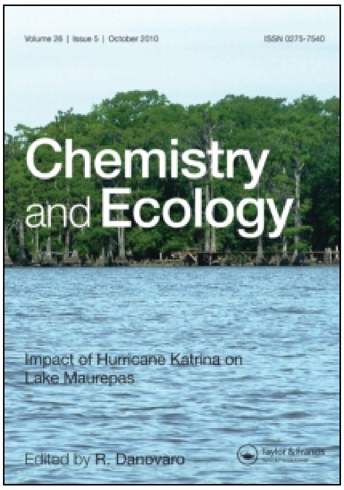

Chemistry and Ecology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

Organochlorines and PCBs in *Tilapia zillii* from Lake El-Manzala, Egypt

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To cite this Article Abdallah, Aly Mohammed Aly and El-Greisy, Zeinab A.(2006) 'Organochlorines and PCBs in *Tilapia zillii* from Lake El-Manzala, Egypt', Chemistry and Ecology, 22: 3, 219 — 224
To link to this Article: DOI: 10.1080/02757540600658906
URL: http://dx.doi.org/10.1080/02757540600658906

Chemistry and Ecology
Vol. 22, No. 3, June 2006, 219–224

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Organochlorines and PCBs in *Tilapia zillii* from Lake El-Manzala, Egypt

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(Received 9 September 2005; accepted 20 February 2006)

A freshwater fish species, *Tilapia zillii*, from Lake El-Manzala was analysed for concentrations of several organochlorine pesticides (OCs) and polychlorinated biphenyl (PCBs) in liver, gonads, mesenteric fat, flesh, and digestive tract in mature fish during the breeding season. PCBs and OCs were calculated in ng g^{-1} dry weight (dw) in homogenized samples. The obtained results revealed differences in lipid content between these different organs. The females showed a higher lipid content than did males. There was a significant positive correlation between the lipid content and the concentrations of detected organochlorines and PCBs. The results are concomitant with the lipophilicity of studied compounds. However, the recorded concentrations of these studied pollutants still do not exceed the international hazardous levels.

Keywords: *Tilapia zillii*; Lake El-Manzala; Organochlorines; PCBs; Egypt

1. Introduction

Although Egypt is the largest pesticide market in Arabian countries, there are no regular monitoring programmes in Egypt for the identification and determination of pesticides in the environment. There are numerous reports on organochlorine residues that were heavily used in the early 1960s in the Egyptian environment [1–5].

The purpose of the present study is to determine the levels of organochlorine pesticides as cyclodienes compounds (heptachlor, c-chlordane, c-nonachlor, and aldrin), DDT isomers (p,p'-isomers of DDT, DDE, and DDD), HCB and HCH isomers (α, β, lindane, and σ), and PCB congeners (52, 101, 110, 118, 138, and 180) in different tissues (liver, gonads, mesenteric fat (MFat), flesh and the digestive tract (DT)) in mature *Tilapia zillii* from the commercial catch at Lake El-Manzala during the breeding season. This species is considered as the most popular fish in Egypt and was selected because it is a popular fish with a desirable flesh taste. However, commercial and edible considerations governed the size selected.

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Chemistry and Ecology
ISSN 0275-7540 print/ISSN 1029-0370 online © 2006 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/02757540600658906

2. Materials and methods

Fish samples were obtained monthly (from June to September 2004). The total length of the fish was measured (10.5 ± 2.1 cm for females and 7.4 ± 1.8 cm for males). The total weights were also measured (27.4 ± 1.8 for females and 18.3 ± 7.3 for males). The different organs and tissues were sampled monthly from at least five individuals of each fish species and then mixed to make a composite sample. Organ samples were homogenized and lyophilized. Subsamples (0.5–1 g) were Soxhlet-extracted for 8 h with hexane (250 ml) and re-extracted for 8 h with dichloromethane (250 ml). Lipids were removed from organs as previously described [6]. The lipid fraction from the GPC was evaporated to dryness to calculate the tissue lipid content. Dichloromethane and the *n*-hexane extracts were combined and evaporated down to few millilitres under a gentle stream of pure nitrogen gas.

The fractionation was performed using a Florisil chromatography column (18 g). Confirmation of peak identity was obtained using GC with mass spectrometry (GC-MS-HP 5889B MS 'Engine'). The accuracy and precision of the techniques were determined through repeated analyses of samples simultaneously with reference materials (SMR 1588) such as cod liver oil, while a fish standard reference material (CARP1) was analysed for QA/Qc purposes. The laboratory results showed a recovery efficiency ranging from 96 to 106% for PCBs with a coefficient of variation of 9–17% for all PCB studies.

3. Results and discussion

The highest percentages of lipid content were found in MFat 17% and 13% for females and males, respectively, while these values were 1.3 and 0.9% in flesh (table 1). The concentrations of 12 organochlorine pesticides (OCs) and six PCBs congeners measured in different tissues (liver, gonads, MFat, flesh and DTC) in both females and males of *Tilapia zillii* are presented in tables 2 and 3. The lipid content of the female tissues analysed is higher than that of male tissues. Among the different studied tissues of both sexes, the lipid content followed the same descending order: MFat > liver > gonad > DTC > flesh.

From tables 2 and 3, it seems that the grand total values (GT) of female fish are higher than those of males in all the tissues studied. This trend agrees well with other fish species, *Oreochromis niloticus* [7], *Tilapia zillii* and *O. niloticus* [3, 5, 8], *Mugil cephalus* [1] and [8], *Cyprinus carpio* [9], *Mugil cephalus*, *Sparus auratus*, *Boops boops*, and *Pegusa lascaris* [10].

The female samples had higher concentrations of the pollutants than males (tables 1–3). This result could be attributed to the higher lipid content of the female fish and the lipophilicity potential of most of the recorded compounds. These results well agree with other studies [4, 9].

The average of the total DDT concentrations in all tissues was most predominant in both sexes, followed by total HCHs and then total cyclodiens. The females had a higher

Table 1. Lipid content (%) in *Tilapia zillii* in El-Manzala Lake.

	Lipid (%)				
	Gonad	Flesh	Liver	Mfat	DT
Female	5.9	1.3	11.1	17.3	2.9
Male	3.1	0.9	8.4	13.7	2.1

Note: MFat: mesenteric fat; DT: digestive tract. The number of fish for each month was six except on 7 July.

Table 2. Mean ± SD of organochlorine concentrations (ng g^{-1} DW) in male *Tilapia zillii* in El-Manzala Lake.

	Organs				
Analyte	Liver	Gonad	Mfat	Flesh	DTC
HCB	0.6 ± 0.13	0.3 ± 0.09	3.8 ± 1.6	0.24 ± 0.08	0.3 ± 0.11
α-HCH	2.9 ± 0.9	1.8 ± 0.3	6.4 ± 1.6	1.8 ± 0.5	2.7 ± 0.9
Lindane	0.22 ± 0.09	0.27 ± 0.1	0.1 ± 0.03	0.13 ± 0.04	0.24 ± 0.1
β-HCH	9.3 ± 2.3	14.4 ± 3.3	5.7 ± 1.7	2.8 ± 0.9	4.8 ± 1.6
σ-HCH	0.35 ± 0.11	1.1 ± 0.05	1.8 ± 0.5	0.09 ± 0.02	1.2 ± 0.3
$\sum$-HCH	12.8	17.6	14.0	4.9	8.9
Heptachlor	0.24 ± 0.09	0.28 ± 0.1	0.5 ± 0.2	0.12 ± 0.09	0.24 ± 0.07
c-chlordane	0.31 ± 0.11	0.22 ± 0.05	0.8 ± 0.4	0.22 ± 0.08	0.13 ± 0.3
c-nonachlor	0.35 ± 0.1	0.29 ± 0.14	0.6 ± 0.2	0.14 ± 0.08	0.35 ± 0.2
Aldrin	1.9 ± 0.5	1.19 ± 0.4	4.3 ± 1.8	0.42 ± 0.17	0.52 ± 0.17
$\sum$cycl.	2.8	2.0	6.2	0.9	1.24
DDE	10.9 ± 2.9	3.2 ± 1.4	67.3 ± 25.2	1.1 ± 0.3	2.2 ± 0.6
DDD	3.6 ± 1.4	2.4 ± 1.1	16.4 ± 4.6	0.5 ± 0.3	1.8 ± 0.24
DDT	0.02	0.03	0.03	0.03	0.01
$\sum$-DDTs	14.5	5.6	83.7	1.6	4.0
OCs	30.7	25.5	106.1	8.8	14.2
PCB52	12.9 ± 3.7	0.83 ± 0.3	30.3 ± 10.7	0.38 ± 0.2	0.93 ± 0.3
PCB101	1.29 ± 0.4	0.69 ± 0.26	4.9 ± 1.6	0.32 ± 0.16	0.44 ± 0.11
PCB110	3.7 ± 1.2	3.5 ± 1.2	16.5 ± 5.9	1.1 ± 0.5	1.5 ± 0.4
PCB118	9.0 ± 2.6	4.0 ± 1.7	47.5 ± 21.8	1.4 ± 0.5	3.1 ± 1.3
PCB138	4.7 ± 1.9	1.7 ± 0.5	25.2 ± 8.4	0.72 ± 0.3	1.1 ± 0.34
PBC180	1.6 ± 0.4	0.47 ± 0.15	7.7 ± 3.9	0.19 ± 0.07	0.36 ± 0.12
$\sum$-PCBs	33.19	11.19	132.1	4.11	7.4
GT	63.88	36.67	238.2	12.88	21.6
DDT/PCBs	0.44	0.50	0.63	0.40	0.54

Note: MFat: mesenteric fat; DT: digestive tract. The number of fish for each month was six except on 7 July.

concentration of OCs than males in all tissues (tables 2 and 3). Meanwhile, similar concentrations of HCB were noticed in Mfat in both females and males (3.8 ng g^{-1}). For DDT isomers, *p,p*′-DDE is the most dominant isomer in all analysed tissues of both sexes, in which MFat showed the highest levels (69 and 67 ng g^{-1} for male and female, respectively).

According to $\sum$HCH concentrations, the highest levels were found in gonad (22.4 and 17.6 ng g^{-1} for females and males fish, respectively. β-HCH was the predominant isomer among the studied HCHs. The highest concentrations of α-HCH were recorded in MFat in both sexes (tables 2 and 3). These data follow the same trend reported from Manzala Lake in 1993 [5], although the use of HCH has been officially restricted in Egypt since the 1970s.

The concentration of $\sum$cyclodienes in MFat was 1.7-fold higher than that in gonad and sixfold higher than that in the flesh of females, while in males it was 3.2- and 6.8-fold higher in gonad and flesh, respectively. Aldrin was the most dominated compound in all analysed tissues and its levels in MFat were 5.7 and 10.2 fold of that in flesh in female and male, respectively. *c*-nonachlor was recorded at higher levels in all analysed female samples than c-chlordane. The same trend was observed in males except in MFat and flesh. Yamashita *et al.* [5] reported that *c*-nonachlor concentration was higher than c-chlordane in Lake Manzala and river Nile Tilapia flesh.

Regarding the $\sum$PCB concentrations, the females had higher levels in all tissues than males except DT. The concentrations of PCBs in MFat represented fourfold higher levels than that in liver in both sex, while these values were 3.5- and 11.8-fold higher than for ovary and testes, respectively. Since all PCB components have a different molecular structure, each component has its own physical and chemical properties, resulting in differences in behaviour in environmental processes, such as bioaccumulation [11]. Throughout PCB congeners, PCB 118 can be considered predominant in all tissues of males and females. The average concentration of

Table 3. Mean ± SD of organochlorines concentration (ng g^{-1} DW) in female *Tilapia zillii* in El-Manzala Lake.

Analyte	Organs				
	Liver	Gonad	Mfat	Flesh	DTC
HCB	0.7 ± 0.3	0.3 ± 0.1	3.8 ± 1.2	0.24 ± 0.13	1.1 ± 0.3
α-HCH	4.1 ± 1.3	2.1 ± 0.3	7.7 ± 2.3	2.2 ± 0.8	2.5 ± 3.7
Lindane	2.1 ± 0.9	2.5 ± 0.9	4.1 ± 1.3	1.2 ± 0.3	3.1 ± 1.1
β-HCH	10.1 ± 4.3	16.4 ± 4.3	7.6 ± 2.3	1.9 ± 0.5	12.4 ± 3.3
σ-HCH	0.43 ± 0.11	1.4 ± 0.05	0.9 ± 0.3	0.8 ± 0.2	1.2 ± 0.5
∑-HCH	16.73	22.40	20.30	6.10	19.20
Heptachlor	0.33 ± 0.1	0.30 ± 0.1	0.7 ± 0.3	0.16 ± 0.1	0.2 ± 0.09
c-chlordane	0.38 ± 0.1	0.29 ± 0.1	1.1 ± 0.4	0.33 ± 0.1	0.4 ± 0.15
c-nonachlor	0.5 ± 0.2	0.61 ± 0.14	0.8 ± 0.2	0.4 ± 0.15	0.7 ± 0.2
Aldrin	2.2 ± 0.6	3.3 ± 1.2	4.6 ± 1.1	0.8 ± 0.3	0.9 ± 0.3
∑cycl.	3.41	4.5	7.3	1.7	2.2
DDE	22.5 ± 5.1	17 ± 4.8	69.0 ± 22.4	7.8 ± 2.2	9.1 ± 3.5
DDD	11.4 ± 2.3	8.6 ± 3.1	57.6 ± 21.5	2.1 ± 0.1	10.4 ± 2.6
DDT	0.06 ± 0.01	0.08 ± 0.02	0.1 ± 0.03	0.09 ± 0.03	ND
∑-DDTs	34.0	25.7	126.7	10.0	19.5
OCs	54.80	52.88	158.00	18.03	42.00
PCB52	5.5 ± 1.4	6.1	15.4 ± 3.9	0.4 ± 0.14	1.4 ± 0.3
PCB101	2.2 ± 0.6	6.1 ± 2.4	7.5 ± 2.2	0.4 ± 0.2	0.11 ± 0.04
PCB110	9.7 ± 2.9	1.1 ± 0.3	33.2 ± 6.4	9.4 ± 2.5	13.1 ± 3.4
PCB118	10.5 ± 3.8	18.5 ± 4.4	55.5 ± 29.1	0.6 ± 0.2	4.5 ± 1.8
PCB138	6.9 ± 3.2	15.0 ± 3.9	31.9 ± 11.1	0.6 ± 0.2	1.5 ± 0.5
PBC180	2.9 ± 1.1	2.9 ± 0.7	10.7 ± 5.2	0.2 ± 0.07	0.62 ± 0.3
∑-PCBs	37.7	0.7 ± 0.2	154	11.6	21.23
GT	92.50	97.18	311.99	29.63	63.23
DDT/PCBs	0.90	0.58	0.82	0.86	0.92

Note: MFat: mesenteric fat; DT: digestive tract. The number of fish for each month was six except on 7 July.

PCB 110 of all tissues in females was threefold higher than that of males. The descending order of the concentration of the most abundant congeners was 28 > 138 > 101 > 153 in El-Mex bay (Mediterranean Sea, Egypt) in different fish species, while this order was 28 > 101 > 138 in the same fish species from lake Maryoute in Egypt [3, 7, 10]. These results are in good agreement with the present study.

The ranges of DDTs, HCHs, and PCBs in *O. mossambicus* collected from Fo Tan (inland water, Hong Kong) were 28.2–40 ng g^{-1} (DW), 2–4 ng g^{-1} (DW), and 267–310 ng (DW), respectively [12], in which the DDT concentrations had a similar range to the present study, while, HCHs and PCBs had higher and lower concentrations, respectively, than those of Tilapia in Hong Kong. Two features of gonadal development of fish could affect the amount of contaminant: the size of the tissue and the increased lipid content. Both features could increase the capacity of the gonads to accumulate OCs from the diet or through mobilization from other tissues [13]. Transfer of liver lipids to the ovary has been observed in the North Atlantic flatfish, *Limanda limanda* [14]. Concentrations of OCs in the present study of Tilapia flesh had the same range as that previously reported by Yamashita *et al.* [5] in Lake El-Manzala and River Nile. Variations in the concentrations of the studied lipophilic compounds occur in fish, both between different sexes and between different tissues, which may be a result of differences in lipid content, sources of contaminants, and physiological and biochemical processes within the fish [15].

The non-parametric analysis of variance (ANOVA) Kruskal–Wallis was used to evaluate statistical significance because of the large heterogeneity of the variances. A probability (P) of 0.05 was considered significant. The ANOVA test (one way) has been used to compare the effect of sex on concentrations in each organ (table 4). The ANOVA test showed clear

Table 4. ANOVA test to study the effects of sex on distribution of studied pollutants in each organ.

	ANOVA		Correlation coefficients	
Organ	df	*P*-value	*r*	*P*
Liver	1	*0.1002*	**0.752**	**0.000**
Gonads	1	0.0081	**0.616**	**0.007**
Mfat	1	*0.1394*	**0.877**	**0.000**
Flesh	1	*0.1028*	**0.375**	**0.125**
DTC	1	0.0171	0.699	0.001

Note: df: 1 refers to sex for ANOVA test (on way). Marked *P* values (ANOVA) mean that there was no significant effect of sex on the distribution of compounds studied for each organ.

significant effects of sex on the concentrations of investigated pollutants in the case of gonads and DTC; on the other hand, concentrations in liver, Mfat, and flesh were not affected by sex. Moreover, the correlation matrix was preceded between each organ of the female and male at $P \leq 0.05$. The results of this analysis (table 4) show that there is a drastic fall in the levels of significance between Mfat and flesh with regard to sex effect. To summarize the present data, the sex effect on the distribution of studied pollutants follows a descending order: Mfat > liver > DTC > gonad > flesh.

4. Hazard levels

Since organochlorine compounds pose a potential health hazard, the maximum permissible levels of toxic substances recommended for protection of aquatic biota have been published. The National Academy of Sciences and National Academy of Engineering [16] recommended limits of $1000\,\mathrm{ng\,g^{-1}}$ for $\sum$DDTs, $500\,\mathrm{ng\,g^{-1}}$ for PCBs, and $100\,\mathrm{ng\,g^{-1}}$ for dieldrin, endrin, and heptachlor (all as weight concentrations in whole body tissue). In Sweden, the recommended tolerance limits are $5000\,\mathrm{ng\,g^{-1}}$ for $\sum$DDTs and $200\,\mathrm{ng\,g^{-1}}$ for HCB [17]. From a public-heath standpoint, residue levels of organochlorines in all analysed biota in this investigation are considerably lower than these tolerance levels. Moreover, Canadian tissue-residue guidelines for the protection of wildlife consumers of aquatic biota recommend a tolerance limit of $14.0\,\mathrm{ng\,g^{-1}}$ for $\sum$DDT [18].

Acknowledgements

The authors acknowledge Ms Amira S. El-Adawi, English Language Department, Alexandria University, for English revision to our manuscript.

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