



Accumulation and health risk assessment of heavy metals in tissues of the shrimp and fish species from the Yumurtalik coast of Iskenderun Gulf, Turkey



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ABSTRACT

In this study, concentrations of heavy metals were determined in the tissues of fish species (*S. solea* and *S. aurata*) and shrimp (*P. semiculatus*) from the Yumurtalik zone of the Iskenderun Gulf, Turkey. The aim of our study is to evaluate potential risks to human health associated with fish and shrimp consumption. Metals concentrations varied significantly depending on the tissues and species. The concentrations of Cu, Fe, Pb and Zn in fish and shrimp tissues were high, while Cd levels were relatively low. In comparing with the permissible limits set by the European Union and Food and Agricultural Organization for fish and shrimp, mean values of Cu, Fe, and Zn were within acceptable limits, but the mean values of Cd and Pb exceeded the limits.

From the standpoint of human health, this study suggests that the observed Pb and Cd accumulation may pose a possible health risk to excessive *S. solea* and *P. Semiculatus* consumers in Turkey.

1. Introduction

The increase in agricultural and industrial activities has caused an increase in contamination of water resources. Heavy metals constitute a major class of pollutants with major ecological concerns. Heavy metals are naturally found at very low concentrations in the water environment, but their concentrations have increased due to anthropogenic activities. Heavy metals are one of the most important pollutants in water environments. They are pollutants that can stay in water environments for long periods without decomposing and cause damage to water organisms. The increase in heavy metal levels left over to the marine environment in recent years results in extensive research on marine pollution [1, 2]. Heavy metals are among the major environmental pollutants entering the food chain. The transfer of chemicals from the sub-components of the food chain to the upper constituents imparts a risk to the ecosystem as the chemicals tend to accumulate and can be transferred

from one food chain to another [3]. The concentration of bioaccumulated heavy metals in the fish body is a function of some environmental parameters, including pH, temperature, alkalinity of the environment, pollutant type, sampling site [4, 5]. The presence of heavy metals in marine environment is the results of two main sources of contamination: natural occurring deposit and anthropogenic activities such as. domestic, industrial, and agricultural activities [4, 6].

Fish are generally considered to be an important bioindicator of aquatic environments and are an important source of protein in human nutrition. Fish, which usually constituent the last ring of the food chain, are considered to be one of the important groups for transferring metals to humans. Lately interest in the consumption of aquatic organisms, especially fish, has increased dramatically in different parts of the world due to high protein content and low saturated fats [7]. Fish, shrimp, crab, bivalve are used in metal accumulation tests because they are higher tropic level organisms and are usually eaten by man [8]. It is important to

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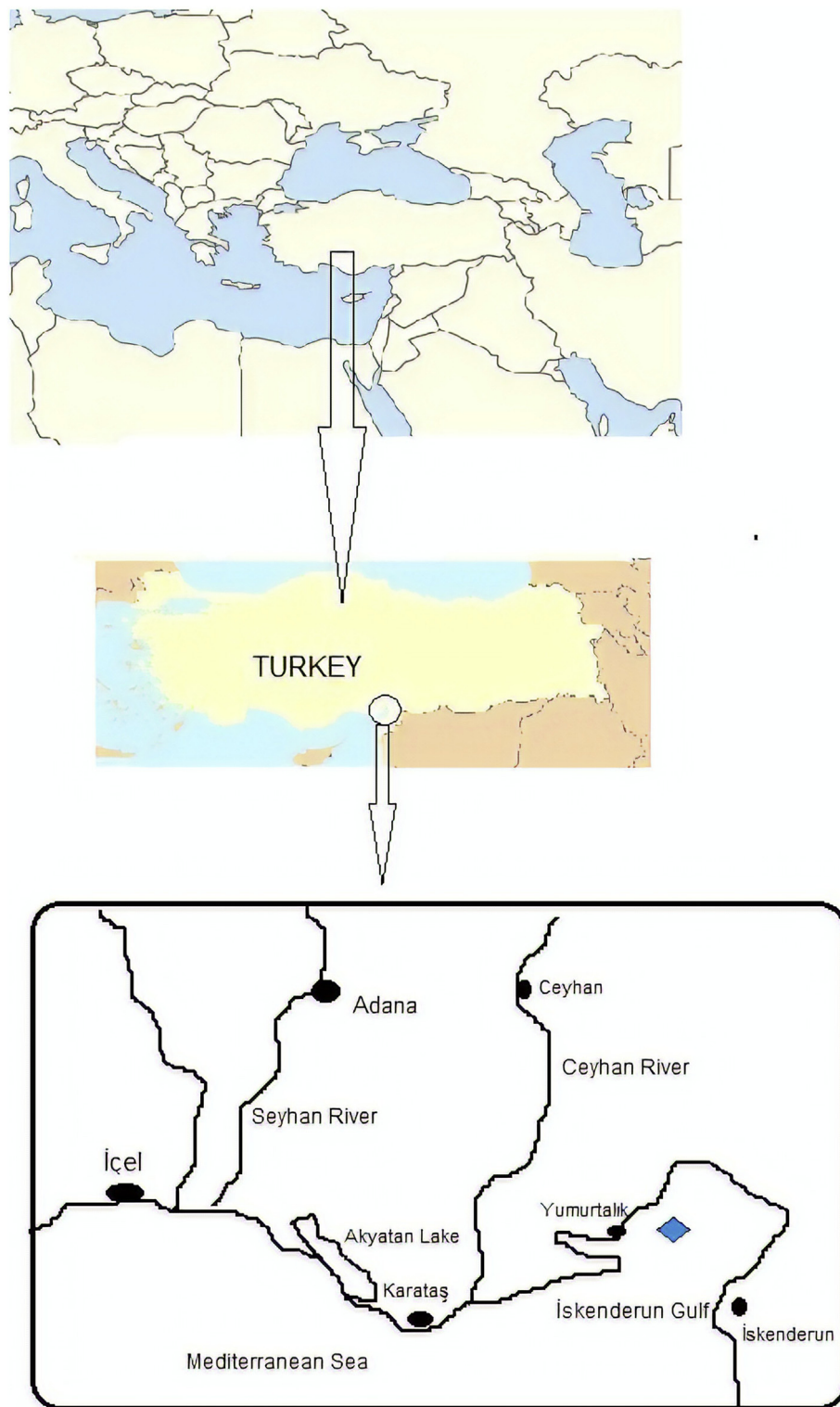


Fig. 1. Map of the sampling station (the Yumurtalik area of Iskenderun Gulf).

determine the metal levels in fish and shrimp tissues because they reflect the concentrations of metals found in water and sediments.

Solea solea, *Sparus aurata* and *Penaeus semiculatus* are commercially important for the inhabitants of the Eastern Mediterranean Sea region. The selected species are very economically important for Adana, Yumurtalik the Mediterranean Sea region and constitute a large part of the total seafood production in this region. For this reason, it is important to identify heavy metal levels in economic species in order to identify

possible risks for consumption of seafood for human health. When heavy metals accumulate in edible animals, they can threaten public health. For this reason, different countries and organizations have developed guidelines to limit the amount of toxic metals present in edible animals [9, 10]. Fish and shrimp are deemed unsafe for consumption if the levels of heavy metals exceed the recommended standards.

The yumurtalik zone of the Iskenderun Gulf is polluted by various human activities such as shipping, and tanker traffic, agricultural and

industrial activities (such as oil and electricity production systems). On the other hand, a much amount of contaminants from the Gulf of Iskenderun are transferred to this region. Fishing and thermal power plant activities (industrial, chemical pollutants) in coastal areas further pollute the yumurtalık zone. Some of the economically important species of fish and shrimp are located in this region, which transforms it into an important region for fisheries.

The aim of present study was to determine accumulation of Cd, Cu, Fe, Pb, and Zn in different tissues of shrimp (*P. semiculatus*) and fish (*S. solea* and *S. aurata*) collected from the Yumurtalık coast of the Iskenderun Gulf and evaluate the human risk assessment associated with the consumption of studied fish and shrimp.

2. Materials and methods

2.1. Study area

This study was carried out in the Yumurtalık area of Iskenderun Gulf (Fig. 1). The Iskenderun Gulf is situated on the Eastern Mediterranean coast of Turkey. The Yumurtalık zone of the Iskenderun Gulf is a semi-enclosed basin which receives many of Turkey rivers. The Yumurtalık area of Iskenderun Gulf has a rich diversity of fauna (crabs, molluscs, shrimps and fish species). The sampling station were selected based on the following factors: industrial effluents, urban and agricultural sewage are being discharged into the waters of Iskenderun Gulf. The Yumurtalık area serves as source of livelihood to the local people for seafood. One site selection was performed based on priorities related to the thermic power station activities. The gulf receives many rivers and has one of the most polluted coastal waters of Turkey.

2.2. Sample preparation and analysis

Samples were collected from the Yumurtalık coast of the Iskenderun Gulf (Fig. 1) during the four seasons of 2017 (winter, spring, summer, and autumn). (one hundred twenty six individuals were collected: 42 *S. solea*, 40 *S. aurata* and 44 *P. semiculatus*). Ten samples were analyzed in every season from each species in order to determine metal in their tissues. The collected samples were immediately placed on ice in an insulated box and moved to the laboratory and stored at -20°C until analyzed. The collected measurements of total length were made for the shrimp and fish. Total weight for all individual was also recorded. For analysis, whole liver, gills and sufficient amount of muscle were dissected and oven-dried at 105°C until they reached a constant weight. Samples were transferred into digestion flasks. Concentrated nitric acid and perchloric acid in the ratio of 2:1 were added and then digestion flasks were put on a hot plate until all the tissues were dissolved and heavy metal concentrations in the tissues were measured on spectrophotometric method (ICP-MS).

The concentration of heavy metals in the samples were analysed with ICP-MS (Perkin Elmer, Waltham, MA), calibrated with C-5524 Sigma Standards. Detection limit of the spectrophotometer was 0.028 ppm and 90% recovery was obtained during measurement. Accuracy of the employed method was tested with a reference material. All data refer to dry weight of fish and shrimp tissues.

2.3. Statistical analysis

Data were given as mean $\pm$ SD for each of the measured variables. All statistical analyzes were performed using SPSS version 21.0 version. A one-way ANOVA test was used to assess significant differences among tissues and season.

3. Result and discussion

The concentrations of metals in liver, gill and muscle tissues in *S. solea*, *S. aurata* and *P. semiculatus* are given in Tables 1, 2, and 3.

Table 1

Average concentrations of heavy metals ($\mu\text{g/g}$ dry wt) in various tissues of *Solea solea* collected from the Yumurtalık coast of Iskenderun Gulf.

Metals	Tissues	Months			
		April	July	October	January
Cu	Muscle	3.75 $\pm$ 0.74 ax	6.20 $\pm$ 0.24 bx	3.58 $\pm$ 0.25 ax	2.64 $\pm$ 0.19 cx
	Gill	7.22 $\pm$ 0.86 ay	16.6 $\pm$ 1.01 by	10.9 $\pm$ 0.47 cy	9.98 $\pm$ 0.56 cy
	Liver	237.7 $\pm$ 4.23 az	362.0 $\pm$ 9.09 bz	296.9 $\pm$ 20.3 cz	236.9 $\pm$ 5.51 az
Cd	Muscle	2.92 $\pm$ 0.20 ax	6.83 $\pm$ 0.34 bx	2.04 $\pm$ 0.69 cx	1.98 $\pm$ 0.16 cx
	Gill	11.25 $\pm$ 0.34 ay	17.0 $\pm$ 0.57 by	3.89 $\pm$ 0.18 cy	5.05 $\pm$ 0.44 cy
	Liver	9.90 $\pm$ 0.32 az	15.5 $\pm$ 0.71 by	7.07 $\pm$ 0.39 cz	6.30 $\pm$ 0.13 cz
Zn	Muscle	22.2 $\pm$ 1.02 ax	32.3 $\pm$ 0.69 bx	25.2 $\pm$ 0.66 cx	22.1 $\pm$ 0.80 ax
	Gill	91.4 $\pm$ 2.40 ay	159.3 $\pm$ 11.2 by	86.9 $\pm$ 0.65 ay	80.9 $\pm$ 2.72 ay
	Liver	121.2 $\pm$ 3.97 az	241.4 $\pm$ 9.13 bz	116.4 $\pm$ 4.49 az	91.4 $\pm$ 6.60 cz
Pb	Muscle	37.6 $\pm$ 0.77 ax	79.5 $\pm$ 3.05 bx	45.9 $\pm$ 1.57 cx	36.7 $\pm$ 1.28 ax
	Gill	93.1 $\pm$ 1.09 ay	112.3 $\pm$ 1.39 by	105.3 $\pm$ 1.27 cy	89.5 $\pm$ 2.73 ay
	Liver	74.9 $\pm$ 3.47 az	161.4 $\pm$ 6.20 bz	120.6 $\pm$ 2.73 cz	80.0 $\pm$ 3.78 az
Fe	Muscle	23.0 $\pm$ 0.85 ax	42.8 $\pm$ 1.96 bx	34.8 $\pm$ 0.72 cx	23.7 $\pm$ 0.62 ax
	Gill	298.5 $\pm$ 23.8 ay	462.2 $\pm$ 14.4 by	309.1 $\pm$ 25.6 ay	237.4 $\pm$ 11.5 ay
	Liver	714.0 $\pm$ 7.50 az	922.6 $\pm$ 69.0 bz	882.6 $\pm$ 20.7 cz	741.3 $\pm$ 31.4 az

Different letters (a, b) within a row indicate significant differences among seasons; different letters (x, y, z) within a column indicate significant differences among tissues (ANOVA $p < 0.05$).

3.1. Heavy metal concentrations in fish and shrimp tissues

The distribution of the heavy metal concentrations in the tissues in *S. solea* and *S. auratus* was $\text{Fe} > \text{Zn} > \text{Pb} > \text{Cu} > \text{Cd}$ whereas in *P. semiculatus* $\text{Zn} > \text{Fe} > \text{Pb} > \text{Cu} > \text{Cd}$ respectively. In general, the concentration orders of heavy metals in the tissues were found to be liver $>$ gills $>$ muscle for the studied fish and shrimp species, except for Pb and Fe in *P. semiculatus* that was gills $>$ liver $>$ muscle. For *S. solea*, *S. aurata*, the levels of all the heavy metals in the liver were significantly higher than those in the muscle and gills. For *P. semiculatus*, the concentrations of Cd, Cu and Zn in the liver were significantly higher than the muscle and gills. The results showed that the orders of the heavy metal concentrations changed between tissues of fish and shrimp. The concentrations of metals in *S. solea*, *S. aurata* and *P. semiculatus* tissues differed significantly and toxic metals (Cd, Pb) levels were higher in the gills and liver than in muscle tissue (Tables 1, 2, and 3).

Heavy metals can accumulate in fish and shrimp tissues, which are generally found in the last zone of the aquatic food chain and they have adverse effects on human health. Metals are usually taken from food and water in fish and shrimp, distributed by circulation and eventually accumulated in target organs. In the present study, the highest concentrations of heavy metals were found in the liver and gill tissues in all species in every season. The liver and gill are metabolically active tissues and tendency to accumulate high levels of heavy metals [11]. Zn, Cu and Cd levels in liver of fish and shrimp were significantly higher than those in other tissues. In comparison, the Pb and Fe levels in the gill tissue of *P. semiculatus* was higher than in the liver and muscle tissues. In the liver level of Cu, Cd, Zn and Fe are much higher than in the gills and muscle, indicating the liver to be a main target for heavy metals. In this study, the

Table 2

Average concentrations of heavy metals ($\mu\text{g/g}$ dry wt) in various tissues of *Sparus aurata* collected from the Yumurtalik coast of Iskenderun Gulf.

Metals	Tissues	Months			
		April	July	October	January
Cu	Muscle	3.52 $\pm$ 0.18 ax	4.38 $\pm$ 0.11 bx	3.48 $\pm$ 0.16 ax	3.24 $\pm$ 0.11 ax
	Gill	6.26 $\pm$ 0.16 ay	9.74 $\pm$ 0.18 by	6.24 $\pm$ 0.41 ay	6.48 $\pm$ 0.34 ay
	Liver	35.8 $\pm$ 0.87 az	69.2 $\pm$ 2.57 bz	46.1 $\pm$ 2.04 cy	35.0 $\pm$ 1.63 az
Cd	Muscle	2.28 $\pm$ 0.11 ax	3.44 $\pm$ 0.18 bx	2.52 $\pm$ 0.17 ax	2.49 $\pm$ 0.15 ax
	Gill	2.74 $\pm$ 0.11 ax	6.81 $\pm$ 0.29 by	3.53 $\pm$ 0.33 ax	2.92 $\pm$ 0.26 ax
	Liver	5.24 $\pm$ 0.48 ay	8.01 $\pm$ 0.28 bz	4.76 $\pm$ 0.18 ay	4.07 $\pm$ 0.27 ay
Zn	Muscle	21.4 $\pm$ 0.59 ax	34.4 $\pm$ 1.06 bx	25.3 $\pm$ 1.21 cx	17.0 $\pm$ 0.64 dx
	Gill	84.4 $\pm$ 0.60 ay	255.9 $\pm$ 17.3 by	96.5 $\pm$ 1.42 ay	88.6 $\pm$ 0.62 ay
	Liver	133.6 $\pm$ 4.53 az	409.3 $\pm$ 2.74 bz	256.6 $\pm$ 11.8 cz	101.6 $\pm$ 2.50 dz
Pb	Muscle	31.2 $\pm$ 0.52 ax	40.0 $\pm$ 2.02 bx	32.7 $\pm$ 0.45 ax	27.3 $\pm$ 1.03 cx
	Gill	56.3 $\pm$ 1.20 ay	95.3 $\pm$ 1.53 by	72.0 $\pm$ 4.00 cy	63.3 $\pm$ 2.79 ay
	Liver	46.1 $\pm$ 1.66 az	69.1 $\pm$ 2.63 bz	52.6 $\pm$ 3.62 az	37.0 $\pm$ 0.95 cz
Fe	Muscle	16.0 $\pm$ 0.95 ax	28.4 $\pm$ 0.50 bx	18.6 $\pm$ 0.75 cx	10.8 $\pm$ 0.28 dx
	Gill	140.9 $\pm$ 13.8 ay	222.1 $\pm$ 3.30 by	166.7 $\pm$ 7.35 cy	119.7 $\pm$ 4.56 ay
	Liver	799.3 $\pm$ 44.1 az	990.4 $\pm$ 66.6 bz	830.7 $\pm$ 41.8 az	742.4 $\pm$ 25.0 az

Different letters (a, b) within a row indicate significant differences among seasons; different letters (x, y, z) within a column indicate significant differences among tissues (ANOVA $p < 0.05$).

presence of high concentrations of Cd, Cu, Pb, Fe, and Zn in the liver compared to muscle tissue may be related to the content of metallothionein protein in the liver tissue. Many studies have shown that liver metal concentration is high when compared to muscle tissue [7, 12, 13]. The liver acts as a filter detoxifying by storing heavy metals. High metal accumulation capabilities make the liver the most important target and storage tissue in aquatic organisms [11, 14]. The results show that metals concentrate in the liver of fish and shrimp and accumulate the highest concentration of Cu and Zn. In three the species, concentration of metals in the gill were significantly higher than the muscles in every season. Fish gills are critical organs for respiratory and excretory functions. Gills usually reflect the levels of metal in the environment. This organ is in directly contact with water, it may absorb the metals present in the water. One of the reasons for the susceptibility of fish to metals is due to high absorption in the gills. Fish muscles are the primary edible parts; but muscles are not the tissues where heavy metals are accumulated. The lowest levels being in fish muscle reflected its lower affinity to metals in the their environment. In this study the metal levels in muscle in all species were significantly lower than in liver and gill tissues. The results show that lower metal concentrations are observed in the muscles when compared to the gills, while the liver showed relatively higher values. In this study, the concentrations of heavy metals in the tested tissues of fish and shrimp species decreased in the following order: liver > gill > muscle.

In this study, essential metals (Fe, Cu and Zn) were accumulated in amounts higher than non-essential metals (Cd and Pb). In this study, significant differences were observed in the mean metal concentrations determined for fish and shrimp from the Yumurtalik region of the Iskenderun Gulf. Fe, Zn, Cu, Pb and Cd were detected in all the tissues

Table 3

Average concentrations of heavy metals ($\mu\text{g/g}$ dry wt) in various tissues of *Penaeus semiculatus* collected from the Yumurtalik coast of Iskenderun Gulf.

Metals	Tissues	Months			
		April	July	October	January
Cu	Muscle	28.50 $\pm$ 3.85 ax	34.23 $\pm$ 1.18 bx	26.44 $\pm$ 1.43 ax	19.35 $\pm$ 1.29 cx
	Gill	210.3 $\pm$ 14.3 ay	423.1 $\pm$ 10.6 by	140.6 $\pm$ 6.21 cy	146.9 $\pm$ 4.77 cy
	Liver	440.6 $\pm$ 21.2 az	710.2 $\pm$ 8.23 bz	577.6 $\pm$ 32.8 cz	404.6 $\pm$ 1.63 az
Cd	Muscle	6.52 $\pm$ 0.90 ax	8.33 $\pm$ 0.13 bx	7.44 $\pm$ 0.13 cx	6.59 $\pm$ 0.10 ax
	Gill	24.86 $\pm$ 1.03 ay	38.07 $\pm$ 2.59 by	25.25 $\pm$ 2.02 ay	18.10 $\pm$ 0.80 cy
	Liver	16.45 $\pm$ 0.15 az	27.62 $\pm$ 0.15 bz	15.88 $\pm$ 0.46 az	15.97 $\pm$ 0.82 az
Zn	Muscle	43.56 $\pm$ 0.78 ax	61.42 $\pm$ 3.33 bx	45.12 $\pm$ 1.87 ax	37.43 $\pm$ 2.35 ax
	Gill	159.7 $\pm$ 11.5 ay	953.4 $\pm$ 43.5 by	125.5 $\pm$ 2.44 ay	147.5 $\pm$ 12.1 ay
	Liver	674.1 $\pm$ 48.9 az	1071.2 $\pm$ 79.4 by	441.4 $\pm$ 13.0 cz	344.2 $\pm$ 9.28 cz
Pb	Muscle	25.03 $\pm$ 1.85 ax	62.75 $\pm$ 0.58 bx	49.78 $\pm$ 4.40 cx	22.18 $\pm$ 0.62 ax
	Gill	127.8 $\pm$ 6.56 ay	237.3 $\pm$ 18.1 by	146.8 $\pm$ 8.39 ay	142.0 $\pm$ 12.3 ay
	Liver	63.99 $\pm$ 0.97 az	85.03 $\pm$ 1.62 bx	63.39 $\pm$ 3.92 ax	61.89 $\pm$ 1.76 az
Fe	Muscle	16.15 $\pm$ 0.77 ax	24.23 $\pm$ 0.94 bx	17.01 $\pm$ 2.67 ax	22.5 $\pm$ 1.64 bx
	Gill	445.4 $\pm$ 24.8 ay	552.2 $\pm$ 17.4 by	311.4 $\pm$ 13.0 cy	259.4 $\pm$ 7.0 d
	Liver	158.0 $\pm$ 5.16 az	346.8 $\pm$ 16.5 bz	101.2 $\pm$ 3.39 cz	148.1 $\pm$ 9.29 az

Different letters (a, b) within a row indicate significant differences among seasons; different letters (x, y, z) within a column indicate significant differences among tissues (ANOVA $p < 0.05$).

studied. In all species, levels of Fe and Zn have been found to be higher than Pb and Cd, and it could be explained because of these metals play a role in the enzymatic and respiratory processes of in fish and shrimp. Nonessential metals do not any function for fish's metabolism and are not regulated by the organism. From the quantitative 5 metals Zn had the highest tissue concentration in shrimp followed by Fe, Cu, Pb and Cd. Zinc is an important element that plays a role in many metabolic events, and its deficiency can lead to many activities such as loss of appetite, growth, and immunology disturbances. Cu is a metal essential for the healthy life of organisms, but high amounts of intake can cause various disorders. The amount of Cd and Pb in fish and shrimps can serve as a marker of the environmental levels of these metals. This study shows that there were little variations in mean concentration of Cd and Pb in all the species investigated whereas higher variation between Zn, Fe and Cu. Since the early 2000s, concentrations of heavy metals entering the Iskenderun Gulf have rapidly accumulated due to rapid local population and industrial development. The Yumurtalik region of the Iskenderun Gulf receives different types of pollution such as heavy metal and pesticides (industrial and agricultural activity) from the surrounding areas. In this study, the concentrations of metals determined by fish and shrimps can reflect the intensities of industrial activities in these regions. The concentrations of heavy metals recorded on the fish and shrimp in this study were compared with other studies to assess the level of metal pollution in the Yumurtalik coast of the Gulf of Iskenderun. The levels of tissue metals of *S. solea*, *S. aurata* and *P. semiculatus* were higher than those obtained in the recent study on the Yumurtalik coast of the Gulf of Iskenderun [13]. Concentration of Cu, Zn, Fe, Cd, and Pb in fish and shrimp has been studied in different regions, including in the Iskenderun Gulf [1, 12, 15]. In the present study, metal levels in the tissues of fish

were higher than fish from other regions of Mediterranean [13,16,17]. These heavy metal concentrations recorded in the present study varied from the concentrations of heavy metals in shrimp and fish in other studies.

In this study, the results showed that there were significant differences in metal concentrations between species. The highest Cu and Zn levels were found in *P. semiculatus* while the highest Fe average was found in *S. solea* and *S. aurata*. In general, different species showed different metal levels. The concentration order of Cu; Zn, Pb, Cd and Fe in the species were *P. semiculatus* > *S. solea* > *S. aurata*. These differences in metal levels of the species may be due to different biotope, metabolic activity and eating habits. In the present study, significant differences were observed between the fish species. In general, among the three species, *P. semiculatus* and *S. solea* are benthic species and have accumulated higher metal concentrations due to the greater exposure to sediment. Therefore, the metal concentration is largely controlled by the habitat, feeding habits, metal accumulation capacity, and organisms type [18].

3.2. Seasonal variations in concentrations of metals in fish and shrimp

Seasonal differences for all metals in the all tissues of *S. solea*, *S. aurata* and *P. semiculatus* were found in this study. In this study, the mean concentrations of Cu, Cd, Zn, Pb and Fe of muscle tissues during summer in *S. solea*, *S. aurata* and *P. semiculatus* were 6.20, 6.83, 32.30 79.50 and 42.80 µg/g, 4.38, 3.44, 34.40, 40.00 and 28.40 µg/g and 34.23, 8.33, 61.42, 62.75 and 24.23 µg/g respectively. However, during winter the average concentrations Cu, Cd, Zn, Pb and Fe of muscle tissues in *S. solea*, *S. aurata* and *P. semiculatus* varied as 2.64, 1.98, 22.10, 36.70 and 23.70 µg/g, 3.24, 2.49, 17.0, 27.30 and 10.80 µg/g and 19.35, 6.59, 37.43, 22.18 and 22.50 µg/g respectively. The levels of Cu, Cd, Zn, Pb and Fe were observed to be relatively higher during summer compared with the winter. Elevated metal levels in tissues in summer could be due to the increase in physiological activity of fish and shrimps in summer and the higher input of metal in the bay. The growth rate of fish would be higher in summer, resulting in higher metal accumulation [19]. Similar increases in metal levels were observed during summer in the Mediterranean fish and shrimp [6, 13].

3.3. Human health risk assessment

Diet is the most common route of human exposure to pollutants and fishes and shrimps have a strong potential for accumulate a number of pollutants including metal. The fish muscle is the most important part of the fish to be eaten by human. Fish is main source of iron for human, and its lack causes anaemia [20]. Regarding the effect of metals on human health, muscle tissue of fish and shrimp is explored more than other organs because it is the part usually consumed by human.

In this study, some of the levels of heavy metals detected in all tissues (except muscle tissue) have been found to be above the limits for fish recommended by the Food and Agriculture Organization/World Health Organization (FAO/WHO) and the European Union (EU) [7, 10].

In this study, the measured metal concentration in edible tissues (muscle) of *S. solea*, *S. aurata*, and *P. semiculatus* were compared with some existing standards for human consumption. Before the comparison, values were converted to µg/g wet weight. The mean muscle metal levels of *S. aurata*, *M. barbatus* and *P. semiculatus* were, respectively; 0.99 Cu/g ww, 0.78 Cd/g ww, 7.82 Zn/g ww, 9.09 Pb/g ww, 7.10 Fe/g ww; 1.4 µg Cu/g ww, 1.55 µg Cd/g ww, 7.34 µg Zn/g ww, 18.1 µg Pb/g ww and 9.72 µg Fe/g ww and 7.8 µg Cu/g ww, 1.89 µg Cd/g ww, 13.9 µg Zn/g ww, 14.3 µg Pb/g ww and 5.52 µg Fe/g ww. Mean values of Fe, Zn and Cu were below recommended limits of the FAO/WHO (Cd: 0.5, Cu: 30, Zn: 50 and Pb: 2 µg/g ww) [10, 21] in sea foods while Pb and Cd values exceeded such limits, suggesting accumulation in *S. solea*, *S. aurata* and *P. semiculatus* of the study area. The toxic metal (Cd and Pb) levels detected in muscle tissues of *S. solea*, *S. aurata* and *P. semiculatus* were not

within safe limits for human consumption. The levels of the essential metals (Fe, Cu, and Zn) were below the limits recommended by the EU and FAO/WHO for fish and shrimp.

4. Conclusion

In the Yumurtalik region of the Iskenderun Bay the three species with different ecological needs determined different metal concentrations in their tissues. The results showed that the concentrations of heavy metals varied among species and tissues. The metal concentrations in different tissues in this study differed in the general order of liver > gill > muscle. The distribution of metal concentrations in *S. solea* and *S. aurata* is as follows: Fe > Zn > Pb > Cu > Cd and *P. semiculatus* Zn > Fe > Pb > Cu > Cd respectively. The highest of concentrations heavy metal in all fish and shrimp species were found in tissues of *P. semiculatus*, followed by *S. solea* these two species are contacted with sediment and *S. aurata*. Generally, the results showed that liver accumulate higher concentrations of the heavy metals in comparison to muscle and gills, except for Pb and Fe in *P. semiculatus*. The present study also demonstrates that Zn and Cd were the most and least accumulated metals, respectively, in the fish and shrimp muscle tissues. The present study showed significant accumulation of Cd and Pb in edible tissues of *P. semiculatus*, *S. solea* and *S. aurata* from the Yumurtalik region of the Iskenderun Bay.

This study shows that some metal concentrations (Cd and Pb) are higher than the acceptable values for human consumption as determined by various health organizations. As a result, since these fish and shrimps are used in the human diet, the results obtained indicate that attention should be taken regarding intake, especially for shrimps and benthic fish. Potential for high risk is possible due to increasing heavy metal levels in Yumurtalik region of the Iskenderun Bay.

Declarations

Author contribution statement

Ferit Kargin: Conceived and designed the experiments; contributed reagents, materials, analysis tools or data; wrote the paper.

Dicle Kargin: Performed the experiments; analyzed and interpreted the data; wrote the paper.

Tüzün Aytekin, Ozge Temiz: Conceived and designed the experiments; performed the experiments; contributed reagents, materials, analysis tools or data; wrote the paper.

Hikmet Coğun: Conceived and designed the experiments; performed the experiments; wrote the paper.

Hazal Sağ Varkal: Analyzed and interpreted the data; wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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