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Organochlorine Pesticide Residues in Estuarine Fish from the Athi River, Kenya

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Organochlorine compounds such as DDT, lindane and aldrin are agricultural and public health pesticides that persist in the environment and accumulate in fatty tissues of living organisms. In Kenya, the chemicals were widely used between the mid 1940's and late 1970's in agriculture and aerial control of mosquitoes in the Lake Victoria region. The use of persistent organochlorine pesticides was banned or restricted in Kenya in 1986 (Pest Control Products Board records, 1986; Kimani, 1990- personal communication). Organochlorine pesticides mainly exert their detrimental effects in non-target organisms through chronic toxicity and sub-lethal exposure. This is the main concern for environmental scientists, conservationists and public health workers. DDT and its metabolites cause microsomal enzyme induction (Oestreicher, 1971), egg-shell thinning in birds (Chang and Stockstad, 1975) and tumour induction. DDT also reduces the reproductive success of birds and fish. Aldrin and dieldrin are potentially carcinogenic (IARC, 1974). Lindane and other hexachlorocyclohexane (HCH) isomers produce liver tumours in mice (IARC, 1974).

Studies of organochlorine pesticide residues in Kenyan fish have previously been focused mainly on Lake Victoria (Koeman *et al*, 1972; Kanja, 1989; Mitema and Gitau, 1990) and the Great Rift Valley lakes (Frank *et al*, 1977; Lincer *et al*, 1981). The present study was done to investigate organochlorine pesticide residue levels in fish from the estuary of Athi River. The main objective of the study was to identify and quantify organochlorine residues in the fish so as to assess the extent of contamination of the river by the pesticides and evaluate the toxicological significance of the findings.

MATERIALS AND METHODS

Sixty seven fish samples representing six species of fish were randomly collected from the estuary of Athi River at Malindi in February, 1989. The number of samples of each species of fish caught. are shown in Table 1. The fish were caught by gill nets. Samples of the fillet, liver and eggs were obtained, wrapped separately in aluminium foil and labeled appropriately. Samples from each fish were packed in a labeled plastic paper bag. The samples were later transported to the laboratory in cool boxes packed with freezer packs and stored at -20°C until the time of analysis.

Extraction, clean-up and analysis of organochlorine pesticide residues was done as described by Bjerk and Sundby (1970) with some slight modifications. Briefly the

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procedure involved grinding of 3g of the sample with equal amounts (4.5g) of acid-washed sea sand and anhydrous sodium sulphate. The pesticides in 4g of the homogenate were extracted with diethylether and the extract cleaned with base (15% methanolic sodium hydroxide) and acid (concentrated sulphuric acid). The final pesticide extract was obtained in 1ml of hexane. Aliquotes (2-5µl) of the pesticide extracts and a chlorinated pesticide mixture (CPM) standard were injected into a gas liquid chromatograph (GLC) for analysis.

A Packard gas liquid chromatograph, Model DX 12362, Series 428 fitted with a ^{63}Ni electron capture detector (ECD) was used for analysis. The GLC operating conditions were: Column, 2.0m x 4mm ID, all glass, packing GP 1.5% SP-2250/1.95% SP- 2401 on 100/120 Supelcoport. Temperature: column 210°C, detector 250°C, injector 230°C. Carrier gas: Nitrogen, flow rate 70ml/min. Attenuation 128; recorder chart speed, 10mm/min and recorder voltage, 10mV. The limit of pesticide residue quantitation was 0.001mg/kg calculated on wet weight basis.

Analysis of variance and Turkey's highest significant difference tests (Wayne, 1983) were used to determine if there was a significant difference in the means of residue levels in the various species of fish. A significant level of 5% was used.

RESULTS AND DISCUSSION

Eight organochlorine pesticide residues were detected in the fish tissues in the following proportions: p,p' DDE- 73%, p,p' DDT- 39%, o,p' DDT- 16%, p,p' DDD- 15%, β-HCH- 10%, α-HCH- 3%, heptachlor- 3% and o,p' DDD- 1%. The number of samples, in each species of fish, positive for at least one of the eight pesticide residues and the mean levels of the various organochlorine residues in the six species of fish are shown in Table 1. In total, 73% of the samples were positive for one or more of the pesticide residues detected. The pesticide residues were detected more frequently and in higher levels in the liver and egg samples than in the fillet. The mean and range of residue levels in the fish tissues analysed are summarized in Tables 2 - 5. There was no significant difference ($p>0.05$) between the levels of residues in the fillet, liver and eggs of the fish.

Sharks had the widest range of pesticide residues (Table 2) and the highest mean of sum DDT level (0.702mg/kg). There was a significant difference ($p<0.05$) between the mean sum DDT levels in sharks, breams and catfish. However, the difference between sum DDT levels in catfish and breams was not significant ($p>0.05$). The highest residue level recorded was 3.148mg/kg sum DDT in a liver sample from a female shark. The pesticide residues reported occurred at levels below the extraneous residue limits (ERL) set by the FAO/WHO Codex Alimentarius Commission (1986).

Organochlorine pesticide residues have previously been detected in Kenyan fish. Koeman *et al.*, (1972) reported extremely low levels (below 0.007mg/kg) of diedrin, p,p' DDE and DDT in fish from lake Nakuru. Greichus *et al.*, (1978) studied the contamination of lake Nakuru by organochlorine pesticides and reported very low levels in *Tilapia grahami*. Lincer *et al.* (1981) found undetectable to low levels of DDE in fish from lake Naivasha in a study conducted to investigate organochlorine pesticide residues in Kenya's Rift Valley lakes. A predatory fish from lake Baringo showed the highest level (2.13mg/kg) of DDE in the study. Kanja (1989) reported sum DDT levels ranging from 0.031 to 0.367mg/kg in fish

Table 1. Mean and range of pesticide residue levels in fish obtained from the estuary of the Athi River

	Samples		Pesticide residue (mg/kg) p,p' DDE	p,p' DDD	o,p' DDD	o,p' DDT	p,p' DDT	sum DDT	α-HCH	β-HCH	Heptachlor
Fish species	total	positive	Mean Range	Mean Range	Mean Range	Mean Range	Mean Range	Mean Range	Mean Range	Mean Range	Mean Range
Shark	31	24	0.397 0.053-1.257	0.046 0.026-0.078	0.039*	0.071 0.031-0.133	0.281 0.011-2.674	0.702 0.082-3.148	0.003*	0.075 0.042-0.095	-
Catfish	20	16	0.124 0.027-0.294	0.039*	-	0.045*	0.065 0.036-0.108	0.145 0.031-0.417	0.104 0.009-0.29	0.025*	0.033** 0.024-0.042
Breams	7	6	0.154 0.028-0.422	-	-	-	0.127** 0.108-0.146	0.213 0.031-0.614	-	0.158*	-
Mono-dactylus	1	1	0.703*	0.039*	-	0.056*	0.191*	1.077*	-	-	-
Soles	1	1	0.011*	-	-	-	-	0.012*	-	-	-
Malindi herrings	7	0	-	-	-	-	-	-	-	-	-

Residue levels are given on wet weight basis. Mean was calculated for positive samples. *Detected in only one sample. **Detected in two samples. (-) Below the detectable limit

Table 2. Mean and range of residue levels of DDT compounds in sharks from the estuary of the Athi River

		Pesticide residue (mg/kg)					
		p,p' DDE	p,p' DDD	o,p' DDT	o,p' DDD	p,p' DDT	Sum DDT
species/sex/ tissue	No. of samples	mean range	mean range	mean range	mean range	mean range	mean range
Male Sharks							
Liver	13	0.522 0.118-1.257 (11)	0.044 0.031-0.065 (3)	0.056 0.031-0.124 (5)	0.039 - (1)	0.154 0.011-0.331 (10)	0.522 0.118-1.257
Fillet	13	-	-	-	-	-	-
Female Sharks							
Liver	18	0.395 0.128-0.668 (12)	0.047 0.026-0.078 (5)	0.089 0.031-0.133 (4)	-	0.411 0.057-2.674 (10)	0.821 0.146-3.148
Fillet	18	0.074 (1)	-	-	-	-	0.082

Residue levels are given on wet weight basis
Mean was calculated for the positive samples
Figures in parentheses represent the number of positive samples for each residue
(-) Below the detectable limit

Table 3. Mean and range of residue levels of DDT compounds in catfish and breams from the estuary of the Athi River

		Pesticide residue (mg/kg)					
		pp' DDE	pp' DDD	op DDT	op' DDD	pp' DDT	Sum DDT
species/sex/ tissue	No. of samples	mean range	mean range	mean range	mean range	mean range	mean range
Male Catfish							
Liver	2	0.119 (1)	-	-	-	-	0.132
Fillet	2	-	-	-	-	0.036 (1)	0.036
Female Catfish							
Liver	18	0.09 0.069-0.294 (15)	0.039 (1)	0.045 (1)	-	0.108 0.108 (2)	0.141 0.03-0.417
Fillet	18	-	-	-	-	-	-
Eggs	16	0.141 0.069-0.294 (16)	-	-	-	-	0.156 0.076-0.326
Male Breams							
Liver	5	0.179 0.028-0.422 (5)	-	-	-	0.127 0.108-0.146 (2)	0.25 0.031-0.614
Fillet	5	-	-	-	-	-	-
Female Breams							
Liver	2	0.028 (1)	-	-	-	-	0.031
Fillet	2	-	-	-	-	-	-
Eggs	2	-	-	-	-	-	-

Residue levels are given on wet weight basis
Mean was calculated for the positive samples
Figures in parentheses represent the number of positive samples for each residue
(-) Below the detectable limit

Table 4. Mean and range of residue levels of DDT compounds in Malindi herrings, soles and Monodactylus spp from the estuary of the Athi River

		Pesticide residue (mg/kg)					
		pp' DDE	pp' DDD	op' DDT	op' DDD	pp' DDT	Sum DDT
species/sex/ tissue	No. of samples	mean range	mean range	mean range	mean range	mean range	mean range
Male Malindi Herrings							
Fillet	6	-	-	-	-	-	-
Female Malindi Herrings							
Fillet	1	-	-	-	-	-	-
Female Soles							
Fillet	1	0.011 (1)	-	-	-	-	0.012
Monodactylus spp							
Liver	1	0.703 (1)	0.039 (1)	0.056 (1)		0.191 (1)	1.077

Residue levels are given on wet weight basis Figures in parentheses represent the number of positive samples for each residue
Mean was calculated for the positive samples (-) Below the detectable limit

from Lake Victoria. Mitema and Gitau (1989) detected sum DDT ranging from 0.002 to 4.51 and 0.004 to 0.19mg/kg in the fat and fillet of Nile perch from Lake Victoria. Other organochlorine residues detected in the two studies were α-HCH, β-HCH, lindane, aldrin and dieldrin but in low levels.

The residue levels in the present study were generally higher than those reported in the other Kenyan studies but compare fairly well with the findings of Mitema and Gitau (1990). DDT and its main metabolite (p,p' DDE) constituted the largest proportion of organochlorine residues detected in the fish tissues. The mean sum DDT level in shark was 0.702mg/kg and the highest value was 3.148mg/kg. Mitema and Gitau (1990) reported mean sum DDT level of 0.45mg/kg and the highest level was 4.51mg/kg in fresh Nile perch fillet and fat from Lake Victoria. The Nile perch, like the shark in Malindi, is at the top of the food chain in Lake Victoria. Residue levels of HCH group residues ranged from 0.003 to 0.29mg/kg while Mitema and Gitau reported a range of 0.001 to 0.11mg/kg in Nile perch.

The levels of organochlorine residues found in this study are lower than most of those reported in fish elsewhere in the 1970's. El Zorgani (1976) reported a sum DDT range of 0.27-16mg/kg in fish from the Gezira region of Sudan. Sum DDT levels ranging from undetectable to 92mg/kg and 90-135mg/kg on wet weight basis have been reported in the United States of America and Norway respectively (Murty, 1986).

None of the samples analysed had residue levels above the extraneous residue limits (ERL) and acceptable daily intake (ADI) for the respective pesticides, set by the FAO/WHO Codex Alimentarius Commission (1986). This indicates that the residue levels were within the acceptable organochlorine pesticide residue limits in fish for human consumption.

The results of the present study show that the Athi River is contaminated with low levels of organochlorine pesticides. However, the levels of the chemicals in the fish are expected to decline with time since the country is phasing out the use of organochlorine pesticides.

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