

Research Article

Evaluation of the Contamination Profile of Oysters from Soumbédioune/Dakar/Senegal Beach by PCB-DL

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Abstract

Contamination of the marine environment by persistent organic pollutants (POPs) is a worrying issue. So-called "dioxin-like" PCBs in particular are pollutants that are widely dispersed in the environment. Furthermore, due to their affinity with fatty tissues, they are highly bioaccumulated by aquatic species. In return, these organisms consumed by humans as food can be a source of contamination. Hence the interest in studying these biological matrices in order to become aware of the risks of degradation of aquatic ecosystems. In this work, the contamination profile of oysters from Soumbédioune beach by DL-PCBs (PCB81; 114; 118; 123; 126; 167; 169; 189) was studied. The analysis method used is Gas Chromatography Coupled with Mass Spectrometry (GC-MS). The average levels of the different campaigns of July, August and September 2021 are respectively 28.218; 119.863; 48.053 µg/Kg in dry weight in oysters. These levels are above the maximum limit according to European Commission Regulation No. 1881/2006 (0.008 µg/Kg). Thus we estimated the exposure of the population to PCB-DL. The factor obtained varies from 0.005 µg/Kg to 0.28 µg/Kg for an individual of 40 Kg and from 0.002 µg/Kg to 0.17 µg/Kg for an individual of 70 Kg. In 2002, the WHO proposed a tolerable daily dose of 0.02 µg/kg/body weight per day for all PCBs. According to these results, the contamination status of Soumbédioune beach is worrying and the consumption of these oysters as food could prove problematic for health. Consequently, a synergy involving the stakeholders, namely the populations, industrialists, authorities and the scientific community, could lead to better solutions. To do this, it is necessary to treat the effluents that are discharged into this coastline and to raise awareness among the populations of the consequences of the contamination of the marine environment.

Keywords

Oysters, PCB-DL, GC-MS, Soumbédioune Beach

1. Introduction

Persistent organic pollutants (POPs) are today the main scourges of the environment but also of health. Indeed, their particularly harmful effects, carcinogenic... in addition to their

persistence, mean that they are present in all ecosystems [1, 2]. These are organic compounds that resist photolytic, biological or chemical degradation. They are characterized by low solubility

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in water and high in lipids, thus leading to their bioaccumulation in adipose tissues. Among these pollutants are the so-called “dioxin-like” polychlorinated biphenyls (PCBs) (PCB-DL) [3].

These are highly chlorinated compounds, which can easily bind to AhR (Aryl Hydrocarbon receptor) receptors, hence their toxicity. They are associated with a number of adverse effects on the thyroid, liver, immune function and reproduction. The International Agency for Research on Cancer (IRAC) has classified these PCBs as carcinogenic to humans [4].

In Senegal, anthropization is not accompanied by a good environmental and health policy. Chemicals and effluents from industries or homes are sometimes dumped into the sea without prior treatment. This can affect endogenous species or the aquatic environment in general [5, 6]. On the other hand, these pollutants can reach humans who are the final link in the food chain. It is in this context that this work is being carried out, which aims to study the contamination of oysters from the beach of Soumbédioune/Dakar/Senegal by PCB-DL (PCB81; 114; 118; 123; 126; 167; 169; 189).

Oysters, widely consumed by populations, are benthic and sedentary. Which exposes them to pollutants. These filter organisms have, in fact, the property of accumulating contaminants in their tissues in significant proportion to their bioavailability in the environment according to the absorption,

excretion and accumulation process [7]. Thus used as food by humans, they can represent a vector of contamination. Hence the interest in studying the bioaccumulation of pollutants by oysters in order to alert populations and decision-makers of the risks of contamination of aquatic ecosystems.

2. Materials and Methods

2.1. Study Site: Soumbédioune Beach

Located on the western cornice of the Dakar/Senegal region, Soumbédioune is a traditional fishing spot. It is located between longitudes 1710 ° and 1732 ° West and latitudes 1453 ° and 1435 ° North (Figure 1). The main activities of this place are fishing and tourism. It is home to Canal IV or West for the evacuation of untreated wastewater. Many researchers such as Cisse et al., 2021 and Dione et al., 2022 have had to work on the contamination of this coastline [8, 9]. This research focuses in particular on sediments and fish. Furthermore, it should be noted that there is a lack of data relating to the contamination of this marine environment, particularly seafood [10].

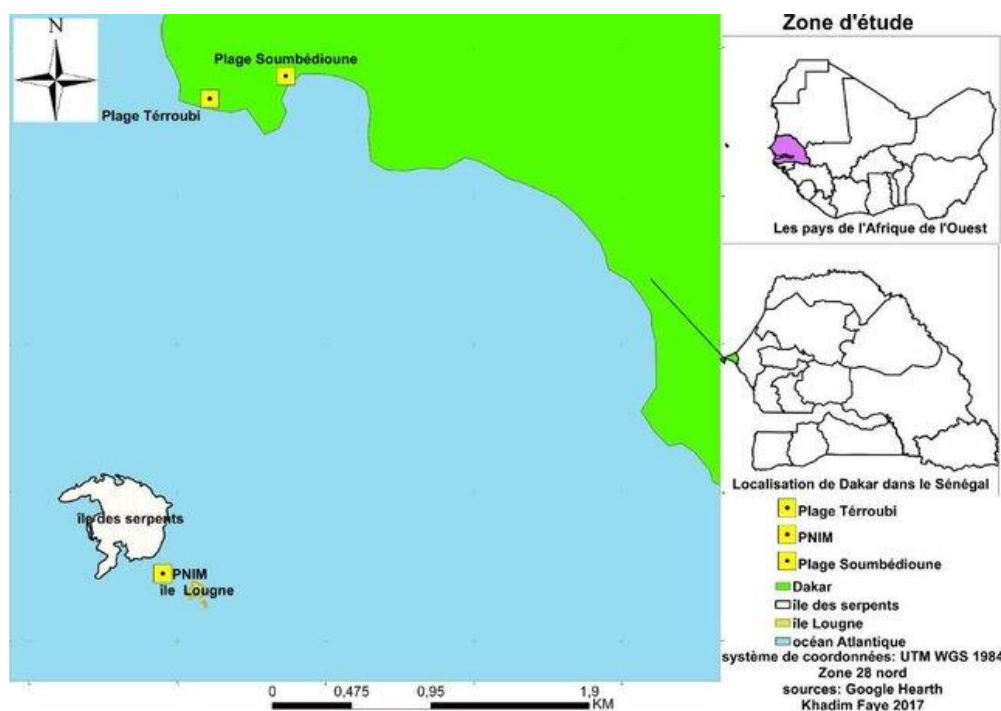


Figure 1. Striped pearl oyster sample collection site.

2.2. Sampling

This step, which consists of taking a sample of the species to be studied, must present all the physicochemical charac-

teristics of the environment. Thus, the oyster samples were collected at Soumbédioune beach around 6 p.m. They were transported in plastic bags and then stored at -20 °C before preparation. We had to take samples for the months of July, August and September 2021 for which five (5) samples were

collected for each campaign.

2.3. Sample Preparation

Pre-preserved samples are thawed before being immersed in distilled water for 2 hours. This process removes the intervalvary fluid before measurements are taken.

In the absence of the age of the different oyster samples, the measurements allow us to have their biometric parameters.

They consist of taking:

1. the width (in cm); it corresponds to the greatest distance separating the anterior edge from the posterior edge of the shell.
2. the height (in cm); it goes from the dorsal hinge to the ventral edge.

3. the bulge (in cm); this is the maximum width of the cavity of the two valves joined.
4. the total weight (flesh + organs + valves) in grams (g); this is the weight of the entire individual sampled.
5. the wet and dry weight (flesh + organs) (after dissection and drying); this is the weight of fresh visceral mass after removal of the shell and intervalvary fluid.

The heights, widths, and bulges were taken using a “vernier caliper” and the masses using a precision electronic balance.

After measurements, the dry samples were ground using a porcelain mortar. Furthermore, all flesh and organs were taken as recommended by UNEP/FAO/IAEA/IOC [11].

Table 1 lists the biometric parameters of the species *Pinctada imbricata radiata* (Leach, 1814) [12].

Table 1. Biometric parameters of the species *Pinctada imbricata radiata* (Leach, 1814) in the different campaigns.

Campaigns	Specimens (oyster)	Length (Cm)	Width (Cm)	Bulge (Cm)	Total weight (g)	Weight Flesh + wet organ (g)	Dry weight (g)
July	No. 1	7.7	6.3	3.2	67.27	25.9	5.03
	No. 2	7.8	6.9	3.2	71.86	30.42	7.78
	No. 3	7.9	7.3	3.3	94.87	33.72	6.38
	No. 4	8.2	6.6	3.2	88.01	33.31	7.13
	No. 5	8.5	6.9	3.2	93.88	34.78	7.23
August	No. 1	8.3	6	3.3	79	16.88	2.01
	No. 2	7.9	7.3	3	62.63	16.9	2.55
	No. 3	8.2	6.9	3.2	66.68	17.27	3.65
	No. 4	8.4	7.3	3.2	81.87	20.77	3.53
	No. 5	9.1	8.1	3.6	138.57	27.29	3.26
September	No. 1	9.6	8.2	3.7	124.03	21.06	3.31
	No. 2	6.9	7	2.7	57.84	16.13	2.52
	No. 3	8	7.3	3.2	74.33	17.32	1.72
	No. 4	9.1	8.4	3.8	101.58	23.6	2.96
	No. 5	9.3	7.4	4.4	118.52	28.01	4.36

2.4. Extraction Method

The method used is QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe). It was developed by Anastassiades et al., in 2003 for the analysis of pesticides in fruits and vegetables. It was used by Dione et al., in 2022, in fish products [10, 13].

A mass of 2g of each sample is weighed and placed in a 50 mL polypropylene tube. To separate the organic and aqueous phases, a volume of 10 mL of acetonitrile (ACN) is added to this mass. The solution thus obtained is vortexed for 30 sec-

onds. Extraction is done with 10 mg of extraction salts: QuEChERS Extraction Salts Q110 Composed of 4g MgSO₄; 1g NaCl; 1g trisodium citrate dihydrate; 0.5g disodium hydrogen-citrate sesquihydrate. The sample is then vortexed before being centrifuged for 10 min at 4000 rpm.

2.5. Purification

It consists of recovering the supernatant in a 15 mL tube already containing the Q-sep brand purification salt. QuEChERS dSPE (composed of primary secondary amine

and magnesium sulfate). This process eliminates remaining fats, sugars, lipids and water to increase the efficiency of the method. Then the sample is vortexed for 30 seconds before being centrifuged for 15 min at 4000 rpm. After this step, the product is recovered in a 10 mL glass tube; which is vaporized under the hood up to 1 mL and then injected into the fiber (PDMS type SPME fiber).

2.6. Analysis by GC-MS

Gas chromatography coupled with mass spectrometry (GC-MS) was used. The equipment used is a Thermo Fischer Scientific brand chromatograph. It consists of a TRACE GC coupled with an ion trap (ITQ 700) operating in tandem mode (MS/MS).

3. Results and Discussion

The analyses thus carried out allowed us to have the results

of the PCB-DL contents of the campaigns of July, August and September 2021.

The data are presented in a table with the mean and standard deviation (σ) of each month. In addition, we estimated the population exposure to PCB-DL following the WHO recommendations, using two individuals (one of 40 kg and another of 70 kg), according to the following formula:

$$Ei = \frac{\sum CijTj}{Pi}$$

Or:

Ei (exposure factor or exposure estimate)

pi is the weight of individual i.

Cij is the consumption of food j by individual i.

Tj is the contamination or average PCB-DL content of food j [14].

The results are reported in Table 2.

Table 2. PCB-DL contents studied.

Campaigns	Settings Samples	PCB81 ($\mu\text{g/Kg}$)	PCB114 ($\mu\text{g/Kg}$)	PCB118 ($\mu\text{g/Kg}$)	PCB123 ($\mu\text{g/Kg}$)	PCB126 ($\mu\text{g/Kg}$)	PCB167 ($\mu\text{g/Kg}$)	PCB169 ($\mu\text{g/Kg}$)	PCB189 ($\mu\text{g/Kg}$)
July	H1	7,721			2,583		0.784	1,324	-
	H2	49,553			8,118		0.722	0.816	3,073
	H3	10,955			2,492		0.380	2,217	2,478
	H4	16,711			4,245		0.648	2,835	3,647
	H5	10,320			2,382		0.565	1,264	2,357
	Mean $\pm \sigma$ ($\mu\text{g/Kg}$)	19,052 $\pm$ 17,363			3,964 $\pm$ 2,445		0.620 $\pm$ 0.156	2.889 $\pm$ 0.816	2,889 $\pm$ 0.594
	E ($\mu\text{g/Kg}$)	0.17 – 0.09			0.03 – 0.01		0.005 - 0.002	0.014 - 0.008	0.2 - 0.01
August	H1	212,560			24,314		7,930	17,914	39,922
	H2	69,374			3,701		1,554	6,808	3,773
	H3	82,161			7,554		1,579	1,349	
	H4	45,994			5,695		2,985	2,700	7,981
	H5	28,142			3,113		1,049	2,700	4,429
	Mean $\pm \sigma$ ($\mu\text{g/Kg}$)	87,646 $\pm$ 72,875			8,875 $\pm$ 8,806		3,019 $\pm$ 2,838	6,294 $\pm$ 6,811	14,026 $\pm$ 17,362
	E ($\mu\text{g/Kg}$)	0.28 – 0.17			0.02 - 0.01		0.009 - 0.005	0.019 - 0.01	0.03 - 0.01
September	H1	89,830			3,786		1,721	3,443	3,630
	H2	20,526			2,469		2,113	1,619	-
	H3	11,660			3,300		1,013	-	5,151
	H4	22,657			2,241		1,587	3,742	-
	H5								

Campaigns	Settings Samples	PCB81 (µg/Kg)	PCB114 (µg/Kg)	PCB118 (µg/Kg)	PCB123 (µg/Kg)	PCB126 (µg/Kg)	PCB167 (µg/Kg)	PCB169 (µg/Kg)	PCB189 (µg/Kg)
	Mean ± σ (µg/Kg)	36,168 ± 36,090			2,949 ± 0.719		1,609 ± 0.455	2,934 ± 1,149	4,391 ± 1,075
	E (µg/Kg)	0.1 – 0.060			0.007 - 0.004		0.005 – 0.003	0.007 - 0.004	0.005 – 0.003

The results of the analyses show significant levels of PCB-DL. Of the eight (8) PCBs analyzed, five (5) were quantified.

PCB 81 has the highest values with 87.646 µg/Kg on average for the month of August. The lowest content obtained for this element is 19.052 µg/Kg (month of July). Thus these concentrations largely exceed the maximum limit according to Regulation No. ^{1881/2006} of the European Commission (0.008 µg/Kg) [15].

PCBs 129; 169; 189 respectively have maximum mean value contents of 8.875; 6.294 and 14.026 µg/Kg in August and a minimum of 2.889; 2.889 in July (with the exception of PCB 129).

As for PCB 167, it presents the lowest values on average ranging from 3.019 µg/Kg in August to 1.609 µg/Kg in September.

PCBs 114; 118 and 126 are not quantified in the various sampling campaigns.

Furthermore, the sum of the PCB-DL contents in each sample is clearly above the maximum limit according to Regulation No 1881/2006 of the European Commission (0.008 µg/Kg) [15]. This can be explained by their bioavail-

ability, a pollution of the environment. Indeed, human activities have a direct or indirect effect on marine ecosystems. Untreated wastewater (domestic or industrial) is discharged directly into the sea. Added to this is a trophic factor due to the fact that oysters are benthic and sedentary. Their mode of nutrition (suspensive type) exposes them to contaminants without the possibility of escape. This results in a biotic balance based on the principle of absorption, excretion and accumulation, hence a significant bioaccumulation of pollutants [16].

Exposure estimation (E) provides results that can inform us about the health risks faced by populations. It is noted that the exposure factors are between 0.005 µg/Kg and 0.28 µg/Kg for a 40 kg individual compared to 0.002 µg/Kg to 0.17 µg/Kg for a 70 kg individual. In 2002, the WHO proposed a Tolerable Daily Intake (TDI) of 0.02 µg/Kg/body weight per day for all PCBs [14]. Based on this reference, the consumption of these oysters as food could prove problematic for health.

In the rest of our analysis, we will study the distribution of PCB-DL contents in each sample. Then, evaluate the variation of these contents in the different campaigns before studying their distribution in the latter.

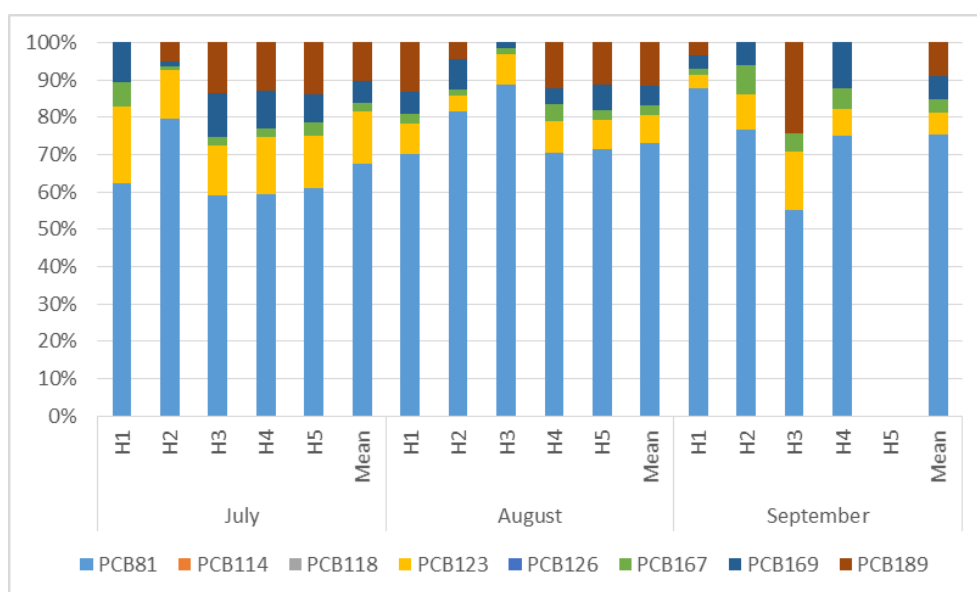


Figure 2. Distribution of PCB-DL contents in the different samples.

3.1. Study of the Distribution of PCB-DL Contents in Each Sample

Figure 2 shows the distribution of PCB-DL contents studied in the different samples.

A significant distribution of contents is noted in each individual. PCB 81 is the most represented among the PCB-DL studied.

The presence of these pollutants in these matrices can be attributed to their bioavailability in the environment, therefore a source of contamination. Indeed, these unconventional entities are persistent and have a high affinity with the human

system of aquatic organisms. In the marine environment, the integration of contaminants into the cycle of living matter is done by adsorption of dissolved substances or suspended matter. This process is all the more important as the particles are small. This results in chronic stress, which over time, leads to a significant accumulation of contaminants [16, 17].

3.2. Study of the Variation of PCB-DL Contents in the Different Campaigns

Figure 3 shows the variation in PCB-DL contents in the different sampling campaigns.

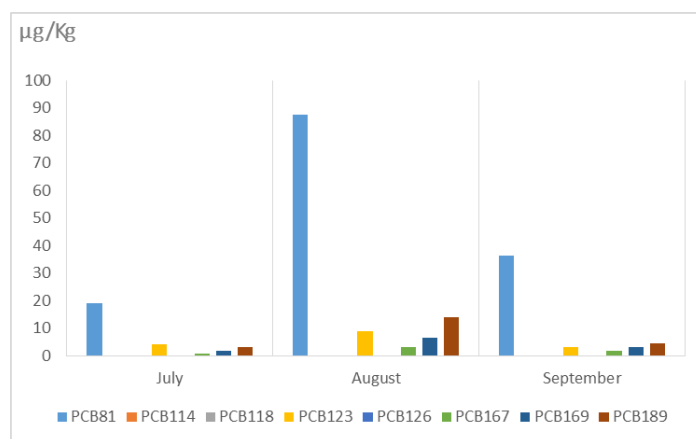


Figure 3. Evaluation of PCB-DL contents in the different campaigns.

The PCB-DL contents vary according to the same dynamics. PCB 81 presents the highest contents in the different campaigns.

For PCBs 123; 167; 169 and 189, there is not a big difference in the values in July and September. Their significant presence in August can be explained by the drainage of rainwater that carries with it a large amount of waste. This phenomenon reinforces the bioavailability of pollutants that,

by bioaccumulation, end up concentrating in these biological matrices [18].

3.3. Study of the Distribution of PCB-DL Contents in the Different Campaigns

Figure 4 shows the distribution of PCB-DL contents in the different sampling campaigns.

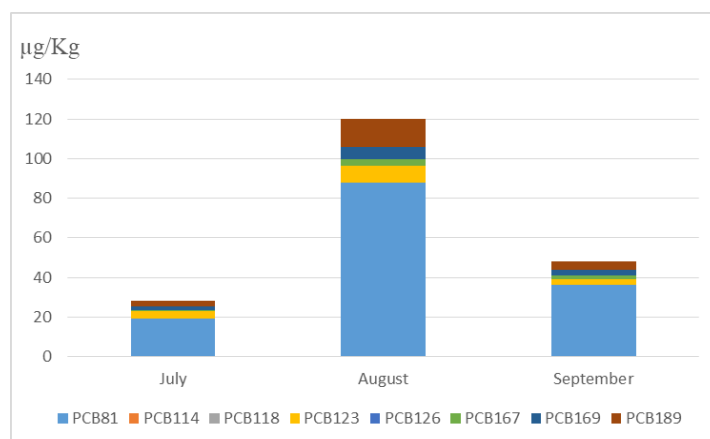


Figure 4. Distribution of PCB-DL contents in the different sampling campaigns.

The distribution of contents is significant in each campaign with sums of average PCB contents exceeding the maximum limit according to Regulation No. 1881/2006 of the European Commission (0.008 µg/Kg) [15]. These contents are more remarkable in August followed by September.

Indeed, from this beach (Soumbédioune) flows the VI or West canal for the evacuation of untreated wastewater from Dakar. In addition to this anthropogenic factor, there is the drainage of rainwater. In addition, the lipophilic nature and

persistence of pollutants promote their accumulation. Organisms subjected to the latter accumulate them at high speed. Also, the longer the oyster has been in the environment, the more it concentrates these pollutants. Which is reflected in these levels [19, 20].

To get a clearer idea of the impact of anthropogenic activities or bioaccumulation, we performed the correlation of PCB-DL contents in the different campaigns. Table 3 represents the correlation matrix based on that of PEARSON.

Table 3. PEARSON correlation matrix of the parameters studied.

Variables	PCB 81	PCB 114	PCB 118	PCB 123	PCB126	PCB167	PCB 169	PCB 189
PCB81	1							
PCB114	0.520	1						
PCB118	0.923	0.250	1					
PCB123	0.846	0.874	0.600	1				
PCB126	0.057	0.250	0.250	0.026	1			
PCB167	0.968	0.342	0.990	0.697	0.168	1		
PCB169	1.000	0.498	0.934	0.830	0.068	0.975	1	
PCB189	0.986	0.635	0.849	0.921	0.015	0.914	0.981	1

The correlation informs us about a possible relationship between the different parameters sought. Thus on the five quantified elements, we note a significant correlation between the different PCB-DL. This explains why they can have the same source. That is to say that their origin can be from the same anthropogenic sources. Furthermore, their persistence parallel to their chemical speciation means that these PCBs can remain in the aquatic environment for a long time.

To get a better idea of the pollution of the marine environment or the health risks faced by populations, we compared our results to those obtained on fish. Indeed, the studies of Dione et al.2022 on fish, *Cephaloplotus taeniops*, from this Soumbédioune beach showed average levels, sometimes higher, of 7.25; 5.85; 2.61; 5.68; 63.88; 138.12; 138.17 and 11.78 µg/Kg respectively for PCBs 81; 114; 118; 123; 126; 167; 169; 189 [21].

These results obtained in these different matrices show that there is a real environmental and health problem that arises: contamination of the marine environment but also of these matrices studied.

4. Conclusion

The contamination of environmental ecosystems by POPs is a key issue for sustainable development. In particular, marine ecosystems are daily affected by the anthropization of

literals. Consequently, these pollutants can on the one hand impact endogenous species in the aquatic environment. On the other hand, they can indirectly affect humans through the food chain.

In this work, the contamination profile of oysters from Soumbédioune beach by PCB-DL (PCB 81; 114; 118; 123; 126; 167; 169; 189) was studied. Of these eight (8) PCBs investigated, five (5) were quantified. The sum of PCB contents in the different campaigns varies between 28.218 and 119.863 µg/Kg in average value in dry weight in oysters. This is beyond the maximum limit according to European Commission Regulation No. 1881/2006 (0.008 µg/Kg). Similarly, the estimation of exposure to PCB-DL gives a factor between 0.005 µg/Kg and 0.28 µg/Kg for an individual of 40 Kg and from 0.002 µg/Kg to 0.17 µg/Kg for an individual of 70 Kg. In 2002, WHO proposed a Tolerable Daily Intake (TDI) of 0.02 µg/kg/body weight per day for all PCBs.

According to these results, the state of contamination of Soumbédioune beach is worrying and that the consumption of these seafoods is problematic for health.

Thus, it is urgent to become aware of this environmental and health threat. A synergy highlighting the actors, namely the populations, industrialists, authorities and the scientific community, could lead to better solutions. To do this, it is necessary to treat the effluents that are discharged into this coastline and to raise awareness among the populations of the

consequences of the contamination of the marine environment.

Abbreviations

POPs	Persistent Organic Pollutants POPs
AhR	Aryl Hydrocarbon Receptor
µg/Kg	Microgram Per Kilo Gram
IRAC	International Agency for Research on Cancer
PCB-DL	Polychlorinated Biphenyls Dioxin-like
GC-MS	Gas Chromatography Coupled with Mass Spectrometry
QuEChERS	Quick, Easy, Cheap, Effective, Rugged, and Safe
PDMS	PolyDiM éthyle Siloxane
SPME	Solid Phase Micro-Extraction
dSPE	Dispersive Solide Phase Extraction
TDI	Tolerable Daily Intake
WHO	World Health Organization

Conflicts of Interest

The authors declare no conflicts of interest.

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