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Diagnosis on the state of healthiness, quality of the coast and biological resources 'case of the Moroccan Atlantic coast' (City of El Jadida)

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Abstract – In this study, we present a diagnosis concerning the state of healthiness of the coast of the city of El Jadida by: characterisation of the various collectors rejected in sea without any preliminary treatment, measure of the physicochemical parameters of seawater from sampling stations, evaluation of the concentration of certain heavy metals (Cd, Cu, Zn, Fe and Mn) in four species of algae, which shows that metal contents vary according to the species and the sampling stations, measure of the metal content in mussels, which varies according to the site. A comparative study with the data of the literature shows that algae and mussels generally present values that are weaker than those coming from other geographical areas. ***To cite this article: A. Kaimoussi et al., C. R. Biologies 325 (2002) 253–260.*** © 2002 Académie des sciences / Éditions scientifiques et médicales Elsevier SAS

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Résumé – Diagnostic sur l'état de salubrité, de qualité du littoral et des ressources biologiques. Cas de la côte Atlantique Marocaine (ville d'El Jadida). Cette étude a permis de présenter un diagnostic sur l'état de salubrité du littoral de la ville d'El Jadida par : caractérisation des différents effluents rejetés en mer sans aucun traitement préalable, analyse des paramètres physicochimiques de l'eau de mer des stations de prélèvements, évaluation de la concentration de certains métaux lourds (Cd, Cu, Zn, Fe et Mn) chez quatre espèces d'algues, montrant que les teneurs en métaux varient en fonction de l'espèce et de la station de prélèvement, mesure de la teneur des métaux chez la moule, qui varie également en fonction des sites. Une étude comparative avec les données de la littérature montre que les algues et les moules présentent en général des valeurs plus faibles que celles provenant d'autres aires géographiques. ***Pour citer cet article : A. Kaimoussi et al., C. R. Biologies 325 (2002) 253–260.*** © 2002 Académie des sciences / Éditions scientifiques et médicales Elsevier SAS

concentration / métaux / algues / moules / littoral atlantique / Maroc

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. Version abrégée

Dans le cadre du programme scientifique de l'Institut national des recherches halieutiques relatif à la surveillance de la pollution chimique sur les côtes marocaines, cette étude se propose d'évaluer de façon qualitative la charge polluante des effluents de la ville d'El Jadida rejetés en mer sans aucun traitement préalable, de caractériser la qualité du milieu par l'analyse qualitative des eaux marines et d'évaluer le degré de pollution métallique dans des organismes vivants, les moules et les algues.

Les eaux usées sont en général très chargées en matière organique, en azote, en phosphore, en matière en suspension et en sels. L'importance de ces paramètres physicochimiques joue un rôle sur l'état biologique du milieu récepteur. Le pH dans les quatre stations S2, S3, S4 et S5 est inférieur à 8, indiquant une légère acidification du milieu. Les fluctuations de la salinité et l'oxygène dissous restent négligeables, traduisant l'effet diluant de l'océan et son pouvoir de réoxygénation.

Le dosage des métaux (Cd, Cu, Zn, Fe et Mn), dans quatre espèces d'algues (*Ulva lactuca*, *Gelidium pulchellum*, *Fucus spiralis* et *Bifurcaria bifurcata*) et la moule (*Mytilus galloprovincialis)* est réalisé à l'aide d'un spectromètre d'absorption atomique (Perkin Elmer 3100) équipé d'un four graphite (Perkin Elmer HGA-600/700).

La teneur en métaux des quatre espèces d'algues n'est pas similaire, *Ulva lactuca* et *Gelidium pulchellum* présentent une faible concentration en Cd, contrairement à *Fucus spiralis* et à *Bifurcaria bifurcata*, qui présentent des concentrations plus élevées. *Gelidium pulchellum* et *Ulva lactuca* présentent une concentration importante en Zn, Fe et Cu. Par ailleurs, *Fucus spiralis* est la seule espèce qui possède une concentration importante en Mn. La concentration des métaux lourds dans *Fucus spiralis* suit l'ordre Fe > Mn ≥ Zn > Cu > Cd, alors que dans *Bifurcaria bifurcata*, *Gelidium pulchellum* et *Ulva lactuca*, l'ordre des concentrations est Fe > Zn > Mn > Cu > Cd. En général, l'abondance des métaux dans les algues prélevées dans d'autres régions du monde suit l'ordre suivant Fe > Mn > Zn > Cu > Cd. La teneur des métaux lourds dans les algues de la côte d'El Jadida n'est pas excessive si on la compare à d'autres données de la littérature.

Les concentrations de Cd chez *Mytilus galloprovincialis* sont faibles pour toutes les stations d'étude, avec des valeurs souvent inférieures à 1 μg g^{-1} de poids sec. Le Cu pour les différentes stations est voisin de 10 μg g^{-1} en poids sec, ce qui est la valeur moyenne de Cu chez les bivalves. Le Zn et le Mn se répartissent dans les différentes stations étudiées de manière comparable. Les teneurs de Fe semblent être légèrement plus élevées dans la station S1. De plus, nous avons comparé nos données avec celles fournies par la littérature, pour les mêmes espèces ou des espèces voisines prélevées dans des zones polluées ou non. Les concentrations déterminées dans les moules de la côte d'El Jadida constituent fréquemment des valeurs intermédiaires entre les valeurs limites de la littérature.

1. Introduction

Coastal environments are subjected to trace metal contamination via inputs from main industrial and urban sources, and diffuse sources natural and atmospheric deposits that are transported via river discharge, oceanic dumping and Aeolian processes [1–3]. Trace metals deposited in coastal systems can become incorporated into the biota and may be influenced by chemical and biological processes in the water column, sediments and biota [2, 4, 5]. The release of large quantities of heavy metals by industries into the environment has resulted in a number of environmental problems [6].

Some marine organisms have the ability to accumulate water-borne chemicals, and therefore can be used to describe the environmental pollution or to monitor the level of contamination [7, 8]. The accumulations of heavy metals in some marine organisms, such as algae and molluscs, have been suggested as indicators of heavy metals contamination in the water column [2, 8–11]. Many algae and molluscs have wide distributions, extensive populations, sedentary nature and the ability to accumulate contaminants. Therefore, monitoring those bioaccumulators of heavy metals is useful as an ideal contamination index in the aquatic environment [10, 12, 13]. Many metals are biologically essential, but all have the potential to be toxic to biota above certain threshold concentrations [14].

The city of El Jadida, which has about 150 000 inhabitants and is considered as the second future industrial pole in Morocco, is undergoing a deep transformation because of the development of its agricultural, tourist and industrial activities, particularly those related to phosphate and the Jorf Lasfar harbour. These activities, which constitute henceforth the backbone of its economic boom, together with the growth of population, can affect the exploitation of its maritime resources (fishing, exploitation of algae, oyster farming, etc.), which are subjected to the fatal influence of numerous discharges (industrial, urban, agricultural...). This, of course, may have an impact on the quality of the maritime environment in the long term.

Our study is part of the framework of the scientific program of the National Institute of Halieutic Research concerning the monitoring of the chemical pollution in the Moroccan coasts. The aim of this study is to evaluate in a qualitative way the effect of the effluents of the city of El Jadida that are discharged in the sea without any preliminary treatment, to characterise the quality of the environment by the chemical analysis of seawater and to evaluate the degree of metal pollution in living organisms, like algae and mussels.

2. Material and method

The seaweeds, were sampled from the intertidal zone at five stations along the El Jadida coast of Morocco (Fig. 1). At each locality, about 10—15 algae were collected. The algae were cleaned of epiphytes and the fragments adhering to thalles, and rinsed with seawater. In the laboratory, the algae were rinsed with bidistilled water, dried at 70 °C for 48 h. Dried material was ground to a fine powder for mineralisation. Weighed samples (1 g) were digested in a mixture of $HCl–HNO_3–HClO_4$ acids [15]. The resulting residue was diluted to 50 ml with double distilled water. This solution was then filtered through a 0.45 µm cellulose nitrate filter (Whatman).

The mussels were collected from three sample stations in El Jadida Atlantic Coast (Fig. 1). At each locality, about 25—30 mussels, 25—30 mm shell length, were collected. After a 36 h purging period, the bivalves were rinsed in distilled water. All tissue samples for metal determinations were dried at 80 °C to a constant weight and then ground prior to digestion. Dried tissue samples (1 g) were digested in a mixture of $HNO_3—H_2SO_4—H_2O_2$ acids [16]. The resulting residue was diluted to 50 ml with double distilled water. This solution was then filtered through a 0.45 µm cellulose nitrate filter (Whatman).

Metal analyses were carried out by atomic absorption spectrophotometry (Perkin Elmer 3100) equipped with an oven with graphite (oven Perkin Elmer HGA-600/700). This procedure was tested with a certified sample of mussel MA-M-2/TM from the IAEA. The calculated margins of error in metal concentrations were between 6% and 15% for different metals [17, 18]. Several water quality and hydrological parameters were determined. Temperature, pH and salinity were measured in situ. Suspended matter levels were obtained by filtration of water samples through 0.45 µm cellulose nitrate filtration (Whatman). Dissolved oxygen, nitrite (NO_2^-) and orthophosphate (PO_4^{3-}) were obtained according to the method of Aminot and Chaussepied [19].

Algae and mussels were taken along the coast precisely near the large discharges of domestic and industrial waste water of the city (Fig. 1). These samples are made monthly at the level of the following stations: S1, located near the collector C1 ("collector receiving rain water", sample of mussels); S2, located near the collector C2 ("collector receiving a mixture of domestic and industrial waste water", sample of algae and mussels); S3, located near the collector C3 ("collector receiving a mixture of domestic waste water and a slaughterhouse", sample of algae and mussels); S4, located near the collector C4 ("collector receiving a mixture of domestic and medical waste water", sample of algae); S5, located near the collector C5 ("collector receiving domestic waste water", sample of algae); S6, situated in the beach of Sidi Bouzid (sample of algae).

3. Results

The characterisation of the discharges of the city is considered as a first step of diagnosis that shows the extent of the pollution and constitutes a basis of possible means and solutions that could reduce it.

The water analysed at the level of the effluents of El Jadida is generally very charged by organic matter, nitrogen, phosphorus, suspended matter (Table 1). The large amounts of these physicochemical parameters affect the biological state of the receiving environment (Table 2).

The study of the physicochemical parameters of seawater shows the quality of El Jadida seawater. The pH in the four stations S2, S3, S4 and S5 is lower than 8. This result indicates a small acidification of the environment compared to Sidi Bouzid (S6) seawater, with pH of 8.15, which is characterised by the absence of discharge of waste water.

4. Concentration of metals in algae

The metal accumulation in the algal tissue is presented in Table 3. The concentration of Cd is low in red algae *Gelidium pulchellum* and green algae *Ulva lactuca*, but high in brown algae *Fucus spiralis* and *Bifurcaria bifurcata*. The mean concentrations of Cd, Cu and Mn in *Gelidium pulchellum* and *Ulva lactuca* are similar. Mn concentrations are higher in *Fucus spiralis* and low in *Bifurcaria bifurcata*, *Gelidium*

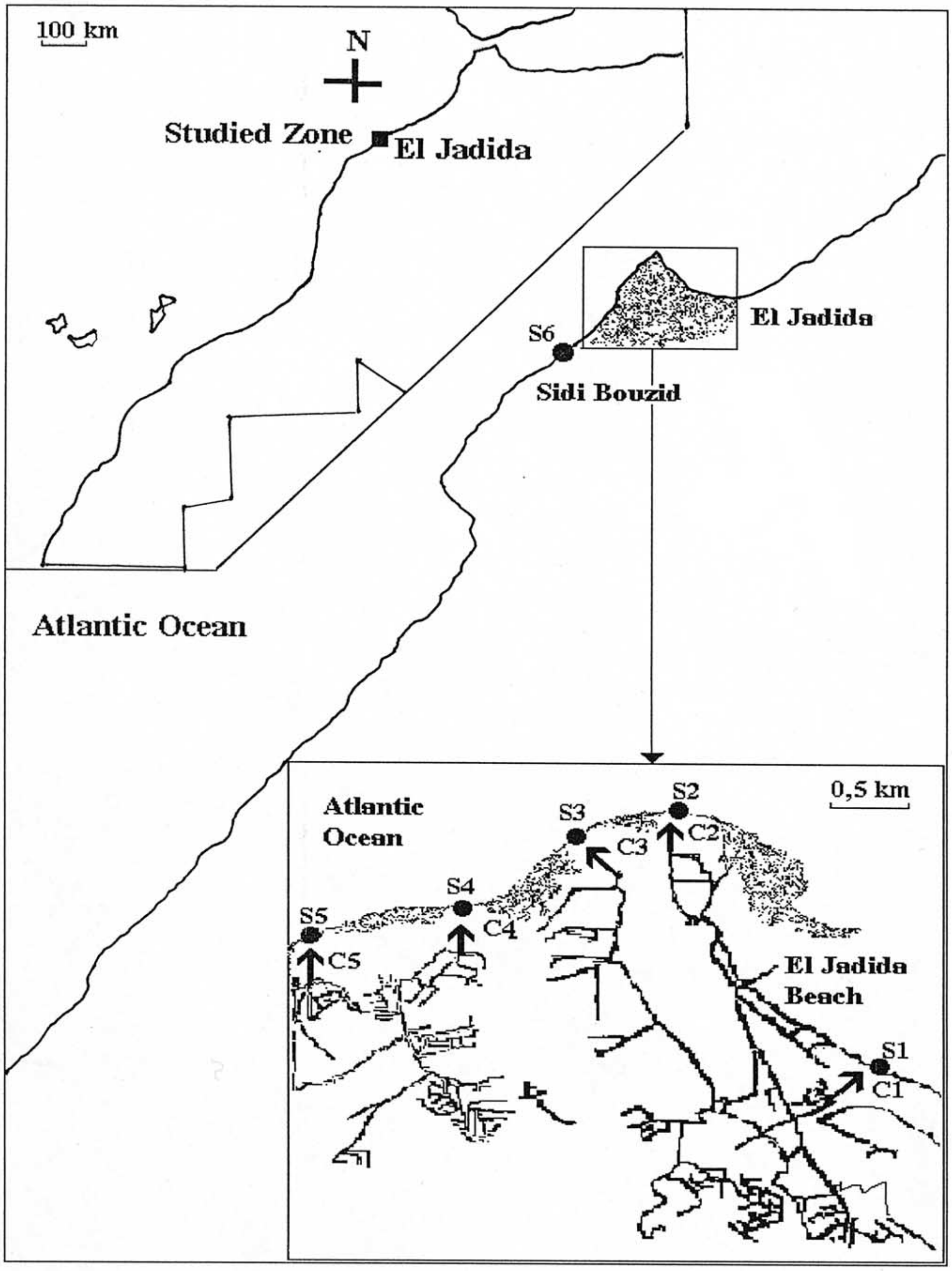

Fig. 1. Location of the sites of the samples of algae, mussels and the collectors of the city of El Jadida (Morocco).

Table 1. Average physicochemical quality of the discharges of the city of El Jadida (May–June 1995).

	pH	EC ($mS\ cm^{-1}$)	COD ($mg\ l^{-1}$)	NH_4^+ ($mg\ l^{-1}$)	NTK ($mg\ l^{-1}$)	PO_4^{3-} ($mg\ l^{-1}$)	Pt ($mg\ l^{-1}$)	SM ($mg\ l^{-1}$)	Cl^- ($mg\ l^{-1}$)	Ca^{2+} ($mg\ l^{-1}$)	Mg^{2+} ($mg\ l^{-1}$)	Na^+ ($mg\ l^{-1}$)	K^+ ($mg\ l^{-1}$)
C2	7,71	4,24	4317	76	122	4,9	8,6	529	1076	161	64	446	383
C3	7,6	2,37	1089	40	67	3,2	5,1	437	671	134	40	246	23
C4	7,43	2,38	801	51	86	3,5	5,9	424	711	121	44	232	43
C5	7,69	2,62	723	39	78	3,4	5,1	222	756	139	42	234	39

EC: Electric conductivity; COD: chemical oxygen demand; NTK: Kjeldahl nitrogen; PO_4^{3-} orthophosphate; Pt: total phosphate; SM: suspended matter.

Table 2. Average physicochemical quality of seawater of the coastal zone of the city of El Jadida (means, standard deviation and ranges).

Studied stations	pH	Salinity	Dissolved O_2 ($mg\ l^{-1}$)	SM ($mg\ l^{-1}$)	PO_4^{3-} ($\mu g\ l^{-1}$)	NO_2^- ($\mu g\ l^{-1}$)
S1	8,04 ± 0.14	29,97 ± 2,64	7,07 ± 0,72	45,52 ± 12,49	97 ± 93	25 ± 9
	(7,80–8,31)	(26,15–34,15)	(6,02–8,12)	(26,25–67,73)	(20–320)	(13–41)
S2	7,96 ± 0,34	27,25 ± 2,80	6,28 ± 0,64	79,72 ± 17,79	555 ± 530	62 ± 53
	(7,03–8,31)	(21,18–30,87)	(5,29–7,68)	(54,07–107)	(61–1940)	(14–160)
S3	7,93 ± 0,25	26,41 ± 2,61	5,67 ± 0,97	65,88 ± 14,56	1189 ± 832	56 ± 32
	(7,40–8,25)	(22,39–30,85)	(3,77–7,21)	(44,66–89,08)	(67–2721)	(3–122)
S4	7,89 ± 0,17	29,19 ± 1,98	6,21 ± 1,17	41,80 ± 4,58	129 ± 59	17 ± 3
	(7,66–8,20)	(26,15–32,85)	(3,77–7,43)	(35,00–51,00)	(50–215)	(12–21)
S5	7,93 ± 0,14	30,14 ± 2,43	7,23 ± 0,46	36,68 ± 3,56	77 ± 32	16 ± 8
	(7,75–8,15)	(26,41–33,9)	(6,20–7,94)	(30,00–42,00)	(30–121)	(4–31)
S6	8,15 ± 0,16	33,14 ± 2,65	7,59 ± 0,46	33,10 ± 5,79	94 ± 258	8 ± 3
	(7,94–8,5)	(28,05–34,95)	(6,60–8,11)	(24,00–43,00)	(1–1002)	(3–14)

pulchellum and *Ulva lactuca*. The concentrations of Fe are low in *Bifurcaria bifurcata* but high in *Fucus spiralis*, *Gelidium pulchellum* and *Ulva lactuca*.

5. Concentration of metals in mussels

The metal accumulation into mussel tissue is presented in Table 4. The concentrations of Cd in mussels are low in all the studied stations with values often lower than 1 $\mu g\ g^{-1}$ of dry weight. Mean concentrations of the essential elements Zn and Mn range from 258 to 312 and from 8.39 to 10.46 $\mu g\ g^{-1}$ dry weight, respectively. Cu is also an essential element in marine invertebrates, being associated with numerous metalloenzymes and metalloproteins [20]. Cu concentrations range from 7,36 to 8,51 $\mu g\ g^{-1}$ dry weight, maximum

Table 3. Metal contents ($\mu g\ g^{-1}$ dry weight) in four species of algae collected from five stations of El Jadida (means, standard deviation and ranges).

		Cd	Cu	Zn	Fe	Mn
Fucus spiralis	S2	3,24 ± 1,65	5,30 ± 4,21	135 ± 86	211 ± 61	105 ± 26
		(1,25–6,80)	(1,30–16,05)	(43–191)	(122–296)	(33–155)
	S4	3,00 ± 1,82	6,31 ± 2,92	102 ± 35	315 ± 107	235 ± 53
		(1,20–8,10)	(2,70–12,10)	(32–161)	(170–500)	(144–309)
	S5	3,10 ± 1,72	5,77 ± 2,55	108 ± 41	269 ± 94	193 ± 61
		(1,00–6,50)	(1,30–10,60)	(46–202)	(92–439)	(99–295)
	S6	5,78 ± 2,16	8,05 ± 3,92	87 ± 86	152 ± 82	66 ± 17
		(3,00–9,85)	(2,40–13,50)	(40–148)	(70–365)	(47–99)
Bifurcaria bifurcata	S5	2,25 ± 1,20	4,65 ± 2,70	63 ± 28	86 ± 27	6,51 ± 1,59
		(0,33–4,65)	(0,65–9,35)	(11–112)	(49–162)	(4,50–9,75)
	S6	3,29 ± 2,44	3,58 ± 2,19	61 ± 36	75 ± 42	5,80 ± 1,37
		(1,00–9,00)	(1,00–9,30)	(11–129)	(29–225)	(3,70–8,70)
Gelidium pulchellum	S2	0,93 ± 0,91	9,62 ± 4,19	254 ± 55	481 ± 184	23,10 ± 4,53
		(0,09–2,91)	(3,95–21,20)	(146–329)	(282–796)	(18,55–34,90)
	S3	0,69 ± 0,65	10,57 ± 4,38	277 ± 75	335 ± 81	27,41 ± 5,61
		(0,08–2,00)	(4,03–18,50)	(152–425)	(167–477)	(17–37,50)
	S5	0,94 ± 0,78	6,67 ± 3,66	206 ± 65	281 ± 100	19,09 ± 3,25
		(0,09–2,50)	(2,65–15,90)	(80–305)	(166–561)	(14,56–27,95)
	S6	0,93 ± 0,69	6,88 ± 4,29	171 ± 42	152 ± 84	14,97 ± 2,25
		(0,10–2,20)	(2,68–18,75)	(87–243)	(72–359)	(10,50–18,50)
Ulva lactuca	S2	1,43 ± 0,80	14,55 ± 7,53	265 ± 92	760 ± 420	29,18 ± 8,75
		(0,09–2,90)	(5,30–29,50)	(72–380)	(333–1949)	(17,50–46,35)
	S4	1,32 ± 0,64	11,12 ± 7,23	259 ± 77	404 ± 96	25,56 ± 6,75
		(0,10–2,50)	(3,9–30,80)	(97–398)	(238–599)	(16,00–39,00)
	S5	1,29 ± 0,82	14,73 ± 11,26	208 ± 94	354 ± 191	21,66 ± 7,58
		(0,09–2,60)	(5,30–42,90)	(69–348)	(113–735)	(13,90–42,70)
	S6	1,92 ± 1,05	11,32 ± 4,13	190 ± 69	269 ± 181	16,02 ± 7,21
		(0,50–3,50)	(4,0–26,80)	(73–316)	(63,4–626)	(6,79–33,40)

Table 4. Metals contents (µg g^{-1} dry weight) of mussels *Mytilus galloprovincialis* collected in three stations of the city of El Jadida (means, standard deviation and ranges). LD: Limits of detection.

	Cd	Cu	Zn	Fe	Mn
S1	1,38 ± 0,74 (< L.D–2,30)	7,36 ± 2,04 (5,32–13,40)	258 ± 92 (148–482)	353 ± 166 (117–789)	10,46 ± 3,43 (5,1–17,6)
S2	1,45 ± 0,76 (< L.D–2,50)	7,76 ± 1,90 (4,40–10,70)	299 ± 96 (160–461)	288 ± 107 (165–557)	8,39 ± 3,53 (4,90–17,60)
S3	0,98 ± 0,77 (< L.D–2,00)	8,51 ± 2,56 (5,36–14,70)	312 ± 107 (170–535)	294 ± 104 (141–486)	8,80 ± 3,01 (5,95–13,95)

levels being observed in S3. Mean concentrations of Fe ranged from 288 to 353 µg g^{-1} dry weight.

6. Discussion

This study represents the first work on seaweed metal concentration in polluted and non-polluted intertidal areas of El Jadida. Due to the lack of previous studies on background chemical concentration in natural seaweed populations, these results represent a baseline for the level of pollutants in four seaweeds in El Jadida. Our results show variability along El Jadida coast in metal concentration within and between seaweed species and sampling sites. The strong concentrations of Cd obtained in algae taken in Sidi Bouzid's zone, could be related to the abundance of this metal in seawater due to coastal upwelling responsible for the rise of deep waters that are especially rich in trace metals, including Cd [21]. Although the metal contents of seaweeds are subjected to a wide range of variations, a trend in concentration of Fe > Mn > Zn > Cu > Cd in seaweeds was observed along El Jadida coast. Seaweeds from other areas were also found to accumulate more Mn than Zn and Cu [22, 23].

The high Fe concentration found in all the seaweeds as compared to the other trace metals, e.g. Mn, Zn and Cu, is probably due to several factors: the established need for the iron normal growth of marine plants, the ability of most algal species to biomagnify iron from the surrounding environment, and the contamination from industrial and other operations [24].

The four species of algae studied (*Fucus spiralis*, *Bifurcaria bifurcata*, *Gelidium pulchellum* and *Ulva lactuca*) present different variations of concentration of metals. This difference can be attributed to the ecology and the morphology of the plant (structural tissue, sites of fixation and the interaction of metals for the fixation in anionic sites) [25]. The trace metals contained in the tissues of algae also depend on the period of dumping and exposure of algae [26].

Studies reported by Mariani et al. [27] have revealed a structural base for the distribution of cations in levels of the cellular walls of the algae of the Adriatic. Difference between studied species is based on the location of sites bearers of cations at the level of the cytoplasm (apoplast). The resemblance between the taxonomic groups can be due to a similar structure of the cellular walls and to the chemical characters of their negatively charged polysaccharides.

Comparison with previous studies in this coast is difficult due to the absence of published data (e.g. *Bifurcaria bifurcata*, *Gelidium pulchellum*). However, the metal concentrations recorded in this study, particularly in *Fucus spiralis* and *Ulva* lactuca, are low. Considerably higher concentrations of Zn, Mn, Fe and Cu have been reported about other algal species from various areas [28–32].

The concentration of heavy metals determined in mussel *Mytilus galloprovincialis* is shown in Table 4. The comparison of our results with the value of Cd in the limit concentrations proposed by the agreements of Paris of 1994 (strong level of Cd: > 5 µg g^{-1}) and the value guides of English Standards–Guidelines (expected levels: 2 µg g^{-1} for Cd) shows that the obtained value is very low. Cu in the various stations is about 10 µg g^{-1} of dry weight, which is Cu average value for bivalves according to Bryan [33]. Generally, the order of concentration of highly toxic metals in mussel examined is Fe > Zn > Mn > Cu > Cd.

The metal concentrations in *Mytilus galloprovincialis* follow the cycle of reproduction. Generally, all the elements analysed, with the exception of Cd, show two major periods of strong concentrations: end of winter–beginning of spring and end of summer–beginning of autumn [15, 18]. Mean concentrations of Cd, Cu, Zn, Fe and Mn were found to vary from 0.98 to 1.45, 7.36–8.51, 258—312, 288—353 and from 8.39 to 10.46 µg g^{-1} of dry weight, respectively. Comparing these values with other reported concentrations of heavy metals in mussels from data with those supplied by the literature for the same species, the concentrations determined in the mussels of coast of El Jadida are similar to (or lower than) those reported in the literature [34–47].

7. Conclusion

This study has allowed us to estimate in a qualitative way the wastewater of the city of El Jadida thrown out in the sea without any preliminary treatment.

– The physicochemical study of the parameters of seawater has informed us about the current state of the quality of the seawater of the city.

– The study of the accumulation of five heavy metals (Cd, Cu, Zn, Fe and Mn) in four species of algae of the city of El Jadida (*Fucus spiralis*, *Ulva lactuca*, *Gelidium pulchellum* and *Bifurcaria bifurcata*) shows that metal contents vary according to the nature of the species, and the stations of the samples. The presence of heavy metals in these algae is relatively lower than that found in other regions of the globe.

– The study of the concentrations of five heavy metals (Cd, Cu, Zn, Fe and Mn) has allowed us to verify the existence of the variations of the concentration of metals according to the site of sample, and to compare the level of these pollutants with other regions of the globe. The concentrations of metals in the mussel of the genre *Mytilus galloprovincialis* constitute intermediate values between the limit values of the literature.

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