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Determination of heavy metal content in commercial marine fish hunted From Southeast Aegean Sea (Turkey) and their potential risk for public health

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ABSTRACT
In this study, heavy metals such as Al, Cr, Cu, Zn, Cd, Hg, Pb etc. content in liver, muscle and gill of three economical marine species [striped seabream (*Lithognathus mormyrus* Linneaus, 1758), two-band bream (*Diplodus vulgaris* Geoffroy Saint-Hilaire, 1817) and Common pandora (*Pagellus erythrinus* Linneaus, 1758)] obtained from 4 stations (Fethiye, Bodrum, Datça, Marmaris) in South Aegean coast were analyzed. After tissues were mineralized with wet-ashing, their heavy metal concentrations were measured with inductively coupled plasma mass spectrometry (ICP-MS). According to the findings, sediment samples had more heavy metals than water samples and none of heavy metal concentrations in the water samples exceeded national legal limits. Furthermore it was reported that the accumulation of heavy metal in liver and gill was the highest whereas in muscle the proportion was the lowest. Results showed that the mean concentration of the studied heavy metals in muscle tissues did not pose a risk in terms of public health in comparison with the international standards.

Key words: Heavy metal, Marine, Striped seabream, Two-band Bream, Common pandora, Water, Sediment, Public health.

INTRODUCTION
Environmental pollution first emerged as a result of the beginning of urban life and increased with industrial development. Especially in the second part of the twentieth century, residual environmental pollution due to the increase in population caused more harm towards living resources and ultimately deterioration in ecosystem has become more serious. Pollutants that disturb the natural balance are organic substances, heavy metals, artificial agricultural fertilizers, detergents, radioactivity, pesticides, inorganic salts, artificially organic chemicals and wastewater (Yarsan & Bilgili 2000; Bat *et al*. 2006). Normally heavy metals are found at very low concentrations in marine water but because of the industrial developments of the last decade, marine environment has been polluted by heavy metals (Yilmaz & Yilmaz 2007; Franca *et al*. 2005; Hu 2000). Heavy metals can easily accumulate and increase their toxicity effects by creating very complex structures, as they mostly are not biodegradable (Sümer *et al*. 2013). Their toxicity have allergic, carcinogenic, mutagenic and specific effects on chemical reactions, transport systems and constituent (Bakar & Baba 2009). The major factors of contagion of heavy metals into environment are heavy metal fabrication, enterprises using heavy metals, fertilizer industry, thermal power stations, incinerators, vehicles, iron-steel, cement and glass production (Kahvecioğlu *et al*. 2003). Heavy metals accumulate in marine organisms with different ways such as respiratory, adsorption and dietary (Coğun *et al*. 2006). For this reason, some marine organisms can take more amounts

of heavy metals from their surroundings, suspending agents, nutrients and directly seawater (Hasmi *et al*. 2002). Fish tissues (muscle, liver, kidney, ovary, stomach, etc.) are used as an indicator to determine the degree of heavy metal concentrations in the marine environment. Especially liver is often recommended as an important indicator of water pollution more than other fish tissues (Olsvik *et al*. 2001). Heavy metals are found in different organs and tissues of fish that are on the top of marine food chain and pass through human metabolism by ingestion. By this way serious health problems in humans could appear (Ajiboye *et al*. 2011; Ozuni *et al*. 2010). Regular monitoring of heavy metal concentration in the marine environment has a substantial importance to environment, food safety, animal health and accordingly human health (Bilyard 1987). For this reason, for the last 30 years researches have started to focus on toxic effects of heavy metals (Örün & Yalçın 2011).

In this study, existence of heavy metals such as Al, Cr, Cu, Zn, Cd, Hg, Pb etc. in the liver, muscle and gill of three economical marine species [striped seabream (*Lithognathus mormyrus* Linneaus, 1758), two-band bream (*Diplodus vulgaris* Geoffroy Saint-Hilaire, 1817) and Common pandora (*Pagellus erythrinus* Linneaus, 1758)] obtained from 4 stations (Fethiye, Bodrum, Datça, Marmaris) in South Aegean coast was analyzed. The heavy metals obtained from muscle tissue were then evaluated in terms of public health.

MATERIALS AND METHODS

Material

Commercial and portion-size striped seabream, two-band bream and Common pandora were obtained from 4 stations (Fethiye, Bodrum, Datça, Marmaris) in South East Aegean coast between May 2012 to May 2013 (Fig. 1). The samples were brought in a sterile polyethylene bag under cold conditions to the laboratory of Muğla Sıtkı Koçman University Faculty of Fisheries together with all water samples after acidified with 1: 3 (HNO_3: H_2O) diluted nitric acid (65% suprapure) as pH <2. During each sampling period (seasonally), at least 3 portion-size fish for each fish species and also 1-litre of seawater were taken. Sediment samples were taken once from the stations during the study. In laboratory, water samples, acidified with nitric acid, were filtered through a membrane filter mesh of 0.45 mm. Moreover fish samples were grouped according to locality and species, then their total lengths and weights were noted. Liver, muscle and gill tissues were kept in freezer at -20ºC until analyses were done after fish were dissected. Sample jars were kept in nitric acid for 15 minutes then washed with deionized water before the samples were taken into.

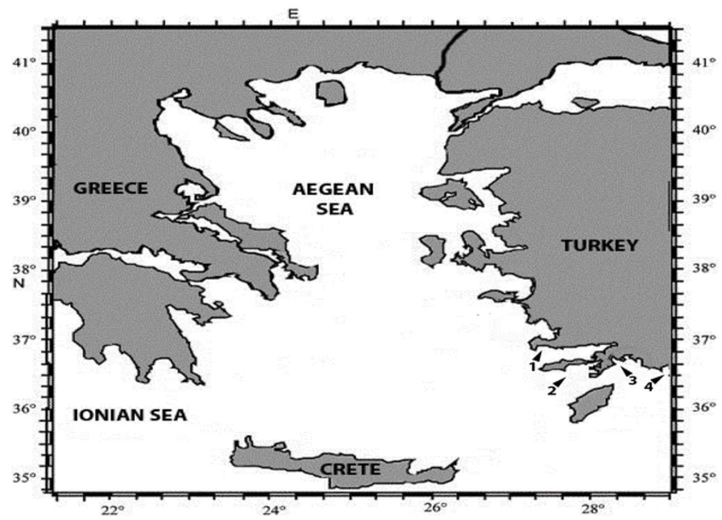

Fig. 1. Description of the study area (1.Bodrum, 2.Datça, 3.Marmaris, 4.Fethiye).

Method

Samples ashing process

Wet-ashing method was used for tissue samples that were dissected (Mendil *et al*. 2010). After 1 g was taken from tissue sample and 6 mL HNO_3 (65%), 2 mL H_2O_2 (30%) were added, burning process was carried out for 4 hours at 150 °C in wet-ashing unit. Then the digested samples were complemented with 10 ml deionized water and were analyzed. Müller (1999) ashing method was used for sediment samples. 3 mL HCl-HNO_3-H_2O (3:1:2) was added to 0.5 g sediment sample and burning process was carried out for 1 hour at 95°C. The obtained volume was complemented to 10 ml with deionized water and was analyzed.

Heavy metal analysis of samples

Heavy metal concentrations of mineralized samples were measured with ICP-MS (Agilent 7700x). Multi-element calibration solutions were prepared at 0, 5, 10, 50, 100, 200 $\mu g.kg^{-1}$ levels and Hg calibration solutions were prepared at of 0, 0.5, 1, 5, in 10 and 20 $\mu g.kg^{-1}$ levels before analysis. TORT 2 lobster hepatopancreas was used to determine the reliability of the heavy metal analysis.

Statistical analysis

IBM SPSS Statistics V.20 program was used for the statistically analyses. Analysis of variance (ANOVA) and Tukey post-hoc tests were used to determine the relationship between groups. Specifically it was used to compare the concentration between tissues and between fish species. The statistical significance was determined as 0.05 ($P < 0.05$) alpha levels.

RESULTS

Heavy metal concentrations in fish Sample

During this study, 447 tissue samples of 149 fish samples were examined. Biometric measurement of fish specimens are given at Table 1.

Table 1. Biometric characteristics of the studied fish species.

Species	Amount of Sample	Total length (cm)			Total weight (g)		
		Min	Max	Mean ± SD	Min	Max	Mean ± SD
Lithognathus mormyrus	49	18.50	26.00	22.95 ± 2.27	102.44	249.11	181.49 ± 42.97
Diplodus vulgaris	52	18.00	25.50	21.99 ± 1.94	81.89	212.70	132.84 ± 32.36
Pagellus erythrinus	48	19.00	26.00	22.70 ± 1.54	149.38	297.53	204.45 ± 45.12

Min: Minimum, Max: Maximum, SD: Standard deviation.

Heavy metal concentration in tissues was provided for each fish species, without discriminate among different stations of collection. The mean heavy metal concentrations found in tissues of striped seabream, two-band bream and Common pandora are shown at Table 2, 3 and 4 respectively. Statistically there were significant differences between tissues of stripped seabream ($p < 0.05$) except liver and gill for lead and cadmium; gill and muscle tissues for zinc ($p > 0.05$). Significant differences were found between tissues of two-band bream ($p < 0.05$) except gill and muscle tissues for zinc; gill and liver for mercury; liver and muscle tissues for lead ($p > 0.05$). For all the analyzed tissues of Common pandora significant statistical differences emerged ($p < 0.05$) in terms of all elements except zinc ($p > 0.05$). By the analyses of element concentrations emerged that, the amount of element concentration found in liver and gill was higher than in muscle. This result could be explained with the physiological metabolism of the fish. Gills are the main entrance of dissolved metals (Gaber, 2007) and responsible for homeostasis of essential metals (Cu, Zn) in hepatic metallothionein biological with detoxification of toxic heavy metal ions (Duquesne *et al.* 1995). For these reasons, the studied elements were found in liver and gills more than muscle tissue. By the results of the Tukey HSD multiple comparisons post-hoc test, any significant difference between fish species in terms of mercury emerged ($p > 0.05$);

however statistical significances were found between fish species and elements (Table 5). The results of Tukey HSD post-hoc multiple comparisons test used to determine statistical significant difference between stations in terms of heavy metals considering the total heavy metal concentrations in fish are reported in Table 6.

Table 2. The mean amount of heavy metals in the tissues of striped seabream (mg.kg^{-1} ± SD, n = 49).

Heavy Metal	G	MT	L	Sequencing of Tissues
Al	0.67 ± 0.11	0.41 ± 0.11	0.51 ± 0.11	G > L > MT
Cr	0.57 ± 0.10	0.38 ± 0.11	0.45 ± 0.12	G > L > MT
Cu	0.25 ± 0.06	0.17 ± 0.05	0.34 ± 0.08	L > G > MT
Zn	5.03 ± 0.20	5.01 ± 0.15	5.12 ± 0.17	L > G > MT
Cd	0.06 ± 0.01	0.03 ± 0.01	0.06 ± 0.02	G = L > MT
Hg	0.15 ± 0.04	0.10 ± 0.03	0.13 ± 0.02	G > L > MT
Pb	0.15 ± 0.04	0.11 ± 0.03	0.13 ± 0.03	G > L > MT

G: Gill, L: Liver, MT: Muscle Tissue.

Table 3. The mean amount of heavy metals in the tissues of two-band bream (mg.kg^{-1} ± SD, n=52).

Heavy Metal	G	MT	L	Sequencing of Tissues
Al	0.74 ± 0.14	0.45 ± 0.13	0.57 ± 0.15	G > L > MT
Cr	0.52 ± 0.17	0.31 ± 0.14	0.40 ± 0.14	G > L > MT
Cu	0.33 ± 0.19	0.22 ± 0.14	0.44 ± 0.20	L > G > MT
Zn	5.02 ± 0.18	4.95 ± 0.16	5.10 ± 0.20	L > G > MT
Cd	0.06 ± 0.02	0.03 ± 0.01	0.05 ± 0.01	G = L > MT
Hg	0.13 ± 0.03	0.09 ± 0.03	0.12 ± 0.03	G > L > MT
Pb	0.14 ± 0.03	0.12 ± 0.05	0.13 ± 0.02	G > L > MT

G: Gill, L: Liver, MT: Muscle Tissue.

Table 4. The mean amount of heavy metals in the tissues of common pandora (mg.kg^{-1} ± SD, n=48).

Heavy Metal	G	MT	L	Sequencing of Tissues
Al	0.74 ± 0.10	0.45 ± 0.12	0.54 ± 0.11	G > L > MT
Cr	0.67 ± 0.17	0.39 ± 0.07	0.48 ± 0.09	G > L > MT
Cu	0.30 ± 0.06	0.21 ± 0.03	0.42 ± 0.07	L > G > MT
Zn	5.10 ± 0.13	5.04 ± 0.27	5.12 ± 0.11	L > G > MT
Cd	0.06 ± 0.01	0.03 ± 0.01	0.05 ± 0.01	G = L > MT
Hg	0.14 ± 0.02	0.09 ± 0.02	0.12 ± 0.02	G > L > MT
Pb	0.15 ± 0.03	0.10 ± 0.02	0.12 ± 0.03	G > L > MT

G: Gill, L: Liver, MT: Muscle Tissue.

Table 5. Statistical significance between fish species obtained all stations and studied heavy metals.

		Common pandora	Two-band bream
Al	Stripped seabream	*	---
	Common pandora		---
Cr	Stripped seabream	*	---
	Common pandora		***
Cu	Stripped seabream	***	***
	Common pandora		---
Zn	Stripped seabream	---	---
	Common pandora		***
Cd	Stripped seabream	*	---
	Common pandora		---
Hg	Stripped seabream	---	---
	Common pandora		---
Pb	Stripped seabream	---	---
	Common pandora		---

*** p<0.01, * p<0.05, --- p>0.05.

Table 6. Statistical significance levels the total heavy metal concentrations in fish in terms of all stations.

		Fethiye	Bodrum	Datça
Al	Bodrum	***		
	Datça	***	---	
	Marmaris	***	---	---
Cr	Bodrum	***		
	Datça	***	---	
	Marmaris	***	---	*
Cu	Bodrum	***		
	Datça	---	***	
	Marmaris	***	***	***
Zn	Bodrum	***		
	Datça	***	---	
	Marmaris	---	***	***
Cd	Bodrum	---		
	Datça	---	---	
	Marmaris	---	---	---
Hg	Bodrum	---		
	Datça	---	---	
	Marmaris	---	---	---
Pb	Bodrum	***		
	Datça	*	---	
	Marmaris	---	***	***

*** $p<0.01$, * $p<0.05$ ---, $p>0.05$

According to results, there was no significant difference between stations in terms of mercury and cadmium ($p>0.05$). On the other hand, Fethiye had a significant difference in terms of other heavy metals. The difference of heavy metal concentrations among, fish species and stations could be due to seasonal and biological (fish species, physiology, etc.) variation, or regional and environmental (water chemistry, salinity, temperature and contaminants) conditions (Alasalvar *et al*. 2002; Bhouri *et al*. 2010; Yildiz 2008).

To assess the risk of heavy metals concentrations for public health, the fish tissue that should be analyzed is the muscle, being it the tissue consumed by human. For this reason, in the study a more attention was given only to heavy metal concentration found in fish muscle tissues. As a result of comparison between the mean heavy metal concentrations determined in fish muscle tissues and international recommended limits, none of fish species had exceeded the limits for none of the examined heavy metals (Table 7).

Table 7. Heavy metal concentration determined in muscle tissues of the studied fish species and international limits values (mg.kg^{-1} wet weight).

Heavy metal	Limit value	Striped seabream	Two-band bream	Common pandora
Al	1.00[a]	0.41 ± 0.11	0.45 ± 0.13	0.45 ± 0.12
Cr	8.00[b]	0.38 ± 0.11	0.31 ± 0.14	0.39 ± 0.07
Cu	10.00[c]	0.17 ± 0.05	0.22 ± 0.14	0.21 ± 0.03
Zn	25.00[d]	5.01 ± 0.15	4.95 ± 0.16	5.04 ± 0.27
Cd	0.05[e]	0.03 ± 0.01	0.03 ± 0.01	0.03 ± 0.01
Hg	0.50[e]	0.10 ± 0.03	0.09 ± 0.03	0.09 ± 0.02
Pb	0.30[e]	0.11 ± 0.03	0.12 ± 0.05	0.10 ± 0.02

a: EFSA (2013); b: Tüzen (2009); c: FAO (1983); d: EFSA, (2006); Anonymous (2006).

Heavy metal concentrations in water and sediment samples

Heavy metal concentrations detected in water and sediment samples are shown at Table 8. Higher heavy metal concentrations were determined in sediment samples than in water samples. A reason for this is that heavy metals tend to subsidence and accumulate in sediment by year to year. All heavy metal concentrations in water samples did not exceed marine water quality criteria limits (Cr: 100, Cu: 10, Zinc: 100, Cd: 10, Hg: 4, Pb: 100 µg.L^{-1}) specified by the Water Pollution Control Regulation (Anonymous 2004).

Table 8. The mean heavy metal concentration in water and sediment samples (water µg.L^{-1}; sediment mg.kg^{-1}).

		Al	Cr	Cu	Zn	Cd	Hg	Pb
Marmaris	Water	29.49 ± 2.26	2.35 ± 0.50	6.52 ± 0.91	10.72 ± 0.35	0.04 ± 0.01	0.12 ± 0.05	3.40 ± 0.32
	Sediment	30.96 ± 0.48	32.47 ± 0.45	22.49 ± 0.32	68.37 ± 0.66	0.07 ± 0.01	0.16 ± 0.01	30.29 ± 0.87
Datça	Water	19.96 ± 1.90	1.93 ± 0.16	3.87 ± 0.25	6.96 ± 0.09	0.05 ± 0.02	0.05 ± 0.01	2.36 ± 0.54
	Sediment	20.89 ± 0.26	29.09 ± 0.83	16.42 ± 0.49	63.06 ± 0.93	0.07 ± 0.02	0.11 ±0.01	24.43 ± 0.33
Bodrum	Water	8.39 ± 1.96	1.94 ± 0.17	5.44 ± 0.35	11.54 ± 0.46	0.03 ± 0.01	0.07 ± 0.01	3.03 ± 0.16
	Sediment	16.57 ± 0.38	29.08 ± 0.43	20.62 ± 0.55	56.86 ± 0.99	0.06 ± 0.01	0.09 ± 0.01	26.09 ± 1.03
Fethiye	Water	21.86 ± 2.95	1.29 ± 0.16	4.15 ± 0.17	8.91 ± 0.97	0.04 ± 0.01	0.06 ± 0.01	1.48 ± 0.27
	Sediment	21.80 ± 0.35	17.99 ± 0.30	18.34 ± 0.20	51.45 ± 0.44	0.06 ± 0.01	0.05 ± 0.01	17.72 ± 0.30

DISCUSSION

Aluminum

Aluminum is the most abundant metallic element. Approximately 8% of the earth's crust is made of aluminum (WHO, 1998). European Food Safety Authority (EFSA) identified weekly maximum tolerable aluminum intake as 1 mgAl.kg^{-1} of body weight (EFSA, 2013). In our study, the highest mean Al concentration was determined in bream and Common pandora (0.45 mg.kg^{-1}) and this value was considerably lower than the limit value. Thus, consumption of this fish species does not involve any dangers in terms of aluminum for public health. A study held in İskenderun Bay, aluminum levels in muscle tissue of *Mullus barbatus* and *M. surmelatus* (respectively 6.67 mg.kg^{-1}, 7.52 mg.kg^{-1}) were found to exceed the limit unlike our results (Dural *et al*., 2010).

Chromium

Chromium is an essential element for humans and animals. However, when it is taken at excessive amount, especially hexavalent form may be toxic (Salem *et al*. 2000). Non-hazard critical limit for public health is 8 mg Cr.kg^{-1} (Tüzen 2009). In our study, the highest mean amount of chromium in muscle tissue (0.39 mg.kg^{-1}) was determined in Common pandora fish. The detected value of the highest chromium content was substantially lower than limit value. No risk for public health was assessed for consumption of fish in terms of chromium. In a study made in Southern coasts of Morocco (Foum I'Oued), the minimum chromium was detected in muscle tissues (0.02 mg.kg^{-1}) and maximum was in gill tissues (0.15 mg.kg^{-1}) of bream (Morhit *et al*. 2013).

Common pandora (*Pagellus acarne*) and sardine (*Sardina pilchardus*) had also been studied in the same research; 0.01 mg.kg^{-1} of chromium were detected in their muscle tissue. In that study carried out by Morhit *et al*. (2013), chromium content of muscle tissue did not constitute a risk to public health, as in this study. Şimşek *et al*. (2009), detected less than limit value as 0.20 mg.kg^{-1} of chromium in muscle tissues of both *M. barbatus* and *Upeneus moluccensis* which were obtained from the Mediterranean Sea. The mean chromium levels (5.49 - 6.82) were identified below the limit values in muscle tissue of *M. barbatus* captured at Çandarlı Gulf (Taş *et al*. 2011).

Copper

Copper is an essential trace element existing at small amounts in a variety of cells and tissues and at high concentrations in the liver (Turnlund 1998). However, it is toxic if taken at large amounts. The recommended limit value of copper is 10 mgCu.kg^{-1} by FAO (1983). In this study, the highest mean copper concentration was detected as 0.22 mg.kg^{-1} in bream. The highest copper concentration (10 mg.kg^{-1}) obtained was about 45 times lower than the limit value. As it can be understood, there is not any risk to public health in consumption of these fish species in terms of copper. In a study held in southern coast of Morocco (Foum I'Oued) by Morhit *et al*. (2013), the highest copper in the muscle tissues of common pandora (*Pagellus acarne*), sardines and sea bream were determined as 0.55 mg.kg^{-1}, 0.36 mg.kg^{-1} and 0.42 mg.kg^{-1} respectively; which were higher than the maximum mean amount of copper (0.22 mg.kg^{-1}) in this study. However their results did also not exceed limit value (10 mg.kg^{-1}) as in this study. In another study that analyzed the muscle tissue of *M. barbatus* and *Upeneus moluccensis*, the species caught in the Mediterranean, results showed similarities with the study mentioned above (00:51 respectively mg.kg^{-1} and 0.48 mg.kg^{-1}) (Simsek *et al*. 2009). Similarly, in the study conducted in the Çandarlı Gulf, the mean copper amount in muscle tissue of *M. barbatus* (0.26-0.79 mg.kg^{-1}) was below the limit value (Taş *et al*. 2011).

Zinc

When examining periodic table, zinc is located in the IIB group with two toxic metals; cadmium and mercury. However, zinc is considered to be relatively non-toxic to humans (Fosmire 1990). On the other hand, being exposed to very high amounts may lead to toxic effects (Plum *et al*., 2010). According to Institute of Medicine of United States, zinc level recommended for adults is 40 mg Zn.day^{-1} (IOM, 2001). But the European Food Safety Authority determined upper limit value of zinc as 25 mg.day^{-1} (EFSA, 2006). These EFSA limits were taken into account due to its being lower than others while evaluating our data in terms of zinc. The highest mean zinc amount was 5.04 mg.kg^{-1} and determined in Common pandora. This amount (5.04 mg.kg^{-1}) does not exceed limit value even when a person consumes one kg mullet per day (25 mg.day^{-1}). Therefore, consuming these studied species does not involve any danger to the public health in terms of zinc. Şimşek *et al*. (2009) determined similar amount of zinc as in this study (5.21 mg.kg^{-1}) in muscle tissues of *M. barbatus* (5.63 mg.kg^{-1}), obtained from the Mediterranean. Likewise, parallel to these study (5.01 mg.kg^{-1}), amount of zinc were determined in fish muscle tissue with 5.83 mg.kg^{-1} in the study on *Lithognathus mormyrus*, obtained from Beymelek Lagoon (Uysal *et al*. 2008). The results of another study held in Izmir Bay were also similar and zinc concentrations of muscle tissue in *M. barbatus*, *M. surmelatus*, *P. erythrinus*, *L. mormyrus* and *D. vulgaris* were: 5:03 mg.kg^{-1}, 4.94 mg.kg^{-1}, 5.68 mg.kg^{-1}, 5.64 mg.kg^{-1}, 5.38 mg.kg^{-1} respectively (Çelik & Oehlenschläger 2005). In the study done on the South coasts of Morocco (Morhit *et al*. 2013); zinc concentration of muscle tissues of *P. acarne*, *S. pilchardus* and *D. vulgaris* (respectively 18.33 mg.kg^{-1}, 9.30 mg.kg^{-1}, 105 mg.kg^{-1}) were found higher than this study and in case of consuming 1 kg muscle tissue of *D. vulgaris* the limit value of EFSA (25 mg.day^{-1}) might be exceeded. Similarly, in a study conducted in the Gulf of Çandarlı, the researchers detected the mean zinc levels in the muscle tissue of *M. barbatus* (0.44-0.63 mg.kg^{-1}) lower than in this study (Taş *et al*., 2011).

Cadmium

Cadmium is a highly toxic element for mammals and fish. Cadmium tends to be accumulated in living organisms very quickly (Besirovic *et al*. 2010). In addition, aquaculture is the main source of human exposure to cadmium. European Union Food Codex determined the maximum amount of cadmium in fish as 0.05 mg Cd.kg^{-1} in EC1881/2006 (Anonymous 2006). In this study, the mean amount of cadmium, obtained for all types of fish was 0.03 mg.kg^{-1} and this amount did not exceed limit value (0.05 mg.kg^{-1}).

Therefore, the consumption of fish species, studied in this research, does not constitute a risk to public health in terms of cadmium.

Similarly in a study held in Yalova the mean cadmium level in muscle tissue of *D. annularis* was determined as 0.03 mg.kg^{-1} (Türkmen *et al*. 2008). Unlike to this study the mean cadmium concentrations of three fish species (*P. acarne* 0.11 mg.kg^{-1}, *S. pilchardus* 0.13 g.kg^{-1} and *D. vulgaris* 0.06 mg.kg^{-1}) in Morocco exceeded the specified limit value (0.05 mg.kg^{-1}) by European Union Food Codex EC 1881/2006 (Morhit *et al*. 2013). In a study conducted in Iskenderun Bay, cadmium was not found in muscle tissue of *M. barbatus* while 0.14 mg.kg^{-1} of cadmium which was above the limit value was found in muscle tissue of *M. surmelatus* (Dural *et al*. 2010).

Mercury

Seafood is generally accepted as the main source of mercury, a highly toxic metal, in food chain (Plessi *et al*. 2001). EC 1881/2006 regulation of European Union indicated that the highest concentrations of mercury could be found in fish as 0.50 mg.kg^{-1} (Anonymous, 2006). The highest mean mercury concentration was detected in striped sea bream as 0.10 mg.kg^{-1} in this study.

The obtained value (0.10 mg.kg^{-1}) was 5 times lower than 0.50 mg.kg^{-1}, limit value, thus species that had been studied could be consumed safely. Likewise, a study done in Eastern Aegean Sea, mercury amount in muscle tissue of *M. barbatus* was determined as 0.096 mg.kg^{-1} (Kucuksezgin *et al*. 2001).

Unlike this study, mercury concentration in muscle tissue of *M. barbatus*, were caught in Adriatic Sea and Ion Sea, were 0.49 mg.kg^{-1}, and 0.40 mg.kg^{-1} respectively (Storelli *et al*. 2005).

In the study conducted in Eastern Aegean Sea, the mean mercury concentration in muscle tissue of *Pagellus erythrinus* were detected in the range of 0.15 to 0.30, and it also did not exceed the limit value (Uluturhan & Kucuksezgin 2007).

Lead

Lead is a potentially toxic chemical when people and mussels, aquatic animals such as fish are exposed (Olaifa *et al*. 2003). Also it is one of the most important heavy metal that can be found in the environment, especially in the aquatic environment (Cigerci *et al*. 2010). The highest mean amount of lead obtained in our study was 0.12 mg.kg^{-1} and determined in bream. This value was below specified limit, 0.30 mgPb.kg^{-1}, specified in EC 1881/2006 food codex of European Union for fish (Anonymous, 2006). There is no risk for public health in consumption of fish species, which were studied in our study, in terms of lead. Similarly, the limit value did not exceed in the muscle tissue of three fish species (*P. acarne* 0.004 mg.kg^{-1}, *S. pilchardus* 0.004 mg.kg^{-1} and *D. vulgaris* 0.038 mg.kg^{-1}) studied in Morocco (Morhit *et al*. 2013). Unlike this study (0.10 mg.kg^{-1} for both species), Dural *et al*. (2010) determined lead in muscle tissue of *M. barbatus* and *M. surmelatus*, caught from Iskenderun Gulf, as 2.26 mg.kg^{-1} and 8.10 mg.kg^{-1} respectively and those values were higher than the limit value. Again, the mean level of lead (2.30 – 8.07 mg.kg^{-1}) detected in muscle tissue of *M. barbatus* was higher than the limits in a study conducted in Çandarlı Gulf (Taş *et al*. 2011). The results obtained from studies on similar subject are summarized at Table 9.

Much more heavy metal concentrations were determined in sediment samples than water samples. The reason was that heavy metals tended to settle to the bottom and accumulate in sediment year after year. Heavy metal concentrations in all water samples did not exceed the marine water quality criteria values (Cr: 100, Cu: 10, Zn: 100, Cd: 10, Hg: 4, Pb: 100 µg.L^{-1}) specified in Water Pollution Control Regulations (Anonymous 2004). Angel *et al*. (2012) detected <8-2120 µg.L^{-1} Al, <0.04 - 2.62 µg.L^{-1} Cr, <0.17 - 2.70 µg.L^{-1} Cu, <0.11 - 3.65 µg.L^{-1} Zn, <0.02 - 0.03 µg.L^{-1} Cd, <0.04 - 0.70 µg.L^{-1} Pb in sea water; 1720 - 26900 mg.kg^{-1} Al, 5 - 32 mg.kg^{-1} Cr, 1 - 22 mg.kg^{-1} Cu, 6 - 53 mg.kg^{-1} Zn, 0.08 - 0.44 mg.kg^{-1} Cd and 2 - 13 mg.kg^{-1} Pb in sediment from Port Curtis in Queensland

(Australia) which had a coast to Pacific Ocean. When their sediment results are compared with our results, while aluminum and cadmium quantities were quite high; chromium, copper and zinc concentrations were found similar. In a study conducted in South West Finland 54 - 110 mg.kg^{-1} Cr, 41 - 85 mg.kg^{-1} Cu, 115 - 315 mg.kg^{-1} Zn, 0.2 - 0.5 mg.kg^{-1} Cd, 25 - 72 mg.kg^{-1} Pb were determined in sediment samples. The mean concentrations were higher than the mean concentrations obtained in this study in terms of all the elements.

Table 9. Comparison of data obtained from the results of muscle tissue with other studies.

Location	Species	Al	Cr	Cu	Zn	Cd	Hg	Pb	Reference
South Coast of Morocco	*P. acarne*		0.01 ± 0.003	0.55 ± 0.63	18.33 ± 3.78	0.11 ± 0.01		0.004 ± 0.0005	Morhit *et al.*, (2013)
	D. vulgaris		0.016 ± 0.002	0.42 ± 0.38	105 ± 5	0.06 ± 0.07		0.038 ± 0.037	
Iskenderun Bay	*M.barbatus*	6.67 ± 0.17	6.56 ± 1.03	ND	0.11	ND		2.26 ± 0.26	Dural *et al.*, (2010)
	M. surmelatus	7.52 ± 0.15	0.48 ± 0.17	1.21 ± 0.15	0.77 ± 0.17	0.14 ± 0.04		8.10 ± 0.87	
Marmara Sea (Yalova)	*D.annularis*		0.07 ± 0.01	0.48 ± 0.14	4.87 ± 0.37	0.03 ± 0.00		0.24 ± 0.09	Türkmen *et al.*, (2008)
Beymelek Lagoon	*L. mormyrus*		ND	1.54 ± 0.4	5.83 ± 0.5				Uysal *et al.*, (2008)
East Aegean Sea	*P. erythrinus*			0.10-0.24	2.62 - 3.38	0.001-0.003	0.15-0.30	0.07 - 0.28	Uluturhan and Kucuksezgin (2007)
Outside the Izmir Gulf	*M. barbatus*			0.29 ± 0.01	5.03 ± 0.75				Çelik and Oehlenschläger (2005)
	M. surmelatus			0.55 ± 0.07	4.94 ± 0.30				
	P. erythrinus			0.32 ± 0.09	5.68 ± 0.47				
	L. mormyus			0.25 ± 0.05	5.64 ± 0.00				
	D. vulgaris			0.21 ± 0.01	5.38 ± 0.23				
South East Aegean Sea	*P. erythrinus*	0.41 ± 0.11	0.38 ± 0.11	0.17 ± 0.05	5.01 ± 0.15	0.03 ± 0.01	0.10 ± 0.03	0.11 ± 0.03	This Study
	L. mormyrus	0.45 ± 0.13	0.31 ± 0.14	0.22 ± 0.14	4.95 ± 0.16	0.03 ± 0.01	0.09 ± 0.03	0.12 ± 0.05	
	D. vulgaris	0.45 ± 0.12	0.39 ± 0.07	0.21 ± 0.03	5.04 ± 0.27	0.03 ± 0.01	0.09 ± 0.02	0.10 ± 0.02	

ND: Not Detection.

CONCLUSIONS

In this study heavy metal concentration levels in sediment samples were higher than water samples and none of the values calculated for the water samples exceeded the limits determined in regulation of water pollution control. The highest and lowest accumulation of heavy metal was found in the liver, the gill and in the muscle respectively for all the studied fish species. Summarizing the results obtained, it can be attested that any risk for public health was assessed in terms of the studied elements and even in terms of the most notorious trio (mercury, cadmium and lead) by the consumption of striped seabream, two-band bream and Common pandora caught in the stations examined.

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تعیین مقدار فلزات سنگین در ماهیان دریایی تجاری صید شده از سواحل جنوب شرقی دریای اژه (ترکیه) و خطر بالقوه آن برای بهداشت عمومی

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چکیده

در این مطالعه، مقدار فلزات سنگینی مانند آلومینیم، کروم، مس، روی، کادمیم، جیوه، سرب و غیره در کبد، عضله و آبشش سه گونه از ماهیان دریایی مهم اقتصادی [سیم دریایی راه راه (لیوگناتوس مورمیروس، لینه ۱۷۸۵) ، سیم دونواری (دیپلودوس ولگاریس جفری سنت هلر ۱۸۱۷) و پاندورای معمولی (پاگلوس اریترینوس لینه ۱۷۵۸)] از چهار ایستگاه (فتیه، بدروم، داتکا، مرمریس) در سواحل جنوبی دریای اژه مورد آزمایش قرار گرفت. پس از تهیه خاکستر مرطوب از بافتها ، غلظت فلزات سنگین با استفاده از روش ماس اسپکترومتری پلاسمای کوپل مورد اندازه‌گیری قرار گرفت. بر اساس یافته‌ها، نمونه‌های رسوب ، فلزات سنگین بیشتری نسبت به نمونه‌های آب داشتند و هیچ یک از غلظت‌های این فلزات در آب از محدوده‌های رسمی ملی فراتر نرفته بود. به علاوه مشاهده شد که تجمع فلزات سنگین در کبد و آبشش در بالاترین مقدار بود، در حالی که در عضله کمترین مقدار را به خود اختصاص می‌داد. نتایج نشان داد که میانگین غلظت فلزات سنگین مورد مطالعه در مقایسه با استانداردهای بین‌المللی در بافت عضله خطری برای بهداشت عمومی ایجاد نمی‌کند.

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