International Journal of Environmental Monitoring and Analysis
2024, Vol. 12, No. 2, pp. 29-35
https://doi.org/10.11648/j.ijema.20241202.12

Research Article

Bioaccumulation of Organochlorine Pesticides (DDT, DDE, Heptachlor, and Aldrin) in Oysters (*Pinctada nested radiata*) from Soumbedioune Beach (Dakar/Senegal) by GC-MS/MS

Sitor Diouf[1], Mame Mor Dione[1], Cheikh Tidiane Dione[1], Birame Ndiaye[1, *], Ibrahima Diagne[1], Dame Cisse[1], Maoudo Hane[1], Momar Ndiaye[1], Cheikhna Diebakate[2], Seydou Ba[1], Abdoulaye Diop[1]

[1]Faculty of Science and Technology, Laboratory of Organic Physical Chemistry and Environmental Analysis (LCPOAE)- Cheikh Anta Diop's University (UCAD), Dakar, Senegal

[2]Department of Animal Biology, Faculty of Science and Technology, Cheikh Anta Diop's University (UCAD), Dakar, Senegal

Abstract

Socio-economic activities have led to the dispersion of polluting agents in all compartments of the environment. The latter largely reach the sea by air, water or land. Thus they can alter the balance of its ecosystems due to their harmful properties. In return, these physical, chic or biological entities can reach humans through the food chain. Hence knowledge of these contaminants is necessary. Indeed, in Senegal, there is little data relating to fishery products, particularly seafood. Hence such work could contribute to good food security but also would allow us to become better aware of the consequences of the destruction of our environment. In this work the profile of the contamination of Soumbedioune beach by OCPs was studied using gas chromatography coupled with mass spectrometry. The average values of 30,470; 149,983 µg/Kg respectively for heptachlor and aldrin are well above the reference 0.1 µg/Kg. And the values 4,255; 149,98 µg/Kg respectively for DDE and DD. This is greater than 50 µg/Kg for the last. This shows that there is a real environmental and health problem that exists on this Dakar coast. Faced with such a situation, it is appropriate to set up wastewater treatment plants and ensure compliance with the ban on these products dangerous to health. Consequently, awareness on the part of decision-makers, populations and industrialists could probably lead to solutions.

Keywords

Oysters, Organochlorine Pesticides, Contamination, Soumbedioune Beach

*Corresponding author: biramendiaye85@yahoo.fr (Birame Ndiaye)

Received: 28 August 2023; **Accepted:**22 November 2023; **Published:** 17 May 2024

1. Introduction

In a health and economic context marked by strong demand and the fight against disease vectors, the use of chemicals is necessary [1]. Consequently, these substances pass through the waters, the air and reach, for the most part, at the level of the estuaries thus constituting areas of high economic and environmental stakes. In addition, persistent organic pollutants (POPs) in general and pesticides in particular, constitute a worrying environmental problem [2, 3].

In Senegal, the agricultural sector employs nearly 60% of the active population and makes significant use of chemicals such as pesticides. In addition, phytosanitary products are used daily with poor management [4]. Thus these pollutants can, on the one hand, end up in crops. On the other hand, they can accumulate in the organs of seafood, especially oysters, which are sedentary organisms with a very high bioaccumulation potential. Indeed, these filtering organisms have the property of accumulating contaminants in their tissues in significant proportion with their bioavailability in the environment. This results in a pseudo-equilibrium of exchanges between the species and the surrounding environment, based on the processes of absorption, excretion and accumulation [5, 6].

Since pesticides are harmful organic compounds that can seriously affect human health, quantitative and qualitative knowledge of their presence in the various compartments of the environment can contribute to good food safety.

It is in this wake that fits our study which aims to study the bioaccumulation of organochlorine pesticides such as DDT (dichlorodiphenyltrichloroethane), DDE (dichlorodiphenyldichloroethylene), heptachlor and Aldrin in oysters, *Pinctada nested radiate* (Leach, 1814), from the beach of Soumbedioune.

DDT, a pesticide long used in the fight against typhus and malaria, has been banned since the Stockholm Convention to which Senegal signed in 2001 and entered into force in 2004 [7, 8]. As well as Aldrin and heptachlor which are widely used pesticides. As for DDE, it is a chemical compound formed during the loss of hydrogen chloride by DDT, of which it is one of the most common decomposition products.

2. Material and Methods

2.1. Study Site

Soumbedioune is a traditional fishing site located on the western cornice of the Dakar region. It is between longitudes 1710 ° and 1732 ° West and latitudes 1453 ° and 1435 ° North (Figure 1). This beach, much coveted by the population, is home to Canal IV or West for the evacuation of waste water. The main activities of this site are fishing and tourism.

In addition, many researchers such as Cisse et al., in 2021 and Dione et al., 2022 have had to work on the contamination of this coastline. This research work focuses in particular on sediments and biological samples such as fish [9, 10].

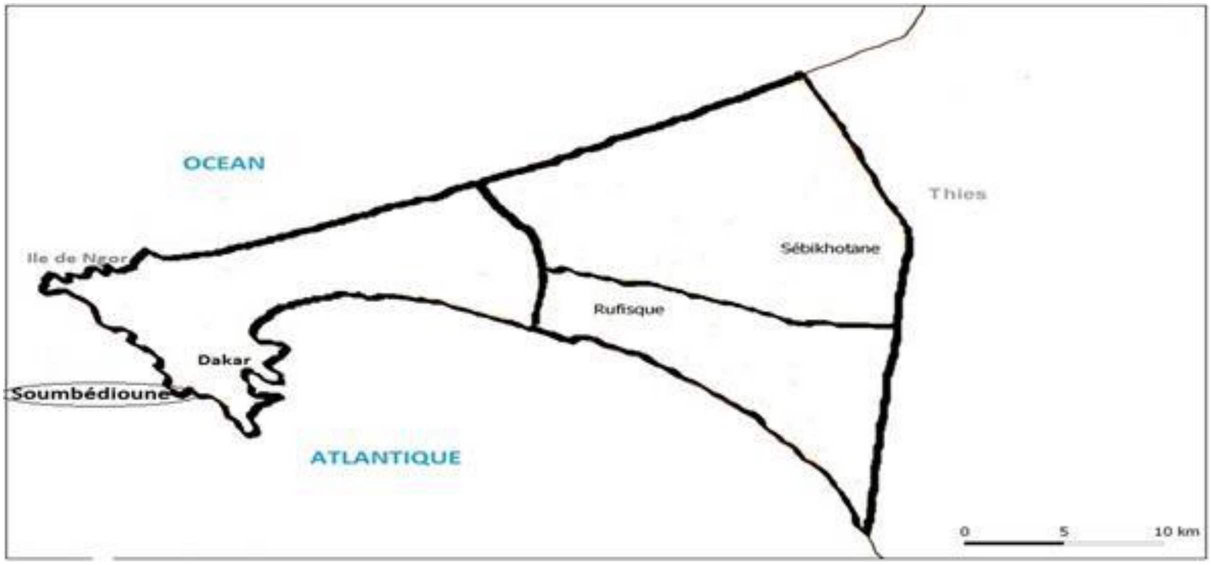

Figure 1. *Sampling site for striped pearl oysters.*

2.2. Sample Collection and Preparation

This is an important step which consists in taking a sample of the species to be studied. It must present all the physico-chemical characteristics of the environment. Thus the oyster samples were purchased at the Soumbédioune beach around 6 p.m. They were transported in plastic bags and then stored at -20 ℃ before preparation. We had to take samples for the months of July, August and September 2021. For each month, five (5) samples were collected.

In the laboratory, previously stored samples are thawed before being immersed in distilled water for 2 hours. This makes it possible to eliminate the intervalvular liquid and then proceed to the measurements.

These measurements allow us to have the biometric parameters of the species (Table 1), more precisely an idea of the size if not the age of the individual. After the measurements, the dry samples are ground using a porcelain mortar. Thus, all flesh and organs were taken as recommended by UNEP/FAO/IAEA/IOC [11].

Table 1. *Biometric parameters of oysters studied according to the campaigns.*

Campaigns	Specimens (oyster)	Length	Width	Bulge	Total weight (g)	Weight Flesh + organ	Dry weight
July	H1	7.7	6.3	3.2	67.27	25.9	5.03
	H2	7.8	6.9	3.2	71.86	30.42	7.78
	H3	7.9	7.3	3.3	94.87	33.72	6.38
	H4	8.2	6.6	3.2	88.01	33.31	7.13
	H5	8.5	6.9	3.2	93.88	34.78	7.23
August	H1	8.3	6	3.3	79	16.88	2.01
	H2	7.9	7.3	3	62.63	16.9	2.55
	H3	8.2	6.9	3.2	66.68	17.27	3.65
	H4	8.4	7.3	3.2	81.87	20.77	3.53
	H5	9.1	8.1	3.6	138.57	27.29	3.26
September	H1	9.6	8.2	3.7	124.03	21.06	3.31
	H2	6.9	7	2.7	57.84	16.13	2.52
	H3	8	7.3	3.2	74.33	17.32	1.72
	H4	9.1	8.4	3.8	101.58	23.6	2.96
	H5	9.3	7.4	4.4	118.52	28.01	4.36

2.3. Chemical Analysis

Easy, Cheap, Rugged and Safe (QuEChERS) method which was developed by Anastassiades et al., in 2003 for the analysis of pesticides in fruits and vegetables. It was validated by Dione et al., in 2022, in fish products [10, 12].

About 2g mass of each sample is placed in a 50 mL polypropylene tube. 10 mL of a solvent solution of acetonitrile (ACN) are added thereto to separate the aqueous phase from the organic phase. The resulting solution is vortexed for 30 seconds. The extraction is done with 10 mg of extraction salts: QuEChERS Extraction Salts Q110 Composed of 4g $MgSO_4$; 1g NaCl; 1g trisodium citrate dihydrate; 0.5 g disodium hydrogen -citrate sesquihydrate. The sample is then vortexed before being centrifuged for 10 min at 4000 rpm.

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

For sample analysis, Gas Chromatography-Mass Spectrometry (GC-MS) was used. Our conditioned samples are analyzed at the Institute of Chemistry and Processes for Energy, Environment and Health (ICPEES) of the University of Strasbourg. The chromatography equipment used is of the Thermo Fischer Scientific brand and consists of a TRACE GC coupled to an ion trap (ITQ 700) operating in tandem mode (MSMS).

3. Results and Discussion

3.1. Analysis of Oysters Sample

Analyzes carried out allowed us to have the results of the campaigns of July, August and September 2021 which are recorded in table 2.

Table 2. Pesticides content in oysters sample from Soumbedioune beach.

Campaigns	Settings Samples	Heptachlor (µg/Kg)	Aldrin (µg/Kg)	DDE (µg/Kg)	DDT (µg/Kg)	∑ pesticides
July	H1	7.09	9.78	1.46	16.1	34.43
	H2	22.56	27.19	2.38	142.22	194.35
	H3	20.02	16.65	1.95	47.63	86.25
	H4	16.09	24.82	1.75	150.43	193.09
	H5	3.39	15.68	1.2	48.98	69.25
	Mean (µg/Kg) ± σ	13.83 ±8.27	18.824 ±7.112	1.748 ±0.45 3	81.072 ±61.072	115.474 ±73.831
August	H1	104.43	131.79	20.86	865.4	1122.48
	H2	5.41	35.95	2.93	117.17	161.46
	H3	63.45	118.67	8.73	340.83	531.68
	H4	15.82	9.93	2.25	63.05	91.05
	H5	32.16	17.17	3.04	57.61	109.98
	Mean (µg/Kg) ± σ	44.254 ±40,166	62.702 ±58,050	7.562 ±7,879	288.812 ±342,433	403.33 ±440.37
September	H1	77.24	31.42	5.06	99.7	213.42
	H2	22.86	7.84	3.13	64.04	97.87
	H3	17.58	11.52	3.19	112.68	144.97
	H4	15.63	75.73	2.45	43.85	137.66
	H5	NF	NF	NF	NF	---
	Mean (µg/Kg) ± σ	33.3275 ±29.4338	31.6275 ±31.1727	3.4575 ±1.1198	80.0675 ±31.7153	148.48 ±47.98

Levels of organochlorine pesticides are remarkably high. The results show that these compounds are present in all the samples analyzed. DDE has the lowest average levels with a minimum of 1.748 µg/Kg in July and a maximum of 7.562 µg/g in August. This compound which comes from DDT by loss of a hydrogen chloride is a stable contaminant which can affect aquatic species but also human health. These average DDE levels exceed not the reference value which is 50 µg/Kg [13]. This shows that there is a significant bioaccumulation of this compound.

Heptachlor contents are between 13.83 µg/Kg in July and 44.254 µg/Kg on average in August. Heptachlor, being an unsystematic insecticide, has been banned since the Stockholm Convention in 2001 to which Senegal is a signatory. Moreover, these concentrations explain the environmental and health problem which is necessary because these average values are well above the reference value which is 0.1 µg/Kg [13].

Average Aldrin contents range from 18.824 to 62.702 µg/Kg respectively for the months of July and August. However, these measured levels clearly exceed the reference value of 0.1 µg/Kg. Consequently, the environmental impact of this persistent carcinogenic insecticide lies in the fact that it can accumulate and affect all ecosystems, in particular the trophic chain of which man is the final jersey [14].

DDT presents the highest average levels with values ranging from 80.0675 to 288.812 µg/Kg for the months of September and August respectively. DDT has long been used to control diseases such as typhus and malaria, and against insect pests in agriculture [15].

It is now banned as an agricultural product since the Stockholm Convention entered into force in 2004, but tolerated with great precautions for the control of insect vectors. This compound remains one of the elements hazardous to health. Indeed, DDT binds to estrogen receptors and can thus alter the normal reproductive process. In addition, DDT alters shellfish mantle tissues, proteins involved in energy metabolism [16].

The levels found during these campaigns are beyond the reference value which is 50 µg/Kg [13].

In this study, we are going to study the evaluation of the organochlorine contents in the different samples as well as their distribution of these elements for each campaign.

3.2. Variation in OCPs Content in the Different Oysters Samples

Figure 2 represents the variations in dry weight of the various pesticides studied in each oyster.

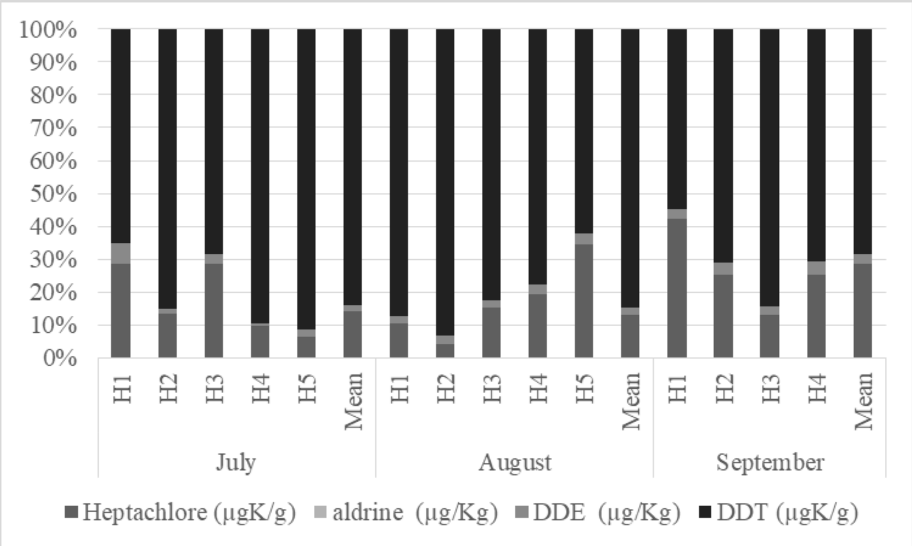

Figure 2. OCPs content, in dry weight, in the studied oysters from soumbedioune beach.

The evaluation of OCPs contents shows that DDT presents the highest contents in all oysters. This can be explained by the persistence of this compound in the aquatic environment (about 150 years) but also by the fact that it has long been used in the fight against disease vectors [17].

Heptachlor and Aldrin contents can be attributed on the one hand to clandestine use; on the other hand, they are easily metabolized, hence the significant bioaccumulation of these pollutants. As for DDE, it is derived from DDT and has no commercial use. This explains these low concentrations.

3.3. Variation in OCPs Content in Oysters Sample According to the Campaigns

Figure 3 represents the variations in dry weight of the different pesticides studied in the different campaigns.

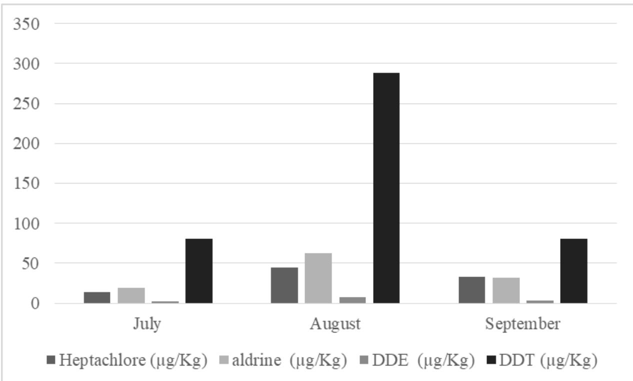

Figure 3. OCPs content, in dry weight, in oysters according to the different campaigns.

The variations in OCPs concentrations follow almost the same dynamics with higher values in August. The presence of these pollutants in biological matrices is closely linked to anthropogenic activities. Indeed, these chemical entities are non-systematic and have no biological role: their absorption is always followed by excretion. But their lipophilicity and their persistence make them difficult or even impossible to eliminate [18]. Consequently, the more the individual is present in the environment subject to these pollutants, the greater the bioaccumulation. This represents a potential danger for the food chain, in particular for humans [19].

3.4. Distribution of OCPs Content in Oysters According to the Different Campaigns

Figure 4 represents the distribution of OCPs contents in the different campaigns carried out in Soumbédioune.

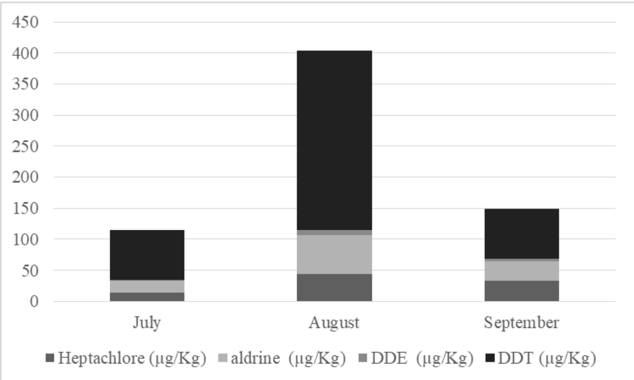

Figure 4. *Distribution of OCPs in oysters according to the different campaigns.*

Sum of the OCPs contents in the five oyster samples studied shows a very significant bioaccumulation of these pollutants. These high values may be linked on the one hand to a biotic factor: a long-term bioaccumulation parallel to their age. On the other hand, in addition to the socio-economic activities that take place there, this coastline of Soumbédioune receives daily untreated wastewater from Canal IV or West of Dakar. This anthropogenic factor can influence the levels in August because the drainage of rainwater carries away all the chemical and biological waste, etc.

Moreover, if we base ourselves on the process of absorption, excretion and accumulation, the contents of these elements only redo the geochemical concentrations, that is to say the availability of the element in the surrounding environment [6]. In 2021, studies by Chueycham Supatta et al on the toxicity of DDT in oysters showed sublethal concentrations of 10 µg/L. Consequently, our results showing concentrations much higher than the reference value (50 µg/Kg), show that there is a real environmental and health problem which is essential.

In the absence of comparative studies, we compared our results to a study carried out on fish at the beach of Soumbédioune. Indeed, the work of Dione et al., in 2022 showed OCPs contents of 0.009; 86.512; 1.95 µg/Kg respectively for Aldrin, DDT and DDE. Heptachlor was not detected in fish from this beach. Thus, these average values are lower than those found in oysters and still remain above 0.1 µg/Kg generally.

4. Conclusion

Marine ecosystems are very often subject to many pollutants that can alter their balance. They are daily subjected to the impacts of anthropic activities. Also, these contaminants can reach humans through the food chain.

In this work, the contamination profile of oysters from Soumbédioune beach by OCPs (DDT, DDE, heptachlor and Aldrin) was studied. In sum, the average contents of OCPs range from 1.748 µg/Kg to 288.812 µg/Kg in dry weight. These concentrations explain a significant bioaccumulation of these elements. In addition, this proves the real environmental and health problem that is needed.

Indeed, the untreated waters of Canal IV and the socio-economic activities that take place at the level of this coast, can impact the marine ecosystem but above all the man who is the final link.

Thus, it should be noted that the morbidity or mortality linked to the consumption of fishery products must be a problem bringing together all the actors, in particular the populations, the scientific community, the industrialists and the decision-makers in order to achieve durable solutions.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Tron I., Piquet O., et Cohuet S., (2001). Effets chroniques des pesticides sur la sante: etat actuel des connaissances. Rev. Epidem., et Santé Publ., 46, 134-142.

[2] Errami M., (2012) Thèse de Doctorat: Devenir atmosphérique de bupirimate et transfert de ses métabolites (les diazines) dans l'atmosphère, sa dissipation dans les fruits de tomate et sa dégradation électrochimique. 230 p.

[3] Lango-Reynoso Fabiola, (2011). DDT in Crassostrea virginica (Gmelin, 1791) of Coastal Lagoons in the Gulf of Mexico. Journal of Agricultural Science Vol. 3, 183-193.

[4] Pesticide Action Network (PAN) Africa/IPEN., (2006). Identification et quantification des rejets de dioxines et furanes dans quelques activités du secteur informel dans Dakar., 61 p.

[5] Derbali A, Kandeel E. Kandeel, Jarboui O., (2009). Comparison of the Dynamics between Coastal and Midshore Populations of Pinctada radiata (Leach, 1814) (Mollusca: Bivalvia) in the Gulf of Gabes, Tunisia, Turc. J. Fish. & Aquat. Sci., 20 (4), p 301-310.

[6] Casas S., (2005). Modélisation de la bioaccumulation de métaux traces (Hg, Cd, Pb, Cu et Zn) Chez la moule, Mytilus galloprovincilais, en milieu méditerranéen., Thèse de Doctorat, Université Toulon Var, 364p.

[7] Stockholm, (2001). Convention de Stockholm sur les polluants Organiques persistants, 15p.

[8] U.S. EPA, 1975. DDT, a review of scientific and economic aspects of the decision to ban its use as a pesticide, Risk Assessment Forum, Washington, D.C. EPA/540/1-75-022.

[9] Cisse D., Ndiaye, B. Ndiaye, M. Diagne, I., Dione C. T., Hane M., et Diop A. (2021). Assessment of Contamination Marine Sediments From Dakar Coast (Senegal) By Chlorine And Metallic Elements (Cu, Zn and Cr). European Journal of Applied Sciences, 9 (2), 107-114.

[10] Dione C. T., Delhomme O., Diagne I., Diebakate C., Ndiaye B., Cisse D., Hane M., Dione M. M., Diouf S., Diop A., Ndiaye M. & Millet M., (2022). Application of the QuEChERS method for the determination of pesticides, PAHs and PCBs in fish in Senegal, Journal of Environmental Science and Health, Part A, 57: 10, 869-879.

[11] UNEP/FAO/IAEA/IOC (1984). Sampling of Selected Marine Organisms and Sample Preparation for Trace Metal Analysis: Reference Method for Marine Pollution Studies No. 7, Rev. 2: 19 p.

[12] Anastassiades M and Lehotay J. S., (2003). Fast and easy multiresidue method employing acetonitrile extraction/partitioning and "dispersive solid-phase extraction" for the determination of pesticide residues in produce, Journal of AOAC International, 86, 412-431.

[13] Afssa, (Février 2008). Évaluation du dispositif de surveillance chimique des zones de production conchylicole et du risque lié à la consommation des coquillages, notamment dans la situation du bassin Arcachon, 71p.

[14] I N E R I S, (2011). Fiche de données toxicologiques et environnementales des substances chimiques. 93p.

[15] Turusov V., Rakitsky V., and Lorenzo T., (2002). Dichlorodiphenyltrichloroethane (DDT): Ubiquity, Persistence, and Risks. Environmental Health Perspectives • VOLUME 110. 125-128.

[16] Meyer A., Chrisman J., Moreira J. C., Koifman S., (2003). Cancer mortality among agricultural workers from Serrana Region, State of Rio de Janeiro, Brazil. Environ Res., 93, 264-271.

[17] Chueycham S., Srisomsap C., Chokchaichamnankit D., Svasti J., Hummel K., Nobauer K., Omid Hekmat, Razzazi-Fazeli E., Kingtong S. (2021). Toxicity of DDT to the hooded oyster Saccostrea cucullata: Mortality, histopathology and molecular mechanisms as revealed by a proteomic approach., Ecotoxicology and Environmental Safety 225., 12 p.

[18] Chahal H., (2013). Etude du comportement hydromécanique des sédiments pollués par les PCB en interaction avec les géomatériaux pour un stockage hors site. Lyon, INSA.

[19] Contreras López M. C., (2003). Determination of potentially bioaccumulating complex mixtures of organochlorine compounds in wastewater: a review. Environment International 28 (8), 751-759.