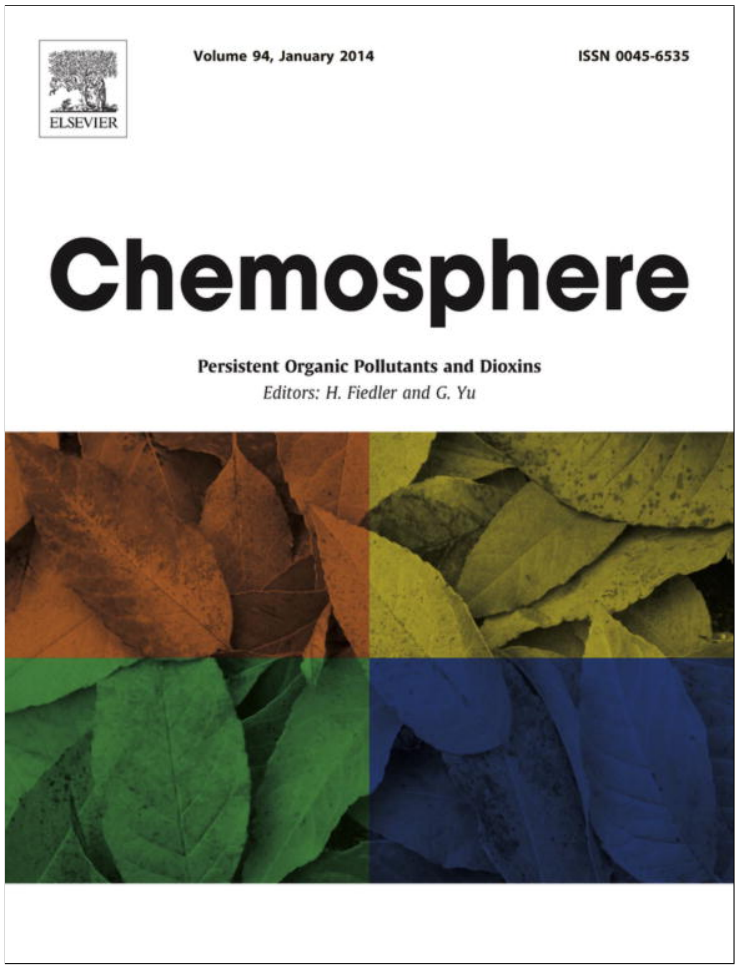

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Organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) in sediments from the Gulf of Batabanó, Cuba

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HIGHLIGHTS

- The first study on POPs in sediments from Gulf of Batabano (CUBA) was performed.
- Levels of DDTs, Lindane, HCB, Heptachlor, Aldrin, Mirex and PCBs were measured.
- The POPs concentrations indicated low contamination of the surface sediments.
- The Gulf of Batabano can be considered like a pristine environment.
- The levels of POPs found not have an adverse effect on sediment dwelling organisms.

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ABSTRACT

The spatial distribution of various organochlorinated compounds, e.g. PCBs, DDTs, HCB and HCHs, were investigated in sediments of the Gulf of Batabanó, Cuba. Among the target organochlorine compounds measured, ΣDDT isomers were the predominant contaminant with concentrations ranging from 0.019 to 1.27 ng g^{-1} dry wt. Lindane was present at very low concentrations in the range n.d. to 0.05 ng g^{-1}, while PCBs and other organochlorine pesticide residues, such as HCB, Heptaclor, Aldrin and Mirex were lower than detection limits (~0.010 ng g^{-1}). According to established sediment quality guidelines, the OCPs concentrations encountered in the surface sediments are probably not having an adverse effect on sediment dwelling organisms. Compared to concentrations reported in coastal environments from other parts of the world, PCBs and OCs concentrations in surface sediments of Batabanó Gulf were low and similar to the reported for remote and pristine environments. These results contribute to the sparse regional database for organochlorinated compounds in the Caribbean marine environment.

1. Introduction

Persistent organic pollutants (POPs) such as organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) are ubiquitous contaminants in different compartments of the environments (Carvalho et al., 2002; Dietz et al., 2000; Leoni et al., 1995; Nhan et al., 1999; Sbriz et al., 1998; Villeneuve et al., 1999). In spite of numerous countries having withdrawn the registered usage of POPs for many years, these man-made chemicals still persist at considerable levels worldwide. These compounds are generally generated by anthropogenic processes and can be introduced into the environment through various routes. Due to their toxic, mutagenic, and carcinogenic characteristics, these persistent compounds are considered to be hazardous to the biota and environment (Gómez-Gutiérrez et al., 2007). Also, these compounds are strongly absorbed onto the surface of particles associated with the organic content of solid-phase matrix and can be deposited to the underlying sediments. Therefore, the investigation of POPs concentrations in aquatic environments is needed to provide important information on anthropogenic impact on the environment and serve as an indicator of contaminant loading (Hong et al., 2008; Zhao et al., 2010).

In Cuba, the use of pesticides has been reduced following the decline of farming activities over several decades. Since 1990, the use and importation of all pesticides included in the Stockholm Convention were prohibited. However, from the national inventory of polychlorinated biphenyls (PCBs) and chlorinated pesticides in disuse, there are in Cuba about 120 tons of dielectric fluid contaminated with PCBs and 9 tons of obsolete pesticides, principally: DDT, Heptachlor, and toxaphene (Abo-Balanza, 2005).

Nowadays, there is scarce information on the status of OCPs in many Caribbean coastal areas (Fernandez et al., 2007). For Cuba,

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some data is only available from the pesticide contamination in soils from the most agro-developed province of Cuba (Dierksmeier, 1996) and few data exist from the International Mussel Watch (Sericano et al., 1995). Recently, Tolosa et al. (2010) published the spatial distribution of various organochlorinated compounds in sediments from Cienfuegos bay. The concentrations reported appeared to be relatively low by global standards and only sediments receiving the impact from the residual waters of the city and thermo-electrical power approached the sediment quality guidelines for DDTs. Relatively higher ∑DDT concentrations and high DDT/(DDE + DDD) ratios in two sites near the outfalls of the city indicated a current DDT usage, probably linked to public health emergencies.

The Gulf of Batabanó is a large semi-enclosed water body in southern Cuba. Its approximate surface is 20 850 km^2 with an average depth of 6 m. The coastal area is predominantly fringed by mangrove forests and the bottom is extensively covered by grass-beds with varying densities of *Thalassia testudinum*. Living coral reefs are found all along the shelf and generate many associated islets called 'cayos'. Biological studies have shown signs of environmental degradation in the Gulf, through loss of biodiversity, shift of benthic communities (Baisre et al., 2003; Cruz et al., 2001; Hernandez-Zanuy and Carballa, 2001) and reduction in size and capture levels of the spiny lobster *Panulirus argus* (Borrell et al., 2004; Puga et al., 1996). *Panulirus argus* is the most valuable species in the fishing industry in Cuba and accounts for approximately 15% of the total near-shore catches. The Gulf of Batabanó is one of the main four fishing areas in the island, providing 63% of the total lobster catches (Baisre et al., 2003).

In terms of inorganic pollution (heavy meals and radioactivity) the gulf environment is considered like a pristine area (Alonso-Hernandez et al., 2011). However, limited information is available on organic contamination produced by anthropogenic activities. In particular, little is known on pollution originated by the use of OCPs in the agricultural practices (rice and tobacco) present in the southern part of the La Havana and Pinar del Rio provinces.

In consideration of the above, the present study measures polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) in sediments to ascertain the contamination status in the Gulf of Batabanó. In addition, a comparison of our results with those from other locations and sediment quality guidelines are included to evaluate the relative significance of the contamination.

2. Methods and materials

2.1. Sampling

Sixteen surface sediment samples were collected with a stainless steel grab in May 2005. Details of the samples sites are shown in Fig. 1 and Table 1. Approximately 2 cm of the top sediments were taken by a stainless steel spoon and stored in glass jar. Samples were cool transported to the laboratory where they were immediately stored in a freezer. Sediment were freeze-dried, hand-sieved (250 μm) and homogenized.

2.2. Chemical analysis

All analysis were carried out in the Marine Environmental Studies Laboratory at Environment Laboratory-IAEA, Monaco. The extraction and clean up of the OCPs and PCB were similar to those previously described by Tolosa et al. (2010).

Approximately 8 g portion of each sediment was spiked with internal standards (PCBs 29 and 198 for the first fraction and

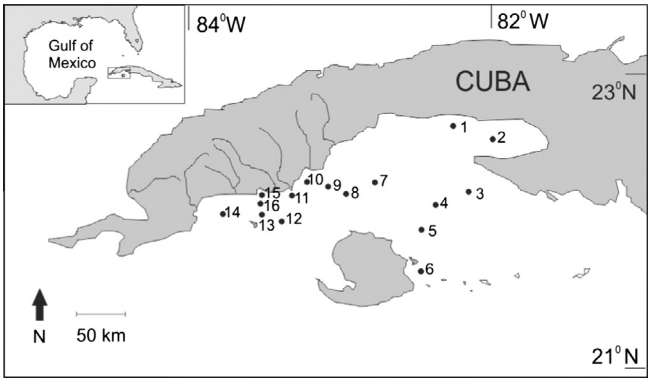

Fig. 1. Study area in the Gulf of Batabanó, Cuba. The inset shows the regional location of the study site. Sampling stations are indicated with black circles.

ε-HCH for the second fraction), and extracted with a hexane: methylene chloride mixture (50/50, v/v) in a microwave at 1200 W and 115 °C for 20 min. Sulfur was removed with activated copper and two fractions were obtained from silica/alumina columns, as described in Tolosa et al. (2010). PCBs, HCB, p,p′-DDE, Aldrin, Heptachlor and Mirex were eluted with 20 ml hexane followed by 20 ml hexane/methylene chloride (90:10). The p,p′-DDD, p,p′-DDT, and γ-HCH (Lindane) were eluted in a second fraction with 40 ml hexane/methylene chloride (80:20). The compounds were determined by HRGC with a ^{63}Ni electron capture detector (HRGC/ECD) on a Hewlett–Packard 6890HP equipped with a split/splitless injector, and an automatic liquid sampler (Hewlett–Packard, Palo Alto, USA). For all the analyses, a fused-silica capillary column HP-5 (30 m, 0.25 mm i.d. and film thickness 0.25 μm) was used. GC parameters were: injector temperature 250 °C; detector temperature 300 °C; helium at a flow rate of 1 ml min1 was used as carrier gas. The GC oven was temperature programmed from 70 °C (2 min isothermal) to 260 °C (at 3 °C min^{-1}) and held isothermally at 260 °C for 20 min.

The quantified analytes were: 25 polychlorinated biphenyl congeners (8, 18, 28, 44, 50, 52, 66, 87, 101, 104, 105, 118, 126, 128, 138, 153, 154, 170, 180, 187, 188, 194, 195, 201, 206), hexachlorobenzene (HCB); the DDT group (p,p′-DDT, p,p′-DDE, P,p′-DDT), γ-HCH, Aldrin, Heptachlor and mirex. The individual PCB congeners were determined by using individual standard congeners. The 25 selected congeners of PCBs are among the major 18 congeners of the NOAA NST list, which provides at least one representative congener from every homolog group. Total PCB estimates were derived from the sum of the 26 congeners analyzed, including the adjustment factor of 2 used by NOAA (Howell et al., 2008).

2.3. Quality control

All data were subject to strict quality assurance and control procedures. For each set of 7 samples, procedural blank and certified reference sediment (IAEA-408, International Atomic Energy Agency) were used to determine the accuracy. The concentration values of the target compounds always fell within the 95% confidence interval of the assigned reference value for concentrations of the analytes (Villeneuve et al., 2000).

The spiked recoveries for PCBs 29 and 198, in the surface sediments ranged from 56% to 80.9% and 61% to 83.9%, respectively.

The precision of the measurements obtained through replicates of the reference materials was better than 10% for all target compounds. The detection limit for each individual compound ranged between 10 and 30 pg g^{-1}.

Table 1
Sampling sites from the Gulf of Batabanó.

Station	Location	Water depth (m)	Remark on sediments
1	22°36.980 N, 82°13.020 W	5	Silty, no vegetation
2	22°34.390 N, 82°03.420 W	7	Silty, no vegetation
3	22°13.900 N, 82°13.730 W	5	Sandy, seagrass vegetation
4	22°06.000 N, 82°25.980 W	5	Sandy, seagrass vegetation
5	22°53.910 N, 82°27.925 W	7	Sandy, seagrass vegetation
6	21°41.420 N, 82°28.305 W	3	Close to mangroves, sulfide smell
7	22°12.450 N, 82°48.646 W	5	Sandy, seagrass vegetation
8	22°11.969 N, 83°01.806 W	7	Sandy, seagrass vegetation
9	22°15.299 N, 83°10.134 W	8	Silty, scarce vegetation
10	22°16.479 N, 83°15.951 W	3	Silty, no vegetation, sulfide smell
11	22°07.884 N, 83°22.313 W	8	Silty, no vegetation
12	22°04.593 N, 83°24.023 W	12	Silty, no vegetation, sulfide smell
13	22°06.530 N, 83°35.760 W	8	Silty, no vegetation, sulfide smell
14	22°09.360 N, 83°40.390 W	6	Silty, no vegetation, sulfide smell
15	22°10.920 N, 83°36.950 W	3	Silty, no vegetation, sulfide smell
16	22°13.399 N, 83°34.694 W	3	Silty, no vegetation, sulfide smell

3. Results and discussion

3.1. PCBs

The concentration of PCB congeners in superficial sediments from the Gulf of Batabanó are presented in Table 2. All the target congeners (8, 18, 28, 44, 50, 52, 66, 87, 101, 104, 105, 118, 126, 128, 138, 153, 154, 170, 180, 187, 188, 194, 195, 201 and 206) were below the detection limits.

The concentration of ΣPCB_{26} in sediments of the Gulf of Batabanó was calculated assuming that concentrations of non-detected contaminants are equal to one half of the detection limit. Therefore, the estimated concentration of ΣPCB_{26} in surface sediments of the Gulf of Batabanó were in the range of 0.11–0.28 ng g^{-1} dry wt., with a mean of 0.19 ng g^{-1} dry wt. The estimated concentration of ΣPCB_{total}, calculated as the sum of 26 congeners multiplied by a standard factor of two (Howell et al., 2008), ranging between 0.22 and 0.56 ng g^{-1} dry wt.

Sovol formulation, which is fairly close in composition to Aroclor 1254, and various mixtures of Sovol and trichlorobenzenes distributed under the common name Sovtol (Ivanov and Sandell, 1992) were the major commercial mixtures produced in the former Soviet Union and exported to Cuba before the Soviet bloc collapsed in 1991. The potential sources of PCBs in the Cuban coastal waters are due in part to equipment/utilities still in use (e.g. old transformers and capacitors), waste incineration, accidental fires and atmospheric deposition. Once released into the water column, and due to their hydrophobic nature and high partition coefficients, PCBs tend to adsorb to the suspended particulate matter of the water column and accumulate in sediments.

All single congeners analyzed in this study were found to be below the detection limit of 0.019 ng g^{-1} dry wt. and consequently no geographical trends could be derived.

No previous data of PCBs in sediments of the Gulf of Batabanó have been reported. However, the obtained values in this study are much lower than those reported from Cienfuegos bay (1.9–16 ng g^{-1} dry wt.: Tolosa et al., 2010), being similar to the reported for remote and pristine environments; such as Alaska: 0.04–0.8 ng g^{-1}, Norway: <0.1–0.5 ng g^{-1}, Finland: 0.1–1.3 ng g^{-1} and Russia: 0.03–3 ng g^{-1} (Cleemann et al., 2000).

Table 2
Concentration (ng g^{-1} dry wt.) of 26 PCB congeners in surface sediments in the Gulf of Batabanó.

PCB	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16
8	<0.048	<0.039	<0.036	<0.023	<0.030	<0.032	<0.032	<0.025	<0.039	<0.055	<0.033	<0.035	<0.046	<0.056	<0.032	<0.048
18	<0.042	<0.034	<0.032	<0.020	<0.026	<0.029	<0.028	<0.022	<0.034	<0.049	<0.029	<0.031	<0.040	<0.049	<0.028	<0.042
28	<0.022	<0.019	<0.017	<0.011	<0.014	<0.015	<0.015	<0.011	<0.019	<0.026	<0.016	<0.016	<0.021	<0.026	<0.015	<0.022
44	<0.021	<0.018	<0.016	<0.010	<0.014	<0.015	<0.014	<0.011	<0.018	<0.025	<0.015	<0.016	<0.020	<0.025	<0.014	<0.021
50	<0.025	<0.020	<0.018	<0.012	<0.015	<0.016	<0.016	<0.013	<0.020	<0.028	<0.017	<0.018	<0.024	<0.029	<0.017	<0.025
52	<0.029	<0.024	<0.022	<0.014	<0.018	<0.020	<0.019	<0.015	<0.024	<0.034	<0.020	<0.021	<0.027	<0.033	<0.019	<0.029
66	<0.018	<0.015	<0.014	<0.009	<0.012	<0.012	<0.012	<0.009	<0.015	<0.021	<0.013	<0.013	<0.017	<0.021	<0.012	<0.018
87	<0.015	<0.012	<0.011	<0.007	<0.009	<0.010	<0.010	<0.008	<0.012	<0.017	<0.010	<0.011	<0.014	<0.017	<0.010	<0.015
101	<0.021	<0.018	<0.016	<0.010	<0.013	<0.015	<0.014	<0.011	<0.018	<0.025	<0.015	<0.015	<0.020	<0.024	<0.014	<0.021
104	<0.028	<0.023	<0.021	<0.013	<0.018	<0.019	<0.019	<0.014	<0.023	<0.033	<0.020	<0.020	<0.027	<0.032	<0.018	<0.028
105	<0.014	<0.011	<0.010	<0.007	<0.009	<0.009	<0.009	<0.007	<0.011	<0.016	<0.010	<0.010	<0.013	<0.016	<0.009	<0.014
118	<0.017	<0.014	<0.013	<0.008	<0.011	<0.012	<0.012	<0.009	<0.014	<0.020	<0.012	<0.013	<0.017	<0.020	<0.012	<0.018
126	<0.021	<0.017	<0.016	<0.010	<0.013	<0.014	<0.014	<0.011	<0.017	<0.025	<0.015	<0.016	<0.020	<0.025	<0.014	<0.021
128	<0.013	<0.011	<0.010	<0.006	<0.009	<0.009	<0.009	<0.007	<0.011	<0.016	<0.009	<0.010	<0.013	<0.016	<0.009	<0.013
138	<0.015	<0.013	<0.012	<0.007	<0.010	<0.010	<0.010	<0.008	<0.013	<0.018	<0.011	<0.011	<0.015	<0.018	<0.010	<0.015
153	<0.018	<0.015	<0.014	<0.009	<0.011	<0.012	<0.012	<0.009	<0.015	<0.021	<0.013	<0.013	<0.017	<0.021	<0.012	<0.018
154	<0.012	<0.010	<0.010	<0.006	<0.008	<0.009	<0.008	<0.007	<0.010	<0.015	<0.009	<0.009	<0.012	<0.015	<0.008	<0.013
170	<0.013	<0.011	<0.010	<0.006	<0.008	<0.009	<0.009	<0.007	<0.011	<0.015	<0.009	<0.010	<0.013	<0.015	<0.009	<0.013
180	<0.013	<0.011	<0.010	<0.006	<0.008	<0.009	<0.009	<0.007	<0.011	<0.015	<0.009	<0.010	<0.012	<0.015	<0.009	<0.013
187	<0.015	<0.013	<0.012	<0.007	<0.010	<0.011	<0.010	<0.008	<0.013	<0.018	<0.011	<0.011	<0.015	<0.018	<0.010	<0.016
188	<0.019	<0.015	<0.014	<0.009	<0.012	<0.013	<0.013	<0.010	<0.015	<0.022	<0.013	<0.014	<0.018	<0.022	<0.012	<0.019
194	<0.013	<0.010	<0.010	<0.006	<0.008	<0.009	<0.008	<0.007	<0.010	<0.015	<0.009	<0.009	<0.012	<0.015	<0.008	<0.013
195	<0.013	<0.010	<0.010	<0.006	<0.008	<0.009	<0.008	<0.007	<0.010	<0.015	<0.009	<0.009	<0.012	<0.015	<0.008	<0.013
201	<0.016	<0.013	<0.012	<0.008	<0.010	<0.011	<0.011	<0.008	<0.013	<0.019	<0.011	<0.012	<0.015	<0.019	<0.011	<0.016
206	<0.014	<0.011	<0.011	<0.007	<0.009	<0.009	<0.009	<0.007	<0.011	<0.016	<0.010	<0.010	<0.013	<0.016	<0.009	<0.014
ΣPCB[a]	0.24	0.20	0.18	0.12	0.15	0.16	0.16	0.13	0.20	0.28	0.17	0.18	0.23	0.28	0.16	0.24

[a] Concentration of sum 26 PCB congeners is calculated assuming that concentrations of not-detected contaminants are equal to one half of detention limit.

3.2. OCPs

Table 3 presents the concentrations of organochlorine pesticides (hexachlorobenzene (HCB); the DDT group: p,p′-DDT, p,p′-DDE, P,p′-DDT, γ-HCH, Aldrin, Heptachlor and mirex) found in surface sediments of the Gulf of Batabanó.

The OCPs concentrations were higher or detected in the area near shore the coast, predominantly in the estuary of Coloma's river, while that for far stations the organochlorine compounds were low or nor detected, particularly for stations: S1, S2, S3, S4, S5 and S6.

Concentrations of p,p′-DDT in the sediments of the Gulf of Batabanó were detected only in 19% of the samples analyzed and varied from <0.013 to 0.74 ng g^{-1} dry wt. The highest values were measured at estuarine zone of Coloma river in SS-16 (0.74 ng g^{-1} dry wt.), SS-14 (0.13 ng g^{-1} dry wt.) and SS-15 (0.10 ng g^{-1} dry wt.). The p,p′-DDE and p,p′-DDD concentrations were detected in 31% and 44% of the samples analyzed, respectively. The levels ranged from <0.006 to 0.15 ng g^{-1} dry wt. for DDE and <0.006 to 0.38 ng g^{-1} dry wt. for DDD. The highest levels for both isomers were also detected in the station SS-16.

The ΣDDTs, calculated assuming that concentrations of not-detected contaminants are equal to one half of detection limit, varied from 0.019 to 1.27 ng g^{-1} dry wt. Fig. 2 shows the spatial distribution of ΣDDTs in the surface sediments from all sampling sites. The maximum values of ΣDDTs were measured at estuarine zone of the Coloma. These results indicated that the effluents of the Coloma river are the principal source of DDT in the area. Analogous conclusions were reported by Alonso-Hernandez et al. (2011) for heavy metal pollutions, particularly for the arsenic.

DDT was used in Cuba since 1950 on a variety of agricultural crops and for the control of human disease vectors. The largest agricultural use of DDT has been on the rice production before its ban in 1989.

Compositional differences in DDT congener profiles in the environment could indicate different sources of contamination. Technical DDT generally contains 75% p,p′-DDT, 15% o,p′-DDT, 5% p,p′-DDE and <5% p,p′-DDD. The average composition of DDT isomers measured in sediment samples was p,p′-DDE(60%) > p,p′-DDD (24%) > p,p′-DDT (17%). It can be seen from Fig. 3 that p,p′-DDE and p,p′-DDD was dominant at most sampling sites, with exception to the SS-15 and SS-16 stations. The pesticide p,p′-DDT gradually degrades to p,p′-DDE and p,p′-DDD through biological and photochemical transformations under both aerobic and anaerobic conditions (Guenzi and Beard, 1976; Purnomo et al., 2008; Thomas et al., 2008; Yao et al., 2006), so it can be inferred from the high percentage of p,p′-DDE that the DDTs input was historical. According to previous studies, a ratio of (DDE + DDD)/ΣDDT > 0.5 is assumed as being due to long term weathering (Jiang et al., 2009; Li et al., 2006). Here a ratio of (DDE + DDD)/ΣDDT > 0.5 were found in all sites (see Table 3), which infers that DDT input at Gulf of Batabanó was historical and significant degradation has occurred.

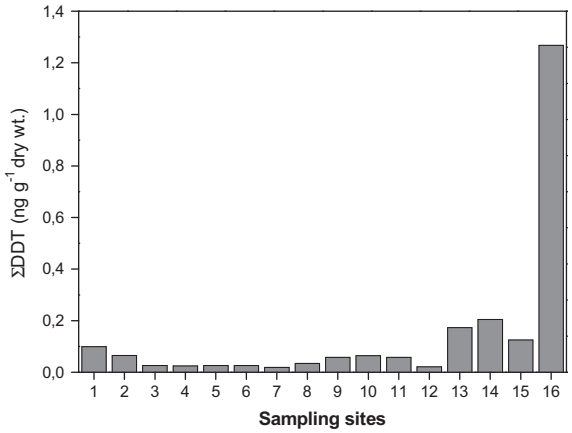

Fig. 2. Spatial distributions of ΣDDT in the surface sediments from the Gulf of Batabanó.

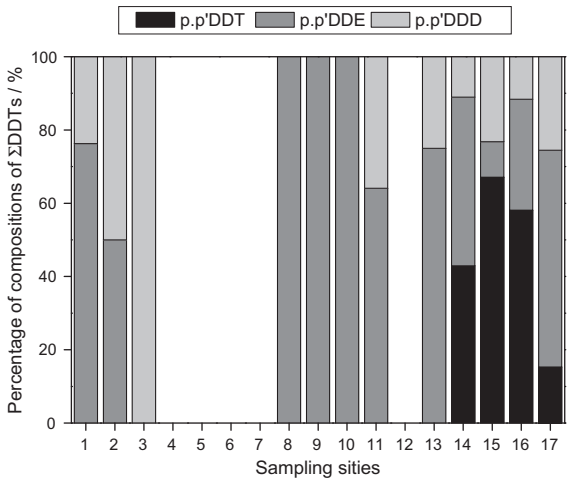

Fig. 3. Percentage of p,p′-DDT, p,p′-DDE and p,p′-DDD in sediments from the Gulf of Batabanó.

Reported soil concentrations of ΣDDT in the most agro-developed and pesticide-consuming province of Cuba averaged 200 ng g^{-1} within the period 1976–1983 (Dierksmeier, 1996) and ranged from 4.6 to 61 ng g^{-1} in the southwestern Cuban coast during the period of 1992–2001 (Dierksmeier, 2002). Overall, concentrations of total DDT measured in Gulf of Batabanó were lower than those reported in other coastal sediments in Cuba, such as Cienfuegos Bay (0.2–12.7 ng g^{-1}: (Tolosa et al., 2010). However, the obtained concentrations compare to those reported for remote

Table 3
Concentration (ng g^{-1} dry wt.) of organochlorine pesticide residues in surface sediments in the Gulf of Batabanó.

OCPs	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16
HCB	<0.008	<0.007	<0.006	<0.004	<0.004	<0.005	<0.005	<0.004	<0.007	<0.009	<0.006	<0.006	<0.008	<0.009	<0.005	<0.008
Heptachlor	<0.011	<0.009	<0.009	<0.005	<0.007	<0.008	<0.007	<0.006	<0.009	<0.013	<0.008	<0.008	<0.011	<0.013	<0.007	<0.011
Aldrin	<0.010	<0.008	<0.008	<0.005	<0.006	<0.007	<0.007	<0.005	<0.008	<0.012	<0.007	<0.008	<0.010	<0.012	<0.007	<0.010
Mirex	<0.005	<0.005	<0.004	<0.003	<0.003	<0.004	<0.004	<0.003	<0.004	<0.006	<0.004	<0.004	<0.005	<0.006	<0.004	<0.005
Lindane	<0.011	<0.009	<0.008	<0.008	0.010	0.013	0.011	<0.008	0.025	<0.008	0.010	0.031	0.016	0.050	<0.007	<0.008
p,p′-DDD	0.019	0.025	0.014	<0.013	<0.014	<0.014	<0.010	<0.013	<0.014	<0.013	0.014	<0.013	0.039	0.036	<0.012	0.147
p,p′-DDT	<0.038	<0.030	<0.028	<0.029	<0.031	<0.031	<0.021	<0.028	<0.031	<0.029	<0.026	<0.029	<0.035	0.140	0.104	0.737
p,p′-DDE	0.061	0.025	<0.009	<0.006	<0.007	<0.008	<0.008	0.013	0.035	0.043	0.025	<0.009	0.117	0.150	0.015	0.384
ΣDDTs[a]	0.099	0.065	0.026	0.024	0.026	0.026	0.019	0.034	0.058	0.064	0.058	0.021	0.173	0.205	0.125	1.268

[a] Concentration of ΣDDTs is calculated assuming that concentrations of not-detected contaminants are equal to one half of detention limit.

and pristine environments, such as Gulf of Alaska, Kara sea (Iwata et al., 1994); (Sericano et al., 2001), Norwegian Artic (Jiao et al., 2009) and deep Mediterranean sea (Tolosa et al., 1995).

Lindane (γ-HCH) was only detected in 50% of sediment samples (Table 3) with values ranging from <0.008–0.050 ng g^{-1}. Maximum values were found in site SS-14, near at estuarine zone of Coloma river. These levels are low and compare with those in surface sediment samples from the Chukchi Sea, Bering Sea and the Gulf of Alaska from 0.04 to 0.21 ng g^{-1} (Iwata et al., 1994).

Other organochlorine pesticide residues, such as HCB, Heptachlor, Aldrin and Mirex (Table 3) were lower than their detection limits (~<10 ng g^{-1} dry wt).

3.3. Ecotoxicological concern

To evaluate the ecotoxicological aspect of sediment contamination the obtained data in this study were compared (Fig. 4) with US-EPA/NOAA (Long et al., 1995) for marine sediments. Similar assessments have been made recently by several authors in other coastal areas (Hong et al., 2008; Zhao et al., 2010). The NOAA guideline specifies the effects range low (ERL) and probable effect levels (PEL). The ERL represents the chemical concentration below which an adverse effect would rarely be observed, while the PEL represents the concentration above which adverse effects are probable.

According to this guideline, the PCBs and OCPs concentrations encountered in the surface sediments are probably not having an adverse effect on sediment dwelling organisms.

Compared to concentrations reported in coastal environments from other parts of the world, PCB and OCs concentrations in surface sediments from the Gulf of Batabanó were similar to those reported for remote and pristine environments, such as Gulf of Alaska, Kara sea (Sericano et al., 2001), Norwegian Arctic (Jiao et al., 2009) and deep Mediterranean sea (Tolosa et al., 1995).

In summary, the contamination of sediments in the Gulf of Batabanó by PCBs, DDTs and other chlorinated pesticides appeared to be low by global standards and the area can be considered like a pristine zone. The present data provides a baseline to develop, target, and assess the effectiveness of environmental management activities against eventually future anthropogenic pollution of POPs.

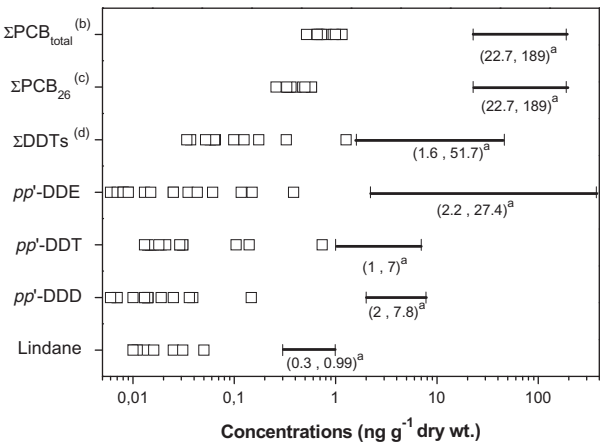

Fig. 4. POPs concentration in the superficial sediments from the Gulf of Batabanó (□) in comparison to with the ERL and PEL. (ERL, PEL)[a]: effects range low and probable effect levels were suggested by Long et al. (1995) (NOAA). [b]ΣPCB_{Total}: estimated derived from the summed 26 congeners multiplied by a standard factor of two (Howell et al., 2008). [c]ΣPCB_{26}: sum of concentrations of 26 congeners (8, 10, 28, 44, 50, 66, 87, 101, 104, 105, 118, 126, 128, 138, 153, 154, 170, 180, 187, 188, 194, 195, 201, 206), calculated assuming that concentration of non-detected contaminants are equal to one half of the detection limit. [d]ΣDDTs: sum of concentration of p,p′-DDD, p,p′-DDT, p,p′-DDE.

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