JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2021, 22(9), 87–98
https://doi.org/10.12911/22998993/141480
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Received: 2021.07.09
Accepted: 2021.08.25
Published: 2021.09.03

Assessment of Trace Metal Concentrations in Three Seafood Deep-Sea Fished Caught in the Moroccan Atlantic

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ABSTRACT

The investigation within the framework of this study was carried out on three marine species fished off in Moroccan coasts, namely: a fish, the sole (*Solea Vulgaris*), a cephalopod, the cuttlefish (*Sepia Officinalis*) and a crustacean, the pink shrimp (*Parapenaeus Longirostris*). The aims of this study were assessing the level of concentration in these three marine species, of three metallic trace elements: lead (Pb), cadmium (Cd) and mercury (Hg) and giving a reflection on the way in which Moroccan deep-sea fishing professionals can join a food safety management system to ensure the safety of their product and promote their competitiveness. Sampling was carried out at the port of Agadir city after landing of the deep-sea fishing boats which operate beyond 10 nautical miles, offshoring the seabed of Agadir for pink shrimp (*Parapenaeus Longirostris*), and in Dakhla city offshore for sole (*Solea Vulgaris)* and cuttlefish (*Sepia Officinalis*). Trace metal analysis was performed on individual muscles belonging to the three species. The results of the conducted investigations show that the Pb content varies between 0.01 ppm and 0.27 ppm in *Solea Vulgaris*; between 0.015 ppm and 0.16 ppm in *Sepia Officinalis* and between 0.022 ppm and 0.38 ppm for *Parapenaeus Longirostris*. For Cd, the concentrations vary between 0.0047 ppm and 0.050 ppm in *Solea Vulgaris*; between 0.0025 ppm and 0.254 ppm in *Sepia Officinalis* and between 0.0065 ppm and 0.11 ppm in *Parapenaeus Longirostris*. Concerning Hg, the contents vary between 0.0006 ppm and 0.075 ppm in *Solea Vulgaris*; between 0.0008 ppm and 0.05 ppm in *Sepia Officinalis* and between 0.0016 ppm and 0.09 ppm in *Parapenaeus Longirostris*. It appears from this study that the metal contents detected at the level of the three species of seafood investigated are below the regulatory thresholds. These results can be considered as the first basis for validating the control measure linked to the absence of metallic contamination of the three species in the sites studied.

Keywords: cephalopods, shrimps, fish, metallic trace elements, deep sea fishing, food safety, validation of control measures.

INTRODUCTION

Despite the fact that the marine environment represents a considerable challenge in terms of socioeconomic development for most of the coastal countries around the world, human, industrial, agricultural and urban activities continue to pollute the marine environment by discarding large quantities of different contaminants (metals, hydrocarbons, pesticides, plastics...). These contaminants represent a threat to aquatic organisms and their accumulation in these organisms can affect the temperature and acidity levels of the oceans [Lacoue-Labarthe et al., 2012]. These contaminants constitute a potential danger to human health by their incorporation into the food chain, of which humans is the last link. Among these contaminants, there are metallic trace elements (MTE) such as Lead, Cadmium and Mercury, known by their toxic effects even at low doses, they are not metabolized by living beings consequently their accumulation within the food chain [Passinet et al., 2003]. The introduction of these metallic trace elements by humans into the marine environment has led to several cases of fatal accidents; this is the case of the Minamata disaster in Japan recognized as the epiphenomenon of mercurial releases to the marine environment. The releases of mercury into the sea, which are accumulated in fish then consumed by the population, resulted in Itai-Itai pathology characterized by health disturbance accompanied by sharp joint and bone pain, due to the consumption of rice irrigated with the water contaminated by cadmium [Kasuya et al., 1992]. These metals are found naturally in our environment and have a direct impact on all ecosystems, in particular seafood. These metallic trace elements enter the environment from natural sources of discharges or anthropogenic sources. The essential nature of these three MTEs has not been detected and they represent the substances considered to be priorities for monitoring the marine environment [Kayalato et al., 2014]. These metallic trace elements, which are undesirable for the safety of seafood, are naturally found in the environment with great variations, due to their geological presence. In addition, they are released from anthropogenic sources and can, to some extent, accumulate in food chains and thus end up in the seafood consumed by humans [Hove et al., 2019].

It is now clear that the pollution by heavy metals in developed and developing countries is a major problem for the 21st century. These metals, still used in many industries, often have very harmful impacts on the environment and the health of populations. These metals are transported to the sea as a final reservoir and are present in all the aquatic ecosystem. Their concentration in the tissues of living organisms can have a harmful effect on the consumers on the top of the food chain, including humans [Belhoucine, 2012].

Following the global assessment of mercury, the United Nations Environment Program (UNEP) launched, after the decision 23/9 of the United Nations Governing Council, a scientific study of lead and cadmium to determine if ‘there is a need to carry out a global action concerning these two substances’ [PNUE, 2002].

The importance of the determination of MMEs in the marine environment is due to the fact that the concentration levels of these elements may be an index of contamination [Lamathe et al., 1982].

National and international studies have been carried out in this direction, and are interested in the variation of the concentration of trace metals in water, molluscs and sediments [Vicente & Chabert, 1979] as well as in the determination of heavy metals in sea water at the level of coasts [Lamathe et al., 1982], to evaluate the heavy metal contamination in marine organisms at the coasts [Pastor et al., 1994]. Other studies have focused on the biological effects of heavy metals in mussels [Moukrim, 2002], on coastal contamination by trace metals [Benbrahim et al., 2006], on the concentration of trace metals in pelagic fish [Kojadinovic et al., 2007]. Studies have also treated trace metal contamination in the fish of sport interest [Ricardo Nolasco, 2013], the bioaccumulation of trace metals in freshwater fish [Putshaka et al., 2015]. The concentration of trace metals (Pb, Cd and Hg) in the muscle and digestive gland of cephalopods (*Octopus Vulgaris*) at the Italian coasts [Ariano et al., 2019].

While these studies focus on coasts and pelagic fish, those focusing on the species caught on the high seas are very limited. In order to bridge this gap, the focus in this study was on the three marine species resulting from the deep-sea fishing, the sole (*Solea vulgaris*), the cuttlefish (*Sepia Officinalis*) and the pink shrimp (*Parapenaeus Longirostris*) known by their accumulations of heavy metals and present target species for the deep-sea fish in Moroccan coast. These seafood species are caught off the Atlantic of Morocco, the city of Agadir for pink shrimp and the city of Dakhla for sole and cuttlefish.

The analysis of these trace elements, Pb, Cd and Hg in these species is necessary in order to assess the level of metallic contamination of these species, and to compare it with the regulatory thresholds, as they are implemented in EC regulation 1881/2006 and with the results found in other regions of the world.

MATERIALS AND METHODS

Species studied

In this study, three different species were used as biological materials, one species of fish, one of cephalopods and one of shrimps. For fish, sole (*Solea Vulgaris*) was chosen, bottom species, sentinel and accumulator of trace metals [Mhadbi et al., 2011], for cephalopods, cuttlefish (*Sepia Officinalis*) was selected, demersal species, sentinel and accumulates trace metals throughout its life cycle [Bustamante et al., 2002, 2004, 2007; Miramand et al., 2008; Labarthe et al., 2008; Labarthe et al., 2009]. Concerning shrimps, the study focused on offshore pink shrimp (*Parapenaeus Longirostris*), which is also a species of the background, sentinel and accumulator of heavy metals [Ghorab Ismahene and Khebbeb Mohamed El Hadi, 2012]. These species are also highly targeted by the offshore fishing activity and are intended for the local and international market in large quantities.

Geographical origin

The three species considered in this study come from the deep-sea fishing carried out of the Dakhla city in southern Morocco for *S. vulgaris* and *S.officinalis*, and of the region of Agadir city for *P. longirostris*. These products are unloaded at the port of Agadir by deep-sea fishing vessels which carry out their fishing activity far from the coast beyond 10 nautical miles.

Owing to a traceability system installed on board of each boat, the different fishing points of the samples were determined, and to represent these points, the ArcGIS geographic information software was used. This software allowed marking the exact geographical position of each sampling point and identifying the distance from this point to the coast.

Figure 1 illustrates different sampling positions which are marked by SV for *Solea Vulgaris*, SO for *Sepia Officinalis* and PL for *Parapenaeus Longirostris*.

Sampling method

The samples were taken at the port of Agadir from frozen products on board and landed by deep-sea fishing boats. The samples were taken monthly, from December 2015 to January 2017 except for the periods of biological rest in which fishing is prohibited for the species mentioned. For *Solea Vulgaris*, a sample of about 3 kg, which contains 25 to 30 pieces with a total length of 16 to 18 cm per piece, was taken. For *Sepia Officinalis*, a 3 kg block which contains 18 to 20 pieces weighing 100

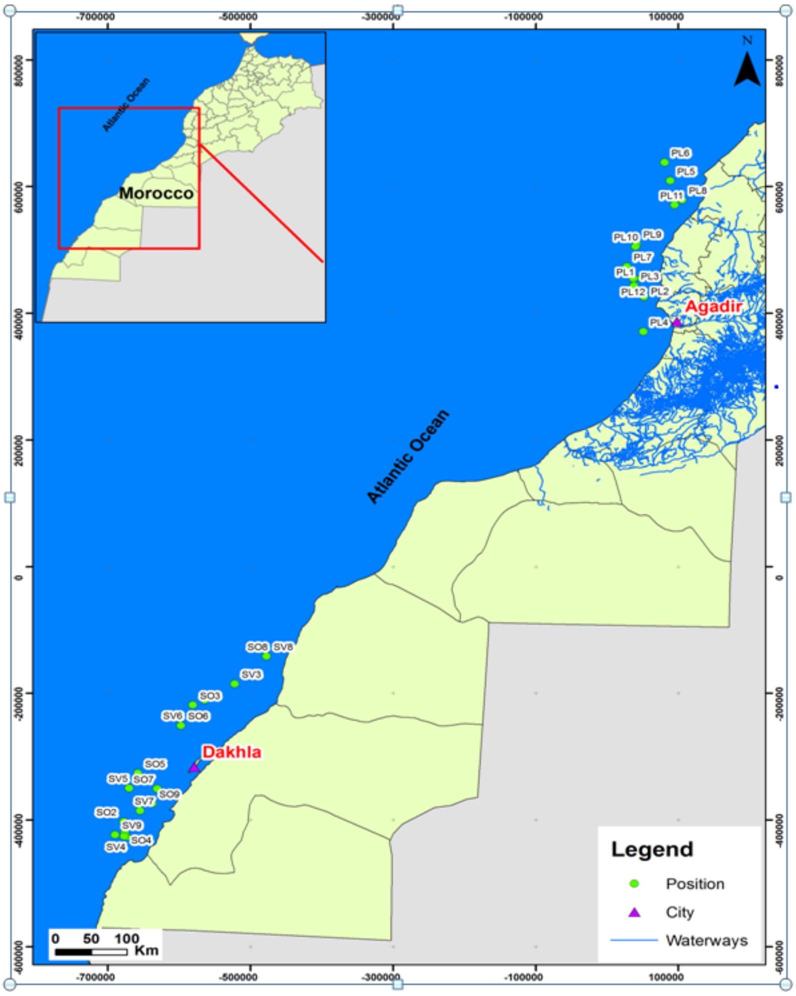

Figure 1. Geographical location of fishing points

to 200 g per piece was taken, and for *Papenaeus Longirostris*, a 1 kg box which contains 140 to 160 pieces of total length from 11 to 12 cm per piece was taken. The three metallic trace elements sought in this study are lead, cadmium and mercury.

The methods used to carry out the analyses are, atomic absorption spectrophotometry in graphite furnace (SAA-FG) published in the official method AOAC 999-10 for cadmium and lead and atomic absorption spectrometry, vapor formation, cold for mercury. The identification of the samples was controlled by an efficient traceability system installed on board of the boats. Indeed, all the information relating to the samples were gathered, namely: the fishing date of the samples, the exact geographical position of the fishing place, the fishing time, the depth, the distance from the coast and any other information related to the production process throughout the on-board processing stages.

Sampling sheet

When the boats unloaded at the port of Agadir, the sample was taken and various information concerning the sample was noted on the sampling sheet. The temperature at the heart of the product was measured using a calibrated thermometer. The fishing date, the time of collection and the serial number of the case containing the sample were noted. The sample taken was immediately placed in a freezer intended for this purpose within a period not exceeding 10 minutes before sending it to the laboratory on the same day of collection. On arrival at the laboratory, the core temperature of the product was measured and the sample was stored at −18° until analysis, far from any possible source of contamination.

METHOD OF ANALYSIS

The assays were carried out on the edible parts of the species considered, in particular the muscles. The samples were topped, eviscerated and homogenized by grinding. A test sample of approximately 0.5 g was mineralized by microwave in a closed system after the addition of 3 ml of HNO_3 and 2 ml of H_2O_2. The mineralization was brought to 50 ml, after addition of ultra pure water. The detection was carried out by a graphite furnace atomic absorption spectrometer (GF-SAA) for lead and cadmium, and cold vapor (CV-SAA) for mercury.

RESULTS

Tables 1, 3 and 5 summarize the different parameters considered for the collected samples of *Solea vulgaris*, *sepia officinalis* and *Parapenaeus logirostris* respectively, namely: the fishing date, the sampling date, the trawling time (TR) which is the time the fishing trawl remains in the water, distance of the coast (DC), the depth (DH), the duration of the preparation steps onboard (DP), which is the time required for sorting, washing and sizing the product. The refrigeration time (DR), which is the time spent in the tunnel by the sample at a temperature ≤ 2°C, the freezing time (DF), the end-of-freezing temperature (FT), the storage temperature (ST) and the product temperature (PT), are also measured. The knowledge of these parameters is useful to give the information about the impact of the lead, cadmium and mercury concentration in the species cited above.

Tables 2, 4 and 6 show the different concentrations of Pb, Cd and Hg obtained respectively for *S.vulgaris*, *S.officinalis* and *P.longirostris*. Figures 2, 3 and 4 represent the Pb, Cd and Hg concentrations for the three species: *S.vulgaris*, *S.officinalis* and *P.longirostris,* respectively.

In *S. vulgaris*

The concentration of Pb for *S.vulgaris* varied between 0.01 ppm in August 2016 and 0.27 ppm in July 2016; that of Cd varied between 0.0047 ppm in December 2015 and 0.05 ppm in December 2016. The Hg concentration varied between 0.0006 ppm in December 2015 and 0.075 ppm in February 2016.

In *S. officinalis*

The concentration of Pb for *S.officinalis* varied between 0.015 ppm in August 2016 and 0.16 ppm in March 2016; that of Cd between 0.0025 ppm in January 2016 and 0.254 ppm in January 2017. The Hg concentration varied between 0.0008 ppm in December 2015 and 0.05 ppm in December 2016.

P. longirostris

The Pb concentration dor *P.longirostris* varied between 0.022 ppm in November 2016 and 0.38 ppm in March 2016. That of Cd varied between 0.0065 ppm in June 2016 and 0.11 ppm in March 2016. The Hg concentration varied between 0.0016 ppm in October 2016 and 0.09 ppm in Junuary 2017.

Table 1. Environmental parameters for *S. vulgaris*

Fishing date	Sampling date	DC (Km)	DH (m)	TR(min)	DP(min)	DR(min)	DF(min)	FT °C	ST°C	PT°C
13/12/2015	28/12/2015	67.41	47	140	135	45	495	-42	-31	-22.33
18/01/2016	02/02/2016	36.83	42	110	60	330	410	-42	-27	-26.67
13/02/2016	22/02/2016	59.33	42	120	105	30	485	-40	-29	-32.33
09/03/2016	05/04/2016	42.10	64	110	80	685	565	-52	-28	-25.33
06/06/2016	11/07/2016	66.34	62	110	90	515	475	-40	-28	-34.33
25/07/2016	29/08/2016	55	58	130	55	190	560	-44	-23	-21.67
07/08/2016	29/08/2016	36.30	26	80	100	80	430	-40	-28	-26
09/12/2016	16/01/2017	28.14	47	120	35	180	480	-40	-29	-25.33
10/01/2017	16/01/2017	52.02	50	160	55	0	600	-49	-31	-28

Table 2. Concentrations of the three metals Pb, Cd and Hg for *S. vulgaris*

Month	Pb(ppm)	Cd(ppm)	Hg(ppm)
Dec -15	0.069	**0.0047**	**0.0006**
Janu-16	0.027	0.04	0.01
Feb-16	0.092	0.006	**0.075**
Marc-16	0.19	0.005	0.017
June-16	0.034	0.014	0.01
July-16	**0.27**	0.04	0.024
Aug-16	**0.01**	0.005	0.01
Dec-16	0.08	**0.05**	0.03
Janu-17	0.06	0.02	0.04

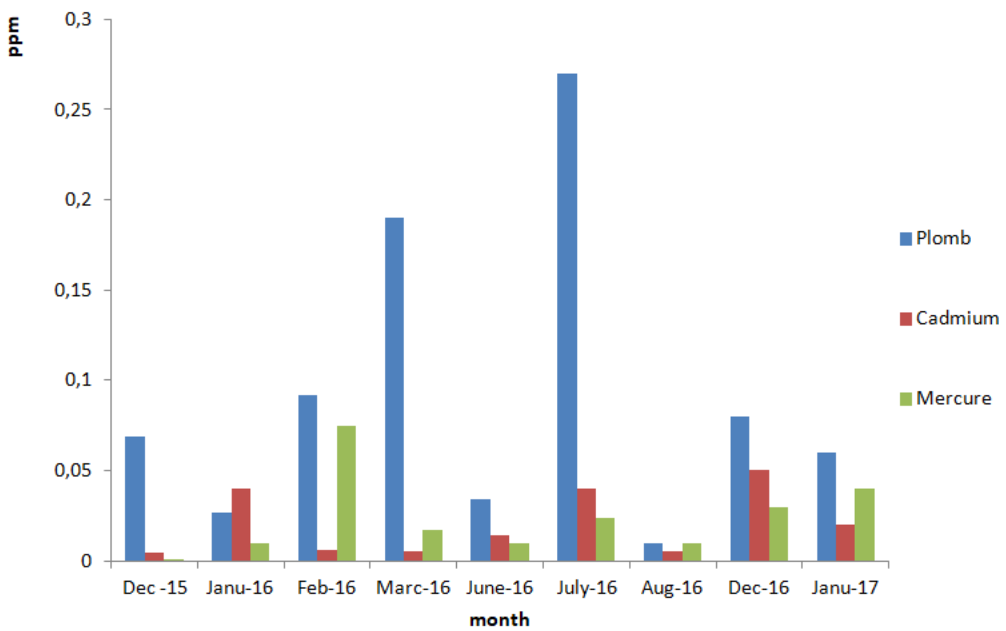

Figure 2. Concentration of Pb, Cd and Hg for the species *S. vulgaris*

Concentration of Pb, Cd and Hg for species of different sizes

In order to identify the concentration of different MTEs studied in the muscles of the same species but with different sizes, a sample of *S. officinalis* of 600 g, *S. vulgaris* of 28 cm and *P. longirostris* of 14 cm was taken. These samples are noted control; they were analyzed in the same way as the other samples and the results obtained were compared with the average

Table 3. Environmental parameters for *S. officinalis*

Fishing date	Sampling date	DC (Km)	DH (m)	TR(min)	DP (min)	DR(min)	DF(min)	FT °C	ST°C	PT°C
12/12/2015	28/12/2015	72.34	55	100	75	80	535	- 42	-31	-22.33
16/01/2016	02/02/2016	51.01	51	125	160	220	410	- 40	-27	-25.33
07/02/2016	22/02/2016	72.37	57	135	80	30	485	- 40	-29	-31
07/03/2016	05/04/2016	39.77	45	125	100	705	495	- 52	-30	-24.33
04/06/2016	11/07/2016	69.68	65	110	75	445	505	- 40	-30	-34.33
25/07/2016	29/08/2016	55	58	130	75	150	520	- 43	-21	-21.67
06/08/2016	29/08/2016	33.87	25	65	125	90	465	- 39	-28	-24
15/12/2016	16/01/2017	28.14	27	120	25	210	480	- 40	-31	-26.33
05/01/2017	16/01/2017	26.90	65	120	65	105	515	- 48	-31	-26

Table 4. Concentrations of the three metals Pb, Cd and Hg for *S. officinalis*

Month	Pb(ppm)	Cd(ppm)	Hg(ppm)
Dec -15	0.055	0.03	**0.0008**
Janu-16	0.076	**0.0025**	0.014
Feb-16	0.1	0.09	0.001
Marc-16	**0.16**	0.09	0.008
June-16	0.095	0.093	0.01
July-16	0.089	0.098	0.01
Aug-16	**0.015**	0.008	0.01
Dec-16	0.07	0.11	**0.05**
Janu-17	0.1	**0.254**	0.03

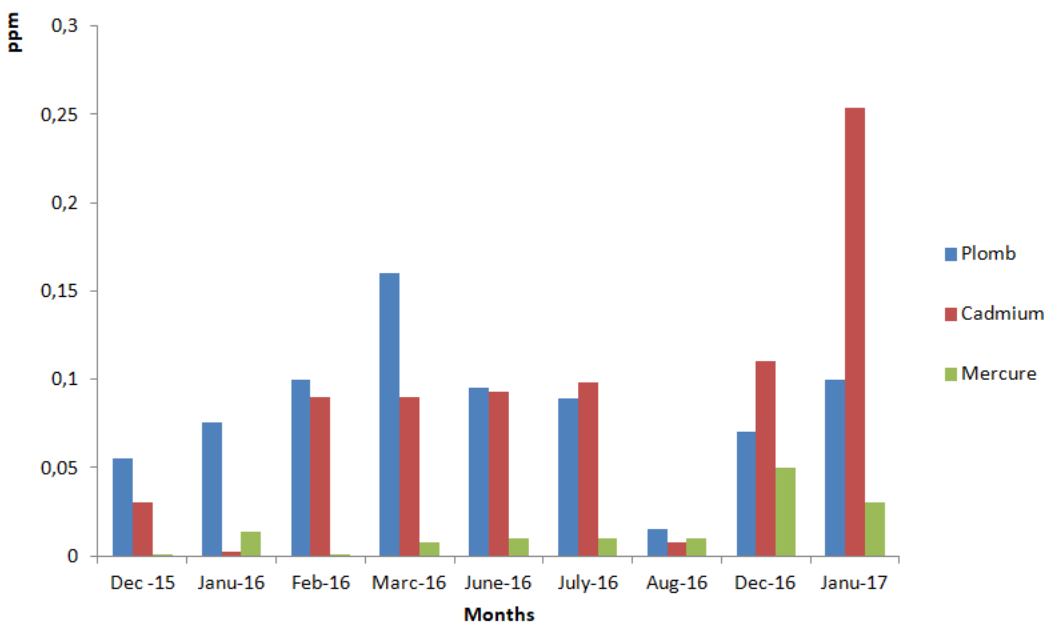

Figure 3. Concentration of Pb, Cd and Hg for the *S. officinalis* species

concentration of the set of samples for each species, as indicated in the Table 7.

Table 7 shows the average concentration of the three metals Pb, Cd and Hg in the muscles of the three species *S.vulgaris*, *S.officinalis* and *P. longirostris*.

For *S. vulgaris*, the Pb concentration in the control muscle was slightly higher than the average value found for all the samples analyzed, that of Cd was ten times lower and that of Hg was twice lower than the average. For *S.officinalis* and *P.longirostris*, the

Table 5. Environmental parameters for *P. longirostris*

Fishing date	Sampling date	DC (Km)	DH (m)	TR(min)	DP(min)	DR(min)	DF(min)	FT °C	ST°C	PT°C
12/12/2015	06/01/2016	29.08	120	180	65	0	150	-28	-23	-22.73
13/01/2016	01/02/2016	21.42	140	200	70	0	375	-29	-22	-19.77
14/03/2016	23/03/2016	39.95	210	230	80	0	170	-37	-23	-21.47
27/04/2016	04/05/2016	41.69	200	285	135	0	180	-29	-23	-22.47
13/05/2016	23/05/2016	45.73	180	195	110	0	190	-29	-22	-21.13
11/06/2016	29/06/2016	57.07	110	225	105	0	210	-30	-24	-20.67
11/09/2016	20/09/2016	49.70	220	265	110	0	210	-28	-22	-22.6
11/09/2016	20/09/2016	25.30	138	190	75	0	180	-30	-22	-20.8
10/10/2016	12/10/2016	38.93	175	170	65	0	180	-29	-24	-20.27
07/11/2016	09/11/2016	38.20	70	205	50	0	180	-29	-23	-19.53
29/12/2016	03/01/2017	28.15	117	245	90	0	185	-30	-23	-21.83
26/01/2017	31/01/2017	40.78	190	190	90	0	210	-29	-23	-24.93

Table 6. Concentration of the three metals Pb, Cd and Hg for *P.longirostris*

Month	Pb(ppm)	Cd(ppm)	Hg(ppm)
Dec -15	0.035	0.016	0.003
Janu-16	0.084	0.086	0.053
Marc-16	**0.38**	**0.11**	0.041
Apr-16	0.026	0.022	0.01
May-16	0.065	0.055	0.01
June-16	0.29	**0.0065**	0.012
Aug-16	0.073	0.013	0.006
Sept-16	0.098	0.018	0.0035
Oct-16	0.074	0.017	**0.0016**
Nov-16	**0.022**	0.045	0.01
Dec-16	0.095	0.01	0.008
Janu-17	0.06	0.06	**0.09**

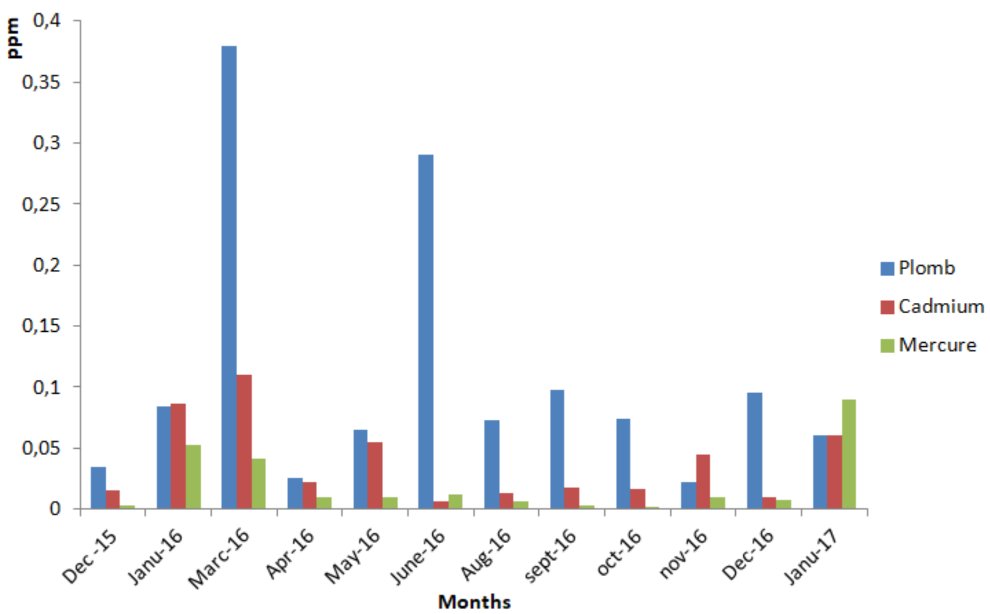

Figure 4. Concentration of Pb, Cd and Hg for the *P.longirostris* species

Table 7. Concentration of the three metals in the control for the three species

Species	Pb (ppm)		Cd (ppm)		Hg (ppm)	
	Control	Average	Control	Average	Control	Average
S.vulgaris	0.097	0.092	0.002	0.021	0.011	0.024
S.officinalis	0.028	0.084	0.0061	0.086	0.0027	0.015
P.longirostris	0.066	0.109	0.0073	0.038	0.0025	0.021

Table 8. Correlation between the different parameters and the concentration of (Pb, Cd and Hg) for the three species

Parameters	SV			SO			PL		
	Pb	Cd	Hg	Pb	Cd	Hg	Pb	Cd	Hg
DC	0.2	-0.59	0.04	0.04	-0.38	-0.73	0.33	-0.18	-0.09
DH	0.59	0.09	-0.08	0.44	0.42	-0.38	-0.15	-0.47	0.26
TR	0.24	0.15	0.27	0.74	0.4	0.11	0.08	-0.12	-0.16

concentration of the three MTEs in the control muscle was always below average.

Correlation between the different parameters and the concentration of the three metals (Pb, Cd and Hg) for the three species:

In order to seek the relationship between the concentration of the three trace elements (Pb, Cd and Hg), in the three species and the different parameters considered (DC, DH and TR), a correlation study was carried out and the results were presented in the Table 8.

For the concentration of lead in the muscles, it correlates positively with depth (DH) for *S. vulgaris* and *S. officinalis*. It also correlates positively with the distance from the coast (DC) for *S. officinalis.* For the cadmium, it correlates negatively with the distance from the coast (DC) for *S. vulgaris*, positively with the depth for *S. officinalis* and negatively with the depth for *P. longoristris*. Concerning mercury, it correlates negatively with the distance from the coast (DC) for *S. officinalis.*

DISCUSSION

The performed investigations focused on the concentration of the three non-essential trace elements, lead, cadmium and mercury in the edible parts of three seafood products from deep-sea fishing offshore of Moroccan Atlantic: a fish (*Solea vulgaris*), a cephalopod (*Sepia officinalis*) and a crustacean (*Parapenaeus longirostris)*. These products are fished by deep-sea fishing vessels which exercise their fishing activity beyond ten nautical miles.

It appears from the results presented in this study that for the fish species *S.vulgaris*, the Pb concentration varied between 0.01 ppm in August 2016 and 0.27 ppm in July 2016. This minimum Pb concentration in the muscle of *S. vulgaris* corresponds – according to the performed study – to the minimum depth which was 26 m and the minimum trawling time which was 80 min. For cadmium, it was between 0.0047 ppm in December 2015 and 0.05 ppm in December 2016. The minimum concentration of Cd in the muscle of the species *S.vulgaris* corresponds to the distance from the greatest coast which was of 67.41 km, and the highest concentration corresponds to the minimum distance from the coast which was 28.14 km. According to these results, the further the position from the coast is, the more the concentration of Cd in the muscle of *S.vulgaris* decreases. This may be influenced by the rise in cold waters due to the upwelling phenomenon which manifests in the Dakhla region throughout the year [Benbrahim et al., 2006; Moujane et al., 2011; Makaoui et al., 2012]. For mercury, the concentration was 0.0006 ppm in December 2015 and 0.075 ppm in February 2016. According to this study, the lowest concentration of Hg in the muscle of *S. vulgaris* corresponds to the longest distance from the coast which was 64.41 km. For comparison, a study carried out in Lebanese ports on the level of concentration of trace metals in three species of fish, *Mugil capito*, *Diplodus sargus* and *Pagillus acarne*, gave the following results: for *Mugil capito*, Hg (0 to 0.08 ppm), Pb (0.09 ppm to 0.88 ppm), Cd (0.02 ppm and 0.07 ppm). For *Diplodus sargus* Hg (0 to 0.1675 ppm), Pb (0.145 ppm to 1.08 ppm), Cd (0.025 ppm and 0.085 ppm For *Pagillus acarne* Hg (0.023 to 0.13 ppm), Pb (0.075 ppm to 0.65 ppm), Cd (0.03 ppm to 0.075 ppm) [Esseily & Daher, 2000]. These results show that the *S.vulgaris* fish species caught off Dakhla in Morocco is less contaminated with Pb, Cd and Hg than the three fish species caught in Lebanon. For the cephalopod species, *S. officinalis*, is considered responsible for the transfer of MTEs to marine predators [Bustamante et al., 2002], the Pb concentration varies between 0.015 ppm in August 2016 and 0.16 ppm in March 2016. The lowest Pb concentration in the muscle of *S. officinalis* corresponds to the minimum depth, which was 25 m and to the shortest trawling time which was 65 mn. For cadmium, it is between 0.0025 ppm in January 2016 and 0.254 ppm in January 2017. This high concentration of Cd corresponded to the maximum depth which was 65 m and the shortest distance from the coast which was 26.9 km. These results confirm other studies carried out on the concentration of MTE in cephalopods and which show that pelagic species accumulate these metals more than benthic species [Rjeibi et al., 2014]. For mercury, the concentration was 0.0008 ppm in December 2015 and 0.05 ppm in December 2016. The high concentration of Hg corresponds to a distance from the coast of 28.14 km and the low concentration of Hg corresponds to a distance from the coast which was 72.34 km. Finally, for the crustacean species *P. longirostris*, the Pb concentration was between 0.022 ppm in November 2016 and 0.38 ppm in March 2016, the low Pb concentration corresponds to the smallest depth which was 70 m. For cadmium, the concentration varied between 0.0065 ppm in June 2016 and 0.11 ppm in March 2016, the low concentration of Cd corresponds to the distance from the largest coast which was 57.07 km. For Hg, the concentration was between 0.0016 ppm in October 2016 and 0.09 in January 2017.

The lowest concentration of Hg in the *P. longirostris* muscles corresponds to the shortest trawling time which was 170 min. The obtained results also reveal that the average Pb concentration in the muscles of *S. vulgaris* was 0.092 ppm, that of Cd was 0.021 ppm and that of Hg was 0.024 ppm. For this same species (*S. vulgaris*) caught on the coasts of the city of Vigo in Spain, the average dry weight concentration of Pb was 0.34 ppm, that of Cd was 0.24 ppm and that of Hg was 0.39 ppm [Mhadhbi et al., 2012]. These results show that the species *S. vulgaris* fished off Dakhla in Morocco is less contaminated than that of the coasts of Vigo in Spain; this may be due to the impact of the larger industrial influx in this city of Spain. Another study in Nigeria found that the concentration of Pb in the muscle of a fish species (*Channa Obscura*) was 1.9 ppm and that of Cd was 0.059 ppm [Tyokumbur, 2014]. These results show that the *C.obscura* fish caught in Alaro Stream in Nigeria is 20 times more contaminated with Pb and twice as much by Cd as the fish species *S. vulgaris* caught off Dakhla in Morocco.

For *S. officinalis*, the average Pb concentration was 0.084 ppm, that of Cd was 0.086 ppm and that of Hg as 0.015 ppm. For this same species (*S. officinalis*) fished in the Portuguese coastal zone at the Aveiro river, the Pb concentration was 0.41 ppm, that of Cd was 0.49 ppm and that of Hg was 0.36 ppm [Dias, 2014]. These results show that the concentration of the three trace elements Pb, Cd and Hg in the muscles of *S. officinalis* fished off Dakhla in Morocco is lower than that of the same species fished at Aviero in Portugal; this can be explained by the impact of different industrial activities in this city. For this same species (*S. officinalis*) fished in Turkey, the Pb concentration was 1.68 ppm and that of Cd was 2.39 ppm [Duysak et al., 2013], these concentrations are much higher than those in the species fished in Morocco. These results explain that the accumulation of these trace metals changes in the muscle of the same species from one region to another. Concerning the species *P.longirostris*, the average Pb concentration was 0.109 ppm, that of Cd was 0.038 ppm and that of Hg as 0.021 ppm. For this same species (*P. longirostris*) fished in two zones in Algeria (Jijel and Bejaia), the concentration of Pb in the muscle of this species was 0.022 ppm in Jijel and 0.028 ppm in Bejaia. For the concentration of Cd, it was 0.0008 ppm in Jijel and 0.0009 ppm in Bejaia [Ismahene & El-Hadi, 2012]. These results show that the concentration of Pb and Cd in the muscles of *P. longirostris* fished off the city of Agadir in Morocco is higher than that of the same species fished in Bejaia and Jijel in Algeria. This may be due to the fact that the open sea of the city of Agadir is part of the areas where the upwelling phenomenon manifests itself more, which influences the concentration of Cd. Another study carried out in the north of the Adriatic Sea on the Crap (*Maya squinado*), crustacean species, showed that the concentration of Cd in the abdomen of this species was 0.092 ppm [Angeletti et al., 2014], which is higher at the level found off Agadir. This can be explained by the fact that this region of the Mediterranean is characterized by a significant industrial activity. It also appears from the obtained results that the fish species *S. vulgaris* accumulates more Pb, followed by Hg then Cd (Pb> Hg> Cd). This order of accumulation is different from that demonstrated in the study carried out in Spain (Hg> Pb> Cd) [Mhadhbi et al., 2012]. For the cephalopod species *S. officinalis*, it accumulates more Cd, followed by Pb then Hg (Cd> Pb> Hg), this result confirms that achieved in Portugal [Dias, 2014] and in Turkey for Cd and Pb [Duysak et al., 2013]. This can be explained by the fact that the *S. officinalis* egg has higher accumulation efficiency for Pb than for Hg [Lacoue-Labarthe et al., 2008]. Cephalopods show great differences in cadmium concentrations depending on their origin. It is possible to classify the families of cephalopods based solely on the concentration of cadmium: *Loliginidae* <*Ommastrephidae* <*Sepiida*e <*Octopodidae* with average concentrations according to the families of approximately 0.13 µg / g, 0.25 mg / g, 0, 50 mg / g and 0.52 µg / g, respectively [Bustamante et al., 2007]. For the crustacean species *P. longirostris*, it accumulates more Pb, than Cd and Hg (Pb> Cd> Hg); the study carried out in two regions in Algeria also showed that this species accumulates Pb more than Cd [Ismahene & El-Hadi, 2012]. The level of metallic trace elements detected in the three species of seafood investigated in this study was below the regulatory thresholds. (Fish – 0.05 ppm for Cd; 0.3 ppm for Pb and 0.5 ppm for Hg – Cephalopods: 1 ppm for Cd; 0.3 ppm for Pb and 0.5 ppm for Hg – Shrimp, 0.5 ppm for Cd; 0.5 ppm for Pb and 0.5 ppm for Hg).

The study of the correlation between the concentration of the three MMEs Pb, Cd and Hg with the different environmental parameters considered (the distance from the coast (DC), the depth (DH) and the trawling time (TR)) revealed that for the species *S.Vulgaris*, the concentration of Pb correlates positively with the depth (R = 0.59). This can be explained by the fact that the origin of the traces of Pb comes from the sediment, since the species solea vulgaris lives constantly on sandy bottoms. For the same species, the concentration of Cd correlates negatively with the distance from the coast (R = −0.59), this result is probably due to the fact that the sole caught near the coasts is more impacted by the Cd than that caught offshore.

For *S.Officinalis*, the concentration of Pb correlates positively with the distance from shore (R = 0.44) and with the trawling time (R = 0.74). This result, likewise for *S.vulgaris*, it shows that contamination by Pb does not necessarily originate from the coast since the Dakhla region is less industrialized and the release of lead into the sea is lower. In addition, the contact between the cuttlefish and the sea bottom at the time of trawling can affect the concentration of Pb in the muscles of the species. For the same species, the concentration of Cd correlates positively with depth (R = 0.42), this can be explained by the fact that cuttlefish caught in deep waters accumulate more Cd. For Hg, the concentration in the cuttlefish muscle correlates negatively with the distance from the coast (R = −0.73), which may be justified by the fact that the risk of mercury contamination can increase when approaching the coast. Finally for the species of *P.Longirostris*, the concentration of Cd correlates negatively with depth (R = −0.47), this result is probably related to the different industrial activities at the level of the Agadir region, and the development of maritime traffic in the region.

CONCLUSIONS

Although these products currently do not present any risk of contamination for the health of consumers of these products, measures of these MTEs are necessary in order to control the subsequent development of these concentrations according to a well-defined surveillance plan.

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