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RESEARCH ARTICLE

LIOLOPHURA JAPONICA (MOLLUSCA: POLYPLACOPHORA) AS POTENTIAL BIOINDICATOR OF HEAVY METALS CONTAMINATION IN ADEN COASTS, YEMEN

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Abstract

The coastal areas of Aden City hold ecological and economic importance for Yemen. However, they face increasing environmental pressures from various anthropogenic activities, leading to heavy metals contamination. The present study aims to assess the effectiveness of using Polyplacophora (***Liolophura japonica)*** as bioindicator for heavy metals contamination in two coasts of Aden City (Al-Hiswah and Amran). To determine heavy metals contamination, samples of ***L. japonica*** and adjacent sediments were collected (three replicates per site) from intertidal zone during low tides. The soft tissues of ***L. japonica*** and sediment samples were dried then digested according to standard methods. An Atomic Absorption Spectrometer (AAS) was used to determine the concentration of (iron, zinc, lead) in study samples. Metal concentrations in sediments were compared to US EPA Sediment Quality Guideline; iron and lead levels in sediments from both coasts were found to be within non-polluted levels, while zinc levels at Al-Hiswah coast indicated moderate pollution. When comparing metal concentrations in ***L. japonica*** to the permissible limits set by FDA and FAO, it was found that iron and lead levels exceeded the permissible limits, while zinc levels were below the permissible limit. Statistical analysis revealed significant differences in iron concentrations in sediments between the two studied coasts while lead and zinc levels in sediments did not show significant differences. In contrast, significant differences in iron, zinc, and lead concentrations were observed in ***L. japonica*** between the two coasts. The results of BSAF indicate that ***L. japonica*** is a reliable bioindicator of lead pollution in the studied coasts.

Keywords: *L. japonica*, Polyplacophora, Aden coasts, Heavy metals contamination, Sediments, Bioaccumulation, Bioindicators, AAS.

1. Introduction:

Aden city is located in the southern part of the Yemeni coast on the Gulf of Aden between longitudes 12°.28',12°.57' N and latitudes 44°.27',45°.07'E. It has a coastline of about 180 km long; this coastline has a multi-topographical nature with different features that led to the formation of different coastal environments [1]. These coastal areas are rich in biodiversity such as various crustaceans, molluscs, fish, echinoderms, marine algae, seaweed, turtles, and other marine organisms [2-4].

It is also an industrial city where there are many factories and industrial facilities such as (Aden Refinery, Thermal Power Plant, ship repair workshops, battery factories and workshops, metal and mechanical workshops, paint and coating factories, waste disposal and incinerators, cement factories, and plastic factories and so on); unfortunately, most of which are directly poured into seawater or poured into sewage treatment basins. These wastes include organic, non-organic, toxic or non-toxic substances that might be decomposed or not. All these waste poured into the sea, which harms the great marine biodiversity living in these waters on the coastline of Aden city.

In addition to the important geographical location of Aden city and its important port, it has a large oil refinery. That made it play an important role movement of global trade and maritime navigation; which led to increase the transit and the passage of giant commercial ships and oil tankers in the region. All of these things definitely lead to increase pollution and harm living organisms in the coastal environment of Aden city.

The coastal and tidal zone are the most marine areas exposed to pollution and risks due to its small area compared to the surrounding water body. Pollution leads to the killing of marine life and entering the food chains, reaching humans [5] The contamination of coastal environment with heavy metals produced by various human activities is a great concern because of its harmful effects on marine health. Heavy metals are those elements their density is more than **5mg /cm^3**, with an atomic weight greater than **40.04**; this class of minerals called heavy metals has not only been known for its high density but more importantly for its harmful effects on the ecosystem and living organism. They are considered as constant inorganic pollutants that last for years in the environment and is deposited in the tissues of living organisms and transmitted through food chains, negatively affecting the environment and human health [6, 7].

Benthos is an encompassing term used to classify organisms found on, in, or in close contact with the bottom region of bodies of water. These organisms are continuously threatened by various anthropogenic activities, and are often regarded as excellent bioindicators and biomonitors of environmental changes due to their susceptibility and sensitivity. Familiar examples of benthic organisms include Molluscs, Echinodermata, Crustacean, Seagrass, Macro algae, and Corals [8].

Chitons (Class Polyplacophora) are among the most common mollusks inhabiting marine rocky shores worldwide. Different from other mollusks, chitons have eight shell valves composed of overlapping aragonite plates called valves. They are mainly plant consumers (especially algae). In contrast, they become food for many different predators, such as fish, crabs, lobsters, octopuses, and birds, which are in turn consumed by humans through the food chain. They are sedentary and semi-sessile, can easily be collected and identified, thus they have the characteristics of a good bioindicator [9].

There have been many local and international studies on the use of Mollusks as bioindicators to monitor contamination with heavy metals, where most of these studies focused on Gastropods and Bivalves, however, there have not been any local studies on the use of Polyplacophora as a bioindicator, despite having the unique characteristics that qualify it to be an active bioindicator, likewise international studies on the use of Polyplacophora as a bioindicator are still limited. Thus, this study aims to evaluate the effectiveness of using Polyplacophora as a bioindicator, which contributes to the expansion of the employment of bioindicators in environmental studies

2. Materials and methods:

2.1. Study sites:

Present study was conducted at Al-Hiswah Coast and Amran Coast, (table 1)

2.2. Sample collection:

Thirty six samples of ***Liolophura japonica*** were collected at low tide from the intertidal zone of study coasts **(Fig. 2),** with three replicates in each coast during February 2024. They were washed well with seawater to get rid of sediments. In the laboratory the plates of ***Liolophura japonica*** shell were removed, soft tissues washed well with distilled water.

Surficial sediment samples were taken using a plastic shovel near biota collection sites from the intertidal zone during the low tide then placed in polyethylene bags. Coordinates of the sites were recorded using the GPS coordinates program, version 5.23 in Smartphone. The sediments were air-dried until they were transported to the laboratory.

Table 1: Description of study sites in the Aden coasts – Yemen

No.	Study Sites	Latitudes	Longitude	Study Site Discretion
1	Al-Hiswah Coast	12°49'26.4"N,	44°55'54.4"E	Sandy coast, large rocks were brought to it during the construction of the thermal power station and these rocks became a habitat for many marine animals. Located near Power plants and transportation and exposed to runoff, oil spill from the oil pipes and fishing activities.
2	Amran Coast	12°45'11.8"N,	44°44'05.2"E	Sandy and rocky coast, quay for fishermen's boats. Exposed to fishing activities, tourism activities and the urban activities.

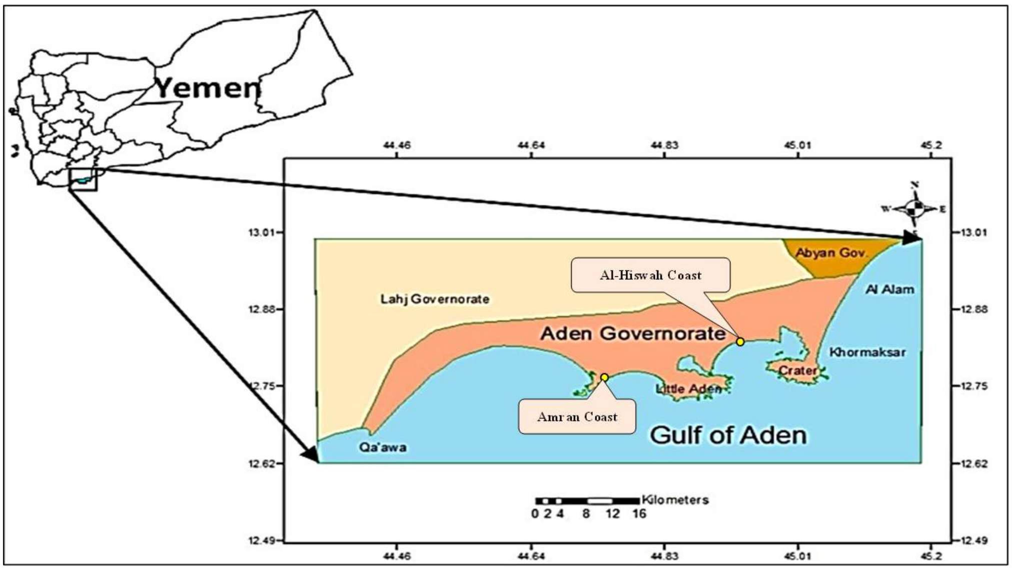

Fig. 1: study sites

Fig. 2: *L. japonica*

* Scale bar is 2 cm

2.3. Laboratory procedures for heavy metals Analysis:

Laboratory procedures for heavy metals Analysis were conducted at two main laboratories: Central Laboratory for Fish Quality Control- Aden, and Al- kood Research Center Laboratory- Abyan.

Glassware was rinsed by (HNO_3 10 %.) then washed well with distilled water before use [5]. ***Liolophura japonica*** samples were dried at 105 °C until reaching constant weight [11].Then they were put in the glass desiccator for about 15 minutes and grind by the electrical blender to powder. The samples were digested by [12] method as following:

1g of dried powder like sample was put in conical Flask, 10 ml of concentrated nitric acid were added, and Conical Flasks were covered with filter paper and lift to stand overnight. Next day they were heated on 100 °C for one hour then 2ml of concentrated Hydrogen peroxide were added and heated again for half an hour. Then filtered into 100 ml volumetric flask and diluted to the mark using distilled water.

Sediment samples were dried at 60 °C until reaching a constant weight then ground with porcelain mortar and pestle, and sieved using (90 micron) mesh. Subsequently sediments were digested by [13, 14] method using **Aquarega** which contain concentrated mixture of hydrochloric acid and nitric acid with a 3:1 ratio, respectively as following:

1 g of dried sample was put in conical Flask; 10 ml of Aquarega were added, Conical Flasks were covered with filter paper and lift to stand overnight. Next day they were heated on 100 °C for one hour and half. Then filtered into 100 ml volumetric flask and diluted to the mark using distilled water.

Blank samples were prepared in the same manner but without using samples. Finely, the Concentration of (Fe, Pb, Zn) were read using Atomic Absorption Spectrometer.

2.4. Statistical analysis:

Heavy metal concentrations in sediments and biota were statistically analyzed using a one-way ANOVA based on a completely randomized design with three replicates. The means were compared according to the value of the least significant difference (LSD) at a probability level of 0.05 using Genstat 5, release 3.

2.5. Sediment Quality Guidelines (SQG):

U.S.EPA Sediment Quality Guidelines are used to assess the extent of sediment contamination by comparing sediment concentration with the corresponding quality guidelines [15]. To evaluate level of contamination, sediments were classified as: non-polluted, moderately polluted, and heavily polluted. Table (2) shows the U.S.EPA Sediment Quality Guidelines according to [16].

2.6. Biota sediment accumulation factor (BSCF):

"**BSAF** is a parameter describing bioaccumulation of sediment-associated organic compounds or metals into tissues of ecological receptors". [17]

$BSAF = C_{Biota} / C_{Sediment}$

Where C_B is metal′s concentration in biota, and C_S is metal′s concentration in surrounding sediment. According to BSAF values, organisms are classified into three groups; BSAF>2, high accumulation, 1<BSAF<2, moderate accumulation, BSAF<1 low accumulation [18].

3. Results and discussions:

3.1. The distribution of heavy metals in sediments:

The results of heavy metals analysis in sediments shown in Table (2) and figure (4) indicate that the distribution of heavy metals in sediments of study coasts is Fe > Zn > Pb.

3.1.1. Iron:

Iron is one of the most abundant elements in the Earth's crust, ranking fourth after oxygen, silicon, and aluminum. The sources of iron pollution include sewage, industrial waste, liquid waste from the petroleum and fertilizer industries, and the discharge of waste from car service stations [19].

The average concentrations of iron in the coasts of Al-Hiswah and Amran shown in Table (2) were **(7946.7, 6670.0 µg/g)** respectively, where the highest value was recorded at Al-Haswa coast. Comparing to the other studied metals, iron levels were the highest in sediments. The high concentrations of iron in present study is due to rocks weathering, as Iron is the fourth most abundant metal in the Earth's crust [20]. Similarly, ships wastes, oil spills, and the old shipwrecks, fishing iron tools and sewage are sources of Iron pollution in those coasts. Comparing to previous studies shown in table (3), recorded iron values in present study are higher than iron values recorded by [21] in some coasts of Aden- Yemen. The difference between present study and [21] study, is likely attributed to the accumulation of iron over time (more than five years interval between the two studies) suggesting that metal levels tend to increase with the passage of time, along with the continued anthropogenic activities. Similarly, iron levels in present study are higher than iron levels recorded by [22] in Jeddah Coast in the Red Sea. The difference between the present study and previous study is attributed to the nature of the studied areas and the degree of their pollution

3.1.2. Zinc:

Zinc is used in many applications that affect our daily lives, therefore the possibility of contamination with it is great with the industrial progress, as it is used as a protective coating for other metals, in paints and construction materials, zinc compounds have applications in automotive components, batteries, dental and home healthcare products [6].

The average concentration of zinc in the coasts of Al-Hiswah and Amran shown in Table (2) were **(98.4, 79.2 µg/g)** respectively, where Al-Hiswah coast recorded the highest concentration of zinc which could be attributed to the proximity of the Al-Hiswah coast to the thermal power station and its exposure to untreated sewage water, runoff from agricultural lands as zinc is included in pesticides, fungicide and fertilizers, and fishing activities as zinc is used in anti- corrosion coating. Comparing to previous studies shown in table (3), recorded zinc levels in present study sediments are higher than zinc levels recorded by [21] in some coasts of Aden- Yemen; the high levels of zinc in present study compared to [21] study, is likely attributed to the accumulation of zinc over time. In contrast, zinc levels in present study sediments are lower than zinc levels recorded by [22] in Jeddah Coast in the Red Sea. The difference between the present study and previous study is attributed to the high degree of pollution in the studied areas, where Jeddah Coast is susceptible to several expected sources of pollution such as Jeddah harbor, electrical power generator plants, municipal discharge stations, desalination plants, a Petroleum refinery plant, and an Armco refinery plant [22].

3.1.3. Lead:

Lead is a non-essential metal naturally occurring in the environment, has been used extensively throughout history. It uses in various applications, such as batteries, plumbing, fuel additives such as leaded fuel which was used to improve fuel combustion and protect engines, likewise it is used in paints as an anti-corrosion coating, those uses have led to widespread environmental contamination of lead [23].

The average concentration of lead in the coasts of Al-Hiswah and Amran shown in Table (2) were **(17.7, 16.5 µg/g)** respectively, Comparing to previous studies on sediments shown in table (3), recorded lead levels in present study are lower than recorded lead levels by [21] in sediments of some coasts of Aden- Yemen. The decrease presence of lead in present study that conducted in winter compared to [21] study that conducted in summer may be attributed to sampling times as heavy metals concentrations increase during summer due to the higher temperature, and intensified evaporation. Furthermore, increase wastewater discharge, weaker winds, and marine currents compared to winter contribute to this rise. Similarly, lead levels in present study are lower than [26] in Al-Hodiedah coasts, Yemen; The difference between the present study and previous study is attributed to the difference of the degree of pollution in the studied areas, where Al-Hodiedah coasts according to [26] receive different amounts of anthropogenic inputs such as oil pollution, untreated sewage, and waste of factories near the study sites. In contrast, recorded lead values in present study are higher than recorded lead values by [24] in Mumbai- India; this deference is attributed to the nature of the studied coasts as well as the degree of their pollutions

3.2. Sediment Quality Guidelines (SQG):

When comparing the average concentrations of metals in sediments of Al-Hiswah and Amran with US. EPA (SQG) that is shown in table (2); the average concentration of iron in the sediments of Al-Hiswah and Amran were within the non-polluted level **(less than 17000 µg/g)**. In contrast, the average concentrations of zinc and lead in sediments of Amran coast were within the non-polluted level, while Al-Hiswah coast recorded moderate pollution level with zinc and lead, as shown in figure (4)

3.3. Statistical analysis of metals in sediments:

The results of the statistical analysis of heavy metals in the sediments showed significant differences in iron concentrations between the coasts of Al-Hiswah and Amran, where **(p-value is 0.002)** indicating that Al-Hiswah coast is more polluted and more susceptible to pollution sources with iron compared to Amran; where Al-Hiswah coast located near the Power Plants and transportation and exposed to runoff, and fishing activities which consider different sources of metals pollution, while Amran coast is mostly subjected to fishing activities. On the other hand, the results of the statistical analysis did not show any significant differences in zinc and lead concentrations between the two coasts, where **(p-value are 0.098, 0.784)** respectively indicating that the pollution sources of zinc and lead may be similar as both costs are subjected to fishing activities where zinc and lead mostly are used in paints as an anti-corrosion coating. Additionally, the two coasts may have comparable environmental conditions influencing metals accumulation such as (PH, salinity, water currents, and O_2 levels in surface sediments layers).

3.4. The distribution of metals in L. japonica at studied coasts:

The results of heavy metals analysis in ***L. japonica*** shown in Table (3) and figure (5) indicate that the distribution of heavy metals in ***L. japonica*** is Fe > Pb > Zn. This is somewhat different from the distribution of metals in the sediments, as ***L. japonica*** recorded a high concentration of lead in its tissues despite the low level of lead in the sediments.

Table 2: Statistical summary of the metal contents in study coasts sediments (Average Conc. ± SD) comparing with (LSD) and sediment quality guidelines (SQG)

Metals		Fe	Zn	Pb
Al-Hiswah		$7946.7^{a} \pm 155.2$	$98.4^{a} \pm 10.2$	$16.5^{a} \pm 6.6$
Amran		$6670.0^{b} \pm 286.9.$	$79.2^{a} \pm 11.6$	$17.7^{a} \pm 0.7$
mean		7308.35	88.8	17.1
LSD		523.2	24.77	10.67
SQG	Non polluted	<17000	<90	<40
	Moderately polluted	17000-25000	90-200	40-60
	Heavily polluted	>25000	>200	>60

Table 3: Metal concentrations (µg g-1 dry wt.) in sediments from the present study compared to previous studies.

Location	Pb	Zn	Fe	Reference
Southwest of Iran	96.39	6.79	-	[25]
Al-Hodiedah, Yemen	63.56	-	-	[26]
Mumbai- India	0.25	4.95	4.6	[24]
Gulf of Tunis	46.9	36.9	-	[27]
Some Coasts of Aden- Yemen	28.15	54.7	2772.7	[21]
Jeddah Coast in the Red Sea	-	390	4472	[22]
Coasts of Al-Hiswah and Amran	17.1	88.8	7308.35	Present study

3.4.1 Iron:

The average concentrations of iron in ***L. japonica*** in the coasts of Al-Hiswah and Amran shown in Table (3) were **(1105.8, 959.8 µg/g)** respectively, where the highest value was recorded in ***L. japonica*** collected from Al-Hiswah coast. The recorded iron values in ***L. japonica*** in studied coasts exceeded the permissible limits **(100 µg/g)** according to [28]. The high concentrations of iron in ***L. japonica*,** indicates the high ability of this organism to accumulate iron within its tissues. Iron is essential metal, but the very high concentration of it in this organism certainly toxic and may disturb its biological process and will transfer through the food chains. Due to lack of researches on class Polyplacophora, this study was compared to researches on Mollusca in general as shown in table (5). The recorded iron values in ***L. japonica*** was higher than iron values obtained by both [14] in soft tissue of some Bivalves at Aden coasts- Yemen, and [29] in soft tissues of *Chiton lamy* in Chabahar Bay, Iran. Bioaccumulation of trace metals in marine organisms such as Mollusks can be influenced by the environmental factors such as (degree of contamination, temperature, salinity, pH, etc.) and biotic factors (metabolic rate, age, etc.) [30]; thus, the difference between the present study and previous studies is attributed to the difference in the environmental factors of studied areas, as well as the difference in studied species

3.4.2. Zinc:

As an essential element for most organisms, zinc levels are carefully regulated within the body. Zinc has been shown to have adverse reproductive, biochemical, physiological, and behavioural effects on a variety of aquatic organisms [31].

The average concentration of zinc in ***L. japonica*** in the coasts of Al-Hiswah and Amran shown in Table (3) were **(ND, 29.7 µg/g)** respectively, where the highest value was recorded in ***L. japonica*** collected from Amran coast. When comparing zinc in ***L. japonica*** with the permissible limits for zinc in Mollusks **(100µg/g)** according to [32], zinc values in ***L. japonica*** in the studied coasts were below the permissible limit. Despite the increased presence of zinc in coastal sediments, ***L. japonica*** recorded low concentrations of zinc, which indicates the high ability of this species to regulate zinc within its tissues, as some Molluscs according to [33] can regulate metal levels in their tissues especially in the polluted environments through various mechanisms such as excreting excess metals, depositing them into the shell, and reducing uptake from sediments. Comparing to previous studies in Mollusca shown in table (5), the recorded zinc values in ***L. japonica*** are lower than zinc values recorded in Bivalvia by both [34], and [14] in coasts of Aden-Yemen. Likewise lower than zinc values recorded in Gastropoda by [35] in Malaysia. The difference between the present study and previous studies as mention before is attributed to the difference in the environmental factors of studied areas, as well as the difference in studied species.

3.4.3. Lead:

Lead is a non-essential metal; does not perform any vital function in the human body, but it causes a lot of harm when enters it through food, water, or air [6]. Likewise, marine organisms are harmed by lead. Higher level of lead can affect and disturb marine ecosystems specially the invertebrates (key species in trophic chain). It may affect different stages of development from fertilization to larval development and lead to disturbance in reproduction and mortality [23]**.**

The average concentration of lead in ***L. japonica*** in the coasts of Al-Hiswah and Amran shown in Table (3) were **(36.9, 24.1 µg/g)** respectively, where the highest value was recorded in ***L. japonica*** collected from Al-Hiswah coast. When comparing lead in ***L. japonica*** with the permissible limits for lead in Mollusks **(2 µg/g)** according to [32], lead values in ***L. japonica*** in the studied coasts highly exceeded the permissible limit**.** Lead is a non-essential element, so its presence in high concentrations in ***L. japonica*** indicates the high ability of this species to accumulate lead within its tissues likewise that may affects the biological processes in the organism and transfer through the food chains. Comparing to previous local and international studies shown in table (5), recorded lead values in ***L. japonica*** are higher than lead values obtained in Mollusca by [34] in Aden coats-Yemen. The difference between this study and the local study [34] may be attributed to the accumulation of metals over time as well as the difference in studied species. Similarly, present study are higher than [18] study in Chabahar Bay, Iran, and [37] study in Malaysian Peninsula, where both previous studies conducted in polluted coasts. The difference between the present study and previous studies as mention before is attributed to the nature of studied areas, the degree of their pollutions, as well as the difference in studied species.

3.5. Statistical analysis of metals in L. japonica:

The results of the statistical analysis of heavy metals in ***L. japonica*** did not show any significant differences in iron concentrations between the coasts of Al-Hiswah and Amran, where **(p-value is 0.117)**. The absence of significant differences may indicate that ***L. japonica*** in the two coasts is exposed to similar environmental conditions influencing metals uptake such as (PH, salinity, water currents, and O_2 levels in surface sediments layers). In contrast, the results of the statistical analysis showed significant differences in zinc concentrations in ***L. japonica*** in the two coasts, where **(p-values is 0.005).** ***L. japonica*** collected from Al-Hiswah recorded lower level of zinc, despite the higher level of zinc recorded in its sediments, and this unexpected finding could be attributed to the presence of zinc in forms that are poorly soluble or not readily bioavailable, which make it hard for ***L. japonica*** to uptake and accumulate zinc within its tissues. Similarly, lead concentrations in ***L. japonica*** showed significant differences between the two coasts, where **(p-value is 0.027),** however lead levels in ***L. japonica*** in both coasts exceeded lead levels in sediments of the two coast, which reflect the high ability of this species to accumulate lead within its tissues.

Table 4: Statistical summary of the metal contents in *L. japonica* (Average Conc. (μg/g dry wt.) ± SD) comparing with (LSD) and permissible limit according to FAD and FAO:

Metal	Fe	Zn	Pb
Al-Hiswah	1105.8 ^{a} ± 41.6	ND ^{b} ± 0.0	36.9 ^{a} ± 7.7
Amran	959.8 ^{a} ± 119	29.7 ^{a} ±9.2	24.1 ^{b} ± 6.1
mean	1032.8	14.85	30.5
LSD	203.3	14.73	10.43
[28]	100	-	-
[32]	-	100	2

* ND means not detected value

* Same letters indicates non-significant differences.

3. 6. Biota sediment accumulation factor (BSCF):

(BSAF) is a ratio used to evaluate the bioaccumulation of metals from sediments into organisms, classifying accumulation levels as low, moderate, or high based on its value [18]. The results of Biota Sediment Accumulation Factor shown in table (6) indicate that the accumulation factor of iron in tissues of ***L. japonica*** at both studied coasts were **less than 1**, indicating a very low capacity for accumulation. This result means that ***L. japonica*** does not tend to accumulate iron within its tissues at a higher concentration than the sediments. Similarly, the accumulation factor of zinc in tissues of ***L. japonica*** at both studied coasts were **less than 1,** indicating a very low accumulation of zinc and reflecting the ability of this species to regulate zinc levels efficiently, either through active excretion or not absorbing it in large quantities. In contrast, the accumulation factor of lead showed higher levels, it was 2.23 in the coast of Al-Hiswah, indicating a high accumulation of lead, while in the coast of Amran, it was 1.37, indicating a moderate accumulation of lead in ***L. japonica***. This result indicates that ***L. japonica*** is able to absorb lead from the environment and accumulated it in its tissues, which makes it a reliable bioindicator of lead pollution.

Table 5: Comparison of heavy metal concentration (μg/g dry wt.) in *L. japonica* from the present study and previous studies in Mollusca:

Location	Pb	Zn	Fe	Studied class	Reference
Malaysia	0.47-0.63	32.3-50.6	-	Gastropoda	[35]
Aden coats, Yemen	-	335.68	336.25	Bivalvia	[14]
Syria	0.12-4.8	10.8 - 875	-	Bivalaia & Gastropoda	[36]
Malaysian Peninsula	0.13-3.04	41.8-158.0	-	Bivalvia	[37]
Aden coats, Yemen	9.8 - 23.7	10.2 - 120.3	-	Bivalvia	[34]
Chabahar Bay, Iran	10.37	-	-	Polyplacophora *(Chiton lamy)*	[18]
Chabahar Bay, Iran	3.77 - 7.03	-	384.95- 554.67	Polyplacophora *(Chiton lamy)*	[29]
Aden coats, Yemen	24.1-36.9	ND, 29.7	959.8-1105.8	Polyplacophora (L. japonica)	Present study

Table 6: Biota sediment accumulation factor Values in *L. japonica* in study coasts:

BSAF in L. japonica			
Sites	Fe	Zn	Pb
Al-Hiswah Coast	0.14	0.00	2.23
Amran Coast	0.14	0.38	1.37
Potential Accumulation	BSAF≤ 1, **low** potential accumulation 2≥ BSAF>1, **moderate** potential accumulation BSAF> 2. **high** potential accumulation		

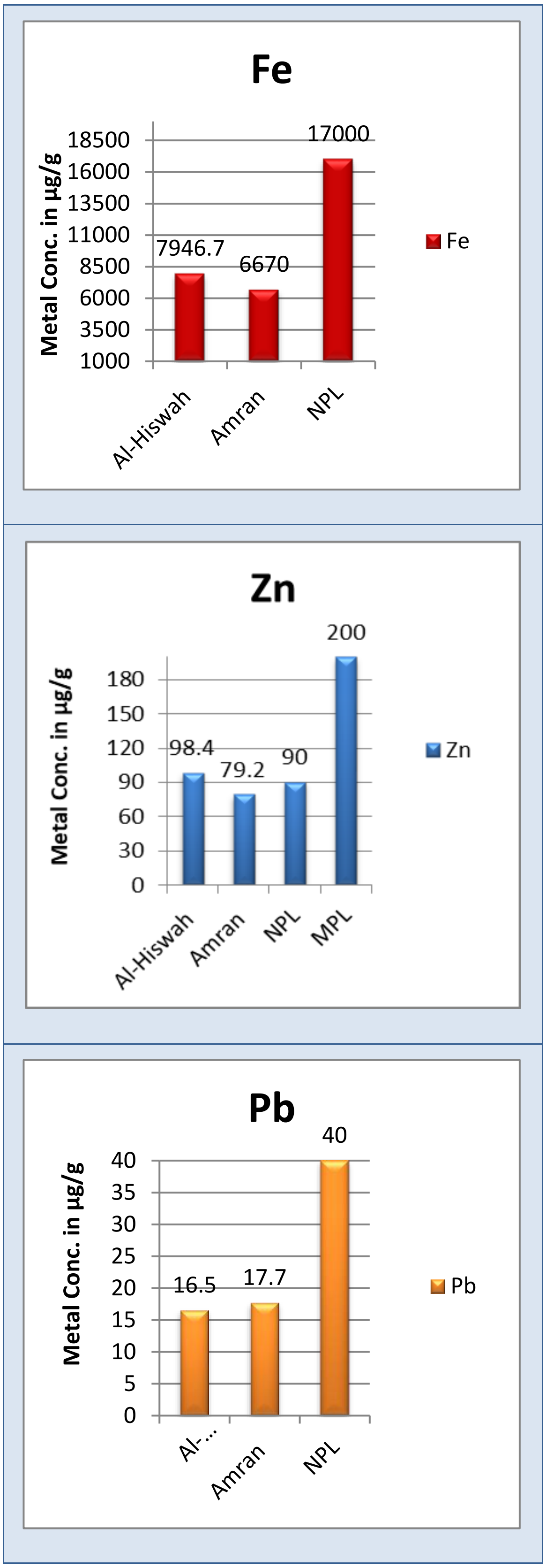

Fig. 4: Metals concentrations in study coasts sediments compared to US. EPA (SQG).
*NPL means non- polluted level
*MPL means moderately polluted level

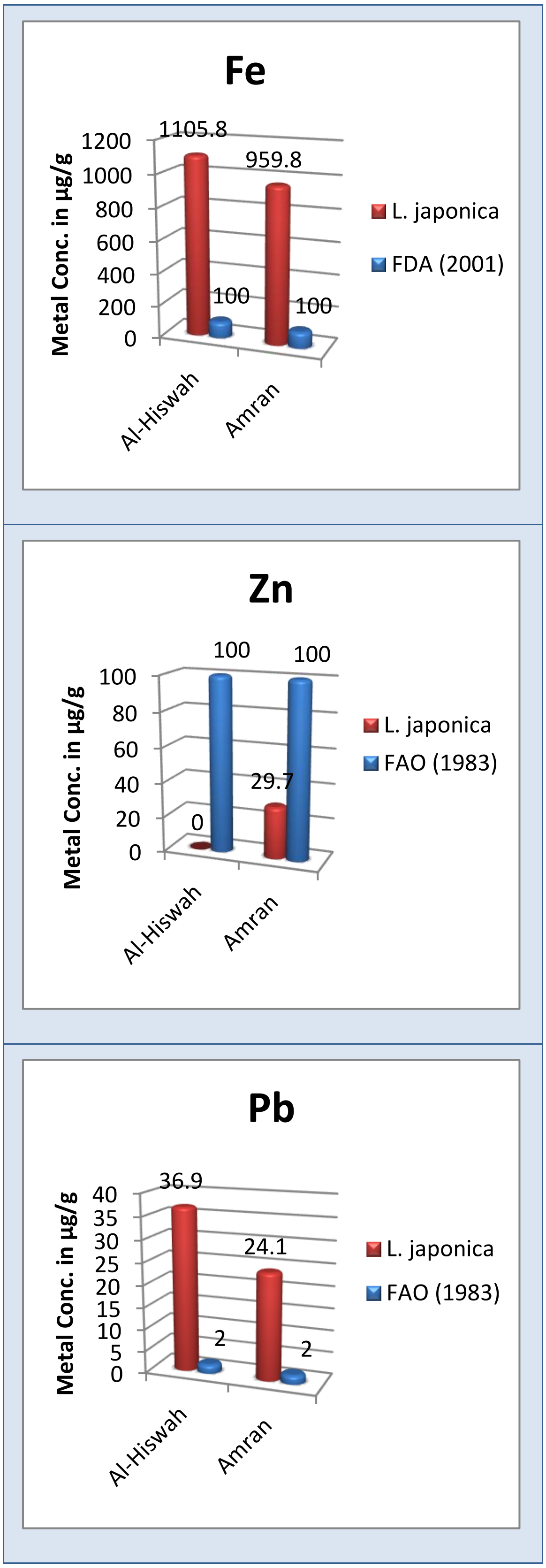

Fig. 5: Metals concentrations in *L. japonica* compared to FDA & FAO Permissible limit.

4. Conclusions:

The sediments of Al-Hiswah coast recorded higher levels of iron and zinc compared to Amran coast; the proximity to the thermal power station and the exposure to sewage water and surface runoff from the nearby Al-Hiswah reserve could be the potential sources of iron and zinc in Al-Hiswah coast. Moreover, based on the Sediment Quality Guidelines (SQG) used in this study, the sediments of the Al-Hiswah coast exhibited moderate zinc pollution.

In contrast, ***L. japonica*** samples recorded higher levels of iron and lead in Al-Hiswah coast compared to Amran coast, however the concentrations of these metals in ***L. japonica*** on both coasts exceeded the permissible limits in Molluscs. Furthermore, based on Biota Sediment Accumulation factor (BSAF) used in this study, ***L. japonica*** showed high efficiency in accumulating lead, making it a reliable bioindicator of lead pollution in the coastal environment.

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مقالة بحثية

LIOLOPHURA JAPONICA (شعبة الرخويات: طائفة عديدات الألواح) كمؤشر حيوي محتمل للتلوث بالمعادن الثقيلة في سواحل مدينة عدن- اليمن

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المُلخّص

تحظى المناطق الساحلية لمدينة عدن بأهمية بيئية واقتصادية كبيرة لليمن. ومع ذلك، فإنها تواجه ضغوطاً بيئية متزايدة نتيجة للأنشطة البشرية المختلفة، مما أدى إلى تلوثها بالمعادن الثقيلة. تهدف هذه الدراسة إلى تقييم فعالية استخدام عديدات الألواح (***Liolophura japonica***) كمؤشر حيوي للتلوث بالمعادن الثقيلة في ساحلين من سواحل مدينة عدن (الحسوة وعمران). لتقييم التلوث بالمعادن الثقيلة، جمعت عينات الكيتون (***L japonica.***) والرواسب المجاورة (ثلاثة مكررات لكل موقع) من المنطقة المدية أثناء الجزر. جففت الأنسجة الرخوة للكيتون (***L. japonica***) والرواسب ثم هضمت وفقًا للطرق القياسية. استخدم جهاز مطياف الامتصاص الذري (**AAS**) لتحديد تركيز (الحديد، الزنك، الرصاص) في عينات الدراسة. قورنت تركيزات المعادن في الرواسب مع إرشادات جودة الرواسب الصادرة عن وكالة حماية البيئة الأمريكية؛ ووجد أن مستويات الحديد والرصاص في الرواسب من كلا الساحلين كانت ضمن المستويات غير الملوثة، في حين أشارت مستويات الزنك في ساحل الحسوة إلى تلوث معتدل. في المقابل قورنت تركيزات المعادن في (***L. japonica***) بالحدود المسموح بها التي حددتها **FDA** و **FAO** ووجد أن مستويات الحديد والرصاص تجاوزت الحدود المسموح بها، في حين كانت مستويات الزنك أقل من الحدود المسموحة. أظهر التحليل الإحصائي وجود فروق معنوية في تركيزات الحديد في الرواسب بين الساحلين المدروسين، في حين لم تظهر مستويات الرصاص والزنك في الرواسب فروقاً معنوية. وعلى النقيض من ذلك، لوحظت فروق معنوية في تركيزات الحديد والزنك والرصاص في انسجة (***L. japonica***) بين الساحلين. أشارت نتائج معامل التراكم الحيوي **BSAF** إلى أن (***L. japonica***) يعتبر مؤشر حيوي موثوق للتلوث بالرصاص في السواحل المدروسة.

الكلمات المفتاحية: *L. japonica*، عديدات الألواح، سواحل عدن، التلوث بالمعادن الثقيلة، المترسبات، التراكم الحيوي، مؤشر بيولوجي، مطياف الامتصاص الذري.

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