

Background

As part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) program, concentration data for 18 hydrophobic chlorinated organic compounds in streambed sediments collected from 100 sites across New Jersey from the late 1970's to 1993 were examined to determine (1) which compounds were detected most frequently, (2) whether detection frequencies differed among selected drainage basins, and (3) whether concentrations differed significantly among selected drainage basins. Sediment samples were obtained from a water-quality-monitoring network established in the late 1960's and maintained by the U.S. Geological Survey (USGS) in cooperation with the New Jersey Department of Environmental Protection (NJDEP). In the late 1970's the scope of sampling was expanded to include annual collection of streambed sediments at one-third of the surface-water-quality sites. Streambed-sediment samples were analyzed for organic compounds and trace elements. The NJDEP has recently expanded its sampling efforts further to include the monitoring of benthic-invertebrate communities in streams across the State. Two studies similar to the current investigation are being conducted to evaluate (1) the presence and distribution of trace elements in bed sediments and (2) benthic-invertebrate communities in streams across the State.

In 1991 the USGS began full implementation of the NAWQA program, which is designed to (1) provide a consistent description of current water-quality conditions for a large part of the Nation's water resources; (2) define long-term trends (or lack of trends) in water quality; and (3) identify, describe, and explain, to the extent possible, the major natural and human factors that affect observed water-quality conditions and trends (Leahy and others, 1990). As currently planned, the program will be conducted in 60 study units across the Nation, which account for 60 to 70 percent of the Nation's water use

as measured by total withdrawals and population served by public water supply (Leahy and others, 1990). In each study unit, long-term, multiscale, interdisciplinary investigations designed to describe surface-water, ground-water, and biological conditions and to assess overall effects on these resources will be undertaken.

One objective of the surface-water component of the NAWQA program is to evaluate the presence and distribution of organic and inorganic compounds in water, suspended and bed sediments, and biota (vegetation, aquatic invertebrates, and fish). This factsheet presents the results of an investigation designed to address this objective for the Long Island-New Jersey (LINJ) NAWQA study by evaluating an extensive data base on chlorinated organic compounds in streambed sediments. Results of this analysis will aid in the design of future surveys of chlorinated organic contaminants in streambed sediments and fish tissues by identifying localities and organic contaminants within the study unit that are of greatest concern.

Chlorinated organic compounds examined in this report are hydrophobic; they tend to sorb to organic carbon in suspended or bed sediments rather than be dissolved in the water column. Because of this behavior, these compounds can be present in sediments in concentrations that are orders of magnitude higher than those in the water column. Therefore, sediments can provide a mechanism by which environmentally persistent hydrophobic organic compounds remain in a surface-water system many years after their initial input (Smith and others, 1988; Rinella and others, 1993). Thus, bed sediments can provide a time-integrated sample of overall water-quality conditions at a site and a means of evaluating the presence and distribution of hydrophobic chlorinated organic compounds over a wide geographical area.

Which compounds are detected and where are detections most frequent?

For this study, 12 drainage basins throughout New Jersey were selected to represent various types and degrees of development (fig. 1). The basins contain a range of land-use patterns and population densities. To ensure an adequate number of samples for statistical comparison among drainage basins, the 12 selected basins were consolidated into seven drainage areas on the basis of similarities in land-use patterns and population densities. Land use and population information for the seven drainage areas is summarized in table 1.

Chlorinated organic compounds detected most frequently were DDT, DDE, DDD, chlordane, dieldrin, and PCB's. DDT and its metabolites DDE and DDD were the most widely distributed organic compounds. These compounds were detected in about 60 to 100 percent of samples from all drainage areas but one

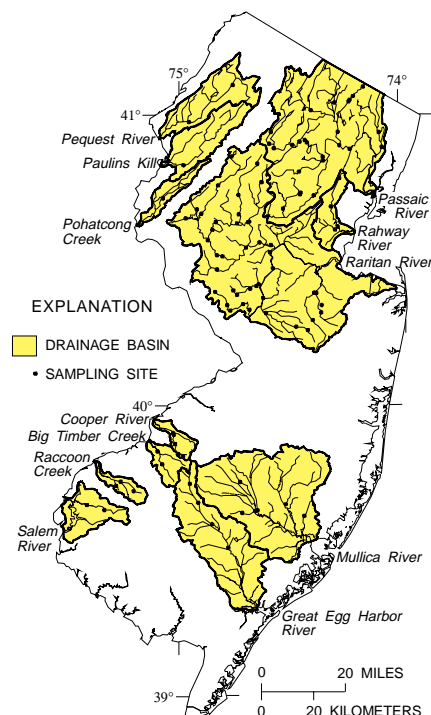


Figure 1. Location of stream-sediment sampling sites in selected drainage basins throughout New Jersey.

(where the detection rate for these compounds was about 20 to 40 percent) (fig. 2). This result reflects the widespread historical application of DDT. Before DDT was banned in the early 1970's, it was used extensively in agricultural areas to control crop pests, in residential areas to control mosquito populations, and in undeveloped and forested areas to control gypsy moths and spruce budworms.

Chlordane and dieldrin were detected in about 80 to 100 percent of samples from highly urbanized and populated drainage areas; detection frequencies for these compounds tended to be smaller in less developed and populated areas (fig. 2). This pattern reflects the more specific application of these compounds; before they were banned in the 1980's, chlordane and dieldrin were used primarily to control termite populations in residential areas.

Chlorinated insecticides that were detected infrequently and at low concentrations include aldrin, endrin, heptachlor, heptachlor epoxide, methoxychlor, perthane, endosulfane, lindane, mirex, and toxaphene.

Polychlorinated biphenyls (PCB's) were detected in about 40 to 85 percent of

samples from all drainage areas; detection frequencies were highest from highly urbanized and populated areas (fig. 2). PCB's are chemically and thermally stable compounds which had a variety of uses primarily associated with industrial applications. The manufacture, processing, distribution and use of PCB's was banned by Congress effective in 1970.

Polychlorinated naphthalenes (PCN's) were not detected in any bed-sediment samples above a detection level of 1.0 microgram per kilogram.

Do concentrations differ among drainage areas?

Analysis of variance (ANOVA) on rank-transformed organic-compound concentrations normalized to sediment organic-carbon content was used to evaluate differences in concentrations among the seven representative drainage areas (Helsel and Hirsch, 1992). The test results indicate whether or not the mean normalized concentration ranks for the organic constituents are equal among all drainage areas. If the mean normalized concentration ranks were found to differ among drainage areas then Tukey's Honest Significant Difference test (Tukey's test) was

performed to determine which mean normalized concentration ranks differed from one another (Helsel and Hirsch, 1992). The distribution of ranked organic-compound concentrations for each drainage area is shown in the boxplots in figure 3 (Helsel and Hirsch, 1992) with Tukey's test results presented as letters for each drainage area. Groups of data with at least one letter in common do not differ significantly from one another.

Because the chlorinated organic compounds discussed in this report are hydrophobic, they tend to sorb to organic carbon in suspended and bed sediments. Thus, sediment samples with greater amounts of organic carbon can sorb higher concentrations of hydrophobic organic compounds. Normalization accounts for differences in concentrations of hydrophobic organic compounds caused by natural variations in the organic-carbon content of sediment samples; therefore, differences observed in normalized concentrations can be attributed to human activities rather than to natural variations in the organic-carbon content of the sediment samples.

Median normalized concentrations of all six of the most frequently detected chlorinated organic compounds were highest in the most heavily urbanized and populated drainage area and lowest in the less populated, predominantly agricultural or forested areas (fig. 3). Concentrations of DDT and DDE, a byproduct of the aerobic degradation of DDT, did not differ significantly among most of the seven representative drainage areas (fig. 3), reflecting the widespread historical application of DDT and the presence of aerobic conditions within most drainage areas. Concentrations of DDD, a byproduct of the anaerobic degradation of DDT, were significantly higher in the three most heavily urbanized and populated drainage areas (fig. 3), reflecting the fact that anaerobic conditions are more likely to be present in highly urbanized basins. Concentrations of DDT differed significantly between the SRRC and PPP drainage areas despite the agricultural nature of both areas (table 2, fig. 3). This pattern reflects the fact that agricultural activities within the PPP drainage area are predominantly associated with livestock produc-

Table 1. Land use and population density in selected drainage areas, New Jersey.

[Land-use data from Fegeas and others (1983); population data from U.S. Bureau of the Census (1991); 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]

Categories	Drainage Areas						
	RAWA	BTCR	PSSC	RRTN	GEMU	SRRC	PPP
Land Use (in percent of drainage area)							
Urban	27.98	16.59	12.39	8.52	1.96	2.79	1.80
Residential	57.21	45.19	35.28	17.19	5.82	5.63	4.21
Agricultural	0.65	15.61	3.26	40.00	11.93	64.08	42.88
Forest	10.24	17.18	40.65	30.22	54.30	11.41	46.65
Water	0.60	1.96	3.12	1.29	2.07	4.51	1.83
Wetland	2.89	1.46	4.06	1.74	22.55	11.29	1.99
Barren	0.44	2.01	1.24	1.04	1.38	0.28	0.64
Average Population							
(people per acre)	7.21	5.71	3.47	1.66	0.38	0.55	0.43

tion; therefore, a large percentage of land classified as agricultural in this area is used for pasture and fodder production, whereas agricultural activities in the SRRC drainage area are primarily associated with row-crop production.

Chlordane and PCB's were identified as the organic compounds with the most highly elevated concentrations in bed sediments across the State. Concen-

trations of chlordane, dieldrin, and PCB's differed significantly among drainage areas with highest median normalized concentrations reported in the most highly urbanized and populated areas and lowest in the least developed, most heavily forested areas (fig. 3).

Relation Between Chlorinated Organic Compounds and Basin Characteristics

Logistic regression (Helsel and Hirsch, 1992) was used to further examine relations between the presence or absence of selected chlorinated organic compounds from 255 sites across New Jersey (fig. 4) and explanatory variables that characterize the type and degree of devel-

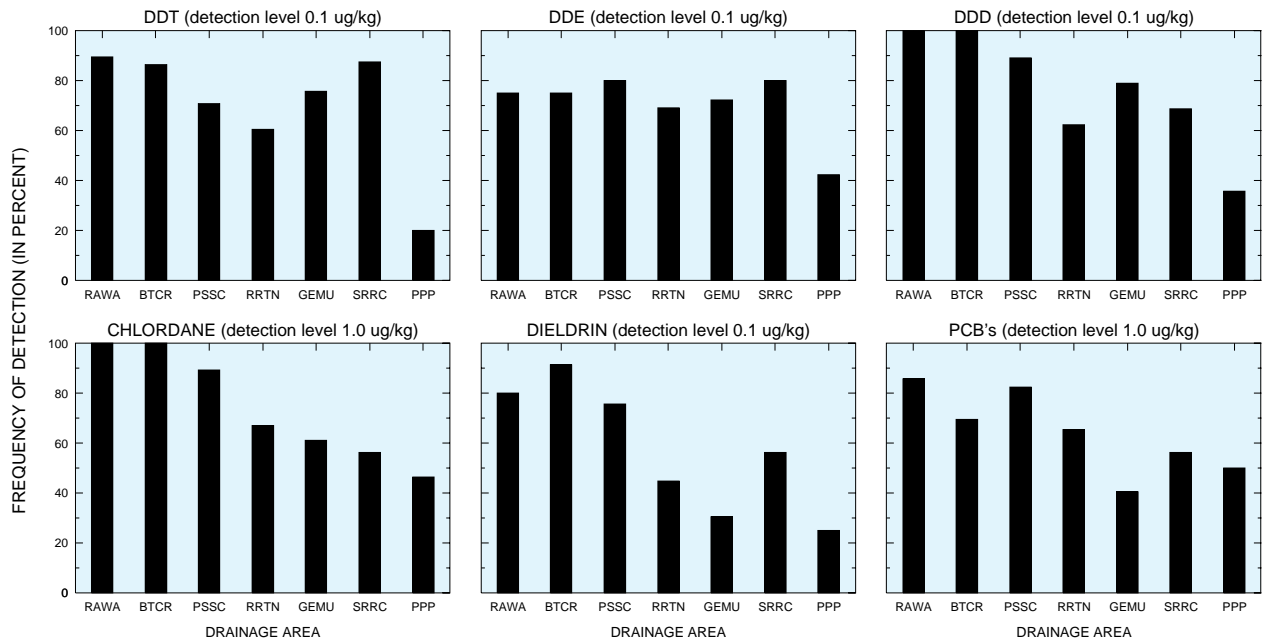


Figure 2. Frequency of detection for selected organic compounds in selected drainage areas, New Jersey. [drainage area abbreviations explained in table 1; ug/kg: microgram per kilogram]

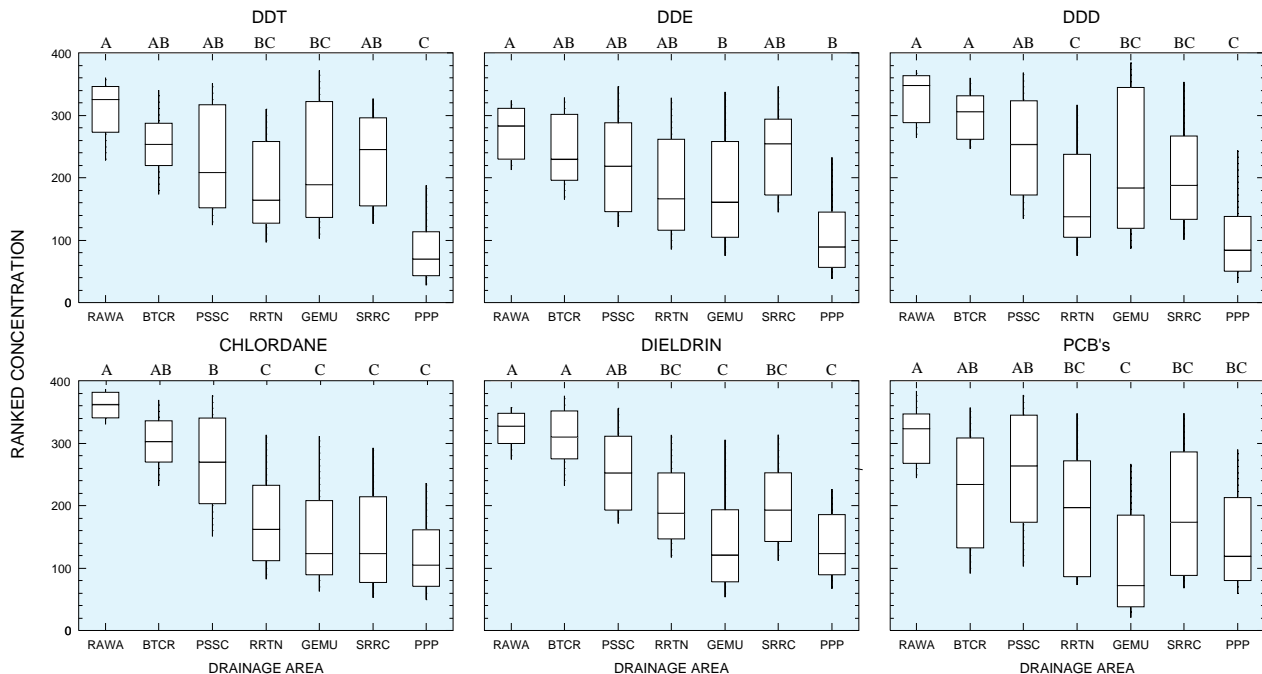


Figure 3. Distribution of ranked concentrations and results of Tukey's test in selected drainage areas, New Jersey. [drainage area abbreviations explained in table 1; boxplots consist of a center line (median) splitting a rectangle defined by the 75th and 25th percentiles, whiskers are lines drawn from the ends of the box to the maximum and minimum data points (Helsel and Hirsch, 1992)]

opment within drainage areas. Results of this analysis confirm that the presence of chlorinated organic compounds in streambed sediments is related to the type and degree of development upstream from sampling sites. Specifically, the total number of people and amount (in square kilometers) of land classified as urban, residential, agricultural, or forested are reliable predictors of the presence or absence of chlorinated organic compounds in streambed sediments.

Summary and Discussion

The six most frequently detected chlorinated organic compounds in bed-sediment samples collected from 100 sites in New Jersey streams from the late 1970's to 1993 were DDT, DDE, DDD, chlordane, dieldrin, and PCB's. Chlorinated insecticides that were detected infrequently and at low concentrations, include aldrin, endrin, heptachlor, heptachlor epoxide, methoxychlor, perthane, endosulfane, lindane, mirex, and toxaphene. Polychlorinated naphthalenes were not detected in any bed-sediment samples above a detection level of 1.0 microgram per kilogram.

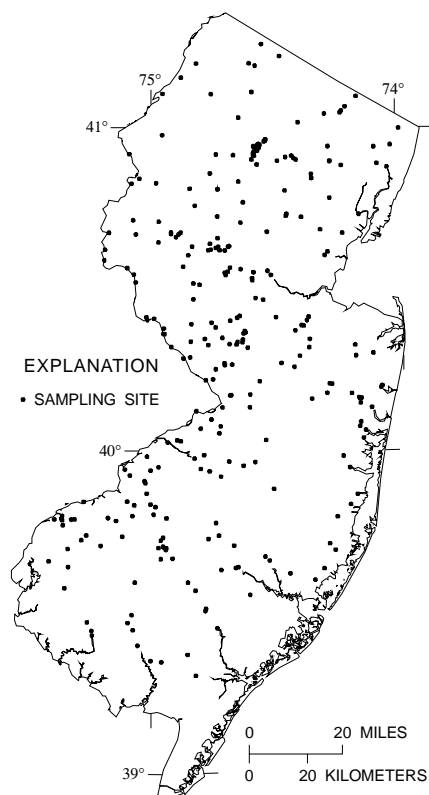


Figure 4. Location of stream-sediment sites throughout New Jersey.

The six most frequently detected chlorinated organic compounds tended to be widely distributed in bed sediments across the State. The most widely distributed compounds, DDT and its metabolites DDE and DDD, were detected frequently in samples from all representative drainage areas. This high detection rate across drainage areas with various land-use patterns and population densities reflects the widespread historical application of DDT in residential, agricultural, and forested areas. The median normalized concentrations of DDT, DDE, and DDD were highest in the most highly urbanized and populated drainage areas; however, concentrations of DDT and DDE were statistically similar in most of the drainage areas.

Chlordane and dieldrin were detected most frequently in bed-sediment samples from the three most highly urbanized and populated drainage areas; detection frequencies tended to be smaller in less urbanized areas. Normalized concentrations of chlordane and dieldrin were also significantly higher in the more highly urbanized and populated areas, and lowest in the agricultural and forested areas reflecting their primary historical use to control termites.

PCB's also were widely distributed. The most frequent detections and the highest normalized concentration were in samples from the most highly urbanized and populated drainage area; the least frequent detections and lowest normalized concentration were in samples from the most heavily forested and undeveloped drainage area, reflecting association of these compounds with industrial applications.

The presence of chlorinated organic compounds in bed sediments was found to correlate significantly with population totals and amounts (in square kilometers) of various land-use categories within the drainage area of each sampling site. These results indicate that the total number of people and amount of land classified as urban, residential, agricultural, or forested upstream from sampling sites are reliable predictors of the presence or absence of specific groups of chlorinated organic compounds in bed sediments.

These results can be used to identify areas where bed-sediment contamination by specific organic compounds is most likely to be found and, thus, can help focus the design of future surveys aimed at assessing the effects of these compounds on stream ecology.

— Paul E. Stackelberg

Selected References

- Fegeas, R.G., Claire, R.W., Guptill, S.C., Anderson, K.E., and Hallam, C.A., 1983. Land use and land cover digital data. U.S. Geological Survey Circular 895-E, 21 p.
- Helsel, D.R., and Hirsch, R.M., 1992. Statistical methods in water resources. Studies in Environmental Science, no. 49. New York, Elsevier Publishers, Inc., 522 p.
- Leahy, P.P., Rosenshein, J.S., and Knopman, D.S., 1990. Implementation plan for the National Water-Quality Assessment program. U.S. Geological Survey Open-File Report 90-174, 10 p.
- Rinella, J.K., Hamilton, P.A., and McKenzie, S.W., 1993. Persistence of the DDT pesticide in the Yakima River Basin, Washington. U.S. Geological Survey Circular 1090, 24 p.
- Smith, J.A., Witkowski, P.J., and Fusillo, T.V., 1988. Manmade organic compounds in the surface waters of the United States-A review of current understanding. U.S. Geological Survey Circular 1007, 92 p.
- U.S. Bureau of the Census, 1991. Census of population and housing, 1990: Public Law 94-171 data for New Jersey: Washington, D.C., U.S. Bureau of the Census, machine-readable data files (CD-ROM).
- For more information, please contact:**
 Chief, Long Island-New Jersey Coastal Drainages NAWQA Program
 U.S. Geological Survey
 810 Bear Tavern Road, Suite 206
 West Trenton, New Jersey 08628
 (609) 771-3943