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Accumulation of Organochlorines in *Tilapia guineensis* and *Sarothorodon melanotheron* from Lagos Lagoon and Agboyi Creek, Nigeria

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Abstract: Two fish species of tilapia, *Tilapia guineensis* and *Sarothorodon melanotheron* were sampled from Lagos Lagoon and Agboyi Creek between December, 2008 and September, 2009 during the dry and wet seasons. They were analysed for organochlorines: aldrin, dieldrin, endrin, DDT, heptachlor, HCH, endosulfan, chlordane and methoxychlor. The muscle tissues and organs of the fishes were subjected to cold extraction and clean-up. The detection and determination of the organochlorine residues were performed using a gas chromatograph with a ^{63}Ni electron capture detector. All the fishes had condition factor >1. The organochlorine residues in the fishes in Lagos Lagoon were more than the level in Agboyi Creek while a higher concentration of the residues was observed during the dry season. The muscle tissues of the female fishes accumulated higher organochlorines than the muscle tissues of the male fishes. *Tilapia guineensis* accumulated higher residues in Agboyi Creek while *Sarothorodon melanotheron* accumulated higher residues in Lagos Lagoon. The order of accumulation of residues was gills>livers>small intestines>kidneys>muscles. Except for endrin and heptachlor, the estimated daily intakes of the organochlorines were within the acceptable daily intakes while the levels of residues in the fishes were within the permissible residue limits.

Key words: Accumulation, organochlorines, Tilapia, POPs, Nigeria

INTRODUCTION

Persistent Organic Pollutants (POPs) are organic compounds that are often halogenated and characterized by low water solubility and high lipid solubility. They are present at parts per trillion levels in water samples and at parts per billion or million levels in sediments and biota, thereby requiring highly specific, sensitive and reliable analytical methods for their measurements (Osibanjo and Ayejuyo, 1994). POPs include organochlorine pesticides, polychlorinated biphenyls, dibenzo-p-dioxins (dioxins) and dibenzo-p-furans (furans). Pesticides are chemicals used to kill or control pests. They play significant roles in increasing food production and eliminating diseases. However, exposure to pesticides can be harmful to humans.

Organochlorine Pesticides (OCPs) are found in the environment as a result of human activities. OCP residues enter aquatic environments through discharges of domestic sewage and industrial wastewater, runoff from agricultural fields, leaching and dumping of wastes into the water systems (Yang *et al*., 2005). The persistence and bioaccumulative tendency of these substances and their metabolites lead to their partitioning between the major environmental compartments in accordance with their physicochemical properties. These environmental distributions may lead to the exposure of living organisms including man that are far removed from intended targets.

Organochlorine pesticides are insecticides that act by poisoning the nervous systems of target harmful insects. Chlorinated pesticides with higher molecular weights have the ability to accumulate in biological tissues and to concentrate in organisms that occupy positions in the upper trophic levels. The aquatic organisms like fish are able to accumulate several fold higher concentration of pesticide residues than the surrounding water (Siddiqui *et al*., 2005). Fishes are affected when their water habitats or food sources are contaminated by pesticides, the extent of damage depending not only on the properties of the pesticides but also on the species of fish, age, size and position in the food chain. Tilapias are paraphyletic and feed on a wide variety of food such as insect larvae, crustaceans, juvenile fish, worms, various plants and detritus (Wikipedia Encyclopaedia).

The ill effects of pesticides may arise from short-or long-term and low-or high-level exposure. The OCPs contribute to many acute and chronic health effects including cancer, neurological damage, birth defects, tremors, headache, dermal irritation, respiratory problems and dizziness (IARC, 2001). They are also suspected endocrine disruptors and are highly toxic to the nervous system. Prenatal exposure to OCPs has been associated with neurological effects such as learning deficits and behavioural changes in infants as their developing organs are more sensitive and their bodies have limited ability to detoxify the pesticide residues.

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Fishes are suitable indicators for environmental pollution monitoring because they concentrate pollutants in their tissues directly from water and through their diet (Fisk *et al*., 2001; Lanfranchi *et al*., 2006). In order to obtain more information about the pathways along which bioaccumulation occurs, it is imperative to investigate the distribution of pesticide residues in muscle tissues and organs of fishes. This study was undertaken to determine the levels of organochlorine residues in muscle tissues and organs of *Tilapia guineensis* and *Sarothorodon melanotheron*, two species of tilapia that are commonly consumed in Nigeria.

MATERIALS AND METHODS

Area of study: The area of study for the investigation is Lagos Lagoon and Agboyi Creek. Lagos Lagoon lies between latitude 6°26'-6°37'N and longitude 3°23'-4°20'E while Agboyi Creek lies between latitude 6.56492 and longitude 3.41086 on the Western part of Nigeria. The lagoon empties into the Atlantic Ocean and is drained by some rivers and creeks including Agboyi Creek.

Sampling: The tilapias were sampled between December, 2008 and September, 2009 during the dry and wet seasons.

Collection of tilapias: Male and female tilapias, *Tilapia guineensis* and *Sarothorodon melanotheron* were harvested and separately wrapped in aluminium foil and stored in ice-packed coolers before they were transferred to the laboratory for biometric determination. They were frozen, thawed, cleaned in distilled water and their scales were sloughed off.

Sex determination: The tilapias were separated into males and females by examining their gonads.

Measurement of length: The total and standard lengths of the tilapias were measured using a ruler.

Calculation of percentage (%) dry matter: About 1.0-2.0 g of muscle tissue of each fresh tilapia was weighed and dried in an oven maintained at 105°C for 8 h. The dried tilapia was cooled in a desiccator and weighed in an analytical balance to constant weight. The percentage dry matter was calculated as follows:

$$\text{Dry matter (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100 \quad (1)$$

Calculation of Condition Factor (CF): The Condition Factor (CF) of the fishes was calculated according to the equation (Busacker *et al*., 1990):

$$CF = \frac{W}{L^3} \times 100 \quad (2)$$

Where:

W = The fish wet weight (g)
L = The fish total length (cm)

Determination of fat content: The 10 g of fish muscle tissue was homogenized with 10 g of anhydrous Na_2SO_4. Cold solvent extraction was carried out using 50 cm^3 petroleum ether/acetone (1:1 v/v) mixture in a reagent bottle. The mixture was well shaken, allowed to stand and then filtered. After evaporating the solvent extracts with the aid of a rotary evaporator, the fat content of the muscle tissue was determined gravimetrically as:

$$\text{Fat (\%)} = \frac{\text{Weight of fat}}{\text{Weight of tissue}} \times 100 \quad (3)$$

Extraction of tilapias for determination of organochlorines: Muscle tissues, livers, gills, kidneys and intestines of the tilapias were extracted. The 10 g of fish sample was homogenized with 10 g of anhydrous granulated Na_2SO_4. Cold solvent extraction was performed. The 50 cm^3 of the petroleum ether/acetone (1:1 v/v) mixture was introduced into a bottle containing the homogenized fish sample. The mixture was shaken, allowed to stand and then filtered into a glass container (USEPA, 2002).

Pre-concentration of tilapia extracts: The tilapia extracts were concentrated to 1 cm^3 using a rotary evaporator and kept for clean-up.

Clean-up of tilapia extracts: The clean-up of the tilapia extracts was carried out using column chromatography (USEPA, 1996). The glass separating column was packed with activated silica gel (90% <45 μm) and washed down with n-hexane. The extracts were demoisturized over 1 g of anhydrous granulated Na_2SO_4 and separated into two eluted fractions using mixtures of dichloromethane, hexane and acetonitrile as eluting solvents. The 30 cm^3 of dichloromethane/hexane (20/80) mixture was used for the first fraction while 30 cm^3 of dichloromethane/hexane/acetonitrile (50/49.5/0.5) mixture was used for the second fraction to ensure that the polar acetonitrile eluted any remaining residue. The two fractions were combined, concentrated to 1 cm^3 using a rotary evaporator and subsequently analysed.

Identification and determination of organochlorine residues by a gas chromatograph: The cleaned-up extracts were dried and re-dissolved in 1.0 cm^3 isooctane

(Pandit *et al*., 2002). Organochlorine Pesticides II EPA Method 8081A was used for the analyses. The detection and determination of the residues were performed by injecting 1 μL of the 1.0 cm^3 purified extract into the injection port of a gas chromatograph with a ^{63}Ni electron capture detector (GC-μECD Agilent Technology 7890A) equipped with the ChemStation Software. The column consisted of a DB-5 fused silica capillary column (30 m length×0.32 mm i.d.×0.25 μm film thickness). The column temperature was programmed from 50°C at a rate of 25°C min^{-1} to 100°C, held for 1 min and then at a rate of 5°C min^{-1} to 300°C, held for 5 min. The temperatures of the injector and detector were 250 and 300°C, respectively. The injection was carried out on a splitless injector at 250°C and the purge activation time was 30 sec. The carrier gas was helium while nitrogen was used as the makeup gas. The run time was 17 mins. Identification of pesticide residues was accomplished using reference standards and relative retention time techniques while the residues were determined by comparing the peak heights of the samples with the corresponding peak heights of the reference standards of known concentrations. The concentrations (ww) of the pesticide residues were calculated by the gas chromatograph after inserting the weights of the samples. The tilapia extracts were analysed for aldrin, dieldrin, endrin, DDT, heptachlor, HCH, endosulfan, chlordane and methoxychlor.

Quality assurance measures: The correlation coefficients of calibration curves of the pesticides were all higher than 0.998. The quality assurance measures included cleaning procedures, recovery of spiked standards and monitoring of detector response. Blank runs were made for background correction. The stock solution of the organochlorine pesticide standards was purchased from Restek Corporation, USA. It contained 1000 ppm in n-hexane and was serially diluted to obtain concentrations of 10, 20 and 40 ng mL^{-1}.

Recovery study: The recovery of organochlorines was carried out in replicate and was determined by spiking the previously analysed samples with the pesticide standard at concentrations similar to those expected in the samples. The recovery percentages were calculated from the chromatograms:

$$\text{Recovery (\%)} = \frac{CS_2\text{-}S_1\times 100}{CS} \quad (4)$$

Where:

CS_1 = Concentration of pesticide residues in the sample
CS_2 = Concentration of pesticide residues in the spiked sample
CS = Concentration of added pesticide

Estimation of Daily Intakes (EDI) of organochlorines by humans: The daily intake of organochlorines by humans was estimated based on questionnaires and interviews conducted in 100 families. Respondents were categorized into males and females. Information on preference of the fish species, age and weight of the respondents and frequency of consumption was collated. The dietary intake of the organochlorines was calculated by multiplying concentrations measured in the muscle tissues of fish by the per capita consumption. The estimated daily intake of the organochlorines was calculated using the equation below (International Programme on Chemical Safety, 2006):

$$EDI = \frac{FDC}{BW}\times CC \quad (5)$$

Where:

FDC = Fish Daily Consumption (g)
CC = Contaminant Concentration (ng/g)
BW = Body Weight (kg)
EDI = Estimated Daily Intake of OCPs (ng kg^{-1} body weight/day)

US EPA recommended values were used for daily intake calculations. The 70 kg was taken as average body weight, 6.5 g as daily fish consumption and 70 years as exposure for a lifetime.

RESULTS AND DISCUSSION

The mean biometric data of *Tilapia guineensis* and *Sarothorodon melanotheron* are shown in Table 1-4. There was a positive correlation between the total lengths and standard lengths of the fishes. Increase in fish lengths resulted in corresponding increase in fish weights. There was no correlation between the % fat and wet weights of the fish species. All the fishes had condition factor >1. This is important as the condition factor describes the physiological condition of fishes (Voight, 2003). An undernourished fish usually has a condition factor <1 while a healthy fish usually has a condition factor >1. The mean recoveries of the residues ranged from 88.45-98.42%.

The mean concentrations of organochlorines in muscle tissues and organs of the male and female fishes are shown in Table 5-10. The level of organochlorine residues in the fishes in Lagos Lagoon was more than the level in Agboyi Creek while a higher concentration of the residues was observed during the dry season. This observation is probably as a result of the higher contamination of the Lagos Lagoon and dilution effect that characterizes the wet season. The muscle tissues of the female fishes generally accumulated higher

Table 1: Mean biometric data of *Tilapia guineensis* and *Sarothorodon melanotheron* in Agboyi Creek during the dry season

Fish species	Feeding mode	Sex	Wet weight (g)	Dry matter (%)	Fat (%)	TL (cm)	SL (cm)	CF
T. guineensis	Carnivorous	Male	83.4±0.5	17.2±0.8	0.2±0.1	17.0±0.6	14.0±0.6	1.7±0.5
		Female	55.0±0.7	10.3±0.1	0.2±0.1	14.0±0.7	12.0±0.7	2.0±0.6
S. melanotheron	Herbivorous	Male	58.7±0.2	19.8±0.4	0.4±0.1	17.0±0.2	13.5±0.2	1.2±0.2
		Female	41.0±0.3	20.4±0.2	0.4±0.2	14.5±0.2	11.0±0.2	1.3±0.2

TL = Total Length of wet fish; SL = Standard Length of wet fish; CF = Condition Factor of fish; The mean value was calculated from 3 fishes of each species

Table 2: Mean biometric data of *Tilapia guineensis* and *Sarothorodon melanotheron* in Agboyi Creek during the wet season

Fish species	Feeding mode	Sex	Wet weight (g)	Dry matter (%)	Fat (%)	TL (cm)	SL (cm)	CF
T. guineensis	Carnivorous	Male	85.4±0.3	17.6±0.3	0.2±0.1	17.0±0.3	14.0±0.3	1.7±0.3
		Female	55.3±0.5	10.4±0.2	0.2±0.3	14.0±0.4	12.0±0.4	2.0±0.3
S. melanotheron	Herbivorous	Male	58.0±0.1	19.0±0.6	0.4±0.2	17.0±0.2	13.5±0.2	1.2±0.2
		Female	41.5±0.2	20.4±0.1	0.4±0.1	14.5±0.2	11.0±0.2	1.4±0.2

Table 3: Mean biometric data of *Tilapia guineensis* and *Sarothorodon melanotheron* in Lagos lagoon during the dry season

Fish species	Feeding mode	Sex	Wet weight (g)	Dry matter (%)	Fat (%)	TL (cm)	SL (cm)	CF
T. guineensis	Carnivorous	Male	32.3±0.6	17.3±0.5	0.2±0.1	13.0±0.5	10.5±0.5	1.5±0.4
		Female	63.2±0.8	22.1±0.8	0.3±0.2	15.5±0.7	12.5±0.7	1.7±0.6
S. melanotheron	Herbivorous	Male	65.2±0.3	26.4±0.3	0.3±0.1	13.5±0.3	11.0±0.3	2.7±0.2
		Female	72.8±0.2	29.9±0.2	0.3±0.2	16.0±0.3	13.0±0.2	1.8±0.2

Table 4: Mean biometric data of *Tilapia guineensis* and *Sarothorodon melanotheron* in Lagos lagoon during the wet season

Fish species	Feeding mode	Sex	Wet weight (g)	Dry matter (%)	Fat (%)	TL (cm)	SL (cm)	CF
T. guineensis	Carnivorous	Male	62.5±0.3	19.3±0.2	0.2±0.1	15.0±0.3	12.0±0.2	1.9±0.2
		Female	64.9±0.2	20.7±0.3	0.3±0.1	16.8±0.2	12.5±0.2	1.4±0.3
S. melanotheron	Herbivorous	Male	63.2±0.5	26.1±0.4	0.3±0.2	13.4±0.5	11.0±0.5	2.6±0.4
		Female	71.6±0.3	29.7±0.3	0.3±0.2	15.9±0.3	13.0±0.3	1.8±0.2

Table 5: Mean concentrations (ng/g) of organochlorine residues in the muscle tissues of male and female *Tilapia guineensis* during the dry and wet seasons

	Agboyi Creek				Lagos Lagoon			
	Dry season		Wet season		Dry season		Wet season	
OCPs	Male	Female	Male	Female	Male	Female	Male	Female
Alpha-BHC	3.9±3.2	ND	6.5±2.4	1.3±1.2	10.6±2.7	12.3±3.4	1.9±2.3	27.9±6.3
Beta-BHC	14.6±7.8	0.9±0.5	55.1±8.5	1.6±1.3	65.7±4.2	107.9±6.5	11.5±8.6	24.3±8.5
Lindane	4.7±2.3	0.9±0.2	18.1±4.6	1.4±1.2	39.8±5.4	11.1±2.7	2.8±3.2	81.6±9.3
Delta-BHC	11.2±4.7	0.6±0.6	10.2±2.2	ND	31.9±7.2	28.1±1.3	6.9±4.3	17.9±4.8
ΣBHC	34.4±18.0	2.4±1.3	88.9±17.7	4.3±3.7	148.0±19.5	159.4±13.9	23.1±18.4	151.7±28.9
Heptachlor	20±8.3	1.5±2.3	13.1±7.2	6.9±5.3	28.8±8.6	26.0±2.2	5.9±2.1	11.1±4.3
Heptachlor-epoxide (B)	38.9±4.4	5.9±3.4	5.6±4.2	ND	57.9±4.2	100.1±5.4	5.7±7.3	26.2±5.5
Aldrin	14.6±1.2	2.9±3.6	11.4±3.2	9.1±3.1	18.9±6.2	19.2±2.2	7.6±5.6	67±4.2
Dieldrin	ND	ND	3.6±4.1	13.6±2.2	41.9±3.2	8.9±3.1	ND	64.8±3.4
Endrin	116.9±9.6	64.9±8.3	16.8±8.4	92.3±3.3	183.3±9.2	40.2±4.3	15.9±7.3	91.2±4.6
Endrin aldehyde	ND	ND	ND	ND	192.2±6.4	216.8±0.7	ND	433.9±6.5
Endrin ketone	ND	ND	ND	ND	554.9±9.5	230.9±6.4	415.6±3.3	161.9±9.3
Cis-Chlordane	ND	ND	7.3±5.5	ND	37.7±5.9	25.6±2.3	5.0±2.4	17.2±5.3
Trans-Chlordane	ND	ND	16.9±6.2	ND	117.6±7.8	92.1±3.2	12.7±5.3	55.9±3.4
Endosulfan 1	46.6±2.2	33.8±5.3	17.1±3.8	69.3±8.2	47.9±2.2	33.3±3.2	20.2±2.9	37.5±3.8
Endosulfan 11	ND	ND	4.2±5.2	ND	26.8±1.3	11.5±5.3	ND	60.2±8.3
Endosulfan sulphate	ND	ND	7.2±3.3	ND	69.3±3.6	31.2±2.2	ND	48.3±4.2
Methoxychlor	ND	ND	15±8.4	ND	50.7±5.2	14.6±6.3	ND	25.7±2.4
p,p´-DDE	ND	ND	3.9±3.5	ND	27.4±2.4	29.6±2.2	8.4±5.4	19.1±7.1
p,p´-DDD	ND	ND	4.1±6.1	ND	67.5±8.2	35.9±4.3	ND	76.2±2.2
p,p´-DDT	ND	ND	ND	ND	122.9±3.6	30.4±6.3	ND	147.8±8.3
ΣDDT	ND	ND	8.0±9.6	ND	217.8±14.2	95.9±12.8	8.4±5.4	243.1±17.6
ΣOCPs	271.5±43.7	111.7±24.2	217.3±92.9	195.6±25.8	1793.8±107.0	1105.7±73.5	17.9±60.0	1495.6±111.7

The mean value was calculated from triplicate determinations

organochlorines than the muscle tissues of the male fishes. This may be due to physiological differences. *Tilapia guineensis* accumulated higher residues in Agboyi Creek while *Sarothorodon melanotheron* accumulated higher residues in Lagos Lagoon. There was no consistent pattern in the residue accumulation bymaleand femaleorgans of the fish species studied. Thetotal detectable organochlorines

Table 6: Mean concentrations (ng/g) of organochlorine residues in the muscle tissues of male and female *Sarothorodon melanotheron* during the dry and wet seasons

	Agboyi Creek				Lagos Lagoon			
	Dry season		Wet season		Dry season		Wet season	
OCPs	Male	Female	Male	Female	Male	Female	Male	Female
Alpha-BHC	11.4±5.4	13.5±6.3	1.1±1.3	4.7±3.4	24.8±5.3	66.7±5.2	1.8±1.5	ND
Beta-BHC	25.9±3.3	108.1±5.6	1.6±1.2	6.5±5.1	98.9±8.2	31.5±6.5	1.8±1.6	0.4±0.7
Lindane	14.8±8.6	11.6±2.5	1.1±1.8	3.7±1.2	15.2±4.4	20.2±3.3	1.2±1.8	0.6±0.5
Delta-BHC	8.9±2.8	37.3±5.6	0.8±3.6	10.8±1.7	57.1±3.5	18.4±5.2	1.7±1.2	ND
ΣBHC	61.1±20.1	170.5±20.0	4.6±7.9	25.7±11.4	196.0±21.4	136.8±20.2	6.5±6.1	1.0±1.2
Heptachlor	31.2±8.3	31.1±6.8	0.9±0.6	17.0±5.3	44.1±8.2	200.5±6.6	2.4±1.1	0.9±0.4
Heptachlor-epoxide (B)	79.4±3.3	61.5±4.6	0.6±0.2	10.4±4.3	17.5±3.8	20.6±4.6	0.7±0.2	0.6±1.4
Aldrin	11.6±5.2	17.5±6.4	1.5±1.9	12.1±2.6	20.5±8.2	48.1±3.1	0.7±0.4	1.5±2.1
Dieldrin	ND	41.0±7.3	ND	10.0±1.2	42.8±3.4	18.5±6.3	0.7±0.6	ND
Endrin	97.9±7.5	152.6±6.5	0.4±0.2	43.6±4.2	74.1±6.1	77.8±5.2	0.5±0.2	0.4±2.2
Endrin aldehyde	ND	211.1±8.6	ND	139.7±7.3	170.5±4.2	358.3±9.5	0.4±0.8	ND
Endrin ketone	ND	370.9±8.3	69.4±8.6	289.1±24.2	296.5±8.7	175.9±6.9	0	ND
Cis-chlordane	83.7±8.4	34.6±8.2	ND	12.0±3.3	30.6±3.2	37.5±3.5	0.6±0.7	ND
Trans-chlordane	15.8±3.0	56.8±4.5	0.6±0.2	13.9±3.2	81.9±5.3	55.4±5.8	0.8±0.7	0.5±0.6
Endosulfan 1	31.7±2.2	46.2±3.8	1.4±1.1	10.6±2.4	44.6±6.2	40.1±2.3	1.3±0.2	0.8±0.6
Endosulfan 11	55.9±6.3	23.4±3.3	ND	ND	20.8±2.1	100.4±9.3	0.5±0.4	ND
Endosulfan sulphate	ND	56.8±7.2	ND	30.4±2.6	85.7±8.4	88.6±6.2	0.5±0.1	ND
Methoxychlor	ND	51.9±8.1	ND	148.7±8.5	45.4±3.2	81.1±3.9	ND	ND
p,p´-DDE	74.7±4.6	42.3±3.2	0.7±0.5	29.5±5.4	22.1±4.1	67.2±9.2	0.7±0.1	ND
p,p´-DDD	55.6±0.3	46.4±0.4	ND	65.1±0.3	43.2±0.2	64.5±7.2	1.7±0.1	1.5±0.3
p,p´-DDT	ND	116.5±0.2	ND	ND	42.1±0.3	118.7±5.5	ND	ND
ΣDDT	130.3±4.9	205.2±3.8	0.7±0.5	94.6±5.7	107.4±4.6	250.4±21.9	2.4±0.2	1.5±0.3
ΣOCPs	598.6±69.2	1531.1±107.4	79.9±21.2	857.2±86.2	1278.2±142.0	1689.9±70.3	17.9±11.7	7.3±8.8

Table 7: Mean concentrations (ng/g) of organochlorine residues in the gills of male and female *Tilapia guineensis* during the dry and wet seasons

	Agboyi Creek				Lagos Lagoon			
	Dry season		Wet season		Dry season		Wet season	
OCPs	Male	Female	Male	Female	Male	Female	Male	Female
Alpha-BHC	21.9±3.2	24.9±7.3	1.5±2.6	1.9±1.4	56.6±6.4	53.9±4.7	53.7±9.5	57.2±2.8
Beta-BHC	33.7±4.3	36.6±5.5	2.7±2.1	2.9±3.6	260.0±12.3	246.3±8.3	240.8±8.7	243.9±6.4
Lindane	10.7±5.4	11.1±8.3	1.3±1.2	1.6±3.5	58.2±7.4	53.1±6.2	49.0±3.6	53.0±3.5
Delta-BHC	12.9±3.5	14.8±7.4	0.8±0.3	0.9±0.3	51.2±2.5	43.8±4.4	43.6±2.5	46.9±6.6
ΣBHC	79.2±16.4	87.4±28.5	6.4±6.2	7.4±8.8	426.0±17.6	397.1±23.6	387.5±24.3	401.0±19.3
Heptachlor	31.9±8.6	34.5±5.6	1.0±1.5	1.4±2.1	405.4±9.9	408.6±3.6	398.5±4.4	400.4±7.5
Heptachlor-epoxide (B)	52.0±7.3	49.7±8.3	3.9±1.6	3.9±5.3	154.1±3.6	148.5±5.5	134.7±2.3	146.1±4.5
Aldrin	16.8±5.6	18.0±1.6	1.7±2.2	1.9±2.2	130.5±5.4	122.7±6.6	102.6±3.4	120.6±5.7
Dieldrin	5.6±6.4	7.6±2.2	4.9±3.7	4.6±2.1	118.6±8.3	115.0±7.2	94.6±4.6	105.7±5.3
Endrin	198.9±16.5	178.2±4.5	46.2±2.4	52.8±5.2	199.3±5.2	195.6±8.2	148.9±8.3	167.7±6.4
Endrin aldehyde	ND	ND	ND	ND	1422.4±8.3	1366.2±25.6	1100.8±5.9	1313.9±8.2
Endrin ketone	ND	ND	ND	ND	615.4±4.5	598.6±8.3	423.8±4.3	590.4±6.4
Cis-chlordane	9.8±2.4	11.9±1.2	8.8±5.5	9.1±0.4	86.2±8.5	83.9±5.6	49.0±7.2	53.4±3.3
Trans-chlordane	14.9±4.5	16.9±3.3	12.9±2.4	13.9±6.3	ND	ND	ND	ND
Endosulfan 1	58.0±3.4	69.3±6.3	4.5±3.5	8.9±5.6	423.2±6.7	412.7±42.8	386.4±8.4	415.9±3.8
Endosulfan 11	ND	ND	ND	ND	161.9±8.3	157.5±5.5	126.4±7.6	135.0±6.4
Endosulfan sulphate	96.9±7.3	98.3±2.4	87.3±8.6	96.7±3.3	586.6±4.3	565.7±6.3	427.1±9.7	547.7±4.5
Methoxychlor	64.6±6.3	67.9±3.5	61.2±4.6	67.1±5.2	237.1±5.6	219.7±10.6	178.5±5.3	229.1±6.5
p,p´-DDE	ND	ND	ND	ND	138.1±12.2	123.1±8.3	90.9±6.2	8.8±3.6
p,p´-DDD	ND	ND	ND	ND	ND	ND	ND	ND
p,p´-DDT	45.5±2.5	47.1±7.6	30.9±2.3	35.8±4.6	375.6±7.5	423.7±13.5	286.5±8.5	345.6±4.4
ΣDDT	45.5±2.5	47.1±7.6	30.9±2.3	35.8±4.6	513.7±19.7	546.7±21.8	377.4±14.7	444.4±8.0
ΣOCPs	674.3±89.2	686.9±75.0	282.2±43.5	303.5±55.1	5480.5±115.9	5338.4±181.2	4335.9±110.4	5071.2±95.8

(wet weight ranged from 7.3 ng g^{-1} in muscle tissue of female *Sarothorodon melanotheron* during the wet season in Lagos Lagoon to 46716.4 ng g^{-1} in the gill of female *Sarothorodon melanotheron* during the dry season in Lagos Lagoon. The values obtained were higher when compared to studies earlier carried out in Ogun and Edo Rivers (Unyimandu and Udochu, 2002; Ize-Iyamu *et al*., 2007).

Table 8: Mean concentrations (ng/g) of organochlorine residues in organs of male and female Tilapia *Sarothorodon melanotheron* during the dry and wet seasons in Agboyi Creek

	Agboyi Creek							
	Liver				Gill			
	Dry season		Wet season		Dry season		Wet season	
OCPs	Male	Female	Male	Female	Male	Female	Male	Female
Alpha-BHC	89.1±1.3	9.4±6.4	70.5±4.6	50.4±7.3	85.5±8.5	1005.7±5.7	67.4±9.3	942.8±8.3
Beta-BHC	21.6±2.6	52.8±7.3	16.8±3.6	26.8±5.0	104.9±16.6	1579.6±8.2	87.4±4.7	1253.6±21.9
Lindane	71.9±5.4	18.5±6.2	80.4±2.6	46.7±9.1	103.0±8.8	1648.5±25.6	88.3±6.3	1428.8±8.3
Delta-BHC	25.7±2.3	14.1±4.5	23.7±2.3	13.9±6.2	34.8±3.4	1210.1±9.5	30.6±2.2	1054.2±7.4
ΣBHC	208.2±11.6	94.8±24.4	191.4±13.1	137.8±27.6	328.2±37.3	5443.8±49.0	273.7±22.5	4679.4±45.9
Heptachlor	246.3±8.3	14.8±6.1	198.2±6.2	75.2±6.6	278.2±9.5	954.2±5.4	265.4±9.4	764.9±6.8
Heptachlor-epoxide (B)	23.1±6.2	8.5±3.4	20.8±2.6	18.6±4.2	273.6±5.6	334.8±8.5	263.3±8.2	298.6±4.5
Aldrin	52.5±9.3	28.3±6.4	47.6±2.5	34.7±2.8	117.3±3.7	876.2±6.4	103.4±3.4	697.2±8.9
Dieldrin	50.8±2.1	7.7±8.1	39.5±8.3	26.6±4.5	ND	374.1±3.8	ND	295.8±3.6
Endrin	49.2±5.3	49.4±24.5	42.8±9.4	41.3±6.7	ND	606.2±4.5	ND	534.6±5.2
Endrin aldehyde	163.7±6.4	14.6±10.2	150.5±4.8	85.5±5.3	ND	1802.9±6.1	ND	1657.8±5.3
Endrin ketone	177±7.6	80.8±5.2	159.2±2.7	103.6±7.5	551.7±7.5	3544.4±68.6	442.1±8.5	2897.3±7.2
Cis-chlordane	79.5±5.2	23.3±6.4	75.7±2.5	34.8±5.2	362.3±5.7	779.6±7.6	356.9±5.5	744.7±6.6
Trans-chlordane	41.7±2.3	32.4±1.2	38.3±7.6	30.5±3.4	126.1±2.8	540.4±5.9	108.6±4.7	456.8±4.8
Endosulfan 1	27.9±1.1	18.9±4.2	28.1±6.3	19.2±2.6	ND	1002.4±7.3	ND	996.3±8.2
Endosulfan 11	45.6±3.7	10.2±3.2	42.4±8.1	28.7±1.2	606.0±3.8	539.2±5.5	547.2±8.3	530.6±6.8
Endosulfan sulphate	108.0±2.2	25.6±8.1	101.8±3.3	38.3±6.5	ND	961.7±5.9	ND	876.3±8.7
Methoxychlor	134.3±7.6	8.4±7.2	122.6±6.3	76.2±8.2	2670.6±7.8	468.4±7.6	2398.4±7.3	397.5±4.4
p,p´-DDE	27.6±3.2	11.3±5.2	24.5±2.3	17.9±3.4	692.2±8.8	872.6±5.7	579.2±6.2	789.5±8.3
p,p´-DDD	42.7±2.1	16.9±7.5	34.6±1.7	28.1±2.3	ND	340.4±6.4	ND	290.3±6.2
p,p´-DDT	68.9±8.3	20.1±3.5	64.1±6.4	51.8±2.4	ND	901.6±8.3	ND	874.3±5.8
ΣDDT	139.2±13.6	48.4±16.2	123.2±10.4	97.8±8.1	692.2±8.8	2114.5±20.4	579.2±6.2	1954.1±20.3
ΣOCPs	1546.7±92.5	466.1±134.8	1382.1±94.1	848.8±100.4	6006.2±92.5	20342.8±212.5	5338.8±85.0	17782.9±148.2

Table 9: Mean concentrations (ng/g) of organochlorine residues in organs of male and female *Sarothorodon melanotheron* during the dry season in Lagos lagoon

	Lagos Lagoon							
	Liver		Kidney		Gill		Small intestine	
OCPs	Male	Female	Male	Female	Male	Female	Male	Female
Alpha-BHC	4.5±3.2	31.3±8.4	4.9±5.3	7.5±1.4	502.7±3.8	1306.9±3.1	22.8±4.3	26.7±5.2
Beta-BHC	26.7±2.3	103.1±5.3	39.0±7.4	45.6±4.6	1413.4±25.6	2712.1±6.3	128.9±5.2	139.7±3.6
Lindane	12.1±4.2	17.9±3.2	13.8±6.5	16.9±6.3	513.9±7.5	1196.4±4.4	76.1±3.4	81.4±8.4
Delta-BHC	4.4±2.5	33.9±4.5	10.8±7.6	11.6±3.0	577.1±5.8	5953.5±6.7	60.5±6.7	63.6±6.5
ΣBHC	47.7±12.2	186.3±20.4	68.4±26.8	81.6±15.3	3007.1±42.7	11168.9±20.5	288.3±19.6	311.3±23.7
Heptachlor	6.1±4.6	70.5±2.5	71.4±4.6	75.6±3.5	484.5±2.6	2592.4±8.4	41.3±4.3	44.8±2.6
Heptachlor-epoxide (B)	6.4±3.4	120.4±6.4	24.5±3.4	26.2±2.3	188.7±3.6	858.9±4.7	52.2±6.3	53.5±4.3
Aldrin	9.8±6.5	80.6±8.3	23.9±5.3	24.2±3.2	411.6±2.4	798.8±7.3	79.5±5.5	85.6±7.5
Dieldrin	12.1±8.2	ND	47.3±7.4	50.9±5.6	481.5±5.4	1468.3±42.8	88.5±3.6	92.9±4.7
Endrin	70.9±7.4	ND	128.7±5.3	139.9±4.7	1403.8±7.3	931.2±3.5	432.1±6.4	444.7±2.8
Endrin aldehyde	25.5±8.9	ND	155.7±2.5	158.9±6.5	1351.7±5.7	2446.9±8.5	378.8±3.6	393.3±3.4
Endrin ketone	259.7±6.8	5459.3±6.8	608.9±7.6	611.1±8.3	2215.7±24.9	2613.7±9.8	998.3±8.4	1014.1±6.5
Cis-Chlordane	24.2±9.4	242.1±5.3	45.7±6.4	47.7±6.4	242.3±6.5	2314.2±5.6	59.1±6.3	65.4±5.2
Trans-Chlordane	33.7±3.3	ND	17.3±5.2	20.6±3.2	318.9±5.4	ND	231.8±5.5	250.4±6.4
Endosulfan 1	32.3±5.7	122.8±4.6	12.4±3.1	15.9±6.5	456.7±3.3	3158.1±3.5	82.5±4.6	86.7±4.5
Endosulfan 11	12.0±8.6	689.7±5.9	25.5±7.3	28.8±7.4	323.6±6.3	1469±6.4	65.2±3.7	69.7±3.3
Endosulfan sulphate	45.2±2.5	ND	ND	ND	583.6±5.2	6558.2±41.1	98.8±6.6	117.9±5.3
Methoxychlor	20.6±4.6	166.9±9.5	64.7±8.3	69.1±6.4	996.7±2.5	2031.7±3.5	100.9±9.4	106.3±9.6
p,p´-DDE	22.7±3.1	ND	ND	ND	ND	514.4±6.3	93.3±5.4	99.6±5.2
p,p´-DDD	19.7±8.6	233.1±8.6	42.4±7.5	47.6±8.7	ND	2577.3±8.9	87.7±6.8	90.2±6.4
p,p´-DDT	46.9±2.5	ND	180.7±5.3	192.1±4.3	588.7±8.3	4404.3±5.4	238.6±7.6	245.3±4.5
ΣDDT	89.2±14.2	233.1±8.6	223.1±12.8	239.7±13.0	588.7±8.3	7495.9±20.6	419.6±19.8	435.1±16.1
ΣOCPs	695.7±106.3	7372.0±78.3	1517.8±106.0	1590.2±92.3	13055.5±132.1	46716.4±186.2	3417.8±113.6	3572.0±105.9

The distribution of the organochlorines in the muscles and organs of the fishes showed varied levels of accumulation of residues, the order of accumulation being gills>livers>small intestines>kidneys>muscles.

Table 10: Mean concentrations (ng/g) of organochlorine residues in organs of male and female *Sarothorodon melanotheron* during the wet season in Lagos lagoon

	Lagos Lagoon							
	Liver		Kidney		Gill		Small intestine	
OCPs	Male	Female	Male	Female	Male	Female	Male	Female
Alpha-BHC	3.2±2.7	26.1±4.3	5.9±3.5	7.2±1.5	495.2±24.5	1215.1±5.8	22.1±2.4	26.7±3.8
Beta-BHC	21.3±3.6	96.8±3.4	34.9±1.3	40.1±3.3	1213±6.6	2432.8±8.4	119.8±5.3	130.8±4.7
Lindane	9.1±4.2	13.8±8.2	12.1±3.4	14.5±2.2	476±4.3	1004.5±6.0	65.4±3.4	81.4±5.6
Delta-BHC	3.9±2.2	31.3±6.2	8.0±2.6	10.1±6.1	525.1±9.2	5300.4±4.9	57.5±2.3	61.3±3.8
ΣBHC	37.6±12.7	168±22.1	60.9±10.8	71.9±13.1	2709.4±44.6	9952.7±25.1	264.7±13.4	300.1±17.9
Heptachlor	4.0±1.5	52.1±2.4	53.7±8.4	72.5±5.4	430.6±3.3	2132.9±8.2	31.1±1.2	40.5±4.4
Heptachlor-epoxide (B)	5.2±2.1	114.9±4.8	19.0±5.6	23.8±2.2	154.1±7.2	798.6±5.4	46.1±5.3	53.5±2.4
Aldrin	7.9±3.4	70.9±8.4	20.9±2.2	22.9±4.3	402.9±5.4	763.8±4.8	74.8±4.4	67.3±6.7
Dieldrin	10.5±4.2	ND	36.9±4.3	45.9±5.4	408.3±6.5	1236.1±4.9	71.1±3.6	87.1±5.1
Endrin	62.1±2.3	ND	119.9±5.6	120.1±6.5	116.2±5.8	897.9±8.4	374.1±4.3	403.8±9.4
Endrin aldehyde	23.9±4.5	ND	122.9±2.5	122.6±3.8	1124.9±8.5	2006.3±3.3	364.9±6.5	376±5.5
Endrin ketone	231.1±8.6	5005.2±8.2	523.0±4.4	562.2±5.3	2052.3±7.2	2310.8±4.7	964.8±8.7	984.1±8.9
Cis-chlordane	19.6±2.5	196.9±5.1	224.8±6.7	31.8±2.6	218.8±4.3	2015.1±6.3	57.3±3.4	59.1±5.5
Trans-chlordane	22.9±3.2	ND	17.9±4.5	12±4.3	254.1±3.6	ND	212.9±8.6	201.3±7.2
Endosulfan 1	27.4±5.4	103.9±8.5	13.5±5.3	11±6.6	357.6±3.2	2895.5±12.9	72.7±8.5	81.8±3.8
Endosulfan 11	12.9±7.2	664.6±6.8	19.9±2.7	24.9±3.3	311.9±2.6	1219.4±9.6	43.1±7.8	52.3±4.3
Endosulfan sulphate	41.5±8.8	ND	ND	ND	513.3±5.3	5642.4±4.4	98.3±6.9	87.5±2.4
Methoxychlor	15.8±4.3	134.7±7.5	38.9±6.5	54.9±4.7	996.7±3.6	1875.3±6.3	96.4±8.6	99.2±5.2
p,p´-DDE	18.5±2.2	ND	ND	ND	ND	476.1±7.6	89.8±6.4	74.7±5.2
p,p´-DDD	16.7±5.1	217.9±5.6	32.8±2.6	42.4±3.5	ND	2129.9±6.4	60.7±5.3	75.8±6.3
p,p´-DDT	34.9±3.2	ND	162.9±6.8	190.6±5.8	500.2±8.8	4003.5±9.8	198.9±7.6	215.5±8.6
ΣDDT	69.9±10.5	217.9±5.6	195.8±9.4	232.9±9.3	500.2±8.8	6609.4±23.8	349.5±19.3	365.9±20.1
ΣOCPs	592.4±81.2	6729.3±79.4	1501.7±78.9	1409.6±83.5	10556.7±119.9	40356.2±128.1	3121.7±110.5	3259.8±110.8

Gills accumulated much organochlorines than other organs in the fishes analysed because accumulation of contaminants in fish lipids largely occurs by diffusion from the water across the gills.

The dietary surveys conducted in 100 families showed a mean fish consumption value of 40 g day^{-1}. The mean consumption of fish in this study compared with the dietary surveys earlier conducted in China (Yang *et al.*, 2006). Again, in a survey conducted in 325 families in Coimbatore city, India, Muralidharan *et al.* (2008) also reported fish mean consumption of 47 g day^{-1}. Muscle tissue was used in determining the dietary intakes to human body as it is the edible portion in a fish. The Estimated Daily Intakes (EDI) of organochlorines by humans are shown in Table 11. ΣBHC, Σaldrin, Σendrin, Σchlordane, Σheptachlor and ΣDDT were used in estimating the daily intakes. Except for endrin and heptachlor, the estimated daily intakes of the pesticides were within the acceptable daily intakes. The appraisal of dietary intake was based on comparison of acceptable daily intakes established by the joint FAO/WHO expert committee, Health Canada and USEPA as shown in Table 12. Levels of organochlorines in the fish species analysed were within the permissible limits (Oostdan *et al.*, 1999; FAO, 2000; USEPA, 2006), confirming that the consumers of the fishes were safe.

Table 11: Estimated Daily Intake (EDI) of organochlorines (ng/g) by humans

Organochlorines	*Tilapia guineensis*	*Sarothorodon melanotheron*
BHC	14.81	18.21
Heptachlor	11.71	20.52
Aldrin	6.22	4.47
Hepta dieldrin	6.02	3.97
Endrin	86.39	68.21
Chlordane	14.42	10.44
Endosulfan	13.55	21.28
Methoxychlor	4.71	7.53
DDT	22.58	23.24

Table 12: Acceptable daily intake (ng/kg body weight/day) of organochlorines in fish

Pesticides	FAO/WHO	Health Canada	USEPA (R_fD)
BHC	42000	18000	18000
Heptachlor	5000	-	-
Aldrin	7000	-	-
Dieldrin	-	-	-
Endrin	6000	-	-
Chlordane	-	3000	30000
Endosulfan	-	-	-
Methoxychlor	-	-	-
DDT	1200000	1200000	30000

CONCLUSION

The residue levels were higher in the Lagos Lagoon than in Agboyi Creek while a higher concentration of the residues was observed during the dry season. The female fishes accumulated higher organochlorines than the male fishes. The order of accumulation of organochlorines in the fishes was gills>livers>small intestines>kidneys> muscles.

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