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ORGANOCHLORINE COMPOUNDS IN A SEDIMENT CORE FROM CORALVILLE RESERVOIR, IOWA

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Many synthetic organic compounds that contain chlorine atoms (organochlorine compounds) were developed and used during the period of 1940–80 as pesticides and for industrial applications. One characteristic of many of these compounds is their stability and persistence in the environment. The compounds were transported to rivers and streams by rainfall runoff and were assimilated into aquatic organisms and adsorbed to suspended sediment. Because of their stability and persistence in the environment and toxic effects on aquatic organisms and humans, use of organochlorine compounds decreased during the 1970's. Many of these pesticides were banned in the United States during this period.

Organochlorine compounds were used extensively as insecticides in the Iowa River watershed during the 1960's and early 1970's (Sato and Schnoor, 1991). Bioaccumulation of one of the compounds, dieldrin, in roughfish resulted in a ban on commercial fishing in Coralville Reservoir (fig. 1). Monitoring for a limited number of organochlorine compounds in the Iowa River at Iowa City continued from 1968–82. Data before and after this period are sporadic or not available; however, it is important to determine the past and present levels of organochlorine compounds in order to understand their effect on human and aquatic organisms. Knowledge of the long-term occurrence of organochlorine compounds will help evaluate the effectiveness of environmental regulations that control chemical use.

Suspended sediments and adsorbed chemicals transported in rivers settle out in the lower velocity environment of a reservoir. Once deposited, sediments are stored for long periods. Sediment cores can indicate the historical occurrence of selected chemical compounds in the watershed. Sections of sediment cores are dated using physical, chemical, and isotopic markers and analyzed to determine residual organochlorine compound concentrations. Plotting the chemical concentration versus the age of sediments shows the trend or lack of trend in the occurrence of selected compounds in the reservoir sediments and in the contributing watershed.

Water-quality trends can indicate the influence of human activities and the effectiveness of environmental regulations in controlling undesirable chemical inputs. Water-quality trends also can provide an indication of future water-quality conditions. A common approach for determining water-quality trends in streams is to apply statistical tests to historical data; however, historical water-quality data have several limitations. In Iowa, these include lack of data, changes in sampling and analytical methods, and numerous measurements below detection levels. Where historical data are lacking or are inappropriate for statistical trend testing, water-quality records can be partly reconstructed using sediment core samples from receiving water bodies such as reservoirs.

This fact sheet describes the concentrations of selected organochlorine compounds in sediment cores from Coralville Reservoir and relates the results to the depositional period of the sediments to indicate possible trends. A secondary purpose is to compare organochlorine compound concentrations in Coralville Reservoir sediments to concentrations in the Iowa River to evaluate whether compounds found in sediments are representative of those in the water. Sediment cores were collected from Coralville Reservoir as part of a National Water-Quality

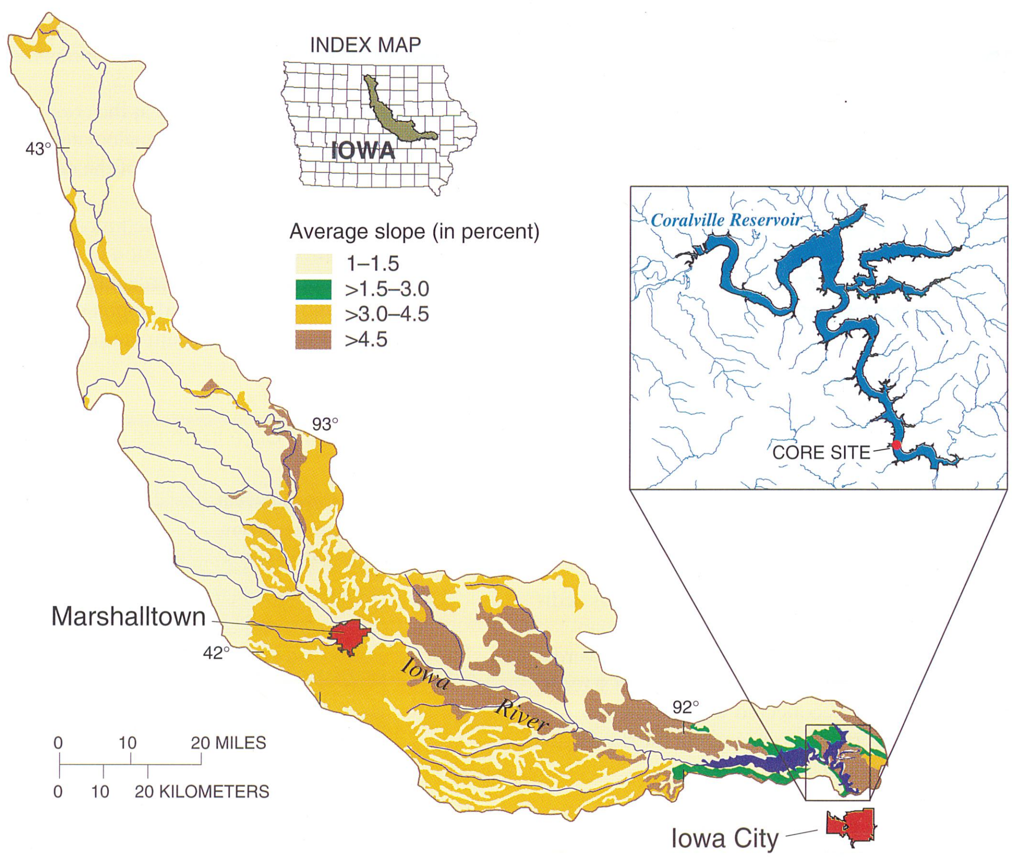

Figure 1. Location of the Iowa River watershed and the sediment-core site in Coralville Reservoir (slope data from Soil Conservation Service, 1993).

Assessment Program (NAWQA) study to use chemical analyses of dated sediment cores from reservoirs to define historical trends in the water quality of the influent rivers and their watersheds in the Central and Southeastern United States (Van Metre and others, 1997).

Setting

Coralville Reservoir (fig. 1) was formed in 1958 by the construction of Coralville Dam, which impounded the Iowa River about 3 miles (mi) north of Iowa City. The reservoir has a surface area of about 8.4 mi^2, a storage capacity of about 41,000 acre-feet (acre-ft) at the normal conservation pool elevation of 683 ft above sea level, and is used for flood control and recreation. Suspended-sediment transport in the Iowa River downstream from the reservoir has decreased significantly since the completion of the dam. The yearly suspended-sediment discharge in the Iowa River at Iowa City (fig. 2) decreased from an average of 980,000 tons per year to 363,000 tons per year after the closure of Coralville Dam (Schuetz and Matthes, 1977). Sediment deposition in the reservoir could partially account for the difference.

The Iowa River drains an agricultural watershed of about 3,100 mi^2 upstream from the dam and is the major source of sediment to Coralville Reservoir (fig. 1). More than 90 percent of the land in the watershed is used for agricultural purposes. Marshalltown, which is about 60 mi upstream from Coralville Reservoir, is the largest urban area in the watershed and has a population of about 25,178 (Bureau of Census, 1992).

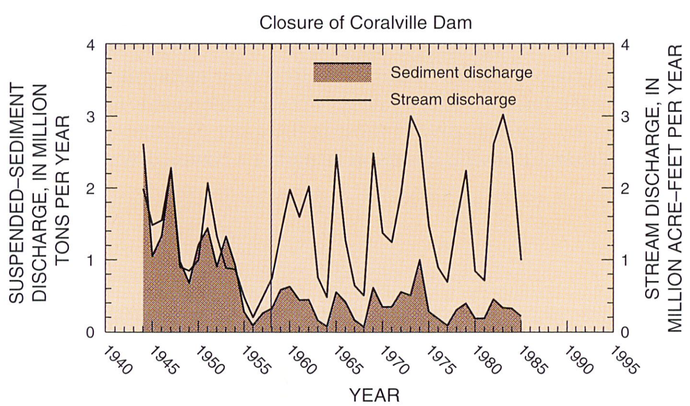

Figure 2. Suspended sediment and stream discharge in the Iowa River downstream from Coralville Reservoir at Iowa City, Iowa.

Data Collection and Interpretation

Cores that penetrated the entire sequence of reservoir bottom sediment were collected November 4, 1993, approximately 1.5 mi upstream from the dam in the former channel of the Iowa River (fig. 1). The cores were collected in late fall following a summer of record flooding in the watershed. The core site was selected as representative of the deep depositional zone containing relatively homogeneous fine-grained sediments. Sediment cores were collected by a gravity corer from a pontoon boat. The gravity corer (fig. 3) has a diameter of 2.5 inches (in.) and is 10 ft long. Discrete horizontal slices of this sediment core were analyzed for organochlorine compounds (Foreman and others, 1994). Other cores collected from the same location were analyzed for cesium-137, major and minor elements, and grain size. A subsequent bottom sediment sample was collected with an Ekman dredge from the core site in November 1996 to document the deposition of organochlorine compounds since 1993.

The core sediments were dated using both physical and chemical markers. The top of the core was assigned the sampling date (November 1993). The bottom of the core, which was determined on the basis of observed physical differences between the sediment and the original

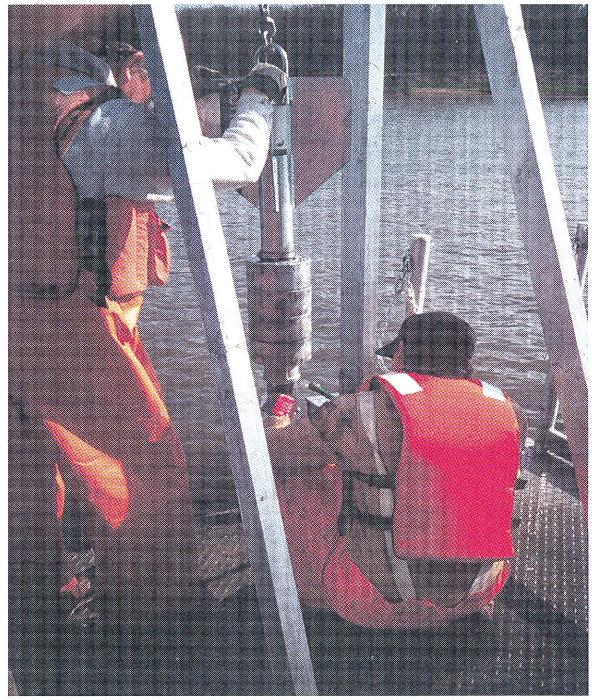

Figure 3. Removing a bed-sediment sample from the gravity corer.

channel-bed material, was assigned the reservoir impoundment date (1958). Concentrations of radioactive cesium-137, a byproduct of atmospheric nuclear weapons testing, were used to identify the sediments deposited during the early 1960's. Significant concentrations of this isotope occurred in the atmosphere beginning in about 1952 and peaked in 1963–64. Ages of the sediments were assigned on the basis of these markers and the assumption of a uniform rate of annual sediment deposition (table 1).

Sediment Deposition

The average depositional rate at the core site was calculated to be about 1.9 in. per year. This rate was calculated by dividing the total length of the core (68 in.) by the age of the deepest interval (35 years).

The physical character of the sediments, as indicated by the core material, changed after completion of Coralville Dam. Before the dam was closed, greater than 70 percent of the channel sediment material was silt- or sand-sized material. Upon closure of the dam, 70–80 percent of the reservoir sediment material was clay-sized material.

Table 1. Core intervals sampled

Core interval (inches below top of core)	Approximate year sediment deposited (midpoint of interval)
0–2.4	1993
2.4–7.1	1992
14–18	1986
28–32	1980
34–37	1977
39–42	1975
46–50	1971
52–55	1969
59–62	1965
66–68	1961

Organochlorine Compounds

Thirty-one organochlorine compounds were analyzed in ten selected intervals from the core. Nine compounds were found in trace or quantifiable concentrations in at least one core interval. These compounds include aldrin, three chlordane compounds, dieldrin, polychlorinated biphenyls (PCB's), and three DDT degradation compounds. Only dieldrin and DDE were detected in the sediment sample collected in November 1996.

Aldrin

Aldrin is an insecticide that was used extensively in Iowa to control corn rootworms and cutworms. Aldrin use decreased between the mid-1960's and 1970's due to increased insect resistance (Sato and Schnoor, 1991). The manufacture and use of aldrin was discontinued in 1976. Aldrin degrades to form dieldrin. Detectable aldrin concentrations were present in sediments deposited in the late 1960's and in a core interval that corresponds to deposition in about 1992 (fig. 4).

Chlordane

Chlordane was used to control rootworms and cutworms until agricultural use was restricted in the mid-1970's. Chlordane use continued in urban areas to control termites until the late 1980's. Both chlordane isomers, cis- and trans-chlordane, were detected in all intervals of the sediment core. Chlordane was not detected in the bottom-sediment sample collected in 1996. Cis-chlordane and the chlorodane degradation compound, trans-nonachlor, were present only in trace amounts. Trans-chlordane was detected in trace concentrations from the oldest and in the youngest sample from the core. Concentrations peaked at 2.2 micrograms per kilogram (µg/kg) in the mid-1970's (fig.4).

DDD, DDE, and DDT

Use of the organochlorine insecticide DDT began in 1939. It's usage peaked in the 1960's, and widespread usage continued until about 1970, just before it was banned in 1972. DDT breaks down to DDE and DDD, which also are toxic and very resistant to further chemical breakdown. Trace concentrations of DDD were detected in all intervals of the core. DDE was detected in all intervals sampled (fig. 5). The greatest concentration (3.4 µg/kg) occurred within the first 10 years after completion of the reservoir. Subsequent concentrations decreased and then peaked again in sediments deposited in the mid-1970's. The overall trend has been one of decreasing concentrations with time. The DDE concentration from sediments deposited in 1996 was 1.2 µg/kg.

Dieldrin

Dieldrin is a contact insecticide that was used extensively for corn. It is also a degradation product of aldrin. Dieldrin was not present in Coralville Reservoir sediments deposited before the mid-1960's. Dieldrin concentrations in sediments increased to 1.6 µg/kg around 1975, decreased during the late 1970's and 1980's and then peaked again in 1993 (fig. 5) following a summer of record flooding. The concentration of dieldrin in sediment deposited in 1996 decreased to 1.4 µg/kg. The dieldrin concentration of a sediment sample collected from Coralville Reservoir in 1970 was 2.7 µg/kg (Morris and Johnson, 1970).

Total PCB's

PCB's have been used as plasticizers, hydraulic lubricants in gas turbines and vacuum pumps, in heat transfer systems, and as dielectric fluids in electrical capacitors and transformers. PCB's generally are a mixture of many closely related compounds known as congeners that differ in their physical, chemical, and biological characteristics. PCB production peaked in the United States in 1968 and essentially ended in 1979 when new uses were banned. Trace amounts were detected in the oldest sediments from Coralville Reservoir (fig. 4).

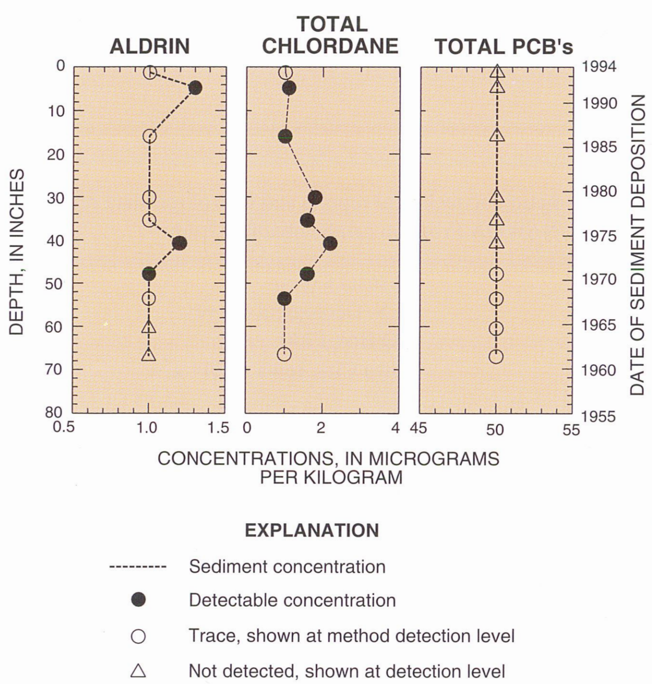

Figure 4. Aldrin, chlordane, and total PCB concentrations in a bed-sediment core from Coralville Reservoir, Iowa, 1993.

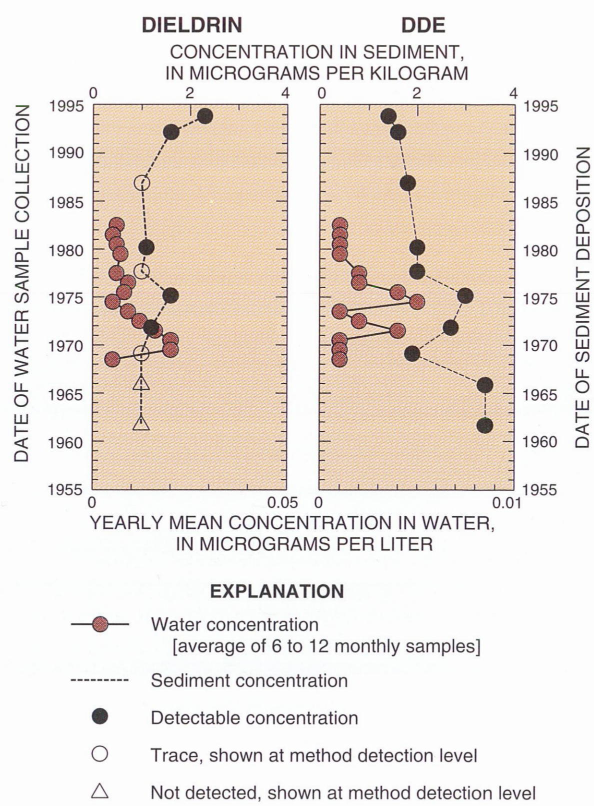

Figure 5. Dieldrin and DDE concentrations in a bed-sediment core from Coralville Reservoir and in water from the Iowa River at Iowa City, Iowa.

Relation Between Concentrations in Water and Sediment

The general trends are similar for dieldrin and DDE concentrations in the Iowa River at Iowa City (Johnson and Morris, 1971; U.S. Environmental Protection Agency STORET data base) and in the sediment core from Coralville Reservoir (fig. 6). Yearly mean dieldrin concentrations in water increased from less than the detection level of 0.005 microgram per liter (µg/L) in 1968 to 0.020 µg/L in 1969 and 1970 and then decreased to 0.012 µg/L in 1972 (fig. 5). During the same period, dieldrin concentrations in sediment increased from trace concentrations in 1969 to 1.6 µg/kg in 1975 and then decreased to trace levels in 1977. Yearly mean DDE concentrations in water peaked twice; at 0.004 µg/L in 1971 and at 0.005 µg/L in 1974. DDE concentrations in sediment peaked during this period. The peak DDE in sediment (3.0 µg/kg) in 1975 corresponds to the second yearly mean peak of DDE in water. The correlation between the concentrations measured in the Iowa River and in the sediment core agrees with previous models (Schnoor, 1981) that estimated about 40 percent of the dieldrin entering Coralville Reservoir is deposited in the bottom sediments.

Conclusions

Chemical data from sediment cores collected in a deep depositional area of Coralville Reservoir near Iowa City, Iowa, show the long-term occurrence of aldrin, DDT compounds, chlordane compounds, and dieldrin in the Iowa River watershed. Even though DDT and dieldrin were banned in the 1970's, detectable concentrations of DDT compounds are still present in the sediment in the mid-1990's, and substantial quantities of dieldrin appear to have been transported to Coralville Reservoir during flooding in 1993. The correlation between concentrations of dieldrin and DDE in reservoir sediments and in the river suggests that chemical data from age-dated Coralville Reservoir sediment cores can be used to evaluate the historical occurrence of selected organochlorine compounds in the Iowa River watershed.

Figure 6. Upper part of Coralville Reservoir (view to the west).

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Information on technical reports and hydrologic data related to the NAWQA Program can be obtained from:

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