of Pollution	References
	Cu	Pb	Zn	Cr	Cd	Al		
Shing Mun River (H.K)	1.660	0.354	2.200	0.370	0.047	114	Heavy	This study
Grand Calumet River (USA)	0.307	1.499	1.767	0.288	0.025	--	Heavy	[9]
River Tees (UK)	0.12	0.249	0.473	--	--	--	Heavy	[22]
Kaohsiung River-Downstream (Taiwan)	0.505	0.14	--	--	0.046	--	Heavy	[10]
Kaohsiung River-Upstream (Taiwan)	0.069	0.05	--	--	0.006	--	Near background level	[10]
River Tigris Impoundment (Iraq)	0.052	0.305	0.080	--	0.064	--	Slight	[23]
River Brantasand (Java)	0.058	0.023	--	--	0.004	--	Slight	[24]
Lingi River (Malaysia)	--	--	--	--	--	0.033	Slight	[25]

The highest metal concentrations were recorded in sediments collected from Fo Tan Nullah (Stations FT-1 and FT-2), which were located inside the Fo Tan Industrial Estate. Along the nullah, the highest concentrations of Cu (1.660 mg/g), Pb (0.345 mg/g), Zn (2.200 mg/g) and Cr (0.066 mg/g) have been found. The industrial effluents discharged from electroplating, metal works plants, garages and dyeing factories have contributed a significant amount of these metals in sediments. The elevated Pb concentration in sediment may also be caused by the road run-off of Pb-containing dust originated from leaded petroleum, as the traffic in the vicinity is heavy.

The stations with the second highest metal levels were LY-1 and LY-2 (Siu Lek Yuen Nullah), which were located near the newly developed industrial area (Shek Mun Industrial Area). Enrichment of Cd (46 µg/g) was found in the upstream of the nullah. The surface run-off discharged from the cottage type industries in the vicinity to the nullah could contribute to the high concentration of Cd, Cu and Zn in the sediment.

Comparing with the tributaries (FT-1, FT-2, LY-1 and LY-2), the main river channel (SM-1, SM-2, SM-3 and SM-4) shows significantly lower concentrations of Cu, Pb, Zn and Cr. This might due to most of the metals in the industrial effluents have already deposited to the sediments in the tributaries prior to discharging into the main river channel. This explanation is supported by the observation that the metal concentrations were, in general, lower in the downstream of the Fo Tan and Siu Lek Yuen Nullahs (FT-2 and LY-2). However significantly higher amounts of aluminum were observed at stations SM-2 and SM-3, 97 and 114 mg/g, respectively. The disposal of alum sludge from the Sha Tin Water Treatment Works caused these elevated aluminum concentrations.

Generally, the upstream of the channel had higher concentrations of heavy metals except Cd. The water flow rate in the main river channel was quite slow. As a result, most of the metals deposited immediately after entering the main river channel. Besides, the downstream of the main river channel was subjected to tidal flushing, which provides some extent of 'cleansing' effect on the sediments in the downstream. The lowest levels of metal concentrations in the sediments except Cd and Cr were, consequently, recorded near the end of the main channel (SM4).

4 Conclusion

The present study demonstrates that the surface sediments of the Shing Mun River have been heavily polluted with heavy metals (Cu, Zn, Pb, Cr, Cd and Al). Though most of the illegal discharges in the area were under control for some time, the highly contaminated sediments of the Shing Mun River could continue to act as secondary sources of pollution to the overlying water column as indicated by the persistently high metal concentrations in the water. Since the polluted environment lowers the beneficial uses of the water body, immediate remedial actions such as dredging and capping appear to be appropriate.

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