ISSN: 2476-6909; ECOPERSIA. 2020;8(3):181-190

Using *Saccostrea cucullata* as a biomonitor of heavy metals (Cu, Pb, Zn, Cd, Ni, and Cr) in water and sediments of Qeshm Island, Persian Gulf

ARTICLE INFO

Article Type
Original Research

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How to cite this article
Nourozifard P, Mortazavi S, Asad S, Hassanzadeh N. Using *Saccostrea cucullata* as a biomonitor of heavy metals (Cu, Pb, Zn, Cd, Ni, and Cr) in water and sediments of Qeshm Island, Persian Gulf. ECOPERSIA. 2020;8(3):181-190.

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Article History
Received: October 06, 2019
Accepted: February 18, 2020
ePublished: September 20, 2020

ABSTRACT

Aim The current study investigated the concentration of Cu, Pb, Zn, Cd, Ni, and Cr in shell and soft tissue of *Saccostrea cucullata*, water, and sediments of seven stations in Qeshm Island of Persian Gulf.
Materials & Methods The samples were digested by a combination of nitric acid and perchloric acid and the concentration of elements was measured by atomic absorption spectroscopy.
Findings The results indicated that the concentrations of Cu and Zn in all samples, Ni in the sediment and Cd in oyster were the highest bio-water accumulation factor were significantly higher than those of bio-sediment accumulation factor. Also, these factors in the soft tissue were higher than in the shell. Furthermore, the macro-concentrators of soft tissue were Cd, Cu, and Zn, while the macro-concentrator of shell was Cd.
Conclusion The shell can be an appropriate monitoring tool for evaluating Cu and Zn in water and Cu in sediments. Also, the soft tissue can be practical for monitoring Cu and Zn in sediments.

Keywords Bioaccumulation; Heavy Metals; Qeshm Island; Saccostrea cucullata; Sediment; Water

CITATION LINKS

[1] Natural and concentration factor distribution ... [2] Effect of toxic metals on human ... [3] Risk assessment and environmental geochemistry ... [4] Bioaccumulation of heavy metals in oyster ... [5] Heavy metals assessment of surface sediments ... [6] Is there a direct relationship between ... [7] Biological risk assessment of heavy metals ... [8] Assessment of Toxic metals concentration using ... [9] First genotoxicity assessment of marine ... [10] Visitor impact on rocky shore communities of ... [11] Qeshm Island (tentative ... [12] Trace metal fractionation in water and sediments ... [13] Correlations between speciation of Cd, Cu, Pb ... [14] Biomarkers and heavy metal bioaccumulation ... [15] Immunity in fish ... [16] Standard test methods for nickel ... [17] Assessment of Cu, Pb, and Zn contamination ... [18] Bioaccumulation of heavy metals in oyster ... [19] Heavy metal concentrations in molluscs ... [20] Accumulation and distribution of Cd, Cu ... [21] Partitioning of trace metals between soft ... [22] Spatial distribution, ecological and health risk ... [23] Chemical and biological assessment of sediments ... [24] Ecological risk assessment of coastal ecosystems ... [25] Heavy metal accumulation in tissues ... [26] Telescopium telescopium as potential biomonitors of Cu, Zn ... [27] A model for bioaccumulation of metals in Crassostrea ... [28] Studies on monitoring the heavy metal contents ... [29] Concentrations of heavy metals in water, sediment ... [30] Copper and zinc contamination in oysters ... [31] Seasonal and spatial variations of biomarker ... [32] Investigation of body size effect on bioaccumulation pattern ... [33] Distribution of heavy metals in marine bivalves ... [34] Distribution of Pb in sediment and shell of rocky ... [35] Investigation of Saccostrea cucullata oyster ... [36] Availability of Venerid Clam, Amiantis umbonella as ... [37] Copper, zinc and lead enrichments in sediments ... [38] Guidelines for managing water quality impacts within ... [39] National recommended water quality ... [40] Incidence of adverse biological effects within ranges ... [41] Geochemical speciation and risk assessment of heavy ...

Introduction

Nowadays, increasing presence of various contaminations such as heavy metals in aquatic ecosystems is very concerning [1]. There are about 300 chemical elements that play an essential role in the biochemical and physiological mechanisms of living organisms and are recognized as essential elements of life. Most metals and metalloids are very toxic to living organisms, and even the essential elements can be toxic if exceeding a certain limit [2]. Today, heavy metals are the most important life-threatening pollutants in the aquatic environment [3]. Heavy metals with high stability and non-degradability have great potential for entering the food chains and threatening the living organisms [4]. Sediments can act as a sink and source of pollutants in aquatic ecosystems. Consequently, the concentration of these elements is far higher compared to the water column [5]. Since oysters are in close contact with sediments and also feed through water filtration, the concentration of heavy metals in their bodies is really high. Sediments and oysters are often used to monitor the contamination of metal elements in water [6]. Bivalves, especially mussels and oysters, have been identified as reliable bioindicators for the bioavailability of heavy metals and used in many studies as biomonitors [7]. *Bivalvia mollusca*, in addition to feeding, due to their immovable nature, ability to tolerate environmental changes and pollution, and easy sampling and identification, are known as excellent bioindicators [8]. *Bivalvia mollusca* have a high potential for bioaccumulation of heavy metals from their habitat.

Measuring the concentration of heavy metals in water and sediments is widely used to evaluate environmental pollutants. Furthermore, the monitoring of contamination using aquatic organisms can provide valuable information regarding the spatial and temporal changes in the bioavailability of existing pollutants and contaminants in the environment. Persian Gulf characteristics such as high evaporation rate and dispersion constraint, and the reduction of pollutant concentrations on the one hand, and environmental accidents, industrial development and population growth on the other hand, have led to more severe consequences with exertion of marine stresses in this ecosystem compared with open sea systems [9]. In the present study, the contamination status of ecosystems of Qeshm Island in the Persian Gulf was studied by expressing the relationship between the concentration of elements (Cu, Zn, Cd, Ni, and Cr) in the soft tissue and shell of *Saccostrea cucullata* and the concentrations in environmental elements as an approach to assessing the effectiveness of an organism as a biomonitor, as well as evaluating metal concentrations in water, sediments, and *Saccostrea cucullata* as a chemical and biomonitoring approach. Furthermore, the concentration of elements in water was compared against the CMC (Criteria Maximum Concentration), CCC (Criteria Continuous Concentration), EQS (Environmental Quality Standards), and USEPA (United States Environmental Protection Agency) standards, while in sediments it was compared against USEPA, NOAA (National Oceanic and Atmospheric Administration) standards, and Canadian sediment quality guidelines.

Materials and Methods

Introducing the study area

Qeshm Island is the largest island in the region with an area of 1491km^2 located in the Strait of Hormuz [10]. The length of this island is about 130km and the average depth is 11-35km [11]. Water, sediment, and oyster samples were taken in April 2017 at 7 stations from the northern part of Qeshm Island with an emphasis on the presence of oysters and probably contaminating sources. Figure 1 demonstrates the location of seven sampling stations in Qeshm Island.

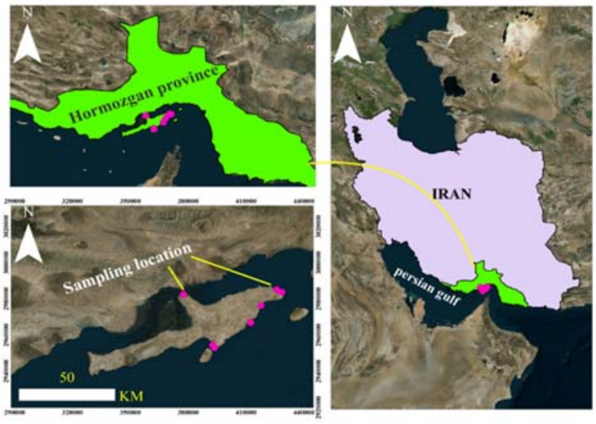

Figure 1) Location of the stations studied in Qeshm Island of Persian Gulf; 1) Kandalou; 2) Shib deraz; 3) Ramcha; 4) Hamoon pond; 5) Zakeri Pier; 6) Naz islands; 7) Laft Pier

Sampling of water, sediment, and oyster

Water samples in each station were collected from a water column and were acidified with concentrated nitric acid (HNO_3) at pH less than 2 [12]. About 2kg of sediment samples were collected with three replications from the surface layer (0-10cm) by a plastic shovel, and oysters were separated from the rocks using a stainless hammer and nail. Oyster samples were collected at the time of low tide. The collected oysters had a length range of 1-9cm. The collected oysters were transferred on ice to the laboratory. In the laboratory, after cleaning the oysters, they were washed by double distilled water and then stored at -20°C until further considerations [13]. Sediment and shell samples were placed in the vicinity of dry air, while the samples of oyster's soft tissue were exposed to the temperature of 60°C until reaching a constant weight [14]. The dried soft and hard tissue samples were powdered separately using glass mortar and were stored in polyethylene pill boxes until chemical digestion [15].

Determining the concentration of elements

In the first step to the quality assurance (QA) of the results, all the dishes used are acid washed (4% nitric acid) and dried in the oven. In the following, 100ml of acidified water sample was combined with 5ml of HCl (hydrochloric acid), with the samples heated on a heater to reach a volume of 15-20ml. Once cooled, the samples were filtered off with acid-washed filter paper. Finally, the samples were brought to a final volume of 100ml [16]. In order to digest the sediment samples, 0.5g of each sample was digested with a mixture of nitric acid (HNO_3) and super-pure ratio of 4 to 1 perchloric acid ($HClO_4$) [17]. Also, for digestion of the oyster's soft tissue, 1g of the powdered texture was combined with 10ml of concentrated pure acid nitric (HNO_3) [13]. Furthermore, to 1g of each digested shell sample, acid nitric (HNO_3) and super-pure hydrogen peroxide (H_2O_2) were added with a ratio of 2 to 1 [18]. Next, the samples were first placed in a digester at low temperature (40°C) for 1h and then were digested completely at 140°C for 3h. After cooling, the samples were passed through a 42-µ filter paper and brought to a final volume of 24ml. Eventually, it was read by the contrAA 700 Analytic Jena Atomic absorption spectroscopy. In this method, the limit of detection (LOD) for copper, lead, zinc, nickel, chromium, and iron is 0.211, 1.385, 0.2095, 0.2927, 0.7694, and 7550mg/L, respectively. The limit of quantification (LOQ) for them is 0.8462, 4.7288, 0.7388, 0.9208, 1.094, and 2.730mg/L, respectively, and for cadmium, LOD and LOQ are 1.172 and 3.988, respectively. In quality control (QC) measurement, recovery of these elements by Spike method was calculated from 87 to 105% and their relative error rate (RSD) from 3.65 to 77.8%.

Analytical methods

Statistical analyses were performed using SPSS 21 and Excel 2010. Bioaccumulation factor (BF) is calculated for evaluating the levels of accumulation of elements in the tissues of organisms in accordance with equations 1 and 2.

$$BWAF = \frac{C_{oyster}}{C_{Water}} \quad (1)$$

$$BSAF = \frac{C_{oyster}}{C_{Sediment}} \quad (2)$$

In these relations, BWAF is a bio-water accumulation factor; BSAF represents bio-sediment accumulation factor; C_{Oyster} shows the concentration of element in the shell or oyster's soft tissue (mg/kg dry weight); C_{Water} denotes the element in water (mg/l); and $C_{sediment}$ is the concentration of element in sediment (mg/kg dry weight) [19]. If BSAF>2, the result will be macro concentrator. If 1<BSAF<2, the result will be micro concentrator, and if BSAF<1, the result will be deconcentrator [20]. The degree of changes in the elemental levels of oyster's tissues can be determined by the coefficient of variation according to Equation 3 [15].

$$CV\ (\%) = \frac{Standard\ Deviation}{\text{Mean}} \times 100 \quad (3)$$

Partitioning factor (P.F) was calculated according to equation (4) in each location [21].

$$P.F. = \frac{C_{Soft\ Tissue}}{C_{Shell}} \quad (4)$$

In this equation, $C_{Soft\ Tissue}$ is the concentration of element in the soft tissue (mg/kg dry weight) and C_{Shell} represents the element concentration in the oyster shell (mg/kg dry weight).

Findings

Table 1 depicts the average concentration of elements in the water and sediment samples of different stations as well as the average total concentration of elements in the study area. According to the results, most concentrations are related to copper and zinc elements and in the sediment samples zinc showed the highest concentration while cadmium presented the lowest concentration.

The concentrations of the elements in the shell and soft tissue of oyster *Saccostrea cucullata* are reported in Tables 2 and 3, respectively. According to the results, the highest concentration is related to zinc. Further, the concentration of the studied elements except lead in the soft tissue is more than in the shell.

Table 4 provides the results of computations of bioaccumulation factors and the coefficient of variation of the studied elements in the soft tissue and shell of oyster *Saccostrea cucullata*. In general, BWAF values are larger than BSAF values, and among the studied elements, the variation coefficients of Cu, Pb, and Cd in the soft tissue are higher than those of the shell.

The results of calculating the partitioning factor are presented in Table 5. According to the results, the highest partitioning factor obtained at various stations belonged to Cu, Zn, and Cd.

According to Table 6, the results indicate the presence or absence of a relationship between environmental elements (water and sediments) and oyster tissues (soft tissue and shell), with the highest correlation obtained with Zn.

Table 1) Concentrations of heavy metals in water (μg/l) and sediment (mg/kg dry weight)

Samples	Cu	Pb	Zn	Cd	Ni	Cr
Water						
1	84.26±1.98	N.D.	39.43±1.16	N.D.	6.50±0.30	0.35±0.04
2	51.03±2.00	N.D.	20.30±2.30	N.D.	6.52±0.30	0.31±0.03
3	54.83±3.74	N.D.	35.92±3.57	N.D.	5.91±0.30	1.74±0.35
4	8.94±0.15	N.D.	36.11±2.01	N.D.	4.59±0.36	0.66±0.02
5	10.97±0.15	N.D.	23.18±2.02	N.D.	3.70±0.20	4.12±0.20
6	7.03±0.30	N.D.	15.82±0.30	N.D.	5.54±0.35	0.68±0.03
7	19.31±2.07	N.D.	25.03±2.00	N.D.	N.D.±0.00	0.62±0.02
Average	33.77	N.D.	27.97	N.D.	4.68	1.21
Sediment						
1	33.32±2.45	26.85±0.67	67.50±1.68	0.16±0.002	30.10±0.43	15.37±0.15
2	31.58±0.42	26.89±0.46	76.95±8.35	0.14±0.001	48.85±4.83	16.81±0.17
3	110.05±1.6	28.80±0.35	104.64±0.41	0.16±0.002	61.61±0.40	17.51±0.12
4	115.40±0.61	31.69±0.28	131.87±1.56	0.11±0.001	109.46±0.15	20.45±0.15
5	127.86±1.31	31.98±0.12	159.22±1.78	0.15±0.004	85.38±1.13	20.56±0.28
6	23.75±0.07	33.48±1.74	61.80±0.56	0.13±0.002	27.35±0.22	14.82±0.23
7	31.75±0.24	27.01±0.08	72.70±0.62	0.11±0.000	51.59±0.30	18.10±0.04
Average	67.67	29.53	96.39	0.14	59.19	17.66

ND: Non-Detect

Table 2) Heavy metals concentrations in shell of oyster (mg/kg dry weight)

Stations	Cu	Pb	Zn	Cd	Ni	Cr
1	17.00±0.54	21.29±0.12	20.09±2.48	10.03±0.02	12.22±0.01	10.79±0.24
2	15.61±0.01	23.18±0.22	17.53±0.32	10.29±0.12	12.19±0.09	10.89±0.01
3	17.13±0.10	21.34±0.12	31.35±1.12	10.22±0.02	12.61±0.06	11.09±0.08
4	14.92±0.15	21.05±0.15	26.28±1.48	10.30±0.01	12.50±0.09	10.85±0.04
5	15.07±0.30	21.00±0.01	25.63±1.30	10.53±0.04	12.31±0.13	9.35±0.15
6	14.34±0.32	20.85±0.26	16.96±0.19	10.60±0.10	12.23±0.02	8.85±0.06
7	15.41±1.96	21.75±0.13	23.69±0.07	11.11±0.24	12.98±0.70	9.05±0.13
Ave.	15.64	21.50	23.08	10.44	12.43	10.13

Table 3) Heavy metals concentrations in soft tissue of oyster (mg/kg dry weight)

Stations	Cu	Pb	Zn	Cd	Ni	Cr
1	114.27±0.62	22.43±1.55	296.72±1.66	60.80±0.99	12.85±0.23	10.94±0.02
2	161.67±3.29	21.06±0.01	290.63±2.11	90.97±1.15	12.83±0.03	11.13±0.00
3	232.34±5.53	20.59±0.01	352.74±6.26	56.44±2.22	13.00±0.04	11.53±0.01
4	178.19±0.87	20.52±0.00	333.35±0.13	33.98±0.18	13.03±0.03	11.09±0.02
5	340.89±12.44	20.85±0.05	391.88±2.30	29.23±0.21	13.04±0.23	11.09±0.03
6	124.95±1.32	20.41±0.01	188.62±1.64	53.51±0.40	13.11±0.04	10.78±0.05
7	289.88±7.73	20.54±0.02	375.12±1.85	32.71±0.69	12.70±0.38	11.78±0.02
Ave.	206.03	20.91	318.44	51.09	12.94	11.19

Table 4) Biowater accumulation factor (BWAF), biosediment accumulation factor (BSAF), Coefficient of variation (CV%) values of shell and S.T. (soft tissue) of oyster in the whole area of investigated

Metals	BWAF	BSAF	CV (%)
Cu			
S.T.	6100.84	3.04	39.35
Shell	463.07	0.23	7.64
Pb			
S.T.	-	0.71	3.96
Shell	-	0.73	3.59
Zn			
S.T.	11384.97	3.30	20.40
Shell	825.02	0.24	21.91
Cd			
S.T.	-	377.05	40.35
Shell	-	77.04	3.31
Ni			
S.T.	2764.44	0.22	1.63
Shell	2656.75	0.21	2.27
Cr			
S.T.	9249.75	0.63	2.95
Shell	8367.77	0.57	9.31

Table 5) Partitioning factors of the oysters from the study sites

Stations	Cu	Pb	Zn	Cd	Ni	Cr
1	6.72	1.05	14.77	6.06	1.05	1.01
2	10.36	0.91	16.58	8.84	1.05	1.02
3	13.57	0.96	11.25	5.52	1.03	1.04
4	11.95	0.97	12.69	3.30	1.04	1.02
5	22.63	0.99	15.29	2.78	1.06	1.19
6	8.71	0.98	11.12	5.05	1.07	1.22
7	18.81	0.94	15.83	2.95	0.98	1.30

Table 6) Relations between the heavy metals concentrations in water, sediment and those in the soft tissue and shell of oyster

Elements	Water	Sediment	Soft tissue	Shell
Cu				
Water	1			
Sediment	-0.275	1		
Soft tissue	-0.409	0.546*	1	
Shell	0.746**	0.041	-0.066	1
Pb				
Water	1			
Sediment	-	1		
Soft tissue	-	-0.401	1	
Shell	-	-0.638**	0.073	1
Zn				
Water	1			
Sediment	0.177	1		
Soft tissue	0.374	0.637**	1	
Shell	0.544*	0.614**	0.721**	1
Cd				
Water	1			
Sediment	-	1		
Soft tissue	-	0.433	1	
Shell	-	-0.646**	-0.478*	1
Ni				
Water	1			
Sediment	-0.219	1		
Soft tissue	0.294	0.196	1	
Shell	-0.783**	0.223	-0.310	1
Cr				
Water	1			
Sediment	0.582**	1		
Soft tissue	0.034	0.308	1	
Shell	-0.255	0.043	0.003	1

*: $p<0.05$; **: $p<0.01$

Discussion

Concentration of heavy metals in water and sediments

The mean concentration of the elements in water samples was obtained in Cd>Cu>Zn>Ni>Cr>Pb. This order varies among stations 4, 5, 6, and 7 for Cu and Zn elements. Ranjbar Jafarabadi *et al.* [22] obtained the highest concentration of Ni and V and the lowest concentration for Cd and Hg in the Persian Gulf. On the other hand, Samara *et al.* [23] in Khalid, Sharjah Bay of United Arab Emirates (UAE), Persian Gulf, obtained the highest concentration for Ni, Fe, and Pb. The mean concentration of elements in the sediments was Zn>Cu>Ni>Pb>Cr>Cd, which corresponds to the studies of Ghasemi *et al.* [24] in Azini sediments in Persian Gulf and Mohammadizadeh *et al.* [25] at the stations 1 and 2 of northern part of Qeshm Island in relation to the arrangement of Cu, Pb, Zn, and Cd. Furthermore, the results of Ranjbar Jafarabadi *et al.* [22] with regards to the lower concentration of Pb and Cd metals have been consistent with the present study. Stations 2, 3, and 6 indicate that the concentrations of Zn, Cu, Ni, and Pb, respectively, are different to the elemental concentrations in the obtained mean values. Studies of Mohammadizadeh *et al.* [25] in the northern part of Qeshm Island at station 3 showed that the Cu concentration is higher than Zn level, which is in accordance with the mentioned exceptions of this study. The mean concentration of elements is significantly in sediments higher than in water, suggesting the tendency of studied elements to accumulate in sediments as well as the role of sediments as a receptor of heavy metals. This is consistent with the studies of Samara *et al.* [23] in Khalid, Sharjah Bay of United Arab Emirates, Persian Gulf. The elements in water are were affected by the rapid changes in the surrounding environment, while sediments recorded a history of environmental changes [6]. Based on the results, the high concentration of Cu, Zn, and Ni in both sediments and water can be due to the impact of a common resource (natural or anthropogenic) in the study area.

The concentration of heavy metals in the *Saccostrea Cucullata*

The concentrations of elements in the soft tissue were obtained as Zn>Cu>Cd>Pb>Ni>Cr and in the shell as Zn>Pb>Cu>Ni>Cd>Cr, with the results obtained in the oyster's soft tissue being consistent with the Shirneshan and Riyahi Bakhtiari [20] studies in the northern part of Qeshem Island, though they obtained the order of elemental concentrations in the shell as Pb>Zn>Cu>Cd. The accumulation of the studied elements except for the Pb in the soft tissue was far higher than that in the shell, where this accumulation was obtained with a significant difference for Cu, Zn, and Cd when compared to the shell. Different elements have various roles and functions, which lead to differences in the accumulation of elements in different tissues. The higher values of Cu and Zn in soft tissues can be due to the tendency of oysters to accumulate these essential elements for cell growth and metabolism. In mollusca, Zn is used in the structure of many enzymes, and Cu is used for the synthesis of hematocyanin [26]. Furthermore, Cd binds to low-molecular-weight proteins called metallothionein, which reduce its toxicity [27]. So, by applying the mechanism of detoxification, the soft tissue of oyster can accumulate more contents of this element. Cravo *et al.* [21] suggested that mollusca may accumulate a portion of absorbed heavy metals in their shell. This issue can be a part of detoxification process of over-absorbed essential elements and unnecessary elements in mollusca. Based on the results, the concentration of Pb in the shell showed high values. Note that Pb does not have any known function in the body of invertebrates. Due to Pb ion tendency to accumulate in calcareous tissue, the oyster shell has a high potential for Pb accumulation than its soft tissue [20]. The main reasons of high Pb concentrations in the oyster shell in comparison with the soft tissue are presented in this study.

Bioaccumulation coefficients

The accumulation of elements in oyster tissues through sediment and water was obtained by BSAF and BWAF, respectively. In these factors, values above 1 signify a higher concentration in the oyster shell than in the target environment. Monitor species or indicators accumulate pollutants in their tissues far larger than in the surrounding area. This causes the accumulation factor values to be greater than one. In this study, a large value of BWAF was obtained. Mollusca absorb a large number of pollutants from the environment and accumulate them in their body. For this reason, the studies of mollusca have been widely used in biomonitoring programs of water [28]. The bivalves' tissue has several methods for accumulation and storage of elements including binding of metals to low-molecular-weight proteins such as metallothioneins and storing them in lysosomes. Alternatively, metal-containing granules for the maintenance of homeostasis of essential elements and detoxification of unnecessary elements are other possible methods [8]. The higher values of BWAF than BSAF in this study are in accordance with the findings of Gawad [29]. In this regard, the soft tissue shows larger BSAF and BWAF values than the shell, indicating the greater tendency of elements to accumulate in the soft tissue than in the shell. The Cu, Zn, and Cd concentrations in the soft tissue of oyster are several times greater than their concentration in the sediments. This suggests the ability of the soft tissue to accumulate metals several times as large as the environment. In sediments, Cd exhibits a significant difference in the BSAF factor compared with other elements, indicating the high ability of Cd accumulation from sediments, especially in the soft tissue. Based on the classification presented for the BSAF factor, the soft tissue of the studied oyster acts as a macro-concentrator for the elements of Cu, Zn, and Cd, and its shell functions accordingly for Cd, which is similar to the findings of Wang *et al.* [30], and Chan and Wang [31], which have presented oyster as a macro-concentrator of metals. Cd function, as a macro-concentrator in oyster tissues, can be based on the fact that this element (unlike other elements) does not diminish during the reproductive period, and also due to its similarity with other essential elements such as Zn and Ca, is not excreted from the oyster body [32]. The lower values of BSAF factor for elements such as Cr, Ni, and Pb in the soft tissue can be due to the fact that they are not biologically needed, which corresponds to the findings of De Mora *et al*. [33] about the Ni element in the oyster *Saccostrea cucullata*. According to the results presented in Table 4, the coefficient of variation (CV%) of Cu, Pb, and Cd in the shell is lower than that in the oyster's soft tissue, which is incongruent with the studies of Shirneshan and Riyahi Bakhtiari [19] on Zn and Pb in the northern part of Qeshm Island, and studies by Kazemi *et al*. [34] in relation to the Pb and Cd elements in the Lengeh Port, Qeshm The concentration of elements in the oyster shell is less influenced by the physiochemical conditions of the environment. The lower values of coefficient variation indicate greater accuracy in determining the biomonitor organism for the studied metals in the region [34]. In this study, the coefficient of variation of elements including Pb, Ni, and Cr has been less than that of other elements. According to the studies Yap *et al*. [15], the lower coefficient of variation for the concentration of metals in a particular tissue suggests the accuracy and validity of that tissue to be used as a biomonitor of metals [35]. Thus, this factor can be effective in choosing a living organism as a biomonitor.

Partitioning factors

The concentration ratio of the accumulated elements in the soft tissue to the shell is captured by the partitioning factor, representing the tendency of each element to accumulate in the intended organ. Accordingly, if the obtained values are greater than one, the intended element has a higher accumulation in the soft tissue than in the shell. According to the results, Cu, Zn, and Cd had the highest values of partitioning factor (approximately 11.2-16.58 for Zn, 6.72-22.63 for Cu, and 2.78-8.84 for Cd). The higher values of the partitioning factor of these elements suggest the multiplicity of their concentration in the soft tissue than in the shell, which is in line with the results of Shirneshan and Riyahi Bakhtiari [20] and Gawad [29], regarding the elements of Cu and Zn. Based on the oyster's need to Cu and Zn for metabolism and other vital activities and also the necessity of these elements in the structure of matallo-enzymes and metalloproteins such as homocyanine and zinc fingers, the higher concentration of these elements in the soft tissue is probably related to their physiological needs, metabolic activities, body structure, and type of phytoplankton nutrition [36]. Oysters store Cd in their soft tissue due to its similarity to essential elements such as Zn, Ca, and Cu, which are essential for biological processes such as enzyme function, cellular homeostasis, and the activity of ion pumps of the membrane [32]. The lowest amount of this factor was found for Pb, suggesting the tendency of Pb to bind in the oyster shell than in its soft tissue. The tendency of Pb ionic form to accumulate in calcareous tissues and binding with organic matter as well as direct contact of calcareous layer of the shell (periostracum) with seawater, can be attributed to the higher concentration of Pb in the shell than in the soft tissue of oyster, thereby lowering the partitioning factor values [15, 20].

Relationship between the concentration of elements in water, sediment, and oyster tissues

In this study, there was a positive and significant relationship between the concentration of Cu in the shell and water, as well as between soft tissue and sediment. For Zn, there is a statistically significant relationship between shell, water, and sediment, as well as soft tissue and sediment. Since the bioaccumulation of toxic metals in the body of biomonitors is proportional to the degree of environmental contamination, their accumulated concentrations can reflect the direct bioavailability of elements and may be an indicator of the quality of the environment [28]. The relationship and correlation between an element in water or sediment and aquatic animals can indicate the impact and reflection of environmental changes in the living organisms, which would present it as an appropriate biological indicator. This corresponds to the findings of Mohammad Karami *et al.* [8] in relation to the *Pinctada radiata* as a biomonitor in the Persian Gulf coastal regions. On the other hand, the positive and significant relationship between Cr in water and sediment suggests the existence of a common source for this element in the environment. The concentration of Zn also showed a positive and significant relationship between shell and soft tissue of the oyster, representing the effect of the environment, in accordance with the findings of Díaz Rizo [37] in *Crassostrea rhizophorae*.

Comparing the concentration of the elements in water, sediment, and soft tissue of the oyster against the relevant guides

One of the water quality guidelines is the Criteria Maximum Concentration (CMC). This criterion is a benchmark of the highest concentration of a pollutant in surface water so that aquatic animals can live without any negative incidence in the environment. Criteria Continuous Concentration (CCC) is another estimate of the highest concentration of a substance in surface water to which aquatic life is exposed indefinitely without creating an unacceptable effect. In addition to these guides, other water and sediment quality guides are provided in Table 7. The comparison of the results of water sample against the relevant guide suggests that, except for Cu, the concentration of other measurable elements was lower compared to the presented guide. Also, in sediment sample, Cu has been larger than ERL, TEL, and USEPA standards. Similarly, Ni has exceeded all of the standards.

Table 7) Guideline values for heavy metal in water (μg/l) and sediment (mg/kg dry weight)

Guideline	Cu	Pb	Zn	Cd	Ni	Cr
Water						
EQS Water quality standards for the protection of saltwater life [38]	15	30	2.5	40	25	5
US EPA standards limits for saltwater [23]	50-1100	8-70	9-40	80-90	8-200	3-5
Water quality criteria (CMC) for saltwater [39]	-	74	42	90	210	4.8
Water quality criteria (CCC) for saltwater [39]	-	8.2	9.3	81	8.1	3.1
Mean concentration (in the current study)	1.21	4.68	N.D.	27.97	N.D.	33.77
Sediment						
NOAA Guidelines [40]						
ERL (Effects Range Low)	34	46.7	150	1.2	20.9	81
ERM (Effects Range Median)	270	218	410	9.6	51.6	370
Canadian Guideline [41]						
TEL (Threshold Effect Level)	18.7	30.2	124	0.7	15.9	52.3
PEL (Probable Effect Level)	108	112	271	4.2	42.8	160
USEPA standards limits for harbor sediments [23]	25-50	40-60	90-200	6	20-50	25-75
Mean concentration (in the current study)	67.67	29.53	96.39	0.14	59.19	17.66

Conclusion

Overall, it can be said that essential elements such as Cu and Zn due to their biological role in the soft tissue, and Pb due to its non-essential nature and tendency to accumulate in calcareous tissues and binding to organic matter, accumulate in the shell. Furthermore, the soft tissue indicated larger BSAF and BWAF factors for the studied elements except for Pb, than the *S. cucullata* shell, which was confirmed by the results of the partitioning factor. According to the BSAF factor, the soft tissue of oyster is considered as a macro-concentrator of Zn, Cu, and Cd, and its shell is a macro-concentrator of Cd.

The reflection of environmental changes in the tissues of living organisms can indicate the competency of that tissue for being used as a biomonitor of the relevant element in the environment. Thus, *S. cucullata* shell can be used as a suitable biomonitor for Cu and Zn in water, Cu in sediments, and soft tissue for Cu and Zn in sediments. It suggests that the lower coefficient of variation of Cu in the shell can indicate the accuracy and validity of this selection in biomonitoring the relevant element.

On the other hand, Cu in water exceeded all the relevant standards, and in sediments, it was higher than ERL, TEL, and USEPA standards. Similarly, Ni in sediments exceeded all the presented standards. This issue can be a serious warning for the living species of these ecosystems including the oysters. The effects of factors such as bioaccumulation and biomagnification cause these elements to transfer throughout the food chain with concentrations far larger than those in the environment. Since these oysters are especially used by the indigenous people, the greater level of these elements from the view of food security can be a threatening factor for the health, and hence it requires continuous monitoring.

Acknowledgments: The authors highly appreciate the efforts and cooperation of Mustafa Mirshahvald, Farnaz Mahmodi, and Bahar roozbahani the head of the Central Laboratory and his experts of the University of Malayer, respectively.

Ethical Permissions: The case was not found by the authors.

Conflict of interests: The author states that there is no conflict of interest.

Authors' Contributions: Parisa Nourozifard (First author), Introduction author/Original researcher (30%); Samar Mortazavi (Second author), Methodologist/Statistical analyst (30%); Sedigheh Asad (Third author), Assistant (10%); Nasrin Hassanzadeh (Fourth author), Discussion author (30%).

Funding/Support: The authors received no specific funding.

References

1- Sayadi M, Rezaei M, Afsari K, PoorMollaeib N. Natural and concentration factor distribution of heavy metals in sediments of Chah Nimeh reservoirs of Sistan, Iran. Ecopersia. 2015;3(2):1003-12.

2- Mudgal V, Madaan N, Mudgal A, Singh RB, Mishra S. Effect of toxic metals on human health. Open Nutraceuticals J. 2010;3(1):94-9.

3- Mortazavi S, Attaeian B, Abdolkarimi S. Risk assessment and environmental geochemistry of Pb, Cu and Fe in surface sediments (case study: Hashilan wetland, Kermanshah, Iran). Ecopersia. 2016;4(2):1411-24.

4- Shakouri A, Gheytasi H. Bioaccumulation of heavy metals in oyster (Saccostrea cucullata) from Chabahar bay coast in Oman Sea: Regional, seasonal and size-dependent variations. Mar Pollut Bull. 2018;126:323-9.

5- Mortazavi S, Saberinasab F. Heavy metals assessment of surface sediments in Mighan wetland using the sediment quality index. Ecopersia. 2017;5(2):1761-70.

6- Rodriguez-Iruretagoiena A, Rementeria A, Zaldibar B, De Vallejuelo SF, Gredilla A, Arana G, et al. Is there a direct relationship between stress biomarkers in oysters and the amount of metals in the sediments where they inhabit?. Mar Pollut Bull. 2016;111(1-2):95-105.

7- Wang XN, Gu YG, Wang ZH, Ke CL, Mo MS. Biological risk assessment of heavy metals in sediments and health risk assessment in bivalve mollusks from Kaozhouyang Bay, South China. Mar Pollut Bull. 2018;133:312-9.

8- Mohammad Karami A, Riyahi Bakhtiari A, Kazemi A, Kheirabadi K. Assessment of Toxic metals concentration using pearl oyster, Pinctada radiate, as bioindicator on the coast of Persian Gulf, Iran. Iran J Toxicol. 2014;7(23):956-61.

9- Leitão A, Al-Shaikh I, Hassan H, Hamadou RB, Bach S. First genotoxicity assessment of marine environment in Qatar using the local Pearl oyster Pinctada radiata. Reg Stud Mar Sci. 2017;11:23-31.

10- Aghajan Pour F, Shokri MR, Abtahi B. Visitor impact on rocky shore communities of Qeshm Island, the Persian Gulf, Iran. Environ Monit Assess. 2013;185:1859-71.

11- UNESCO. Qeshm Island (tentative lists). In: Centre UWH, editor. Paris: UNESCO; 2016.

12- Kumar R, Rani M, Gupta H, Gupta B. Trace metal fractionation in water and sediments of an urban river stretch. Chem Speciat Bioavailab. 2014;26(4):200-9.

13- Yap CK, Ismail A, Tan SG, Omar H. Correlations between speciation of Cd, Cu, Pb and Zn in sediment and their concentrations in total soft tissue of green-lipped mussel Perna viridis from the west coast of Peninsular Malaysia. Environ Int. 2002;28(1-2):117-26.

14- Giarratano E, Duarte CA, Amin OA. Biomarkers and heavy metal bioaccumulation in mussels transplanted to coastal waters of the Beagle Channel. Ecotoxicol Environ Saf. 2010;73(3):270-9.

15- Yap CK, Ismail A, Tan SG, Rahim IA. Can the shell of the green-lipped mussel Perna viridis from the west coast of Peninsular Malaysia be a potential biomonitoring material for Cd, Pb and Zn?. Estuar Coast Shelf Sci. 2003;57(4):623-30.

16- ASTM D1886-03. Standard test methods for nickel in water. West Conshohocken: ASTM International; 2003.

17- Yap CK, Pang BH. Assessment of Cu, Pb, and Zn contamination in sediment of north western Peninsular Malaysia by using sediment quality values and different geochemical indices. Environ Monit Assess. 2011;183(1-4):23-39.

18- Huanxin W, Lejun Z, Presley BJ. Bioaccumulation of heavy metals in oyster (Crassostrea virginica) tissue and shell. Environ Geol. 2000;39(11):1216-26.

19- Usero J, Morillo J, Gracia I. Heavy metal concentrations in molluscs from the Atlantic coast of southern Spain. Chemosphere. 2005;59(8):1175-81.

20- Shirneshan G, Riyahi Bakhtiari A. Accumulation and distribution of Cd, Cu, Pb and Zn in the soft tissue and shell of oysters collected from the northern coast of Qeshm Island, Persian Gulf, Iran. Chem Speciat Bioavailab. 2012;24(3):129-38.

21- Cravo A, Bebianno MJ, Foster P. Partitioning of trace metals between soft tissues and shells of Patella aspera. Environ Int. 2004;30(1):87-98.

22- Ranjbar Jafarabadi A, Bakhtiyari AR, Toosi AS, Jadot C. Spatial distribution, ecological and health risk assessment of heavy metals in marine superficial sediments and coastal seawaters of fringing coral reefs of the Persian Gulf, Iran. Chemosphere. 2017;185:1090-111.
23- Samara F, Elsayed Y, Soghomonian B, Knuteson SL. Chemical and biological assessment of sediments and water of Khalid Khor, Sharjah, United Arab Emirates. Mar Pollut Bull. 2016;111(1-2):268-76.
24- Ghasemi S, Siavash Moghaddam S, Rahimi A, Damalas CA, Naji A. Ecological risk assessment of coastal ecosystems: The case of mangrove forests in Hormozgan Province, Iran. Chemosphere. 2018;191:417-26.
25- Mohammadizadeh M, Bastami KD, Ehsanpour M, Afkhami M, Mohammadizadeh F, Esmaeilzadeh M. Heavy metal accumulation in tissues of two sea cucumbers, Holothuria leucospilota and Holothuria scabra in the northern part of Qeshm Island, Persian Gulf. Mar Pollut Bull. 2016;103(1-2):354-9.
26- Yap CK, Noorhaidah A, Azlan A, Azwady AN, Ismail A, Ismail AR, et al. Telescopium telescopium as potential biomonitors of Cu, Zn, and Pb for the tropical intertidal area. Ecotoxicol Environ Saf. 2009;72(2):496-506.
27- Apeti DA, Johnson E, Robinson L. A model for bioaccumulation of metals in Crassostrea virginica from Apalachicola Bay, Florida. Am J Environ Sci. 2005;1(3):239-48.
28- Waykar B, Petare R. Studies on monitoring the heavy metal contents in water, sediment and snail species in Latipada reservoir. J Environ Biol. 2016;37(4):585-9.
29- Gawad SS. Concentrations of heavy metals in water, sediment and mollusk gastropod, Lanistes carinatus from Lake Manzala, Egypt. Egypt J Aquat Res. 2018;44(2):77-82.
30- Wang WX, Yang Y, Guo X, He M, Guo F, Ke C. Copper and zinc contamination in oysters: Subcellular distribution and detoxification. Environ Toxicol Chem. 2011;30(8):1767-74.
31- Chan CY, Wang WX. Seasonal and spatial variations of biomarker responses of rock oysters in a coastal environment influenced by large estuary input. Environ Pollut. 2018;242(Part B):1253-65.
32- Alavian Petroody SS, Hamidian AH, Ashrafi S, Eagderi S, Khazaee M. Investigation of body size effect on bioaccumulation pattern of Cd, Pb and Ni in the soft tissue of rock oyster Saccostrea cucullata from Laft Port. J Persian Gulf. 2013;4(14):39-45.
33- De Mora S, Fowler SW, Wyse E, Azemard S. Distribution of heavy metals in marine bivalves, fish and coastal sediments in the Gulf and Gulf of Oman. Mar Pollut Bull. 2004;49(5-6):410-24.
34- Kazemi A, Riyahi Bakhtiari A, Kheirabadi N, Mohammad Karimi A. Distribution of Pb in sediment and shell of rocky oysters (Saccostrea cucullata) of Lengeh Port, Qeshm and Hormoz Islands in Persian Gulf, Iran. Ecopersia. 2013;1(2):191-8.
35- Bagheri Z, Reyahi Bakhtiari A, Khandan Barani H. Investigation of Saccostrea cucullata oyster as monitoring of zinc, copper, lead and cadmium in intertidal island of Hormuz, the Persian Gulf. Oceanography. 2015;5(20):71-7. [Persian]
36- Saeedi H. Availability of Venerid Clam, Amiantis umbonella as potential metal bioindicator in Bandar Abbas coast, the Persian Gulf. Egypt J Aquat Res. 2012;38(2):93-103.
37- Rizo OD, Reumont SO, Fuente JV, Arado OD, Pino NL, Rodríguez KA, et al. Copper, zinc and lead enrichments in sediments from Guacanayabo Gulf, Cuba, and its bioaccumulation in oysters, Crassostrea rhizophorae. Bull Environ Contam Toxicol. 2010;84(1):136.
38- Cole S, Codling ID, Parr W, Zabel T. Guidelines for managing water quality impacts within UK European marine sites [Report]. Swindon: WRc Swindon; 1999.
39- EPA US. National recommended water quality criteria. [Report]. Washington, D.C.: Environmental Protection Agency; 2004.
40- Long ER, MacDonald DD, Smith SL, Calder FD. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environ Manag. 1995;19(1):81-97.
41- Sundaray SK, Nayak BB, Lin S, Bhatta D. Geochemical speciation and risk assessment of heavy metals in the river estuarine sediments-a case study: Mahanadi basin. J Hazard Mater. 2011;186(2-3):1837-46.