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Polychlorinated Biphenyls and Chlorinated Pesticides in Sediments along the Semi-Closed Areas of Alexandria, Egypt

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ABSTRACT

The residues of 19 EPA-organochlorine pollutants were analyzed in sediments collected from 49 different locations along the semi-closed areas of Alexandria, Egypt. The pollutants studied were 7 individual polychlorinatedbiphenyl (PCB) congeners, α,β,γ-hexachlorocyclohexane (HCHs), cyclodienes (aldrin, endrin, dieldrin) and dichlorodiphenyltrichloroethanes (DDTs) (o,p-DDE, p,p-DDE, o,p-DDD, p,p-DDD, o,p-DDT, p,p-DDT). The concentration of total DDTs ranged between ND and 123.76 $ng \cdot g^{-1}$ (dry wt) whereas the concentration of PCBs, HCHs and cyclodienes ranged from ND to 192.24 $ng \cdot g^{-1}$; ND to 20.78 $ng \cdot g^{-1}$ and ND to 8.04 $ng \cdot g^{-1}$ dry wt, respectively. The average total organic carbon (TOC) percent was varied from 0.04% to 7.65%.

Keywords: Surface Sediment; Organochlorine Pollutants; Alexandria; Egypt; GC-ECD; GC-MS

1. Introduction

Organochlorines (OCs), including PCBs and OCPs, represent an important group of persistent organic pollutants (POPs) that have caused worldwide concern as toxic environmental contaminants. They are strongly particle associated in aquatic ecosystems due to their hydrophobic properties, and tend to accumulate in sediments [1]. Also, residues of these chemicals have long half-life, they continue to be detected in sediment through out the world after banning 20 years later [2]. Sediments have been extensively used to assess the pollution of water bodies and to reflect the sources and history of pollution, because of the general importance of sediment phase in fate and transport of contaminants. In addition, contaminated sediments may constitute a particular threat for associated biota and even for other organisms throughout marine food web [3]. Being one of the principle reservoirs of environmental OCs, the estuary represents a source from which residues can be released to the atmosphere, groundwater and living organisms. It is one of the best media for long-term monitoring of many contaminants [4]. To date, POPs in estuarine and rivers sediments have been studied in several parts of the world [5,6]. The results show that POPs were detected in most estuary areas, especially in estuaries close to urbanized and industrialized areas. They receive and retain large quantities of organic pollutants, and have negative impacts on both the surrounding ecological environment and human health. OCPs such as hexachlorocyclohexane (HCH) and DDT are ubiquitous anthropogenic environmental contaminants. They are persistent, broad-spectrum toxicants that accumulate in the food web with high risks to ecosystem and human health. Many of these compounds are considered to act as hazardous environmental hormones, which disrupt reproductive cycles of humans and wildlife [7-9]. PCBs are man-made chemicals and synthesized by substituting variable number of chlorine atoms (from 1 to 10 chlorine atoms) onto the biphenyl aromatic molecular structure to produce 209 congeners. These congeners were manufactured and processed primarily for use as insulating fluids and coolants in electrical equipment and machinery in USA from 1929-1977, with a peak production in the year 1970 about 100,000 tons [10].

The present work is the first systematic record to be undertaken along the semi-closed areas of Alexandria (Egyptian Mediterranean Sea coast) as a comparative study between four sectors of different identity.

2. Materials and Methods

A total of 49 surface sediment samples were collected

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during January 2010 at sites shown in **Figure 1**. Sediments were collected utilizing a stainless-steel grab. Six grabs were taken from each location from which the top 3 cm were scooped into pre-cleaned wide-mouth glass bottles, frozen and transported to the laboratory and stored at −20˚C until analysis. The procedure for extracting OCPs and PCBs from sediments was modified from the USEPA Method [11-14]. Before chemical treatment, individual samples were removed from the refrigerator and allowed to thaw at room temperature for about 5 hr. Each sample was then thoroughly mixed and 30 g of the sediment was mixed with 90 g of anhydrous sodium sulfate. Duplicates were taken from each sediment sample. The sediment sample was then extracted with 250 ml (1:1) of n-hexane-dichloromethane for 8 hr in a Soxhlet apparatus cycling 5 - 6 times·h^{-1} [14]. The extracts were then combined and desulfurized through activated copper powder and then concentrated to a few milliliters in a rotary evaporator at temperature of 35˚C. Anhydrous sodium sulfate (90 g) was extracted in the same fashion as the sample and used as the blank. The extracted samples and blanks were then concentrated with a pure nitrogen gas stream down to a volume of 2 ml. 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 Gas chromatograph (Thermo Scientific Company) equipped with ^{63}Ni electron capture detector. A fused-silica capillary column; Thermo TR-35 MS (30 m, 0.25 mm, 0.25 μm) with 35% phenyl polysilphenylene-siloxane was used for the quantification. The temperature was programmed from 90˚C - 140˚C with rate of 5˚C·min^{-1}, then held at 140˚C for 1min, and from 140˚C - 250˚C with rate of 3˚C·min^{-1} and was held at 250˚C for 1min, and from 250˚C - 300˚C with rate of 20˚C·min^{-1} and was held at 300˚C for 1 min. The injector and detector temperatures were set at 280˚C and 310, respectively. Three μL volume of each sample was injected in the split less mode and the purge time was 1 min.

To control the analytical reliability and assure recovery efficiency and accuracy of the results, four analyses were conducted on organochlorine compounds reference material SRM-2974a freeze-dried mussel tissue (Mytilus edulis) provided by EIMP-IAEA. The laboratory results showed that recovery efficiency ranged from 92% to 108% with coefficients of variation of 8% - 15% for all organochlorine compounds. The limit of detection in the present study was estimated to be 0.015 ng·g^{-1} for PCB and 0.016 ng·g^{-1} for pesticides based on the minimum quantity of sample required for a discernible peak appeared on the chromatogram. For comparison, the data given by GC-ECD was qualitatively confirmed by GC-MS with the same method and column.

3. Results and Discussion

Sediments showed the presence of a wide variety of organochlorine including α, β, and γ-HCH, dieldrin, aldrin, endrin, DDT and the metabolites of DDT as well as PCBs (**Tables 1** and **2**). The concentrations of organochlorines

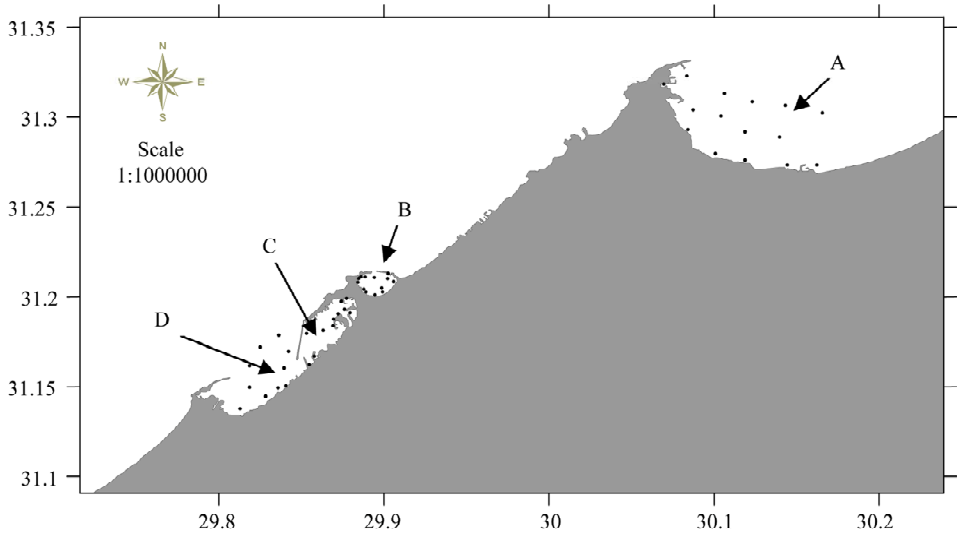

Figure 1. Sampling locations collected from the area of investigation. A: Abu Qir Bay, B: Eastern Harbour, C: Western Harbour and D: El Max Bay during 2010.

Table 1. Pesticides concentration (ng·g^{-1}; dry wt) in sediments samples collected from the semi-closed areas of Alexandria, Egypt.

Compounds / Site		α-HCH	β-HCH	γ-HCH	HCHs	Aldrin	Dieldrin	Endrin	TC	o,p-DDE	p,p-DDE	o,p-DDD	p,p-DDD	o,p-DDT	p,p-DDT	DDTs	TP
A.Q	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	2	ND	ND	ND	ND	0.22	ND	ND	0.22	ND	ND	ND	ND	ND	ND	ND	0.22
	3	0.11	1.02	0.48	1.61	0.98	ND	ND	0.98	4.21	ND	ND	1.14	ND	ND	5.35	7.94
	4	0.02	ND	ND	0.02	ND	ND	ND	ND	0.9	ND	0.19	ND	2.19	ND	3.28	3.29
	5	ND	ND	ND	ND	0.29	ND	ND	0.29	ND	ND	ND	ND	ND	ND	ND	0.29
	6	ND	ND	ND	ND	ND	0.06	ND	0.06	0.61	ND	0.39	ND	ND	ND	1.00	1.06
	7	0.04	0.68	0.08	0.8	ND	0.06	ND	0.06	0.71	ND	ND	ND	ND	ND	0.71	1.57
	8	0.02	ND	ND	0.02	0.34	ND	ND	0.34	ND	ND	ND	ND	ND	ND	ND	0.36
	9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	11	ND	ND	ND	ND	0.56	ND	ND	0.56	0.99	ND	ND	ND	ND	ND	0.99	1.56
	12	ND	ND	ND	ND	ND	0.14	2.55	2.69	ND	11.07	ND	ND	4.75	ND	15.81	18.51
	13	ND	ND	ND	ND	2.70	0.06	ND	2.76	ND	ND	ND	ND	ND	ND	ND	2.76
	14	ND	ND	ND	ND	0.20	ND	ND	0.20	ND	ND	ND	ND	ND	ND	ND	0.2
	15	ND	ND	ND	ND	ND	ND	0.48	0.48	ND	ND	ND	ND	ND	ND	ND	0.48
E.H	16	ND	ND	ND	ND	1.82	ND	ND	1.82	ND	ND	ND	ND	ND	18.25	18.25	20.07
	17	ND	ND	ND	ND	3.05	ND	ND	3.05	5.72	42.51	ND	ND	ND	ND	48.23	51.29
	18	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	20.24	20.24	20.24
	19	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.19	15.00	17.19	17.19
	20	ND	ND	ND	ND	8.04	ND	ND	8.04	ND	ND	ND	ND	ND	38.3	38.3	46.35
	21	ND	ND	ND	ND	2.21	ND	ND	2.21	ND	18.60	1.45	ND	ND	ND	20.05	22.26
	22	0.02	0.88	0.03	0.93	0.34	ND	ND	0.34	ND	ND	ND	ND	ND	ND	ND	1.27
	23	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	86.81	86.81	86.81
	24	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	54.5	54.5	54.5
	25	ND	ND	ND	ND	2.01	ND	ND	2.01	ND	26.31	2	ND	ND	ND	28.31	30.63
	26	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	27	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	28	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
W.H	29	0.03	0.10	0.15	0.28	0.65	ND	ND	0.65	ND	2.01	ND	1.92	ND	ND	3.93	4.86
	30	ND	0.21	0.33	0.54	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.54
	31	0.03	0.23	0.11	0.38	0.07	ND	ND	0.07	ND	ND	ND	ND	ND	ND	ND	0.45
	32	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	33	ND	ND	ND	ND	0.07	0.03	ND	0.09	ND	ND	ND	ND	ND	ND	ND	0.10
	34	ND	0.02	0.01	0.03	ND	ND	ND	ND	ND	ND	ND	ND	ND	38.35	38.35	38.39
	35	0.03	ND	ND	0.03	0.45	ND	ND	0.45	18.91	3.66	ND	ND	ND	ND	22.57	23.05
	36	ND	0.57	1.01	1.57	ND	1.36	ND	1.36	ND	62.80	ND	2.2	ND	ND	65	68.53
	37	ND	ND	ND	ND	3.79	ND	ND	3.79	ND	ND	ND	ND	ND	33.6	33.6	37.4
	38	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.51	6.51	6.51
	39	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
El-Max	40	ND	1.12	2.21	3.33	0.65	ND	ND	0.65	ND	ND	ND	0.52	ND	123.24	123.76	127.75
	41	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	42	ND	ND	0.14	0.14	0.46	ND	ND	0.46	ND	ND	ND	ND	ND	78.02	78.02	78.62
	43	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	40.87	40.87	40.87
	44	11.36	5.57	3.86	20.78	1.07	0.11	ND	1.18	6.58	ND	ND	ND	ND	22.61	29.19	51.15
	45	7.36	3.35	1.27	11.98	ND	ND	ND	ND	ND	ND	ND	ND	15.81	ND	15.81	27.8
	46	1.42	2.23	0.57	4.23	ND	0.10	ND	0.1	ND	ND	ND	ND	6.03	ND	6.03	10.36
	47	ND	ND	ND	ND	1.12	ND	ND	1.12	1.52	ND	ND	ND	ND	ND	1.52	2.64
	48	0.07	ND	ND	0.07	ND	0.13	ND	0.13	1.16	3.37	0.26	ND	72.75	ND	77.54	77.74
	49	0.04	8.47	0.12	8.63	ND	1.35	1.93	3.28	ND	3.86	0.37	ND	40.76	ND	44.99	56.91

ND: Below Detection Limit; TP: Total Pesticides.

Table 2. PCBs concentration (ng·g^{-1}) in sediments samples collected from the semi-closed areas of Alexandria, Egypt.

Compounds Sites		PCB 28	PCB 52	PCB 101	PCB 118	PCB 138	PCB 153	PCB 180	Total PCBs
A.Q	Marina area of Abu Qir	ND	ND	71.12	ND	28.68	ND	ND	99.8
	Rakta	ND	ND	9.56	ND	4.09	ND	ND	13.65
	El Amia Drain	1.48	ND	46.41	ND	10.05	ND	ND	57.94
	Power Station	ND	ND	33.74	ND	2.29	ND	ND	36.04
	In front of Petroleum Company	ND	ND	12.17	ND	78.05	ND	ND	90.22
	3 Km right from Nelson Island	0.58	ND	1.48	0.84	2.25	ND	ND	5.14
	Nelson Island	0.53	ND	10.97	ND	1.91	ND	ND	13.41
	3 Km left of Nelson Island	0.40	ND	ND	ND	10.66	ND	ND	11.06
	In front of the Dry Dock	ND	ND	6.18	ND	1.36	ND	ND	7.53
	El Fanar area	ND	ND	0.38	ND	1.05	ND	ND	1.43
	Northern tip of Abu Qir Bay	0.73	ND	ND	ND	2.5	ND	0.6	3.83
	West of El Maadyia	0.42	ND	ND	ND	2.28	ND	0.51	3.22
	East of El Maadyia	0.47	ND	7.43	ND	12.21	ND	ND	20.1
	Edku	ND	ND	ND	ND	0.83	ND	ND	0.83
	Rashid	ND	ND	ND	ND	3.36	ND	ND	3.36
E.H	In front of Yacht Club	ND	ND	ND	ND	ND	ND	ND	ND
	Precipitation Region	2.41	ND	ND	ND	6.52	ND	ND	8.93
	Egyptian Union for Diving	ND	ND	12.17	ND	78.08	ND	ND	90.25
	Wastewater Treatment Plant	ND	ND	33.74	ND	ND	ND	ND	33.74
	In front of Italy Council (Sesil)	1.8	ND	ND	ND	ND	ND	ND	1.8
	Eastern Harbour Center	ND	ND	ND	ND	67.99	ND	ND	67.99
	In front of Sutter Street	0.4	ND	ND	ND	10.66	ND	ND	11.06
	300m from Eastern Harbour Boughaz	ND	ND	ND	ND	ND	ND	ND	ND
	Eastern Boughaz Opening	ND	ND	ND	ND	ND	ND	ND	ND
	Western Boughaz Opening	ND	ND	ND	ND	53.54	ND	ND	53.54
	In front of NIOF	ND	ND	ND	ND	1.29	ND	1.29	2.59
	In front of the Marine Science Department	ND	ND	ND	ND	0.43	ND	ND	0.43
	Marina area of Eastern Harbour	ND	ND	ND	ND	0.33	ND	ND	0.33
W.H	Alexandria Petroleum Company (APCO)	1.15	ND	25.12	ND	17.38	ND	ND	43.64
	El Ghelal platform	ND	ND	37.29	ND	57.22	ND	ND	94.51
	Coal platform	ND	ND	3.87	ND	1.04	ND	ND	4.92
	Navigation way (Western Harbour)	ND	ND	26.27	ND	85.14	ND	ND	111.4
	Concrete Waves Wall (Western Harbour)	0.49	ND	ND	0.13	35.37	0.24	ND	36.23
	Shipping Control Tower	ND	ND	0.13	ND	ND	ND	ND	0.13
	In front of Egyptian Navy	ND	ND	ND	ND	6.12	ND	ND	6.12
	Containers platform	11.04	ND	ND	ND	183.2	ND	ND	194.2
	El Gona	10.99	ND	ND	ND	ND	ND	ND	10.99
	Repairing Ship area	ND	ND	ND	ND	ND	ND	ND	ND
	Marina area of the Western Harbour	ND	ND	ND	ND	ND	ND	ND	ND
El-Max	Beside Western Harbour offshore of El Max	3.21	ND	ND	ND	1.76	ND	0.92	5.89
	300m from El Nobariya drain	ND	ND	ND	ND	ND	ND	ND	ND
	El Nobaryia drain	1.19	ND	0.51	ND	ND	ND	ND	1.70
	Cement Company	1.26	ND	0.54	ND	ND	ND	0.72	2.53
	Petro-Chemical Company	10.88	ND	0.67	1.39	ND	ND	0.96	13.9
	Boundary area	10.36	ND	ND	ND	ND	ND	ND	10.36
	In front of Polyethylene Factory	1.10	ND	ND	ND	ND	ND	0.66	1.76
	300m away From Polyethylene Factory	ND	ND	0.75	ND	21.27	ND	ND	22.02
	El Max offshore 1	0.90	ND	ND	ND	ND	ND	2.57	3.48
	El Max offshore 2	1.20	ND	1.35	ND	ND	ND	ND	2.55

PCB 28 = 2,4,4-Trichlorobiphenyl; PCB 52 = 2,2,5,5-tetrachlorobiphenyl; PCB 101 = 2,2,4,5,5-pentachlorobiphenyl; PCB 118 = 2,3,4,4,5-pentachlorobiphenyl; PCB 138 = 2,2,3,4,4,5-hexachlorobiphenyl; PCB 153 = 2,2,4,4,5,5-hexachlorobiphenyl; PCB 180 = 2,2,3,4,4,5,5-Heptachlorobiphenyl.

in sediments decreased in the order of DDTs > PCBs > HCHs > cyclodienes for most of the samples. Concentrations of DDTs in sediments were in the range from ND to 123.76 ng/g with an average of 31.37 ng·g^{-1}; dry wt. Among DDT metabolites, p,p-DDE accounted for a range from 4.35% at El Max offshore 1 (St. 48) to 96.62% at Containers platform (St. 36) of total DDT concentrations. This composition is indicative of fresh inputs of DDT. Higher concentrations of p,p-DDE and p,p-DDT were found in the Containers platform (St. 36) and Beside Western Harbour offshore of El Max (St. 40) and the lowest concentration of p,p-DDD and p,p-DDT were found in Alexandria Petroleum Company (APCO) (St. 2) and Repairing Ship area (St. 38). Metabolic transformation of DDT under oxidative conditions leads to p,p-DDE, whereas under anaerobic conditions, p,p-DDD is formed [15-17]. The concentration of total DDTs showed a range of 45% - 100% of total pesticides concentration (**Figure 2(a)**). These high concentrations may reflect the intensive use of pesticides (especially DDT) in cotton fields of Egypt over many years.

Average concentrations of HCHs in sediments were 3.08 ng·g^{-1}; dry wt with a range of 3 - 13-fold lower than those of DDTs (**Table 1**). Although use of HCHs in agriculture has been greater than DDTs, the relatively low concentration of HCHs in sediments reflects their lower potential for bioaccumulation. Furthermore, higher vapor pressures of HCHs facilitate relatively rapid atmospheric dissipation in the tropics, leaving fewer residues in soil and water [18].

The concentrations of cyclodienes (aldrin, endrine and dieldin) in sediments were in concentrations the range of 0.06 ng·g^{-1}; dry wt at St. 6, and 7 - 8.04 ng·g^{-1}; dry wt at St. 20 with average of 1.31 ng·g^{-1}; dry wt. These were on average, 15-fold less than DDTs (**Table 2**) and almost the same as the concentrations of HCHs (**Figure 2(b)**).

PCBs were at 2nd concentrations relative to other organochlorines in this study (**Table 2**). The PCBs concentrations were in the range of 1.70 - 194.20 ng/g·ng·g^{-1} dry wt at St. 42 and St. 36 (**Figure 2(c)**), respectively, with an average concentration of 28.01 ng·g^{-1} dry wt. PCBs concentration were on average, 2-fold lower than DDTs.

Concentrations of PCBs recorded in present work were much lower than concentrations observed in Mediterranean Sea sediments and in other coastal sediments in different geographical positions except for the northwestern basin of the Mediterranean Sea, Barcelona Offshore, Spain, and the Western Baltic Sea (**Table 3**). At the same time detected concentrations of DDTs in the bay sediments in the present study were lower than concentrations previously recorded in Mediterranean Sea coastal sediments, but higher than concentrations recorded in other coastal sediments worldwide (**Table 3**). Concentration of HCHs recorded in present work was generally lower than concentration previously recorded in sediments, but concentrations of Aldrin, Dieldrin, DDTs, and PCBs were slightly higher than concentrations previously recorded in sediments (**Table 3**). De-

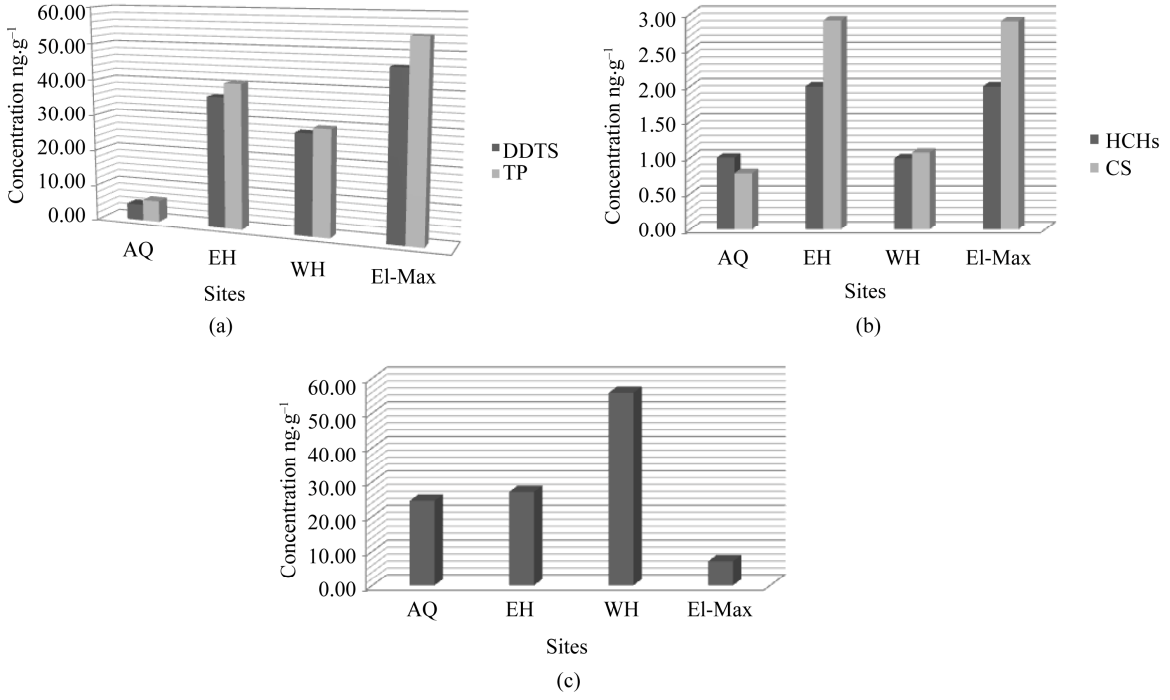

Figure 2. Distribution of organochlorine pesticides in the area of investigation. AQ: Abu-Qir; EH: Eastern Harbour; WH: Western Harbour; El-Max. (a) DDTs and total pesticides, TP; (b) HCHs and cyclodienes, Cs; (c) PCBs.

Table 3. Comparison between PCBs and organochlorine pesticide concentrations (ng·g^{-1}) in sediments of the present study with that recorded in previous work.

Location	Year	HCHs	Aldrin	Dieldrin	DDTs	PCBs	References
Abu-Qir Bay, Egypt	2010	<DL-1.61	<DL-2.70	<DL-0.14	<DL-15.86	0.83 - 99.80	Present study
Eastern Harbour, Egypt	2010	<DL-0.93	<DL-8.04	<DL-5.72	<DL-86.81	<DL-90.25	Present study
Western Harbour, Egypt	2010	<DL-1.57	<DL-3.79	<DL-1.36	<DL-62.80	<DL-194.24	Present study
El-Max bay, Egypt	2010	<DL-20.78	<DL-1.12	<DL-1.35	<DL-123.76	<DL-22.02	Present study
Abu Qir Bay, Egypt	2006	<DL-34.5	<DL-9.32	<DL-19.2	<DL-128	<DL-22.2	[19]
Eastern Harbour, Egypt	2007	0.49-23.38	0.38 - 5.07	<DL-1.23	1.28 - 15.74	3.32 - 48.35	[20]
Eastern Harbour, Egypt	2005	3.8 - 16.2	NA	NA	0.5 - 9.6	NA	[21]
El-Max Bay, Egypt	1989	16 - 82	13 - 72	<0.1-5	32.3 - 78	68 - 164[a]	[22]
Western coast of Alexandria, Egypt	2005	<DL-2.25	0.04 - 7.9	0.001 - 0.14	0.02 - 3.19	0.79 - 64.9	[23]
Alexandria Harbour, Egypt	1998	0.25 - 6	<DL-4.6	<DL-3.1	<0.25 - 885	0.9 - 1210	[24]
Lake Burullus, Egypt	2006	1.19 - 134.99	0.65 - 30.59	<DL-39.99	1.95 - 17.39	4.60 - 143.67	[25]
Lake Mariut, Egypt	1998	52.8 - 143[b]	NA	NA	318 - 982[c]	NA	[26]
Nile Delta, Egypt	NA	NA	0.1 - 59	NA	NA	NA	[27]
Mediterranean Sea sediments	NA	NA	NA	NA	0.003 - 75600	0.03 - 3938	[28]
San Francisco Bay-Delta Estuary	1992	NA	NA	NA	0.1 - 8.8	NA	[29]
Casco Bay, Maine, USA	1991	<DL-0.48	NA	NA	<0.2-20	0.4 - 485	[30]
Northwest Basin, Mediterranean Sea	1990	NA	NA	NA	1.2 - 5.8	1.4 - 5.8	[31]
Barcelona Offshore, Spain	1990	NA	NA	NA	4.9 - 79.0	4.0 - 64	[31]
Rhone Prodelta, France	1990	38 - 230	73 - 704	NA	NA	NA	[31]
Western Baltic Sea	1993	<DL-1.0	NA	NA	<DL-9.0	<DL-11.4	[32]
San Francisco Bay, California, USA	1993	NA	NA	NA	11 - 30212	NA	[33]
Arabian Sea, West Coast of India	NA	0.85 - 7.87	0.1 - 0.27	0.7 - 3.33	1.5 - 25.2	NA	[34]
Ho Chi Minh City´s Canals, Vietnam	1996	NA	NA	NA	1.8 - 254	<DL-123	[35]
Da-han River, Taiwan	1998	<DL-2.5	<DL-5.8	<DL-0.56	<DL-3.89	NA	[36]
Tonghui River, Beijing, China	2002	0.06 - 0.38	<DL-0.08	<DL-8.83	0.11 - 3.78	0.78 - 8.47	[37]
Amur Bay, Russia	2001	0.2 - 0.8	NA	NA	1.7 - 16.3	NA	[38]
Danube Delta, Romania	2001	0.9 - 6.8	NA	NA	0.9 - 17	<DL	[39]
Ariake Bay, Japan	2005	0.78 - 1.5	0.38 - 0.4	<DL-0.01	1.0 - 1.5	NA	[40]
Hanoi, Vietnam	2006	0.2 - 36	NA	NA	4.4 - 1100	1.3 - 384	[16]
Haihe River, China	2007	0.997 - 1620	NA	NA	<DL-155	<DL-253	[15]
Lower Mekong River Basin	2008	NA	NA	NA	0.027 - 52	0.18 - 310	[17]

<DL: below detection limit; PCB: sum of PCBs congener numbers; HCHs: sum of alpha, beta and gama-HCH; DDTs: sum of DDT, DDE DDD; NA: not available.

tected concentrations of organochlorine pesticides (Aldrin, and Dieldrin) in sediments were generally slightly higher compared to concentrations observed in other parts of the world (**Table 3**).

No significant correlation between total pesticides and total organic carbon (TOC) for sediment samples (**Figure 3(a)**). But it was detected a significant positive correlation between PCBs and TOC for sediment samples where $r = 0.31$ at $P > 0.01$ (**Figure 3(b)**); this is due to low solubility of PCBs in water, so precipitate until reach to the bottom water and contaminate with sediment.

For comparison, the data given by GC-ECD was qualitatively confirmed by GC-MS. 25% from all samples in different areas (Abu-Qir Bay, Eastern Harbour, Western Harbour, and El-Max Bay) were randomly selected. Good results were obtained by coinciding between both techniques. The identification of different detected compounds was more pronounced using GC-ECD more than that obtained by GC-MS. This is due to the selectivity of ECD detector for chlorinated hydrocarbons.

Hazard Levels

The maximum permissible levels of organochlorine pol-

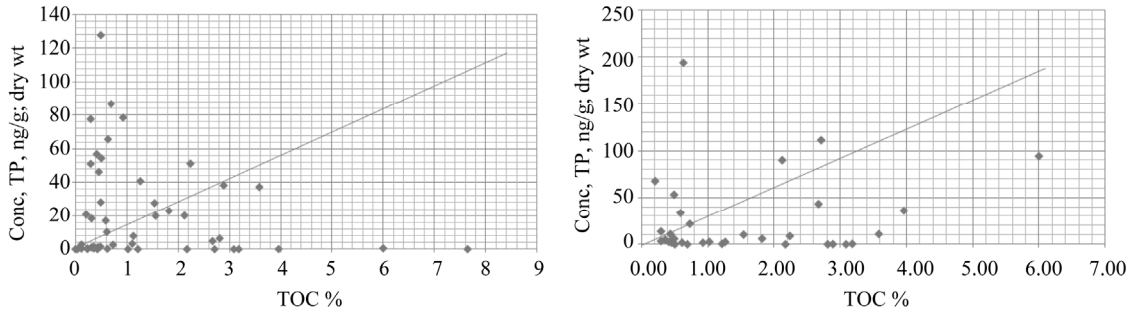

Figure 3. Effect of TOC% on TP and PCBs of the studied sediment samples: (a) Concentration of TP concentration ($ng \cdot g^{-1}$; dry wt) vs %TOC; (b) Concentration of PCBs ($ng \cdot g^{-1}$; dry wt) vs %TOC of sediments collected from the studied sediments.

lutants recommended by the National Academy of Sciences and National Academy of Engineering (NAS-NAE, 1972) [41] are 1000 - 5000 $ng \cdot g^{-1}$ for PCBs and 100 $ng \cdot g^{-1}$ for cyclodienes (wet wt). The recommended levels by Swedish Food Regulation are 5000 $ng \cdot g^{-1}$ for DDTs, 2000 $ng \cdot g^{-1}$ for PCBs and 200 $ng \cdot g^{-1}$ for HCB (SFR, 1983) [42]. The US Food and Drug Administration (FDA) tolerance limit of 2000 $ng \cdot g^{-1}$ wet wt for total PCBs in fish and shellfish. Our results clearly indicate that PCBs concentrations (ND to 192.24 $ng \cdot g^{-1}$; wet wt), DDTs (ND and 123.76 $ng \cdot g^{-1}$ (dry wt), cyclodienes (ND to 8.04 $ng \cdot g^{-1}$ dry wt), HCHs (ND to 20.78 $ng \cdot g^{-1}$ dry wt) recorded in this study were much lower than that recorded as permissible levels.

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