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Pesticides in Fish Tissue and Water from Tuttle Creek Lake, Kansas

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Since 1977, several agricultural pesticides have been detected frequently in water from Kansas rivers and lakes. Atrazine has been the most commonly detected pesticide, with alachlor, metolachlor, and 2,4-D detected at lesser frequencies (Butler and Arruda 1985). The ecological integrity of aquatic ecosystems could be compromised by the contamination of surface waters with agricultural pesticides.

Tuttle Creek Lake is an impoundment of 6,397 hectares on the Big Blue River, a major tributary of the Kansas River in northeastern Kansas. The lake controls a primarily agricultural-based watershed of 249,040 km^2 in both Kansas and Nebraska. This paper considers the occurrence of pesticides in fish and water from Tuttle Creek Lake, including a comparison of pesticides detected from water and fish and a consideration of the environmental significance of the data.

MATERIALS AND METHODS

Tuttle Creek Lake is unique because of its long, narrow, and shallow morphology. The lake is about 21 km long and 2 km wide, with a relatively shallow average depth of 8.25 m and a maximum depth of 20 m. Hydraulic retention time is 0.40 years. As a result of its morphology, flow through Tuttle Creek Lake probably proceeds mostly as pulsed slugs. Sampling sites were chosen to represent conditions at the upper and lower ends of this impoundment (Figure 1).

Fish samples were collected in April, July, and October 1985 using gill nets. The nets were set late in the evening and retrieved the next morning. Fish were wrapped in aluminum foil and immediately frozen. Common carp (Cyprinus carpio) and white bass (Morone chrysops) were the target species. Carp were chosen to provide a

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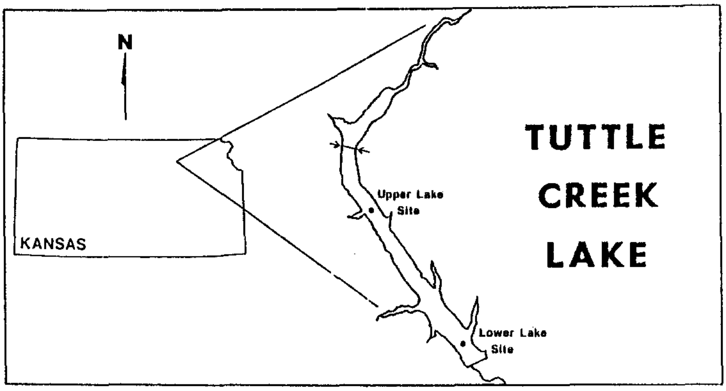

Figure 1. Map of Tuttle Creek Lake showing sampling locations.

comparison to routine carp tissue collections made elsewhere in the state for trend analysis. White bass were chosen to represent a fish of more importance to anglers. From two to six individual fish of each species were composited as one sample. Duplicate samples were taken at each location. Surface water samples were collected at approximately monthly intervals from April to October 1985.

The selection of species and tissue type for analysis represents a compromise to achieve the objectives of this study and to provide data comparable to other state fish tissue collection programs. Since carp are not a top trophic level predator, data on contaminant levels in whole carp may not represent maximum bioaccumulation potential. While the white bass fillet analyses are appropriate for evaluating human health implications, it falls short of providing information on organ or whole body contaminant levels in a predator.

All laboratory analyses were performed by the Environmental Protection Agency, Region 7 according to Method 608 - Organochlorine Pesticides and PCBs (July 1982) and Method 625 - Base Neutrals and Acids (July 1982). Carp were analyzed as whole fish and white bass as fillets with scales removed and skin left on.

Fish tissue data were analyzed two ways: (1) with a Type I fixed effects model analysis of variance with species, date of sampling, location of sample, and their interactions as main effects, and (2) with the nonparametric Kruskal-Wallace test using four groups (each species and location).

RESULTS AND DISCUSSION

Chlordane, dieldrin, heptachlor epoxide, 4,4'-DDE, and 4,4'-DDD were detected in most of the carp whole tissue and white bass fillet samples (Table 1). Chlordane was detected at higher concentrations than other contaminants in both species and averaged approximately 0.1 mg/kg. Dieldrin and 4,4'-DDE were detected at the next highest concentration, averaging approximately 0.05 mg/kg to 0.07 mg/kg. Heptachlor epoxide and 4,4'-DDD were detected at lower concentrations, averaging about 0.005 mg/kg to 0.008 mg/kg.

Table 1. Mean concentrations of pesticides detected in fish tissue samples with fish tissue guidelines and frequency of exceedence.

	Common Carp[1]			White Bass			Guideline		Exceedences of NAS/NAE Guideline and Range			
									Common Carp		White Bass	
Substances	n	N	Mean	n	N	Mean	FDA	NAS/ NAE	#	range	#	range
alpha-BHC	5	8	0.003	6	12	0.001	none	0.1[2]	0	-	0	-
chlordane	8	8	0.100	10	12	0.092	0.3	0.1[2]	3	0.13-0.17	4	0.11-0.16
dieldrin	8	8	0.069	11	12	0.058	0.3	0.1[2]	1	0.17	2	0.12-0.16
heptachlor epoxide	7	8	0.008	10	12	0.005	0.3	0.1[2]	0	-	0	-
4,4'-DDE	8	8	0.062	11	12	0.070	5.0	1.0	0	-	0	-
4,4'-DDD	7	8	0.008	8	12	0.008	5.0	1.0	0	-	0	-
o,p'-DDT	0	8	-	1	12	0.008	5.0	1.0	0	-	0	-

[1]n = number of samples with pesticides detected, N = number of samples analyzed, mean = mean of detected samples in ug/kg; [2]either singly or in combination.

There were some differences in fish tissue contaminant concentrations between species or between sample sites based on analysis of variance with nondetected values set to zero (Table 2). Whole carp had slightly higher a-BHC levels than did the white bass fillets. The other pesticides had no significant difference ($P>0.05$) in contaminant levels between species.

This result of no difference between species analyzed as different tissue types (whole and fillet) must be examined against the feeding habits of the two species. This is especially true for chlordane and the other organochlorine pesticides which are found mostly in fatty tissue that is removed when the fish is filleted. Because there are interspecific differences in feeding habits and habitat (carp is a bottom-feeding omnivore and white bass an open-water predator) between these

Table 2. Comparison of fish tissue pesticide concentrations in common carp and white bass from the upper and lower lake sites.

Substance	Species	Lake Site	Concentration and Frequency[1] n	N	Mean	P[2]	MEAN RANK[3]
a-BHC	common carp	upper	2	4	0.003	a	11.0
		lower	3	4	0.003	a	13.9
	white bass	upper	4	6	0.002	b	10.7
		lower	2	6	0.001	b	7.0
chlordane	common carp	upper	4	4	0.113	a	11.0
		lower	4	4	0.088	b	11.5
	white bass	upper	6	6	0.106	a	13.0
		lower	4	6	0.070	b	7.0
dieldrin	common carp	upper	4	4	0.060	a	13.8
		lower	4	4	0.078	b	12.0
	white bass	upper	6	6	0.077	c	13.0
		lower	5	6	0.034	d	4.8
heptachlor epoxide	common carp	upper	4	4	0.006	a	12.6
		lower	3	4	0.011	b	11.3
	white bass	upper	6	6	0.006	c	12.4
		lower	4	6	0.004	d	6.7
4,4'-DDE	common carp	upper	4	4	0.075	a	13.9
		lower	4	4	0.048	a	8.6
	white bass	upper	6	6	0.103	a	12.0
		lower	5	6	0.029	a	7.5
4,4'-DDD	common carp	upper	4	4	0.009	a	11.5
		lower	3	4	0.006	b	12.3
	white bass	upper	5	6	0.009	a	11.8
		lower	3	6	0.007	b	7.3

[1]n = number of samples with pesticides detected; N = number of samples analyzed; mean = mean of detected samples in mg/kg; [2]for each pesticide, the means with different letters are significantly ($P<0.05$) different based on analysis of variance; [3]mean ranks of each subgroup, based on Kruskal-Wallace test.

species, the potential for bioaccumulation would be expected to be greater in white bass than in carp. From our analysis, one would predict that had the whole body analysis been performed on white bass, differences between contaminant levels in carp and white bass would have been significant, with white bass showing greater levels.

The concentrations of dieldrin, 4,4'-DDD, and chlordane differed between fish samples from the upper and lower lake sites (Table 2, $P<0.05$). Concentrations of chlordane and 4,4'-DDD in both species were greater at the upper lake site. Dieldrin in white bass was also higher at the upper lake site. This trend may be due to the greater sediment deposition at the upper end of the lake and the tendency of these organochlorine pesticides to be associated with sediments. The site-related differences in white bass are not consistent with their behavior of being a highly mobile, non-sedentary, pelagic species. However, Tuttle Creek Lake is a very long lake and the specific habits of this species in the lake are not known.

There were also significant differences ($P<0.05$) due to the date of sampling in tissue concentrations of heptachlor epoxide, dieldrin, and 4,4'-DDE. This kind of pattern in persistent pesticides is not expected and is unexplained.

The treatment of "not detected" data in statistical analyses is important. Samples without detectable pesticides can be treated as zeros, as being at the detection limit, or in some intermediate fashion. For these data, the nondetected samples were made zero. When the analysis was redone, treating nondetecteds at the detection limit, the statistical significance in Table 2 disappeared.

Nonparametric testing may be used for data sets with nondetected results, if few ties in ranking exist, to avoid the problem of how to treat nondetecteds. With the Kruskal-Wallace test, the only statistically significant effect was for dieldrin ($P<0.05$). Location seemed to have the greater effect, with the mean rank of fish dieldrin concentrations from the upper lake being greater than those from the lower lake (Table 2). There was only a small difference in mean rank between species.

Since some statistical significance was found related to location in the lake using both nonparametric and parametric tests, there is an indication of a relationship between higher tissue contaminant levels and the upper end of the lake. There is no strong evidence for differences between the two species.

None of the fish tissue pesticide concentrations, including the whole fish carp samples, were above US Food and Drug Administration (FDA) action limits (FDA 1982) for regulating inter-state commerce (Table 1). FDA action levels are based on analysis of fillet tissue alone. These limits are often interpreted as safe levels for human health, but their derivation also includes other considerations.

The concentrations of chlordane and dieldrin in common carp were sometimes in excess of National Academy of Science/National Academy of Engineering (NAS/NAE 1972) guidelines for protection of predators of fish (Table 1). These guidelines are based on analysis of whole fish. For common carp, 37.5% (3 of 8) of the samples with detections were above the guideline for chlordane and only 12.5% (1 of 8) for dieldrin. The mean chlordane concentration in common carp was at the predator protection guideline level.

In white bass, 40.0% (4 of 10) of the samples with detections were above the guideline for chlordane and 18.2% (2 of 11) for dieldrin. Since white bass were analyzed as fillets, the actual concentration (in whole fish to compare to these guidelines) was probably greater. Indeed, if chlordane accumulation in the biota is due more to biomagnification (food chain concentration) than by bioconcentration (uptake from the physical environment), then white bass, a carnivore, may have much higher whole fish tissue contaminant levels than are indicated by the data presented here.

If the whole body levels of contaminants in white bass, or other species consumed by wildlife, are higher than estimated here, there is potential for environmental concern. For example, the Big Blue River from the Tuttle Creek Lake dam to its confluence with the Kansas River, and nearby segments of the Kansas River, are critical habitat for the bald eagle. There are no data that indicate whether the levels found in fish are, in fact, harmful to piscivorous wildlife.

Atrazine, alachlor, and metolachlor were the major pesticides detected in water (Table 3) None of these pesticides were detected in fish tissue. Atrazine does not significantly bioaccumulate (Klaassen and Kadoum 1979; Lynch et al. 1982), but if present in the water column at high concentrations, atrazine can be detected in aquatic life. Klaassen and Kadoum (1979) found some tissue concentrations in most aquatic life in farm ponds dosed with atrazine at 300 ug/l, higher than found here in water. In artificial streams, Lynch et al. (1982) also showed low bioaccumulation of atrazine in invertebrates and fish and a rapid (in days) decrease in atrazine tissue concentrations when the organisms were removed from waters with atrazine.

The failure to detect atrazine in fish tissue may have been due to a real lack of significant bioaccumulation. However, tissue concentrations, if present, may not

Table 3. Mean concentrations of pesticides detected in Tuttle Creek Lake.

Location	Atrazine*			Alachlor			Metolachlor			Ramrod			Sencor		
	n	N	Mean	n	N	Mean	n	N	Mean	n	N	Mean	n	N	Mean
Upper Tuttle Creek Lake	5	7	8.60	5	7	0.75	4	7	1.23	0	7	-	1	7	0.33
Lower Tuttle Creek Lake	6	7	6.42	4	7	0.71	4	7	0.93	1	7	0.25	0	7	-

*n = number of samples with pesticides detected, N = number of samples analyzed, mean = mean of detected samples in ug/l.

have been detected by the analytical procedures used. Analysis in May had a laboratory detection limit of 8.0 mg/kg. Atrazine was not scanned in July, and the October detection limit was 0.3 mg/kg. In comparison, Klaassen and Kadoum (1979) found atrazine at 0.2 to 0.3 mg/kg in bluegill (Lepomis machrochirus) and Lynch et al. (1982) detected atrazine in tissue at concentrations as low as 0.04 mg/kg. Another consideration is that atrazine may be transformed by the fish tissue into substances not detectable by the methods used.

While the concentrations of contaminants in fish tissue are of concern in terms of their effects on both human and non-human consumers of fish, they are also of concern for their potential effects on the survival and reproduction of the fish themselves. There are few data to evaluate this possibility.

The most significant contaminant of those found in water, in terms of relative concentration, is atrazine. The primary impacts of atrazine are on plant communities. Atrazine can impair phytoplankton photosynthesis and growth at the 0.1-25 ug/l concentration range (DeNoyelles et al. 1982; Brockway et al. 1984; Stratton 1984).

Although macrophyte and phytoplankton communities can be effected by atrazine, effects higher in the food chain have not been demonstrated. Such effects could be of potential significance. However, since the plankton are diverse to begin with, subtle changes in lower trophic level species composition may not produce demonstrable or environmentally significant results higher in the food chain.

Additionally, Tuttle Creek Lake is usually an extremely turbid lake, due to its largely agricultural watershed. There are no data that examine the effects of herbicides on ecosystems that are chronically turbid. It might be expected, for example, that phytoplankton communities already effected by the low-light high-nutrient environment of turbid midwestern reservoirs might show responses to herbicides different from that shown in less turbid lab culture or experimental ponds.

While the levels of atrazine found in the lake are above the levels thought to impair plants, there is as yet no demonstration of significant impacts to fish physiology, reproduction, or survival of eggs or fry. Such impacts, should they occur, could be significant.

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