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# Distribution of organochlorine pesticides in the Egyptian aquatic ecosystem

**A. A. K. Abou-Arab, M. N. E. Gomaa, A. Badawy & Khayria Naguib**

*Department of Food Science and Technology, National Research Centre, Dokki, Cairo, Egypt*

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The distribution of organochlorine pesticides among the major components of the Egyptian aquatic ecosystem (fish, water and sediment) were studied to explore the effect of sampling area, season, and fish species. The samples were collected from two catching areas that represent two different models of the aquatic ecosystem (El-Malek-El-Saleh and Manzala lake). Data showed that DDT and its analogues were predominant in fish samples collected from Manzala lake. On the other hand, total DDT followed by heptachlor were predominant in fish samples collected from the River Nile. The same organochlorine pesticides were found in water samples collected from Manzala lake and the River Nile during the two seasons, Winter and Summer. The concentrations of pesticides in samples from the River Nile were lower than those from Manzala lake. Pesticide residues detected in sediment samples from Manzala during Winter and Summer, followed the same descending order: total DDT > heptachlor > aldrin > lindane > gamma chlordane > β-BHC during the two seasons. During Winter, total DDT predominated in all the samples, analyzed from the River Nile, followed by heptachlor, aldrin, γ-chlordane, β-BHC and lindane. Meanwhile, during Summer, residues were found in the following descending order: total DDT > heptachlor > β-BHC > γ-chlordane > aldrin > lindane.

## INTRODUCTION

Food contamination with health-hazardous materials is a target of investigations for scientists concerned with environmental pollutants. Among the food contaminants are pesticides. Pollution with these materials is a serious problem facing the world. However, its risk is increasing in the third world countries due to lack of regulations, lack of awareness among consumers, lack of research, and lack of efficient monitoring programmes dealing with the incidence of these hazardous materials in foods.

Egypt is a typical third world country as well as being mainly an agricultural economy. It has relied heavily on pesticides to control pests harmful, mainly, to cotton, maize, and rice. The human population is exposed to pesticides both through the drinking water and via the food supply.

The stability of certain pesticides of chlorinated hydrocarbons, and the fact that residues can remain in the food, increases the human health hazard by exposure to such carcinogens (Hayes, 1982).

Medical reports assert that liver and kidney diseases have increased in the past few years in Egypt. However, the widespread use of pesticides during the last twenty years in Egypt has created serious problems following chronic exposure to trace residues (personal communication).

In Egypt, there are no available data concerning the distribution of different pesticides among fish, water, and sediments. However, a few studies were carried out in other countries. In this regard, Bradshaw *et al.* (1972) reported that the concentrations of the detected pesticides in fish samples collected from Utah lake (USA) were 0·123 to 0·956 (ΣDDT), 0·530 to 0·230 (dieldrin), and an average for β-BHC of 0·030 ppm. They added that the concentrations of ΣDDT, aldrin, and β-BHC were found in water samples at mean concentrations 0·0041, 0·0010, and 0·0013 ppm, respectively. Additional data were reported concerning the detection of pesticide residues in fish. In Egypt, Hamza and Micheal (1979), Sharaf (1984), Abou-Donia (1990), and Dogheim *et al.* (1990), showed that total DDT was the predominant pesticide detected in fish samples being 0·114, 0·061, 0·291 and 4·170 ppm, respectively. Lindane (av. 0·590 ppm), β-BHC (av. 0·435), and *r*-chlordane (av. 0·059) were also reported by Abou-Donia (1990), while Dogheim (1990) found lindane (av. 0·07 and 0·20 ppm), heptachlor + heptachlor epoxide (av. 0·56 and 0·14 ppm), aldrin + dieldrin (av. 0·59 and

0·61 ppm), and endrin (av. 3·34 and 0·70 ppm) in fish samples collected from Peni-Suef and Fayoum Governorates. Moreover, Hamza and Micheal (1979) and Sharaf (1984) recorded that lindane was present at concentrations of 0·033 and 0·035 ppm, respectively.

Studies in other countries showed that the organochlorine pesticides were also detected in fish. Stout (1980), Falandysz (1986), and Cocchieri and Arnese (1988) reported that DDT and its derivatives predominated and recorded mean concentrations of 0·18 ppm, 2·60 ppm, and 0·018–0·153 ppm. Stout (1980) detected residues of total endrin and dieldrin in the Northwestern Atlantic Ocean and Northern Gulf of Mexico with mean values of 0·008 and 0·007 ppm, respectively. However, Cocchieri and Arnese (1988) analyzed fish samples collected from four rivers in Italy. They detected range values for lindane of 0·005–0·008 ppm, heptachlor 0·0–0·005 ppm, and endosulfan 0·0–0·008 ppm.

The objective of this study was to determine the distribution of organochlorine pesticides among the major components of the Egyptian aquatic ecosystem, and to explore the effect of sampling area, season, and fish species on the distribution of these chemical contaminants in fish, water, and sediment samples of two different but typical catching areas.

## MATERIALS AND METHODS

Fish, water and sediment samples were collected from two catching areas that represent two different models of the aquatic ecosystem. The first location was a selected site on the River Nile at Cairo (El-Malek-El-Saleh), which typifies an important catching area with running water. The second location was on Manzala lake which is a lake surrounded by agricultural fields and drainage water.

Fish (16), water (20), and sediment (16) samples were collected from Manzala lake and El-Malek-El-Saleh during Winter and Summer of 1991 to determine the distribution of pesticides among the tested samples. The types of the collected fish samples were Karmout (*Clarias snguillaris*), Bolti (*Tilapia sp.*) and Shall (*Synodontys shall*).

Pesticide standards of benzene hexachloride ($\beta$-BHC), lindane, heptachlor, aldrin, *r*-chlordane, dichloro diphenyl dichloroethylene (0·P-DDE), dichloro diphenyl dichloroethylene (0·P-DDE), dichloro diphenyl trichloroethane (0·P-DDT), and dichloro diphenyl trichloroethane (P·P-DDT) were provided by Environmental Protection Agency (EPA).

Fish samples were extracted with acetonitrile and then diluted with water. Pesticide residues were extracted into petroleum ether and purified by column chromatography on florisil, eluting with a mixture of petroleum ether (40–60) and diethyl ether according to the method of the Association of Official Analytical Chemists (AOAC, 1980). Water samples were prepared according to the method of Thompson (1974) and the samples of sediment were prepared according to the method of Alikhan *et al.* (1990).

Aliquots of 1 or 2 $\mu$l of extract were injected into a Hewlett-Packard gas chromatograph Model 5890A with $^{63}$Ni electron capture detector and HP5970 series mass-selective detector and capillary column HP-101 (methyl silicon fluid), 25 M × 0·2 mm, 0·2 $\mu$m film thickness. Operating temperatures were started at 80°C, increased to 160°C at 3°C/min, held 3 min, increased to 200°C at 4°C/min, held 6 min, increased to 225°C at 6°C/min, held 24 min. Injection temperature was 210°C, and detector temperature 270°C.

Determination of organochlorine pesticide residues was based on peak area given by an HP3392A computing integrator coupled to the gas chromatograph. Confirmation of the results was performed by GC-Mass Spectra.

The main effect of fish species and season on pesticide residues in Manzala lake or River Nile were analyzed using Two Way Analysis of Variance according to the following model (Winer, 1971).

$$Yijk = (\mu + \propto i + Bj + \Sigma ijk$$

where, *Yijk* is the observation on element *K* under effect of $\propto$ *Bij*, $\mu$ is the general population mean, $\propto i$ is the fish effect (Bolti, Karmout & Shilan), *Bj* is the season effect (Winter & Summer) and $\Sigma ijk$ is the experimental error associated with measurement on element *K*.

The effect of location (Manzala lake and River Nile), season (Winter and Summer), matrix (fish, water, and sediment), and their interaction on the content of different pesticides were tested according to the following model (Winer, 1971).

$$Yijkm = \mu + \propto i + Bj + tk + \propto Bij + \propto tik + Btik + \propto Btijk + \Sigma ijkm$$

where, *Yijkm* is the observation on element m under effects of $\propto Btijk$, $\propto i$ is the location effect (Manzala lake and River Nile), *Bj* is the season effect (Winter and Summer), *tk* is the matrix effect (fish, water and sediment) and $\Sigma m(ijk)$ is the error tested within the individual observation.

A General Linear Model of SAS (SAS, 1988) was used to perform the Analysis of Variance.

## RESULTS AND DISCUSSION

To study the distribution of organochlorine pesticides among fish (Tables 1 and 2), water (Tables 3 and 4), and sediment (Tables 5 and 6), the samples were collected from two catching areas that represent two different models of the aquatic ecosystem (El-Malek-El-Saleh and Manzala lake). On the other hand, effects of sampling area, season, matrix, and fish species on such distribution of pesticides were also studied.

Table 1 shows that DDT and its analogues and aldrin were more predominant in fish samples collected from Manzala lake during Winter 1991, than other detected organochlorines. Total DDT concentrations ranged between 23·7 and 33·3 $\mu$g/kg in the analyzed fish samples, while aldrin concentrations ranged

**Table 1. Pesticide residues (μg/kg fresh weight) in fish samples collected from Manzala lake**

| Type | Date | β-BHC | Lindane | Heptachlor | Aldrin | τ-Chlordane | O, P-DDE | P, P-DDE | O, P-DDT | P, P-DDT | ΣDDT | Total O.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Karmout | W 91 | 0·3 | — | 2·8 | 8·3 | 0·60 | 10·5 | 12·3 | — | 10·5 | 33·3 | 45·30 |
| Karmout | W 91 | 0·5 | — | 1·9 | 6·3 | 0·40 | — | 11·6 | 6·1 | 9·5 | 27·2 | 36·30 |
| Bolti | W 91 | 1·2 | 2·25 | — | 4·5 | 0·40 | 3·3 | 8·6 | 3·5 | 8·3 | 23·7 | 32·05 |
| Bolti | W 91 | 1·4 | 1·93 | — | 3·5 | 0·55 | 3·3 | 13·5 | 3·1 | 11·2 | 31·1 | 38·48 |
| Karmout | S 91 | 0·5 | — | 3·6 | 8·3 | 0·30 | 0·92 | 12·6 | 10·8 | 22·5 | 46·82 | 59·52 |
| Karmout | S 91 | 0·7 | — | 3·4 | 10·5 | 0·60 | 1·33 | 13·5 | — | 20·3 | 35·13 | 50·33 |
| Bolti | S 91 | 1·0 | 3·25 | 1·5 | 15·6 | 1·30 | 4·20 | 10·8 | 2·3 | 15·8 | 33·10 | 55·75 |
| Bolti | S 91 | 2·25 | 2·60 | 1·2 | 10·8 | 1·80 | — | 10·9 | — | 13·9 | 24·80 | 43·45 |

W = Winter, S = Summer.

between 3·5 and 8·5 μg/kg. On the other hand, ΣDDT, aldrin, and heptachlor predominated in the corresponding Summer 1991 samples. Their concentration ranged as follows: 24·80–46·82 (ΣDDT), 8·3–15·6 (aldrin), and 1·2–3·6 μg/kg (heptachlor).

Table 2 indicates that during Winter 1991, ΣDDT followed by heptachlor predominated in fish samples from the River Nile. The minimum concentrations were 30·3 and 0·96 μg/kg, while the maximums were 40·6 and 3·5 μg/kg, respectively.

During the second season, Summer 1991, ΣDDT still predominated in the analyzed samples. γ-chlordane was detected in all the analyzed samples, but the determined concentrations of heptachlor were higher than that for *r*-chlordane. The determined concentration ranges were 38·4–57·7 μg/kg for ΣDDT, 3·9–5·2 μg/kg for heptachlor, and 0·7–1·2 μg/kg for *r*-chlordane.

Table 1 indicates that Karmout samples collected from Manzala lake had higher concentrations of ΣDDT (27·2–46·82), and heptachlor (1·9–3·6 μg/kg) than the Bolti samples. However, the Bolti samples were found to have the highest concentration of *r*-chlordane, lindane, β-BHC, and aldrin, which were 0·4–1·8, 1·93–3·25, 1·0–2·25, and 3·5–15·6 μg/kg, respectively. On the other hand, Table 2 shows that Shilan had concentrations of *r*-chlordane (nd–1·20), aldrin (nd–3·5), and heptachlor (0·26–5·2 μg/kg) higher than did Karmout and Bolti samples, while Karmout had the highest concentrations of lindane (nd–2·3 μg/kg) and Bolti samples had the highest concentrations of ΣDDT (37·15–63·02 μg/kg) and β-BHC (nd–2·2 μg/kg).

The same organochlorine pesticides were detected in water samples collected from Manzala lake and the River Nile during the two seasons Winter and Summer, 1991 (Table 3) and (Table 4). During Winter 1991 it was found that the maximum concentrations of the detected pesticides followed the descending order: ΣDDT

**Table 2. Pesticide residues (μg/kg fresh weight) in fish samples collected from River Nile (Cairo)**

| Sample | Date | β-BHC | Lindane | Heptachlor | Aldrin | τ-Chlordane | O, P-DDE | P, P-DDE | O, P-DDT | P, P-DDT | ΣDDT | Total O.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shilan | W 91 | 0·6 | — | 3·50 | — | — | 7·3 | 12·3 | — | 10·7 | 30·3 | 34·40 |
| Shilan | W 91 | 0·9 | 1·2 | 0·96 | — | — | — | 16·5 | 10·2 | 13·9 | 40·6 | 43·66 |
| Karmout | W 91 | 0·3 | — | 3·25 | 0·83 | — | 6·8 | — | 6·7 | 20·6 | 34·1 | 38·48 |
| Bolti | W 91 | — | 2·2 | 2·63 | 1·02 | — | 1·2 | 6·9 | 4·8 | 18·4 | 31·3 | 37·15 |
| Shilan | S 91 | 0·3 | — | 5·2 | 2·20 | 1·20 | 7·2 | 15·6 | 10·0 | 23·10 | 55·9 | 64·80 |
| Shilan | S 91 | 0·6 | — | 3·9 | 3·50 | 0·90 | 2·1 | 22·8 | 2·9 | 10·6 | 38·4 | 47·30 |
| Karmout | S 91 | 1·2 | 2·3 | — | — | 0·70 | — | 33·5 | 3·6 | 20·6 | 57·7 | 61·90 |
| Bolti | S 91 | 3·6 | — | — | 2·70 | 0·92 | 6·5 | 16·8 | — | 32·5 | 55·8 | 63·02 |

W = Winter, S = Summer.

**Table 3. Pesticide residues (ng/litre) in water samples collected from Manzala lake**

| Sample | Date | β-BHC | Lindane | Heptachlor | Aldrin | τ-Chlordane | O, P-DDE | P, P-DDE | O, P-DDT | P, P-DDT | ΣDDT | Total O.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Winter 91 | — | — | 15·6 | 23·5 | — | — | — | 16·3 | 15·2 | 31·5 | 70·60 |
| 2 | Winter 91 | 3·6 | 2·3 | — | — | — | 13·3 | 26·2 | — | 22·9 | 62·4 | 68·30 |
| 3 | Winter 91 | 2·0 | 8·5 | 6·0 | — | — | 15·5 | — | 12·8 | 10·3 | 38·6 | 55·10 |
| 4 | Winter 91 | — | — | 10·2 | 12·3 | 2·3 | — | 15·3 | 10·9 | — | 26·2 | 51·00 |
| 5 | Winter 91 | 7·3 | — | 8·3 | 15·2 | — | — | 12·8 | 8·3 | 16·8 | 37·9 | 68·70 |
| 1 | Summer 91 | 5·2 | 8·0 | 30·0 | 42·2 | — | — | 22·5 | — | 52·3 | 74·8 | 160·20 |
| 2 | Summer 91 | 3·5 | 12·3 | 18·3 | 13·6 | 2·0 | 13·7 | — | 22·7 | 44·6 | 81·0 | 130·70 |
| 3 | Summer 91 | 7·5 | 20·6 | 6·5 | 22·8 | 10·0 | — | 18·3 | — | 12·5 | 30·8 | 98·20 |
| 4 | Summer 91 | 8·1 | 15·8 | 9·3 | 15·7 | — | 33·8 | 34·5 | 18·6 | — | 86·9 | 135·80 |
| 5 | Summer 91 | 12·6 | 9·5 | 10·2 | 14·3 | 15·3 | 16·7 | 38·3 | — | — | 55·0 | 116·90 |

**Table 4. Pesticide residues (ng/litre) in water samples collected from River Nile (Cairo)**

| Sample | Date | β-BHC | Lindane | Heptachlor | Aldrin | r-Chlordane | O, P-DDE | P, P-DDE | O, P-DDT | P, P-DDT | ΣDDT | Total O.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Winter 91 | — | — | 3·50 | 5·00 | — | 8·6 | 12·3 | 4·3 | 12·8 | 38·0 | 46·50 |
| 2 | Winter 91 | 3·0 | — | 2·40 | 8·0 | — | — | 7·5 | 8·3 | 20·4 | 36·2 | 49·60 |
| 3 | Winter 91 | — | — | — | — | 3·20 | 12·2 | — | 10·6 | 22·3 | 45·1 | 48·30 |
| 4 | Winter 91 | 2·5 | 2·3 | — | — | — | — | 10·3 | 2·8 | — | 13·1 | 17·90 |
| 5 | Winter 91 | 3·0 | — | 4·15 | — | 4·61 | — | 3·8 | — | 25·6 | 29·4 | 41·16 |
| 1 | Summer 91 | — | 5·8 | 5·90 | 3·50 | — | 10·3 | 10·8 | — | 20·8 | 41·9 | 57·10 |
| 2 | Summer 91 | 5·4 | — | 10·30 | 10·6 | — | — | 2·5 | 18·9 | — | 21·4 | 47·70 |
| 3 | Summer 91 | — | 7·3 | — | — | 3·9 | 12·6 | — | — | 18·9 | 31·5 | 42·70 |
| 4 | Summer 91 | 6·3 | — | — | 18·6 | — | — | 3·9 | 19·7 | 10·8 | 34·4 | 59·30 |
| 5 | Summer 91 | — | — | 8·60 | 10·9 | 4·8 | 15·8 | 4·8 | 18·7 | 9·3 | 48·6 | 72·90 |

(62·4)>aldrin (23·50)>heptachlor (15·6)>lindane (8·5)>β-BHC (7·3)>r-chlordane (2·3 ng/litre). On the other hand, during Summer, 1991, pesticide residues in the analyzed samples followed the following descending order: ΣDDT>aldrin>heptachlor>lindane>r-chlordane >β-BHC. The concentrations detected ranged between 30·8 and 86·9 ng/litre for ΣDDT, 13·6 and 42·2 ng/litre for aldrin, and 6·5 and 30·0 ng/litre for heptachlor, (8·0 and 20·6 ng/litre) lindane, (2·0 and 15·3 ng/litre) r-chlordane, and (3·5 and 12·6 ng/litre) β-BHC (Table 3).

Table 4 indicates that the concentrations of the analyzed pesticides in water samples collected from the River Nile were lower than those of Manzala lake. Total DDT predominated in the samples analyzed during Winter 1991 and its concentrations ranged between 13·1 and 45·1 ng/litre. The maximum and minimum concentrations of the other detected pesticides were 8·0 and 5·0, 4·61 and 3·20, 4·15 and 2·40, 3·0 and 2·5, and nd and 2·3 ng/litre for alrdin, r-chlordane, heptachlor, β-BHC, and lindane, respectively. During Summer 1991, the concentrations of pesticide residues determined in the analyzed samples were as follows: ΣDDT, 21·4–48·6 ng/litre; aldrin, 3·5–18·6 ng/litre; heptachlor, 5·9–10·3 ng/litre; lindane, 5·8–7·3 ng/litre; β-BHC, 5·4–6·3 ng/litre; and r-chlordane, 3·9–4·8 ng/litre.

In water samples (Tables 3 and 4), it was notable that the detected concentrations of different organochlorine pesticides in samples collected from Manzala lake were higher than from the River Nile. This could be attributed to Manzala lake being located in the most productive agricultural region of the Nile Delta where it receives industrial and productive waste-waters (Badawy & El-Dib, 1984). Pollution of catching areas by pesticides applied to agricultural areas could arise by water moving through soil, by leaching (Luthin, 1957; Part & Bertand, 1960), run-off (Guenzi & Beard, 1967), water erosion (Swoboda & Thomas, 1968) and wind erosion (Chepil & Woodrunoff, 1960; Aly & Badawy, 1984). Furthermore, concentrations in both locations (River Nile and Manzala lake) for all pesticides were lower during Winter than during Summer. This decrease is mostly caused by biological degradation, chemical hydrolysis, and/or photodecomposition (Aly & Badawy, 1984). This phenomenon may be also due to the greater sediment deposition at that season and the tendency of organochlorine pesticides to be associated with sediments (Arruda *et al.*, 1988). In addition, the concentrations of organochlorine pesticides in the analyzed water may have exceeded the solubility of such compounds (Train, 1979); consequently, the given values represent the sum of soluble and suspended residues (El-Dib & Badawy, 1985).

The results for the sediment samples collected from the two locations, Manzala lake and River Nile during two seasons (Winter and Summer 1991) are given in Tables 5 and 6. All the surveyed pesticides were detected in all of the sediment samples analyzed.

Table 5 shows that Winter 1991 and Summer 1991, the concentrations of the pesticide residues from Manzala lake followed the order: ΣDDT>heptachlor > aldrin > lindane > r-chlordane > β-BHC.

Table 6 shows that, during Winter 1991, ΣDDT predominated in all the samples from the River Nile, followed by heptachlor, aldrin, r-chlordane, β-BHC, and lindane. During Summer 1991, the descending order of the pesticides predominating in the samples analyzed

**Table 5. Pesticide residues (mg/kg) in sediment samples collected from Manzala lake**

| Sample | Date | β-BHC | Lindane | Heptachlor | Aldrin | r-Chlordane | O, P-DDE | P, P-DDE | O, P-DDT | P, P-DDT | ΣDDT | Total O.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Winter 91 | 10·7 | 15·6 | 90·3 | 16·7 | 10·6 | 93·7 | 210 | 113 | 100 | 517 | 661 |
| 2 | Winter 91 | 9·3 | 20·3 | 80·3 | 25·2 | 20·3 | 100 | 215 | 220 | 90·8 | 626 | 781 |
| 3 | Winter 91 | 4·3 | 17·3 | 77·3 | 30·2 | 15·6 | 103 | 250 | 115 | 200 | 668 | 813 |
| 4 | Winter 91 | 2·9 | 12·6 | 72·6 | 16·1 | 12·3 | 113 | 290 | 190 | 191 | 783 | 900 |
| 1 | Summer 91 | 2·3 | 10·6 | 93·6 | 12·6 | 10·6 | 100 | 220 | 190 | 104 | 614 | 744 |
| 2 | Summer 91 | 0·9 | 8·3 | 86·1 | 23·6 | 3·5 | 220 | 216 | 180 | 90·8 | 707 | 829 |
| 3 | Summer 91 | 9·3 | 6·9 | 72·3 | 11·2 | 9·2 | 216 | 300 | 79·0 | 66·3 | 661 | 770 |
| 4 | Summer 91 | 1·9 | 9·4 | 10·5 | 10·3 | 1·8 | 140 | 314 | 113 | 104 | 671 | 705 |

**Table 6. Pesticide residues (mg/kg) in sediment samples collected from River Nile (Cairo)**

| Sample | Date | β-BHC | Lindane | Heptachlor | Aldrin | r-Chlordane | O, P-DDE | P, P-DDE | O, P-DDT | P, P-DDT | ΣDDT | Total O.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Winter 91 | 2·3 | 10·6 | 90·6 | 22·8 | 10·8 | 93·6 | 194 | 171 | 210 | 669 | 806 |
| 2 | Winter 91 | 16·5 | 5·9 | 89·5 | 10·9 | 18·9 | 211 | 178 | 161 | 201 | 749 | 891 |
| 3 | Winter 91 | 22·3 | 6·8 | 107 | 11·9 | 2·66 | 190 | 153 | 112 | 191 | 646 | 817 |
| 4 | Winter 91 | 15·8 | 3·9 | 112 | 20·8 | 10·3 | 188 | 141 | 134 | 189 | 651 | 816 |
| 1 | Summer 91 | 10·7 | 10·8 | 92·3 | 18·6 | 10·9 | 109 | 121 | 107 | 191 | 528 | 671 |
| 2 | Summer 91 | 23·6 | 6·6 | 91·8 | 16·7 | 22·5 | 172 | 191 | 110 | 161 | 634 | 795 |
| 3 | Summer 91 | 15·7 | 9·2 | 60·1 | 13·8 | 13·6 | 121 | 130 | 114 | 150 | 518 | 627 |
| 4 | Summer 91 | 12·8 | 3·8 | 87·3 | 18·8 | 11·7 | 112 | 111 | 151 | 201 | 574 | 708 |

was as follows: ΣDDT > heptachlor > β-BHC > r-chlordane > aldrin > lindane.

It is clear from the aforementioned data (Tables 5 and 6) that the sediment samples contained higher concentrations of pesticide residues than did water and fish. This trend reflects its great capacity to adsorb and accumulate such pollutants (Arruda *et al.*, 1988; Kalmaz & Kalmaz, 1979). Variation in the values of the concentration factor reflects the effects of the ongoing process of adsorption–desorption and uptake by living organisms (El-Dib & Badawy, 1985).

Statistical analyses were used to determine the interrelationships among matrix, season, and location and effects on the concentration of the pesticides under study. The concentrations of β-BHC and P,P-DDT were significantly higher in the River Nile than in Manzala lake, whereas the concentrations of lindane, aldrin, and P,P-DDE, were significantly higher in Manzala lake than in the River Nile. No significant differences between Manzala lake and the River Nile were detected for the concentrations of r-chlordane, heptachlor, O,P-DDE, O,P-DDT, or ΣDDT. No effect of sampling season was detected for any of the pesticides analysed in this study either because there were no significant differences between Summer and Winter and/or because of the presence of interactions between season and other factors. Therefore no general inference could be made. The concentrations of all pesticides under study were higher in sediments than in water and fish. Except for the concentration of aldrin, which was significantly higher in water than in fish, all other pesticides under study showed no significant trends for fish or water. To determine the effect of fish type on the concentration of the pesticides under study, statistical analysis using the analysis of variance for each of the River Nile and Manzala lake data were analyzed separately. The River Nile data showed no significant differences between fish types. However, analysis of Manzala lake showed that β-BHC and lindane were significantly higher in Bolti than in Karmout and Shilan, whereas the concentrations of heptachlor were significantly higher in Karmout than in Bolti and Shilan.

From these results it could be concluded that the concentrations of pesticides varied between the different fish species analyzed. This might be due to the fact that the concentrations of organochlorine residues in fish depends on environmental conditions, level of exposure, nature of the pesticide and its solubility, fish species and its ability to excrete the compound (Phillips; 1980; Mance, 1987; Bryan, 1984). In Winter and Summer, ΣDDT and aldrin predominated in Manzala lake samples as well as samples collected from the River Nile, followed by heptachlor in Winter samples and followed by r-chlordane and heptachlor in Summer samples. The presence of ΣDDT in all samples in both seasons was another indication of the high stability of such compounds in the environment.

The concentrations of the analyzed pesticides in water samples collected from the River Nile were lower than those collected from Manzala lake, possibly because Manzala lake is located in the most productive agricultural region of the Nile Delta and receives industrial and productive waste-waters.

Sediment samples had higher concentrations of pesticide residues than water and fish samples. This trend reflects its great capacity to adsorb and accumulate such pollutants. Variation in the values of the pesticide concentrations in sediment samples reflects the effects of the ongoing processes of adsorption–desorption and uptake by living organisms (El-Dib & Badawy, 1985).

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