WATER-QUALITY ASSESSMENT OF THE RIO GRANDE VALLEY, COLORADO, NEW MEXICO, AND TEXAS - Organic compounds and trace elements in bed sediment and fish tissue, 1992-93

By Lisa F. Carter

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<http://wwwrvares.er.usgs.gov/nawqa/nawqa_home.html>

FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS

Multiply	By	To obtain
mile	1.609	kilometer
square mile	2.590	square kilometer

WATER-QUALITY ASSESSMENT OF THE RIO GRANDE VALLEY, COLORADO, NEW MEXICO, AND TEXAS - ORGANIC COMPOUNDS AND TRACE ELEMENTS IN BED SEDIMENT AND FISH TISSUE, 1992-93

By Lisa F. Carter

ABSTRACT

The occurrence and distribution of contaminants in aquatic systems are major components of the National Water-Quality Assessment (NAWQA) Program. Bed-sediment samples were collected at 18 sites in the Rio Grande Valley study unit between September 1992 and March 1993 to characterize the geographic distribution of organic compounds, including chlorinated insecticides, polychlorinated biphenyls (PCB's), and other chlorinated hydrocarbons, and also trace elements. Two-millimeter-size-fraction sediment was analyzed for organic compounds and less than 63-micron-size-fraction sediment was analyzed for trace elements. Concentrations of *p,p'*-DDE were detected in 33 percent of the bed-sediment samples. With the exception of DDT-related compounds, no other organochlorine insecticides or polychlorinated biphenyls were detected in samples of bed sediment. Whole-body fish samples were collected at 11 of the bed-sediment sites and analyzed for organic compounds. Organic compounds were reported more frequently in samples of fish, and more types of organic compounds were found in whole-body fish samples than in bed-sediment samples. Concentrations of *p,p'*-DDE were detected in 91 percent of whole-body fish samples. Polychlorinated biphenyls, *cis*-chlordane, *trans*-chlordane, *trans*-nonachlor, and hexachlorobenzene were other organic compounds detected in whole-body samples of fish from at least one site. Because of the extent of mineralized areas in the Rio Grande Basin arsenic, cadmium, copper, lead, mercury, selenium, and zinc concentrations in bed-sediment samples could represent natural conditions at most sites. However, a combination of natural conditions and human activities appears to be associated with elevated trace-element concentrations in the bed-sediment sample from the site Rio Grande near Creede, Colorado, because this sample exceeded the background trace-element concentrations calculated for this study. Fish-liver samples were collected at 12 of the bed-sediment sites and analyzed for trace elements. Certain trace elements were detected at higher concentrations in fish-liver samples than in bed-sediment samples from the same site. Both bed-sediment and fish-tissue samples are necessary for a complete environmental assessment of the occurrence and distribution of trace elements.

INTRODUCTION

In 1991, the U.S. Geological Survey implemented the National Water-Quality Assessment (NAWQA) Program to assess the status and trends of the Nation's water quality (Hirsch and others, 1988; Leahy and others, 1990). The program is based on a multidiscipline approach using standard protocols to collect data in 60 study units. Intensive data collection is conducted within a study unit for 3 years, followed by several years of low-level monitoring; the cycle is then repeated (Hirsch and others, 1988; Leahy and others, 1990).

An Occurrence and Distribution Assessment is a major component of the intensive study phase in each study unit (Gilliom and others, 1995). Characterizing the geographic and seasonal distribution of contaminants with regard to background conditions and sources is the goal of the assessment. One component of the Occurrence and Distribution Assessment is a bed-sediment and tissue study. It is designed to assess the presence and geographic distribution of hydrophobic organic compounds, including chlorinated pesticides, polychlorinated biphenyls (PCB's), and other chlorinated hydrocarbons, and trace elements in bed sediment and fish tissue. Concentrations of hydrophobic organic compounds and trace elements have been shown to be higher in bed sediment and biota than in water (Lynch and others, 1988; Smith and others, 1988), thus sampling bed sediment and biota increases the probability of detecting trace amounts of these contaminants in the environment. Bed sediments are used in contaminant studies to assess the fate and distribution of organic compounds and trace elements (Smith and others, 1988; Horowitz, 1990; Roy and others, 1992). The use of biota in contaminant studies is a widely accepted method for determining the distribution and bioavailability of contaminants over time and area (Phillips, 1980; Farrington and others, 1983; Bryan and others, 1985; Campbell and others, 1988; Schmitt and others, 1990). The use of sediment and biota analyses provides a better understanding of the fate, distribution, and potential effects of contaminants.

The Rio Grande Valley study unit encompasses about 45,900 square miles in Colorado, New Mexico, and Texas (fig. 1). The Rio Grande traverses about 750 stream miles from its headwaters in the San Juan Mountains in southwestern Colorado to the International Boundary and Water Commission streamflow-monitoring station at El Paso, Texas. Rangeland, forest land, and cropland are the major land uses. Surface-water-quality issues in the study unit are associated with both nonpoint and point sources of contamination. Contamination of surface water includes nonpoint sources such as mining, agriculture, and urbanization, and point sources such as discharge from wastewater treatment plants (Ellis and others, 1993; Anderholm and others, 1995).

Purpose and Scope

The purpose of this report is to: (1) identify the occurrence and distribution of selected organic compound and trace-element contaminants in bed sediment and fish tissue at sampled sites; and (2) evaluate fish-tissue use in contaminant surveys by comparing contaminant concentrations in fish tissue to bed sediment. Bed-sediment samples were collected at 18 sites in the Rio Grande Valley study unit between September 1992 and March 1993 (table 1 and fig. 1). Whole-body fish samples were collected at 11 of the bed-sediment sites and analyzed for organic compounds. Fish-liver samples were collected at 12 of the bed-sediment sites and analyzed for trace elements.

Acknowledgments

Special thanks are extended to individuals from the following agencies for their contributions to data collection: U.S. Fish and Wildlife Service, National Park Service, Bureau of Land Management, Los Alamos National Laboratory, and Colorado Division of Wildlife. In addition, the volunteer efforts of Christine Lowry and John Harvey in data collection are greatly appreciated.

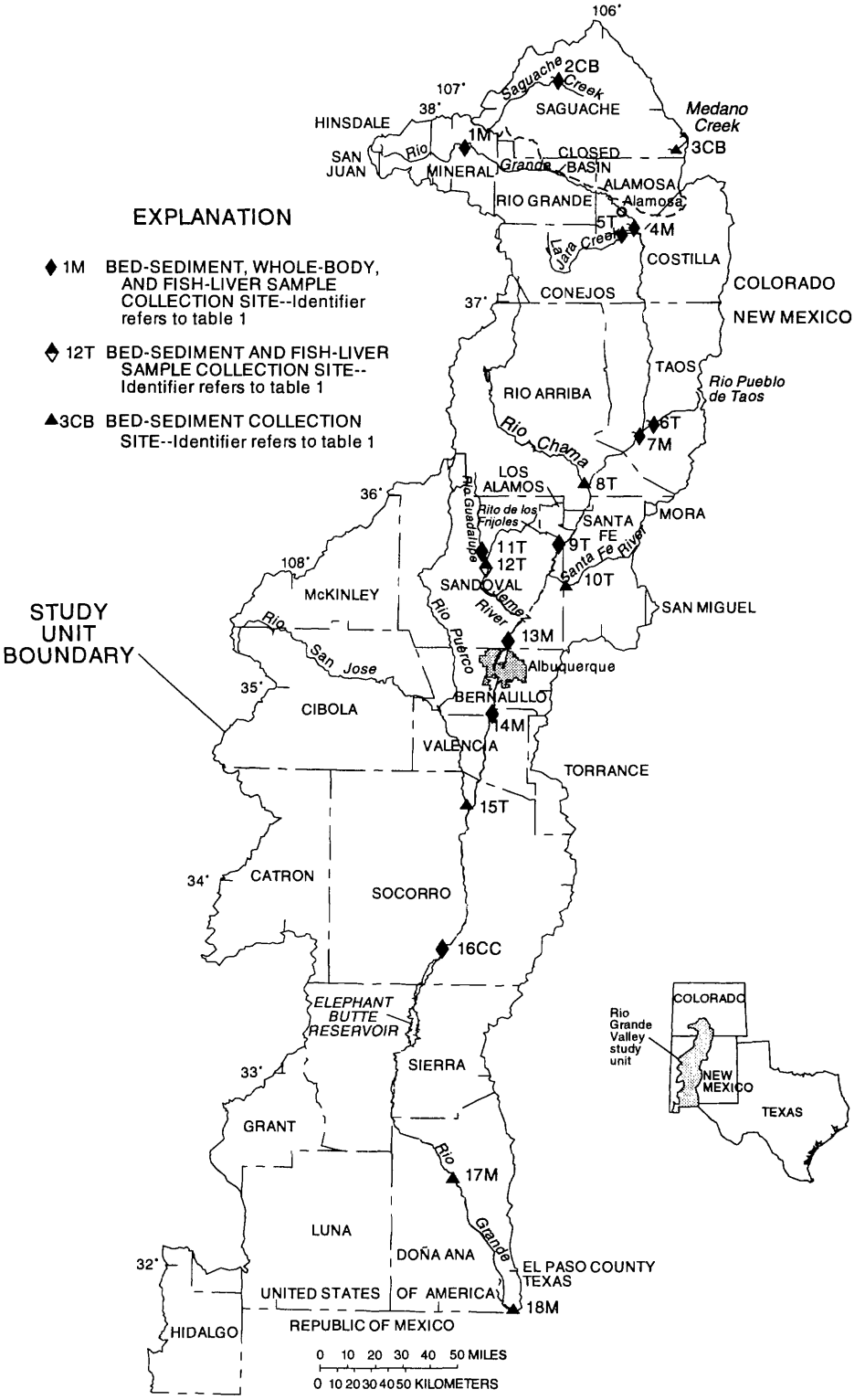


Figure 1.--Location of bed-sediment and fish-tissue sample collection sites.

Table 1.--Site number, station name, station ID, and latitude and longitude of bed-sediment and fish-tissue sites in the Rio Grande Valley study unit

[Site location shown in figure 1; M, main-stem site; T, main-stem tributary site; CB, closed basin site; CC, Rio Grande Conveyance Channel site]

Site number	Station name	Station ID	Latitude	Longitude
1M	Rio Grande near Creede, Colo.	374922106542901	37°49'22"	106°54'29"
2CB	Saguache Creek near Saguache, Colo.	08227000	38°09'48"	106°17'24"
3CB	Medano Creek near Mosca, Colo.	374752105300801	37°47'52"	105°30'08"
4M	Rio Grande at Alamosa Refuge, Colo.	372334105470001	37°23'34"	105°47'00"
5T	La Jara Creek at Alamosa County line, Colo.	372124105510601	37°21'24"	105°51'06"
6T	Rio Pueblo de Taos below Los Cordovas, N. Mex.	08276300	36°22'39"	105°40'05"
7M	Rio Grande below Taos Junction Bridge near Taos, N. Mex.	08276500	36°19'12"	105°45'14"
8T	Rio Chama near Chamita, N. Mex.	08290000	36°04'26"	106°06'40"
9T	Rito de los Frijoles below Frijoles Falls, N. Mex.	354511106151010	35°45'11"	106°15'10"
10T	Santa Fe River above Cochiti Lake, N. Mex.	08317200	35°32'49"	106°13'41"
11T	Rio Guadalupe at Box Canyon, near Jemez, N. Mex.	08323000	35°43'52"	106°45'44"
12T	Jemez River near Jemez, N. Mex.	08324000	35°39'42"	106°44'34"
13M	Rio Grande at State Highway 44 Bridge, near Bernalillo, N. Mex.[1]	351921106332710	35°19'21"	106°33'27"
14M	Rio Grande at Isleta, N. Mex.	08331000	34°54'21"	106°41'04"
15T	Rio Puerco near Bernardo, N. Mex.	08353000	34°24'33"	106°51'09"
16CC	Rio Grande Conveyance Channel at San Marcial, N. Mex.	08358300	33°41'15"	106°59'40"
17M	Rio Grande at Leasburg Dam, near Las Cruces, N. Mex.	322948106551910	32°29'48"	106°55'19"
18M	Rio Grande at El Paso, Tex.	08364000	31°48'10"	106°32'25"

[1]Trace-element concentrations in bed sediment reported in Cruz and others (1994) as station ID 08329500.

METHODS OF SAMPLE COLLECTION AND ANALYSIS

The bed-sediment and fish-tissue study was conducted between September 1992 and March 1993. Collection and field processing of bed sediment and fish tissue for analysis of organic compounds and trace elements followed established NAWQA protocols (Crawford and Luoma, 1993; Shelton and Capel, 1994).

Bed-sediment samples were collected at 18 sites within the Rio Grande Valley study unit: 7 main-stem sites, 8 main-stem tributary sites, 2 sites in the San Luis Closed Basin in Colorado, and 1 Rio Grande conveyance channel site (table 1). Sites were identified numerically (1-18) followed by alphabetical distinctions of M for main-stem sites, T for main-stem tributary sites, CB for San Luis Closed Basin sites, and CC for the Rio Grande conveyance channel site. For data analysis, site 16CC was grouped with the main-stem sites, and sites 2CB and 3CB were grouped with the main-stem tributary sites.

Samples of bed sediment were collected from depositional areas near streambanks, downstream from obstacles such as large boulders and islands, or wherever fine sediments were deposited. Sampling was confined to the upper 2 centimeters of bed sediment. Field processing of bed sediment included wet sieving samples through a 2.0-millimeter stainless steel sieve for organic compound analysis and through a 63-micrometer teflon sieve for trace-element analysis (Shelton and Capel, 1994).

Bed-sediment samples were analyzed for organic compounds at the U.S. Geological Survey National Water Quality Laboratory in Arvada, Colorado, and for trace elements at the U.S. Geological Survey sediment laboratory in Denver, Colorado. Table 2 contains the complete list of constituents included in the bed-sediment analysis. These data and quality-control data for field replicate samples are stored in the New Mexico District National Water Information System (NWIS) data base. All organochlorine pesticides and PCB's, but only selected trace elements, listed in table 2 were used in the data analysis for this report. Table 2 also lists the minimum reporting level (MRL) or lower limit of determination (LLD) for each constituent. The MRL is the smallest measured concentration of a constituent that may be reliably reported using a given analytical method (Timme, 1995). The LLD is three times the standard deviation of the blank added to the average of the blank (Arbogast, 1990). The analytical methods of determination for each constituent are listed by Timme (1995). Organic compounds and trace elements in bed-sediment samples are expressed as dry weight concentrations.

Fish were collected from a 150- to 400-meter length of stream by electroshocking, processed in the field according to Crawford and Luoma (1993), and analyzed for the constituents shown in table 3. The fish taxa chosen for contaminant analysis were selected from a NAWQA National Target Taxa list, which consisted of, but was not limited to, bottom-feeding fish and nonmigrating game fish. Where possible, samples of fish tissue were collected at sites where bed-sediment samples were collected. At some sites fish tissue could not be collected because of the lack of target taxa or restrictions on fish collection. As a result, samples of fish tissue were collected at 11 sites for organic compound analysis and at 12 sites for trace-element analysis (table 4).

In the field, individual fish were identified, length and weight were measured, external signs of disease or parasites were noted, and sex was determined. Each sample consisted of a composite of whole-body fish (for selected organic compound analysis) or liver (for selected trace-element analysis) of approximately five fish of the same species and size. These sample types were chosen to increase the probability of detecting contaminants in the environment, but not necessarily to demonstrate any risks to public health or wildlife. Field replicate samples of fish tissue were not collected because of the small number of fish at each site.

Table 2.-- Constituents included in the bed-sediment analysis

[LLD, lower level of determination[1] for trace elements, major metals, and carbon, in micrograms per gram dry weight unless expressed as a percentage (%); MRL, minimum reporting level[2] for organic compounds, in micrograms per kilogram dry weight]

TRACE ELEMENTS AND MAJOR METALS (LLD)				
Aluminum (0.05%)	Cobalt (1)	Lithium (2)	Potassium (0.05%)	Tin (10)
Antimony (0.1)	Copper (1)	Magnesium (0.005%)	Scandium (2)	Titanium (0.005%)
Arsenic (0.1)	Europium (2)	Manganese (4)	Selenium (0.1)	Uranium (0.05)
Beryllium (1)	Gallium (4)	Mercury (0.02)	Silver (0.1)	Vanadium (2)
Bismuth (10)	Gold (8)	Molybdenum (2)	Sodium (0.005%)	Ytterbium (1)
Cadmium (0.1)	Holmium (4)	Neodymium (4)	Strontium (2)	Yttrium (2)
Calcium (0.05%)	Iron (0.05%)	Nickel (2)	Sulfur (0.05%)	Zinc (4)
Cerium (4)	Lanthanum (2)	Niobium (4)	Tantalum (40)	
Chromium (1)	Lead (4)	Phosphorus (0.005%)	Thorium (4)	

Carbon (LLD)		
Carbonate (0.01%)	Total carbon (0.01%)	Total organic carbon (0.01%)

ORGANIC COMPOUNDS			
Organochlorine pesticides and polychlorinated biphenyls (MRL)			
Aldrin (1)	*o,p'*-DDT (2)	Beta-HCH (1)	*trans*-nonachlor (1)
cis-chlordane (1)	*p,p'*-DDT (2)	Delta-HCH (1)	Oxychlordane (1)
trans-chlordane (1)	Dieldrin (1)	Gamma-HCH (Lindane) (1)	Pentachloroanisole (1)
Chloroneb (5)	Endosulfan 1 (1)	Isodrin (1)	*cis*-permethrin (5)
Dacthal (5)	Endrin (2)	*o,p'*-methoxychlor (5)	*trans*-permethrin (5)
o,p'-DDD (1)	Heptachlor (1)	*p,p'*-methoxychlor (5)	Polychlorinated biphenyls (total PCB's) (50)
p,p'-DDD (1)	Heptachlor epoxide (1)	Mirex (1)	Toxaphene (200)
o,p'-DDE (1)	Hexachlorobenzene (1)	*cis*-nonachlor (1)	
p,p'-DDE (1)	Alpha-HCH (1)		

Semivolatile organic contaminants (MRL = 50 for each constituent)		
Acenaphthene	Dibenzo(a,h)anthracene	2-methylanthracene
Acenaphthylene	Dibenzothiophene	2-methyl-4,6-dinitrophenol
Acridine	1,2-dichlorobenzene	4,5-methylenephenanthrene
C8-alkylphenols	1,3-dichlorobenzene	1-methyl-9H-fluorene
Anthracene	1,4-dichlorobenzene	1-methylphenanthrene
Anthraquinone	2,4-dichlorophenol	1-methylpyrene
Azobenzene	Diethyl phthalate	Naphthalene
Benzo(a)anthracene	3,5-dimethylphenol	Nitrobenzene
Benzo(b)fluoranthene	1,2-dimethylnaphthalene	2-nitrophenol
Benzo(k)fluoranthene	1,6-dimethylnaphthalene	4-nitrophenol
Benzo(g,h,i)perylene	2,6-dimethylnaphthalene	N-nitroso-diphenylamine
Benzo(a)pyrene	Dimethyl phthalate	N-nitroso-di-n-propyl amine
Benzo(c)quinoline	Di-n-butyl phthalate	Pentachlorobenzene
2,2'-biquinoline	2,4-dinitrophenol	Pentachloronitrobenzene
4-bromophenylphenylether	2,4-dinitrotoluene	Pentachlorophenol
Butylbenzyl phthalate	2,6-dinitrotoluene	Phenanthrene
9H-carbazole	Di-n-octyl phthalate	Phenanthridine
bis(2-chloroethoxy) methane	*bis*(2-ethylhexyl) phthalate	Phenol
bis(2-chloroethyl) ether	2-ethylnaphthalene	Pyrene
bis(2-chloroisopropyl) ether	Fluoranthene	Quinoline
4-chloro-3-methylphenol	9H-fluorene	2,3,5,6-tetramethylphenol
2-chloronaphthalene	Hexachloroethane	1,2,4-trichlorobenzene
4-chlorophenylphenylether	Indeno(1,2,3-cd) pyrene	2,4,6-trichlorophenol
p-cresol	Isophorone	2,4,6-trimethylphenol
Chrysene	Isoquinoline	2,3,6-trimethylnaphthalene

[1]The LLD is three times the standard deviation of the blank added to the average of the blank (Arbogast, 1990).
[2]The MRL is the smallest measured concentration of a constituent that may be reliably reported using a given analytical method (Timme, 1995).

Table 3.-- Constituents included in the fish-tissue analysis

[MRL, minimum reporting level,[1] in micrograms per gram dry weight for trace elements and major metals and in micrograms per kilogram wet weight for organic compounds]

TRACE ELEMENTS AND MAJOR METALS (MRL) FROM FISH LIVER			
Aluminum (1)	Chromium (0.5)	Manganese (0.1)	Silver (0.1)
Antimony (0.1)	Cobalt (0.1)	Mercury (0.1)	Strontium (0.1)
Arsenic (0.1)	Copper (0.5)	Molybdenum (0.1)	Uranium (0.1)
Beryllium (0.1)	Iron (1)	Nickel (0.1)	Vanadium (0.1)
Cadmium (0.1)	Lead (0.1)	Selenium (0.1)	Zinc (0.5)

ORGANIC COMPOUNDS (MRL) FROM WHOLE-BODY FISH			
Aldrin (5)	*o,p'*-DDT (5)	Delta-HCH (5)	Oxychlordane (5)
cis-chlordane (5)	*p,p'*-DDT (5)	Gamma-HCH (Lindane) (5)	Polychlorinated biphenyls (total PCB's) (50)
trans-chlordane (5)	Dieldrin (5)	*o,p'*-methoxychlor (5)	Pentachloroanisole (5)
Dacthal (5)	Endrin (5)	*p,p'*-methoxychlor (5)	Toxaphene (200)
o,p'-DDD (5)	Heptachlor (5)	Mirex (5)	
p,p'-DDD (5)	Heptachlor epoxide (5)	*cis*-nonachlor (5)	
o,p'-DDE (5)	Hexachlorobenzene (5)	*trans*-nonachlor (5)	
p,p'-DDE (5)	Beta-HCH (5)		
Onachlor (5)			

[1]The MRL is the smallest measured concentration of a constituent that may be reliably reported using a given analytical method (Timme, 1995).

Organic compounds and trace elements in fish tissue were analyzed at the U.S. Geological Survey National Water Quality Laboratory, and the data are stored in the New Mexico District NWIS data base. The analytical methods of determination for each constituent are listed by Timme (1995). Organic compounds in whole-body fish samples are expressed as wet weight concentrations; trace elements in fish-liver samples are expressed as dry weight concentrations.

ORGANIC COMPOUNDS

Organochlorine pesticides and PCB's are characterized by relatively low aqueous solubilities and tend to partition into sediment organic matter and biological lipid reservoirs. As a result of their chemical properties, these organic compounds have been reported in soils, sediment, and aquatic organisms throughout the United States and many parts of the world. Field studies also have shown that organochlorine pesticides and PCB's are extremely persistent and ubiquitous environmental contaminants (Smith and others, 1988). Although the use of many pesticides, including organochlorine insecticides such as DDT and chlordane, and PCB's was discontinued in the early 1970's (Smith and others, 1988), several of these compounds were detected in whole-body fish samples and to a lesser extent in bed-sediment samples (tables 5 and 6).

Table 4.--Taxa collected for analysis of organic compounds and trace elements

[Site location shown in figure 1; M, main-stem site; T, main-stem tributary site; CB, closed basin site; CC, Rio Grande Conveyance Channel site; +, taxa collected; --, taxa not collected]

Site number	Taxa	Analysis	
		Organic compound	Trace element
1M	White sucker (*Catostomus commersoni*)	+	+
2CB	White sucker (*Catostomus commersoni*)	+	+
4M	Common carp (*Cyprinus carpio*)	+	+
5T	White sucker (*Catostomus commersoni*)	+	+
6T	White sucker (*Catostomus commersoni*)	+	+
7M	White sucker (*Catostomus commersoni*)	+	+
9T	Rainbow trout (*Oncorhynchus mykiss*)	+	+
11T	Brown trout (*Salmo trutta*)	+	+
12T	White sucker (*Catostomus commersoni*)	--	+
13M	Common carp (*Cyprinus carpio*)	+	+
14M	Common carp (*Cyprinus carpio*)	+	+
16CC	Common carp (*Cyprinus carpio*)	+	+

Technical grade DDT is composed of about 80 percent *p,p'*-DDT and 20 percent *o,p'*-DDT (Verschueren, 1983). Total DDT concentrations do not include concentrations of *o,p'*-DDD, *o,p'*-DDE, and *o,p'*-DDT. Metabolic degradation of *p,p'*-DDT in fish is generally accomplished by dehydrodechlorination to *p,p'*-DDE and to a lesser extent by reductive dechlorination to *p,p'*-DDD (Edwards and Millburn, 1985; Uchida and others, 1988). Total DDT concentrations were calculated by summing the concentrations of *p,p'*-DDD, *p,p'*-DDE, and *p,p'*-DDT (tables 5 and 6). Biodegradation is one of the major processes that govern the fate of organochlorine pesticides in the environment (Klecka, 1985). A proportionally higher *p,p'*-DDT concentration to total DDT concentration in fish suggests a recent or continuing source of DDT to the environment (Aguillar, 1984). However, the presence of *o,p'*-DDT in fish is an indication of a point source of DDT, rather than the areal application of DDT (Schmitt and others, 1985).

The historical use of DDT in the Rito de los Frijoles watershed was documented by Allen (1989). The persistent environmental effect of DDT at site 9T is demonstrated by a greater number of DDT compounds exceeding the MRL in bed-sediment and whole-body rainbow trout samples than in samples from other sites (tables 5 and 6). The presence of *o,p'*-DDT in both bed-sediment and fish samples from site 9T suggests a point source of DDT. Furthermore, the relative percentage of *p,p'*-DDT was higher in the bed-sediment sample (53 percent) than in the fish sample (16 percent).

Table 5.--Concentrations of detected organic compounds in bed-sediment samples from sites in the Rio Grande Valley study unit

[Site location shown in figure 1; M, main-stem site, T, main-stem tributary site; CB, closed basin site; CC, Rio Grande Conveyance Channel site; --, less than the minimum reporting level (see table 2); values in micrograms per kilogram dry weight]

Site number	*o,p'*-DDD	*o,p'*-DDT	*p,p'*-DDD	*p,p'*-DDE	*p,p'*-DDT	Total DDT[1]
1M	--	--	--	--	--	--
2CB	--	--	--	--	--	--
3CB	--	--	--	--	--	--
4M	--	--	--	--	--	--
5T	--	--	--	--	--	--
6T	--	--	--	1.5	--	1.5
7M	--	--	--	--	--	--
8T	--	--	--	--	--	--
9T	1.1	1.2	2.1	5.6	8.7	16.4
10T	--	--	1.7	1.8	--	3.5
11T	--	--	--	1.2	--	1.2
12T	--	--	--	1.0	--	1.0
13M	--	--	--	--	--	--
14M	--	--	--	--	--	--
15T	--	--	--	--	--	--
16CC	--	--	--	--	--	--
17M	--	--	--	--	--	--
18M	--	--	--	3.2	--	3.2

[1]Total DDT concentrations were calculated by summing the concentrations of *p,p'*-DDD, *p,p'*-DDE, and *p,p'*-DDT.

Table 6.--Concentrations of detected organic compounds in whole-body fish samples from sites in the Rio Grande Valley study unit

[Site location shown in figure 1; M, main-stem site; T, main-stem tributary site; CB, closed basin site; CC, Rio Grande Conveyance Channel site; --, less than the minimum reporting level (see table 3); values in micrograms per kilogram wet weight in whole-body fish]

Site number	*cis*-chlordane	*trans*-chlordane	*o,p'*-DDT	*p,p'*-DDD	*p,p'*-DDE	*p,p'*-DDT	Total DDT[1]	Hexachloro-benzene	Gamma-HCH	*trans*-nonachlor	Total PCB's	Taxa
1M	--	--	--	--	5.0	--	5.0	--	--	--	--	White sucker
2CB	--	--	--	--	--	--	--	--	--	--	--	White sucker
4M	--	--	--	17	64	--	81	--	--	--	--	Common carp
5T	--	--	--	20	48	--	68	--	--	--	--	White sucker
6T	--	--	--	7.2	26	--	33.2	--	--	--	57	White sucker
7M	--	--	--	--	28	--	28	--	--	--	--	White sucker
9T	--	--	5.6	35	110	28	173	--	--	--	--	Rainbow trout
11T	--	--	--	10	51	--	61	--	--	--	97	Brown trout
13M	--	--	--	--	66	--	66	8.2	--	--	100	Common carp
14M	6.9	5.0	--	15	79	--	94	--	6.9	9.2	410	Common carp
16CC	--	--	--	--	16	--	16	--	--	--	82	Common carp

[1]Total DDT concentrations were calculated by summing the concentrations of *p,p'*-DDD, *p,p'*-DDE, and *p,p'*-DDT.

Total DDT concentrations in bed-sediment and whole-body fish samples from site 9T are higher than those in samples from other sites in this study. The total DDT concentration found in bed sediment from site 9T (16.4 micrograms per kilogram (µg/kg) dry weight) is within the range (non-detect to 31.7 µg/kg dry weight) reported by Roy and others (1992) in a study of the Rio Grande in New Mexico. The total DDT concentration found in the whole-body fish sample from site 9T (173 µg/kg wet weight) also is within the range (non-detect to 6,820 µg/kg wet weight) reported by Roy and others (1992). The DDT concentration is much larger at site 9T than at other sites sampled in this study; the concentration is not exceedingly high, however, when compared with concentrations in other parts of the Rio Grande Basin in New Mexico (Roy and others, 1992). The DDT concentration at site 9T probably represents a localized source that is related to historical DDT use in the watershed.

Total DDT concentrations in whole-body fish samples collected during this study were compared with those in whole-body fish samples collected in the Rio Grande at Elephant Butte Reservoir, New Mexico, and Alamosa, Colorado, for the U.S. Fish and Wildlife Service National Contaminant Biomonitoring Program (Schmitt and others, 1990). In whole-body common carp, total DDT concentrations detected during this study (table 6) generally were larger than that in a sample from Elephant Butte (10 µg/kg wet weight; Schmitt and others, 1990). The white sucker sample from site 5T contained more total DDT (68 µg/kg; table 6) than the whole-body white sucker sample from Alamosa (60 µg/kg wet weight; Schmitt and others, 1990), whereas other samples of white suckers collected during this study contained smaller concentrations. The sample of brown trout from site 11T contained about one-fifth the total DDT concentration of a whole-body sample of brown trout from Alamosa (300 µg/kg wet weight; Schmitt and others, 1990). These differences in total DDT concentrations could be the result of different sample collection protocols, geographic location, habitat, environmental effects, or sampling seasons.

At 10 of 11 sites in this study, *p,p'*-DDE was detected in whole-body fish samples; however, these concentrations were less than the national geometric mean concentration of 190 µg/kg wet weight for whole-body fish (Schmitt and others, 1990). When the relative percentage of *p,p'*-DDE was calculated for each fish sample, *p,p'*-DDE composed between 64 and 100 percent of total DDT. Because *p,p'*-DDE is the major metabolic degradation product of DDT, its proportional composition of total DDT suggests a degradation of DDT at the study sites.

The whole-body sample of common carp from site 14M had the largest number of detections of different organic compounds, which is indicative of populated (urban) areas (Arruda and others, 1987). The common carp sample from site 14M generally had the highest concentrations of organic compounds (except for site 9T) compared with other samples. The total PCB concentration in the common carp sample from 14M was more than four times that detected in fish samples at other sites in this study and was approximately double the total PCB concentration (200 µg/kg wet weight) reported by Roy and others (1992) in common carp from a drain near Albuquerque, New Mexico. Other organochlorine insecticides, including *cis*-chlordane, *trans*-chlordane, gamma-HCH, and *trans*-nonachlor, were detected in the whole-body sample of common carp from site 14M and at no other sites.

In this study, whole-body fish samples were a more sensitive indicator of the presence of organic compounds than bed-sediment samples because of higher detection frequencies and concentrations in whole-body fish. For example, 10 of the 28 organic compounds analyzed were detected in whole-body fish samples. In contrast, only 5 of the 36 organic compounds analyzed were detected in bed-sediment samples. Of the total number of samples, the most commonly detected organic compound, *p,p'*-DDE, was detected more frequently in samples of whole-body fish (91 percent) than in samples of bed sediment (33 percent). With the exception of DDT-related compounds, no other organochlorine insecticides or PCB's were detected in bed-sediment samples.

TRACE ELEMENTS

Trace elements are unevenly distributed in the aquatic environment and, by the process of adsorption, tend to be associated with fine-grained sediment. Upon entry into aquatic environments the fate of trace elements is variable. Trace elements can remain biologically unavailable in the aquatic environment, transform into more or less toxic forms, or become bioavailable (Namminga and Wilhm, 1977). The bioavailability of trace elements is an important factor in assessing threats to aquatic organisms, ecosystems, and public health. Results of trace-element analyses of samples of bed sediment and fish liver are presented in tables 7 and 8. Trace-element concentrations in bed sediment from site 6T were not determined because of an insufficient amount of sample. With the exception of mercury, molybdenum, and silver, all trace elements listed in table 7 were detected in bed-sediment samples from each site. All trace elements listed in table 8, with the exception of antimony, beryllium, lead, and uranium, were detected in fish-liver samples from at least 50 percent of the sites. Arsenic, cadmium, copper, lead, mercury, selenium, and zinc are discussed in detail because they are assumed to be appropriate indicators of environmental quality and are known to be persistent environmental contaminants and toxic to most forms of life (Hodson and others, 1979; Weatherley and others, 1980; Eisler, 1985a, 1985b, 1987, 1988a, 1988b; Schmitt and Brumbaugh, 1990; Roy and others, 1992). Although a number of studies have used bed sediment and fish as indicators of trace elements in the environment, directly comparing the results of this study to the results of previous studies (Jenkins, 1981; Salomons and Forstner, 1984; Shacklette and Boerngen, 1984; Wiener and others, 1984; Schmitt and Brumbaugh, 1990; Roy and others, 1992) may not be appropriate. Different methods of sample treatment, location and time of sample collection, and variations in fish species and tissue type reduce comparability among study results.

To date, no region-scale studies of trace-element concentrations in bed sediment have identified elevated trace-element concentrations. To identify elevated trace-element concentrations in the study unit a background or uncontaminated concentration is needed. Data from Jenkins (1981), Salomons and Forstner (1984), and Shacklette and Boerngen (1984) provide a guideline for background concentrations based on concentrations in soils from the Western United States. These studies, however, are not basin specific. Therefore, background concentrations in the study unit were determined for each of the seven trace elements identified as appropriate indicators of environmental quality (modified after Velz, 1984). For each of these trace elements, cumulative frequency curves were plotted for the concentrations in the bed-sediment samples collected during this study. For these distributions, the first point of substantial change in concentration (as shown in fig. 2) was considered the background concentration in the study unit (table 9).

Because of the extent of mineralized areas in the Rio Grande Basin (New Mexico Geological Society, 1971, 1981; Cordell and others, 1985; Kirkham and Holm, 1988) arsenic, cadmium, copper, lead, mercury, selenium, and zinc concentrations in bed-sediment samples from most sites could represent natural conditions. Arsenic, cadmium, copper, selenium, and zinc background concentrations determined for the study area exceeded the concentrations reported by Jenkins (1981), Salomons and Forstner (1984), and Shacklette and Boerngen (1984) (table 9). The higher trace-element concentrations reported in this study, as compared to those of other studies, could be due to the higher ratio of surface area to volume of the fine-grained bed sediment analyzed for this study. Background lead concentrations determined in this study were within the range of concentrations reported by Jenkins (1981) and higher than the concentrations reported by Salomons and Forstner (1984) and Shacklette and Boerngen (1984). Background mercury concentrations determined in this study were similar to those reported by Jenkins (1981) and Shacklette and Boerngen (1984).

Table 7.--Concentrations of selected trace elements in bed-sediment samples from sites in the Rio Grande Valley study unit

[Site location shown in figure 1; M, main-stem site; T, main-stem tributary site; CB, closed basin site; CC, Rio Grande Conveyance Channel site; --, less than the lower limit of determination (see table 2); values in micrograms per gram dry weight unless expressed as a percentage (%)]

Site number	Alumi-num (%)	Anti-mony	Arse-nic	Beryl-lium	Cad-mium	Chro-mium	Co-balt	Cop-per	Iron	Lead	Manga-nese	Mer-cury	Molyb-denum	Nickel	Sele-nium	Silver	Stron-tium	Ura-nium	Vana-dium	Zinc
1M	6.8	19	200	3.0	56	20	13	150	3.7	6,300	1,900	0.18	6	8	1.1	13.0	270	5.8	76	9,000
2CB	6.7	0.4	6.1	2	0.1	20	11	19	3.3	17	790	0.08	--	7	0.5	0.1	340	4.7	67	78
3CB	7.0	0.4	3.0	2	0.2	59	18	40	5.4	21	1,100	0.04	--	20	1.0	0.2	330	7.4	140	130
4M	7.3	0.7	8.2	2	1.0	24	19	29	4.9	49	4,500	0.02	--	11	0.5	0.2	410	3.7	110	250
5T	7.8	0.6	7.1	2	0.5	21	19	75	4.5	26	1,200	0.08	--	14	1.0	0.2	400	3.2	110	150
7M	6.6	0.7	7.3	2	1.8	51	20	49	3.5	37	1,700	--	--	30	0.5	0.3	260	4.1	82	320
8T	6.2	0.6	5.3	2	0.2	56	12	19	3.1	18	700	--	--	21	0.2	--	380	4.2	78	64
9T	5.8	0.5	3.0	4	0.2	27	8	13	2.4	28	1,000	0.03	--	13	0.6	0.2	110	5.6	38	98
10T	7.3	0.8	6.3	2	0.3	58	14	43	3.5	33	750	0.07	--	27	0.4	2.4	230	6.2	77	120
11T	5.5	0.5	5.6	2	0.3	49	10	16	2.5	20	850	--	--	20	1.1	--	140	5.0	50	81
12T	6.1	0.7	20	3	0.1	54	13	18	3.0	18	840	0.03	--	24	0.4	--	150	3.8	61	84
13M	6.2	0.7	6.4	2	0.6	47	12	21	2.8	19	680	0.03	--	20	0.4	0.1	260	4.1	74	65
14M	6.6	0.7	6.3	2	0.3	48	12	24	2.9	23	570	0.04	--	21	0.4	0.5	250	4.0	75	77
15T	6.8	1.0	9.6	2	0.1	41	13	23	2.8	31	400	--	--	17	0.4	0.1	200	4.3	77	86
16CC	6.3	0.9	12	2	1.2	53	13	23	2.9	21	3,700	0.04	--	19	0.4	0.3	270	4.2	72	71
17M	6.0	0.6	4.4	2	0.2	89	16	24	4.2	20	860	--	--	23	0.2	--	370	5.5	120	85
18M	5.8	0.9	8.9	2	0.7	50	11	55	2.8	30	2,300	0.05	--	18	0.4	0.2	450	4.1	68	94

Table 8.--Concentrations of selected trace elements in fish-liver samples from sites in the Rio Grande Valley study unit

[Site location shown in figure 1; M, main-stem site, T, main-stem tributary site; CB, closed basin site; CC, Rio Grande Conveyance Channel site; values in micrograms per gram dry weight in fish liver; species code: ws, white sucker, cc, common carp, rt, rainbow trout, bt, brown trout; <, less than]

Site number	Species code	Alumi-num	Anti-mony	Arse-nic	Beryl-lium	Cad-mium	Chro-mium	Cobalt	Cop-per	Iron
1M	ws	<0.08	<0.17	0.17	<0.17	3.36	0.50	<0.17	34.9	207
2CB	ws	<0.07	<0.13	0.41	<0.13	0.25	1.21	0.32	60.3	785
4M	cc	0.59	<0.19	0.37	<0.19	0.45	0.85	0.20	99.0	248
5T	ws	9.05	<0.25	0.56	<0.25	<0.25	1.14	0.28	38.9	284
6T	ws	<0.10	<0.19	0.46	<0.19	<0.19	0.58	<0.19	16.9	251
7M	ws	<0.08	<0.17	<0.17	<0.17	0.22	0.47	<0.17	44.7	78
9T	rt	1.65	<0.20	0.59	<0.20	0.38	0.72	0.32	81.6	455
11T	bt	<0.08	1.29	1.76	1.77	1.27	0.62	0.87	342	472
12T	ws	<0.11	<0.22	0.33	<0.22	0.72	0.65	0.35	31.5	403
13M	cc	8.14	<0.23	0.54	<0.23	2.59	0.52	<0.23	84.0	476
14M	cc	3.62	<0.18	0.19	<0.18	1.98	0.36	<0.18	80.4	351
16CC	cc	8.80	<0.22	0.90	<0.22	1.10	0.48	0.28	77.2	1,326

Site number	Lead	Manga-nese	Mer-cury	Molyb-denum	Nickel	Sele-nium	Silver	Stron-tium	Ura-nium	Vana-dium	Zinc
1M	1.24	10.20	0.07	1.11	<0.17	1.80	0.42	0.30	<0.17	<0.17	87.8
2CB	<0.13	4.69	0.16	1.23	0.85	3.60	0.42	0.17	<0.13	0.73	82.0
4M	<0.19	7.53	0.20	0.92	0.56	4.98	1.46	1.20	<0.19	0.69	379
5T	<0.25	8.81	0.04	0.93	0.85	3.97	<0.25	1.13	<0.25	0.37	73.9
6T	<0.19	7.17	0.10	0.85	<0.19	2.25	0.35	0.16	<0.19	<0.19	62.6
7M	<0.17	6.08	0.07	0.84	<0.17	2.10	0.97	0.22	<0.17	<0.17	60.0
9T	<0.20	4.57	0.20	1.20	0.21	4.62	1.56	0.19	<0.20	0.22	92.7
11T	1.27	3.86	0.57	2.38	1.66	53.32	0.17	0.22	<0.17	0.78	81.8
12T	<0.22	6.83	0.17	1.36	0.31	2.74	0.35	0.27	<0.22	0.62	82.4
13M	<0.23	7.14	0.32	2.94	<0.23	4.24	0.79	0.89	<0.23	1.00	370
14M	<0.18	5.03	0.22	1.34	<0.18	3.37	1.44	1.16	<0.18	0.49	366
16CC	<0.22	12.60	0.37	1.69	<0.22	3.37	0.81	1.44	<0.22	1.12	353

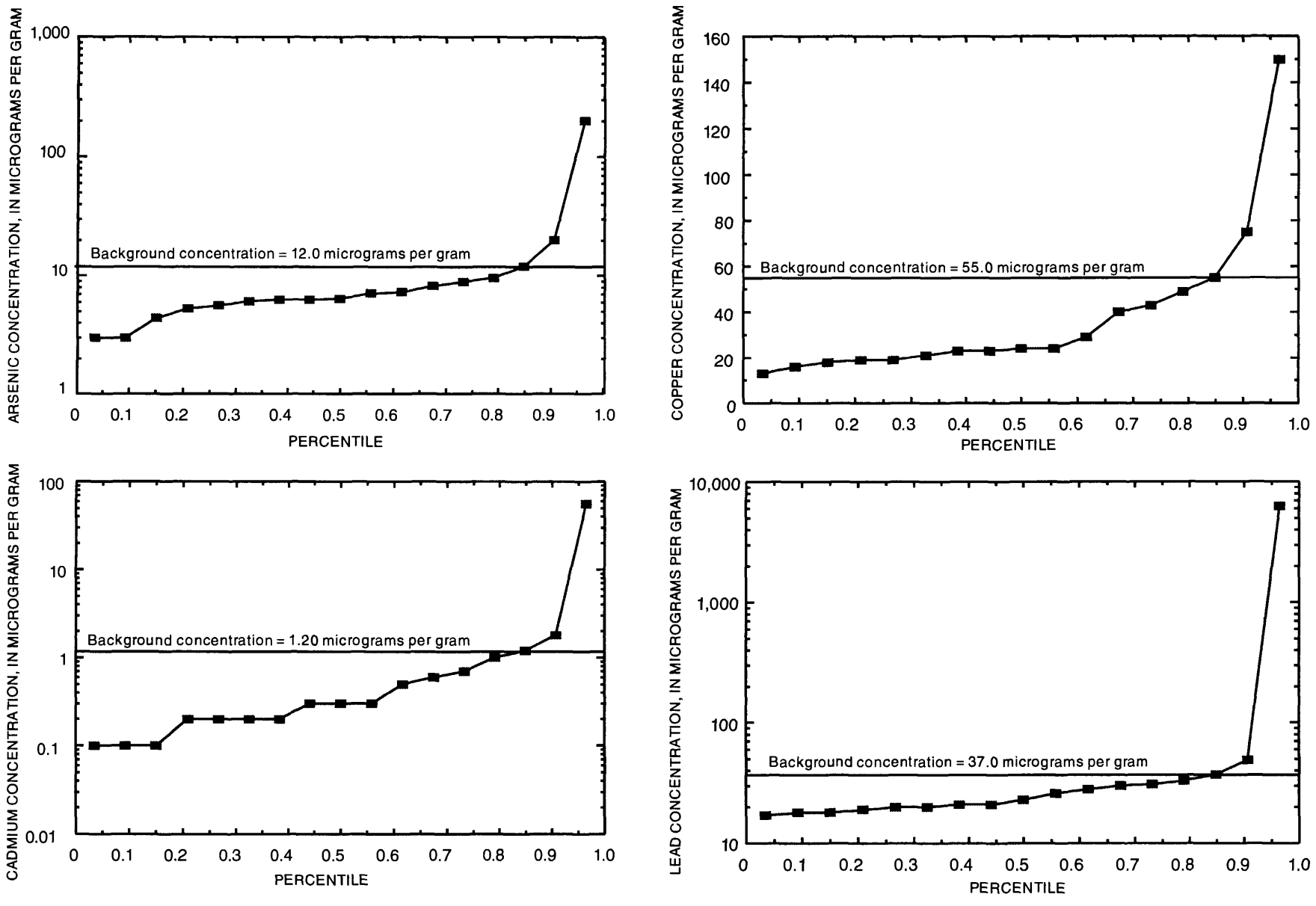
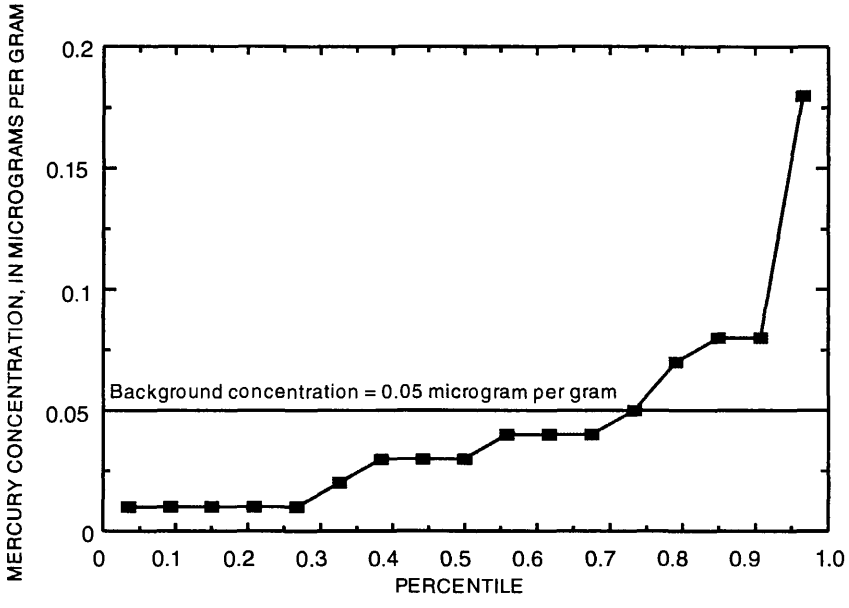
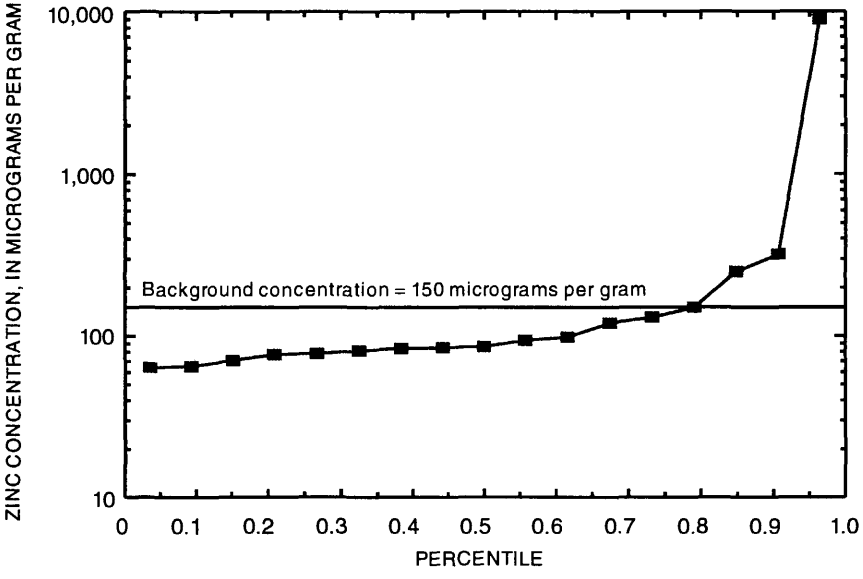


Figure 2.--Sample cumulation frequency curve used to determine the background concentration of selected trace elements in bed sediment.





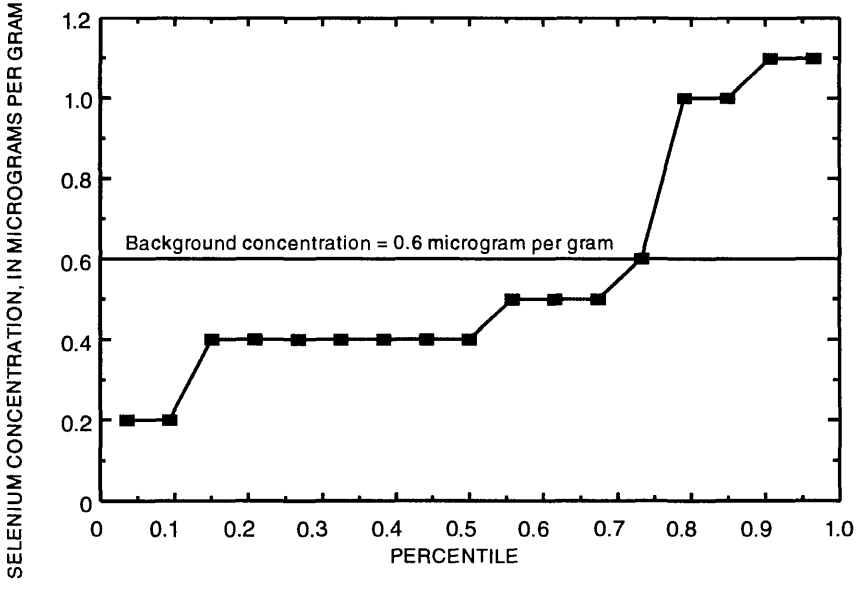


Figure 2.--Sample cumulative frequency curve used to determine the background concentration of selected trace elements in bed sediment--Concluded.

Table 9.--Background concentrations of selected trace elements in soils and bed sediment

[Values in micrograms per gram; --, not available]

Element	Jenkins (1981)[1]	Salomons and Forstner (1984)[1]	Shacklette and Boerngen (1984)[1]	Bed sediment from this study[2]
Arsenic	1.80-6.60	--	5.50	12.0
Cadmium	0.06	0.62	--	1.20
Copper	20.0	25.8	21.0	55.0
Lead	10.0-40.0	29.2	17.0	37.0
Mercury	0.02	--	0.05	0.05
Selenium	0.20	--	0.23	0.60
Zinc	--	59.8	55.0	150

[1]Value established for soil of the Western United States.

[2]Value determined from technique described by Velz (1984); see text for general description of technique.

A combination of natural conditions and human activities appears to be associated with elevated trace-element concentrations in the sample of bed sediment from site 1M. Bed-sediment concentrations at this site exceeded the background concentrations determined for all seven trace elements (table 9). In addition, concentrations of arsenic, cadmium, copper, lead, mercury, and zinc in the sample of bed sediment from site 1M were significantly larger ($p < 0.05$) than those in samples from other sites (table 7). At site 1M and other sites, no consistent pattern was evident when trace-element concentrations were compared with background concentrations or with trace-element concentrations among sites.

Main-stem and tributary sites have a similar spatial distribution in the relative composition of trace-element concentrations in bed-sediment samples, and they were not significantly different ($p > 0.05$) regardless of whether site 1M was included in the analysis, except for cadmium. Cadmium concentrations were significantly larger at main-stem sites than at tributary sites.

Variability among trace-element concentrations in common carp liver samples from main-stem sites (table 8) could be attributed to the proximity of these sites to geographically dispersed sources of trace elements and to the hydrological influences such as reservoirs and diversions. Copper, selenium, and zinc concentrations in common carp samples generally decreased with increasing distance from site 4M, and these trace-element concentrations in the sample from site 4M were significantly greater than the mean concentrations for the main-stem samples ($p < 0.05$). Other trace-element concentrations in samples did not show a similar decrease in concentration

with increasing distance from site 4M. Other samples, however, did have significantly greater trace-element concentrations than the mean concentration for samples from main-stem sites. The cadmium concentration in the sample from 13M was significantly greater ($p < 0.05$) than the mean cadmium concentration for the main-stem samples. The sample from site 14M had a lead concentration that was significantly greater ($p < 0.05$) than the mean lead concentration of main-stem samples; the sample from site 16M had an arsenic concentration that was significantly greater ($p < 0.05$) than the mean arsenic concentration of main-stem samples.

Both bed-sediment and fish-tissue samples are needed for a complete environmental assessment of the occurrence and distribution of trace elements. Fish-tissue samples also are essential for an indication of trace-element bioavailability because comparisons of trace-element concentrations in samples of bed sediment and fish liver indicate variability between the two sample types. Common carp and white sucker were used to compare trace-element concentrations in bed-sediment and fish-liver samples because each species was collected at a number of sites. Most trace-element concentrations in bed-sediment samples do not correlate to concentrations in fish-liver samples from the same site, and selected trace elements were detected at higher concentrations in fish samples than in bed-sediment samples from the same site. Bed-sediment and common carp trace-element concentrations were not significantly correlated ($p > 0.05$), and copper was the only trace element that showed a correlation between bed sediment and white sucker ($p < 0.08$). Mean concentrations of copper, mercury, selenium, and zinc were generally higher in common carp liver than in bed sediment from the same site. Mean concentrations of mercury and selenium were generally higher in white sucker liver than in bed sediment from the same sites.

Comparison of selected trace-element concentrations in liver samples from common carp and from white sucker suggests that trace-element accumulation may be species dependent. Zinc concentrations in samples of common carp liver from sites 4M, 13M, 14M, and 16CC were three to four times those in samples of white sucker from sites 1M, 2CB, 5T, 6T, 7M, and 12T. Schmitt and Brumbaugh (1990) also found that common carp had higher whole-body zinc concentrations than other fish species analyzed during the U. S. Fish and Wildlife Service National Contaminant Biomonitoring Program. The environmental variability associated with bed-sediment chemistry was reduced by using the ratios of trace-element concentrations in samples of fish liver to those in samples of bed sediment from the same site. The mean ratios of copper, mercury, selenium, and zinc concentrations were significantly greater ($p < 0.05$) for common carp than those for white sucker. The two species had no significant differences ($p > 0.05$) in the ratios of mean concentrations of arsenic and cadmium. Because common carp tend to accumulate higher concentrations of trace elements than white sucker, they are probably the more sensitive indicator of the bioavailability of trace elements.

Brown trout appear to accumulate higher concentrations of some trace elements than other fish species. The brown trout liver sample from site 11T had a substantially higher concentration of arsenic, copper, mercury, and selenium (of the seven elements of most concern) than all other fish samples (table 8). Trace-element concentrations in the brown trout liver sample from site 11T can probably be attributed to factors other than bed-sediment chemistry. For instance, arsenic concentrations in samples of bed sediment were lower at site 11T than at site 12T (table 7). However, the brown trout liver sample from site 11T had a higher arsenic concentration than the white sucker liver sample from site 12T. Selenium concentrations in samples of bed sediment from sites 1M and 11T were the same, but the sample of white sucker from site 1M contained a lower selenium concentration than the sample of brown trout liver from site 11T or the samples

of fish liver from all other sites (table 8). Furthermore, neither common carp nor white sucker accumulated concentrations of copper or mercury to the extent that brown trout did. Common carp and white sucker samples contained smaller mean concentrations of copper (85.2 and 37.9 micrograms per gram (μg/g), respectively) and mercury (0.28 and 0.10 μg/g, respectively) than the brown trout sample from site 11T (table 8). A similar NAWQA study in the South Platte River Basin also reported that liver samples from brown trout often had higher concentrations of cadmium, copper, and selenium than samples of common carp or white sucker (J.S. Heiny and C.M. Tate, U.S. Geological Survey, written commun., 1996). Although only one sample of brown trout was analyzed during this study, results of that sample indicate that brown trout may accumulate certain trace elements more effectively than other species. To differentiate between environmental and species-dependent factors, however, the collection of multiple species at a number of individual sites would be necessary.

SUMMARY

The persistent environmental effect of DDT at site 9T is demonstrated by a greater number of DDT compounds exceeding the MRL in bed-sediment and whole-body rainbow trout samples than in samples from other sites. The presence of *o,p'*-DDT in both bed-sediment and whole-body fish samples from site 9T suggests a point source of DDT. Total DDT concentrations in the bed-sediment and whole-body fish samples from site 9T are higher than those in samples from other sites in this study. However, total DDT concentrations in samples from site 9T are not exceedingly high when compared with concentrations reported in other parts of the Rio Grande Basin in New Mexico. Concentrations of DDT at site 9T probably represent a localized source that is related to historical DDT use in the watershed.

The whole-body sample of common carp from site 14M generally contained the largest number of detections of different organic compounds, which is indicative of populated (urban) areas. The common carp sample from site 14M generally had the highest concentrations of organic compounds (except for site 9T) compared with other samples. Other organochlorine insecticides, including *cis*-chlordane, *trans*-chlordane, gamma-HCH, and *trans*-nonachlor, were detected in the whole-body sample of common carp from site 14M but at no other sites.

In this study, whole-body fish samples were a more sensitive indicator of the presence of organic compounds than bed-sediment samples because of higher detection frequencies and concentrations in whole-body fish. Of the total number of samples, the most commonly detected organic compound, *p,p'*-DDE, was detected more frequently in samples of whole-body fish than in samples of bed sediment. With the exception of DDT-related compounds, no other organochlorine insecticides or PCB's were detected in samples of bed sediment.

Because of the extent of mineralized areas in the Rio Grande Basin arsenic, cadmium, copper, lead, mercury, selenium, and zinc concentrations in bed-sediment samples at most sites could represent natural conditions. However, a combination of natural conditions and human activities appears to be associated with elevated trace-element concentrations in the bed-sediment sample from site 1M because these concentrations exceeded the background trace-element concentrations calculated for this study.

Variability among trace-element concentrations in common carp liver samples from main-stem sites could be attributed to the proximity of these sites to geographically dispersed sources of trace elements and to hydrological influences such as reservoirs and diversions. Copper,

selenium, and zinc concentrations in common carp samples generally decreased with increasing distance from site 4M, and these trace-element concentrations in the sample from site 4M were significantly greater than mean concentrations for the main-stem samples. Other trace-element concentrations in samples did not show a similar decrease in concentration with increasing distance from site 4M, but other samples did have significantly greater trace-element concentrations than the mean concentration for samples from main-stem sites.

Both bed-sediment and fish-tissue samples are needed for a complete environmental assessment of the occurrence and distribution of trace elements. Tissue samples of fish also are essential for an indication of trace-element bioavailability because comparisons of trace-element concentrations in samples of bed sediment and fish liver indicate variability between the two sample types. Most trace-element concentrations in bed-sediment samples do not correlate to those in fish-liver samples from the same site. Selected trace elements were detected at higher concentrations in fish-liver samples than in bed-sediment samples from the same site.

Accumulation of trace elements by fish appears to be species dependent. Zinc concentrations were higher in liver samples from common carp than from all other fish samples, whereas a brown trout sample contained significantly higher concentrations of arsenic, copper, mercury, and selenium than all other fish samples. To differentiate between environmental and species-dependent factors, however, the collection of multiple species at a number of individual sites would be necessary.

REFERENCES

Aguillar, A., 1984, Relationships of DDE/DDT in marine mammals to the chronology of DDT input into the ecosystem: Canadian Journal of Fish and Aquatic Science, v. 21, p. 840-844.

Allen, C.D., 1989, Changes in the landscape of the Jemez Mountains, New Mexico: Berkeley, University of California, Ph.D. dissertation.

Anderholm, S.K., Richey, S.F., and Radell, M.J., 1995, Water-quality assessment of the Rio Grande Valley study unit, Colorado, New Mexico and Texas--Analysis of selected nutrient, suspended-sediment, and pesticide data: U.S. Geological Survey Water-Resources Investigations Report 94-4061, 203 p.

Arbogast, B.F., 1990, Quality assurance manual for the Branch of Geochemistry, U.S. Geological Survey: U.S. Geological Survey Open-File Report 90-668.

Arruda, J.A., Cringan, M.S., Gilliland, D., Haslouer, S.G., Fry, J.E., Broxterman, R., and Brunson, K.L., 1987, Correspondence between urban areas and the concentrations of chlordane in fish from the Kansas River: Bulletin of Environmental Contamination and Toxicology, v. 39, p. 563-570.

Bryan, G.W., Langston, W.J., Hummerstone, L.G., and Burt, G.R., 1985, A guide to the assessment of heavy-metal contamination in estuaries using biological indicators: Occasional Publication Number 4 of the Marine Biological Association of the United Kingdom, Plymouth, England, 92 p.

Campbell, P.G.C., Lewis, A.G., Chapman, P.M., Crowder, A.A., Fletcher, W.K., Imber, B., Luoma, S.N., Stokes, P.M., and Winfrey, M., 1988, Biologically available metals in sediments: Ottawa, National Research Council of Canada, Publication NRCC 27694, 298 p.

Cordell, C., Long, C.L., and Jones, D.W., 1985, Geological expression of the batholith beneath Questa caldera, New Mexico: Journal of Geophysical Research, v. 90, p. 263-269.

Crawford, J.K., and Luoma, S.N., 1993, Guidelines for studies of contaminants in biological tissues for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 92-494, 69 p.

Cruz, R.R., DeWees, R.K., Funderburg, D.E., Lepp, R.L., Ortiz, D., and Shaull, D., 1994, Water resources data, New Mexico, water year 1993: U.S. Geological Survey Water-Data Report NM-93-1, 590 p.

Edwards, R., and Millburn, P., 1985, The metabolism and toxicity of insecticides in fish, *in* Hutson, D.H., and Roberts, T.R., eds., Insecticides: New York, John Wiley and Sons.

Eisler, Ronald, 1985a, Cadmium hazards to fish, wildlife, and invertebrates--A synoptic review: U.S. Fish and Wildlife Service Biological Report 85(1.2), 46 p.

_____1985b, Selenium hazards to fish, wildlife, and invertebrates--A synoptic review: U.S. Fish and Wildlife Service Biological Report 85(1.5), 57 p.

_____1987, Mercury hazards to fish, wildlife, and invertebrates--A synoptic review: U.S. Fish and Wildlife Service Biological Report 85(1.10), 90 p.

_____1988a, Arsenic hazards to fish, wildlife, and invertebrates--A synoptic review: U.S. Fish and Wildlife Service Biological Report 85(1.12), 92 p.

REFERENCES--Continued

Eisler, Ronald, 1988b, Lead hazards to fish, wildlife, and invertebrates--A synoptic review: U.S. Fish and Wildlife Service Biological Report 85(1.14), 134 p.

Ellis, S.R., Levings, G.W., Carter, L.F., Richey, S.F., and Radell, M.J., 1993, Rio Grande Valley, Colorado, New Mexico, and Texas: American Water Resources Association, Water Resources Bulletin, v. 29, no. 4, p. 617-646.

Farrington, J.W., Goldberg, E.D., Risebrough, R.W., Martin, J.H., and Bowen, V.T., 1983, U.S. "Mussel Watch" 1976-1978--An overview of the trace-metal, DDE, PCB, hydrocarbon, and artificial radionuclide data: Environmental Science and Technology, v. 17, no. 8, p. 490-496.

Gilliom, R.J., Alley, W.M., and Gurtz, M.E., 1995, Design of the National Water-Quality Assessment program--Occurrence and distribution of water-quality conditions: U.S. Geological Survey Circular 1112, 33 p.

Hirsch, R.M., Alley, W.M., and Wilber, W.G., 1988, Concepts for a National Water-Quality Assessment Program: U.S. Geological Survey Circular 1021, 42 p.

Hodson, P.V., Borgmann, U., and Shear, H., 1979, Toxicity of copper to aquatic biota, *in* Nriagu, J.O., ed., Copper in the environment, Part 2--Health effects: New York, John Wiley and Sons.

Horowitz, A.J., 1990, The role of sediment-trace element chemistry in water-quality monitoring and the need for standard analytical methods, *in* Hall, J., and Glysson, D., eds., Monitoring water in the 1990's--Meeting new challenges: Philadelphia, American Society for Testing and Materials STP 1102.

Jenkins, D.W., 1981, Biological monitoring of toxic trace elements: U.S. Environmental Protection Agency Report 600/S3-80-090, p. 1-9.

Klecka, G.M., 1985, Biodegradation, *in* Neely, W.B., and Blau, G.E., eds., Environmental exposure from chemicals--v. 1: Boca Raton, Fla., CRC Press, Inc.

Kirkham, P.M., and Holm, J.D., 1988, Environmental problems and reclamation activities at inactive metal mines and milling sites in San Luis Valley, Colorado: Denver, Mined Land Reclamation Division and Colorado Department of Health, Water Quality Control Division.

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.

Lynch, T.R., Popp, C.J., and Jacobi, G.Z., 1988, Aquatic insects as environmental monitors of trace metal contamination--Red River, New Mexico: Water, Air, and Soil Pollution, v. 42, p. 19-31.

Namminga, H., and Wilhm, J., 1977, Heavy metals in water, sediments, and chironomids: Journal of the Water Pollution Control Federation, p. 1725-1731.

New Mexico Geological Society, 1971, James, H.L., ed., Guidebook to the San Luis Basin, Colorado: 22d Field Conference.

_____1981, New Mexico highway geological map: Socorro, New Mexico Bureau of Mines and Mineral Resources.

Phillips, D.J.H., 1980, Quantitative aquatic biological indicators: London, Applied Science Publishers Ltd., 488 p.

REFERENCES--Concluded

Roy, Richard, O'Brien, T.F., and Rusk-Maghini, Monica, 1992, Organochlorine and trace element contaminant investigation of the Rio Grande, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, N. Mex., 39 p.

Salomons, W., and Forstner, U., 1984, Metals in the hydrocycle: Berlin, Springer-Verlag.

Schmitt, C.J., and Brumbaugh, W.G., 1990, National Contaminant Biomonitoring Program--Concentrations of arsenic, cadmium, copper, lead, mercury, selenium, and zinc in U.S. freshwater fish, 1976-1984: Archives of Environmental Contamination and Toxicology, v. 19, p. 731-747.

Schmitt, C.J., Zajicek, J.L., and Peterson, P.H., 1990, National Contaminant Biomonitoring Program--Residues of organochlorine chemicals in U.S. freshwater fish, 1976-1984: Archives of Environmental Contamination and Toxicology, v. 19, p. 748-781.

Schmitt, C.J., Zajicek, J.L., and Ribick, M.A., 1985, National Contaminant Biomonitoring Program--Residues of organochlorine chemicals in freshwater fish, 1980-1981: Archives of Environmental Contamination and Toxicology, v. 14, p. 225-260.

Shacklette, H.T., and Boerngen, J.G., 1984, Element concentrations in soils and other surficial materials of the conterminous United States: U.S. Geological Survey Professional Paper 1270, 105 p.

Shelton, L.R., and Capel, P.D., 1994, Guidelines for collecting and processing samples of stream bed sediment for analysis of trace elements and organic contaminants for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 94-458, 20 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, p. 2.

Timme, P.J., 1995, National Water Quality Laboratory 1995 services catalog: U.S. Geological Survey Open-File Report 95-352.

Uchida, N., Musachi, T., Katuura, H., Anzai, H., and Nishide, E., 1988, Uptake and fate of *p,p'*-DDT in carp and tilapia: Nip Suis Gak, v. 54, p. 129-133.

Velz, E.J., 1984, Applied stream sanitation, (2d ed): New York, John Wiley and Sons.

Verschueren, Karel, 1983, Handbook of environmental data on organic chemicals (2d ed.): New York, Van Nostrand Reinhold.

Weatherley, A.H., Lakes, P.S., and Rogers, S.C., 1980, Zinc pollution and the ecology of freshwater environments, *in* Nriagu, J.O., ed., Zinc in the environment, Part 1--Ecological cycling: New York, John Wiley and Sons.

Wiener, J.G., Jackson, G.A., May, T.W., and Cole, B.P., 1984, Longitudinal distribution of trace elements (As, Cd, Cr, Hg, Pb, and Se) in fishes and sediments in the upper Mississippi River, *in* Wiener, J.G., Anderson, R.V., and McConville, D.R., eds., Contaminants of the upper Mississippi River: Stoneham, Mass., Butterworth Publishing, p. 139-170.

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