Heavy Metal Accumulation in the Sediments of a Washington Lake

R. W. Wisseman and S. F. Cook, Jr.
The Evergreen State College
Olympia, Wash. 98505

INTRODUCTION

The accumulation of heavy metals in estuarine and lake sediments is becoming a problem of some concern, especially in more industrial and urban environments (ISKANDAR and KEENEY 1974). PITT and AMY (1973) and SARTOR and BOYD (1972) found that street surface particulate matter contributed high levels of certain heavy metals (particularly lead and zinc) to storm water drainage. VALIELA et al. (1974) were concerned with the fate of metals added to salt marsh sediments. Lead was found to be highly retentive, while zinc and cadmium showed some transport from the marsh sediments. BANUS et al. (1974) found that lead was transported from salt marsh sediments through uptake by vegetation and its subsequent decay. HOLMES et al. (1974), found that zinc and cadmium were accumulated in harbor sediments under stagnant summer conditions and redistributed in bay sediments during increased circulation in the winter.

This study reports the findings of heavy metal accumulation in the sediments of Wapato Lake, Tacoma, Washington. Of particular concern was the contribution of highway and city street runoff, and the distribution of these materials within the lake basin.

DESCRIPTION OF AREA

Wapato Lake is a shallow (mean depth of 2.0 m), urban lake of glacial origin, located in south Tacoma, Pierce County, Washington. The 12 hectare lake exists as a perched aquifer underlain by a glacial till hardpan. A 32 hectare municipal park surrounds the majority of the lake. Recent urbanization has created an almost entirely artificial drainage basin of city streets and storm drains.

The approximate area of the drainage basin is 4.2 km^2, of which 76% is urban residential, 13% undeveloped park land, 8% Interstate Highway 5, and 3% lake surface (CANNING et al. 1976). Surface water enters the lake almost exclusively from two storm drains. The north shore storm drain carries water from 2.7 km of Highway 5 (80,000 veh./day), and 17.7 km of city streets. Surface water draining from 27.4 km of city streets enters the lake on the east shore via a leveed channel. This storm drainage water enters the lake with no treatment. Of the 98.6 cm average annual rain-

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fall, most occurs in low intensity storms in the winter. Water flux through the lake is extremely slow.

Emergent macrophytes (Typha latifolia and Polygonum hydropiperoided) cover a significant portion of the north end of the lake, slowing water flow from the north shore conduit. The leveed channel carrying drainage from the east shore conduit is free of macrophytes and obstructions.

SAMPLING AND LABORATORY PROCEDURES

Sampling stations for the main lake sediments were located in open water. Littoral areas were avoided due to the presence of emergent vegetation and disturbance by gravel filling. Transects were placed at 60 meter intervals at the north end of the lake basin, and 120 meter intervals at the southern end. One to four samples were taken from each transect with a 6x6 inch Eckman dredge during January 1976. Approximately equal portions of the top 3 cm of sediment were taken from each of three seperate grabs at a station, homogenized into one composite sample, and stored at 4°C until analyzed.

Sediment samples were thoroughly mixed, dried at 60°C for 48-72 hours, and pulverized in porcelain mortars and pestles. A 3 g subsample was weighed into a 125 ml boiling flask, and 20 ml of concentrated nitric acid was added. Distilling columns (400 mm), were then fitted to the flasks and the samples vigorously refluxed for 3 hours. Samples were then cooled, filtered through glass fiber filters (preleached with 6M HCl), and brought to a 200 ml volume with 2% HNO_3.

Metal analysis was done on a Perkin-Elmer Model 305-B Atomic Absorption Spectrophotometer using an air/acetylene flame. Standard operating conditions were used for all metals (PERKIN-ELMER 1973). Sample concentrations were confirmed by the method of standard additions (using mixed metal standards), with regression analysis.

Recovery of the analytical procedure ranged from 96-104%. The precision of replicate analysis was within 5%.

RESULTS AND DISCUSSION

Surface sediments in the main lake basin were reasonably homogenous, consisting of fine grain muds of high organic matter and moisture content. A representative sampling of sediments indicated the moisture content to be 85$\pm$5%. Of the dried solids, 23$\pm$5% was found to be volatile (550°C ignition). Probings indicated that from 0.5-1.5 meters of mud overlays the glacial till hardpan.

Concentrations of heavy metals found in the sediments of Wapato Lake are presented in Figs. 1 and 2. As can be noted, Pb was found in the heaviest concentrations, followed by Mn, Zn, Cu, Ni, Cr, Co, and Cd. These were the only metals analyzed.

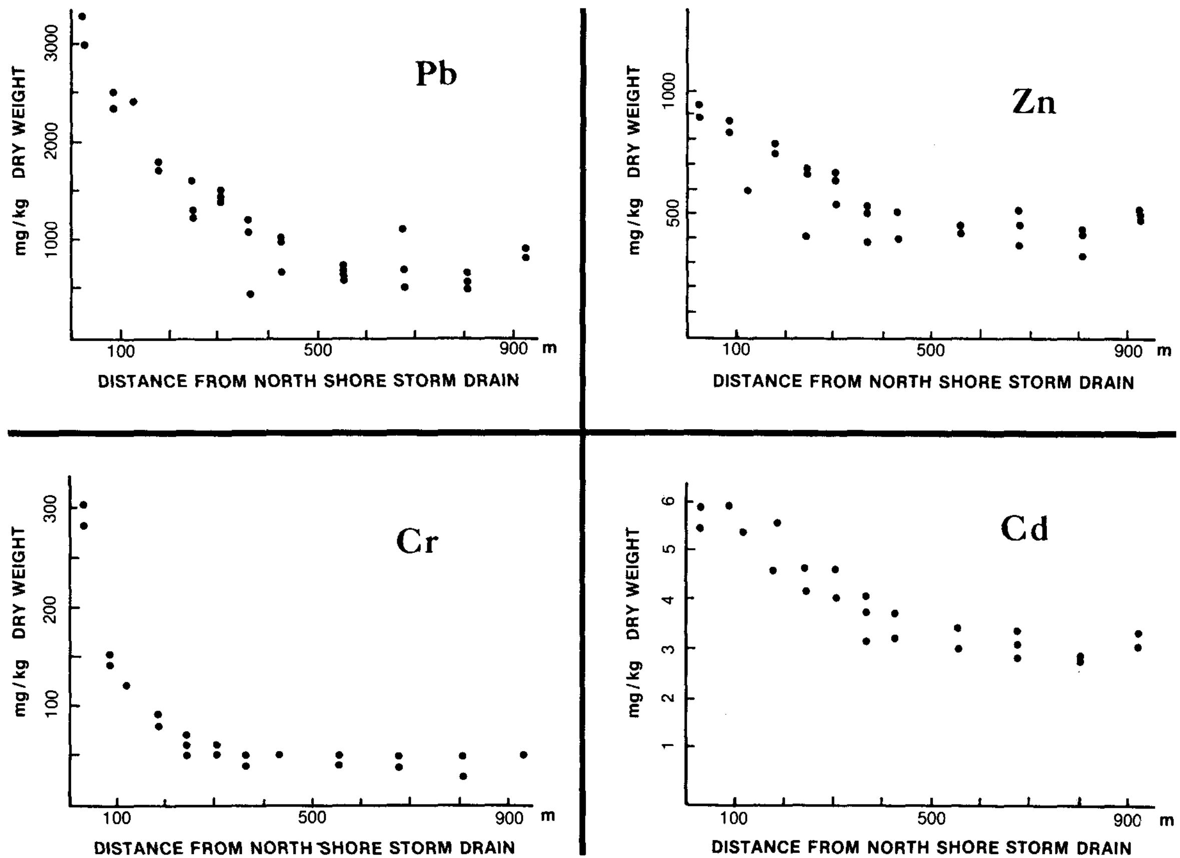

FIG.1. Concentrations of heavy metals in Wapato Lake surface sediments with increasing distance from the north short storm drain.

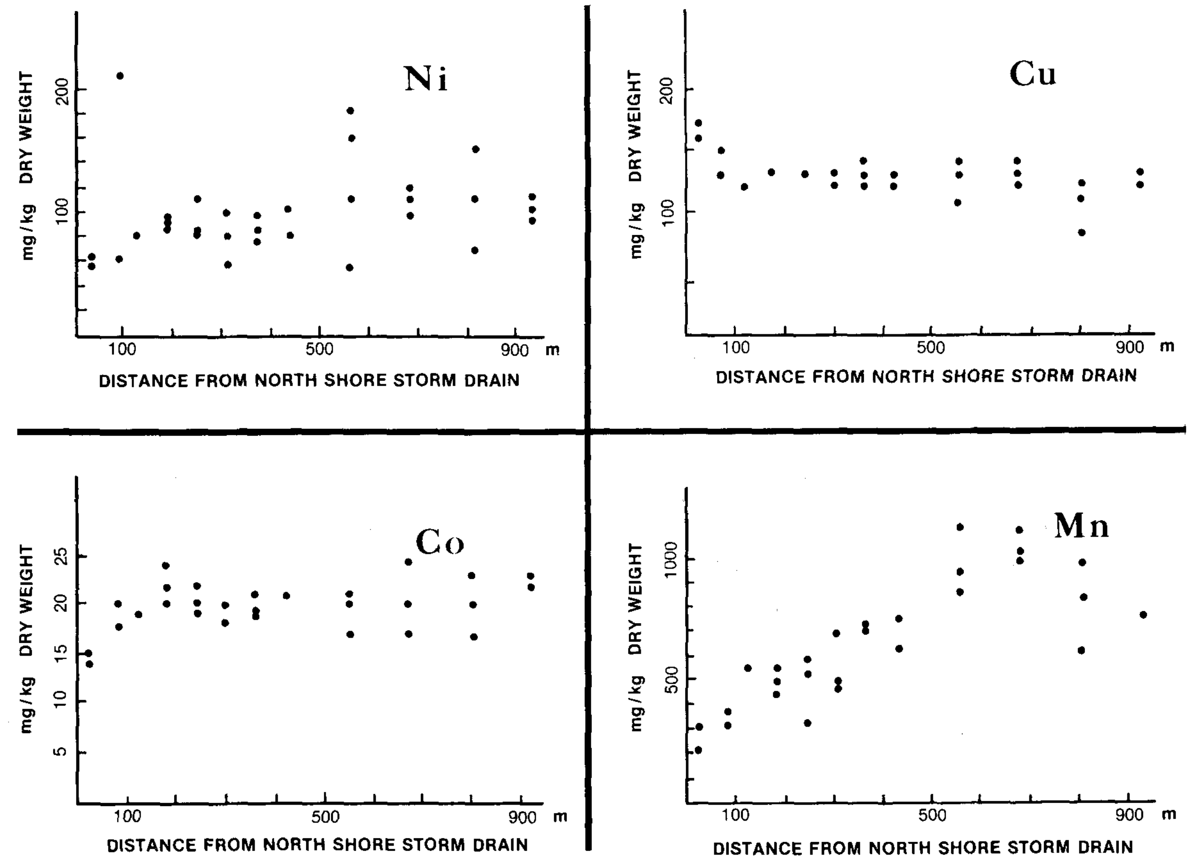

FIG. 2. *Concentrations* of heavy metals in Wapato Lake surface sediments with increasing distance from the north shore storm drain.

Chromium, lead, zinc, and cadmium were found to have a negative correlation (Figs. 1 and 2) between concentration and distance from the conduit draining Interstate Highway 5 and city streets. The rate of falloff of these metals follows the order Cr>Pb>Zn>Cd. Chromium and lead have a particularly high rate of falloff in the shallow area of emergent vegetation at the north end of the lake. Zinc and cadmium show a more gradual falloff.

It appears that the conduit at the north shore, recieving drainage from a heavily traveled highway and city streets, is the major contributor of metals to the lake. Sediments sampled at the mouth of the leveed channel on the east shore (draining water from residential sectors) contained significantly less metals than the north end of the lake. A significant elevation in concentration was not found at the transect in the lake, located immediately out from the east shore channel.

No significant correlation was found between Co, Ni, and Cu with distance down the lake from the north shore conduit. The lake has a history of copper sulfate treatments. Exact dates and amounts added could not be ascertained, however. Copper and cobalt exhibited a relatively narrow range of concentrations throughout the lake basin. Nickel displayed a high variability, with large variations noted from samples taken from the same transect. Although the storm drains are undoubtedly a source of these metals to the lake basin, the distribution observed cannot be related to them from the present data.

Manganese was found to be positively correlated with distance from the north shore storm drain. INGOLS and ENGINUM (1968) have indicated that reducing conditions favor the solubilization of precipitated manganese forms. Stagnant summer conditions in the north end of Wapato Lake may cause the solubilization of considerable amounts of manganese which may be transported to the deeper portions of the lake, where the highest concentrations were observed.

From observation, the emergent vegetation at the north end of the lake is sufficiently effective in slowing water movement from the storm drain, to allow for a significant portion of particulate matter to settle out in the north end of the lake.

CONCLUSIONS

Freshwater and marine sediments are known to be potential sinks for heavy metals discharged into the atmosphere and into water through man's activities. Under natural conditions lake sediments may concentrate heavy metals to a certain extent over surrounding geological material.

Wapato Lake is accumulating high levels of certain heavy metals, particularly lead and zinc, in its sediments from street surface contaminants. This situation is probably of widespread occurrence wherever street surface drainage is discharged directly into natural settling basins of this sort.

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