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Seasonal Variations in the Heavy Metal Concentrations of Sediments Influenced by Highways of Different Traffic Volumes

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The distribution of contaminating waste products, particularly heavy metals, to the roadside ecosystem is cause for considerable concern, due to both the documented toxicity of these metals at low concentrations and their accumulation by resident organisms. The elements of major concern are lead from gasoline engine exhausts, nickel from both diesel fuel and lubricating oil, and cadmium and zinc from rubber tires.

Lead has been correlated to traffic density in various components of the terrestrial ecosystem (MOTTO et al. 1970, JEFFRIES and FRENCH 1972, GOLDSMITH and SCANLON 1977). Similar results were reported by GISH and CHRISTENSEN (1973) for nickel, cadmium, and zinc, as well as lead. Information concerning concentration of heavy metals in roadside aquatic ecosystems is very limited. To provide an initial assessment of contamination from this source, we determined seasonal concentrations of heavy metals in stream sediment as related to traffic density. Heavy metals entering the stream ecosystem in runoff are rapidly adsorbed to sediment (GALE et al. 1973, GETZ et al. 1977), providing a stable indicator of local contamination. Analysis of seasonal change in the heavy metal load of the sediment provides insight concerning the importance of runoff relative to sediment-water interaction and uptake by other components of the system.

METHODS

Study sites were located on Back Creek, a part of the Roanoke River watershed near Roanoke, Virginia. The Back Creek area is lightly populated and lacks industrial development. Two sites were located at points of contact of highways with the stream, while a third site upstream of all traffic contact served as a reference. Traffic averaged 15,000 vehicles/day at the most downstream site (Rte. 220) and 6,550 vehicles/day at the second site, 6.5 km upstream (Rte. 221). Basic water quality was comparable at all sites. Water hardness ranged from 16-54 mg/l as $CaCO_3$.

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Sediment collections were made at each site during each of the four seasons over a one-year period. The samples were then dried, ashed, and allowed to digest thoroughly in a solution of 1 HNO_3:1 HCl:2 H_2O. Analyses for lead, nickel, cadmium, and zinc content were then performed using a Perkin-Elmer Model 460 atomic absorption spectrophotometer. Water analyses for temperature, dissolved oxygen, alkalinity, hardness, turbidity, and dissolved, suspended, and total metals were performed according to standard methods (APHA et al. 1976).

Subsequent analysis of the data indicated a nonnormal distribution with symmetry about the medians. Testing for differences between groups was therefore performed using the Kruskal-Wallis test for one-way layouts and the Jonckheere procedure for *a priori* ordered alternatives, while correlations were tested using Spearman's rank correlation method (HOLLANDER and WOLFE 1973).

RESULTS AND DISCUSSION

Analysis of streamwater indicated that during normal flow periods, concentrations of lead, cadmium, nickel, and zinc are extremely low(TABLE 1), not exceeding values reported for uncontaminated North American streams (U.S. ENVIRONMENTAL PROTECTION AGENCY 1971, DURUM 1974).

TABLE 1

Concentrations of lead, nickel, cadmium, and zinc in streamwater at each area.

Study area	Component	Concentration (mg/l) Lead	Nickel	Cadmium	Zinc
220	Dissolved	≤.004	≤.004	≤.0005	≤.018
	Suspended	≤.038	≤.017	≤.0025	≤.110
	Total	≤.004	≤.004	≤.0005	≤.020
221	Dissolved	≤.004	≤.004	≤.0005	≤.018
	Suspended	≤.026	≤.011	≤.0006	≤.100
	Total	≤.004	≤.003	≤.0005	≤.021
Ref.	Dissolved	≤.003	≤.003	≤.0005	≤.015
	Suspended	≤.010	≤.010	≤.0010	≤.080
	Total	≤.003	≤.003	≤.0005	≤.014

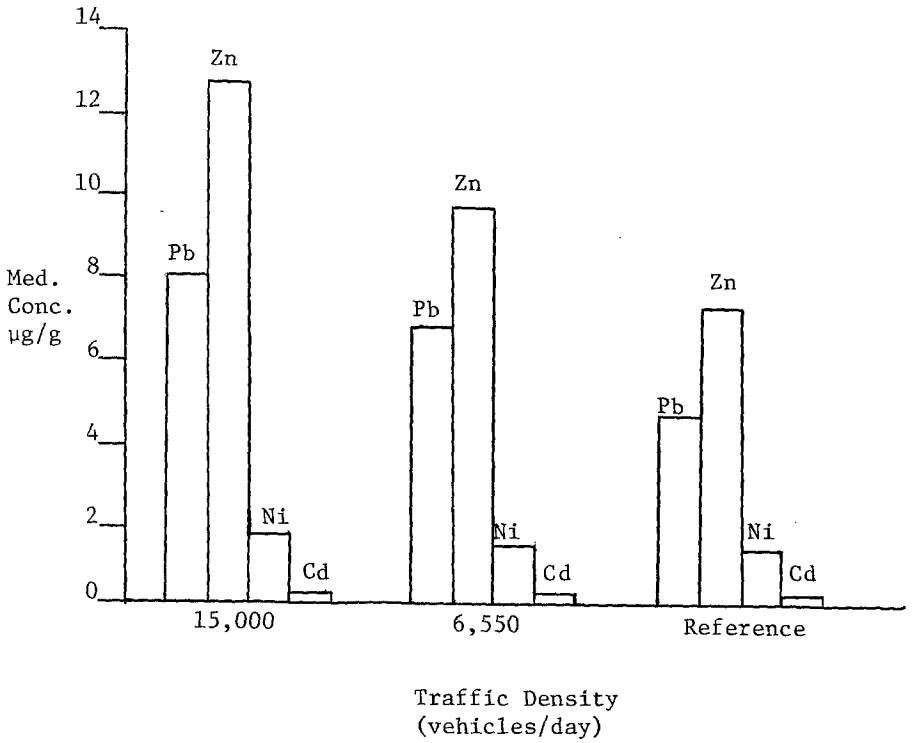

Fig. 1. Median concentrations of lead, nickel, cadmium, and zinc in sediments at each area over a one-year period.

Sediment loads of lead, nickel, and zinc were all highly correlated ($P < .003$) to the traffic volumes received by each study area, respectively (Fig. 1). Only cadmium was not significant ($P > .15$). Concentrations of sediment cadmium were very low (<0.02-0.24 µg/g) at all sites. Concentrations of other metals ranged from 200 to 9000 times greater in sediment than in stream water.

Sediment concentrations of lead and zinc were highest at each area in the spring, showing similar decreases through summer, fall, and winter. Fig. 2 illustrates the significantly higher ($P < .005$) concentrations of lead and zinc for all areas in spring, and the gradual decrease over the remainder of the year. The high concentrations in spring are most likely a result of runoff of metal-laden snow from the roadsides and surrounding regions of particulate deposition, and subsequent adsorption to trapped sediments in the stream. Uptake by other components of the system and the gradual tendency toward an equilibrium sediment-water interaction may account for the decrease in sediment loads of lead and zinc during the remainder of the year.

Seasonal variations in nickel and cadmium were not significant ($P > 0.25$) at any site. No spring data were obtained for nickel, which followed a pattern similar to lead and zinc for summer, fall, and winter concentrations. Concentrations of cadmium in sediment were so low that no significant seasonal variation was apparent.

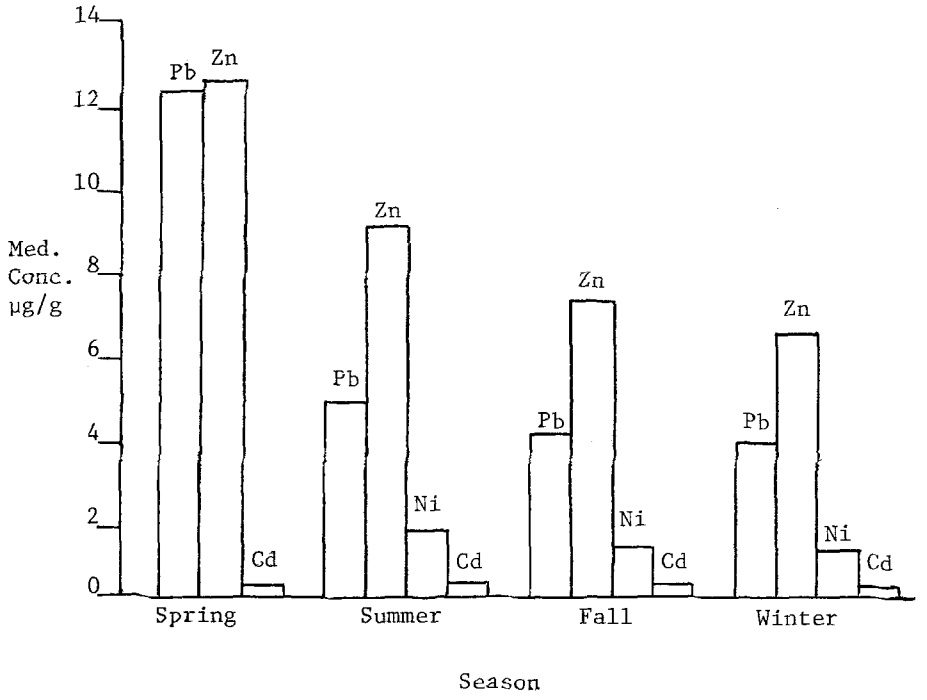

Fig. 2. Median concentrations of lead, nickel, cadmium, and zinc in sediments for combined areas over a one-year period.

These findings indicate the potential impact of highway-generated heavy metals on nearby stream ecosystems, especially when runoff is the major contributor of contaminants. The availability of these metals for assimilation by stream organisms is likely to vary widely among systems, depending upon sediment characteristics, the amount of organic matter in sediments and as suspended particulates, the degree of sediment-water interaction, and the characteristics of the organisms themselves. Investigations of these and other relationships between highway-generated heavy metals and aquatic ecosystems are currently underway.

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