Asian Journal of Chemistry Vol. 19, No. 1, (2007), 810–812

NOTE

Streamflow-Metal Relationship in a Highly Urbanized River Basin: The Blackstone River, Massachusetts, USA

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Although many water contaminants can be found in urban runoff, certain pollutants depending on site specific characteristics can be used as representative indicators. In this study, copper and lead were taken into account as metal contaminants. The Blackstone River, an interstate river with 74 km length, was examined. Total lead concentration and both lead and copper loads in the river were found to be a function of flow rate. Lead concentration and load is highly depended upon streamflow than that of copper concentration. Furthermore, wet weather was found to be the main responsible factor of increasing total metal concentrations and loads in the river.

Key Words: Copper, Lead, Blackstone River, Urbanized stream, Streamflow.

The Blackstone River is known to be the most important heavy metals contributing factor to the Narragansett Bay[1], one of the most popular summer sightseeing and recreational locations in New England. Besides, two remarkably populated urban centres with over 170,000 inhabitants, Worcester in Massachusetts and Providence in Rhode Island, are located within this river basin boundary. Noteworthy contamination in the area had even occurred in the 19th century when water mills, textile industries and other industrial production facilities were realizing the American Industrial Revolution and at the same time discharging all kinds of their wastes into the river[2]. From early to late 1900s, a 47% increase in total residues in the river was recorded[1] due to increased (mostly treated) wastewater discharges, soil erosion and road salting during winter months. The river basin occupies approximately 850 km^2 in its upper sector situated in Massachusetts. Its total basin area is approximately 1400 km^2. Despite its small size, it is located on a remarkably populous area (population density of over 400 people per km^2) in New England. 21% of the river basin is classified as urban

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and for this reason, municipal wastewater discharge yield in the basin is remarkably high (daily 3340 tons km^{-2})[1].

Daily rainfall data was obtained from NOAA. Four remarkable precipitation events happened between May 9 and June 2, 2001 (total 24 days).

Stream water samples were collected daily at around 1.00 pm from the output of Rice City Pond (Coordinates: 42°05′56″ N and 71°13′58″ W). A Perkin-Elmer® AAnalyst 300 Atomic Absorption Spectrometer situated at Worcester Polytechnic Institute Environmental Engineering Lab was engaged in completing the analyses. The analysis of water column samples was performed on furnace method and 15, 40 and 60 $\mu g\ L^{-1}$ standards of copper and of lead were prepared from the stock solution before the samples were analyzed. The correlation coefficients for copper and lead were read as 99.65 and 99.57% respectively. The water column sample lead and copper concentrations were determined by using furnace method. The impact of contaminants on a water body might be affected by both the concentration and by the load. Load (mass over time) is computed by multiplying pollutant concentration (mass over volume) with water flowing with a rate Q (volume over time)

$$L_{pollutant} = C_{pollutant} \times Q$$

Along with contaminant level and flow rate, the number of dry days before the first precipitation event in urbanized or industrialized basins is another important independent variable that affects contaminant concentration and load in any stream which is called 'first-flush effect'.

There is a distinction between copper and lead concentrations in the water column. With respect to streamflow, lead concentration changes more orderly compared to copper. While lead level and lead load were found to change linearly as a function of streamflow, only copper load was observed to depend linearly on streamflow. Fig. 1 illustrates both concentrations and loads of lead and copper in the Blackstone River.

The average lead concentration in the Blackstone was computed to be approximately 28 $mg\ L^{-1}$. Mean lead load was calculated to be 12 $kg\ d^{-1}$. The minimum and maximum lead concentrations, 10.87 and 86.37 $mg\ L^{-1}$, and loads, 2.93 and 59.4 kg d^{-1}, were found to be highly variable during the study period despite the fact that there is only 2.5 times difference between the maximum and minimum flow rates. There are 8 and 20 times differences between the maximum and minimum lead concentration and loads, respectively.

The minimum and maximum copper concentrations were observed to be 44.2 and 76.4 $mg\ L^{-1}$, respectively. Less than two-fold difference exists between these values. Furthermore, the minimum and maximum copper loads were found to be 12.64 and 52.5 $kg\ d^{-1}$, respectively. There is slightly more than 4 times difference between the maximum and minimum copper loads exists. It is interesting that while lead concentration keeps increasing as a function of riverflow between 3 and 6 $m^3\ s^{-1}$, a slight decrease, if not stagnant, in copper concentration between the same flow rate occurred. Lead and copper loads, however, were both found to increase with respect to the streamflow.

Following a long dry period, a 0.5 $cm\ m^{-2}$ rainfall caused a 47.8% increase in the copper load at the sampling station (Rice City Pond outlet on the Blackstone River) on 12th of May, 2001 occurred. 22nd, 23rd and 24th of May were also observed to have rainfall (1.52, 0.74 and 1.07 $cm\ m^{-2}$) and while discharge increase was

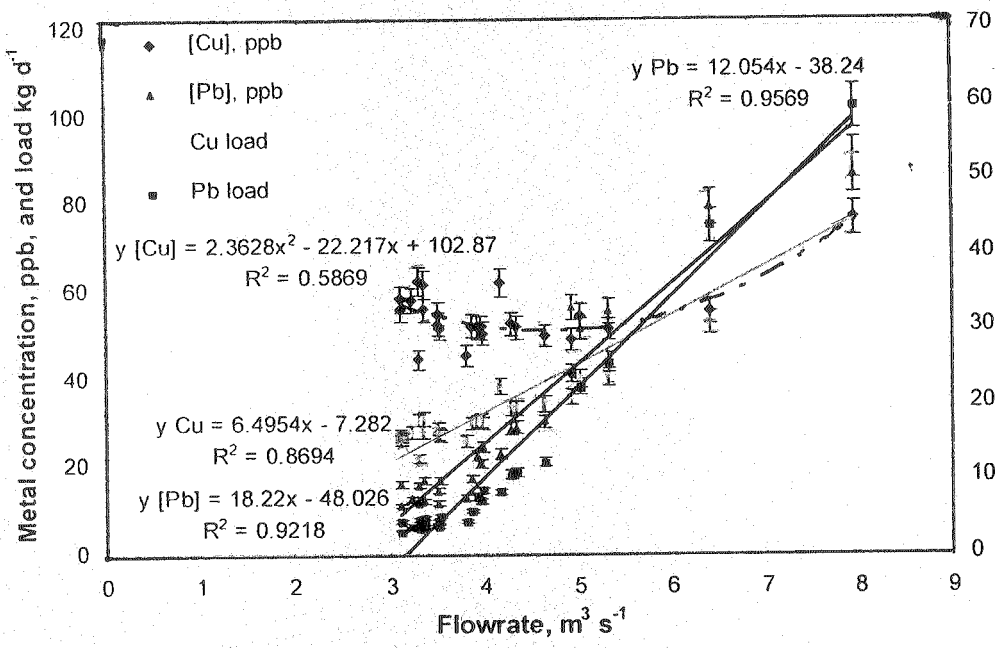

Fig. 1. Copper and lead levels and loads with respect to flow rate in the Blackstone River, Massachusetts (left y-axis is for concentration and right y-axis is for metal load).

computed to be 12.7, 18.5 and 53.7%, respectively, 10.3, 34.1 and 37.8% increases, with respect to the previous day, in the copper load were computed.

At the same time a 414% increase in lead load, which is more than 8-fold higher than the copper load, was computed on 12th of May. On the following wet days, 18.6, 134 and 438% increases in lead loads were computed on 22nd, 23rd and 24th of May. This means accumulation of rainfall amount increases the lead load in the river remarkably.

Lead load, as well as lead concentration in the water column in the Blackstone River, was found to be more sensitive to changes in streamflow. As noted by Windom *et al.*[3], the increase in suspended solids with elevations in urban runoff and streamflow is responsible for rise of lead concentration and load due to the fact that 90% of lead, however only 40% of copper, is carried as suspended solid particles in eastern US rivers. In Fig. 1, larger slope coefficient in fit line for lead load confirms this situation. Özdilek *et al.*[4] postulated that notably high increases in metal loads do not only depend upon urban runoff but also are caused by metal contaminated sediment resuspension from impoundments.

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(*Received*: 29 December 2005; *Accepted:* 30 June 2006) AJC-5018