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Contamination and risk assessment of organochlorines in surface sediments of Egyptian Mediterranean coast

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Abstract The levels of 20 organochlorine pesticides (OCPs) in addition to 10 polychlorinated biphenyls (PCBs) in sediments of Egyptian Mediterranean coast were investigated to evaluate their pollution potential on the environment. The OCPs were HCHs, DDTs and cyclodienes (aldrin, dieldrin, endrin, endrin aldehyde, endrin ketone, heptachlor, heptachloro epoxide, γ-chlordane, α-chlordane, methoxychlor, endosulfan I, endosulfan II and endosulfan sulfate). Concentrations of PCBs, HCHs, DDTs and cyclodienes ranged from 0.31 to 1.95, 0.09 to 3.31, 0.08 to 3.31 and 0.23 to 2.51 ng/g dry weight, respectively. Investigation of OCPs leads to the fact, that DDTs have greater potential for distribution than both HCHs and cyclodienes. Risk assessment of organochlorines in surface sediment was conducted and the results indicate that the concentrations of some OCPs contaminated in the sediments may pose few risks to the local aquatic system. Principal component factor and cluster analysis concluded that it is impossible to predict the distribution patterns of the OCPs in contaminated area, and there is a lack of correlation between PCBs and most of OCPs. This explains the variety of organochlorines input sources to studied locations.

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Introduction

Environmental occurrence of persistent organic pollutants is not only a regional but also a global problem, they are produced, and temporarily deposited in river drainage basins, and subsequently transported down-river over time, to end up, in ports, estuarine and coastal sediments. Upon entering into the sea a compound interacts with various types of materials and undergoes many transitions between different compartments such as water, suspended matter, sediments and organisms. These compounds pose potential threats to ecosystems and human health (Xu et al., 2007). Although their production, usage and disposal have been regulated or prohibited in most of the developed countries, organochlorine pesticides (OCPs) are still used at present in many developing countries (Zhou et al., 2008). These substances present a risk to the environment because they have been associated to significant environmental impact in a wide range of species and at virtually all trophic levels (UNEP, 1996; Lohmann et al., 2007).

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Due to their resistance to chemical, photochemical, and biological degradation they persist in various media to such extent that despite having been forbidden in most countries in 1970s they can be found in soils, sediments, biota, and even in human blood and tissues (Lee et al., 2001; Fillmann et al., 2002; Hernández et al., 2002; Gómez-Gutiérrez et al., 2007; Pikkarainen, 2007; Hong et al., 2008; Fontcuberta et al., 2008; Porta et al., 2008; Hu et al., 2009; Malik et al., 2009; Jan et al., 2009; El Nemr et al., 2012a,b).

OCPs have been effectively used in reducing crop damages from insects, disease and weed and for increasing additional yield for the crops worldwide. Despite the benefits of these chemicals, people are now aware of the toxic effects of these chemicals (Khan et al., 2010). Over the past 30 years, the occurrence of OCPs in the environment is of great concern due to their persistent (Doong et al., 2002) and long-range transportable nature (Fillmann et al., 2002) as well as toxic biological effects (Tanabe et al., 1994). Studies have suggested that OCPs may affect the normal function of the endocrine system of humans and wildlife (Colborn and Smolen, 1996). In addition, some congeners have shown some effects on the endocrine system such as reducing serum concentrations of the thyroid hormones like thyroxine and triiodothyronine (Corine et al., 1994). Chlorinated pesticides as HCH and DDT are effective pest control chemicals, used in agriculture and public health activities (malaria eradication, etc.) worldwide for the past several decades and are still in use in many developing countries. Similar to PCBs, these pesticides also cause endocrine disruption and food chain biomagnification, because of their lipophilicity and environmental persistent. In 2001, the Stockholm Convention on persistent OCPs has acknowledged OCPs as a global problem. Polychlorinated biphenyls (PCBs) belong to persistent OCPs group of chemicals primarily used in transformers, capacitors, paints and printing inks, and also in many other industrial applications. They are amongst the industrial chemicals banned and included in the list of priority contaminants to be monitored regularly in western countries (Hedgecott, 1994). They have been reported to cause variety of effects including immunologic, teratogenic, carcinogenic, reproductive and neurological problems in organisms (Kodavanti et al., 1998).

The input pathways of various pollutants into the marine environment are rivers, atmosphere, direct dumping into the sea and shipping activities. Coastal sediments act as temporary or long-term sinks for many classes of anthropogenic contaminants and consequently act as the source of these substances to the ocean and biota. Because of hydrophobic characteristics, OCPs are the least soluble in water but show a high affinity for different surface including particulate matter. Smaller particles with large surface area and those with organic content show the highest adsorption capacity (Elder and Weber, 1980).

OCPs have been used substantially in Egypt for the control of agricultural pests. Although the usage of PCBs in Egypt is not known, the past use of these substances in transformers, electrical equipment, ship painting and other industries has been common. OCPs and PCBs have been previously monitored in Egyptian Mediterranean mussels by El Nemr et al. (2003, 2012b) and in Egyptian marketable fish by El Nemr and Abd-Alla (2004). The aim of the present work is to investigate the distribution of different OCPs and PCBs in the sediments of the hot spot along the Egyptian Mediterranean coast and study their correlations with the total organic carbon of the sediments as well as evaluate the risk posed due to the contamination of sediment with OCPs and PCBs.

Materials and methods

The following are summarized.

Sampling

The 10 sampling stations were located along approximately 500 km of the Egyptian Mediterranean coast, from El Saloom city to El Arish city (Fig. 1). Ten surface sediment samples were collected during August 2009 with a van Veen grab. The surface layer (0–5 cm) was carefully taken to avoid disturbing. The upper 5 cm layer was selected because it is more biologically and chemically active than deeper layers, and exchanges of substances between sediment and water occur in this layer. Immediately after collection, samples were placed in aluminum bags, refrigerated, and transported to the laboratory. Samples were dried in an oven at 105 °C to constant weight, and sieved to separate the stones and shells, lightly ground in an agate mortar for homogenization, and prepared for analysis.

Grain size analysis

Grain size composition was examined on surface sediment by treatment the raw samples with 30% hydrogen peroxide to destroy the organic matter content followed by using standard sieve and pipette methods (Galehouse, 1971). Dried sediments (500 g) were successively separated into particle-size fractions, using six sieves. The sieves [2.25 phi (0.210 mm), 2.5 phi (0.177 mm), 2.75 phi (0.149 mm), 3.0 phi (0.125 mm), 3.25 phi (0.105 mm), 3.5 phi (0.088 mm), 3.75 phi (0.031 mm), and 4.0 phi (0.0625 mm)] were shaken with topmost sieve using mechanical shaker "Betriebsanleitung vibration testing sieve mechanical machine Thyr 2" for 20 min. The fractions 0.063–0.210 mm and fractions < 0.063 mm were used for sand and mud fractions, respectively, during this research work.

Statistical analysis

Principal component analysis (PCA) and cluster analysis (CA) are the most common multivariate statistical methods used in environmental studies (Reyment, 1996; Diaz et al., 2002; El Nemr et al., 2006, 2007, 2012c; Khaled et al., 2010). PCA, a multivariate technique whose aim is to reduce the number of variables (measured OCls content in sediment samples) to a smaller set of orthogonal factors of easier interpretation by displaying the correlations existing among the original variables was applied to the selected data set. Data submitted for the analysis were arranged in matrix, where each column corresponds to one OCl component and each row represents sediment location. The number of factors extracted from the variables was determined according to Kaiser's rule. This criterion retains only factors with eigenvalues that exceed one. The first step in the multivariate statistical analysis was application of PCA with the aim to group the individual OCl components by the loading plots for 10 contaminated locations. Since the raw data have provided negative loadings, we applied the varimax rotation for the correlation greater than 0.30
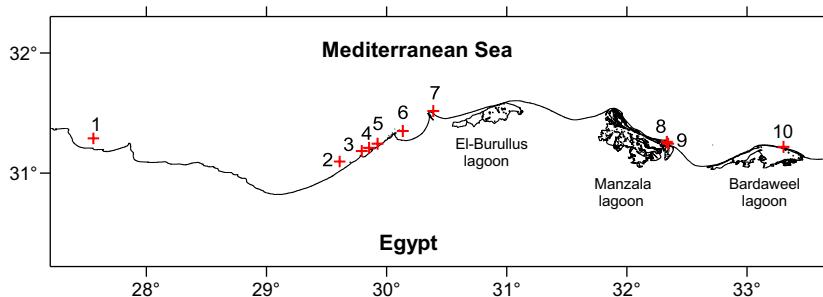
Figure 1 Sampling locations map, (1) El-Saloom, (2) Sidi-Kereer, (3) El-Mex, (4) Eastern Harbor, (5) El-Shatby, (6) Abu-Quir, (7) Rosetta, (8) El-Jamil, (9) Port Said, (10) El-Arish.

concentrations of 30 OCls as active variables and 10 locations were selected. In the present study, SPSS for Windows, Version 19, was utilized for the multivariate analysis and for correlation analysis. PCA is widely used to reduce data (Loska and Weichula, 2003) and to extract a small number of latent factors for analyzing relationships among the observed variables. In this study, PCA was therefore applied to the correlation matrix and with VARIMAX normalized rotation. Cluster analysis (CA) was performed to further classify elements of different sources on the basis of the similarities of their chemical properties. As the variables have large differences in scaling, standardization was performed before computing proximities, which can do automatically by the hierarchical cluster analysis procedure. A dendogram was constructed to assess the cohesiveness of the clusters formed, in which correlations among elements can be readily being seen.

Extraction

Dry sediment was homogenized and 15 grams were analyzed for PCB congeners and pesticides following well-established techniques (UNEP/IOC/IAEA, 1989, 1991; IOC, 1993). Sediment (15 g of dry weight) was transferred to a pre-cleaned extraction thimble and extracted with *n*-hexane /dichloromethane [(1:1), 250 ml] for 8 h in a Soxhlet apparatus cycling 5–6 times per hour. Thimble was extracted in the same fashion as the sample and used as the blank and its value was subtracted from the results. The extracted solvents were concentrated with a rotary evaporator down to about 15 ml (maximum temperature: 40 °C), and then concentrated to 1 ml under a gentle stream of pure nitrogen gas. The remaining extract was transferred to the top of a glass column (50 ml) packed with 20 g Florisil followed by elution with 70 ml of hexane for PCBs congeners fraction (F1). Then the column was eluted with 60 ml of mixture containing 70% of hexane and 30% of dichloromethane for the pesticide fraction (F2). Activation of the Florisil was achieved by heating at 130 °C for 12 h, followed by partial deactivation with 0.5% water by weight and stored in a tightly sealed glass jar with ground glass stopper and the mixture were allowed to equilibrate for one day before use.

Each fraction was concentrated and injected into a CLASS-GC10 gas chromatograph (Shimadzu, Japan) equipped with a ^{63}Ni electron capture detector. A fused-silica capillary column (30 m × 0.32 mm × 0.52 μm) coated with DB-1 (5% diphenyl and 95% dimethyl polysiloxane) was used for the quantification. The oven temperature was programmed from an initial

temperature of 70 °C (2 min hold) to 280 °C at a rate of 5 °C min^{-1} and was then maintained at 280 °C for 20 min. Injector and detector temperatures were maintained at 270 and 300 °C, respectively. Helium was used as the carrier (1.5 ml min^{-1}) and nitrogen as the make-up (60 ml min^{-1}) gas. Concentrations of individually resolved peaks were summed to obtain the total PCB concentration.

Compound identification was confirmed by GC coupled to mass spectrometry in the chemical ionization mode and negative ion recording (Trace DSQ II Ms. with capillary column: Thermo TR-35 MS Mass Selective Detector. Ion repeller was 1.5 V. Data were scanned from *m/z* 50 to 450 at 1 s per decade. Data were also acquired in selected ion monitoring mode with dwell time and span of 0.06 s and 0.10 a.m.u., respectively.

To control the analytical reliability and assure recovery efficiency and accuracy of the results, four analyses were conducted on organochlorine compounds in IAEA – 408 reference materials provided by EIMP–IAEA. The laboratory results showed that recovery efficiency ranged from 89% to 109% with coefficients of variation of 9–14% for all organochlorine compounds (Table 1). The limit of detection in the present study was estimated to be 0.2 ng/g for PCBs and 0.3 ng/g for pesticides based on the minimum quantity of sample required for a discernible peak appeared on the chromatogram.

Risk assessment

Comparisons between the organochlorines concentrations in the sediments and their corresponding sediment quality values were performed in the present investigation. The levels of risks posed by certain chemicals in the sediments were characterized by risk quotients (RQ), which were calculated as the following equations:

$$RQ = \frac{C_{sed}}{SQV} \qquad (1)$$

where C_{sed} is concentration of chemical in sediment and SQV is sediment quality value.

Also, two of these values could be used to calculate risk quotients under the best-case (RQ$_{bcs}$) (Eq. 2) and worst-case (RQ$_{wor}$) scenarios (Eq. 3).

$$RQ_{bes} = \frac{MC_{sed}}{SQV_{UL}} \qquad (2)$$

$$RQ_{wor} = \frac{MC_{sed}}{SQV_{LL}} \qquad (3)$$

Table 1 Reference material IAEA-408 (PCBs and pesticides concentrations (ng/g dry weight)).

Pesticide Name	Found (ng/g)	Reported (ng/g)	Reported range (ng/g)
α-HCH	0.65	0.61	0.21–1.50
β-HCH	0.47	0.55	0.38–1.70
Heptachlor	0.63	0.42	0.23–0.70
Aldrin	0.69	0.41	0.20–2.30
Heptachloro epoxide	0.49	0.64	0.43–1.50
γ-chlordane	0.34	0.12	0.10–0.34
Dieldrin	0.30	0.30	0.30–0.48
p,p'-DDE	1.70	1.40	0.88–2.00
Endrin	0.41	0.57	0.14–1.20
Endosulfan I	1.52	1.60	0.30–6.20
p,p'-DDD	0.79	0.87	0.56–1.70
p,p'-DDT	0.71	0.67	0.48–0.98
Endosulfan sulfate	1.30	1.60	0.50–8.20
PCB 101	1.07	1.20	0.81–1.70
PCB 118	1.51	1.20	0.90–1.60
PCB 153	2.02	1.90	0.98–2.10
PCB 138	1.69	1.60	1.10–2.10
PCB 180	1.03	1.10	0.85–1.20
PCB 194	0.23	0.20	0.20–0.23

where MC_{sed} is the maximum chemical concentration in sediment, SQV_{UL} is the upper limit of sediment quality value and SQV_{LL} is the Lower limit of sediment quality value.

In most cases, sediment quality values are not singe numbers, but often represented in ranges of values which have lower and upper limits. These two values could be used to calculate risk quotients under the best- case (RQ_b) and (RQ_w) scenarios (Eqs. 2 and 3).

The calculation of RQ_b and RQ_w provides a simple way to distinguish chemicals, which may or may not require further analysis. In principle, $RQ_b > 1$ would indicate that the chemical would require attention, and probably some control measure or remedial action is needed. In contrast, if $RQ_w < 1$, the chemical is probably of little concern, and thus should be accorded a lower priority in terms of management actions (Fung et al., 2005).

Results and discussions

Here the results of investigation are discussed.

Grain size analysis

Grain size estimated for the sediment samples under investigation are presented in Table 2. Sediment samples were fluctuated from coarse sand at El-Mix station, medium sand at El-Areesh, El-Shatby, Eastern Harbor, Abo-Quir and Rosetta to fine sand at Sidi-Kereer and El-Jamil. The grain size of El-Saloom stations is mainly silty sand, while it is sand at Port Said.

Levels of PCBs and pesticides residues in sediments

Tables 3–6 show the concentrations of PCBs and pesticides in the analyzed surface sediment samples from the 10 stations along the Mediterranean coast expressed in terms of dry weight. The analyzed sediment samples show the presence of PCB 18, 28, 44, 52, 101, 118, 138, 153, 180 and 194, as well as the following pesticides: α-HCH, β-HCH, γ-HCH, δ-HCH, p,p'-DDE, p,p'-DDD, p,p'-DDT, aldrin, dieldrin, endrin, endrin aldehyde, endrin ketone, heptachlor, heptachloro epoxide, γ-chlordane, α-chlordane, methoxychlor, endosulfan I, endosulfan II and endosulfan sulfate. Concentrations of organochlorine ranged from 0.31–1.95 ng/g dry weight for total PCBs, 0.09–3.31 ng/g dry weight for total HCHs, 0.08–2.14 ng/g dry weight for DDTs and from 0.23 to 2.51 ng/g dry weight for cyclodienes.

Fig. 2 shows that the maximum ΣHCHs was present at El Mex Station, while the next higher amounts of ΣHCHs were

Table 2 Percentage of total organic carbon, sand-silt and textural class of the surface sediments of the sampling stations along the Egyptian Mediterranean Coat.

Station	Position	TOC	TOM	Sand%	Silt%	Mud%	Sorting	Sediment type
El-Saloom	31.24N–27.54E	0.26	0.47	72.43	27.57	0.00	0.89	Silty Sand
Sidi-Kereer	31.08N–29.63E	0.38	0.69	98.14	1.86	0.00	0.54	Fine Sand
El-Mex	31.18N–29.78E	0.30	0.54	99.43	0.57	0.00	0.98	Coarse sand
Eastern Harbor	31.20N–29.78E	0.68	1.23	93.79	6.21	0.00	1.39	Medium Sand
El-Shatby	31.25N–29.92E	0.41	0.74	100.00	0.00	0.00	0.78	Medium Sand
Abu Quir	31.35N–29.92E	0.11	0.20	98.05	1.95	0.00	0.99	Medium Sand
Rosetta	31.52N–30.39E	0.15	0.27	99.10	0.90	0.00	0.97	Medium Sand
El-Jamil	31.24N–32.34E	0.11	0.20	98.16	1.84	0.00	0.54	Fine Sand
Port Said	31.26N–32.33E	0.38	0.69	100.00	0.00	0.00	1.10	Sand
El-Arish	31.22N–33.30E	0.34	0.61	99.72	0.28	0.00	0.70	Medium Sand

Table 3 PCBs concentration (ng/g of dry weight) in sediment samples collected from the Egyptian Mediterranean coast.

Site No	Location	18	28	44	52	101	118	138	153	180	194	Total	Mean ± SD
1	El-Saloom	0.04	0.11	0.28	0.36	0.02	0.01	0.02	0.01	0.01	0.01	0.88	0.08 ± 0.13
2	Sidi-Kereer	0.04	0.11	0.08	0.26	0.20	0.08	0.13	0.04	0.05	0.01	0.98	0.09 ± 0.07
3	El-Mex	0.07	0.19	0.28	0.09	0.03	0.01	0.04	0.02	0.08	0.02	0.82	0.083 ± 0.09
4	Eastern Harbor	0.07	0.46	0.34	0.52	0.22	0.09	0.06	0.09	0.07	0.02	1.95	0.19 ± 0.18
5	El-Shatby	0.01	0.03	0.06	0.04	0.12	0.07	0.13	0.12	0.05	0.01	0.65	0.06 ± 0.04
6	Abu Quir	0.07	0.34	0.14	0.29	0.01	0.01	0.01	0.03	0.12	0.01	1.03	0.1 ± 0.12
7	Rosetta	0.03	0.21	0.40	0.34	0.03	0.07	0.04	0.01	0.15	0.02	1.30	0.13 ± 0.14
8	El-Jamil	0.01	0.04	0.11	0.06	0.20	0.01	0.01	0.04	0.08	0.01	0.58	0.057 ± 0.05
9	Port Said	0.06	0.06	0.04	0.07	0.01	0.01	0.02	0.02	0.02	0.02	0.31	0.03 ± 0.02
10	El-Arish	0.01	0.02	0.07	0.03	0.09	0.15	0.04	0.04	0.24	0.01	0.69	0/06 ± 0.07
ERL												5000	
ERM												40000	
CSQG												27700	

18 = 28 = 2,4,4$'$-Trichlorobiphenyl; 44 = 52 = 2,2$'$,5,5$'$-Tetrachlorobiphenyl; 101 = 2,2$'$,4,5,5$'$-Pentachlorobiphenyl; 118 = 2,3$'$,4,4$'$,5-Pentachlorobiphenyl; 138 = 2,2$'$,3,4,4$'$,5$'$-Hexachlorobiphenyl; 153 = 2,2$'$,4,4$'$,5,5$'$-Hexachlorobiphenyl; 180 = 2,2$'$,3,4,4$'$,5,5$'$-Heptachlorobiphenyl; 194 = ERL: effects range low; ERM: effect range median (pg/g dry weight); SCQG: Canadian Sediment Quality Guidelines; Long ER, Macdonald DD, Smith SL, Calder FD. Incidence of adverse biological effects with ranges of chemical concentrations in marine and estuarine sediments. Environ. Manag. 1995;19:pp. 81–97.

Table 4 DDTs concentration (ng/g of dry weight) in sediment samples collected from the Egyptian Mediterranean coast.

Station	p,p'-DDE	p,p'-DDD	p,p'-DDT	ΣDDT	p,p'-DDT/p,p'-DDE
El Saloom	0.01	0.01	0.32	0.33	320
Sidi-Kereer	n.d.	0.02	0.35	0.37	n.d.
El Mex	n.d.	0.01	1.02	1.03	n.d.
Eastern Harbor	n.d.	0.03	2.11	2.14	n.d.
El Shatby	n.d	0.03	0.93	0.96	n.d.
Abu Ouir	n.d.	0.02	0.06	0.08	n.d.
Rosetta	n.d.	0.01	0.23	0.24	n.d.
El Jamil	0.05	0.02	0.11	0.17	2.3
Port Said	n.d.	0.01	0.20	0.21	n.d.
El Arish	n.d.	0.02	0.25	0.27	n.d
CSQG	6.75	8.51	4.77		
ERL				3.00	
ERM				350.0	

CSQG: Canadian sediment quality guideline; ERL: effects range low.
ERM: effects range median; ΣDDT: sum of DDT, DDE and DDD.

Table 5 HCHs concentration (ng/g of dry weight) in sediment samples collected from the Egyptian Mediterranean coast.

Station	α-HCH	β-HCH	γ-HCH	δ-HCH	Σ-HCH	α/γ-HCH
El-Saloom	0.11	0.02	0.10	0.25	0.48	1.16
Sidi-Kereer	0.03	0.02	0.01	0.03	0.09	1.85
El-Mex	0.35	0.15	0.05	2.76	3.31	7.04
Eastern Harbor	0.31	0.79	0.86	0.25	2.21	0.46
El-Shatby	0.05	0.15	0.04	0.12	0.36	1.32
Abu Ouir	0.12	0.14	0.05	0.03	0.33	2.57
Rosetta	0.12	0.08	0.02	0.02	0.23	7.05
El-Jamil	0.03	0.03	0.02	0.04	0.12	1.28
Port Said	0.01	0.02	0.06	0.01	0.09	0.14
El-Arish	0.03	0.14	0.04	0.04	0.26	0.67

observed in Eastern Harbor with the maximum amounts of ΣPCBs, ΣDDTs and Σcyclodienes which is expected because of the harbors' activities which may cause runoff of large amounts of pesticides in the marine environment. For the rest of stations it can be seen that the predominance is for PCBs except for El Mex and El Shatby where the predominance is for DDTs. The next higher amounts of pesticides in all stations were the cyclodienes, while the lowest levels of all kinds of

Table 6 Cyclodienes concentration (ng/g of dry weight) in sediment samples collected from the Egyptian Mediterranean coast.

Cyclodienes	1	2	3	4	5	6	7	8	9	10	Total
Aldrin	0.01	0.06	0.02	0.35	0.05	0.04	0.04	0.03	0.02	0.04	0.66
Dieldrin	n.d.	n.d.	0.01	0.01	n.d.	n.d.	n.d.	0.01	n.d.	n.d.	0.03
Endrin	0.03	0.10	0.07	0.19	0.08	0.02	0.10	0.05	n.d.	0.14	0.78
Endrin Aldehyde	0.01	0.01	0.02	0.09	0.01	n.d.	0.01	n.d.	n.d	n.d.	0.17
Endrin Ketone	n.d.	n.d.	0.02	0.05	n.d.	0.01	n.d.	n.d.	0.01	n.d.	0.09
Heptachlor	0.06	0.03	0.09	0.34	0.09	0.01	0.11	0.05	0.06	0.04	0.88
Heptachloro epoxide	0.02	0.04	0.09	0.09	0.01	0.02	0.01	0.03	n.d.	0.01	0.31
γ-Chlordane	0.15	0.07	0.28	0.53	0.15	0.29	0.09	0.25	0.06	0.07	1.94
α-Chlordane	0.03	0.30	0.30	0.60	0.09	0.11	0.09	0.05	0.06	0.07	1.70
Methoxychlor	0.49	n.d.	0.07	n.d.	n.d.	n.d.	n.d.	0.12	n.d.	n.d.	0.68
Endosulfan I	n.d.	0.01	0.01	n.d.	n.d.	n.d.	n.d.	0.01	n.d.	0.01	0.04
Endosulfan II	0.01	0.02	0.04	0.10	0.01	0.04	0.02	0.09	0.01	0.03	0.37
Endosulfan sulfate	0.05	0.02	0.07	0.17	0.01	0.01	0.02	n.d.	0.01	0.02	0.35
ΣCyclodienes	0.84	0.64	1.06	2.51	0.50	0.54	0.50	0.66	0.23	0.42	7.89
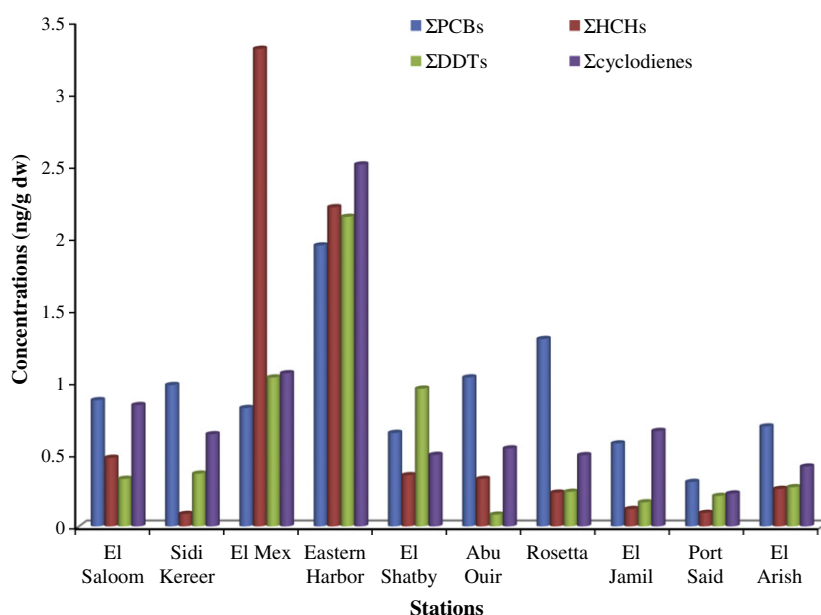
Figure 2 Concentrations of PCBs, HCHs, DDTs and cyclodienes in sediments from Egyptian Mediterranean coast.

pesticides were present in the sediment samples collected from Port Said station.

The concentrations of PCBs in sediment are summarized in Table 3. The highest concentration of total PCBs (1.95 ng/g dry weight) was found in sediment from Eastern Harbor. The most likely source of organochlorine in harbors is from urban drains discharging. The second highest concentration (1.30 ng/g dry weight) was observed at Rosetta, which may be attributed to the fact that Rosetta is an agricultural town and it is the final station of the river Nile water before entering the Mediterranean which means that the accumulation of the pesticides along the river will be obvious in this station. Next highest concentration of 1.03 ng/g dry weight was detected at Abu Quir station.

Among the 10 identified PCBs congeners, PCB 28, 44, 52, 101 and 180 are found to be dominant, and this can be attributed to industrial discharge along the Mediterranean coast. The absence of the higher chlorinated congeners 128 and 187 and very low concentrations of 194 suggest that there are no

significant local sources of PCBs. According to Tolosa et al. (1995), a significant depletion of the higher chlorinated congeners is found in samples from remote areas because these less volatile congeners are more easily removed from the atmosphere and cannot be transported to those regions. The lower chlorinated congeners (below PCB 101) represented 17.46–22.4% of total PCBs concentrations in the sediments. The presence of tetrachlorobiphenyl (44 and 52), pentachlorobiphenyl (101 and 118) and hexachlorobiphenyl (138 and 153) suggests a contribution from the commercial mixtures, which have been widely used in transformers, electrical equipment and other industries (Barakat et al., 2002). Generally the persistent of PCBs is due to their low rate of degradation, vaporization, low water solubility and partitioning to particles and organic carbon (Kennish, 1992).

DDT was widely used in Egypt on a variety of agricultural crops and for the control of disease vectors. The largest agricultural use of DDT has been on cotton, which accounted for more than 80% of the use before its ban (Barakat et al.,
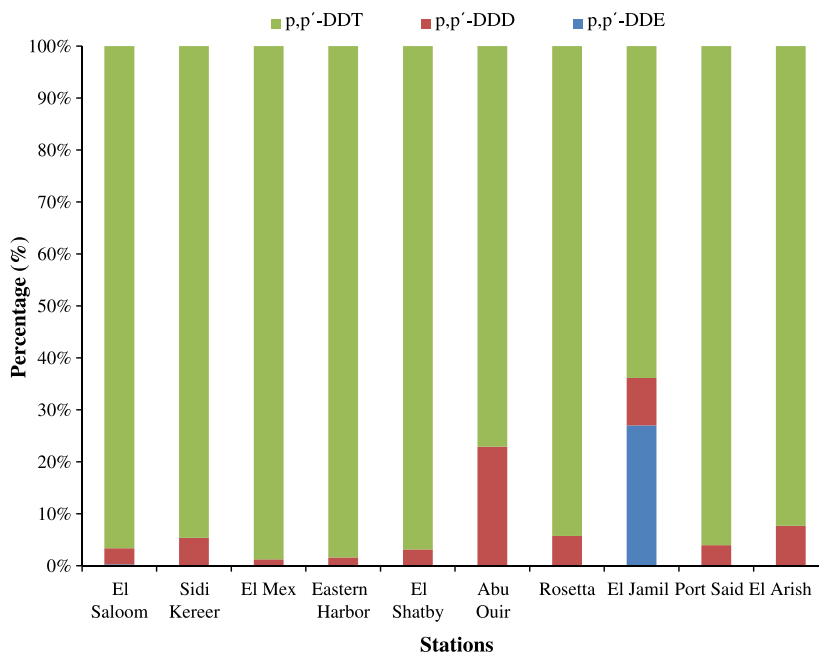
Figure 3 Percentage of total DDTs represented by DDTs and their metabolites DDDs and DDEs in sediments from Egyptian Mediterranean coast.
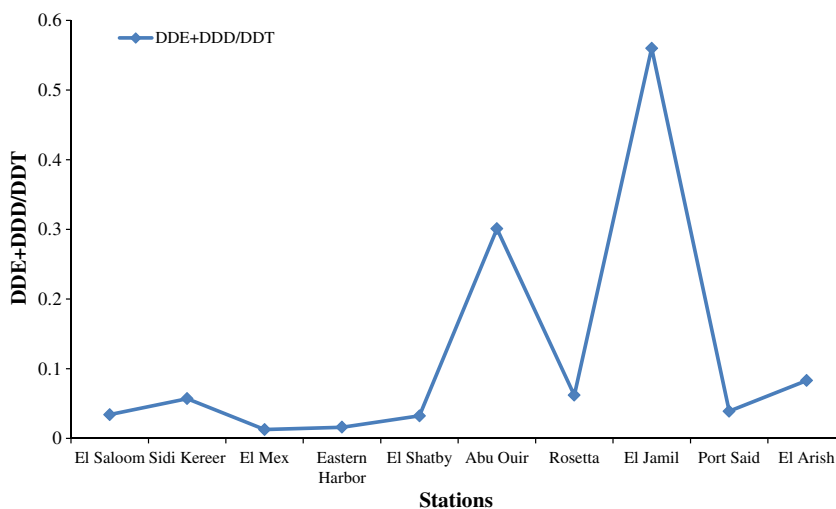

Figure 4 Ratio of (DDE + DDD)/DDT of sediment samples collected from the Egyptian Mediterranean Coast.

2002). Although its usage was banned in 1988, its detection, along with detection of its breakdown products (i.e., DDEs + DDDs), in sediments is expected because the reported environmental half-life of DDTs is estimated to 10–20 years (Woodwell et al., 1971).

The contents of DDTs in the 10 sites along the Mediterranean coast were presented in Table 4. The residues of DDTs were detected in all samples. In the present study, ΣDDT (equivalent sum of p,p'-DDE + p,p'-DDD + p,p') ranged from 0.08 to 2.14 ng/g dry weight. DDTs were detected in all sediment samples, but the contribution of individual metabolites showed differences. The concentration of total DDT reached maximum value at Eastern Harbor (2.14 ng/g dry weight) followed by El Mex (1.03 ng/g dry weight) and El

Shatby (0.96 ng/g dry weight). The minimum value of total DDT was recorded at Abu Quir (0.08 ng/g dry weight), whereas the other six stations followed almost an equal trend of DDT distribution ranging from 0.17 to 0.37 ng/g dry weight.

DDTs undergoes degradation to DDDs and DDEs in natural environment by chemical and biological processes (Baxter, 1990). Fig. 3 shows DDTs and their metabolites as a percentage of total DDTs at the different sampling sites. Over 94% of the total DDTs in sediments from all stations except Abu Quir and El Jamil (in which DDT% ranges from 55% to 75% of the total DDTs) was present as p,p'-DDT. The dominance of DDTs in the sediment indicates slow degradation of DDTs or recent inputs of fresh DDT at these locations (Tavares et al., 1999).
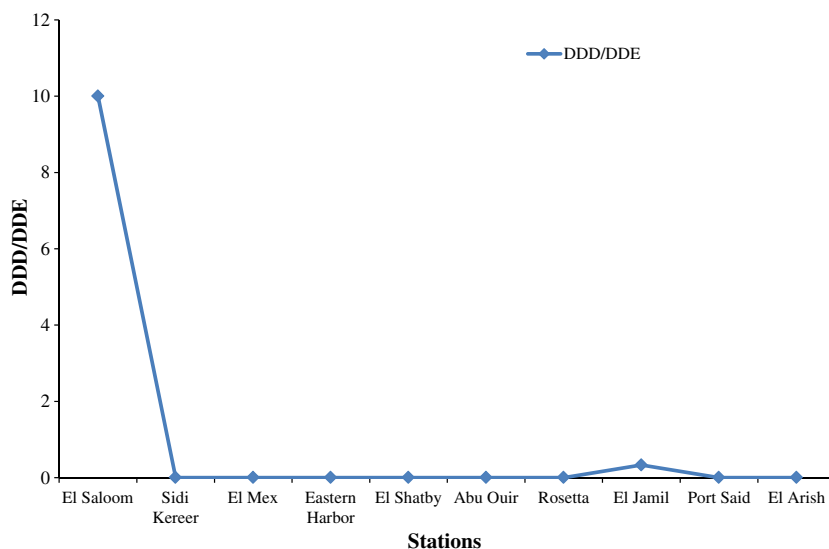
Figure 5   Ratio of DDD/DDE of sediment samples collected from the Egyptian Mediterranean Coast.
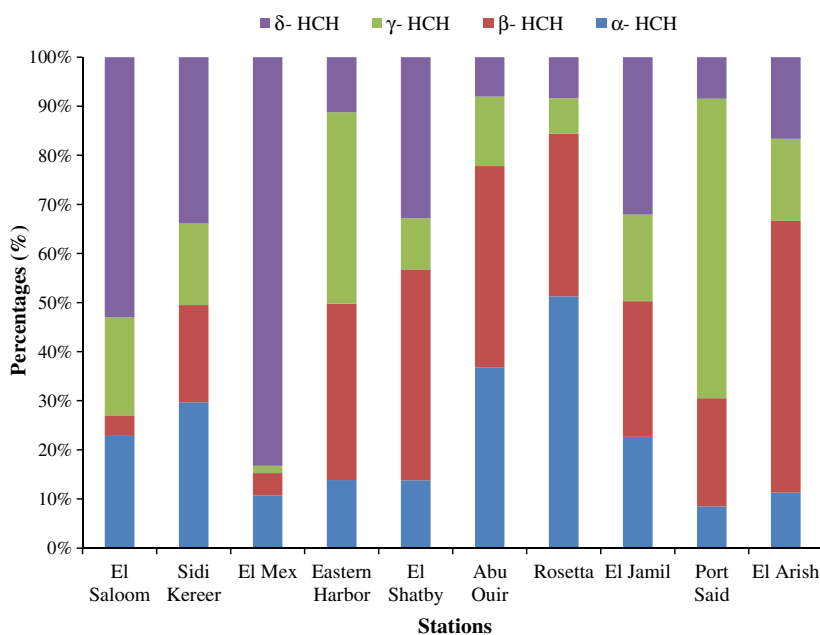

Figure 6   Composition of HCHs in sediments from Egyptian Mediterranean Coast.

According to Stranberg et al. (1998), the ratio of p,p'-DDT/ p,p'-DDE provides an useful index to know whether the DDTs at a given site is fresh or aged input. Further a value < 0.33 generally indicates an aged input. In the present study the value of > 0.33 was found in two sites (El-Jamil and El-Saloom), indicating fresh inputs of DDT to those locations (Table 4). This clearly shows the possibility of long range transport of DDT to open ocean environment and/or poor degradation of DDT in offshore sediments.

The relative concentration of the parent DDT compared to its biological metabolites, DDD and DDE can be used as indicative indices for assessing the possible pollution sources. Since the degradation pathway of DDT in sediments is redox potential dependent, the DDD/DDE balance may indicate

the prevalent conditions in the area. DDE is the main metabolite of DDT in oxic conditions, whereas the main metabolite in anoxic conditions is DDD (Tolosa et al., 1995). Ratio of (DDE + DDD)/DDT > 0.5 can be thought to be subjected to a long-term weathering (Hitch and Day, 1992; Zhang et al., 1999). In our study this ratio ranges from 0.01 to 0.56 (Fig. 4) and it was more than 0.5 in one site (El Jamil) showing that DDT in the sediment from this site mainly came from the weathered agriculture soils.

When the ratio of DDD/DDE is less than unity this reflecting that biodegradation of DDTs was predominant under aerobic conditions, while it is more than unity that means the biodegradation was under anaerobic conditions (Hitch and day, 1992). In all studied sediment samples, the degradation
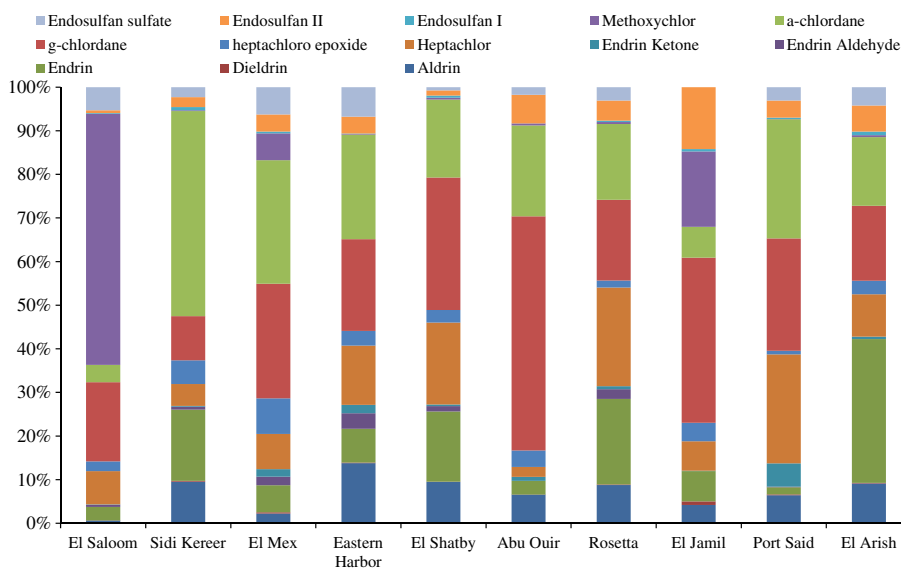
Figure 7 Composition of cyclodienes in sediments from Egyptian Mediterranean Coast.

was carried out under aerobic conditions except for El-Saloom at which the DDT degradation took place under anaerobic conditions (Fig. 5).

Concentrations of total HCHs were in the range of 0.09–3.31 ng/g dry weight, and these two values were recorded in Sidi-Kereer and El-Mex, respectively. Sediment sample collected from Eastern Harbor has the next higher value of total HCHs (2.21 ng/g). All the remaining stations showed relatively low values ranged from 0.09 to 0.48 ng/g dry weight (Table 5).

Composition differences of HCH isomers in the environment could indicate different contamination sources (Doong et al., 2002). Technically, HCHs has been used as a broad spectrum pesticide for agricultural purpose. The HCHs generally contains 55–80% of α-HCH, 5–14% of β-HCH, 8–15% of γ-HCH and 2–16% of δ-HCH (Lee et al., 2001). The physico-chemical properties of these HCH isomers are different. β-HCH has the lowest water solubility and vapor pressure, which is the most stable and relatively resistant to microbial degradation (Ramesh et al., 1991). Also it should be noted that α-HCH can be converted to β-HCH in the environment (Walker et al., 1999). Therefore, the predominant of α-HCH isomer in some environmental samples reflects the recent use of technical HCH (Kannan et al., 1995). Many studies have reported that β-HCH was dominant in sediments from the river or estuary environment after long term migration and transformation (Lee et al., 2001; Doong et al., 2002). Investigation of the composition of HCH isomers measured in this work (Fig. 6) showed that the average compositions of HCH isomers are α-HCH: 15.38, β-HCH: 20.67, γ-HCH: 16.62 and δ-HCH: 47.31.

The contamination of HCH isomers is a serious problem worldwide (Walker et al., 1999). HCH pesticide has used for agricultural purpose to control the insects in fruit, grain and vegetable crops and is still used in some developing countries. Among the HCH isomers, α-HCH is more likely to partition to the air and transport for a long distance, while β-HCH is more resistant to hydrolysis and environmental degradation and is the dominant isomer in soils and animal tissue and fluids (Willett et al., 1998). The ratios of α- to γ-HCH isomer were

ranged from 0.14 to 7.05, which indicated that there is a fresh input of HCHs to the studied locations.

Total cyclodienes (Aldrin, Dieldrin, Endrin, Endrin aldehyde, Endrin ketone, Heptachlor, Heptachloro epoxide, γ-chlorodan, α-chlordane, Methoxychlor, Endosulfane I, Endosulfan II and Endosulfane sulfate) ranged from 0.23 ng/g dry weight at Port Said station to 2.51 ng/g dry weight at Eastern Harbor. The α-chlordane was the predominant in all studied samples, which is expected since α-chlordane is one of the main components of technical grade chlordane (Dearth and Hites, 1991). α-chlordane ranged from 0.03 ng/g at El-Saloom to 0.60 ng/g dry weight at the Eastern Harbor. The next higher contaminant was γ-chlordane (0.528 ng/g dry weight) at the Eastern Harbor, then methoxychlor at El-Saloom with concentration of 0.49 ng/g dry weight. Aldrin is present with its higher quantity in Eastern Harbor (0.35 ng/g dry weight), also heptachlor with its higher quantity (0.34 ng/g dry weight) at the same site (Table 6).

Aldrine ranged from 0.01 at El-Saloom to 0.35 ng/g dry weight at Eastern Harbor. Dieldrin was not detected at El-Shatby, Abu Quir, Port Said and El-Saloom. Aldrine concentration ranged from 0.001 ng/g dry weight to 0.01 ng/g dry weight in the rest of the sites. Endrin ranged from 0.004 ng/g dry weight at Port Said to 0.19 ng/g dry weight at Eastern Harbor, where it ranged between 0.02 and 0.14 ng/g dry weight at the other sites. Endrin aldehyde was not detected at Abu Ouir, El-Jamil, Port Said and El-Arish, while ranged from 0.004 to 0.09 ng/g dry weight at the rest of the studied sites. Endrin Ketone ranged from 0.001 to 0.05 ng/g dry weight.

Heptachlor and heptachloro epoxide were ranged from 0.01 to 0.34 and 0.002 to 0.087 ng/g dry weight, respectively. Heptachlor epoxide residues were lower than its parent heptachlor due the higher solubility of heptachlor epoxide in water beside it can stay in sediment for many years (Khan et al., 2010). γ-chlordane, α-chlordane and methoxychlor were ranged from 0.06 to 0.53, 0.03 to 0.60 and n.d. to 0.485 ng/g dry weight, respectively. Endosulfan is a cyclodiene organochlorine widely used as an insecticide in agriculture. Nevertheless, plant protection products containing endosulfan cannot be applied

any longer since 2006 as the European Decision EC/864/2005 established the withdrawal of the products containing endosulfan (Gómez et al., 2011). Endosulfan contains two isomers, endosulfan I and endosulfan II, in approximately a 7:3 ratio along with impurities and degradation products (Rice et al., 1997). In this study Endosulfan I, Endosulfan II and Endosulfan sulfate were ranged from n.d. to 0.004, 0.01 to 0.10 and n.d. to 0.17 ng/g dry weight, respectively, with the isomer endosulfan II is the predominant over endosulfan I isomer, which may be due to the fact that isomerization between the parent isomers can occur in aqueous systems rather than the sediments, being the reaction favorable to the formation of the isomer endosulfan I. Endosulfan sulfate is the predominant residue of technical grade endosulfan, which finds its way into aerobic and anaerobic aquatic environments (Gómez et al., 2011). It is less volatile than the parent compounds and more persistent than them, which explains that the quantities of it is almost equal that of endosulfan II and more than that of endosulfan I in most of the studied stations.

The average composition of cyclodienes components are 24.57% for γ-chlordane, 21.5% for α-chlordane, 11.18% for heptachlor, 9.77% for endrin, 8.6% for methoxychlor, 8.15% for aldrin, 4.46% for endosulfan II, 4.4% for endosulfan sulfate, 3.93% for heptachloro epoxide, 1.73% endrin aldehyde, 1.19% for endrin ketone and 0.29% for endosulfan I (Fig. 7) .

Correlation of OCPs and characteristics of sediments

The observed variation in concentration of OCPs and their metabolites in the marine sediments can be expected to be due to several reasons such as high rate of influx of contaminants into the marine environment and drainage of contaminated water from the surrounding agricultural fields, abiotic degradation of pesticides being influenced by various physico-chemical characteristics of the sediments (i.e. texture, pH, salinity, clay mineral composition, elemental concentration, total organic matter), as well as microbial growths (Sarkar, 1991, 1994). The concentration of contaminant in sediment depends largely on the retaining capacity of the sediments as it is evident from the fact that sediments with large amounts of clay

Table 7 Factor loadings (varimax normalized with Kaiser normalized: marked loadings are > 0.70) for five principal component factors (PCFs) for non-contaminated and for fairly contaminated areas.

Organochlorines	Factor component				
	PCF-1	PCF-2	PCF-3	PCF-4	PCF-5
γ-HCH	**0.960**	0.152	−0.058	0.088	0.016
β-HCH	**0.956**	0.181	0.028	0.063	0.144
Endrine aldehyde	**0.954**	0.175	0.156	0.077	0.066
Aldrine	**0.942**	0.263	−0.066	0.113	0.123
Endrineketone	**0.934**	0.031	0.213	0.040	−0.044
Endosulfan sulfate	**0.910**	0.088	0.272	0.018	0.032
Heptachlor	**0.908**	0.225	0.056	0.056	0.080
PCB-28	**0.886**	−0.280	0.064	−0.102	−0.016
γ-Chlordane	**0.855**	−0.064	0.181	0.329	−0.168
α-Chlordane	**0.833**	0.277	0.356	0.026	0.044
p,p′-DDT	**0.826**	0.410	0.319	−0.014	−0.020
PCB-52	**0.717**	−0.134	−0.163	−0.182	-0.017
PCB-18	**0.576**	−0.458	**0.288**	−0.367	−0.383
PCB-138	0.002	**0.927**	0.052	−0.244	0.059
PCB-153	0.357	**0.786**	−0.179	0.092	−0.028
PCB-101	0.337	**0.672**	−0.123	0.562	0.114
p,p′-DDD	0.598	**0.630**	−0.150	0.028	0.232
δ-HCH	0.044	−0.127	**0.971**	−0.021	−0.090
Heptachloro epoxide	0.643	0.114	**0.701**	0.215	−0.043
α-HCH	0.670	−0.162	**0.690**	−0.045	−0.010
PCB-194	0.310	−0.151	**0.670**	0.258	−0.189
Endosulfane I	−0.439	0.334	**0.490**	**0.464**	**0.428**
p,p′-DDE	−0.221	−0.058	−0.127	**0.950**	−0.148
Dieldrine	0.240	−0.003	0.368	**0.889**	0.085
Endosulfane II	0.600	−0.092	0.074	**0.782**	0.057
PCB-180	−0.078	−0.229	−0.080	0.053	**0.913**
PCB-118	0.146	0.467	−0.144	−0.149	**0.833**
Endrine	**0.590**	0.463	0.076	0.077	**0.645**
Methoxychlor	−0.170	−0.141	−0.007	0.030	**−0.354**
PCB-44	**0.520**	−0.303	**0.319**	−0.064	0.168
% of Variance	**42.641**	**12.979**	**11.653**	**11.264**	**8.855**
Cumulative %	**42.641**	**55.620**	**67.273**	**78.537**	**87.392**

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Rotation converged in 7 iterations.
Bold Numbers: This organochlorine is loaded to this PCF.

Table 8 Correlations matrix between organochlorines (OCls) components.

No.	OCLs	1	2	3	4	5	6	7	8	9	11	12	14	16	17	18	19	20	22	23	24	25	26	27	28
1	α-HCH	1.00																							
2	ß-HCH	0.63																							
3	γ-HCH		0.96																						
4	δ-HCH	0.74																							
5	Heptachlor		0.93	0.94																					
6	Aldrine		0.96	0.97		0.93																			
7	Heptachloro epoxide	0.88	0.66	0.62	0.69	0.61	0.61																		
8	γ-Chlordane	0.74	0.83	0.80		0.73	0.76	0.76																	
9	Dieldrine																								
10	p,p'-DDE									0.73															
11	α-Chlordane	0.70	0.83	0.82		0.79	0.87	0.85	0.71																
12	Endrine		0.74	0.66		0.71	0.77				0.70														
14	Endrine aldehyde	0.71	0.96	0.97		0.97	0.96	0.74	0.81		0.89	0.71													
15	Endosulfane II		0.62	0.61			0.63		0.80	0.87				0.62											
16	P,P'-DDD		0.74	0.63		0.61	0.74					0.75	0.62												
17	P,P'-DDT	0.72	0.90	0.86		0.91	0.85	0.78	0.74		0.86	0.68	0.92	0.70											
18	Endrine ketone	0.73	0.92	0.93		0.90	0.89	0.75	0.80		0.87		0.95		0.88										
19	Endosulfan sulfate	0.79	0.90	0.93		0.90	0.88	0.80	0.80		0.87	0.64	0.96		0.90	0.93									
20	TOC		0.66	0.77		0.73	0.72				0.71		0.74		0.79	0.71	0.75								
21	TOM		0.66	0.77		0.73	0.72				0.71		0.74		0.79	0.71	0.75	1.00							
22	PCB-18	0.62																							
23	PCB-28	0.70	0.75	0.73		0.67	0.73		0.80		0.71		0.76		0.75	0.73		0.72							
24	PCB-52		0.65				0.63						0.63			0.64		0.79							
25	PCB-44	0.71																	0.71						
26	PCB-101											0.63		0.66											
27	PCB-118											0.82													
28	PCB-138													0.63											
29	PCB-153														0.89								0.64		0.72
30	PCB-180																	-0.65						0.66	
31	PCB-194	0.76				0.65			0.70												0.75				

Correlation is significant at p < 0.05 (low) (n, red); Correlation is significant at P < 0.005 (Medium) (B, blue); correlation is significant at P < 0.001 (high) (u, green).

minerals can retain larger amounts of pesticides residues than the sandy-clay or sandy silt sediments (Sarkar, 1994). From Table 2 it is clear that all the samples are sandy sediments, which explain the low levels of OCPs in most of the samples. Moreover, the diffusion of organochlorine contaminants through the pores of the sedimentary layers quite efficiently influences the variation in concentration of various OCPs in sediments of different characteristics (Sarkar, 1994).

Statistical analysis

The majority of the variance (87.39%) of the scaled data was explained by five eigenvectors-principal components. The first principal component factor (PCF-1) explained 42.64%. The second (PCF-2), the third (PCF-3), the fourth (PCF-4) and the fifth (PCF-5) principal component factors explained 12.98%, 11.65%, 11.26% and 8.85% of the total variances, respectively (Table 7). PCF-1 had a strong significant correlation with γ-HCH (0.960), ß-HCH (0.956), endrine-aldehyde (0.954), aldrine (0.942), endrine-ketone (0.934), endosulfan sulfate (0.910), heptachlor (0.908), PCB-28 (0.886), γ-chlordane (0.886), α-chlordane (0.833), p,p'-DDT (0.826), PCB-52 (0.717), PCB-18 (distributed in PCF-1: 0.576 and PCF-3: 0.288), p,p'-DDD (distributed in PCF-1: 0.598 and PCF-2: 0.630) and PCB-44 (distributed in PCF-1, 0.520 and PCF-3, 0.319). As displayed in Table 8, these compounds gave strong correlation with each other (p < 0.001). PCF-2 dominated only by three PCBs, which are PCB-138 (0.927), PCB-153 (0.786) and PCB-101 (distributed in PCF-2: 0.672 and PCF-4: 0.562), PCF-3 dominated by δ-HCH (0.971), heptachloro epoxide

(0.701), α-HCH (0.690), PCB-194 (0.670) and endosulfane I (distributed in three factors PCF-3: 0.490, PCF-4: 0.464 and PCF-5: 0.428). PCF-4 represents p,p'-DDE (0.950), dieldrine (0.889) and endosulfane II (0.782). PCF-5 represents PCB-180 (0.913), PCB-118 (0.833), endrine (distributed between PCF-1: 0.590 and PCF-5: 0.645). The property of individual organochlorine components which causes their dominancy in each factor cannot be clearly indicated and their clustering was not observed (Fig. 8). Therefore, it is impossible to predict the distribution patterns of individual organochlorine components in contaminated areas. The strong adsorption of organochlorines by sediments caused by long-range atmospheric transport processes and regional fallout deposition in combination with their transformation, behavior in sediment–water system and mobility imply the random distribution.

Hierarchical cluster analysis (Ward's method applying Pearson correction) of organochlorine components using average linkage between groups and square Euclidean distance and standard deviation <1 showed a good efficiency for sediment samples collected from Mediterranean cost, which present different sources deposition (Fig. 8). Four big clusters with subgroups and two small clusters could be distinguished, which coincides with the previously defined factor analysis. The linkage distance between classes is high (10.0–15.0) implying a significant distance between them. Statistically sufficient number of data can explain the high values obtained for linkage distance. The dendrogram of Fig. 8 shows that the main cluster contains dominantly γ-HCH, endrine aldehyde, ß-HCH, aldrine, endrine ketone, endosulfan sulfate, heptachlor, p,p'-DDT, α-chlordane, α-HCH, heptaepoxide and γ-chlordane and could be conditionally named "pesticides" since they are

Dendrogram using Average Linkage (Between Groups)
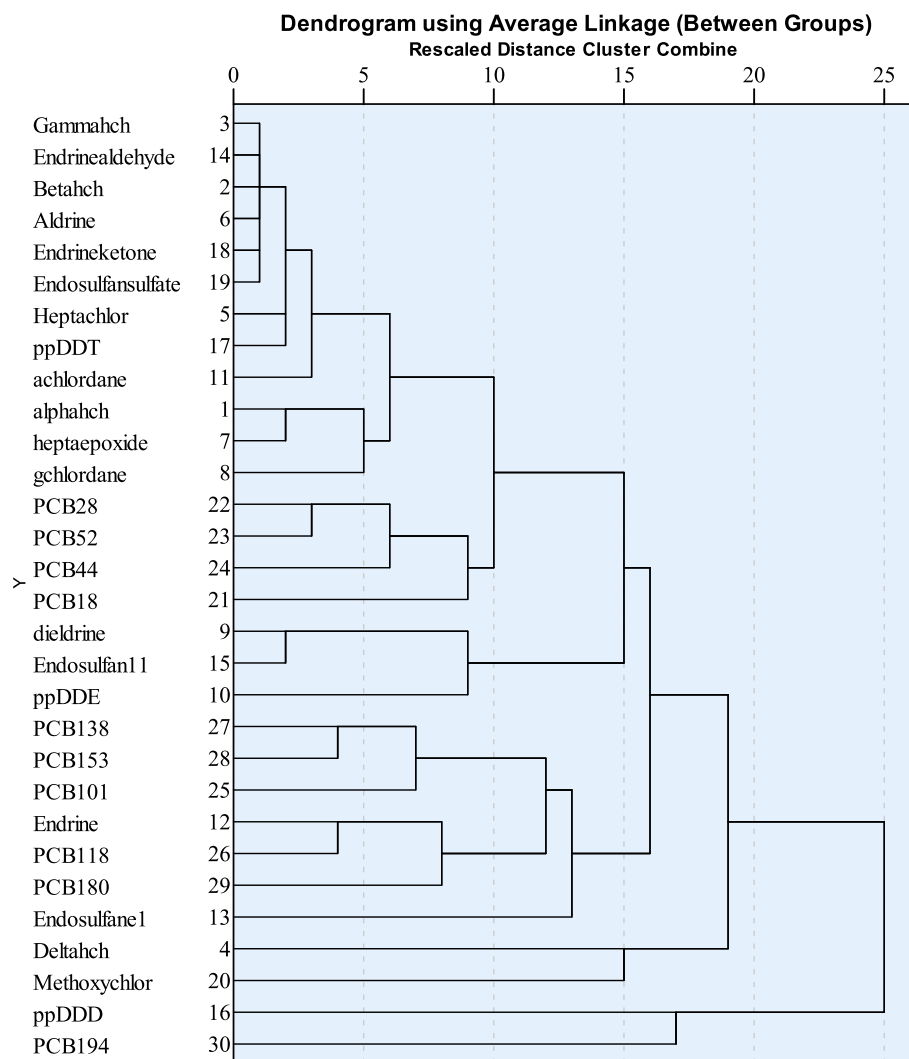**Rescaled Distance Cluster Combine**

Figure 8   Hierarchical dendogram for 30 objects represented by three variable obtained by Ward's hierarchical clustering method.

various combinations of OCPs. The second group includes PCB-28, PCB-52, PCB-44 and PCB-18 and can be named "PCBs" since they are various combinations of PCBs. The third group includes three OCPs (dieldrine, endosulfan II and p,p'-DDE), while the fourth cluster contains only three PCBs (PCB-138, PCB-153 and PCB-101). The remaining cluster groups represent mixture of OCPs and PCBs.

The OCls whose concentrations are susceptible of covering in the environment were identified in this study on the basis of the correlation factor values (Table 8). This statistical approach is based on the fact that each pollution source produces a characteristic OCls pattern; so, the correlations of all the individual OCls can give an idea whether they all originate from the same source or not. A lack of correlation was noticed between PCBs and most of OCPs, which may suggest different sources. The correlation represented in Table 8 gave similar results with that obtained by the factor and cluster analysis.

Comparison with data from other regions

Marine sediments considered as one of the most important sinks for OCPs, concentrations of these compounds in

sediments have been used in monitoring programs to indicate environmental quality. Concentrations of OCPs measured worldwide were compared with the results obtained from this study (Table 9). It is clear that the levels of all kinds of OCPs recorded in the Egyptian Mediterranean coast are lower than that mentioned in Table 9 for the worldwide results.

Risk assessment

An assessment of potential environmental risks associated with POPs measured in the present study was conducted and the results are summarized in Table 10. Sediment quality values used in the calculation of risk quotients included the Hong Kong Interim Sediment quality value (HK-ISV and CSQG. Concentrations of contaminants recorded in the sediment samples are taken as the measured environmental concentrations (MECs). Where, all the RQ_{bes} estimated were below 0.1 and this might suggest that the pollutants under investigation pose little hazard to the ecosystem. RQ_{wor}, PCB's < 1, based on HK_ISQV and CSQG. Similarly, the risk quotients for, DDD, DDE and dieldrin were all below unity, even under the worst-case scenario. These results indicate that the concentrations of these

Table 9 Concentrations (ng/g dry weight) of PCBs and Organochlorine pesticides residues in sediments collected worldwide.

Location	Pollutant	Range	Survey year	Reference
Cantabria (northern Spain)	ΣDDTs	0.5–0.9	2006	Gómez et al. (2011)
	Aldrin	0.4–0.5		
	Dieldrin	0.4–0.7		
	Methoxychlor	n.d.-0.4		
	Endosulfan I	0.2–0.6		
	Endosulfan II	t-0.4		
Upper reach of Huaihe River (East China)	ΣHCHs	1.95–22.05	2007	Sun et al., 2010
	ΣDDTs	4.07–23.89		
Karachi Harbour (Pakistan)	ΣDDTs	0.003–4.573	2002–2003	Khan et al., 2010
	ΣHCHs	0.002–0.483		
	ΣCyclodienes	0.006–1.461		
Bohai Sea (China)	ΣDDTs	0.3–12.6	2007	Tan et al., 2009.
	ΣHCHs	1.1–8.5		
	ΣCyclodienes	0.1–8.8		
Beijing Guanting Reservoir (China)	ΣDDTs	3.25–17.2	2003-	Xue et al., 2006
	ΣHCHs	0.28–10.8	2004	
	Chlordane	0.087–0.54		
Pearl River (China)	ΣPCBs	6.0–290	2003	Fung et al., 2005
	ΣDDTs	1.4–600		
Bengal Bay (India)	ΣPCBs	19.9–6570 pg/g		Rajendran et al., 2005
	ΣDDTs	0.04–4.79		
West Bengal (Northeast India)	ΣHCHs	0.11–0.4	2003	Guzzella et al., 2005
	ΣDDTs	0.18–1.93		
	ΣPCBs	0.18–2.33		
Alexandria Harbou (Egypt)	ΣPCBs	0.9–1210	1998	Barakat et al., 2002
	ΣDDTs	0.25–885		
	Σchlordane	<0.25–44		
	Chloropyrifos	<0.25–51		
	Endosulfan II	<0.25–22		
	Aldrin	<0.25–4.6		
	Dieldrin	<0.25–3.1		
	Endrin	<0.25–6.7		
	ΣHCHs	<0.25–6.0		
Black Sea (Turkey)	ΣPCBs	0.4–4.4	1995	Fillmann et al. (2002)
	ΣDDTs	0.2–7.2		
	ΣHCHs	0.08–1.1		
Mediterranean Sea	ΣPCBs	0.31–1.95		Present study
	ΣDDTs	0.08–2.14		
	ΣHCHs	0.09–3.31		
	ΣCyclodienes	0.23–2.51		

Table 10 Estimated risk quotients (RQs) based on the concentrations of organic contaminants in sediment samples (MECs) Hong Kong Interim sediment Quality Value (HK-ISQV) and the Canadian Sediment Quality Guidelines (CSQG).

Pollutants	MECs	According to HK-ISQV (ng/g)		According to CSQG (ng/g)		$0.1 < RQ_w < 1$	$1 < RQ_w < 10$	$RQ_w > 10$
		Lower limit	Upper limit	Threshold	Probable			
Total PCBs	0.308–1.96	0.0017	0.085	0.0016	0.091	◇•		
Total DDTs	0.081–2.144	0.0017	1.356	0.00157	0.551	•	◇	
p,p'-DDD	0.01–0.034	0.0005	0.017	0.00128	0.027	◇•		
p,p'-DDE	0–0.045	–	0.02	–	0.0217	◇•		
p,p'-DDT	0.063–2.111	0.009	2.111	0.0132	1.773		◇•	
Chlordane	0.137–1.129	0.022	2.258	0.0286	0.499	◇	•	
Dieldrin	0–0.005	–	0.25	–	0.00704	◇•		
Endrin	0.022–0.333	0.0275	16.65	0.0352	0.124		•	◇
HE	0.002–0.087	–	–	0.0729	0.145		•	

Risk quotients were calculated based mainly on two sediment quality criteria (◇ = HK-ISQV; • = CSQG).

chemicals in the sediments posed few risks to the local aquatic system. For other contaminants, such as total DDTs, chlordane and endrin, RQ_{wor} are less than unity only for one of the sediment quality criteria (Table 10). Compounds with $1 < RQ_{wor} < 10$ for both sediment quality criteria included total DDTs, p,p'-DDT and Chlordane. The RQ_{wor} for endrine

was above 10, suggesting that these contaminants may be of concern to the integrity of the risk quotients. For these contaminants were all below unity under the best-case scenario, so the "actual" risk posed by these chemicals should be subjected to further studies. This type of preliminary assessment provides a simple and useful means of screening OCs pollutants of concern, and assists in prioritizing management efforts. This procedure also allows a more refined assessment to proceed when more information becomes available in the future.

Conclusion

The OCPs concentrations in the sediments along the Egyptian Mediterranean Coast considered in the present study range among the allowable values. Organochlorine pesticide residues detected were PCBs, DDTs, HCHs, aldrin, dieldrin, endrin, endrin aldehyde, endrin ketone, heptachlor, heptachloro epoxide, γ-chlordane, α-chlordane, methoxychlor, endosulfan I, endosulfan II and endosulfan sulfate. It was concluded that the PCBs are predominant over all kinds of pesticides except for El Mex, Eastern Harbor and El Shatby stations. For HCHs the δ-HCH was the most abundant among the studied isomers of HCHs along the coast. The ratio of DDE + DDD/ΣDDT indicated that DDT in the sediment from these sits mainly came from the weathered agriculture soils. The ratio of DDD/DDE showed that DDT degradation took place under anaerobic conditions. Principal component analysis shows that the property of individual organochlorine components which causes their dominancy in each principal component factor cannot be clearly indicated and their clustering was not observed. Therefore, it is impossible to predict the distribution patterns of individual organochlorine components in contaminated area. By applying statistical analysis it was concluded that there is a lack of correlation between PCBs and most of OCPs, which suggested the presence of different sources for organochlorines input to the studied locations. Risk assessment study showed that the organochlorines in Egyptian Mediterranean coast sediment should receive more studies concern.

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