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Persistent organochlorine contaminants(PCDD, PCDF, and PCB) in fishsamples: Sepetibabay, Rio de Janeiro, Brazil

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ABSTRACT

Polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and polychlorinated biphenyls (PCBs) concentrations were determined in three species of edible fish from Sepetiba bay, Rio de Janeiro, Brazil: silver scabbardfish (Lepidopuscaudatus), Whitemouth croaker (Micropogoniasfurnieri), and mullets (Mugilliza), which were collected in July 2012. PCDD/Fs and PCBs were determined by high-resolution mass spectrometer (HRGC/HRMS) according to the US EPA 1613B, 8290A, and US EPA 1668B methods. The concentration of total PCDDs/PCDFs ranged from 0.10105 ~ 0.2141 pg-WHO-TEQ/g ww and PCBs ranged from 0.08834 ~ 0.62304 pg-WHO-TEQ/g ww. Judging from the European Union regulation limit levels of PCDD/PCDFs and PCDD/PCDFs/PCBs were lower than the criteria in all samples. The main objective of the survey was to obtain information about existing levels of pollutants, having as a consequence the possibility of providing preventive actions and assessing risk; but, the results showed the dietary consumption of fish from Sepetiba region, did not represent a risk for human health.

Keywords*: Pollution, fish, organ chlorine contaminants, Sepetiba bay*

1. INTRODUCTION

Polychlorinated dibenzo-p-dioxin (PCDDs), polychlorinated dibenzo-p-furan (PCDFs), and polychlorinated biphenyls (PCBs) are a group of toxic and highly persistent organic compounds. Due to its chemical stability, their lipid solubility, and its ubiquitous prevalence in environmental, PCDDs/Fs and PCBs constitute which is called persistent organic pollutants (POPs)[1,2]. Human chronic exposure to those highly lipophilic and persistent compounds via food chain has led to the accumulation of both parent compounds and its metabolites in lipid rich tissues such as adipose tissues and human breast milk [3]. One possible exposure pathway by which humans and other upper trophic level species can be exposed to POPs is through consumption of dietary fish[4,5].

POPs are hazardous to the environment and human health. Due to their physical and chemical properties, particularly their high stability, POPs can accumulate in the tissues of humans and animals [6]. POPs consist of intentionally produced compounds such as pesticides or industrial chemicals, and unintended by-products of industrial processes [7].

Among the POPs, PCDD/Fs and PCBs constitute three groups of relevant persistent organic pollutants with chronic toxicity to humans and biota [2,8,9]. Due to their persistency, the distribution and recirculation in the environment often continues for a long period of time. They are chemically stable, have low solubility's in water, and have been shown to be accumulated in foodweb [10]. Those isomers with chlorines substituted in the 2,3,7,8 positions are thought to pose a risk to human health due to their toxicity, carcinogenic potency and potential effects on animal reproductive and immunological systems [11,12]. It has been reported recently that PCDD/F possesses the toxicity of endocrine disrupting [13].

There are 75 different PCDDs and 135 PCDFs, which differ from each other in the number and positions for the chlorine atoms [14]. From the human/biota point of view, 17 PCDD/Fs chlorine substitution in the (2,3,7,8-) positions are considered to be toxicologically important [9,15]. PCDDs have a planar aromatic tricyclic structure with 1-8 chlorine atoms as substituents (Figure 1).

There are 209 possible congeners of PCBs, but even the technical mixtures of PCBs have only a fraction of the total possible number. Some PCBs are called dioxin-like (co-planar/non-ortho-) PCBs. Those congeners do not have any or have only one chlorine atom (mono-ortho-PCBs) in the ortho-position to the carbon-carbon bond between the two benzene rings. Approximately 120 of PCBs are present in commercial products such as Aroclor 1254, Aroclor 1260 and Chlopen A60 [16]. Ballschmiterand Zell [17] proposed a simple numbering system of the PCB congeners, giving each congener a number from one to 209. PCBs have two benzene rings attached to each other, with 1-10 chlorine atoms as substituents (Figure 1).

Contaminants enter the sea from the air or by several waterways being deposited in the sediments, where they accumulate over time. In the aquatic food chain, poorly water-soluble dioxins are adsorbed on mineral and organic particles suspended in water, where they are subjected to bioconcentration in trophic chains [6,7].

Fish store chemical substances either directly from the surrounding environment or from their diet [18,19]. Humans are consumers of fish, and exposure

valuations now routinely consider fish ingestion as a potential route of human exposure to chemicals in the environment [4]. To evaluate the risk of dioxins exposure in the general population and to determine the time trends, regular testing of levels of these compounds in environmental food chain is very important for evaluating dioxins concentrations that pose a potential health hazard [20,21].The immediate objective of monitoring studies is to obtain information about the levels of contaminants and congener profiles actively identifying potential for reducing human exposure.

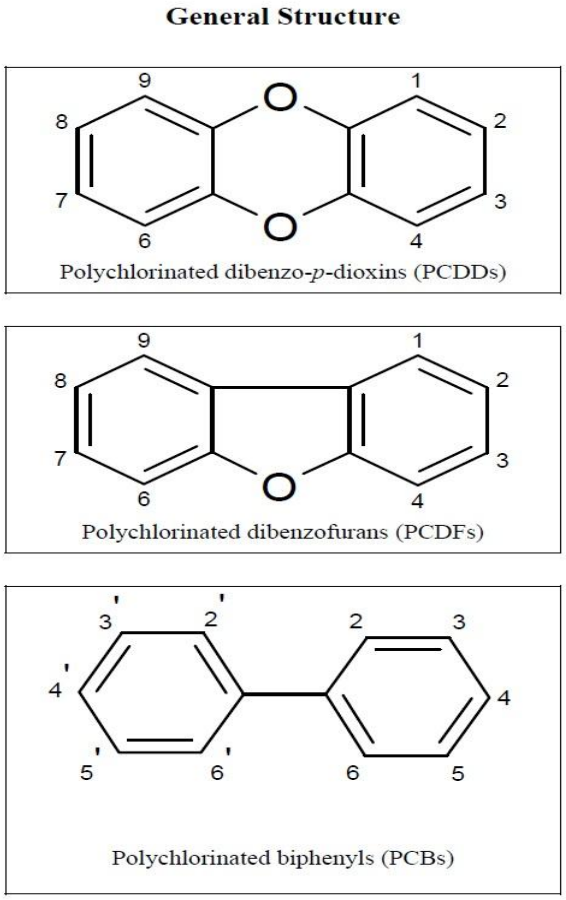

Fig 1: Chemical structures of PCDDs, PCDFs, and PCBs

The aim of this study was to determine the concentration levels of PCDD/Fs and PCBs in muscle and tissue samples of Lepidopuscaudatus (Euphrasen, 1788), Micropogoniasfurnieri (Desmarest, 1823), and Mugilliza (Valenciennes, 1836), collected in July 2012, from SepetibaBay, situated in the southern Atlantic Coast of Rio de Janeiro State, Brazil.

2. MATERIALS AND METHODS

2.1 Study Site

Sepetiba Bay is located in the State of Rio de Janeiro, Brazil, (22º 55' and 23º 05'S / 43º 40' and 44º 40'W) with a 520 km^2area housing a wide range of habitats including mangroves, sandbanks, and small estuarine areas (Figure 2). Depth overall is below 5 m, and waters are rich in organic nutrients from continental drainage; bottom is predominantly muddy. This region present its northern and eastern area limited by the continent, a sandbank vegetation on southern limit, and Ilha Grande Bay on the west. Its greatest length is 42.5 kilometers from east to west and its greatest width is 17.2 kilometers from north to south, with a perimeter of 122 km. The bay plays an important role in regional aquatic ecology, mainly for juvenile fishes that use the area as a rearing ground.

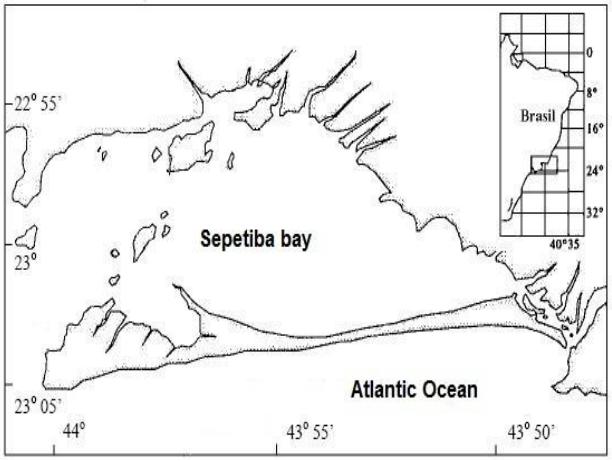

Fig 2: Study area: Sepetiba Bay, Rio de Janeiro, Brazil

2.2 Sampling

A total of 36 fishes (Lepidopuscaudatus, n= 10, Micropogoniasfurnieri, n=14, and Mugilliza, n=12) were caught from Sepetiba Bay in July 20121. Prior to analysis, each sample was categorized upon its sample number, fish species, length (cm), weight (g) and gender, which are presented in Table 1.The gender was determined macroscopically by gonad observation after dissection; gonad stage was determined according to Vazzoler[22]. The head, tail fin and viscera were removed from the fish, before analysis. The samples were sealed in polyethylene bags and stored at -20 ºC for subsequent analysis.

2.3 Analytical Procedures

PCDD/Fs and PCBs were determined by high-resolution mass spectrometer (HRGC/HRMS) according to the US EPA 1613B[23], 8290A[24], and US EPA 1668B [25]methods. 10 g of freeze-dried combined pooled tissue samples from each species were weighed and lyophilised. Dry tissues were inserted in a steel extraction cell and placed in the Accelerated Solvent Extractor (ASE 200, Dionex). This machine using organic solvents operates under high pressure and temperature conditions (10 minutes at 125°C and 1500psi) and allows the extraction of the different organic compounds present from the biological matrix. After being extracted, the samples were concentrated using

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Kuderna-Danish, the extract evaporated down to 1 ml, and the solvent was transferred to 10 ml of n-hexane.

Seventeen 2,3,7,8-substituted ^{13}C-labeled tetra- through octa-CDD and CDF congeners and 12 dioxin-like PCBs (IUPAC - 81, 77, 126, 169, 105, 114, 118, 123, 156, 157, 167, 189) were spiked. Furthermore, aliquots were treated with sulfuric acid (approximately 7-10 times) in a separation funnel. Then the hexane layer with PCDDs/DFs and PCBs was rinsed with hexane-washed water and dried by passing through anhydrous sodium sulfate in a glass funnel. The solution was concentrated to 2 ml and sequentially subjected to silica gel, alumina, and silica gel-impregnated activated carbon column chromatography.

Table 1: Morphometric information of studied fishes from Sepetiba Bay, Rio de Janeiro State, Brazil

Fish species/Sample number	Length (cm)	Weight (g)	Gender
Lc 01	114.0	863.8	male
Lc 02	82.5	851.3	male
Lc 03	126.4	1244.7	female
Lc 04	109.5	867.6	female
Lc 05	100.2	948.7	female
Lc 06	104.5	977.3	female
Lc 07	98.6	802.2	male
Lc 08	95.7	1089.3	female
Lc 09	99.8	793.2	female
Lc 10	95.1	945.5	male
Mf 01	25.3	356.3	female
Mf 02	29.6	408.3	male
Mf 03	21.5	501.7	male
Mf 04	26.7	376.0	female
Mf 05	29.2	488.8	female
Mf 06	24.9	445.3	male
Mf 07	29.0	391.1	female
Mf 08	32.7	384.1	male
Mf 09	22.3	599.0	male
Mf 10	31.2	489.2	male
Mf 11	28.4	401.4	male
Mf 12	25.5	354.2	male
Mf 13	27.2	387.5	female
Mf 14	22.4	293.3	male
Ml 01	33.5	523.2	female
Ml 02	34.2	432.4	male
Ml 03	37.6	671.0	male
Ml 04	41.1	780.7	female
Ml 05	35.7	643.7	male
Ml 06	28.9	562.6	male
Ml 07	33.5	670.4	female
Ml 08	37.2	790.3	female
Ml 09	30.5	845.9	female
Ml 10	34.2	651.9	male
Ml 11	33.7	743.0	male
Ml 12	39.0	880.2	female

Lc= Silver scabbardfish (Lepidopuscaudatus, Euphrasen, 1788)
Mf= Whitemouth croaker (Micropogoniasfurnieri; Desmarest, 1823)
Ml= Mullets (Mugilliza; Valenciennes, 1836)

Extracts were passed through a silica gel-packed glass column (Wakogel, silica gel 60; 2g) and eluted with 130 ml of hexane. The hexane extract was Kuderna-Danish concentrated and passed through alumina column (Merck-Alumina oxide, activity grade 1; 5g) and eluted with 30 ml of 2% dichloromethane in

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hexane as a first fraction, which contained multi-ortho-substituted PCBs. The second fraction eluted with 30 ml of 50% dichloromethane in hexane, containing non- and mono-ortho-PCBs and PCDDs/DFs, was Kuderna-Danish concentrated and passed through silica gel-impregnated activated carbon column (0.5g). The first fraction eluted with 25% dichloromethane in hexane contained mono- and di-ortho-PCBs. The second fraction eluted with 250 ml of toluene containing PCDDs/DFs was concentrated and analyzed using a high-resolution gas chromatograph interfaced with a high-resolution mass spectrometer (HRGC/HRMS).

Identification and quantification of 2,3,7,8-substituted congeners of PCDDs/DFs and dioxin-like PCBs (non- and mono-ortho-substituted congeners) was performed by use of a (i) Shimadzu GC-14B gas chromatograph with AOC-1400 auto-sampler. Columns: CBP-1 (SE-30) and CBP-5 (SE-52/54 confirmatory column). Injection: Splitless (30seg.) 300^{o}C. Temperature program of the oven: 110^{o}C (1 min.); 15^{o}C/min up 170^{o}C; 7.5^{o}C/min up to 290^{o}C, hold for 10 minutes. Total run time: 25 minutes. Electron Capture Detector (^{63}Ni) temperature: 310^{o}C; (ii) HPLC: Shimadzu LC-10AS; Mobile phase: acetonitrile: water 80%, isocratic run. Column: Shimadzu STR-ODS-II (C-18 reverse phase) 25cm, L: 4mm ID. UV/VIS detector model: Shimadzu SPD-10A.

The toxic equivalency (TEQ) value of each sample was calculated by using the toxic equivalency factors (TEF) provided by the World Health Organization [16]. TEQ is the product of the concentration of an individual dioxin-like compound (DLC) in an environmental mixture and the corresponding TCDD TEF for that compound. Equation 1 is the formula for calculating exposure concentration for n DLCs in a mixture in TCDD TEQ. Exposure to the i^{th} individual PCDD, PCDF, or PCB compound is expressed in terms of an equivalent exposure of TCDD by computing the product of the concentration of the individual compound (Ci) and its assigned TEFi. TEQ is then calculated by summing these products across the n DLCs compounds present in the mixture. The TEQ may be compared to the dose-response slope for TCDD and used to assess the risk posed by exposures to mixtures of DLCs.

$$TEQ= \sum_{i=1}^{n}(C_i \times TEF_i) \quad \text{(Eq. 1)}$$

All statistical tests were performed using Origin software (7.5, 2004) with a significant level of $p<0.05$. Data were checked for adherence to the standard assumptions of parametric tests using the Kolmogorov-Smirnov test for normality and the Levene's test for homogeneity of variances.

3. RESULTS AND DISCUSSION

3.1 PCDD/F and PCB Concentrations

A total of 36 composite fish samples were analyzed.The European legislation quoted previously sets limits for PCDD/Fs and PCBs in fish muscle for human consumption, and these levels were used as base in this study. According to European Commission [1], legal limit in fish for the sum of PCDD/PCDFs is 4 pg WHO-TEQ/g wet weight, while for the sum of PCDDs, PCDFs, and PCBs cannot exceed 8 pg WHO-TEQ/g wet weight.

Summaries of PCDD/Fs and PCBs levels are illustrated in Table 2 and Table 3, showing the average concentrations (min ~ max concentration) for each species. The column headed WHO-TEQ refers to the total toxicity from all 17 2,3,7,8-substituted PCDDs/Fs and PCBs congeners based on the World Health Organization Toxic Equivalents' method[16].For the purpose of calculating WHO-TEQ for PCDDs/Fs and PCBs, a concentration of 1/2 of the detection limit was used for each no detect. The concentration of total PCDDs/PCDFs ranged from 0.10105 ~ 0.2141 pg-WHO-TEQ/g wwand PCBs ranged from 0.08834~ 0.62304 pg-WHO-TEQ/g ww.

Judging from the European Union regulation limit levels of PCDD/PCDFs and PCDD/PCDFs/PCBs were lower than the criteria in all samples. The sum of PCDD/PCDFs concentration found was 0.19241 pg WHO-TEQ/g w.w. in silver scabbardfish, 0.2141 pg WHO-TEQ/g w.w. in Whitemouth croaker, and 0.10105 pg WHO-TEQ/g w.w. in mullets. The sum of PCDD/PCDF/PCBs was 0.48014 pg WHO-TEQ/g w.w.in silver scabbardfish, 0.83445 pg WHO-TEQ/g w.w. in Whitemouth croaker, and 0.18939pg WHO-TEQ/g w.w. in mullets. For comparison, similar study done in Brazil by Lavandier[26] detected levels similar found in this research, in silver scabbardfish, Whitemouth croaker, and mullets from Ilha Grande Bay, Rio Janeiro, with levels of PCBs of 196.06 ng/g ww, 229.45 ng/g ww, and 131.95 ng/g ww, respectively.

By means of the toxicity factors WHO-TEF, the contribution to the toxicity found was caused by PCBs 77, 81, 126, 156, 169, furan (2,3,4,7,8-PeCDF), and two dioxins: 1,2,3,7,8-PeCDD and 2,3,7,8-TCDD (Figure 3). The sum concentrations of PCBs constituted 81.3% in silver scabbardfish, 80.03% in Whitemouth croaker, and 84.79% in mullets of the total of PCBs in all fish samples collected.

The presence of anthropogenic pollutants, such as PCDD/F and PCB-congeners, throughout all compartments of the marine environment has been of international concern for a number of decades [7,27]. While a great number of datasets documenting absolute concentrations of persistent organic pollutants in a variety

of marine biota are available, the bioaccumulative nature, toxicity, biomagnifications, and the fate of these compounds in the marine ecosystem is still poorly understood.

Reported adverse effects of POPs in wildlife include population declines, increases in cancers, reduced reproductive function, disrupted development of immune and nervous systems, and also elicit toxic responses which could result in the disruption of the endocrine system [13,28,29].

3.2 Comparison with Other Countries

Bayarri et al. [18] studying edible fish species from Adriatic sea found levels of PCDD/Fs and PCBs between 0.23 and 1.07 pg I-TEQ/g of wet weight (ww) in these species. Kiviranta et al. [30] inmarket basket study on dietary intake in Finland found PCDD/Fs; sum: 2.0 pg WHO-TEQ/g ww PCBs; sum: 1.5 pg WHO-TEQ/g ww. In study to determine the levels of PCDD/Fs and PCBs in 14 edible marine species randomly purchased in various cities of Catalonia, Bocio et al. [31] found values of PCDD/F and PCB of 10.28 pg/g ww and 88.10 ng/g ww, respectively. Concentrations and congener-specific profiles of PCDDs, PCDFs, dl-PCBs, and ndl-PCBs were determined by Piskorska-Pliszczynska et al. [20] in five species of edible fish from the Baltic Sea: salmon (Salmosalar), Baltic herring (Clupeaharengusmembras), sprat (Sprattussprattusbalticus), sea trout (Salmotruttam.trutta), and cod (Gadusmorhuacallarias). Marker PCBs were the dominant compounds (0.07–60.84 ng/g w.w.), followed by dl-PCBs (0.64–6.07 pg WHO-TEQ/g w.w.) and PCDD/PCDFs (0.22–5.67 pg WHO-TEQ w.w). Data from Koenig et al. [32], the levels and profiles of organ chlorine (OC) contaminants, including PCBs, dichlorodiphenyltrichloroethanes (DDTs), hexachlorocyclohexanes (HCHs) and penta- (PeCB) and HCB, as well as PBDEs were determined in muscle samples of the deep-sea fish Alepocephalusrostratus, Coelorinchusmediterraneus and Lepidionlepidion from the NW Mediterranean Sea.

Table 2: Medians (range) of concentrations (pg/g, w.w.) of PCDD/Fs and toxic equivalents of PCDD/Fs (pg TEQ/g, w.w.) in silver scabbardfish, Whitemouth croaker, and mullets

Elements	Silver scabbardfish		Whitemouth croaker		Mullets	
	Concentration	WHO TEQ (fish)	Concentration	WHO TEQ (fish)	Concentration	WHO TEQ (fish)
Dibenzo-p-dioxins (PCDD)						
2378-TCDD	0.03 (0.01 – 0.09)	0.03	0.045 (0.02 – 0.06)	0.045	0.02 (0.01 – 0.06)	0.02
12378-PeCDD	0.055 (0.02 – 0.07)	0.055	0.05 (0.03 – 0.09)	0.05	0.025 (0.01 – 0.045)	0.025
123478-HxCDD	0.01 (ND – 0.038)	0.005	0.01 (ND – 0.04)	0.005	0.025 (0.01 – 0.055)	0.0125
123678-HxCDD	0.025 (0.016 – 0.051)	0.0025	0.05 (0.04 – 0.08)	0.005	0.03 (0.01 – 0.07)	0.003
123789-HxCDD	0.01 (ND – 0.029)	0.001	0.01 (ND – 0.028)	0.001	0.01 (ND – 0.05)	0.001
1234678-HpCDD	0.17 (0.04 – 0.24)	0.0017	0.16 (0.03 – 0.38)	0.0016	0.09 (0.04 – 0.12)	0.0009
OCDD	0.15 (0.08 – 0.24)	0.00015	0.17 (0.12 – 0.299)	0.00017	0.25 (0.17 – 0.32)	0.00025
Dibenzofurans (PCDF)						
2378-TCDF	0.45 (0.1 – 0.7)	0.00045	0.27 (0.12 – 0.34)	0.00027	0.16 (0.13 – 0.26)	0.00016
12378-PeCDF	0.16 (0.05 – 0.23)	0.008	0.16 (0.09 – 0.31)	0.008	0.05 (0.01 – 0.09)	0.0025
23478-PeCDF	0.17 (0.073 – 0.18)	0.085	0.18 (0.12 – 0.35)	0.09	0.06 (0.03 – 0.14)	0.03
123478-HxCDF	0.03 (0.01 – 0.068)	0.003	0.04 (0.02 – 0.064)	0.004	0.02 (0.01 – 0.05)	0.002
123678-HxCDF	0.025 (0.01 – 0.056)	0.0025	0.025 (0.01 – 0.07)	0.0025	0.01 (ND – 0.04)	0.001
1234789-HxCDF	ND	ND	ND	ND	0.01 (ND – 0.05)	0.001
234678-HxCDF	ND	ND	0.01 (ND - 0.02)	0.001	0.01 (ND – 0.04)	0.001
1234678-HpCDF	0.035 (0.01 – 0.056)	0.00035	0.03 (0.01 – 0.06)	0.0003	0.045 (0.02 – 0.09)	0.00045
1234789-HpCDF	0.025 (0.01 – 0.04)	0.00025	0.025 (0.01 – 0.049)	0.00025	0.028 (ND – 0.04)	0.00028
OCDF	0.11 (0.07 – 0.23)	0.000011	0.12 (0.09 – 0.16)	0.000012	0.11 (0.04 – 0.14)	0.000011
	Σ= 1.455	Σ= 0.19241	Σ= 1.355	Σ= 0.2141	Σ= 0.953	Σ= 0.10105

ND = concentration below the limit of detection

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Mean PCB and DDT levels ranged from the highest concentrations in the fish A. rostratus (Σ(7)PCBs 6.93±0.71ng/gw.w. and ΣDDTs 8.43±1.10ng/gw.w.). Ben Ameur et al. [33] analyzed thirty one persistent organic pollutants including OCPs and its metabolites (DDTs), HCHs and HCB, PCBs, PBDEs and methoxylatedpolybrominateddiphenyl ethers (MeO-PBDEs) in soleasolea muscle, from Bizerte Lagoon (northern Tunisia) and from the Mediterranean Sea (reference area) (northern Mediterranean). Mean levels of organ chlorine compounds were 1018 and 380ng.g$^{(-1)}$ lipid weight (lw) in fish from Bizerte Lagoon and the Mediterranean Sea, respectively.

Table 3: Medians (range) of concentrations as (pg/g, w.w.) of PCBs and toxic equivalents of PCBs (pg/g, w.w.) in silver scabbardfish, Whitemouth croaker, and mullets

Elements	Silver scabbardfish		Whitemouth croaker		Mullets	
	Concentration	WHO TEQ (fish)	Concentration	WHO TEQ (fish)	Concentration	WHO TEQ (fish)
Non-ortho PCBs						
3,3',4,4'-TCB (77)	137 (89 – 211)	0.0685	296 (166 – 434)	0.148	33 (12.5 – 44)	0.0165
3,4,4',5-TCB (81)	319 (145 – 522)	0.0319	852 (556 – 1023)	0.0852	43 (19 – 66.5)	0.0043
3,3',4,4',5-PeCB (126)	12 (4.5 – 18)	0.06	20 (14 – 37)	0.1	5 (2.3 – 9.8)	0.025
3,3',4,4',5,5'-HxCB (169)	900 (671 – 1228)	0.045	2506 (1744 – 2990)	0.1253	450 (208 – 688)	0.0225
Mono-ortho PCBs						
2,3,3',4,4'-PeCB (105)	361 (122 – 645)	0.00181	810 (455 – 1190)	0.00405	46 (19-77)	0.00023
2,3,4,4',5-PeCB (114)	1203 (887 – 1472)	0.00602	2589 (2134 – 3376)	0.01295	423 (277 – 672)	0.00212
2,3',4,4',5-PeCB (118)	8 (2.5 – 17)	0.00004	12 (4.5 – 19.3)	0.00006	2 (0.03 – 4.4)	0.00001
2',3,4,4',5-PeCB (123)	4200 (3680 – 6340)	0.021	14774 (11741 – 18799)	0.07387	998 (682 – 1476)	0.00499
2,3,3',4,4',5-HxCB (156)	5703 (4201 – 7334)	0.02852	8025 (5635 – 11437)	0.04013	1322 (944 – 1540)	0.00661
2,3,3',4,4',5'-HxCB (157)	2.2 (0.03 – 4.6)	0.00001	1.3 (0.01 – 2,21)	0.00001	ND	ND
2,3',4,4',5,5'-HxCB (167)	3200 (2560 – 4555)	0.016	6623 (5289 – 8776)	0.03312	550 (422 – 986)	0.00275
2,3,3',4,4',5,5'-HeCB (189)	1786 (945 – 2238)	0.00893	2660 (1873 – 3622)	0.0133	665 (278 – 877)	0.00333
	Σ= 17.831,2	Σ= 0.2817	Σ= 39.168,3	Σ= 0.6525	Σ= 4.537,00	Σ= 0.0883

ND = concentration below the limit of detection

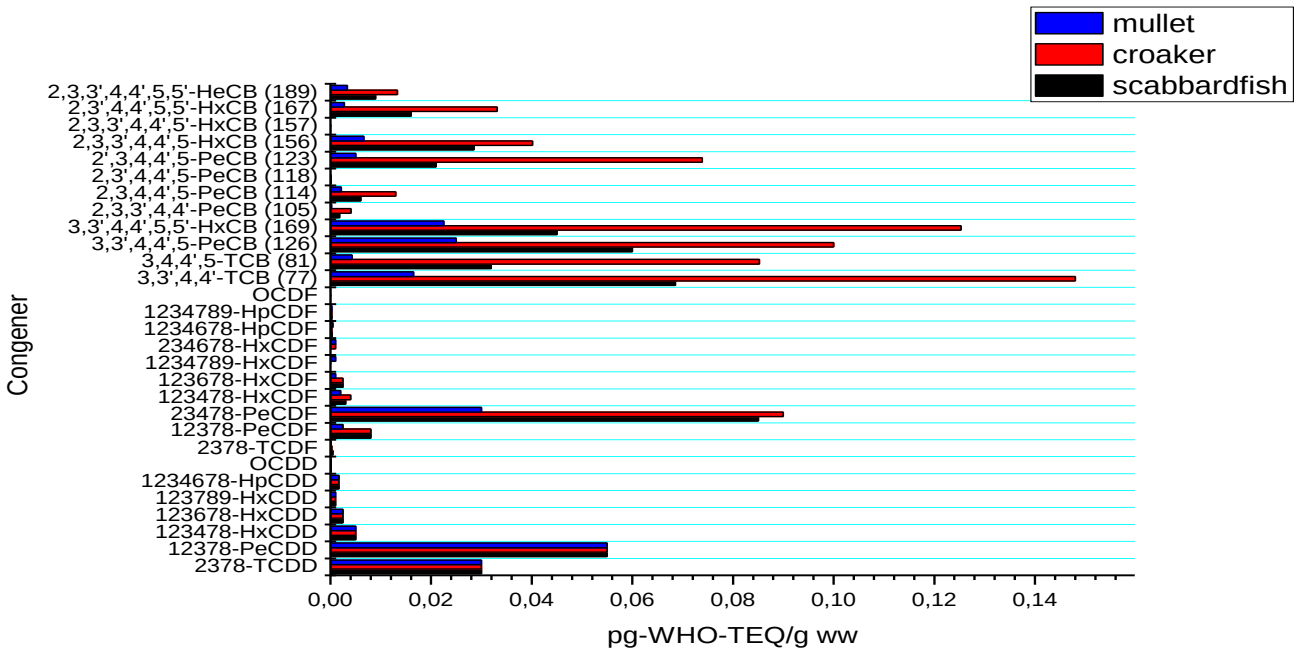

Fig 3: Congener contribution to dioxin-like toxicity in silver scabbardfish, Whitemouth croaker, and mullets

4. OVERALL CONCLUSION

There is no chance of removing dioxin and related pollutants from the bay, but the level of fish contamination is dependent on the aquatic environment, and human exposure can only be reduced through systematically effective fish control. The main objective of the survey was to obtain information about existing levels of pollutants, having as a consequence the possibility of providing preventive actions and assessing risk, although the results showed the dietary consumption of fish from Sepetiba region, did not represent a risk for human health.

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