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Heavy Metals (Hg, Cd, Pb) Concentrations on *Mytilus galloprovincialis* (Lamarck, 1819) in Oran Coastal Waters (Western Algeria): New Evidences

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ABSTRACT

Concentrations of three heavy metals (Hg, Cd and Pb) were determined in tissues of wild mussels (*Mytilus galloprovincialis*) collected at 4 sites located in Oran's coast to assess levels and spatial distribution of metals in the sea water. A pool of mussel soft tissue was prepared using 30 individuals, representing the size range present at the sampling points. In general, high metal contents (µg/g dry weight) were found in mussels from two sites close to Oran harbour, these sampling points are located near human inputs in Cueva-del-Agua and Fort-Lamoune, showed respectively, high concentrations of Hg: 2.27 to 0.58; Cd: 5.96-6.24; Pb: 8.27-7.79. Moderate levels were respectively detected, in Ain-Defla and Cap-Falcon, with low variation of Hg: 0.49-0.24; Cd 2.97-2.81; Pb: 6.34-7.72. According to the OSPAR norms, results revealed that all samples are assessed as toxic.
KEY WORDS: heavy metals, *Mytilus galloprovincialis,* sea water, contamination levels, Oran, Algeria.

1. INTRODUCTION

Analysis of chemical compounds in tissues of sessile filter-feeding organisms is employed in routine studies of marine pollution, in particular for toxic mercury and cadmium, since it provides a time-integrated pattern of bioavailable fraction of contaminants, and often in higher concentrations than those present in water or sediments, thus facilitating their determination (Adams 1995; Rainbow and Phillips 1993), to monitor environmental situation at different coastal regions in west Algeria(Taleb and Boutiba 2007; Boutiba et al. 2003), because the control measures of ecosystem response to pollution can be best assessed there, close to discharge and emission sources. Mussels constitute one of the best biological indicators of coastal pollution; easy to collect in coastal areas and large enough for analysis (Widdows et al. 1995). In addition, most of them are commercially valuable species as they are regularly exploited for human consumption at local markets. Thus, their use has been strongly recommended by international organizations/conventions, such as the 'Barcelona Convention' (Convention for the Protection of the Mediterranean Sea against Pollution). Profrane, Medpol and CIESM confirm that the Mediterranean Sea is one of the most controlled seas for pollution.

Metals occur naturally in the environment, it has long been recognized that some metals concentration in coastal shellfish can be increased by natural processes (run-off from mineralised areas, or upwelling of deep oceanic water), though anthropogenic sources (e.g., fossil fuel, waste burning, mining and other processing of chemical productions) are responsible for most of the concentrations observed in coastal waters (Webster et al. 2009). Metals accumulate throughout the trophic chain; it leads to concentrations several orders of magnitude higher than those of the surrounding water (Casas et al. 2008). But, the accumulation ratio depends on environmental situation (temperature, pH, salinity, etc.), and biological condition (age, sex, sexual maturity stage, etc.) (Mubiana et al. 2006; Saavedra et al. 2004).

Oran has an important industrial area (iron and steel factories), whose untreated residues generate an important environmental impact. In addition, the industrial development promoted activity in its harbours which received numerous industrial and boating discharges; the absence of urban and industrial waste water treatments for many years caused an important environmental degradation

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(Boutiba et al. 2003). The principal inputs of fresh water to the coastal zone are the wastewater discharges from Oran city.

This paper studies the spatial patterns of environmental water quality, caused by three heavy metals (Hg, Cd and Pb) in wild mussels, sampled at 4 sites all over Oran's bay, and the main objectives of the present work are to compare the patterns of pollution obtained from toxicological data to OSPAR, Norway and NOAA international quality criteria to evaluate the environmental situation of coastal water for several well-known hazardous metals, as Hg, Cd and Pb (when measured in wild mussels). When Algeria ratified the MED POL program, legislation establishes that pollutant concentrations in water or tissues of bivalves must not exceed levels that cause toxic effects on the adults or their larvae, but has not establish specific concentration, that is why it need background concentrations of trace metals.

2. MATERIALS AND METHODS

2.1. Sampling and environmental parameters

From a geographical point of view, both sampling sites are included in the semi enclose Oran Bay, from 4 different areas, chosen because of their differences in typology (Fig. 1). Map of the Oran Mediterranean coast showing the study sampling sites around the circular coast insert in 34, 86 Km of diameter. Fort Lamoune and Cueva del Agua are the opening emissaries of town sewage carrying mixed waters to the sea, washing out various discharges along the coast, situated, at the urbanised coast, respectively above Mers El Kebir and Oran City, with an expected human impact linked to the high population city, approximately 5.000.000 inhabitants, located around Oran Bay, gathering harbour activities, sewage loads and other anthropogenic impacts. These two exposed sites are classified as polluted (trace metals, inorganic elements, polycyclic aromatic hydrocarbons …etc) (Boutiba et al. 2003). The two other sites, have a limited population, at the eastern and western limits of Oran studied coast: Ain-Defla is approximately, 19,58 km west of Oran City and Cap Falcon is situated at 15,51 km west of Mer El Kebir harbour, are both expected to have relatively pristine or clear water masses, with an important ecological and economical interest, far from the influence of huge pollution sources. Despite, Cap Falcon and Ain-Defla receive intermittent and few village rejects.

Contaminant concentrations vary seasonally in *Mytilus*, Metal uptake is also influenced by mussel age, size, sex and shore position, water temperature, pH, salinity, and ability to absorb or excrete this contaminant (Miller 1986). The sampling protocol was designed to limit variation in these variables, so 30 intertidal specimens of *M. galloprovincialis* were collected simultaneous, pre-spawning period, Maturation State III (Lubey 1959; Lucas 1965), during spring, in May 2011, linked to commercial extraction times (April–June period). Samples were gathered from the rocks at low tide in natural areas, with similar (small) size, weight, and shape to minimize species differences in our results (Boyden 1977; Duquesne et al. 2004). Collected samples were placed into sealed polyethylene bags, transported at laboratory, rinsed, measured (length 4 ± 1 cm), weighed and deep frozen at -20 °C, and freeze-dried prior to chemical analysis.

The seawater temperature (T °C), pH and salinity, recorded *in situ* by means of electrodes are shown with geographical locations and sampling dates in Table 1.

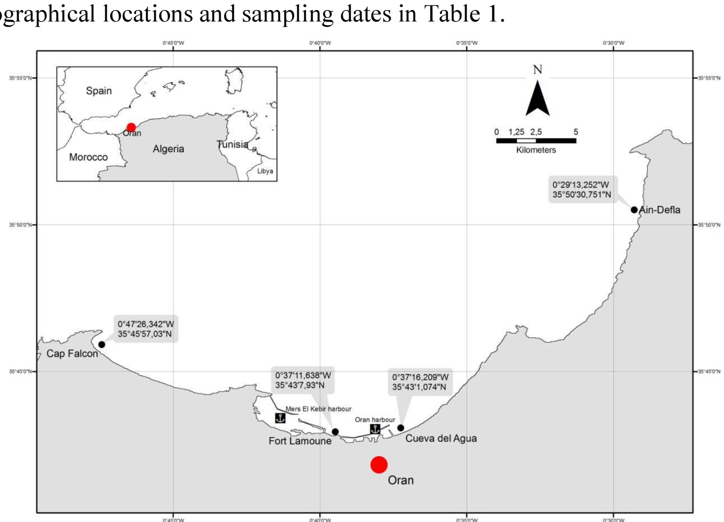

Fig. 1.Sampling sites of *Mytilus galloprovincialis* in Oran coastal waters.

2.2. Metals analysis in mussels

To analyse metals in mussels we used the same: (i) equal numerosity sample in each subgroup ($n_1=n_2= n_3=n_4=30$, where n_1, n_2, n_3 and n_4 are the number of samples of mussels picked up in Fort Lamoune, Cueva del Agua, Ain-Defla and Cap Falcon, respectively); (ii) the trace elements simultaneously determined, i.e. Pb, Cd, and Hg; (iii) the same analytical methods used for the trace elements considered here in order to avoid the variability due to different procedures; (iv) fresh samples available in both sites every time.

Mussel samples were digested with a mixture of HNO_3 and H_2SO_4 (for mercury) or HNO_3 only (for the other elements) in teflon digestion bombs. Hg was determined by cold-vapor atomic absorption spectrometry with Flow Injection. Cd and Pb were determined by flam spectrometry. Cconcentrations of all metals are expressed in µg/g dry weight of soft tissue. Reference material consisting of mussel tissue (SRM 2976) in provenance from the international agency of atomic energy of Monaco was digested and analyzed along with each sampled site.

3. RESULTS

3.1. Environmental parameters

Physico-chemical characteristics of the sampling sites are summarized in Table 1.The spectrum of physico-chemical conditions shows some regularity. Fort Lamoune and Cueva del Agua are influenced by freshwater (at sampling period), as reflected in low salinities <39 PSU and pH <8.

Table 1: Sampling dates and location with physical and chemical parameters recorded in water samples taken from Oran coast.

Sites	Date	Location	T °C	S (PSU)	pH
Fort Lamoune	May, 2	0°37'11,638"W : 35°43'07,930"N	23.5	38.4	7,82
Cueva del Agua	May, 3	0°37'16,209"W : 35°43'01,074"N	24	38.5	7,99
Ain-Defla	May, 4	0°29'13,252"W : 35°50'30,751"N	22.9	39	8,23
Cap Falcon	May, 5	0°47'26,342"W : 35°45'57,030"N	23,2	39	8,18

T: temperature; S: salinity; pH: Hydrogen potential;

3.2. Metal concentrations

Concentrations were expressed in µg/g dry weight (which corresponded to mg/kg d.w. or ppm d.w.). The experimental concentrations are resumed in Table 2. All sites showed a high values for Pb, Cd and Hg. Nevertheless, metal concentrations in mussels were variable evidence of bioaccumulation (Tab. 2).

Table 2: Trace elements concentrations (µg/g dry weight) in the soft tissues of *Mytilus galloprovincialis*.

Sites	Hg	Cd	Pb
Cueva del Agua	**2.27**	5.96	**8.27**
Fort Lamoune	0.58	**6.24**	7.79
Ain-Defla	0.49	2.97	6.34
Cap Falcon	0.24	2.81	7.72

For trace elements, maximum values are marked in bold.

Mean metal concentrations values decreased in the following order: Pb > Cd > Hg (Tab. 2). The highest values of Pb and Hg were found in Cueva del Agua; the 4 time upper peak concentrations of Hg and maximum Pb, respectively, (2.27 and 8.27 mg/kg d.w.) still obtained at Cueva del Agua emissary, while Cd presented higher concentrations in Fort Lamoune; where the highest concentration were registered (6.24 mg/kg d.w.) near Cueva del Agua (5.96 mg/kg d.w.) concentration is more than 2 higher concentrations than Ain-Defla and Cap Falcon (Tab. 2).

Metals concentration shows different mean or range of data reported for soft tissue of *Mytilus galloprovincialis*species all over the world (Tab. 3).

Table 3: Comparison of concentration data (mg/g d.w.), or (□g/g d.w.) "median" (means) and [minima-maxima] for soft tissues of wild *Mytilus galloprovincialis* obtained in the present study with literature data for *M. galloprovincialis* from various regions of the world.

Region Year	Pb	Cd	Hg	References
Oran coat, Algeria 2011	[6.34-8.27]	[2.81-6.24]	[0.24-**2.27**]	This study
Moroccan Atlantic coastal waters 1993–1997	-	(0.4)–(**8.0**)	-	(Chafik et al. 2001)

Algarve Coast of southern Portugal (Atlantic Ocean) 1994	No values	[1.3–3.1]	No values	(Bebianno and Machado 1997)
Shores of the Northern Adriatic Sea : Edible to Polluted mussels	(0.93)– (2.99) : [0.48- 5.74]	(0.24) –(0.31) : [0.12 - 0.42]	(0.029) -(0.032): [0.016- 0.063]	(Favretto et al. 1997)
North Adriatic Sea 1991–1999	(1.01)–(5.25)	(0.46)–(1.40)	(0.11)–(0.61)	(Besada et al. 2002)
Western Anatolia, Turkey: 1999-2000	**(17)–(63)**	-	-	(Uğur et al. 2002)
Balearic Islands : 2 of Menorca, and 2 of Mallorca(ppm dw) 1991 – 2005	(9.98) [3.3–**18.6**]	(0.66) [0.25–1.70]	(0.78) [0.13–2.21]	(Deudero et al. 2007)
Spain–South Mediterranean (in ppm dw) (clean area)	(2.45) [0.5–**11.2**]	(0.6) [0.2–1.25]	(0.15) [0.05–1.80]	(Benedicto et al. 2003)
France–Mediterranean(in ppm dw) (clean area)	(3.24) [0.1–**83.2**]	(0.87) [0.1–**36.2**]	(0.18) [0.02–1.24]	(RNO 1991)
France–Mediterranean (in ppm dw)(clean area)	(2.62) [0.1–**34.6**]	(0.9) [0.03–2.62]	(0.1) [0.03–0.6]	(RNO 2000)
France–Mediterranean (in ppm dw) (clean area)	(1.8[a]) [0.7–2.8]	(1.2[a]) [0.9–3.7]	(0.2[a]) [0.1–0.5]	(Andral et al. 2001)
France–Mediterranean (in ppm dw) (clean area)	(1.0[b]) [0.5–5.4]	(0.9[b]) [0.1–5.85]	(0.1[b]) [0.05–0.34]	(Andral et al. 2001)
Galician Rias (in ppm dw) (clean area)	[0.3–5.4]	[0.20–0.77]	[0.10–0.58]	(Beiras et al. 2003)
Galician Rias (in ppm dw) (clean area)	5.7–6.1	No values	0.58–0.63	(Beiras et al. 2003)
Spanish, Balearic Islands: 15 sites: (Western Mediterranean) 2005	[1.816- 3.252]	[1.556- 3.374]	[0.158- 0.256]	(Deudero et al. 2009)
Safi coastal waters, Morocco 2004–2005	(10.75) [0.1–**26.45**]	(9.92) [2.12-**34.71**]	(0.70) [0.01–**2.31**]	(Maanan 2007)
El Jadida coast, Morocco 2004–2005	[0.50–**34.2**]	[1.33–**25.3**]	[0.02–**2.3**]	(Maanan 2008)
Korean waters 1998–1999	[3.62–**52.7**]	[0.06–2.36]	[0.02–0.07]	(Szefer et al. 2004)
Goro Bay, Italy No years	[15.8–**29**]	[3.7–4.3]	[0.167–0.231]	(Locatelli 2003)
Spanish North Atlantic coast 1991–1999	[0.9–3.0]	[0.46–1.40]	[0.11–0.61]	(Besada et al. 2002)

For trace elements, exceed values are marked in bold.
[a] Standarised at condition index of 0.124 lg/g or ng/g dw.
[b] Standarised at condition index of 0.24 lg/g or ng/g dw.

In constancy, both Pb, Cd and Hg concentrations, six sites are lower than study site; Northern Adriatic Sea, North Atlantic coast 1991–1999; Edible to Polluted mussels (Besada et al. 2002; Favretto et al. 1997), or Spanish; 15 sites of Balearic Islands: (Western Mediterranean)2005(Deudero et al. 2007), and two clean area in France-Mediterranean (Andral et al. 2001), and Galician Rias (Beiras et al. 2003). But, metal concentrations of the two Moroccan coastal waters (2004–2005) are higher, for all considered metals; Safi, (Maanan 2007), and El Jadida (Maanan 2008) (Tab. 3).

3.2.1. Mercury, Our highest concentrations values [0.24-2.27] mg/kg d.w., of Hg concentrations was found. More than 4 higher concentrations differences were observed between, Cueva del Agua (2.27mg/kg d.w.) and sites without marked nearby pollution sources (cities, industries, emissary, etc.) with low Cd values in Fort Lamoune, Cap Falcon or Ain-Defla coasts, respectively: 0.58, 0.49, 0.24 mg/kg d.w., (Tab. 2).
According to our data, onlyMorocco2004-2005 coastal waters; Safi and El Jadida, (Maanan 2007, 2008) (Tab. 3), exceed Oran Hg concentration values (Tab. 3). Those Moroccan sites are more contaminated by all calculated metals;it means that, mercury is the lower contaminant in all Oran studied sites.

3.2.2. Cadmium, Higher ranges 2.81-6.24 mg/kg d.w., of Cd concentrations were found. More than 2 higher concentrations differences are observed between, the Cueva del Agua or Fort Lamoune emissaries, respectively, 5.96-6.24 mg/kg d.w., and sites without marked nearby pollution sources (cities, industries, emissary, etc.) with low Cd values in Cap Falcon or Ain-Defla coasts, respectively, 2.81-2.97 mg/kg d.w., (Tab. 2).

Cd concentrations levels are higher than those reported from other monitoring surveys at Portugal 0.46–1.25 mg/kg d.w., (Coimbra et al. 1991), France 0.17–3.03 mg/kg d.w., (Ifremer 2006), Baja California 0.43–11.6 mg/kg d.w., (Muñoz-Barbosa et al. 2000)), Algarve Coast of southern Portugal (Atlantic Ocean)[1.3–3.1] (Bebianno and Machado 1997), shores of the Northern Adriatic Sea : Edible to Polluted mussels [0.12 - 0.42] (Favretto et al. 1997), Balearic Islands 1991 – 2005 [0.25–1.70] (Deudero et al. 2007), Spanish, Balearic Islands: 15 sites: (Western Mediterranean) [1.556- 3.374] (Deudero et al. 2009). Korean waters [0.06–2.36] (Szefer et al. 2004), Goro Bay, Italy [3.7–4.3] (Locatelli 2003), and clean area of Spain–South Mediterranean[0.2–1.25] (Benedicto et al. 2003), or France–Mediterranean[0.03–5.85] (RNO 2000).But, lower than Moroccan Atlantic coastal waters (8.0 mg/kg (Chafik et al. 2001)), and clean area France–Mediterranean(in ppm dw) [0.1–36.2] (RNO 1991). So we can consider that Oran sites are clean in regards of Cd concentration (Tab. 3).

3.2.3. Lead The experimental range 6.34-8.27 mg/kg d.w., was homogenous and slightly lowers from Ain-Defla and Cap Falcon, respectively, 6.34 and 7.72 mg/kg d.w., to Cueva del Agua and Fort Lamoune, with highest measured values, respectively, 8.27 and 7.79 mg/kg d.w., (Tab. 2).
Comparisons with other reports about mussels revealed that Pb concentrations were lower than those of the Western Anatolia, Turkey (17)–(63) (Uğur et al. 2002)), Korean waters [3.62–52.7] (Szefer et al. 2004),Goro Bay, Italy [15.8–29] (Locatelli 2003),Spain Mediterranean area, 1.05–52.5 mg/kg d.w. (Rodríguez et al. 1997)), 4 sites of Balearic Islands [3.3–18.6] ppm dw. (Deudero et al. 2007), or clean area of Spain-South Mediterranean[0.5–11.2] ppm dw. (Benedicto et al. 2003) and France–Mediterranean[0.1–83.2] and [0.1–34.6] ppm dw (RNO 1991, 2000) (Tab. 3).So, it seems that Pb concentration leave Oran sites in clean situation.

3.4. Site comparison and classification with international quality criteria

To assess the different degrees of pollution, for different concentration ranges, international organism correspond a different degree/class of environmental pollution (Tab.3). The OSPAR, based on Background Concentrations (BCs) the concentration of a contaminant at a "pristine" or "remote" site based on contemporary or historical data' (Moffat et al. 2004), have been recently recommended for use throughout the OSPAR maritime area; BACs values in wild mussels are 0.090 mg/kg d.w. (dry weight) for Hg; 0.96 mg/kg d.w. for Cd and 1.3 mg/kg d.w. for Pb (Webster et al. 2009). US National Oceanic and Atmospheric Administration (NOAA) at the National Status and Trends 'Mussel Watch' Program assign three levels of contaminants : high, medium and low (Kimbrough et al. 2008). The Norwegian Pollution Control Authority (Norway) (Green et al. 2008; Molvær et al. 1997) shows five quality levels from Class I, 'insignificantly polluted', to Class V "extremely polluted".

Table 4: Pollution levels in wild mussels found in this study compared to international criteria (values in mg/kg dry weight). The sampling sites are indicating in parenthesis included within each class.

	JAMP(Joint Assessment and Monitoring Program)		
Contaminant	Not polluted	Polluted	
Mercury	0.01	(AD) (CF) (FL) (CA)	
Cadmium	0.003	(AD) (CF) (FL) (CA)	
Lead	0.1	(AD) (CF) (FL) (CA)	
	OSPAR (Oslo and Paris Commissions) upper limit for Class (site)		
Contaminant	Not polluted	Polluted	
Mercury	0.090	0.090 (AD) (CF) (FL) (CA)	
Cadmium	0.96	0.96 (AD) (CF) (FL) (CA)	
Lead	1.3	1.3 (AD) (CF) (FL) (CA)	
	Norway		
Contaminant	Moderate	Market	Severe
Mercury	0.5 (CF) (AD)	1.54 (FL)	4 (CA)
Cadmium	5 (CF) (AD)	20 (CA) (FL)	40
Lead	15 (CF) (AD) (FL) (CA)	40	100
	NOAA		
Contaminant	Low	Medium	High
Mercury	0.00–0.17	0.18–0.35 (CF)	0.36–1.28 (AD) (FL) (CA)
Cadmium	0–3 (CF) (AD)	4–9 (CA) (FL)	10–20
Lead	0–3	4–6	7–13 (AD) (CF) (FL) (CA)

Fort Lamoune (FL); Cueva del Agua (CA); Ain-Defla (AD); Cap Falcon (CF).

JAMP and OSPAR norms classed all sites as polluted. When, Norway international criteria according we have a moderate contamination of lead, cadmium concentration classified, Fort Lamoune and Cueva del Agua, respectively as market contaminations. But, Mercury concentration, raise contamination level of Cueva del Agua to severe contamination. Finally, for Norway, Ain-Defla and Cap Falcon showed a Moderate contamination, where Fort Lamoune exhibit Market and Cueva del Agua display Severe contamination. NOAA norms estimate that, all sites (Ain-Defla, Cap Falcon, Fort Lamoune and Cueva del Agua) display the maximum degree of contamination (high contamination). After All, JAMP, OSPAR for all metals or NOAA norms for lead are more rigorous and homogenous than Norway international criteria (Tab. 4).

4. DISCUSSION

4.1. Environmental parameters

In this study, pollutants were assessed at a sufficient scale level (40 km of coastline) to avoid the influence of factors such as variations in physicochemical characteristics and food availability in the studied zones. Thus, environmental parameters do not differ in terms of physico-chemical, which allows comparing mussels' bioaccumulation contaminants ability, as done in the same way, since sample period is the same, collected small mussels have relatively high concentrations of metals. Concentrations in mussels are for sites similar trophically-comparable with each other for a reliable representation of the contamination of an area and whatever local trophic resource (abundance or without food). Then, the spatial assessment of contamination levels in the environment can be made on the basis of bio accumulated concentrations for different sectors which are not necessarily all at the same tropic resource.

4.2. Metal concentrations

Untreated wastewater effluents from urban and industrial activities in coastal areas introduce significant amounts of heavy metals into marine environment, causing permanent disturbances in marine ecosystems, leading to environmental and ecological degradation (Boutiba et al. 2003).

The predominant origin of the metals in the coastal area is 1) the emissaries which might transport polluted water, coming principally from the manager and also industrial outcome, respectively, 69 704 and 24 935 (m^3/jour) (Sogreah ingénierie, 1998), 2) the fossil fuel due to boating activities and waste water emissary, close to harbour of Mer El Kebir and Oran city, 3) in addition to waste and petroleum burning (combustion processes), especially for mercury.

Distribution processes of Hg, Cd or Pb are not the same. Differences between Hg and Pb or Cd in seawater are due mainly to the fact that the distribution of Pb in the ocean is controlled by effluent and atmospheric deposition, the distribution of Cd is mainly controlled by upwelling and advection.

Hg levels are explained by the presence of a chlorine- alkali industry and a paper pulp factory, emitting to the sampling area. Significant quantities of mining and metallurgical wastes were stored in piles on the ground surface and both the release and dispersion of these materials through air and rain drainage can be an important source of Hg pollution.

The main sources of cadmium are the electrical industry, situated in Oran harbour. Other incriminate sources are petroleum combustion and chemical fertilizer.

The spatial Pb distributions were regulated by anthropogenic origin (inputs), affinity to plankton and removal processes. Cueva del Agua and Fort Lamoune, has an important harbours (boating), urban and industrial areas, these explains the high concentrations found at its closest sites. Values for Pb observed at sites located close to the largest urban and industrial areas, where two of the most important harbours are located (Oran, Cueva del Agua; and Mers El Kebir, Fort Lamoune, around 8.03 mg/kg d.w.), are similar to the other supposed clean (edible) sites Ain-Defla and Cap Falcon, around 7.03 mg/kg d.w.

The present results for trace and toxic metal concentrations in mussels of the investigated locations are compared also with the findings of different workers from Mediterranean Sea. Hg level is higher than find in Mediterranean coasts of Italy (Favretto et al. 1997; Locatelli 2003), Spain (Benedicto et al. 2003; Besada et al. 2002 ; Deudero et al. 2007) or France (Andral et al. 2001 ; RNO 1991, 2000) but still within the range obtained in morocco Atlantic coasts (Maanan 2007, 2008), while Cd and Pb results are in the same order obtained in other studies carried out elsewhere in the Mediterranean sea of the Iberian Peninsula, France, and Italy. Lead is less than concentrations locatein coastal water of Turkey (Uğur et al. 2002).

4.3. Site comparison and classification with international quality criteria

All sites exceeded the values for Hg, Cd and Pb compare to the neither OSPAR background/reference nor JAMP concentrations of metals in mussels to produce environmental quality criteria (Webster et al. 2009). According to these criteria, no case of poor conditions in the present study is shown due to heavy metal concentration. In contrast, Norway or NOAA reference concentrations of metals in mussels' status of Cd, Hg and Pb pollution seem too conservative to be applicable to Oran bay.

Metals in mussels may show a wide range of concentrations, depending on the anthropogenic impact "high concentrations are near gully hole". Mercury, cadmium and lead concentrations, respectively, 0.24-2.27, 2.81-6.24 and 6.34-8.27µg/g d.w., according to the evaluating Norway international criteria, contaminations were moderate to market. But, environmental impact was always high in NOAA norms.

In both norms, mercury produce a big damage on the environment quality, nevertheless for Norway norm lead is less contaminant (moderate contamination) as the Cadmium in NOAA (low to medium contaminations). In contrast, the Cadmium in shellfish-farming zone classification norm is the forbidden metal.

5. CONCLUSIONS

In general, the levels of the metals studied in wild mussels were lower for Cap Falcon and Ain-Defla coasts than for the others sampling points, Fort Lamoune and Cueva del Agua, close to the harbour and urban region which had larger concentrations and showed extremely high values of Hg and Cd. These sites were affected by: a very important industrialisation, iron and steel factories; an active boating harbour; and numerous industrial and domestic discharges, which caused the high levels of typically anthropogenic-related metals into mussels.

Hence, maximum concentrations for Hg and Cd in mussels correspond to the harbour area, where large mining facilities and/or processing chemical production of large industrial areas, exist for many years ago. On the contrary, some sampling points, far from human inputs seemed affected by the moderately upwelling (cadmium), phytoplankton transport (lead) and indirectly by fossil fuel emanate from boats and waste burning circulating through the air (mercury). Pb levels are regular from west to east. It seems related to the natural contents into the sea water and their distributions were very homogeneous throughout the four studied geographical regions. The Pb from all sites has one classification in each international monitoring and classifications were all sites show different water quality. Geological variability, stream or upwelling of Mediterranean waters near the studied Oran's coast does not lead to variations in background concentrations of this contaminant.

The results of this study support the need to complement current chemical monitoring of contaminant concentrations in Algerian coast in order to improve the ecological relevance of the patterns of pollution described, and to protect important marine resources from anthropogenic substances that will affect this bioindicator, which provide an ecologically-relevant and cost-effective tool to complement routine monitoring and analysis of chemical contaminants in the marine environment. Finally, efforts should be made to treat sewage effluents and industrial atmospheric residues.

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