Chlorinated Hydrocarbon Residues in the Fish of Lake Tanganyika

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INTRODUCTION

The use of chlorinated hydrocarbon pesticides for the control of tropical diseases and the treatment of agricultural crops in Central Africa has increased tremendously since it was started in 1954 (LAMBRECHT, 1954; BRION, 1962). Even though the levels of residues from such pesticides have been studied extensively in many parts of the world, there are few data from this region (KOEMAN and PENNINGS, 1970; EVERAARTS, et al., 1971; KOEMAN, et al., 1971, 1972). The purpose of this study was to determine the level of pesticides over a period of time in the fish in the northern portion of Lake Tanganyika which are used as a source of protein by the surrounding populations. Lake Tanganyika should make an excellent study area since it is almost a closed system and is surrounded by cotton plantations, especially at the northern end.

AREA AND SCOPE OF STUDY

Lake Tanganyika, situated in the Rift Valley of Africa, is 650 km long and up to 70 km wide (see Figure 1). The surface is approximately 800 m above sea level and the lake has a maximum depth of 1500 m and an estimated volume of 30,000 km^3. The annual rainfall of approximately 1 m and river inflow from the Ruzizi and Malagarasi rivers could raise the level by 0.5 m per year except for loss by evaporation (95 %) and drainage into the Lukuga river (5 %). This small drainage makes the lake similar to many closed systems. The wet season in the northern part of the lake starts near the first of October and the dry season near the 20th of May. The water chemistry of the lake is described by several authors (BEAUCHAMP, 1940, 1964; KUFFERATH, 1952; CAPART, 1952; TALLING and TALLING, 1965; DEGEN, et al., 1971).

During the cotton season of 1971-72 (primarily in May), the cotton fields in Burundi at the northern end of the lake were

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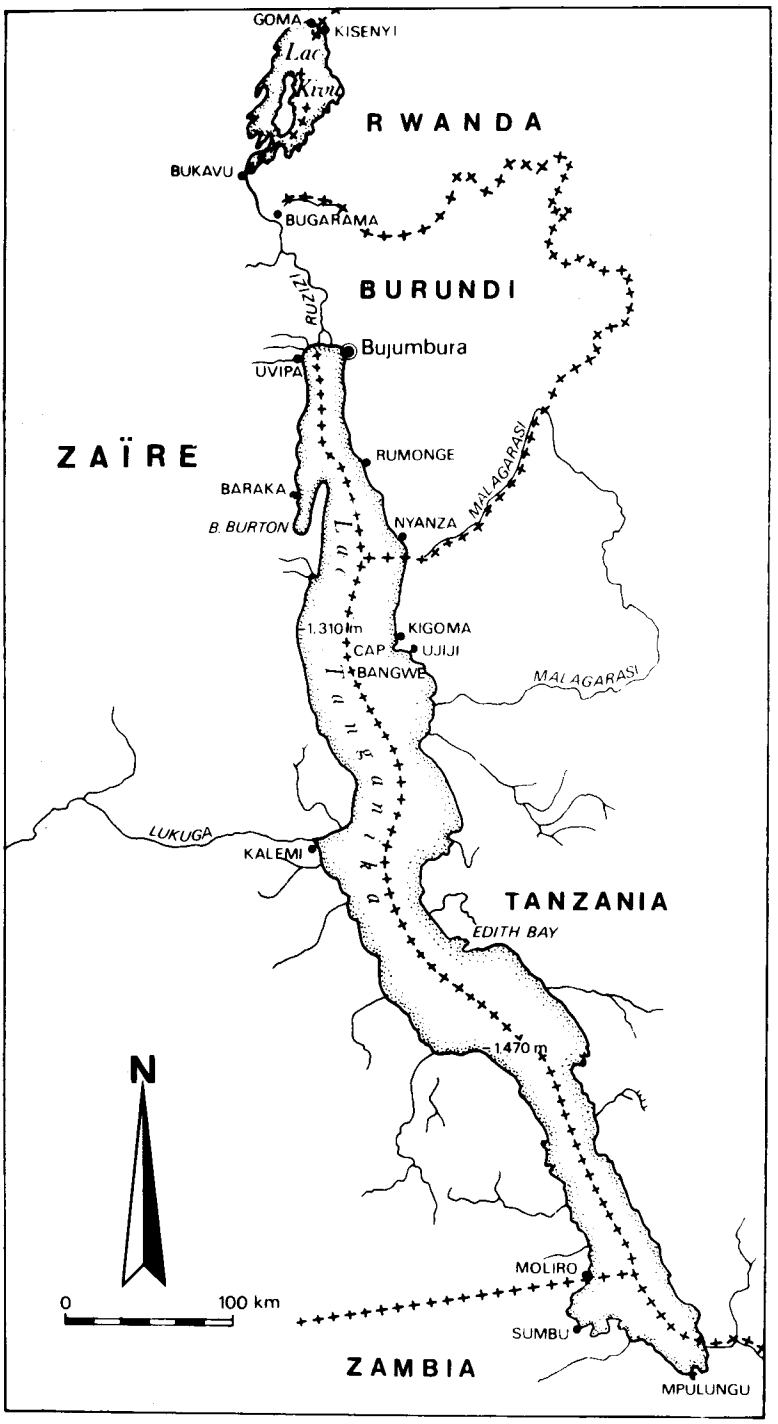

Figure 1. Lake Tanganyika

treated with a total of 30,900 kg of DDT, 9,200 kg of endosulfan, 4,200 kg of endrin, 1,000 kg of kelton, and 600 kg of metasystox. Residue from these pesticides could reach the lake by direct contamination from aerial spray but the greatest source is the run-off from treated fields in the plains along the Ruzizi river. Pesticides can also enter the lake water by unauthorized disposal and by accident such as the spillage of 6,510 liters of pesticide solutions due to a boat accident in February 1972.

The lake has been used since 1970 as a source of drinking water for Bujumbura (population 80,000) but the major ingestion of pesticide residues by the populace probably comes from the consumption of dried fish which is an important element of their daily diet. In Burundi the fish catch per year ranges from 12,000 tons to 17,000 tons (COULTER, 1970). Eighty-five per cent of this total catch consists of two clupeid species: Stolothrissa tanganicae Regan (commonly called ndagala) and Limnothrissa miodon Boulenger (known as lumpu). Their predators, the Lates (called sangala) and the Luciolates stapersii Boulenger (centropomidae) (called mukeke) represent 5% and 10% respectively of the catch. These species are all endemic to the lake.

The Stolothrissa and Limnothrissa occur together but the Stollothrissa constitutes the largest fraction of the offshore catch while the Limnothrissa is more abundant in the catches closer to the shore line. Growth rate and survival data indicate that both live about one year and that the adults are most abundant when the plankton concentration is the greatest. The clupeids feed on zooplankton and phytoplankton but the Luciolates seem to feed on the clupeids exclusively. Traditionally, the majority of the clupeids and the young Luciolates are sun-dried and eaten whole. Additional details of the biology and ecology of these fish species can be found in the works of POLL (1953), MARLIER (1957), COLLART (1958), COULTER (1966, 1970), MATTHES (1967), and ELLIS (1971).

Samples of fish were obtained from the commercial fisheries operating in the northern end of the lake at various times during 1971-2-3. The clupeids were adult specimens and the Luciolates were juveniles of approximately the same size as the clupeids. They were dried whole on cement floors in the sun for two or three days and were analyzed for residual moisture, nitrogen, lipids, ash, and pesticides.

EXPERIMENTAL

The percentage of weight loss (moisture) during sun-drying was determined by weighing the fish before and after exposure. The residual moisture was obtained by heating weighed, finely powdered samples of the sun-dried fish at 105 °C for 24 hours, followed by ignition for three hours at 500 °C to determine the ash content. The total nitrogen was found by the Kjeldahl method and the lipid content by the procedure of FOLCH, et al. (1957). The variation of crude fat content of Limnothrissa caught during 1973 was also determined by the FOLCH, et al. (1957) extraction method.

The chlorinated hydrocarbon residues were determined (except for the column substrate used) by the BERTUZZI, et al. (1967) modification of the MILLS, et al. (1963) method routinely used by the Food and Drug Administration for pesticide analysis. The fish were extracted with 35:65 water-acetonitrile, partitioned into petroleum ether, adsorbed on fluorisil, and eluted with ethyl ether-petroleum ether (6 % and 15 %). Aliquots of these solutions were injected into a Barber-Colman Model 5000 Gas Chromatograph which contained a 6 ft x 4 mm glass column of (2+1) 15 % QF-1 (10, 000 cst), 5 % DC 710 (10, 000 cst) on 80/100 mesh Gas-Chrom W (HP) and was fitted with an electron-capture detector.

Twenty-seven oven-dried (105 °C) flour samples of fish caught during November and December of 1971 and 18 samples of flours of sun-dried Limnothrissa caught between January and December of 1972 were analyzed for pesticides. Also, four of the oven-dried samples were analyzed for heavy metals by the BAETZ and KENNER (1973) method and the flour of one sun-dried adult specimen of Tilapia Tanganicae caught soon after the 1972 accident was analyzed for pesticide residues.

RESULTS AND DISCUSSION

The average per cent of moisture lost by drying in the sun was 74.9 % for the Stolothrissa, 73.5 % for the Limnothrissa, and 74.0 % for the Luciolates. The average compositions of the sun-dried fish flours are shown in Table I.

The seasonal variation of crude fat in fish flours from catches during 1973 is shown in Table II.

TABLE I

Average Composition of Sun-dried Fish Flours

Specie[1]	Residual Moisture 105 °C, (%)	Protein %	Lipids %	Ash %
Stolothrissa	8.3	69.7	6.3	14.6
Limnothrissa	9.9	63.3	8.2	13.5
Luciolates	8.8	70.1	6.5	13.9

TABLE II

Variation of Crude Fat in Fish Flour of Limnothrissa Caught in 1973

Date of Catch	Place of Catch	Residual Moisture 105 °C, %	Crude Fat %
January 26	Minago	7.3	13.4
February 28	Minago	9.0	4.39
March 14	Kitaza	8.6	7.19
April 26	Minago	12.5	4.12
May 26	Minago	13.3	5.15
July 20	Kitaza	10.5	4.04
August 8	Rutunga	8.6	6.51
September 8	Magara	11.2	9.88
October 31	Kitaza	11.6	9.88
November 18	Magara	14.8	6.00
December 5	Minago	11.5	4.81
Average		10.8	6.84

The results of the pesticide analysis of the oven-dried fish flour samples are shown in Table III. These values may be low due to the loss of pesticides by vaporization or codistillation (EVERAARTS, et al., 1971) during the oven-drying procedure. Except for the fish caught near Minago, there is a general decrease in the total amount of DDT (o, p'-DDT + p, p'-DDT) and its metabolites (DDE and TDE) as the distance increases from Bujumbura or the head of the lake. The average total DDT + DDE + TDE is approximately the same for Limnothrissa and Stolothrissa which feed on plankton and this average is more than twice the average for Luciolates which feed on the clupeids. Trace amounts (0.01-0.03 ppm) of endrin were found in some of these samples.

TABLE III

Chlorinated Hydrocarbon Residues in Oven-dried Fish Flour From Lake Tanganyika

	Bujumbura		Kitaza 27 km[1]		Rutunga 34 km[1]		Magara 43 km[1]		Minago 53 km[1]		Kagongo 60 km[1]		Muguraka 113 km[1]	
	Amounts Found (ppm)													
Specie[2]	DDE +TDE	DDT[3,4]	DDE +TDE	DDT[3,4]	DDE +TDE	DDT[3,4]	DDE +TDE	DDT[3,4]	DDE +TDE	DDT[3,4]	DDE +TDE	DDT[3,4]	DDE +TDE	DDT[3,4]
Limnothrissa			0.53	0.09	0.44	0.05	0.48	0.06	0.90	0.15	0.32	0.02	0.30	0.06
			0.89	0.44					0.74	0.35	0.45	0.24		
											0.58	0.24		
Stolothrissa	0.49	0.15	0.56	0.18	0.66	0.11	0.53	0.36	0.38	0.07	0.41	0.22		
			0.59	0.50					0.44	0.29	0.47	0.26		
									0.43	0.09				
Luciolates					0.32	0.02	0.17	0.03	0.53	0.07	0.20	0.04	0.20	0.02
									0.35	0.25	0.28	0.21		

[1]Distance from Bujumbura

[2]Caught during November and December 1971.

[3]Includes both o, p′-DDT and p, p′-DDT. Percentage of total due to o, p′-DDT ranges from 0 to 50% with an average of 17% and a median of 14%.

[4]Average total DDT + DDE + TDE is 0.70 for Limnothrissa, 0.73 for Stolothrissa, and 0.38 for Luciolates.

The results of the heavy metal analysis on the flours from four samples caught off Kagongo in November 1971 are shown in Table IV. No lead, cadmium, nickel, or cobalt were detected in any of these samples. The results of the analysis of the sun-dried

TABLE IV

Heavy Metal Analysis of Oven-dried Fish Flours

Specie	Amounts found (ppm) Cu	Fe	Mn	Zn
Limnothrissa[1]	0.04	0.67	0.15	1.27
Limnothrissa[2]	0.06	0.74	0.11	1.23
Luciolates[2]	0.04	1.83	0.08	1.00
Stolothrissa[2]	0.08	1.42	0.13	1.29

[1]Caught close to shore.

[2]Caught 10 km off shore.

flours of Limnothrissa caught during 1972 are shown in Table V. The amount of Total DDE + TDE + DDT varied from 0.45 ppm to 2.39 ppm with an overall average of 1.30 ppm. The DDE + TDE was always greater than the DDT (o, p'-DDT + p, p'-DDT) with the DDT averaging approximately 25 % of the total of these isomers. The average total amounts decreased the further the catch was from Bujumbura which indicates that the primary cause of residues is run-off from the treatment of the cotton fields along the Ruzizi plain. The total amounts of chlorinated hydrocarbons averaged 0.60 ppm from January through early April but fell to an average of 0.47 ppm in late April and then increased from June through September to an average of 2.04 ppm. From October through December the average was 1.30 ppm. The samples caught between June and July contained small amounts (0.02 to 0.17 ppm, average 0.07) of other chlorinated hydrocarbons (dieldrin, endrin, lindane). The sample caught September 29 off Kitaza had 0.65 ppm of these pesticides and was excluded from the average.

The analysis of the sun-dried flour from the adult Tilapia caught soon after the spillage accident in the lake showed (in ppm) DDE-1.57; TDE-7.54; o, p'-DDT - 1.97; p, p'-DDT - 17.83; dieldrin-0.11; lindane-0.18; endrin 3.55; total 32.75.

The results on the sun-dried samples of the fish used as a source of protein indicate that the amounts of chlorinated pesticides present are below the allowable limits set in most countries. On the basis of the fresh fish, assuming an average loss during drying of 75 %, the values are all less than 0.6 ppm. The

TABLE V

Chlorinated Hydrocarbon Residues in Sun-dried Limnothrissa From Lake Tanganyika

Date of catch (1972)	Amounts found (ppm) DDE + TDE[1]	DDT[2]	Total	DDE + TDE[1]	DDT	Total	DDE + TDE[1]	DDT	Total
	Bujumbura			Kitaza 27 km[3]			Rutunga 34 km[3]		
Feb. 11							0.57	0.19	0.76
Feb. 24							0.66	0.25	0.91
April 6							0.62	0.45	1.07
April 16							0.31	0.14	0.45
June 6	1.29	1.02	2.31						
July 5	0.81	0.92	1.74						
Aug. 3				1.21	0.97	2.18			
Sept. 13				1.20	1.19	2.39			
Sept. 29				1.00	0.63	1.63			
Oct. 12				0.96	0.34	1.30			
Oct. 31				0.87	0.37	1.24			
Nov. 17				1.11	0.81	1.92	0.55	0.38	0.93
Dec. 30	0.92	1.14	2.06	0.51	0.55	1.06			
Avg.			2.04			1.67			0.82
	Magara 43 km[3]			Kagonga 60 km[3]					
Jan. 26				0.49	0.20	0.69			
April 6	0.63	0.40	1.03						
April 16	0.31	0.18	0.49						
Avg.			0.76			0.69			

[1]DDE percentage averages 74.5 % of the DDE + TDE for all samples.

[2]Includes both o, p′-DDT and p, p′-DDT. Percentage of total due to o, p′-DDT ranges from 0 to 9 with average of 4 % and a median of 5 %.

[3]Distance from Bujumbura.

extremely high values found in the Tilapia indicates that fish caught in the area of such accidents soon after the accident should not be eaten.

The amino acid, fatty acid, and mineral content of these fish are being published separately (DEELSTRA, in press).

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