U.S. Department of the Interior
U.S. Geological Survey

Presence and Distribution of Trace Elements in Streambed Sediments, New Jersey

Background

The National Water Quality Assessment (NAWQA) Program, developed by the U.S. Geological Survey (USGS), was implemented in 1991 to (1) provide a nationally consistent description of the status of surface- and ground-water quality in systems that represent a large part of the Nation's water resources, (2) determine water-quality trends, and (3) determine relations between past and present water quality and land- and waste-management practices. Information collected and interpreted as part of NAWQA will add to the scientific basis for water-management decisions and policy formulation (Leahy and others, 1990).

The NAWQA Program is organized into 59 study units distributed throughout the United States on the basis of regional aquifers and major river basins. Work in the Long Island-New Jersey (LINJ) study unit (6,000 square miles), one of the most heavily urbanized and populated of the study units, began in 1994.

Along with organic contaminants, trace elements have been identified by water-quality experts as a high-priority issue in New Jersey. Streambed sediments can be a source or sink of trace elements depending on the physicochemical conditions in the water column. Concentrations of trace elements in bed sediments are of particular interest because they may reflect the concentrations in aquatic organisms.

In this study, results of analyses of streambed sediments collected at 295 sites throughout New Jersey during 1976-93 were analyzed. Samples were collected as part of the USGS/ New Jersey Department of Environmental Protection (NJDEP) cooperative water-quality monitoring network. Primary objectives were to (1) document the distribution of trace elements in streambed sediments throughout the State and (2) determine whether the presence of elevated concentrations of trace elements is related to basin characteristics, particularly land use. This fact sheet presents the results of these analyses.

Trace elements in streambed sediments are derived from a variety of sources, including weathering of rocks and soils and both indirect and direct anthropogenic sources. Major indirect sources include atmospheric deposition; industrial emissions from activities such as plating, smelting, and refining; wastewater discharges; landfills; stormwater runoff; and automobile exhaust. Examples of direct sources are fertilizers, inorganic pesticides, and industrial solvents (Fields and others, 1993). Distinguishing among these sources is extremely difficult because of the widespread, undocumented use and industrial release of metals.

Data Analyses

The distribution of trace elements was examined with respect to both physiographic province and major drainage area (figs. 1 and 2). The New England and Piedmont Physiographic Provinces were divided into the northern part, which was modified by glaciation, and the southern part, which was not (fig. 1). Land-use and population-density information for the physiographic provinces is summarized in table 1.

Because land use and population-density vary within the provinces,

Table 1. Land use and population density in major physiographic provinces of New Jersey [Anderson level I and level II land-use data from Fegeas and others (1983); population data from U.S. Bureau of the Census (1991). Land-use values are in percent. CP, Coastal Plain; PD, Piedmont; PDG, Piedmont (glaciated); NE, New England; NEG, New England (glaciated); VR, Valley and Ridge; <, less than]

Land-use category	Physiographic province					
	CP	PD	PDG	NE	NEG	VR
Land use (in percent of physiographic province)						
Urban	6	8	27	3	3	1
Residential	13	17	51	11	13	3
Agricultural	24	48	1	33	8	45
Forest	35	23	11	51	69	46
Water	4	2	4	< 1	5	2
Wetland	16	2	4	< 1	< 1	2
Barren	2	< 1	2	< 1	1	1
Average population density						
People per acre	1.0	1.4	7.1	0.8	0.8	0.2

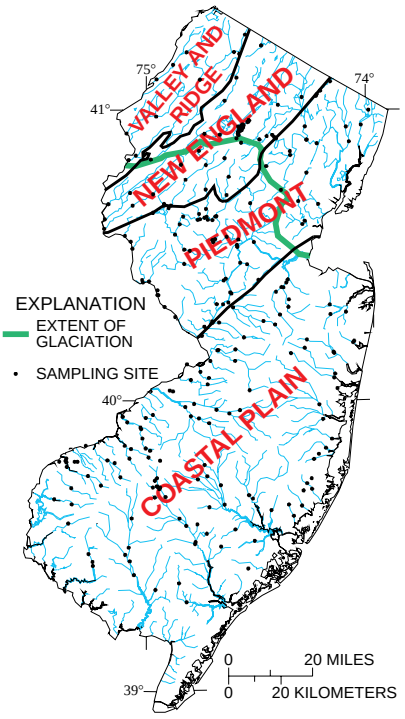

Figure 1. Locations of streambed-sediment sampling sites and physiographic provinces in New Jersey.

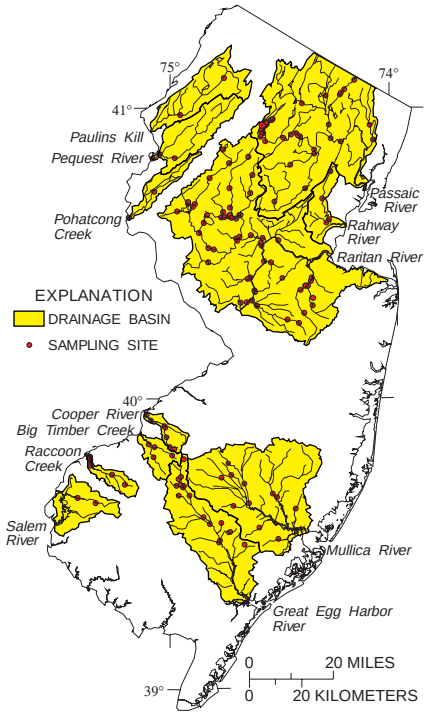

Figure 2. Locations of streambed-sediment sampling sites in selected drainage basins throughout New Jersey.

particularly the Coastal Plain, analyses by major drainage area also were conducted to examine differences in trace-element concentrations with land use. Twelve major drainage basins were selected to represent various stages of development. In order to ensure an adequate number of samples per basin for comparison, the 12 basins were combined into 7 drainage areas (fig. 2). The combined basins are adjacent to one another and had similar land use and population density in the 1970's. Land-use and population-density information for the 7 drainage areas is summarized in table 2.

The Pequest River/Paulins Kill/ Pohatcong Creek drainage area lies entirely within the Valley and Ridge Physiographic Province and the Salem River/Raccoon Creek, Big Timber Creek/ Cooper River, and Great Egg Harbor/ Mullica River drainage areas are entirely within the Coastal Plain. The Rahway River drainage area lies entirely within the Piedmont (glaciated) Province. The Passaic and Raritan River drainage areas encompass parts of several physiographic provinces.

Which trace elements are present at high concentrations and where are trace-element concentrations highest?

Summary statistics were calculated with a log-probability regression technique (Helsel and Hirsch, 1992) to accommodate censored data reported at multiple detection limits. Censored data are concentrations reported as less than the method reporting level. Analysis of variance (ANOVA) was performed on rank-transformed bed-sediment trace-element concentration data to determine whether median ranked concentrations differed among the major drainage areas. Tukey's Honest Significant Difference test (Tukey's test) was performed to determine which concentration ranks differed ($p < 0.05$).

Median concentrations of copper, chromium, lead, and zinc were highest in streambed-sediment samples from the New England (glaciated) Physiographic Province (fig. 3). Results of Tukey's test showed that the concentrations of these trace elements were significantly higher in samples from the New England (glaciated) province that in those from

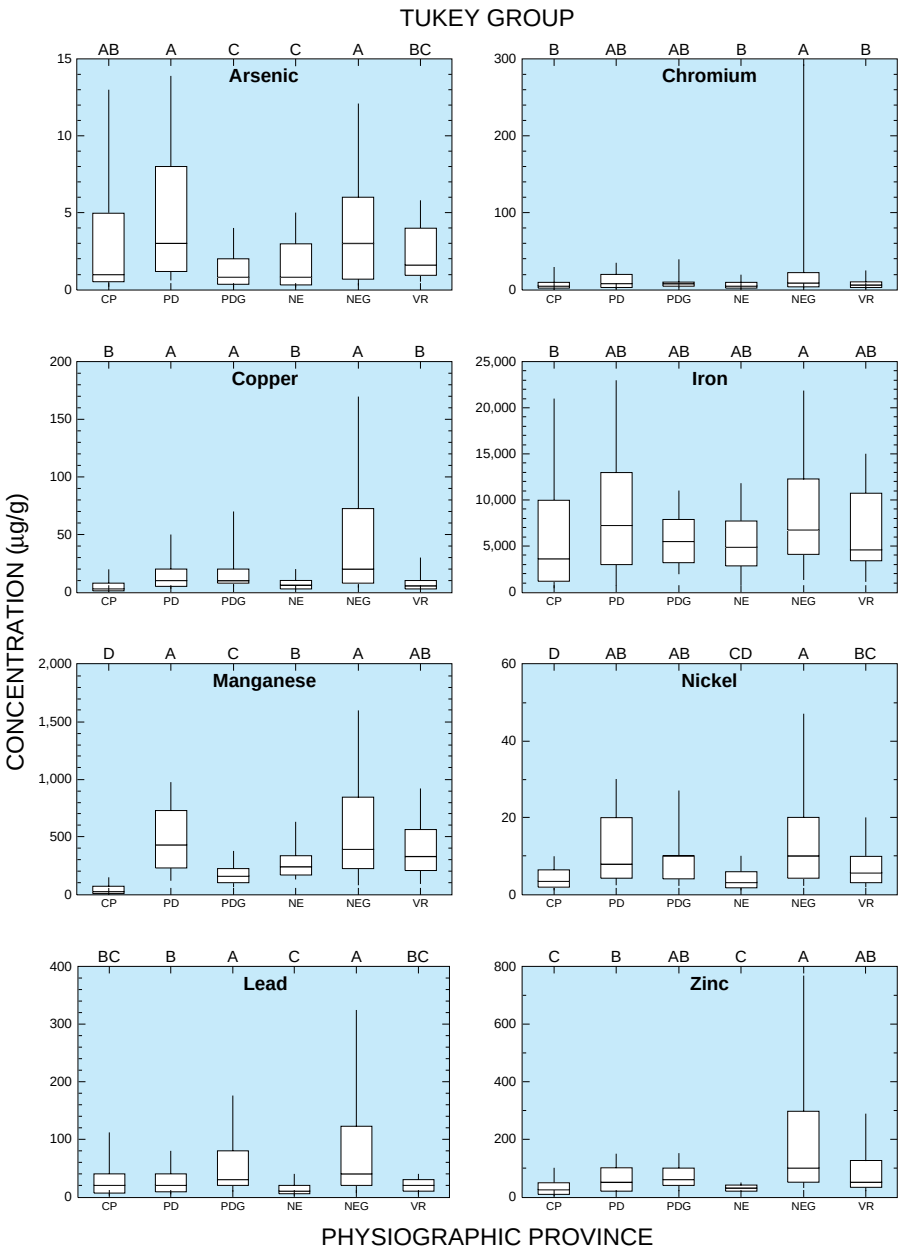

Figure 3. Summary statistics for trace element concentrations and results of Tukey's test of ranked concentrations among physiographic provinces of New Jersey. [Tukey groups are represented by letters A through D; basins in group A have the highest mean concentration rank whereas basins in groups B through D have successively lower mean concentration ranks. Basins that have letters in common do not differ significantly from one another. Physiographic province abbreviations explained in table 1; boxplots consist of a center line (median) splitting a rectangle defined by the 75th and 95th percentiles, whiskers are lines drawn from the ends of the box to the maximum and minium data points (Helsel and Hirsch, 1992)]

Table 2. Land use and population density in selected drainage areas of New Jersey [Anderson level I and level II land-use data from Fegeas and others (1983); population data from U.S. Bureau of the Census (1991). Land-use values are in percent. RAWA, Rahway River; BTCR, Big Timber Creek and Cooper River; PSSC, Passaic River; RRTN, Raritan River; GEMU, Great Egg Harbor and Mullica rivers; SRRC, Salem River and Raccoon Creek; PPP, Pequest River, Paulins Kill, and Pohatcong Creek; <, less than]

Land-use Category	Drainage area						
	RAWA	BTCR	PSSC	RRTN	GEMU	SRRC	PPP
Land use (in percent of drainage area)							
Urban	28	17	13	9	2	3	2
Residential	57	45	35	17	6	6	4
Agricultural	1	16	3	40	12	64	43
Forest	10	17	41	30	54	11	47
Water	<1	2	3	1	2	5	2
Wetland	3	1	4	2	23	11	2
Barren	<1	2	1	1	1	<1	<1
Average population							
People per acre	7.2	5.7	3.5	1.7	0.4	0.6	0.4

the Valley and Ridge, New England, and Coastal Plain provinces (fig. 3). Median concentrations in samples from the Piedmont and Piedmont (glaciated) provinces typically were between the two extremes and could be the same statistically as those in either Tukey group, depending on the trace element (fig. 3).

Median concentrations of copper, chromium, lead, and zinc were highest in streambed-sediment samples from the Rahway and Passaic River drainage areas (fig. 4). Concentrations in samples from these drainage areas were significantly higher than those in samples from the Great Egg Harbor/Mullica River, Salem River/Raccoon Creek, and Pequest River/ Paulins Kill/Pohatcong Creek drainage areas (fig. 4).

The median iron concentration was lowest (3,650 µg/g (micrograms per gram)) in streambed-sediment samples from the Coastal Plain Physiographic Province, but results of Tukey's test show that only the median iron concentrations in samples from the New England (glaciated) and Coastal Plain provinces differ significantly from each other (fig. 3). Median iron concentrations in samples from the other provinces were not significantly different from those in samples from either the Coastal Plain or New England (glaciated) province (fig. 3).

Results of Tukey's test show that the median iron concentration in streambed-sediment samples from the Great Egg Harbor/Mullica River drainage area (1,000 µg/g) was significantly lower than those in samples from the other drainage areas. Median iron concentrations in samples from the other drainage areas ranged from 4,600 µg/g for the Pequest River/Paulins Kill/ Pohatcong Creek drainage area to 8,700 µg/g for the Salem River/ Raccoon Creek drainage area, but these concentrations are not significantly different from one another (fig. 4).

The median manganese concentration was lowest (23.5 µg/g) in streambed-sediment samples from the Coastal Plain Physiographic Province. Results of Tukey's test indicate that the median manganese concentration in sediments from the Coastal Plain is significantly lower than those in sediments from all the other physiographic provinces (fig. 3). Median manganese concentration was lowest (4.0 µg/g) in streambed sediments from the Great Egg Harbor/ Mullica River drainage areas and highest (280 µg/g) in those from the Raritan and Pequest River/Paulins Kill/ Pohatcong Creek drainage areas. Results of Tukey's test show that median manganese concentrations for the Great Egg Harbor/Mullica River and Big Timber/ Cooper River drainage areas are significantly lower than those for all of the other drainage areas (fig. 4).

Concentrations of arsenic in streambed sediments are generally lower and show a smaller range than those of other trace elements. Results of Tukey's test show that the median concentrations in streambed-sediment samples from the New England (glaciated), Coastal Plain, and Piedmont Physiographic Provinces were significantly higher than those in samples from the Piedmont (glaciated) and New England Provinces. Median concentrations of arsenic ranged from 0.8 µg/g for the Rahway River drainage area to 2.0 µg/g for the Raritan River and Salem River/ Raccoon Creek drainage areas. Although median concentration of arsenic was lowest in samples from the Rahway River drainage area, median concentrations of most of the other trace elements were higher in samples from the Rahway River drainage area than in those from all the other drainage areas. Results of Tukey's test, however, did not distinguish among the drainage areas with respect to median concentrations of arsenic.

Median nickel concentrations were lowest in streambed-sediment samples from the New England and Coastal Plain Physiographic Provinces (3.1 and 3.4 µg/g, respectively) and highest in those from the New England (glaciated) and Piedmont (glaciated) provinces (10.0 µg/g). Tukey's test results show that only median nickel concentrations in samples from the Coastal Plain and New England provinces differ significantly from those in samples from the New England (glaciated), Piedmont, and Piedmont (glaciated) provinces (fig. 3). Median nickel concentrations were lowest in samples from the Great Egg Harbor/ Mullica River (2.5 µg/g) and Big Timber Creek/Cooper River (3.1 µg/g) drainage areas and highest in those from the Rahway and Passaic River drainage areas (10.0 µg/g). Tukey's test identified four groups, but none was significantly different from all the others (fig. 4).

Overall, where significant differences in median trace element concentrations were present among the physiographic provinces, streambed sediments from the

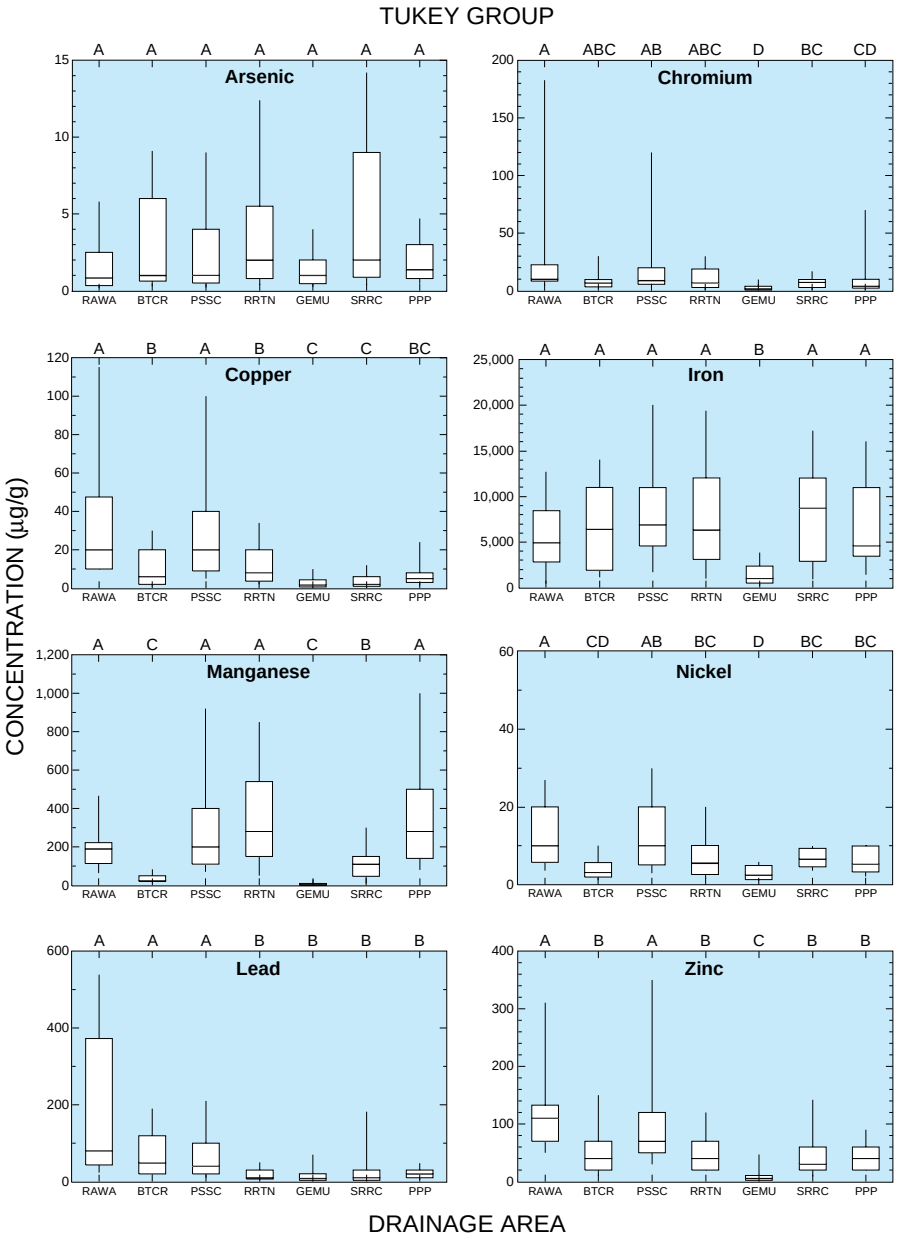

Figure 4. Summary statistics for trace elements and results of Tukey's test of ranked concentrations among selected major drainage areas of New Jersey. (Drainage area abbreviations explained in table 2; Tukey groups and box plots explained in fig. 1)

New England (glaciated) and Piedmont provinces generally contained higher concentrations of trace elements than those from the other provinces. High concentrations in sediments from the New England (glaciated) province reflect the presence of extensive magnetite deposits previously mined for iron ore. High concentrations in sediments from the Piedmont (glaciated) province reflect the high population density and percentage of urban land use in the province (table 1). The Piedmont (glaciated) province placed in the Tukey group with the highest median concentrations of chromium, copper, lead, and zinc, but was not in the Tukey group with highest median concentrations of arsenic, suggesting that the urban environment is a less important source of arsenic than of chromium, copper, lead, and zinc.

Where significant differences in median trace element concentrations were present among the basins, streambed sediments from the Rahway and Passaic River drainage areas, the most highly urbanized drainage areas, generally contained higher concentrations of trace elements than those from the other basins. The Great Egg Harbor/Mullica River drainage area, the least developed of the drainage areas, had significantly lower trace-element concentrations in streambed sediments than the other drainage areas (fig. 4)

Is the concentration of trace elements in streambed sediments related to land use in the basin?

Logistic-regression analysis was used to determine if the distribution of trace elements could be explained by basin characteristics specific to sampling location. Results of this analysis show that the presence of arsenic is related to agricultural land use; that variability in concentrations of chromium results from differences in geology rather than differences in land use among drainage areas; and that the presence of elevated concentrations of copper, lead, and zinc is related to basin population. Results of an analogous study of organic contaminants in streambed sediments in New Jersey show that the presence of organic contaminants is related to basin population (Stackelburg, 1996).

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