

CHLOROPHENOXY HERBICIDE RESIDUES IN FISHES AND SEDIMENTS OF LAKE TEXOMA

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Eighty-eight whole fishes and 16 sediment samples from Lake Texoma, Oklahoma and Texas, were analyzed for concentrations of 2,4-D and 2,4,5-T residues. Relationships between herbicide residues and species, trophic level, and total lengths of fishes were determined. Also, the relationship between herbicide concentrations and sampling sites was examined. Both 2,4-D and 2,4,5-T residues were considerably higher in fishes from Lake Texoma than those reported from other studies. 2,4-D residues averaged 244 $\mu\text{g}/\text{kg}$ wet weight in fishes and 284 $\mu\text{g}/\text{kg}$ dry weight in sediments. Mean concentration of 2,4,5-T was 1001 $\mu\text{g}/\text{kg}$ in fishes and 861 $\mu\text{g}/\text{kg}$ in sediments. Differences between residues of either herbicide and species or trophic levels of fishes were not significant ($p = 0.05$). Correlations between 2,4-D or 2,4,5-T levels and fish length were also not significant ($p = 0.05$), which indicates that bioaccumulation does not occur. Differences between concentrations of either compound in fishes, sediment, or sampling sites were not significant ($p = 0.05$).

INTRODUCTION

Interest in effects of various herbicides on the aquatic environment has increased recently. Nationwide concern over suspected birth defects and cancer attributed to impurities associated with herbicides is evident (1). A recent plan to use 2,4-dichlorophenoxyacetic acid (2,4-D) to control Eurasian water milfoil [*Myriophyllum spicatum*] in Fort Cobb Lake, Oklahoma, elicited strong public opposition.

It is commonly assumed the bioaccumulation potential of chlorophenoxy herbicides is low, on the basis of studies of relatively short-term accumulations (2, 3). Such studies followed large-scale applications of 2,4-D for control of aquatic macrophytes. The purpose of this study was to determine concentrations of 2,4-D and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) in the biota and sediments of a lake which has not been subjected to large-scale aquatic weed eradication treatments. Instead, input into Lake Texoma appears to be from long-term, low-level usage of herbicides in the watershed.

Lake Texoma is a 36,032-ha impoundment that occupies portions of Texas and Oklahoma (Figure 1). The dam, located at river mile 726 on the Red River, was completed in January 1944 by the US Army Corps of Engineers. Authorized project purposes are hydro-electric power generation, flood control, water supply, improving navigation, and regulating flows of the Red River. The lake is also heavily used for sport and commercial fishing, and for recreation. The maximum depth is 34 m and the mean depth is approximately 9.4 m at normal pool level. Leifeste, *et al.* (4) described the water as well-buffered with carbonates (pH 8.0-8.7), moderately to

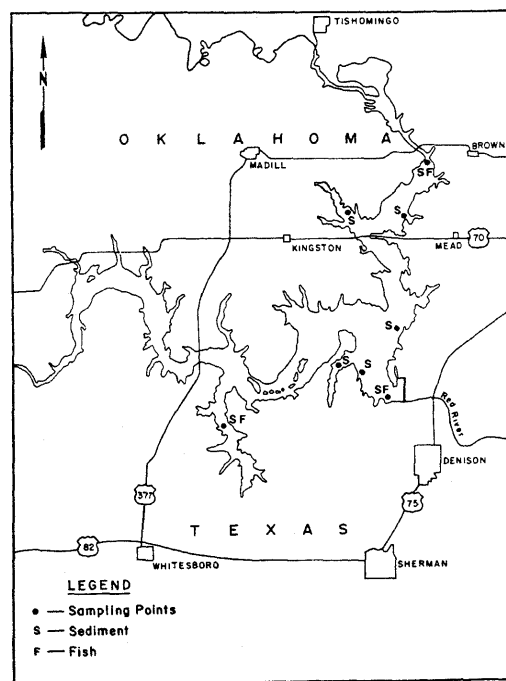


FIGURE 1. Map of Lake Texoma, Texas and Oklahoma, showing the location of sample points.

highly mineralized, and dominated by sodium and calcium sulfates and chlorides. The lake is thermally stratified during the summer months and also contains haloclines due to the high chloride content (5). The watershed has an area of 102,899 km² and is predominantly cropland and pasture. Principal crops of the basin are wheat, cotton, and grain sorghum. Much of the pasture is subject to invasion by scrub oaks (*Quercus* spp.), mesquite (*Prosopis juliflora*), and red cedar (*Juniperus virginiana*). Little industry exists in the basin except for petroleum production.

MATERIALS AND METHODS

Eighty-eight fishes were collected in gill nets from three areas of Lake Texoma on 25-26 June 1979 and duplicate sediment samples were collected with an Ekman dredge at eight sites on 30-31 May 1979 (Figure 1). Trophic levels and fish species were:

- Planktivores: Gizzard shad (*Dorosoma cepedianum*)
- Omnivores: Channel catfish (*Ictalurus punctatus*)
Freshwater drum (*Aplodinotus grunniens*)
- Carnivores: Striped bass (*Morone saxatilis*)

Overlap exists in the food habits of some of these species, but these groupings provide a general indication of feeding habits. Analysis of herbicide residues was performed at North Texas State University for the Tulsa District, Corps of Engineers. Each fish was wrapped in aluminum foil and transported to the laboratory where it was frozen for analysis at a later time. Analysis of fish filets followed methods recommended by the U.S. Food and Drug Administration (6). Individual whole fish were ground in a blender and an aliquot of each was removed and weighed. Chlorophenoxy herbicides residues were extracted and concentrations were determined with a Perkin-Elmer gas chromatograph.

Ten-gram samples of sediments from each site were dried at 95°C and the percentage of solids was determined. Chlorophenoxy herbicide residues were extracted from the sediment samples and the concentrations were determined as before by gas chromatography. The minimum detection limit of residues in both fishes and sediments was 50 µg/kg. Quality control measures included four spiked samples, in which recovery ranged from 93 to 105%. Herbicides in three replicate sediment samples were within 10% of the mean. Statistical analysis of the data was done with analysis of variance and a Newman-Kuells test when

TABLE 1. Ranges, means, and standard deviations of concentrations of chlorophenoxy herbicide residues in fishes from Lake Texoma, Oklahoma and Texas (concentrations in µg/kg).

Species	N	2,4-D		
		Mean	Range	SD
Gizzard shad	30	199	25-1888	373
Freshwater drum	29	165	25-1349	290
Channel catfish	17	316	25-1027	304
Striped bass	12	443	25-1277	354
Total	88	244	25-1888	338
Species	N	2,4,5-T		
		Mean	Range	SD
Gizzard shad	30	1263	25-11063	2090
Freshwater drum	29	809	25-2537	803
Channel catfish	17	995	25-2742	779
Striped bass	12	819	25-1653	567
Total	88	1001	25-11063	1362

the latter was required. Samples found to contain nondetectable levels of herbicide were assumed to contain 25 $\mu\text{g}/\text{kg}$ for statistical purposes.

RESULTS

Seventy-one percent of the fishes contained detectable concentrations of 2,4-D, with the largest amount being 1888 $\mu\text{g}/\text{kg}$, and 85% of the fish contained detectable concentrations of 2,4,5-T, with a maximum of 11063 $\mu\text{g}/\text{kg}$ (Table 1). Although both maxima occurred in gizzard shad, differences were not significant ($p = 0.05$) between concentrations of either substance and species or trophic levels of fishes. Sampling sites also were not correlated significantly ($p = 0.05$) with concentrations of 2,4,5-T or 2,4-D in fishes. Fish length was not correlated ($p = 0.05$) with amounts of either 2,4-D or 2,4,5-T in the individuals.

Sediment

All sediment samples contained 2,4,5-T in detectable quantities, and only one sample lacked 2,4-D (Table 2). The concentrations did not vary significantly ($p = 0.05$) between sampling sites for either compound. The mean content of 2,4-D in the sediment samples was 284 $\mu\text{g}/\text{kg}$ and the maximum was 844 $\mu\text{g}/\text{kg}$. 2,4,5-T averaged 861 $\mu\text{g}/\text{kg}$ and was as high as 2197 $\mu\text{g}/\text{kg}$.

TABLE 2. Ranges, means, and standard deviations of concentrations of chlorophenoxy herbicide residues in sediments from Lake Texoma, Oklahoma and Texas (concentrations in $\mu\text{g}/\text{kg}$).

Herbicide	N	Mean	Range	SD
2,4-D	15	285	25- 844	246
2,4,5-T	16	862	262-2197	477

DISCUSSION

The lack of significant correlation between chlorophenoxy herbicide residues in fishes and sediment and sampling sites indicates that the herbicides are rather uniformly distributed. A similar study of another class of organic compounds, polychlorinated biphenyls (PCB), which was localized in sediments showed a relationship between sediment "hot-spots" and the distribution of contamination in various species of fishes (7). The PCB in this previous study exhibited bioconcentration, and elevated concentrations of PCB in bottom-feeding fishes was evidence of direct ingestion of contaminated sediments. Apparently, this does not occur with chlorophenoxy herbicides since bottom-feeding fishes did not contain significantly larger amounts of herbicide residues. The lack of significant difference between herbicide residues and trophic levels shows that biomagnification does not occur. Lack of correlation between herbicide concentration and fish length also shows that bioconcentration does not occur. Bioaccumulation was obvious, although this is in contrast to observations made by Bovey and Young (8). The 2,4-D and 2,4,5-T concentrations found in Lake Texoma were considerably greater than those reported by other investigators (9, 10). The mechanism responsible for these accumulations is not clear, since bioconcentration and biomagnification do not appear to occur.

A possible explanation for these variable, elevated concentrations of herbicide residues in fishes and sediments of Lake Texoma is related to frequent high concentrations of turbidity throughout the lake. Data obtained from the US Environmental Protection Agency's STORET water quality file shows that maximum turbidity varied little among stations on Lake Texoma. During a 4-year period, minimum Secchi disk visibility at five stations in various areas of the lake ranged from 2 to 15 cm. Much of this suspended material is fine-grained particles and colloidal clays which are common in the watershed (11). The herbicide 2,4-D is strongly cationic and will bind with soil particles upon contact (12). The relative electronegativity of sediment particles is responsible for their ability to retain 2,4-D molecules, and clay or silt will tend to bind 2,4-D more strongly than sandy particles (13). It is probable that 2,4,5-T follows a similar pattern of binding by soil. A possible mechanism for the observed contamination begins when chlorophenoxy herbicides used for brush control operations in the Lake Texoma watershed adsorb to soil particles which wash into the lake. The finer soil particles remain suspended in the water where the associated herbicides may contaminate fish by various methods. All species would be susceptible to diffusion of herbicide across the gill membrane, and filter feeders would be especially likely to ingest contaminated

particles. This would explain why the highest concentrations of both compounds were found in gizzard shad. Heavier soil particles, with the attached chlorophenoxy herbicides, would settle to the bottom where they might be ingested by bottom-feeding fish. The variety of methods by which contamination could occur would result in the variable concentrations of herbicide residues observed in the fishes from Lake Texoma. High herbicide concentrations in the sediments, lakewide, would also be produced from such a mechanism.

No standard or action concentrations for chlorophenoxy herbicides in fish tissue have been established by the Food and Drug Administration. The U.S. Geological Survey has adopted an alert limit of 20 $\mu\text{g}/\text{kg}$ for 2,4-D or 2,4,5-T in sediments. Although 20 $\mu\text{g}/\text{kg}$ is below the detection limit in this study, the mean value for all sediment samples from Lake Texoma was 14 (2,4-D) to 43 (2,4,5-T) times as great as the alert limits.

The following conclusions can be drawn from this study:

1. Neither bioconcentration nor biomagnification of chlorophenoxy herbicides occurs.
2. Bioaccumulation occurs and concentrations of herbicide residues in whole fish can be substantial.
3. The primary mechanism for chlorophenoxy herbicide contamination at Lake Texoma appears to be adsorption to soil particles which are washed into the lake from the watershed.
4. Lake Texoma sediments contain 2,4-D and 2,4,5-T residues at levels above the USGS alert limit.

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