Bull. Environ. Contam. Toxicol. (1987) 39:563–570


Bulletin of Environmental Contamination and Toxicology

# Correspondence Between Urban Areas and the Concentrations of Chlordane in Fish from the Kansas River

Joseph A. Arruda,[1] M. Steve Cringan,[1] Donald Gilliland,[1] Stephen G. Haslouer,[1] James E. Fry,[1] Russell Broxterman,[2] and Kenneth L. Brunson[3]

[1]Division of Environment, and [2]Division of Laboratories and Research, Kansas Department of Health and Environment, Forbes Field, Topeka, Kansas 66620; and [3]Kansas Department of Wildlife and Parks, RR2, Box 54A, Pratt, Kansas 67174

Contaminant levels in fish tissue are monitored by the Kansas Department of Health and Environment (KDHE) and the Kansas Fish and Game Commission (KFGC). Chlordane is detected more frequently and at higher levels than other contaminants. Over 80 percent of the locations sampled in Kansas have detectable chlordane in fish (KDHE 1987). At over 50% of those locations, the levels of chlordane exceed 0.1 mg/kg, a guideline for the protection of predators (NAS/NAE 1973). At three locations associated with urban areas, chlordane concentrations have approached or exceeded the FDA action level for chlordane of 0.30 mg/kg (KDHE 1987).

The lack of river-wide fish tissue data from the Kansas River, a major river and fishery resource in Kansas, and the potential health and environmental implications of high levels of chlordane previously found in fish tissue at one location on the Kansas River, led to the development of this study. This report presents the results of that study and discusses its environmental and human health significance.

## MATERIALS AND METHODS

Fish were collected from thirteen sites (Figure 1, Table 1) extending over 125 miles from the Kansas River below the confluence of the Big Blue River near Manhattan to just above its confluence with the Missouri River in Kansas City. The sites were chosen to bracket major urban areas and to include segments of the river between such areas. Eleven sites were sampled in September 1986 and two sites (#6 and #13) in December 1986. Electrofishing techniques were used at each site. Collections were made by staff of KDHE, KFGC, and the U.S. Environmental Protection Agency (EPA) Region 7. At each site, except site #12, sufficient biomass was collected to provide duplicate

Send reprint requests to Joseph A. Arruda at the above address.

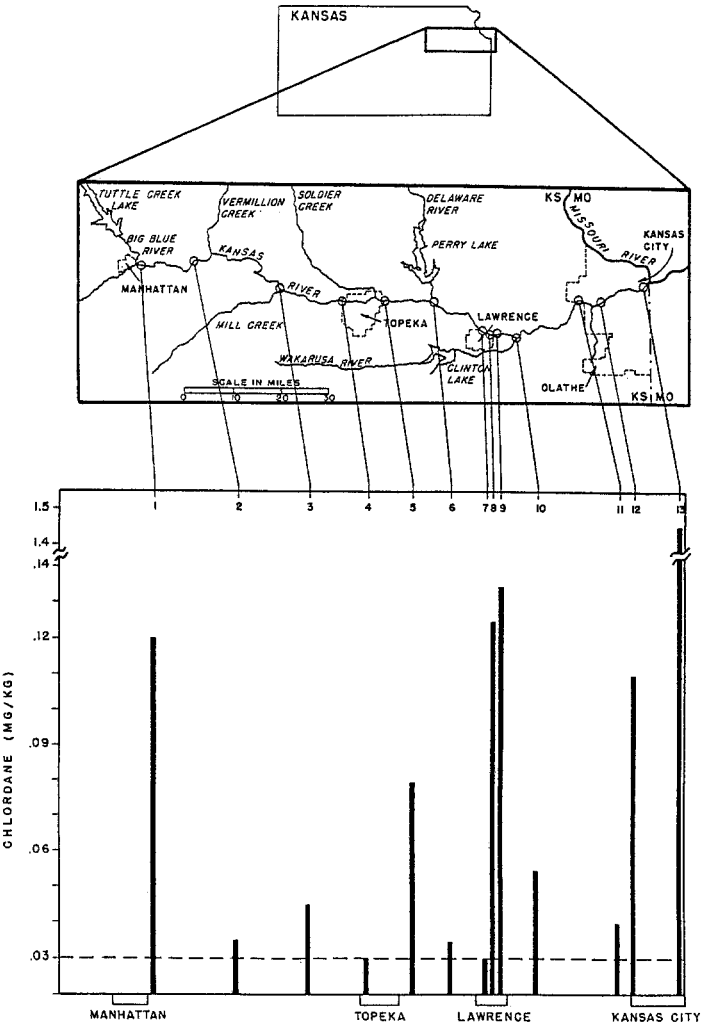


Figure 1. Distribution of sample locations and mean concentrations of chlordane (mg/kg) at each location. Horizontal axis in river miles.

---

samples for analysis and each sample was a composite of three to five fish (Table 2).

Common carp (Cyprinus carpio) were collected at all sites, except at site #11 where river carpsucker (Carpiodes carpio) was substituted as a duplicate because of poor carp collection success. Samples were placed on dry ice or ice and frozen at the KDHE laboratory within 2 hours of collection. Edible portions of individual fish were prepared by removing both scales and skin.

Table 1. Description of sample sites on the Kansas River.

| Site # | General Location | Type* | Legal Description |
|---|---|---|---|
| 1 | downstream of Manhattan | urban | S15,T10S,R08E |
| 2 | at Wamego | agric | S09,T10S,R10E |
| 3 | downstream of Mill Cr. near Willard | agric | S08,T11S,R13E |
| 4 | at Topeka (near water intake) | agric | S27,T11S,R15E |
| 5 | downstream of Topeka | urban | S31,T11S,R17E |
| 6 | at Lecompton | agric | S19,T11S,R18E |
| 7 | upstream of Lawrence | agric | S25,T12S,R19E |
| 8 | below Bowersock Dam at Lawrence | urban | S30,T12S,R20E |
| 9 | downstream of Lawrence MWWTP | urban | S32,T12S,R20E |
| 10 | above Wakarusa R. near Eudora | mixed | S04,T13S,R21E |
| 11 | at Bonner Springs | mixed | S32,T11S,R23E |
| 12 | at Edwardsville | mixed | S31,T11S,R24E |
| 13 | at Kansas City | urban | S11,T11S,R25E |

* urban = direct urban sources predominate due to sewage treatment plant discharge or urban streams, agric = agricultural nonpoint sources predominate, mixed = both

Each composite was processed three times through a meat grinder, with the ground tissue being thoroughly homogenized by hand between grindings. A representative 25 grams of this tissue were used for extraction. Chlordane was then determined according to EPA (1980a). The detection limit was 0.03 mg/kg wet weight for all samples. The % lipids was also determined.

The historical data in Table 3 are the results of composite samples analyzed for technical chlordane. The data are from the Regional Ambient Fish Tissue Monitoring Program (EPA Region 7), except the Bonner Springs location data (U.S. Fish and Wildlife Service) and the Willard data (KDHE). Site numbers correspond to the current study.

## RESULTS AND DISCUSSION

Sample chlordane concentrations ranged from not detected at eight sites to 2.1 mg/kg at site #13 in Kansas City (Table 2). Mean chlordane concentration increased at or below each major urban area and then decreased further downstream (Figure 1, Table 2). This overall correspondence between urban areas and elevated chlordane concentrations had been suggested from data collected in the midwest through various fish tissue collection programs (KDHE 1987). This pattern is demonstrated by considering the river in four sections, each with a major urban area: Manhattan (Sites #1-3), Topeka (Sites #4-6), Lawrence (Sites #7-10), and Kansas City (Sites #11-13).

Table 2. Results of Kansas River fish tissue analysis.

| Site | Species | Sample Number | No. Fish | Average Length (in.) | % Lipid | Chlordane (mg/kg) |
|---|---|---|---|---|---|---|
| #1 | Common Carp | 1 | 5 | na* | 3.7 | 0.11 |
| | Common Carp | 2 | 5 | na | 2.3 | 0.13 |
| #2 | Common Carp | 1 | 5 | 20.1 | 1.1 | 0.04 |
| | Common Carp | 2 | 5 | 19.8 | 0.44 | < 0.03 |
| #3 | Common Carp | 1 | 5 | na | 1.2 | 0.06 |
| | Common Carp | 2 | 5 | na | 0.2 | < 0.03 |
| #4 | Common Carp | 1 | 5 | 19.5 | 0.2 | 0.03 |
| | Common Carp | 2 | 5 | 20.3 | 0.1 | < 0.03 |
| #5 | Common Carp | 1 | 5 | 22.3 | 2.4 | 0.13 |
| | Common Carp | 2 | 5 | 22.4 | 1.4 | < 0.03 |
| #6 | Common Carp | 1 | 5 | 20.8 | 0.32 | < 0.03 |
| | Common Carp | 2 | 5 | 20.0 | 0.60 | 0.04 |
| #7 | Common Carp | 1 | 5 | 18.7 | 0.32 | < 0.03 |
| | Common Carp | 2 | 5 | 19.7 | 0.32 | < 0.03 |
| #8 | Common Carp | 1 | 5 | 19.5 | 0.70 | 0.15 |
| | Common Carp | 2 | 5 | 19.8 | 0.64 | 0.10 |
| #9 | Common Carp | 1 | 5 | 18.0 | 0.88 | 0.19 |
| | Common Carp | 2 | 5 | 17.4 | 0.44 | 0.08 |
| #10 | Common Carp | 1 | 4 | 20.5 | 1.6 | 0.06 |
| | Common Carp | 2 | 4 | 20.1 | 0.92 | 0.05 |
| #11 | Common Carp | 1 | 4 | 20.5 | 1.0 | 0.05 |
| | River Carpsucker | 2 | 5 | 15.7 | 0.12 | < 0.03 |
| #12 | Common Carp | 1 | 3 | 22.9 | 1.4 | 0.11 |
| #13 | Common Carp | 1 | 4 | 23.4 | 10.5 | 2.1 |
| | Common Carp | 2 | 4 | 24.0 | 3.0 | 0.81 |

*na = not available.

In the Manhattan segment, mean chlordane concentration was higher below the city (Site #1) than further downstream at Sites #2 and #3. In the Topeka segment, mean chlordane concentration was low above the city (Site #4), but higher immediately below Topeka (Site #5), before decreasing further downstream from Topeka at Lecompton (Site #6). In the Lawrence segment, mean chlordane concentration was low above a river dam in

the city (Site #7), but markedly higher at two sites (#8 and 9) below the dam. Further downstream, at Eudora (Site #10), mean chlordane concentration was lower. In the Kansas City segment, mean chlordane concentration was low at Bonner Springs (Site #11) but increased at Edwardsville (Site #12) and, especially, at Kansas City (Site #13), near the junction of the Kansas River with the Missouri River.

Locations such as Site #4 in Topeka or Site #7 above the dam in Lawrence might initially be considered to be urban sites, but they are above sewage treatment plant discharges, do not receive major urban drainage streamflow, and have lower chlordane concentrations. The concentration of chlordane at Site #12 at Edwardsville is higher than what might be expected for a river segment that is not directly urbanized. However, this site is at the confluence of Mill Creek, which drains a rapidly developing area of eastern Kansas (Fig. 1).

Chlordane has been found nationwide in water, sediments, and fish tissue (EPA 1908b). In Kansas, it is found only rarely in water (Butler and Arruda 1985; KDHE 1987). Since chlordane has a high bioaccumulation factor (on the order of 10,000, EPA 1980b), levels below the analytical detection limit could result in significant accumulation in fish tissue. The accumulation of chlordane in fish tissue is likely the result of the movement of chlordane from the sites of application on land into the river via water and/or sediment transport. Each site with chlordane levels greater than 0.10 mg/kg is located in or below urban areas, but specifically below sewage treatment plant discharges or streams draining urban areas.

Chlordane is one of the few persistent chlorinated hydrocarbon pesticides currently used in quantity and available to the general public. Chlordane was used widely as an agricultural pesticide and as a home and garden pesticide until EPA restricted its use in 1978 to subterranean termite control, non-food plants, and root dip. Limited agricultural use was permitted until 1980. In 1987, EPA re-registered chlordane, limiting its sale and use to licensed applicators for subterranean termite control. Much anecdotal information exists which suggests that significant home and garden use exists, especially for homeowner termite control or for control of undesirable lawn insects.

The percent lipid concentration also varied among the locations. The fish with highest percent lipid were found at Kansas City (Site #13), which also corresponds with the highest chlordane levels found. At Site #1 below Manhattan, however, sample 1 had more lipid than

sample 2 from Kansas City, yet it had only one-eighth of the chlordane. Other factors such as extent of exposure to a localized source, magnitude of source contamination, and size of fish might be controlling the body burden of chlordane, since there is not a consistent relationship between % lipid and chlordane concentration.

Chlordane is known to be metabolized in mammals to various products, including the more toxic oxychlordane, and to be deposited in fatty and muscle tissues, the liver, and the kidney (EPA 1980b). Oxychlordane also has been found in human breast milk (Savage et al. 1981). The recent EPA Health Advisory (EPA 1985) for chlordane in drinking water summarizes the health effects of chlordane, which includes effects to the central nervous system, liver and kidney damage, blood disorders and an increase in cerebrovascular disease. EPA (1985) considers chlordane to be a probable human carcinogen (defined as inadequate evidence from human studies and sufficient evidence from animal studies) with the liver as the major target organ in mice.

Two criteria are used to assess the health significance of the data. The first is the federal Food and Drug Administration's (FDA) action level for chlordane of 0.30 mg/kg. The second is the United Nation's Food and Agricultural Organization/World Health Organization (FAO/WHO) acceptable daily intake (ADI) for chlordane of 0.001 mg chlordane/kg body weight/day. The weight of an average adult, 70 kg, is used to calculate estimated safe consumption levels based on average chlordane concentrations at each site. Consumed fish are considered to be the only source of chlordane. As a reference value, about 8 ounces of fish with a chlordane concentration at the FDA action level could be consumed per day using the FAO/WHO ADI.

At non-urban sites, chlordane concentrations were below the FDA action level and less than 0.10 mg/kg. Estimated safe consumption levels are greater than 40 ounces per day. Fish from these sites are not representative of immediate or long-term health risks. The chlordane concentrations at urban Sites #1, 5, 8, 9, and 12 were approximately 1/3 to 2/3 of the FDA action level. Estimated safe consumption levels are in the range of 18 to 30 ounces per day. While still a high consumption level for even regular (e.g. daily) consumers of fish, the sites could be of concern depending on whether these particular samples represent the low or high range of concentrations from all fish at each location.

Chlordane concentrations in previous edible portion fish tissue samples from Site #8 were high enough (Table 3) to warrant a health advisory limiting consumption. The concentrations found here are at the lower end of the range of data. Site #13, at Kansas City, had the highest mean chlordane concentration (1.46 mg/kg): greater than 4 times the FDA action level. At this average chlordane concentration, the estimated safe consumption level would be only 1.6 ounces per day. Even one meal per week at this concentration is of potential health significance. One historical sample for this location (1980) had no detected chlordane in whole fish (Table 3).

Table 3. Previous fish tissue data collected from the Kansas River.

| Location | Species | Year | Type* | Chlordane (mg/kg) |
|---|---|---|---|---|
| at Willard (near Site #3) | carp | 1979 | W | < 0.24 |
| below Lawrence (at Site #8) | carp | 1983 | W | 0.99 |
| | carp | 1984 | W | < 0.03 |
| | carp | 1984 | E | < 0.03 |
| | carp | 1985 | W | 0.98 |
| | carp | 1985 | W | < 0.15 |
| | carp | 1985 | E | 0.45 |
| | carp | 1985 | E | 0.23 |
| near Eudora (near Site #10) | carp | 1980 | W | < 0.02 |
| | carp | 1982 | W | 0.72 |
| at Bonner Springs (at Site #11) | carp | 1977 | W | 0.28 |
| | carp | 1977 | W | 0.27 |
| | carp | 1979 | W | 0.47 |
| | carp | 1981 | W | 0.45 |
| | freshwater drum | 1977 | W | 0.11 |
| | river carpsucker | 1979 | W | 1.46 |
| | river carpsucker | 1981 | W | 0.46 |
| | channel catfish | 1981 | W | 0.43 |
| Kansas City (at Site #13) | carp | 1980 | W | < 0.02 |

*W = whole fish samples and E = edible portion samples

The criterion for examining the significance of chlordane concentrations in fish tissue for piscivores has been 0.10 mg/kg (NAS/NAE 1973). While this criterion is in need of revision, no other general guidelines are available.

The results of this study using edible portions suggests that concentrations of chlordane in whole fish (to which the 0.10 mg/kg criterion would be applied) would be exceeded. For example, at 5 of the 13 sites, mean chlordane concentrations were at or above the NAS/NAE guideline.

Previous fish tissue data from the Kansas River (Table 3), most of which are from whole fish, show that the NAS/NAE guideline has been exceeded in whole fish. The concentrations of chlordane in fish tissue at Bonner Springs and Lawrence were among the highest found in the Kansas River. This section of the Kansas River is critical habitat for the bald eagle. The effects of chlordane on piscivores and the ecological implications of chlordane based on altering fish physiology are not well known.

In the Kansas River, a major drainage and fishery resource in Kansas, higher concentrations of chlordane in fish tissue correspond to urbanization. The urban and suburban use of chlordane as a termiticide, and other uses or misuses in the urban environment, are suggested to be likely contributors to the presence of elevated concentrations of chlordane in fish tissue.

Acknowledgments. We thank biologists from KDHE, KFGC, and EPA Region 7 for sample collection and Kathy Nadeau and Cathy Fagan for drawing Figure 1.

REFERENCES

Butler MK, Arruda JA (1985) Pesticide monitoring in Kansas surface waters: 1973-1984. In: Perspectives on Nonpoint Source Pollution, A National Conference. US Environmental Protection Agency, Washington, DC, p 196

Kansas Department of Health and Environment (1987) Water Quality Implications of Chlordane in Kansas. KDHE, Topeka, Kansas

National Academy of Science - National Academy of Engineering (1973) Water Quality Criteria 1972. A Report of the Committee on Water Quality Criteria. EPA-R-73-033, US EPA, Washington, DC

Savage EP, Keefe TJ, Tessari JO, Wheeler HW, Applehans FM, Goes EA, Ford SA (1981) National study of chlorinated hydrocarbon residues in human milk, U.S.A.. Am J Epidem 113:413-422

US EPA (1980a) Modification of Mills, Onley, Gaither Method for the Determination of Multiple Organochlorine Pesticides and Metabolites in Human of Animal Adipose Tissue. Manual of Analytical Methods for the Analysis of Pesticides in Humans and Environmental Samples, EPA-600/8-80-038, US EPA, Washington, DC

US EPA (1980b) Ambient Water Quality Criteria for Chlordane. Office of Water Regulations and Standards, US EPA, Washington, DC

US EPA (1985) Chlordane Health Advisory. Office of Drinking Water, US EPA, Washington, DC

Received May 26, 1987; accepted June 16, 1987.