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Evaluation of the status and distributions of heavy metal pollution in surface sediments of the Langat River Basin in Selangor Malaysia

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ABSTRACT

The concentration of four metals: Cd, Ni, Cr, and Sn, in the surface sediment samples from the Langat River were evaluated. Multivariate techniques were used to apportion the sources of the metals. The results showed that the highest concentration of metals in the Langat River were found at Jenjarom station, with the concentration of these metals decreasing in the order of Sn > Cr > Ni > Cd (114.27, 21.03, 7.84, 0.59 $\mu g\ g^{-1}$ dry weight). The level of pollution in the sediment was assessed using contamination factor (CF), pollution load index (PLI), geo-accumulation index (Igeo), and enrichment factor (EF). The results of the pollution assessment showed that the Langat River sediments have severe enrichment of Sn and moderate to severe enrichment of Cd. The results of the PLI for the Langat River suggest that the sampling stations are not polluted with the exception of the Jugra, Jenjarom, and Jalan Hulu Langat stations.

Langat River has grown to be one of the most developed areas in Selangor, serving approximately 1.2 million populations. It is an important energy source and acts as a control for flood discharges (Juahir et al., 2011). Langat River is known as an important water source that is not only limited to supplying water to the consumer but is also used for other purposes such as recreation, fishing, effluent discharge, irrigation, and sand mining (Juahir, 2009). Recently, the river was exposed to different pollution problems such as industrial, domestic sewage, agriculture activities, and sand mining. Previous studies have shown various levels of Cd, Ni, and Cr in the Langat River adjacent to industrial estates and urban areas and Sn has rarely been studied before in the Langat River. However, Wan et al. (2012) and Shafie et al. (2014) reported that the potential impact of metals appeared to be low in Langat River and that it was generally unpolluted by Cd, Ni, and Cr in regard to surface sediment. The objectives of the present study are: (i) to monitor the current concentrations of Cd, Ni, Cr, and Sn in the surface sediments of the Langat River of Malaysia and (ii) to identify possible sources and locations of anthropogenic metals using multivariate techniques.

Twenty-seven surface sediment samples (0–5 cm) from nine stations in Langat River were collected with an Ekman grab from January to February 2015. To avoid metal interaction between sample locations, the Ekman grab was washed in clean water after each sampling (Doherty et al., 2000). The sampling locations include Jugra, Jenjarom, Banting, UKM, Kajang, Cheras, Hulu Langat, Batu Hulu Langat, and Pangsun (Fig. 1). The location, designation, description, longitudes, and latitudes of the sampling stations are recorded and documented in Table 1. About 0.5–1 g of dried sediments were digested in a mixture of 10 ml of HNO_3 solution (AnalaR grade, R&M 65%) and $HClO_4$ (AnalaR grade, R&M 70%) according to a ratio of 4:1 (v/v), into a pre-heated block digester at low temperature (40 °C) for 1 h and then at 140 °C for 3 h (Ismail, 1993). The digested samples were left to cool and then diluted to 40 ml with double-distilled water (DDW) and filtered through a Whatman No. 1 filter paper into pre-cleaned 40 ml volumetric flasks. The filtered sample was measured for trace metal concentration using an air-acetylene flame Atomic Absorption Spectrophotometer (Perkin-Elmer Model AAnalyst 800). The data was measured based on a dry weight basis (μg/g dry weight).

Quality assurance and quality control (QA/QC) were implemented to check the analytical performance of the measurements for the studied metals in sediments and in order to avoid contamination; all glassware was soaked in an acid wash (10% HNO_3) for at least 24 h and later rinsed with double distilled water and air-dried before use. To ensure precision and accuracy of the analytical method, quality control calibration curves were generated by analyzing multiple-level calibration standards, and standard solutions of each metal studied were prepared from 1000 mg/l (BDH Spectrosol®) stock solution. Laboratory quality control consisted of analyses of sediment certified reference materials (PACS-2, Canada). The results for the contents of this experiment in regard to the three replicates are reported in Table 2. A blank was used to zero the instrument and quality control samples were analyzed after every 5 samples during the metal analysis.

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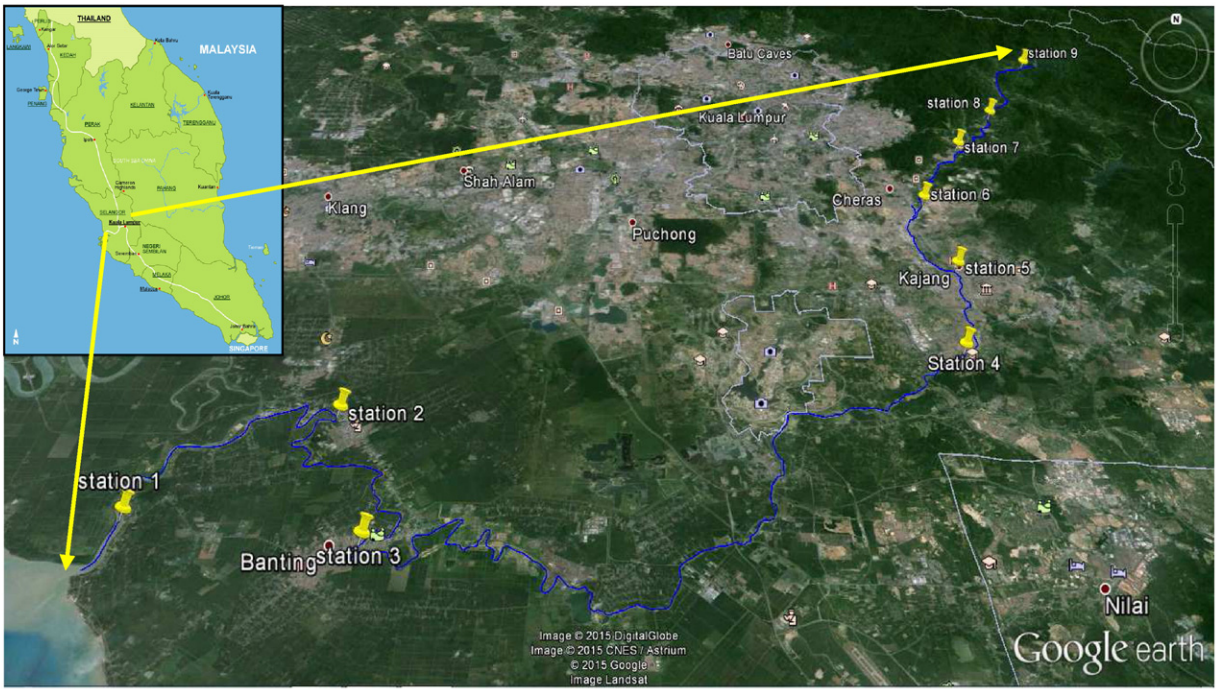

Fig. 1. Map of Langat River catchment and sampling stations.

Sediment pH was determined according to McLean (1982) and the total organic matter (TOM) was expressed as loose on ignition (L.O.I.) by calculating the difference between the dry weight of the sediment samples before and after ashing in a muffle furnace at 550 °C for 5 h (Arain et al., 2008; Kazi et al., 2005).

The river water sample was collected from nine stations and the determination of the physicochemical properties of water was conducted using the YSI method. Water samples were only collected at a single depth, which was 1 m, without disturbing the muddy sediment surface.

Heavy metals, pH (sediment), TOM (%), pH (H_2O), DO, and salinity of the surface sediment and water were collected from nine locations and are summarized in Table 3. The mean values of heavy metal in the surface sediment of Langat River in the previous studies are also presented, which are used as reference values (Wan et al., 2012; Shafie et al., 2014). The mean concentration of Cd, TOM, and salinity of the samples was significantly higher when compared with the reference values from previous studies. The highest pH.sediment value was 6.77 (station 5) but the lowest pH value was 4.38 (station 7) and the highest pH (H_2O) value was 7.91 (station 1) whereas the lowest pH value was 6.25 (station 7). Changes in pH will have profound effects on the speciation of dissolved heavy metals. Decreasing pH reflects increasing hydrogen ion concentrations. Positively charged hydrogen ions protonate ligands in solution, thus, replacing metals and causing an increase in free metal ion activity. The additional H^+ ions at low pH may also compete with metal ions at the membrane binding site and decrease the rate of metal uptake (Luoma and Rainbow, 2008). The mean TOM and salinity values were highest in station 1 (34.6%) and lowest in station 9 (8.7%). Organic matter levels in sediments provide a good indicator of metal bioavailability and mobility due to its great affinity to heavy metals (Arain et al., 2008; Hu et al., 2013). The salinity range in Langat River ranged from 8.14 ppt to 22.21 ppt. The mean of dissolved oxygen (DO) water ranged from 2.56 mg/l to 6.60 mg/l. Salinity can also affect the mobility and bioavailability of the metals because changes in salinity from freshwater to saline waters often induce the precipitation of iron and manganese oxyhydroxides from both soluble ions and colloids, carrying other metals and organics (ANZECC, 1999).

The concentration of the studied metals decreased in the order of Sn > Cr > Ni > Cd (114.27, 21.03, 7.84, 0.53 μg g^{-1} dry weight) respectively. In order to predict the heavy metal pollution, a comparative study was performed using the sediment quality guidelines (SQGs) proposed by USEPA (Luo et al., 2010). The effect range low (ERL), and the effect range median (ERM) (NOAA, 1999) are listed in Table 3. The present results show that Cd concentration in all the stations are below the values of ERL (1.2 μg/g) and ERM (9.6 μg/g). However, the concentration of Cd in most stations was above the background concentration of non-contaminated sediment (0.17 μg/g) suggested by Salomon and Forstner (1984). Concentrations of Ni in sediments at all stations were below the ERL values (20.9 μg/g) and ERM (51.6 μg/g) and Cr concentrations in all stations were well below the values for ERL (81 μg/g) and ERM (370 μg/g). There were no ERL and ERM values

Table 1
Names and coordinates of the sampling stations for the surface sediment and water at Langat River.

No.	Sampling site	Coordinates	Description
1	Jugra	N 2°49′27.94″ E 101°24′52.39″	Agriculture area, boat harbor, oil palm
2	Jenjarom	N 2°52′57.81″ E 101°29′20.06″	Fisheries, residential area, oil palm agriculture
3	Banting	N 2°48′56.87″ E 101°30′46.66″	Residential area, factory
4	UKM	N 2°55′52.99″ E 101°46′31.22″	Residential area, bridge
5	Jalan sungi Kajang	N 2°59′35.75″ E 101°47′07.58″	Waste dumping, fisheries, industrial or human settlements nearby
6	Cheras Bandar	N 3°03′06.55″ E 101°46′46.76″	Domestic waste discharge, industrial or human settlements nearby, fisheries
7	Jalan Hulu Langat	N 3°06′32.55″ E 101°48′41.48″	Waste dumping, sand mining, fisheries
8	Batu, Hulu Langat	N 3°08′46.2″ E 101°50′22.3″	Agricultural area
9	Pangsun	N 3°12′45.63 ″ E 101°52′42.17″	Dam river, recreational area