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Research Article

Measuring the Amount of Heavy Metals Lead and Cadmium in the Muscle Tissue of SHAARI (Lethrinus Nebulosus) FISH

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A B S T R A C T

Heavy metals are among the most important aquatic pollutants due to their persistence, bioaccumulation potential, and adverse effects on living organisms, particularly humans. The present study was conducted during winter 2023 and summer 2024 to determine lead (Pb) and cadmium (Cd) concentrations in the muscle tissue of Lethrinus nebulosus collected from Bandar Lengeh, Bandar Abbas, and Qeshm coastal waters (Hormozgan Province, Iran), and to evaluate the potential human health risks associated with fish consumption. Following acid digestion of the samples, metal concentrations were determined using flame atomic absorption spectrophotometry (FAAS). The results showed that the highest concentrations of Pb and Cd were detected in samples collected from Qeshm, whereas the lowest concentrations were observed in Bandar Lengeh. The concentrations of both metals were below the maximum permissible limits established by FAO, WHO, FDA, NHMRC, and UKMAFF guidelines. Furthermore, the Estimated Daily Intake (EDI) values for both adults and children were lower than the reference doses recommended by the United States Environmental Protection Agency (USEPA). The calculated Hazard Index (HI) values were also below 1, indicating no significant non-carcinogenic health risk associated with the consumption of Lethrinus nebulosus from the studied areas. Continuous monitoring of heavy metal contamination in marine ecosystems is recommended to ensure seafood safety and environmental protection.

K E Y W O R D S

Lead, Cadmium, Lethrinus nebulosus, Heavy metals, Estimated Daily Intake (EDI), Hazard Index (HI), Persian Gulf.

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1. INTRODUCTION

Food safety has become one of the major concerns worldwide due to increasing environmental pollution and its potential impact on human health. Rapid population growth, industrial development, urbanization, and agricultural activities have resulted in the discharge of various contaminants into aquatic ecosystems. Among these pollutants, heavy metals are of particular concern because of their persistence, non-biodegradability, and tendency to accumulate in aquatic organisms. [1] Lead (Pb) and cadmium (Cd) are among the most hazardous heavy metals released into aquatic environments through both natural and anthropogenic sources, including industrial effluents, agricultural runoff, shipping activities, mining operations, and petroleum-related industries. Unlike essential trace elements, these metals have no known biological function and may cause adverse health effects even at relatively low concentrations. Long-term exposure to Pb and Cd has been associated with neurological, renal, developmental, and metabolic disorders in humans. [1 – 4]

The Persian Gulf is one of the most important marine ecosystems in the world and represents a major source of fisheries resources in southern Iran. However, intensive industrialization, oil exploration and transportation activities, urban wastewater discharge, and maritime traffic have increased the risk of environmental contamination in this semi-enclosed marine basin. Due to limited water exchange and high evaporation rates, pollutants introduced into the Persian Gulf may persist for extended periods and accumulate in marine organisms. Fish are widely recognized as useful bioindicators for monitoring heavy metal contamination because they occupy different trophic levels and can accumulate contaminants from water and food sources.[3,5] Lethrinus nebulosus (Spangled Emperor), commonly known as Shaari fish, is an economically and commercially important species in the Persian Gulf and constitutes a significant component of the local diet. Therefore, assessing heavy metal concentrations in its edible tissues is important for both environmental monitoring and public health protection.[5]

Therefore, the present study was conducted to determine the concentrations of Pb and Cd in the muscle tissue of Lethrinus nebulosus collected from the coastal waters of Bandar Lengeh, Bandar Abbas, and Qeshm in Hormozgan Province. Furthermore, the study aimed to evaluate the potential human health risks associated with the consumption of this commercially important fish species by estimating the Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), and Hazard Index (HI). The findings are expected to provide valuable information on the level of heavy metal contamination in the study area and contribute to the assessment of food safety and public health risks related to fish consumption in the region.[5,6]

2. MATERIALS AND METHODS

2.1. Study Area

The study was conducted in three coastal areas of Hormozgan Province located along the northern Persian Gulf, namely Bandar Abbas (26°35.080′ N, 55°23.233′ E), Qeshm Island (26°46.854′ N, 55°43.472′ E), and Bandar Lengeh (26°59.075′ N, 55°45.350′ E). These areas represent important fishing grounds and are potentially influenced by different anthropogenic activities, including shipping, urban development, and industrial operations. Sampling was carried out during winter 2023

and summer 2024. The selected sites were chosen based on their ecological importance, accessibility, and potential exposure to environmental contaminants. The geographical locations of the sampling stations are presented in Fig. 1.[7]

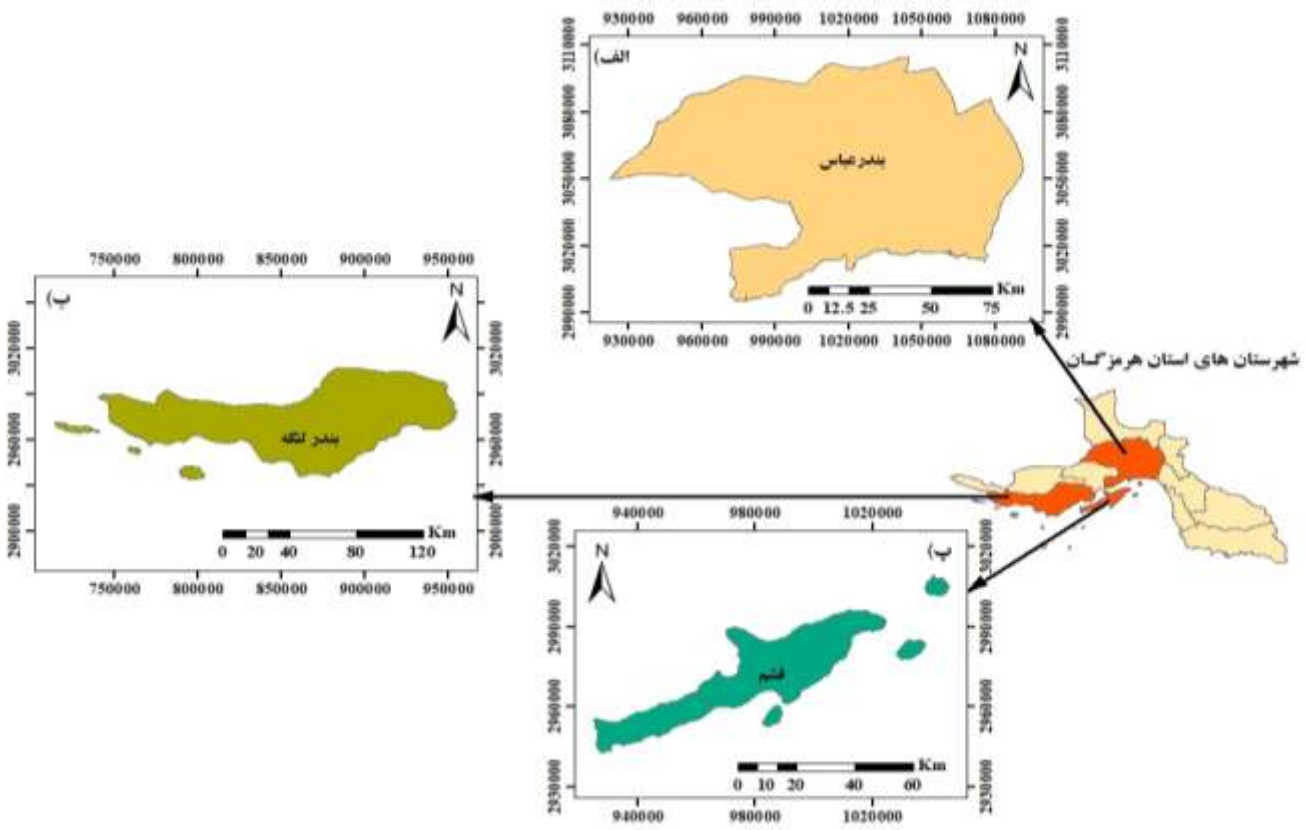


Fig 1. Sampling locations in Hormozgan coastal waters, including Bandar Abbas, Qeshm Island, and Bandar Lengeh.

2.2. Sample Collection

Lethrinus nebulosus specimens were collected from Bandar Abbas, Qeshm Island, and Bandar Lengeh during winter 2023 and summer 2024 using hook-and-line and net fishing methods. In each season, 30 fish specimens were randomly collected from the study areas for heavy metal analysis. Following collection, the samples were individually packed in clean polyethylene bags, transported to the laboratory in insulated ice containers, and stored at −20 °C until further processing and analysis.[5]

2.3. Sample Preparation and Digestion

Muscle tissues were excised from the collected fish samples and freeze-dried (VaCo 5, Germany) at −40 °C for 8–10 h. The dried tissues were homogenized using a porcelain mortar and pestle. Approximately 0.5 g of each dried sample was accurately weighed and transferred into microwave digestion vessels (ETHOS 1). Subsequently, 7 mL of concentrated HNO_3 (65%) and 1 mL of H_2O_2 (30%) were added to each sample. Digestion was performed using a microwave digestion system according to the manufacturer's instructions. After cooling, the digested solutions were filtered through Whatman No. 42 filter paper and diluted to a final volume of 50 mL using deionized water. The prepared solutions were stored at 4 °C until metal determination. [5]

2.4. Determination of Pb and Cd

Lead (Pb) and cadmium (Cd) concentrations were determined using a Varian SpectrAA 220 atomic absorption spectrophotometer (FAAS)(Varian, USA). Calibration curves were prepared using certified standard solutions (1000 mg L^{-1}, Fine Chemical). Metal concentrations were calculated based on the absorbance values obtained from the instrument and expressed as mg kg^{-1} dry weight. [6]

2.5. Human Health Risk Assessment

Potential human health risks associated with the consumption of Lethrinus nebulosus were assessed using the Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), and Hazard Index (HI) approaches. The EDI of heavy metals was calculated using the following equation:

$$EDI = (Mc \times CR) / ABW \quad (1)$$

where Mc is the concentration of the metal in fish muscle (mg kg^{-1}), CR is the daily fish consumption rate (93 g day^{-1} for adults and 50 g day^{-1} for children), and ABW is the average body weight (55.9 kg for adults and 32.7 kg for children).

The non-carcinogenic health risk was evaluated using the Target Hazard Quotient (THQ) according to the USEPA methodology:

$$THQ = (EF \times ED \times CR \times MC) / (RfD \times ABW \times AET) \quad (2)$$

where EF is the exposure frequency (365 days $year^{-1}$), ED is the exposure duration (70 years), RfD is the oral reference dose (mg kg^{-1} day^{-1}), MC is the metal concentration in fish muscle (mg kg^{-1}), ABW is the average body weight (kg), and AET is the averaging exposure time (EF × ED).

The overall non-carcinogenic risk was estimated using the Hazard Index (HI), calculated as the sum of individual THQ values:

$$HI = \Sigma THQ \quad (3)$$

Values of THQ and HI lower than 1 indicate that the consumption of fish does not pose a significant non-carcinogenic health risk to consumers.[4,6]

2.6. Statistical Analysis

Statistical analyses were performed using SPSS software (Version 21.0, SPSS Inc., Chicago, IL, USA). Data are presented as mean ± standard deviation (SD). The normality of the data distribution was evaluated using the Kolmogorov–Smirnov test. Differences in Pb and Cd concentrations among sampling locations and seasons were assessed using one-way analysis of variance (ANOVA), followed by Tukey's post hoc test when significant differences were observed. Comparisons between measured concentrations and international guideline values were performed using Student's t-test. Statistical significance was considered at $p < 0.05$. [7]

3. RESULTS AND DISCUSSION

3.1. Concentrations of Pb and Cd in Fish Muscle

The mean concentrations of Pb and Cd in the muscle tissue of *Lethrinus nebulosus* collected from Bandar Lengeh, Bandar Abbas, and Qeshm are presented in Table 1. Significant differences were observed among the sampling locations for both metals ($p < 0.05$). The highest mean concentration of Pb was recorded in fish samples collected from Qeshm (0.55 ± 0.04 μg g^{-1}), followed by Bandar Abbas (0.49 ± 0.05 μg g^{-1}), whereas the lowest concentration was observed in Bandar Lengeh (0.31 ± 0.04 μg g^{-1}). Similarly, Cd concentrations showed significant spatial variation, with the highest value measured in Qeshm (0.41 ± 0.05 μg g^{-1}), followed by

Bandar Abbas (0.32 ± 0.04 μg g^{-1}) and Bandar Lengeh (0.11 ± 0.01 μg g^{-1}).

The results of Tukey's post hoc test indicated that Pb and Cd concentrations in Qeshm were significantly higher than those in Bandar Abbas and Bandar Lengeh ($p < 0.05$). Furthermore, metal concentrations in Bandar Abbas were significantly higher than those measured in Bandar Lengeh ($p < 0.05$). These findings suggest a greater degree of metal contamination in the coastal waters of Qeshm compared with the other studied regions.

Table 1. Mean concentrations of Pb and Cd (μg g^{-1} dry weight) in the muscle tissue of Lethrinus nebulosus across different seasons and sampling locations (n = 30).

Element	Bandar Lengeh	Bandar Abbas	Qeshm
Lead (Pb)	0.31 ± 0.04	0.49 ± 0.05	0.55 ± 0.04
Cadmium (Cd)	0.11 ± 0.01	0.32 ± 0.04	0.41 ± 0.05

Values are presented as Mean ± SD.

3.2. Spatial and Seasonal Variations

Significant spatial and seasonal variations were observed in the concentrations of Pb and Cd in the muscle tissue of Lethrinus nebulosus ($p < 0.05$). Among the studied locations, Qeshm consistently exhibited the highest concentrations of both metals, whereas Bandar Lengeh showed the lowest values. Bandar Abbas displayed intermediate concentrations. Seasonal comparison revealed that Pb and Cd concentrations were significantly higher during summer than winter in all sampling locations ($p < 0.05$). In Bandar Lengeh, Pb concentrations increased from 0.26 ± 0.08 μg g^{-1} in winter to 0.35 ± 0.02 μg g^{-1} in summer, while Cd concentrations increased from 0.09 ± 0.04 μg g^{-1} to 0.12 ± 0.01 μg g^{-1}. Similar trends were observed in Bandar Abbas, where Pb concentrations increased from 0.44 ± 0.03 μg g^{-1} to 0.53 ± 0.01 μg g^{-1} and Cd concentrations increased from 0.28 ± 0.01 μg g^{-1} to 0.36 ± 0.02 μg g^{-1}. In Qeshm, the highest seasonal concentrations were recorded, with Pb increasing from 0.50 ± 0.03 μg g^{-1} in winter to 0.59 ± 0.02 μg g^{-1} in summer and Cd increasing from 0.36 ± 0.5 μg g^{-1} to 0.45 ± 0.02 μg g^{-1}. These findings indicate that both geographical location and season play important roles in the accumulation of heavy metals in fish tissues.

Table 2. Values are presented as mean ± SD (n = 30). Significant seasonal differences were observed for both Pb and Cd concentrations ($p < 0.05$).

Variables	Bandar – e – lengeh		Bandar –e – abbas		Qeshm	
	Summer	Winter	Summer	Winter	Summer	Winter
Lead	0.35±0.02	0.26±0.08	0.53±0.01	0.44±0.03	0.59±0.02	0.50±0.03
Cadmium	0.12±0.01	0.09±0.04	0.36±0.02	0.28±0.01	0.45±0.02	0.36±0.5

Table 3. Human health risk assessment parameters (EDI, THQ and HI) for Pb and Cd through consumption of Lethrinus nebulosus collected from Hormozgan coastal waters.

Location	Metal	EDI (Adult)	EDI (Child)	THQ(Adult)	THQ(Child)	HI (Adult)	HI (Child)
Bandar Lengeh	Pb	0.51	0.04	0.17	0.15	0.35	0.31

3.3. Human Health Risk Assessment

The estimated daily intake (EDI), target hazard quotient (THQ), and hazard index (HI) for Pb and Cd through the consumption of Lethrinus nebulosus are presented in Table 3. The calculated EDI values for both adults and children across all sampling locations were lower than the oral reference doses (RfD) recommended by the USEPA (3.0 μg kg^{-1} day^{-1} for Pb and 1.0 μg kg^{-1} day^{-1} for Cd), indicating no immediate health concern associated with fish consumption. Among the investigated locations, the highest EDI values for both Pb and Cd were observed in Qeshm, followed by Bandar Abbas and Bandar Lengeh.

Similarly, the THQ values for individual metals and the overall HI values were below the threshold value of 1.0 for both adult and child consumer groups in all three locations. The highest HI values were recorded in Qeshm (0.98 for adults and 0.90 for children), while the lowest values were observed in Bandar Lengeh (0.35 for adults and 0.31 for children). Although children exhibited relatively lower risk indices compared with adults all calculated values remained within safe limits (HI < 1.0). Consequently, the consumption of Lethrinus nebulosus from these coastal waters does not pose significant non-carcinogenic health risks to consumers.

Table 3. Estimated Daily Intake (EDI, μg kg^{-1} day^{-1}), Target Hazard Quotient (THQ), and Hazard Index (HI) for Pb and Cd through consumption of Lethrinus nebulosus in Hormozgan coastal waters.

Bandar Lengeh	Cd	0.18	0.16	0.18	0.16	0.35	0.31
Bandar Abbas	Pb	0.81	0.74	0.27	0.24	0.80	0.72
Bandar Abbas	Cd	0.53	0.48	0.53	0.48	0.80	0.72
Qeshm	Pb	0.91	0.84	0.30	0.28	0.98	0.90
Qeshm	Cd	0.68	0.62	0.68	0.62	0.98	0.90

EDI: Estimated Daily Intake; THQ: Target Hazard Quotient; HI: Hazard Index.

The present study demonstrated significant spatial and seasonal variations in Pb and Cd concentrations in the muscle tissue of *Lethrinus nebulosus* collected from coastal waters of Hormozgan Province. Among the investigated locations, Qeshm consistently exhibited the highest concentrations of both metals, whereas Bandar Lengeh showed the lowest values [8]. These findings may be attributed to differences in anthropogenic activities, including shipping operations, coastal urbanization, industrial development, and maritime transportation. Similar spatial variations in heavy metal accumulation have been reported in other aquatic ecosystems exposed to human activities [9].

The elevated concentrations observed in Qeshm may be associated with increasing coastal development, port activities, and the influence of petroleum-related operations in the Persian Gulf region. Previous studies have indicated that industrial and shipping activities can contribute substantially to the release of heavy metals into marine environments, leading to their accumulation in aquatic organisms [3 – 8].

Seasonal analysis revealed significantly higher concentrations of Pb and Cd during summer compared with winter. This pattern may be related to increased evaporation rates, reduced water circulation, and enhanced pollutant concentration during warmer months. Seasonal fluctuations in heavy metal concentrations have also been documented in previous investigations of marine and estuarine ecosystems [8]. Although significant differences were observed among locations and seasons, the measured concentrations remained below the maximum permissible limits established by international organizations, including FAO, WHO, and FDA. These findings are consistent with previous studies conducted on commercially important fish species, where heavy metal concentrations were generally within acceptable safety limits for human consumption [10].

The human health risk assessment further confirmed the safety of consuming *Lethrinus nebulosus* from the studied regions. The calculated EDI values were lower than the corresponding oral reference doses, while THQ and HI values remained below the critical threshold value of one. Similar conclusions have been reported in previous studies, indicating that heavy metal exposure through fish consumption did not pose significant non-carcinogenic health risks under normal consumption patterns. [4,6]

Overall, the results indicate that although Pb and Cd contamination is present in the coastal waters of Hormozgan Province, the current levels do not represent an immediate threat to public health. Nevertheless, the relatively higher concentrations detected in Qeshm emphasize the importance of continuous environmental monitoring and effective pollution management programs to prevent future increases in heavy metal contamination.

4. CONCLUSIONS

The present study demonstrated that the concentrations of lead (Pb) and cadmium (Cd) in the muscle tissue of Lethrinus nebulosus collected from Bandar Lengeh, Bandar Abbas, and Qeshm Island in the Persian Gulf were below the permissible limits. Significant spatial and seasonal variations were observed in the concentrations of both metals ($p < 0.05$). The

highest concentrations were recorded in Qeshm, followed by Bandar Abbas and Bandar Lengeh. In addition, Pb and Cd levels were significantly higher during summer than winter at all sampling locations. Although the measured concentrations varied among regions and seasons, all values remained below the permissible limits established by international organizations, including WHO, FAO, and FDA. Human health risk assessment indicated that estimated daily intake (EDI) values for both adults and children were below the corresponding reference doses. Furthermore, the calculated target hazard quotient (THQ) and hazard index (HI) values were lower than 1, suggesting that consumption of Lethrinus nebulosus from the studied areas does not pose significant non-carcinogenic health risks to consumers.

Nevertheless, the relatively higher concentrations detected in Qeshm highlight the potential influence of anthropogenic activities and emphasize the need for continuous environmental monitoring and effective pollution management strategies in the Persian Gulf coastal regions.

Declaration of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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نشریه ایرانی شیمی تجزیه

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مقاله پژوهشی

اندازه‌گیری میزان فلزات سنگین سرب و کادمیوم در بافت عضله ماهی شعری

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چکیده

فلزات سنگین به دلیل پایداری، قابلیت تجمع زیستی و آثار نامطلوب آن‌ها بر موجودات زنده، به‌ویژه انسان، از مهم‌ترین آلاینده‌های محیط‌های آبی به شمار می‌روند. مطالعه حاضر در زمستان ۲۰۲۳ و تابستان ۲۰۲۴ با هدف تعیین غلظت سرب و کادمیوم در بافت عضلانی ماهی شعری جمع‌آوری‌شده از آب‌های ساحلی بندر لنگه، بندرعباس و قشم در استان هرمزگان، ایران، و همچنین ارزیابی خطرات بالقوه ناشی از مصرف این ماهی برای سلامت انسان انجام شد. پس از هضم اسیدی نمونه‌ها، غلظت فلزات با استفاده از دستگاه طیف‌سنجی جذب اتمی شعله‌ای تعیین گردید. نتایج نشان داد که بالاترین غلظت‌های سرب و کادمیوم در نمونه‌های جمع‌آوری شده از قشم و پایین‌ترین غلظت‌ها در نمونه‌های بندر لنگه مشاهده شد. غلظت هر دو فلز پایین‌تر از حداکثر حدود مجاز تعیین‌شده توسط دستورالعمل‌های سازمان خواربار و کشاورزی ملل متحد، سازمان جهانی بهداشت، سازمان غذا و داروی ایالات متحده آمریکا، شورای ملی تحقیقات پزشکی و سلامت استرالیا و وزارت کشاورزی، شیلات و غذای بریتانیا بود. همچنین، مقادیر دریافت روزانه برآورد شده برای هر دو گروه بزرگسالان و کودکان، کمتر از مقادیر دوز مرجع توصیه‌شده توسط آژانس حفاظت محیط‌زیست ایالات متحده آمریکا بود. مقادیر محاسبه‌شده شاخص خطر نیز کمتر از ۱ به دست آمد که نشان‌دهنده نبود خطر قابل‌توجه غیرسرطانی برای سلامت انسان در ارتباط با مصرف ماهی شعری صیدشده از مناطق مورد مطالعه است. با توجه به اهمیت ایمنی آبزیان و حفاظت از محیط زیست، پایش مستمر آلودگی فلزات سنگین در اکوسیستم‌های دریایی توصیه می‌شود.

واژه‌های کلیدی

سرب، کادمیم، ماهی شعری، فلزات سنگین؛ دریافت روزانه برآوردشده، شاخص خطر، خلیج فارس.

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