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The Bioremediation Potential of *Ulva lactuca* (Chlorophyta) Causing Green Tide in Marchica Lagoon (NE Morocco, Mediterranean Sea): Biomass, Heavy Metals, and Health Risk Assessment

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Abstract: Pollution by heavy metals is one of the most serious issues in the world, and the principal sources are manufacturing, fertilizers, mining, pesticides, transport, and wastewater discharge. In this study, the presence of macroelements (Nitrogen (N) and Phosphorus (P)) and heavy metals (Chromium (Cr), Nickel (Ni), Cadmium (Cd), Iron (Fe), Zinc (Zn), Lead (Pb), Cooper (Cu), and Manganese (Mn)) in the green tide caused by the green seaweed *Ulva lactuca* from Marchica lagoon (NE-Morocco, Mediterranean) was evaluated. The mean values of P and N in the algae were 1773.33 mg·kg $^{-1}$ and 44.4 g·kg $^{-1}$, respectively. The heavy metals have mean values following this descending sequence: Fe > Mn > Zn > Cu > Ni > Pb > Cr > Cd. This finding has suggested that *Ulva* has the strongest affinity to Fe and Mn among the metals examined. Mn, Fe, and Pb recorded the highest bioconcentration factors (BCFs), which were 1687, 1656, and 1643, respectively. Regarding their contribution to the Recommended Dietary Allowance (RDA), Fe showed a contribution of 13.58% to the RDA, while that of Mn varied between 4.42 % and 28.42%. The health risk assessment did not indicate any hazard related to the ingestion of *Ulva lactuca*. Therefore, this study suggests that *Ulva lactuca* in the Nador lagoon has the potential to bioaccumulate heavy metals and mitigate eutrophication.

Keywords: *Ulva lactuca*; seaweeds; Marchica; bioaccumulation; pollution; heavy metals; eutrophication; phosphorus; nitrogen

1. Introduction

Coastal zones are increasingly subject to degradation due to pollution caused by human activities [1]. Wastewater containing various concentrations of heavy metals, persistent organic pollutants, and nutrients is discharged into coastal areas, causing environmental degradation [1]. Due to the high levels of trace elements detected mainly in the Mediterranean Sea [2,3], monitoring the environmental state of coastal zones is important for better management of marine ecosystems and for the conservation of marine ecosystems and associated biodiversity [4]. Dried or fresh macro and microalgae are widely used for their ability to remediate different kinds of pollution, either in the laboratory or in the field [5–8].

Pollution by heavy metals is among the most serious environmental issues in the world, and the principal anthropogenic sources are mining, manufacturing, fertilizers, pesticides, discharges of sewage, and transport [9]. Toxic heavy metals such as Cd, Hg, Pb, As, Co, Ni, and Cr in marine ecosystems, even at small levels, pose a serious risk to the entire marine environment [10].

One promising technique, phycoremediation (remediation using algae), and another, phytoremediation (remediation using plants), are currently accepted worldwide as the most environmentally friendly and cost-effective methods for remediating water and soil [11]. The main sources of phosphorus are urbanization, wastewater discharges, septic tanks, and the use of synthetic fertilizers and animal manure in agriculture [12–14].

In different parts of the world, various species of seaweed have been proposed as organisms for biomonitoring of heavy metal pollution in coastal zones [15]. In this regard, many studies have concluded that *Ulva lactuca* has many characteristics that make it a good candidate for environmental applications: its wide distribution, high growth rates under normal conditions and in eutrophic waters, resistance to high salinity variations, high rates of nutrient uptake, and tolerance to different pollutants under toxic conditions [1]. *Ulva lactuca* is a green marine macroalga (Chlorophyta), very common in coastal zones, which has several interesting characteristics for water remediation. Among other characteristics, it is perfectly adapted to the variations of salinity caused by tides in estuaries with moderate eutrophication conditions [16,17]. It has been widely studied for its contaminants accumulation, as a bioindicator, as well as for its restoration capabilities [1]. Several studies have previously reported the use of *Ulva lactuca* and other species as bioindicators of metal pollution [1,4,18–25]. Nitrogen and phosphorus are the two main nutrients causing eutrophication [26]. The nitrogen cycle is more complex than that of phosphorus. Nitrogen can enter and leave the water body as free nitrogen gas through atmospheric exchange; phosphorus, on the other hand, can enter the aquatic environment through precipitation, dry deposits, and sediments. The phosphorus content is considered the critical variable for the control of eutrophication in a marine environment such as lakes. The total phosphorus content includes absorbed, particulate organic, soluble organic, and inorganic phosphorus [26].

In aquatic environments, the sources and the evolution of nutrients are defined by their biogeochemical cycle. The exchange of these elements takes place through two main pathways [27]: (a) A hydrogeochemical pathway characterized by external inputs in the form of freshwater or internal inputs by marine waters and exports characterized by outflows of marine waters and losses in gaseous forms. (b) A biological pathway where the imports and exports of elements are done via processes of assimilation, excretion, and transfer to higher trophic levels.

In the context of this study, it is clearly evident that the Nador lagoon has been subjected to high anthropogenic pressure for several years and that the aquatic ecosystem in which macroalgae have been collected has been contaminated by heavy metals and eutrophication [14,28,29] in several areas. However, only a few studies have been conducted on heavy metal contamination of water and sediment [28,30]. However, no studies have been conducted on the accumulation of heavy metals in the most common seaweed species occurring naturally or farmed in the Marchica lagoon. Therefore, the present study focuses on the level of metal contamination in *Ulva lactuca*: a macroalga causing green tides in the Marchica lagoon. Maicu et al. [31] reported that water renewal time in the sampling area is less than 20 days. To highlight the implication of these algae in the bioremediation of pollution, the bioconcentration factor (BCF), which is the ratio between the metal content in *Ulva* and the concentration of the same metal in seawater [32,33], was calculated using the average values of the heavy metal results from the lagoon waters [28].

This study aimed to (1) assess the presence of heavy metals (Fe, Zn, Mn, Cu, Ni, Cr, Cd, and Pb) and macroelements (P and N) in the green seaweed *Ulva lactuca* from Marchica lagoon (NE-Morocco, Mediterranean), to (2) calculate the contribution of *Ulva lactuca* to the Recommended Dietary Allowance (RDA), and to (3) assess the health risk using several indices including targeted hazard quotient (THQ) and hazard index (HI) [34,35] due to consumption of this seaweed as human food or animal feed.

2. Materials and Methods

2.1. The Study Area

The Marchica lagoon is 25 km long, 7.5 km wide, and has an estimated surface area of about 115 km^2, making it one of the largest coastal lagoons in the Mediterranean. It is located in the northeast of Morocco between the "Cap des trois fourches" and the "Ras Kebdana" (Figure 1).

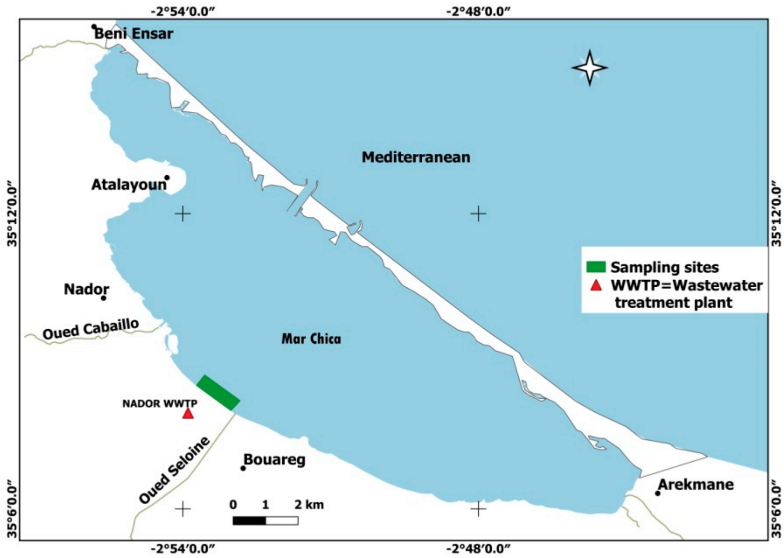

Figure 1. Locations of sampling sites in the study area.

2.2. Sample Collection, Preparation, and Analysis

A sampling mission was conducted in July 2021. The seaweed was collected from the bottom using a quadrat (0.5 m × 0.5 m) to estimate the total biomass and then was washed carefully with seawater on site. The biomass obtained from each quadrat was transferred to plastic bags and taken to the laboratory. To remove residual water, the samples were dried at 60°C until the material reached a constant dry weight [36] to determine the percentage of the dry matter (DM). The sample comprised three independent samples from three different sites in the green tide of *Ulva lactuca*. In situ, the environmental variables of water temperature, dissolved oxygen (DO), pH, turbidity, and chlorophyll (a) were measured by a multi-probe device. The collected water samples were also analyzed for ammonium (NF T90-015), total phosphorus (TP), nitrates, and nitrites [37]. Dissolved inorganic nitrogen (DIN) is the result of the nitrate added to the nitrite and the ammonium.

2.3. Metal Analysis Description

All chemical reagents used in the analysis were of analytical reagent grade. Nitric acid (65%), Lab Expert, hydrogen peroxide (30%), Flukaand hydrochloric acid (37%) Fluka were used for algae digestion. A multi-element stock standard solution, Sigma Aldrich (Periodic table mix 1 for ICP) 10 mg/L^{-1}, was purchased for preparing working standard solutions after appropriate dilution. A high-pressure laboratory microwave oven (Milestone Ethos UP, Italy) was used for the microwave digestion of algal samples. Weighed seaweed powder was transferred to 50 mL Teflon containers of the system digestion and a solution of 8 mL HNO_3 and 2 mL H_2O_2 was added. Microwave digestion was carried out with the following temperature program: 30 min ramping to 210 °C and 20 min holding at 210 °C (1800 W in both cases). After completion of the procedure, the digested samples were transferred after cooling to volumetric flasks, 2 mL of concentrated hydrochloric acid was added, and the samples were adjusted to a final volume of 50 mL with MilliQ water. Blank samples were subjected to the same procedure. The digestion procedure was performed in duplicate for each algal sample. The determination of heavy metals was performed using an Agilent 5100 simultaneous vertical dual view inductively coupled plasma optical emission spectrometer (ICP-OES). Instrumental parameters (Table 1) for ICP-OES measurements of studied elements were as follows: RF incident power (1.2 kW), plasma argon flow rate (12 L·min^{-1}), auxiliary argon flow rate (1 L·min^{-1}), nebulizer argon flow rate (0.7 L·min^{-1}), using concentric nebulizer, cyclonic double passspray chamber, and axial viewing. Three replicates were performed.

Table 1. Emission wavelengths and the detection limits of the analyzed parameters.

Metals	Emission Wavelengths (nm)	Detection Limits (μg·L^{-1})
Cd	214.439	0.3
Cr	267.716	1.0
Cu	327.395	1.0
Fe	238.204	1.0
Mn	257.610	0.3
Ni	231.604	3.0
Pb	220.353	3.0
P	213.618	10.0
Zn	13.857	1.0

2.4. Health Risk Assessment

The bioconcentration factor was calculated as the ratio between the metal concentration in *Ulva lactuca* and the content of the element in seawater [32,33]. An assessment of potential risk to human health was determined based on exposure dose, the targeted hazard quotient (THQ), and hazard index (HI) described by US EPA's IRIS database [34,35,38].

The HI was calculated from the concentration of each metal in the samples of *Ulva lactuca* along with standard values of US EPA (2013) guidelines [38].

Based on the US EPA (2013) guidelines, HI < 1 indicates that there is no risk to human health [34,35].

2.5. Determination of Intake

The determination of the dietary intake requires the calculation of the estimated daily intake (EDI) [39], which is obtained as follows:

$$\text{EDI (mg/day)} = \text{content of each metal (mg·kg}^{-1}\text{) dry weight} \times \text{average consumption (kg·day}^{-1}\text{)}. \quad (1)$$

The contribution percentage is calculated as follows [39]:

$$\text{Contribution percentage (\%)} = ((\text{EDI (mg·day}^{-1}))/(\text{Guideline value}))/100 \quad (2)$$

The Recommended Dietary Allowance (RDA) was calculated considering the percentage contribution of a 5.2 g portion of dry seaweed [40].

2.6. Data Analysis

To explore the relationship between trace and major elements in all samples studied, Pearson's correlation analysis was performed. The bioconcentration factor (BCF), which is the ratio between the concentration of each metal in *Ulva* and the concentration of the same element in seawater [32,33], was calculated to highlight the implication of these algae in the bioremediation process. ANOVA test was used to determine if the difference between the mean values of the biomass is statistically significant. The correlation of the Pearson and ANOVA tests was performed in SPSS 26.0 software. The map of the lagoon was produced with QGIS software.

3. Results and Discussions

3.1. Physicochemical Parameters of Water and *Ulva lactuca*

The results of the physicochemical parameters of water are listed in Table 2. These results show a remarkable variation in chlorophyll and turbidity. The results of oxygen, temperature, pH, and salinity in the sampling sites did not show large variations, with a high temperature (30 °C), a slightly basic pH, high oxygenation, and salinity close to the open sea values. In this sampling area where algal blooms appeared, a previous study by [14] on the trophic status of the lagoon water showed that the trophic index was between 4 and 6, indicating a mesotrophic to eutrophic condition. The overall quality of the lagoon's water was generally good and improved after the opening of the new pass with the Mediterranean Sea [14]. This new inlet has improved water exchange and hydrodynamics in the lagoon; however, nutrient discharges from agricultural activities, sewage treatment plants, and watersheds are still significant, as reported by [28] in this area.

Table 2. The results of physicochemical and nutrient parameters in water.

T°	Turbidity	Salinity	pH	DO (mg·L $^{-1}$)	Chlorophyll a (µg·L $^{-1}$)	DIN (mg·L $^{-1}$)	PT (mg·L $^{-1}$)
30.60 ± 0.61	20.64 ± 17.09	35.64 ± 0.62	8.24 ± 0.05	9.72 ± 3.81	206.24 ± 164.1	0.09 ± 0.006	0.45 ± 0.05

The results of biomass from the green tide caused by *Ulva lactuca* during July 2021 are listed in Table 3. No significant difference was observed between sites ($p > 0.05$). This green tide covers an area of 4 km long, 200 m wide, and an average depth of 2 m. The green tide of *Ulva* (Figure 2) is a real threat to other algae in this area.

Table 3. Biomass ($p > 0.05$) of *Ulva lactuca* from the green tide that occurred during July 2021.

Sampling Sites	N° of Quadrat	Total Fresh Weight (kg)	Sub-Sample Fresh Weight (g)	Sub-Sample Dry Weight (g)	Dry Matter (%)
Site 1	1	2.56	250	28.76	11.50
Site 2	2	3.10	250	32.18	12.87
Site 3	3	3.55	250	32.84	13.14
Mean values (±Sd)		3.07 ± 0.49	250	31.26 ± 2.19	12.50 ± 0.87

Figure 2. Photo showing the Bloom of *Ulva lactuca* in Marchica lagoon during the study period.

This bloom of green algae has been reported in the Bouareg zone. In this area, and in the framework of "integrated coastal area management," the fishers' community has received a grant for seaweed farming, especially for *Gracilaria*, from the "Global Environment Fund" and the World Bank. Blooms of *Ulva lactuca* have been reported in this *Gracilaria* farm and would be a source of nutritional competition in favor of *Ulva lactuca* and would cause problems to the algae farm by clogging the culture nets.

Our results showed that the critical nitrogen level, the nitrogen content of the tissue at which growth will be below the maximum level for a species [41], is higher than the 3.2% reported by [42] for *Ulva lactuca.* Thus, our observations of *Ulva* species proliferation in Marchica lagoon during the summer are in agreement with the results of [43], who showed that a strong association exists between the warmest sites and the highest biomass of *Ulva prolifera*, while pH and salinity are not considered factors explaining the spatial variability of this species' growth. Under experimental conditions, [44] found that both light and nitrate concentrations affected the pigment composition of *Ulva lactuca* and, consequently, the nitrogen content. A higher growth rate and consistently higher biomass yield have also been reported in *Ulva lactuca* fertilized with ammonium than with nitrate [45]. In addition, Li et al. [46] showed that the nitrogen and phosphorus content of seawater can significantly increase the growth rate and the fresh weight of *Ulva prolifera* and their carbon uptake through photosynthesis.

During the study period, no algal blooms were reported in other locations in the lagoon. The bloom observed in the sampling area might be caused by wastewater discharges and agricultural runoff [47]. This area of Bouareg is characterized by moderate levels of the trophic index [14], and the occurrence of *Ulva* bloom was expected, as previously reported by Li et al. [46], who indicated that the algal bloom is a nuanced result of the eutrophication process. Choi and al [48] reported that longer poor water exchange in coastal zones and continuous supply of submarine groundwater discharge with high content of dissolved inorganic nitrogen are among the factors controlling the growth and the extension of *Ulva* blooms.

The matrix of Pearson's correlations is summarized in Table 4. Positive correlations were found between the following pairs: Ni–Mn, Ni–Cu, Fe-Zn, Cu-Mn, and Cu–Fe, indicating similar accumulation behavior of those elements in *Ulva lactuca* [34], and negative correlations between Cr-Fe, Cr-Zn, and Cr-Cu without significance ($p > 0.05$). These findings suggested that the two combined metals exhibited comparable bioaccumulation behavior in seaweeds [49].

Table 4. Correlation matrix of the analyzed metals.

	Pb	Ni	Zn	Cu	Mn	Fe	Cr
Pb	1.0						
Ni	0.115	1.0					
Zn	0.567	0.883	1.0				
Cu	0.468	0.932	0.993	1.0			
Mn	−0.022	0.991	0.811	0.874	1.0		
Fe	0.807	0.680	0.944	0.900	0.573	1.0	
Cr	−0.684	−0.803	−0.989	−0.965	−0.714	−0.983	1.0

3.2. Heavy Metals in Water and Ulva lactuva

The bioconcentration of Pb, Cr, Zn, Cd, Mn, Cu, Ni, and Fe by *Ulva lactuca* samples collected from the Marchica lagoon are depicted in Table 5. The phosphorus mean was 1773.33 mg·kg $^{-1}$. Cadmium was not detected in the species *Ulva lactuca*. The heavy metals with mean values can be sequenced in descending order, Fe > Mn > Zn > Cu > Ni > Pb > Cr > Cd. This finding suggests that *Ulva* has the strongest affinity to Fe and Mn bioaccumulation among the assessed metals. Our results show that *Ulva lactuca* has a great affinity to Mn and Fe, which are the most abundant metals in the Marchica lagoon because of its watershed and the mineralogical characteristics of the deposits of the old iron mine of Nador [28,47]. These results are in agreement with the finding of [50], who reported that

Ulva has a particular affinity for Mn, Fe, and Pb. In the previous studies on heavy metals in the Marchica lagoon [28,47], Mn and Fe recorded the strongest concentrations in waters and sediments.

Table 5. The bioaccumulation of heavy metals (mg·kg $^{-1}$), N (mg·g $^{-1}$), and P (mg·g $^{-1}$) in *Ulva lactuca* and in water (mg·L^{-1}).

		Pb	Cd	Cr	Ni	Zn	Cu	Mn	Fe	N	P
Ulva lactuca	site 1	4.8	-	0.9	4.2	9.93	5.9	25.5	418	42.4	1.61
	site 2	2.7	-	1	4	8.52	1.9	164	213	52.17	1.84
	site 3	3.2	-	0.9	4.5	10.2	7.4	49.2	378	37.67	1.86
Mean values in water (mg·L^{-1})		0.0021	-	0.0334	0.0235	0.0283	0.0089	0.018	0.203	0.09	0.45
Mean values of BCF		1728	-	27	179	336	568	1687	1656	48,986	3940
Uptake: mean values (mg·m^2)		43.77	-	11.45	51.95	117.19	62.17	976.4	4127.4	539 × 1000	21,762

The BCFs of P, N, Pb, Cr, Zn, Cd, Mn, Cu, Ni, and Fe in *Ulvalactuca* and water samples from the Marchica lagoon are listed in Table 5. Mn, Fe, and Pb recorded the highest BCFs, which were 1687, 1656, and 1643, respectively. Our results were in agreement with those of [21], where a higher transfer factor (TF) from water to *Ulva lactuca* was found, suggesting a higher accumulation of metals from water. Zeroual and al [33] also reported values of bioconcentration factors greater than one unity, suggesting high transfer of heavy metals from water to *Ulva lactuca* rather than from sediments.

Regarding the contents of metals in *Ulva lactuca* and their contribution to RDA (Table 6), phosphorus contribution to RDA was very low (1.52–1.76%), while that of Mn ranged between 4.42 and 28.42%. Fe showed a maximum contribution of 13.58% to the RDA. Zn does not contribute much to the RDA, with a maximum value of 0.44%. Our findings are in agreement with studies that concluded that edible Chlorophyta have a low content of the essential minerals Zn and Cu and a high content of Ca [51] compared to brown and red seaweeds. In our results, the seven g of dried *Ulva lactuca* as suggested by [52] is not sufficient to achieve the RDA requirement for Cu and Zn. [52] reported that consumption of seven g of dried *Ulva lactuca* every day ensures the Cu RDA but is not enough to reach the Zn RDA. Similarly, [40] found that all green species studied, including *Ulva* sp., contributed less than 15% of the RDA of Cu and Zn but made a major contribution toward the RDA of Fe.

Table 6. Values of Estimated daily intake (EDI) (mg·day^{-1}), Dietary Reference Values (DRVs) (mg.day^{-1}), and the percentage of contribution to the Recommended Dietary Allowance (RDA).

	Parameters	P	Mn	Fe	Cu	Zn
Estimated daily intake (EDI) (mg·day^{-1})	site 1	8.38	0.132	2.173	0.031	0.051
	site 2	9.57	0.852	1.107	0.010	0.044
	site 3	9.70	0.255	1.965	0.038	0.053
Dietary Reference Values (DRVs) (mg·day^{-1})		550	3	11–16.0	1.6–1.3	12.7–6.3
Contribution (%) to the Recommended Dietary Allowance (RDA)	site 1	1.52	4.42	13.585	2.36	0.43
	site 2	1.74	28.42	6.923	0.76	0.37
	site 3	1.76	8.52	12.285	2.96	0.44

3.3. Health Risk Assessment

The results of the THQ and HI are listed in Table 7. In particular, no validated guidelines have been reported for the human consumption of seaweed in Morocco. Thus, values recommended by the USEPA (2013) on human risk assessment were considered. Since the consumption of algae in Morocco is very low, the values of algae consumption in Asian countries were used to calculate THQ and HI [35].

Table 7. Values of the reference dose for heavy metals in foods (RfD), the targeted hazard quotient (TQH), and the hazard index (HI).

Parameters		Cr	Mn	Fe	Ni	Cu	Zn	Cd	Pb	HI = ∑ THQ
RfD ($\mu g \cdot g^{-1} \cdot day^{-1}$)		0.003	0.14	0.7	0.02	0.04	0.3	0.001	0.004	
					THQ					
Ulva lactuca	site 1	0.025	0.013	0.044	0.015	0.011	0.002	nd	0.089	0.201
	site 2	0.022	0.087	0.022	0.017	0.003	0.002	nd	0.050	0.204
	site 3	0.022	0.026	0.040	0.016	0.013	0.002	nd	0.061	0.182

The TQH for each element was below 1.0 for all elements, suggesting that the exposure dose calculated in all samples was less than the *RfD* established by the US EPA. In addition, in all samples, the calculated hazard index (HI), including the sum of THQ, showed an HI below the value of 1. The HI values demonstrated the following sequence: Pb > Mn > Fe> Cr > Ni > Cu > Zn > Cd.

3.4. Comparative Study

Generally, the chemical composition and bioaccumulation of metals by macroalgae might vary greatly according to species, provenance area, and collection time [40,53,54]. *Ulva lactuca* has a strong capability to accumulate heavy metals. Thus, under experimental conditions, living *Ulva lactuca* proved to be a viable tool for accumulating the content of Cd, Pb, Cu, Cd, Cr, Pb, Ni, and Mn in contaminated waters [55].

When heavy metal levels in the *Ulva lactuca* species collected from the Marchica lagoon are compared to similar *Ulva* species throughout the Mediterranean, our results indicate generally high concentrations and are even closer to the results from contaminated areas. The results are summarized in Table 8.

The results of Fe were lower than those reported from the Venice lagoon [56], which recorded a maximum of 1630 mg/kg. Thus, our Fe results were lower than those reported from open sea areas such as the Sea of Marmara [57] and the Lebanon coast [50]. However, the results of Fe in the Marchica lagoon were similar to the values reported on the Tunisian coast and in the Aegean Sea [58,59].

The results of Zn, Mn, and Cu were higher than those reported by [60] on the Egyptian coast. The values of Mn were close to the values recorded in the eastern Mediterranean Sea [50,57] and higher than the results from the Tunisian coast [59]. Regarding Zn and Cu, our results were similar to the results recorded from the coast of Sicily, Syria, Lebanon, and Algeria [4,50,61,62], and they were lower than those from the Sea of Marmara [57], the Venice lagoon [56], and some areas of the Algerian coast [32].

Nickel in *Ulva lactuca* from the Marchica lagoon was higher than those reported in *Ulva* spp. from the Sicilian coast [4], the Venice lagoon [56], and the Lebanese coast [50]. Lead and chromium results in Marchica were higher than those reported from the Algerian coast [62], Egypt [60], and the Sicilian coast [4]; they were similar to results from the Lebanese coast [50] and lower than results from the Aegean coast [58].

Table 8. Comparison of heavy metal concentrations (mg·kg^{-1} DW) measured in *Ulva* spp. from some Mediterranean areas (minimum and maximum levels are marked "–", means are marked "±", nd = no data).

Reference	Location	Pb	Cr	Ni	Zn	Cu	Mn	Fe	Cd
This study	Morocco	2.7–4.8	0.9–1	4.2–4.5	8.55–10.2	1.9–7.4	25.5–164	213–418	nd
[60]	Egypt	0.05 ± 0.01	0.46 ± 0.14	nd	0.31 ± 0.05	2.02 ± 0.13	nd	1.43 ± 0.05	nd
[4]	Sicily coast, Italy	0.67–5.77	0.25–2.21	0.97–8.12	8.21–85.1	1.48–10.4	nd	nd	0.06–0.26
[63]	Algeria	nd–154.78	0.00	nd	16.6–106.88	0.33–44	nd	nd	nd–7.02
[61]	Syria	0.55 ± 0.99	4.71 ± 0.02	nd	11.0 ± 0.33	5.48 ± 0.28	nd	nd	11.0 ± 0.33
[57]	Marmara	4.92–19.31		nd	15.15–41.29	6.67–18.31	8.26–25.31	553.31–989.32	0.451–3.21
[62]	Algeria	1 ± 0.002	0.979 ± 0.002	nd	5.400 ± 0.001	2.587 ± 0.002	nd	nd	0.038 ± 0.008
[32]	Algeria	1.88–6.25	0.00	nd	92–178.9	nd	nd	nd	nd
[50]	Lebanon	1.04 ± 1.03	1.08 ± 0.90	2.13 ± 0.63	5.12 ± 2.29	2.30 ± 1.49	29.4 ± 37.8	516 ± 473	0.05 ± 0.03
[56]	Italy	0.7–17.6	0.7–8.6	2.2–5.0	25–179	4–29	nd	173–1630	<0.1–0.7
[59]	Tunisia	12.6	nd	nd	68	8	13	410	nd
[58]	Aegean coast	0.94–5.65	0.78–4.78	nd	40.4–81	7.78–13.9	nd	146–307.5	14.9–54.2

4. Conclusions

This study showed the bioconcentration of some heavy metals (Fe, Cr, Ni, Zn, Cu, Pb, Zn, and Cd) and the nutrients that were responsible for the Marchica lagoon's eutrophication (N and P) in the species *Ulva lactuca* (Chlorophyta) collected from the lagoon during a green tide in July 2021.

The study revealed that *Ulva lactuca* has a higher bioavailability and capacity towards Fe and Mn than the other metals. In addition, it revealed the capability to mitigate eutrophication because of the high bioavailability of nitrogen and phosphorus. Therefore, because it revealed important levels of metals, *Ulva lactuca* is recommended for biomonitoring and phycoremediation of heavy metals and eutrophication.

Furthermore, human ingestion of the assessed heavy metals from the consumption of Ulva species would not pose a risk to human health. Hence, further analysis of toxic metals is needed to obtain a comprehensive overview of the metal profile of this alga.

The results of this study suggest that the naturally occurring or cultivated macroalgae, especially *Ulva lactuca*, in the Marchica lagoon has the potential to absorb heavy metals in this coastal region, which can then be evaluated in fields without risks to human health, such as energy recovery.

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References

1. Areco, M.M.; Salomone, V.N.; dos Santos Afonso, M. Ulva Lactuca: A Bioindicator for Anthropogenic Contamination and Its Environmental Remediation Capacity. *Mar. Environ. Res.* **2021**, *171*, 105468. [CrossRef]
2. Zohra, B.S.; Habib, A. Assessment of Heavy Metal Contamination Levels and Toxicity in Sediments and Fishes from the Mediterranean Sea (Southern Coast of Sfax, Tunisia). *Environ. Sci. Pollut. Res.* **2016**, *23*, 13954–13963. [CrossRef]
3. Bonanno, G.; Orlando-Bonaca, M. Chemical Elements in Mediterranean Macroalgae. A Review. *Ecotoxicol. Environ. Saf.* **2018**, *148*, 44–71. [CrossRef]

4. Bonanno, G.; Veneziano, V.; Piccione, V. The Alga Ulva Lactuca (Ulvaceae, Chlorophyta) as a Bioindicator of Trace Element Contamination along the Coast of Sicily, Italy. *Sci. Total Environ.* **2020**, *699*, 134329. [CrossRef]
5. Ashour, M.; Alprol, A.E.; Heneash, A.M.M.; Saleh, H.; Abualnaja, K.M.; Alhashmialameer, D.; Mansour, A.T. Ammonia Bioremediation from Aquaculture Wastewater Effluents Using Arthrospira Platensis NIOF17/003: Impact of Biodiesel Residue and Potential of Ammonia-Loaded Biomass as Rotifer Feed. *Materials* **2021**, *14*, 5460. [CrossRef]
6. Mansour, A.T.; Alprol, A.E.; Abualnaja, K.M.; El-Beltagi, H.S.; Ramadan, K.M.A.; Ashour, M. Dried Brown Seaweed's Phytoremediation Potential for Methylene Blue Dye Removal from Aquatic Environments. *Polymers* **2022**, *14*, 1375. [CrossRef]
7. Baghour, M. Effect of Seaweeds in Phyto-Remediation. In *Biotechnological Applications of Seaweeds*; Nova Publishers Sciences: Hauppauge, NY, USA, 2017; pp. 47–83, ISBN 978-1-5361-0983-2.
8. Ben Chekroun, K.; Baghour, M. The Role of Algae in Phytoremediation of Heavy Metals: A Review. *J. Mater. Environ. Sci.* **2013**, *4*, 873–880.
9. Ameen, F.; Al-Homaidan, A.A.; Almahasheer, H.; Dawoud, T.; Alwakeel, S.; AlMaarofi, S. Biomonitoring Coastal Pollution on the Arabian Gulf and the Gulf of Aden Using Macroalgae: A Review. *Mar. Pollut. Bull.* **2022**, *175*, 113156. [CrossRef]
10. Bonanno, G.; Orlando-Bonaca, M. Trace Elements in Mediterranean Seagrasses: Accumulation, Tolerance and Biomonitoring. A Review. *Mar. Pollut. Bull.* **2017**, *125*, 8–18. [CrossRef]
11. Shackira, A.M.; Jazeel, K.; Puthur, J.T. Chapter 13—Phycoremediation and Phytoremediation: Promising Tools of Green Remediation. In *Sustainable Environmental Clean-Up*; Kumar Mishra, V., Kumar, A., Eds.; Elsevier: Amsterdam, The Netherlands, 2021; pp. 273–293, ISBN 978-0-12-823828-8.
12. Valiela, I.; Foreman, K.; LaMontagne, M.; Hersh, D.; Costa, J.; Peckol, P.; DeMeo-Andreson, B.; D'Avanzo, C.; Babione, M.; Sham, C.-H.; et al. Couplings of Watersheds and Coastal Waters: Sources and Consequences of Nutrient Enrichment in Waquoit Bay, Massachusetts. *Estuaries* **1992**, *15*, 443–457. [CrossRef]
13. Orlandi, L.; Calizza, E.; Careddu, G.; Carlino, P.; Costantini, M.L.; Rossi, L. The Effects of Nitrogen Pollutants on the Isotopic Signal (Δ15N) of Ulva Lactuca: Microcosm Experiments. *Mar. Pollut. Bull.* **2017**, *115*, 429–435. [CrossRef]
14. Rahhou, A.; Layachi, M.; Akodad, M.; El Ouamari, N.; Aknaf, A.; Skalli, A.; Oudra, B.; Baghour, M. Assessment of the Trophic Status of Marchica Lagoon (Ne Morocco, Mediterranean) After Restoration Activities Using Trophic Index (Trix): Seasonal and Spatial Variations. *Appl. Ecol. Environ. Res.* **2022**, *20*, 4667–4679. [CrossRef]
15. García-Seoane, R.; Fernández, J.A.; Villares, R.; Aboal, J.R. Use of Macroalgae to Biomonitor Pollutants in Coastal Waters: Optimization of the Methodology. *Ecol. Indic.* **2018**, *84*, 710–726. [CrossRef]
16. Yamashita, M.; Tomita-Yokotani, K.; Hashimoto, H.; Sawaki, N.; Notoya, M. Sodium and Potassium Uptake of Ulva—Application of Marine Macro-Algae for Space Agriculture. *Adv. Space Res.* **2009**, *43*, 1220–1223. [CrossRef]
17. Costa, S.; Crespo, D.; Henriques, B.M.G.; Pereira, E.; Duarte, A.C.; Pardal, M.A. Kinetics of Mercury Accumulation and Its Effects on Ulva Lactuca Growth Rate at Two Salinities and Exposure Conditions. *Water Air Soil Pollut.* **2011**, *217*, 689–699. [CrossRef]
18. Ho, Y.B. Ulva Lactuca as Bioindicator of Metal Contamination in Intertidal Waters in Hong Kong. *Hydrobiologia* **1990**, *203*, 73–81. [CrossRef]
19. Haritonidis, S.; Malea, P. Bioaccumulation of Metals by the Green Alga Ulva Rigida from Thermaikos Gulf, Greece. *Environ. Pollut.* **1999**, *104*, 365–372. [CrossRef]
20. Kamala-Kannan, S.; Prabhu Dass Batvari, B.; Lee, K.J.; Kannan, N.; Krishnamoorthy, R.; Shanthi, K.; Jayaprakash, M. Assessment of Heavy Metals (Cd, Cr and Pb) in Water, Sediment and Seaweed (Ulva Lactuca) in the Pulicat Lake, South East India. *Chemosphere* **2008**, *71*, 1233–1240. [CrossRef]
21. Diop, M.; Howsam, M.; Diop, C.; Goossens, J.F.; Diouf, A.; Amara, R. Assessment of Trace Element Contamination and Bioaccumulation in Algae (Ulva Lactuca), Mussels (Perna Perna), Shrimp (Penaeus Kerathurus), and Fish (Mugil Cephalus, Saratherondon Melanotheron) along the Senegalese Coast. *Mar. Pollut. Bull.* **2016**, *103*, 339–343. [CrossRef]
22. Shuang, Q.; ShiJian, G.; Champagne, P.; Robertson, R.M. Potential of Ulva Lactuca for Municipal Wastewater Bioremediation and Fly Food. *Desalination Water Treat.* **2017**, *91*, 23–30.
23. Farias, D.R.; Hurd, C.L.; Eriksen, R.S.; Simioni, C.; Schmidt, E.; Bouzon, Z.L.; Macleod, C.K. In Situ Assessment of Ulva Australis as a Monitoring and Management Tool for Metal Pollution. *J. Appl. Phycol.* **2017**, *29*, 2489–2502. [CrossRef]
24. Bonanno, G.; Orlando-Bonaca, M. Trace Elements in Mediterranean Seagrasses and Macroalgae. A Review. *Sci. Total Environ.* **2018**, *618*, 1152–1159. [CrossRef]
25. Li, J.-Y.; Yang, F.; Jin, L.; Wang, Q.; Yin, J.; He, P.; Chen, Y. Safety and Quality of the Green Tide Algal Species Ulva Prolifera for Option of Human Consumption: A Nutrition and Contamination Study. *Chemosphere* **2018**, *210*, 1021–1028. [CrossRef]
26. Naeem, M.; Idrees, M.; Khan, M.M.A.; Moinuddin; Ansari, A.A. Task of Mineral Nutrients in Eutrophication. *Eutrophication Causes Conseq. Control* **2014**, 223–237. [CrossRef]
27. Le Fur, I. Role of Macrophytes in the Restoration of Lagoon Environments: Ecological Succession. Ph.D. Thesis, Université Montpellier, Montpellier, France, 2018.
28. Oujidi, B.; Tahri, M.; Layachi, M.; Abid, A.; Bouchnan, R.; Selfati, M.; Bounakhla, M.; El Bouch, M.; Maanan, M.; Bazairi, H.; et al. Effects of the Watershed on the Seasonal Variation of the Surface Water Quality of a Post-Restoration Coastal Wetland: The Case of the Nador Lagoon (Mediterranean Sea, Morocco). *Reg. Stud. Mar. Sci.* **2020**, *35*, 101127. [CrossRef]

29. Rahhou, A.; Layachi, M.; Akodad, M.; Ouamari, N.E.; Aknaf, A.; Gueddari, H.; Oudra, B.; Baghour, M. The Potential Role of Sediments in Nutrients (N, P) Cycle in Marchica Lagoon (Mediterranean Sea, Morocco). *IOP Conf. Ser.Earth Environ. Sci.* **2022**, *1090*, 012009. [CrossRef]
30. Aknaf, A.; Akodad, M.; Layachi, M.; Baghour, M.; Oudra, B.; Vasconcelos, V. The Chemical Characterization and Its Relationship with Heavy Metals Contamination in Surface Sediment of Marchica Mediterranean Lagoon (North of Morocco). *Environ. Sci. Pollut. Res.* **2022**, *29*, 4159–4169. [CrossRef]
31. Maicu, F.; Abdellaoui, B.; Bajo, M.; Chair, A.; Hilmi, K.; Umgiesser, G. Modelling the Water Dynamics of a Tidal Lagoon: The Impact of Human Intervention in the Nador Lagoon (Morocco). *Cont. Shelf Res.* **2021**, *228*, 104535. [CrossRef]
32. Gherib, A.; Bedouh, Y.; Messai, K.; Menad, A. Biomonitoring of Maritime Pollution by Heavy Metals (Pb and Zn) in the Coast of Jijel (Algeria). *Int. J. Environ. Stud.* **2016**, *73*, 214–225. [CrossRef]
33. Zeroual, S.; El Bakkal, S.E.; Mansori, M.; Lhernould, S.; Faugeron-Girard, C.; El Kaoua, M.; Zehhar, N. Cell Wall Thickening in Two Ulva Species in Response to Heavy Metal Marine Pollution. *Reg. Stud. Mar. Sci.* **2020**, *35*, 101125. [CrossRef]
34. Ali, A.Y.A.; Idris, A.M.; Eltayeb, M.A.H.; El-Zahhar, A.A.; Ashraf, I.M. Bioaccumulation and Health Risk Assessment of Toxic Metals in Red Algae in Sudanese Red Sea Coast. *Toxin Rev.* **2021**, *40*, 1327–1337. [CrossRef]
35. Arisekar, U.; Jeya Shakila, R.; Shalini, R.; Jeyasekaran, G.; Sivaraman, B.; Surya, T. Heavy Metal Concentrations in the Macroalgae, Seagrasses, Mangroves, and Crabs Collected from the Tuticorin Coast (Hare Island), Gulf of Mannar, South India. *Mar. Pollut. Bull.* **2021**, *163*, 111971. [CrossRef] [PubMed]
36. Żbikowski, R.; Szefer, P.; Latała, A. Comparison of Green Algae Cladophora Sp. and Enteromorpha Sp. as Potential Biomonitors of Chemical Elements in the Southern Baltic. *Sci. Total Environ.* **2007**, *387*, 320–332. [CrossRef] [PubMed]
37. Rodier, J.; Bernard, L.; Nicole, M.; Bernard, L. *Merlet Nicole L'analyse de l'eau/Jean Rodier, Bernard Legube, Nicole Merlet et Coll*; Dunod: Paris, France, 2009; ISBN 978-2-10-007246-0.
38. US EPA Integrated Risk Information System. Available online: https://www.epa.gov/iris (accessed on 20 September 2022).
39. Paz, S.; Rubio, C.; Frías, I.; Gutiérrez, Á.J.; González-Weller, D.; Martín, V.; Revert, C.; Hardisson, A. Toxic Metals (Al, Cd, Pb and Hg) in the Most Consumed Edible Seaweeds in Europe. *Chemosphere* **2019**, *218*, 879–884. [CrossRef] [PubMed]
40. Véliz, K.; Toledo, P.; Araya, M.; Gómez, M.F.; Villalobos, V.; Tala, F. Chemical Composition and Heavy Metal Content of Chilean Seaweeds: Potential Applications of Seaweed Meal as Food and Feed Ingredients. *Food Chem.* **2023**, *398*, 133866. [CrossRef] [PubMed]
41. Hanisak, M.D. Nitrogen Limitation of Codium Fragile Ssp. Tomentosoides as Determined by Tissue Analysis. *Mar. Biol.* **1979**, *50*, 333–337. [CrossRef]
42. Wheeler, P.A.; Björnsäter, B.R. Seasonal Fluctuations in Tissue Nitrogen, Phosphorus, and N:P for Five Macroalgal Species Common to the Pacific Northwest Coast. *J. Phycol.* **1992**, *28*, 1–6. [CrossRef]
43. Keesing, J.K.; Liu, D.; Shi, Y.; Wang, Y. Abiotic Factors Influencing Biomass Accumulation of Green Tide Causing Ulva Spp. on Pyropia Culture Rafts in the Yellow Sea, China. *Mar. Pollut. Bull.* **2016**, *105*, 88–97. [CrossRef]
44. Van Alstyne, K.L. Seawater Nitrogen Concentration and Light Independently Alter Performance, Growth, and Resource Allocation in the Bloom-Forming Seaweeds Ulva Lactuca and Ulvaria Obscura (Chlorophyta). *Harmful Algae* **2018**, *78*, 27–35. [CrossRef] [PubMed]
45. Ale, M.T.; Mikkelsen, J.D.; Meyer, A.S. Differential Growth Response of Ulva Lactuca to Ammonium and Nitrate Assimilation. *J. Appl. Phycol.* **2011**, *23*, 345–351. [CrossRef]
46. Li, S.; Yu, K.; Huo, Y.; Zhang, J.; Wu, H.; Cai, C.; Liu, Y.; Shi, D.; He, P. Effects of Nitrogen and Phosphorus Enrichment on Growth and Photosynthetic Assimilation of Carbon in a Green Tide-Forming Species (Ulva Prolifera) in the Yellow Sea. *Hydrobiologia* **2016**, *776*, 161–171. [CrossRef]
47. Oujidi, B.; El Bouch, M.; Tahri, M.; Layachi, M.; Boutoumit, S.; Bouchnan, R.; Ouahidi, H.; Bounakhla, M.; El Ouamari, N.; Maanan, M.; et al. Seasonal and Spatial Patterns of Ecotoxicological Indices of Trace Elements in Superficial Sediments of the Marchica Lagoon Following Restoration Actions during the Last Decade. *Diversity* **2021**, *13*, 51. [CrossRef]
48. Choi, Y.; Yang, K.; Lee, M.Y.; Youn, S.H.; Son, M.; Park, S.R.; Kim, T.-H. Factors Controlling Massive Green Tide Blooms on the Coasts of Jeju Island, Korea. *Mar. Pollut. Bull.* **2023**, *186*, 114446. [CrossRef] [PubMed]
49. Peng, Z.; Guo, Z.; Wang, Z.; Zhang, R.; Wu, Q.; Gao, H.; Wang, Y.; Shen, Z.; Lek, S.; Xiao, J. Species-Specific Bioaccumulation and Health Risk Assessment of Heavy Metal in Seaweeds in Tropic Coasts of South China Sea. *Sci. Total Environ.* **2022**, *832*, 155031. [CrossRef]
50. Ghosn, M.; Mahfouz, C.; Chekri, R.; Ouddane, B.; Khalaf, G.; Guérin, T.; Amara, R.; Jitaru, P. Assessment of Trace Element Contamination and Bioaccumulation in Algae (Ulva Lactuca), Bivalves (Spondylus Spinosus) and Shrimps (Marsupenaeus Japonicus) from the Lebanese Coast. *Reg. Stud. Mar. Sci.* **2020**, *39*, 101478. [CrossRef]
51. Lozano Muñoz, I.; Díaz, N.F. Minerals in Edible Seaweed: Health Benefits and Food Safety Issues. *Crit. Rev. Food Sci. Nutr.* **2022**, *62*, 1592–1607. [CrossRef]
52. Afonso, C.; Cardoso, C.; Ripol, A.; Varela, J.; Quental-Ferreira, H.; Pousão-Ferreira, P.; Ventura, M.S.; Delgado, I.M.; Coelho, I.; Castanheira, I.; et al. Composition and Bioaccessibility of Elements in Green Seaweeds from Fish Pond Aquaculture. *Food Res. Int.* **2018**, *105*, 271–277. [CrossRef]
53. Chen, Q.; Pan, X.-D.; Huang, B.-F.; Han, J.-L. Distribution of Metals and Metalloids in Dried Seaweeds and Health Risk to Population in Southeastern China. *Sci. Rep.* **2018**, *8*, 1–7. [CrossRef]

54. Roleda, M.Y.; Marfaing, H.; Desnica, N.; Jónsdóttir, R.; Skjermo, J.; Rebours, C.; Nitschke, U. Variations in Polyphenol and Heavy Metal Contents of Wild-Harvested and Cultivated Seaweed Bulk Biomass: Health Risk Assessment and Implication for Food Applications. *Food Control* **2019**, *95*, 121–134. [CrossRef]
55. Henriques, B.; Teixeira, A.; Figueira, P.; Reis, A.T.; Almeida, J.; Vale, C.; Pereira, E. Simultaneous Removal of Trace Elements from Contaminated Waters by Living Ulva Lactuca. *Sci. Total Environ.* **2019**, *652*, 880–888. [CrossRef]
56. Caliceti, M.; Argese, E.; Sfriso, A.; Pavoni, B. Heavy Metal Contamination in the Seaweeds of the Venice Lagoon. *Chemosphere* **2002**, *47*, 443–454. [CrossRef] [PubMed]
57. Özyiğit, İ.İ.; UYanık, Ö.L.; Şahin, N.R.; Yalçın, İ.E.; Demir, G. Monitoring the Pollution Level in Istanbul Coast of the Sea of Marmara Using Algal Species *Ulva lactuca* L. *Pol. J. Environ. Stud.* **2017**, *26*, 773–778. [CrossRef] [PubMed]
58. Akcali, I.; Kucuksezgin, F. A Biomonitoring Study: Heavy Metals in Macroalgae from Eastern Aegean Coastal Areas. *Mar. Pollut. Bull.* **2011**, *62*, 637–645. [CrossRef] [PubMed]
59. Yaich, H.; Garna, H.; Besbes, S.; Paquot, M.; Blecker, C.; Attia, H. Chemical Composition and Functional Properties of Ulva Lactuca Seaweed Collected in Tunisia. *Food Chem.* **2011**, *128*, 895–901. [CrossRef]
60. Khairy, H.M.; El-Sheikh, M.A. Antioxidant Activity and Mineral Composition of Three Mediterranean Common Seaweeds from Abu-Qir Bay, Egypt. *Saudi J. Biol. Sci.* **2015**, *22*, 623–630. [CrossRef]
61. Al-Masri, M.S.; Mamish, S.; Budier, Y. Radionuclides and Trace Metals in Eastern Mediterranean Sea Algae. *J. Environ. Radioact.* **2003**, *67*, 157–168. [CrossRef]
62. Laib, E.; Leghouchi, E. Cd, Cr, Cu, Pb, and Zn Concentrations in Ulva Lactuca, Codium Fragile, Jania Rubens, and Dictyota Dichotoma from Rabta Bay, Jijel (Algeria). *Environ. Monit. Assess.* **2012**, *184*, 1711–1718. [CrossRef]
63. Gherib, A.; Bounamous, A.; Aissaoui, A.; Charchar, N.; Bouchaala, L.; Bouaarouj, S.; Ahmed, M. Biomonitoring of Metallic Pollution in the Coast of Jijel (Algeria) by Using Algological Biomarkers. *Int. J. Environ. Stud.* **2018**, *77*, 61–81. [CrossRef]