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A Meta Analysis on The Heavy Metal Content of Two Shrimp Species, *Penaeus Semisulcatus* (De Hann, 1844) and *Metapenaeus Monoceros* (Fabricius, 1798) From İskenderun Bay

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ABSTRACT
Different studies even on same shrimp species and same heavy metals from same locations may be inconsistent with each other. Because of their importance on a food safety risk, a meta-analysis is required to evaluate the true risk level to human consumption for these aquatic organisms. In this study, commercially important two shrimp species, *Penaeus semisulcatus* (de Hann, 1844) and *Metapenaeus monoceros* (Fabricius, 1798), from İskenderun Bay were subjected to a meta-analysis for some heavy metal contents (Cadmium-Cd, Zinc-Zn, Lead-Pb, and Copper-Cu). Meta-analysis results (mean±Sd) were evaluated according to the reference values that are maximum permissible limit (dry-wet, mg kg^{-1}) for shrimp as follow; Cd (1 mg kg^{-1}), Zn (50 mg kg^{-1}), Pb (2 mg kg^{-1}) and Cu (20 mg kg^{-1}). For Cd, *M. monoceros* (0.93±0.02 mg kg^{-1}) was not exceeded the reference limit ($P>0.05$), while, *P. semisulcatus* (3.93±0.12 mg kg^{-1}) was exceeded ($P<0.05$). For Zn, *M. monoceros* (58.69±7.25 mg kg^{-1}) was exceeded the reference limit ($P<0.05$), but *P. semisulcatus* (50.28±8.00 mg kg^{-1}) was not exceeded ($P>0.05$). For Pb, both *M. monoceros* (10.14±4.09 mg kg^{-1}) and *P. semisulcatus* (6.30±2.02 mg kg^{-1}) were exceeded the reference limit ($P<0.05$). For Cu, *M. monoceros* (23.25±4.34 mg kg^{-1}) was not exceeded the reference limit ($P>0.05$), while *P. semisulcatus* (49.68±14.71 mg kg^{-1}) was exceeded ($P<0.05$). Despite the meta-analysis results, the harmful effects of heavy metals on human health only occur when long-term consumption of contaminated crustaceans occurs, much more well-organized studies (with more samples, suitable sampling strategy, etc.,) are needed to make an ultimate decision on whether the contents of these considered heavy metals in these two shrimp species.

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İskenderun Körfezi'ndeki İki Karides Türünün, *Penaeus semisulcatus* (de Haan, 1844) ve *Metapenaeus monoceros*'un (Fabricius, 1798) Ağır Metal Içeriği Üzerine Bir Meta Analiz

ÖZET
Aynı bölgeden alınmış ve aynı ağır metaller çalışılmış olsa bile aynı karides türlerinin ağır metal içerikleri farklı çalışmalarda birbirleri ile tutarsız olabilir. Gıda güvenliği riski açısından önemli olmaları nedeniyle, bu anlamda karideslerin insan tüketimine yönelik gerçek risk düzeyini değerlendirmek için bir meta-analiz gereklidir. Bu çalışmada, İskenderun Körfezi'nden ticari açıdan önemli iki karides türü olan *Penaeus semisulcatus* (de Hann, 1844) ve *Metapenaeus monoceros* (Fabricius, 1798)'un bazı kas dokularının ağır metal içerikleri (Kadmiyum-Cd, Çinko-Zn, Kurşun-Pb ve Bakır-Cu) bir meta-analiz çalışması ile dikkate alınmıştır. Meta-analiz sonuçları (ortalama±Sd) karides için izin verilen maksimum sınır (kuru-yaş ağırlık, mg / kg) olan referans değerlere göre aşağıdaki şekilde değerlendirilmiştir; Cd (1 mg kg^{-1}), Zn (50 mg kg^{-1}), Pb (2 mg kg^{-1}) ve Cu (20 mg kg^{-1}). Yapılan değerlendirme sonucunda, Cd için M.

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monoceros (0.93±0.02 mg kg^{-1}) referans sınır aşılmamışken (P>0.05), *P. semisulcatus* (3.93±0.12 mg kg^{-1}) için referans sınır aşmıştır (P <0.05). Zn için M. monoceros (58.69±7.25 mg kg^{-1}) türü için referans sınır (P<0.05) aşılmış, *P. semisulcatus* (50.28±8.00 mg kg^{-1}) için referans sınır aşılmamıştır (P>0.05). Pb için hem *M. monoceros* (10.14±4.09 mg kg^{-1}) hem de *P. semisulcatus* (6.30±2.02 mg kg^{-1}) referans sınır aşılmıştır (P<0.05). Cu için *M. monoceros* (23.25±4.34 mg kg^{-1}) türünde referans sınır (P>0.05) aşılmazken, *P. semisulcatus* (49.68±14.71 mg kg^{-1}) referans sınır aşılmıştır (P<0.05). Meta-analiz sonuçlarına rağmen, ağır metallerin insan sağlığı üzerindeki zararlı etkileri yalnızca kontamine kabukluların uzun süreli tüketimi gerçekleştiğinde ortaya çıktığı ve bununla birlikte iki karides türünün ağır metal içeriklerinin referans noktalarını aşıp aşmadığı konusunda nihai olarak karar vermek için çok daha iyi organize edilmiş çalışmalara (daha fazla örnek, uygun örnekleme stratejisi vb.) ihtiyaç olduğu da dikkate alınmalıdır.

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INTRODUCTION

Pollution from metals is a vital problem affecting estuaries and coastal areas (Rushinadha et al., 2016). Among pollutants, metals are particularly important because of their potential toxic effects and their ability to bioaccumulate in aquatic environments (Censi et al., 2006).

Heavy metals contamination in shrimp has become a major problem worldwide not only because of the threat to shrimp but also because of the non-carcinogenic health risks associated with shrimp consumption. For example, kidney failure and liver damage may occur due to the presence of lead in food (Lee et al., 2011). Prolonged exposure to lead cause coma, mental rejuvenation and even death (Al-Busaid et al., 2011). Cadmium damages the kidneys and causes chronic toxicity symptoms such as impaired kidney function, infertility, hypertension, tumors, and liver dysfunction (Rahman et al., 2010). Also, Chromium can attack proteins and membrane lipids, thus disrupting cellular integrity and functions (Mattia et al., 2004; Brien et al., 2003). Therefore, the global attention is increasing to heavy metal contamination in shrimp.

İskenderun Bay is located in the eastern part of the Northeastern Mediterranean Sea and it is characterized having dense industrial establishments (iron steel factory, petrochemical industry, fertilizer industry, etc.), fishing, transportation, and urbanization. Due to its in and outer currents systems, pollutants resulting from above activities are spreading into the Bay and they lead it having a potential risk of pollution. (Can et al., 2019).

Trawling fishery for crustacean in Iskenderun Bay is highly important due to the amount and the economic value of its landings and their fishery, particularly for penaeid shrimp, has been carried out in this region using a specially designed bottom trawl called shrimp trawl (Can et al., 2004). Due to its importance, many studies have been conducted on heavy metal accumulation in shrimp from İskenderun Bay. Yılmaz et al. (2017) reported a review consisting of 86 articles and 4 theses on all heavy metal studies conducted on aquatic organisms in Iskenderun Bay. However, in this review, they only tabulated previous published studies without any critical evaluation. After then, Can et al. (2019) conducted a meta-analysis with a geo-statistical approach on THQ (Target Hazard Quotients) values of Cu, Zn and Fe accumulation in some fish species in Iskenderun Bay. They concluded that fish caught from İskenderun Bay could be consumed safely in terms of metals and also, they found there was spatial structure with consistently high THQ values along the İskenderun Bay.

Meta-analysis is a technique used in some cases such as quantitatively combining, synthesizing, and summarizing data and results from different studies. (i) When sources of heterogeneity are to be examined, (ii) When the relationship between environmental exposures and health effects is not clear, (iii) When refinement of the estimate of an effect is important, (iv) When there are questions about the generalizability of results, (v) When it is clear that there is a hazard exists, but no indication of its magnitude, and (vi) When information is needed beyond that provided by individual or narrative studies. Different studies even on same shrimp species and same heavy metals from same locations may be inconsistent with each other. Because of their important on a food safety risk, meta-analysis is required to evaluate the true risk level for these aquatic organisms. Hence, a meta-analysis that based on the previous publications from İskenderun Bay was conducted for the some heavy metal contents (Cadmium, Zinc, Lead, and Copper) of the commercially important two shrimp species, *Penaeus semisulcatus* (de-Hann, 1844) and *Metapenaeus monoceros* (Fabricus, 1798).

MATERIALS and METHODS

Study area

Iskenderun Bay covers an area of approximately 2275 km^2, 65 km long and approximately 35 km wide in the northeastern corner of the Mediterranean. The bay is known for its intense port activities, filling facilities, industrial facilities and establishments, especially the iron and steel industry, as well as fishing activities.

Shrimp species

Penaeus semisulcatus (de Haan, 1844) is an exotic Indo-West Pacific species especially catching in the Bay of Iskenderun and is thought to have reached the Eastern Mediterranean coast via the Suez Canal and the Red Sea. As in many parts of the world, it has a great economic value in this region (Yılmaz et al., 2009).

*Metapenaeus monoceros (*Fabricius) is an Indo-Pacific species that is widely caught in Iskenderun Bay and is also distributed along the Eastern Mediterranean coasts. This species is originally a lessepsian that had migrated from the Red Sea to the Mediterranean Sea over the Suez Canal.

Document indexing

Most of the existing literature on heavy metal accumulation for shrimps reported from Iskenderun Bay was taken from Yılmaz et al. (2017) that they reviewed and tabulated for 86 articles and 4 theses from Iskenderun Bay. To get more update literatures, although they were few, the searching was acquired using some key words as "İskenderun Bay, heavy metal, shrimp" from Google. The studies considered in this meta-analysis met the following criteria: (a) Zn, Pb, Cd and Cu accumulation in the two shrimp species, *P. semisulcatus*, *M. monocerus*, and (b) studies reported mean accumulation values (considered as ES-effect size), sample size (n) and any of dispersion and variability measures (standard deviation-Sd, standart error-SE, and Range).

Expression of the results on dry weight base

To calculate some statistics and to make more, some measurements reported were converted or transformed as follows: (i) In these publications some results are given in wet weight basis (WWB) and some in dry weight basis (DWB). We preferred the expression of the results on DWB from shrimp muscle due to giving less bias. For this reason, the results given in WWB were converted to DWB multiplying by factor (Yılmaz, 2010). This conversion was made on the basis of by assuming 80% moisture content of shrimp. (ii) We used standard deviation-SD as a measure of variability. Therefore, the results given in the previous study as standard error-SE and range (max-min) were converted to SD using $SD = SE*(n)^{0.5}$ and SD = (Range) / 4, respectively.

Data Analysis

The ESCI (Exploratory Software for Confidence Intervals) was used for Meta-analysis (2011). One-tail tests were used to detect whether significant differences between mean heavy metal concentrations and maximum acceptable levels (in mg kg^{-1}) for both shrimp species by metals. (Null hypothesis: mean concentration $\mu_0 \leq$ referenced level, with 5% significance level). Referenced levels (maximum acceptable levels in mg kg^{-1}) of heavy metals for shrimp species were chosen according to the Turkish Ministry of Agriculture and Forestry (2002) as follows: Cadmium-Cd: 1 mg kg^{-1}, Pb: 2 mg kg^{-1}, Cu: 20 mg kg^{-1}, and Zn: 50 mg kg^{-1}.

RESULTS and DISCUSSION

Heavy metal accumulation in aquatic organisms has been a serious problem due to environmental pollution caused by anthropogenic activities (Yılmaz et al., 2017). Therefore, there is an increasing interest around the world in "food safety" and in keeping food quality at acceptable levels for human consumptions.

Crustaceans are generally considered as key species at the bottom of the food chain. They are benthic organisms that live on the bottom of oceans or seas. They are omnivores that consume foraminifera, polychaeta, crustaceans, algae, phytoplankton and other tiny, drifting aquatic organisms and detritus. They are highly exposed to aquatic pollutants and are also important food sources for human consumption (Mazlum et al., 2016). Heavy metals taken up by aquatic organisms can occur in multiple ways. These can be directly from the body surface or respiratory organs, or through food or a combination of these. Although the most important input of heavy metal intake is through dissolved metal in water and food (Ali et al., 2019) and eventually accumulates in target organs, it is still unclear which the most important factor is. Many studies have that revealed the effect of metals on human health. Since the edible part of shrimps is the part consumed by humans, it is studied more than other organs. In studies conducted in Iskenderun Bay, when the heavy metal values recommended by the Food and Agriculture Organization/World Health Organization (FAO/WHO) and the European Union (EU) (Nabavi et al., 2011) were compared for shrimps, it was observed that some heavy metal levels detected in some tissues were higher. The Table 1 below shows the standard values of metals for crustaceans.

Table 1. Acceptable heavy metal concentration in fisheries products set by the Ministry of Agriculture and Forestry (Anonymous, 2002).

Çizelge 1. Tarım Orman Bakanlığı tarafından belirlenen su ürünlerinde kabul edilebilir ağır metal konsantrasyonu (Anonim, 2002).

Metals	Max. Level in Crustaceans (mg kg^{-1})
Cd	1.00
Pb	2.00
Cu	20.00
Zn	50.00

İskenderun Bay is an important ecosystem in terms of fish diversity. This ecosystem attracts attention with studies investigating the toxic mineral effects on aquatic organisms, especially in recent years, depending on the development of technology and industry (Bosch et al., 2016). Due to the increasing technology, the Bay has recently attracted attention with its intense port activities, filling facilities, thermal power plants, industrial facilities and businesses. Iskenderun Bay as a gateway to the Middle East, especially in the northern part of Iskenderun, the ports of various sizes and İSDEMİR (İskenderun Demir Çelik A.Ş.) have become important both in transportation and in the iron and steel sector. The Bay is also crucial for local fisherman for their fishing activities, and also for economic aspect having free zone and harbor. Therefore, the accumulation of heavy metals and their levels in fishery product are considered to be critical for both environmental and food safety aspect.

Among the most hazardous toxic metals, including Cd, Pb, Hg and arsenic are widely distributed in aquatic environment. However, arsenic in seafood is the form of organic arsenic and know to be no toxic effect on human health. Certain elements may become toxic when the limit exceed.

Cadmium, one of the most toxic heavy metals, has extremely harmful effects for aquatic organisms even at low concentrations. It has been shown in many studies that cadmium accumulates in living creatures in environmentally polluted seas and creates toxic effects at different levels. Cadmium is considered a toxic metal with teratogenic and carcinogenic effects. Cadmium is found in the environment in the form of salts that differ in solubility. Currently, it is reported that the amount of cadmium released into the environment as a result of industrial activities is 10 times higher than that of natural origin. Cadmium found in water and sediments concentrates especially in plankton, vegetative macrophytes, shellfish and mollusks. Molluscs and crustaceans can concentrate cadmium 300-10,000 times (Ray et al., 1980). Cadmium has been defined as a wide spread source in agriculture and industry (Sireli et al., 2006). Fertilizers are important sources of Cd-based agricultural chemicals commonly used in intensive agriculture (Alloway, 1990). The presence of significant cadmium concentrations in the exoskeleton of some decapod crustaceans may be attributed to the role of this tissue in the excretion of these metals (Keenan and Alikhan, 1991). It has been determined that inhalation of cadmium metal causes lung diseases and high blood pressure, and intake with water and food causes many damages such as liver, kidney, brain, nerve diseases, sensitivity in bones and iron deficiency, and many of them can be fatal (Barone et al., 2018; Korkmaz et al., 2017).

Meta-analysis results for cadmium accumulation on *M. monoceros* (I-square = 0.000%) and *P. semiculcatus* (I-square = 99.32%) were not consistent with each other (Table 2-3, Figure 1).

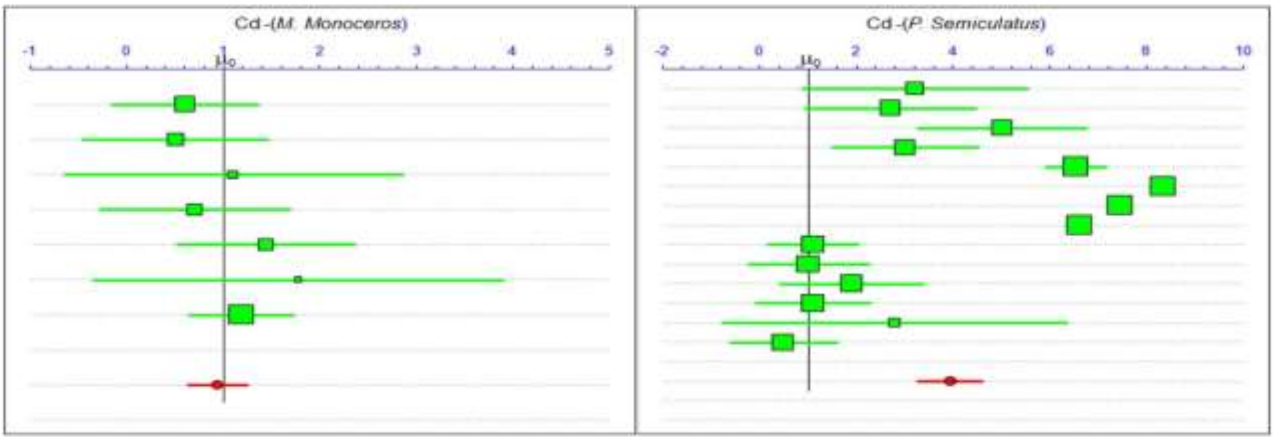

Figure 1. The squares on the horizontal bars show the mean and their confidence limit limits of Cd accumulation in M. monoceros and *P. semiculcatus* according to Table 2 and Table 3, respectively. The circles at the bottom are the result of the meta-analysis. The μ_0 point on the horizontal exes above indicates that the Zero hypothesis was tested against the reference value at the 5% significance level (Ho: $\mu_0 \leq 1$ mg kg^{-1} Cd).

Şekil 1. Yatay çubuklar üzerindeki kareler, sırasıyla Tablo 2 ve Tablo 3'e göre M. monoceros ve P. semiculcatus'ta Cd birikiminin ortalama ve bunların güven sınır limitlerini göstermektedir. Alt kısımda bulunan daireler meta-analizin sonucudur. Üstte yatay eksen üzerindeki μ_0 noktası,%5 anlamlılık düzeyinde (Ho: $\mu_0 \leq 1$ mg kg^{-1} Cd) referans değerine karşı sıfır hipotezinin test edildiğini gösterir.

Table 2. Mean and Standard deviation-Sd with their sample size (n) and confidant intervals (95 %) of the studies on Cd accumulation in *M. monoceros* and tested referenced value (μ_0) ≤1 mg kg^{-1} Cd, α = 0.05) with their weighting (%) in meta-analysis.

Çizelge 2. M. monoceros için Cd birikiminin ortalama ve standart sapma, örnek büyüklüğü, güven aralığı, referans değerleri ((μ_0) ≤1 mg kg^{-1} Cd, α = 0.05) ve ağırlık yüzdesi (%).

	P. Semiculcatus			**C. interval (95 %)**		**(μ_0) ≤1 mg kg^{-1}**	
References	**Mean (Cd)**	**sd**	**n**	**Lower L.**	**Upper L.**	**Sig. (α = 0.05)**	**Weighting (%)**
Çoğun et al. 2005	3.20	5.813	26	0.852	5.548	ns	4.664
Çoğun et al. 2005	2.70	4.436	26	0.908	4.492	ns	5.888
Çoğun et al. 2005	5.00	4.385	26	3.229	6.771	(>μ_0)***	5.937
Çoğun et al. 2005	3.00	3.773	26	1.476	4.524	(>μ_0)*	6.550
Aytekin et al. 2019	6.52	0.900	10	5.876	7.164	(>μ_0)***	8.745
Aytekin et al. 2019	8.33	0.130	10	8.237	8.423	(>μ_0)***	9.273
Aytekin et al. 2019	7.44	0.130	10	7.347	7.533	(>μ_0)***	9.273
Aytekin et al. 2019	6.59	0.100	10	6.518	6.662	(>μ_0)***	9.278
Kargın et al. 2001	1.10	1.328	10	0.150	2.050	ns	8.184
Kargın et al. 2001	1.00	1.771	10	-0.267	2.267	ns	7.493
Kargın et al. 2001	1.90	2.087	10	0.407	3.393	ns	6.970
Kargın et al. 2001	1.10	1.676	10	-0.099	2.299	ns	7.647
Kaymacı, 2011	2.78	18.810	108	-0.803	6.373	ns	2.655
Kaymacı, 2011	0.48	5.924	108	-0.650	1.610	ns	7.442
Meta-Analysis	3.93	0.122	400	3.253	4.621	(>μ_0)***	

Table 3. Cd content (mean±standard deviation Sd) of *P. semiculcatus* with their sample size (n) and confidant intervals (95 %) of the studies on Cd accumulation in tested referenced value (μ_0) ≤1 mg kg^{-1} Cd, α = 0.05) with their weighting (%) in meta-analysis.

Çizelge 3. P. semiculcatus için Cd birikiminin ortalama ve standart sapma, örnek büyüklüğü, güven aralığı, referans değerleri ((μ_0) ≤1 mg kg^{-1} Cd, α = 0.05) ve ağırlık yüzdesi (%).

	M. Monoceros			**C. interval (95 %)**		**(μ_0)≤1 mg kg^{-1}**	
References	**Mean (Cd)**	**Sd**	**n**	**Lower L.**	**Upper L.**	**Sig. (α = 0.05)**	**Weighting (%)**
Kargın et al. 2001	0.60	1.075	10	-0.169	1.369	ns	22.172
Kargın et al. 2001	0.50	1.360	10	-0.473	1.473	ns	13.862
Kargın et al. 2001	1.10	2.467	10	-0.664	2.864	ns	4.213
Kargın et al. 2001	0.70	1.391	10	-0.295	1.695	ns	13.239
Kaymacı, 2011	1.44	4.839	106	0.508	2.372	ns	11.603
Kaymacı, 2011	1.77	11.068	106	-0.362	3.902	ns	2.218
Kaymacı, 2011	1.18	2.883	106	0.625	1.735	ns	32.693
Meta-Analysis	0.93	0.026	358	0.620	1.247	ns	22.172

Considering the *M. monoceros,* none of the studies including resulted meta-analysis were not statistically important (μ_0≤1 mg kg^{-1}) (Table 2 and Figure 1). However, for *P. semiculcatus*, 6 out of 14 studies were statistically importance with changing significance degrees (Table 3 and Figure 1), and the resulted meta-analysis showed that it was also a significantly important at a very high level (μ_0> 1 mg kg^{-1} Cd ***).

These values were found above the limit (1.0 ppm) and (0.2 ppm) allowed for consumption in shrimp by WHO (2005) and FAO (2007), respectively. Moreover, similar studies in *P. martia, P. edwardsii and A. antennatus* (Olgunoglu et al., 2015) and *P. semisulcatus* (Heidarieh et al., 2013) did not exceed the permissible limits. Therefore, these shrimp in this area of study did not pose any threat to humans upon their consumption. However, Cd was discovered in other shrimp species reported by different authors across the world.

Kaya and Türkoğlu (2017) stated that Cd levels are 0.008-0.026 mg kg. They found that all cadmium levels were below the maximum allowable cadmium levels by Turkish standards. 0.1 mg kg^{-1} (Anonymous, 2008) and the allowable cadmium level of the EU commission is 0.05 mg kg^{-1} (European Union, EU, 2001; European Union, (EU), 2008). Gökoğlu et al. (2008) Heavy metal results for Antalya Bay reported that the cadmium concentration in the shrimp muscle (*P. semisulcatus*) was 2.36 mg kg^{-1} and the cadmium concentration in the P. longirostris muscle was 0.23

mg kg^{-1} (Gokoglu et al., 2008). Pourang and Dennis (2005) reported that cadmium concentrations in *P. semisulcatus* muscle were between 0.001 and 1,210 mg kg^{-1}, and Cd levels in the *Penaeus merguiensis* muscle were between 0.01 and 0.18 mg kg^{-1}. Pourang et al. (2005) in another study of *P. semisulcatus* in the muscle and exoskeleton, mean Cd concentrations in muscle were 0.103-0.790 µg g^{-1}, and 0.557 and 1.016 µg g^{-1} in the exoskeleton, respectively. In another study conducted off the coast of Tanzania, the lowest and highest levels of cadmium in the muscle of the grant tiger shrimp were found to be 0.01-0.03 mg kg^{-1} (Rumisha et al., 2016). Olmedo et al. (2013) reported that the mean and range of cadmium concentrations in edible parts of Sole fish were 0.001 (0.000-0.067) mg kg^{-1}, and the mean concentration and range in shrimp (*P. longirostris*) was 0.029 (0.014-0.063). Sivaperumal et al. (2007) reported that cadmium levels in the muscles of different shrimp species were n.d - 0.07 mg kg^{-1} by wet weight (not detected). Therefore, in the present some differences obtained as a result of meta-analysis may actually be caused by a sample size, duration of study, poor evaluation of the results, and lack of analysis results. This situation emerges as a situation that should be examined well in terms of human health. We believe that it will be better to follow the annual monitoring data and technological developments in order to reach the right conclusion.

High heterogeneities among the studies on Zn accumulation in *P. semiculcatus* (I-square = 99.088 %) and *M. monoceros* (I-square = 90.387 %) were observed. Despite of that high heterogeneity, meta-analysis showed that zinc accumulation on *P. semiculcatus* was not significant ($\mu_0 \leq 50$ mg kg^{-1}). Half of the studies on *M. monoceros* were significant ($\mu_0 > 50$ mg kg^{-1} Zn***), and meta-analysis yielded an moderate significant result on zinc accumulation in that species ($\mu_0 > 50$ mg kg^{-1} Zn **) (Table 4-Table 5 and Figure 2).

The organic and inorganic compounds of lead are used as paint, accumulator, city water supply, ceramic, rubber production, printing, pesticide, various children's toys and gasoline additives. Lead is mixed with natural water from limestone and lead bed and accumulates in the bodies of fish and creatures that join the food chain of fish. Lead salts, which are poorly soluble in water, dissolve in the stomach with the effect of hydrochloric acid and pass into the blood. However, since the excretion of absorbed lead is very slow, there is a continuous accumulation. Lead is an element with multiple effects. The absorbed lead passes into the blood and is distributed to various organs (aorta, cartilage, kidney, pancreas, lung, spleen and muscles) through the blood circulation. The hematopoietic system, central nervous system, peripheral nerves and kidneys suffer the most from this distribution. Although most of lead is stored in bones, it can also pass into the brain, fetus in the womb and breast milk. The low rate of lead in infants and children increases with age and lead exposure. When it exceeds 40 mg l^{-1} in the blood, blood pressure increasing effect occurs. On the other hand, it is reported that chronic lead intake limits sperm count and morphology. According to the classification of the World Health Organization (WHO, 2005), it has been reported that lead is in the class 2 carcinogenic group (Neda et al., 2017).

Ecologically, lead tends to collapse as a solid and does not form a complex except in special circumstances. Generally, lead released to nature forms hardly soluble compounds [Pb_3 (PO_4] 2, Pb_4O (PO_4) 2, Pb_5 (PO_4) 3OH, ($PbCO_3$) and (PbS) Therefore lead intake from plants in the food chain is out of question. It has been reported that single-celled creatures and fish can tolerate water containing 0.04–0.198 mg l^{-1} inorganic lead, but show acute poisoning when ingestion of lead through food in lower amounts (Neda et al., 2017).

Table 4. Mean and Standard deviation-Sd with their sample size (n) and confidant intervals (95 %) of the studies on Zn accumulation in *M. monoceros* and tested referenced value (μ_0) ≤50 mg kg^{-1} Zn, α = 0.05) with their weighting (%) in meta-analysis.

Çizelge 4. M. monoceros için Zn birikiminin ortalama ve standart sapma, örnek boyutu, güven aralığı, referans değerleri ((μ_0) ≤50 mg kg^{-1} Zn, α = 0.05) ve ağırlık yüzdesi (%).

	M. Monoceros			**C. interval (95 %)**		**(μ_0) ≤50 mg kg^{-1}**	
References	**Mean (Zn)**	**Sd**	**n**	**Lower L.**	**Upper L.**	**Sig. (α = 0.05)**	**Weighting (%)**
Kargın et al. 2001	61.8	3.637	10	59.199	64.401	(>μ_0)***	20.192
Kargın et al. 2001	60.4	4.237	10	57.369	63.431	(>μ_0)***	19.930
Kargın et al. 2001	71.3	6.767	10	66.459	76.141	(>μ_0)***	18.513
Kargın et al. 2001	63.2	3.953	10	60.372	66.028	(>μ_0)***	20.058
Kaymacı, 2011	46.945	87.307	106	30.131	63.759	ns	6.809
Kaymacı, 2011	52.65	193.403	106	15.403	89.897	ns	1.872
Kaymacı, 2011	32.62	49.213	106	23.142	42.098	ns	12.625
Meta-Analysis	**58.69379**	**7.252**	**358**	**53.416**	**63.972**	**(>μ_0)****	

Table 5. Mean and Standard deviation-Sd with their sample size (n) and confidant intervals (95 %) of the studies on Zn accumulation in *P. semiculcatus* and tested referenced value (μ_0) ≤50 mg kg^{-1} Zn, α = 0.05) with their weighting (%) in meta-analysis.

Çizelge 5. *P. semiculcatus* için Zn birikiminin ortalama ve standart sapma, örnek büyüklüğü, güven aralığı, referans değerleri ((μ_0) ≤50 mg kg^{-1} Zn, α = 0.05) ve ağırlık yüzdesi (%).

	P. Semiculcatus			**C. interval (95 %)**		**(μ_0) ≤50 mg kg^{-1}**	
References	**Mean (Zn)**	**sd**	**n**	**Lower L.**	**Upper L.**	**Sig. (α = 0.05)**	**Weighting (%)**
Çoğun et al. 2005	50.40	11.422	26	45.787	55.013	ns	5.557
Çoğun et al. 2005	51.50	9.127	26	47.813	55.187	ns	5.627
Çoğun et al. 2005	63.10	11.524	26	58.445	67.755	(>μ_0)***	5.553
Çoğun et al. 2005	50.10	9.892	26	46.104	54.096	ns	5.605
Aytekin et al. 2019	24.00	9.000	15	19.016	28.984	ns	5.542
Aytekin et al. 2019	21.50	11.000	15	15.408	27.592	ns	5.442
Aytekin et al. 2019	30.50	8.000	15	26.070	34.930	ns	5.586
Aytelkin et al. 2019	51.50	14.500	15	43.470	59.530	ns	5.232
Kargın et al. 2001	27.75	5.360	5	21.095	34.405	ns	5.529
Kargın et al. 2001	43.56	0.780	10	43.002	44.118	ns	5.753
Kargın et al. 2001	61.42	3.330	10	59.038	63.802	(>μ_0)***	5.711
Kargın et al. 2001	45.12	1.870	10	43.782	46.458	ns	5.742
Kaymacı, 2011	37.43	2.350	10	35.749	39.111	ns	5.733
Kaymacı, 2011	72.60	3.921	10	69.795	75.405	(>μ_0)***	5.693
Meta-Analysis	**50.28**	**8.00**	**465**	**44.723**	**55.851**	**ns**	

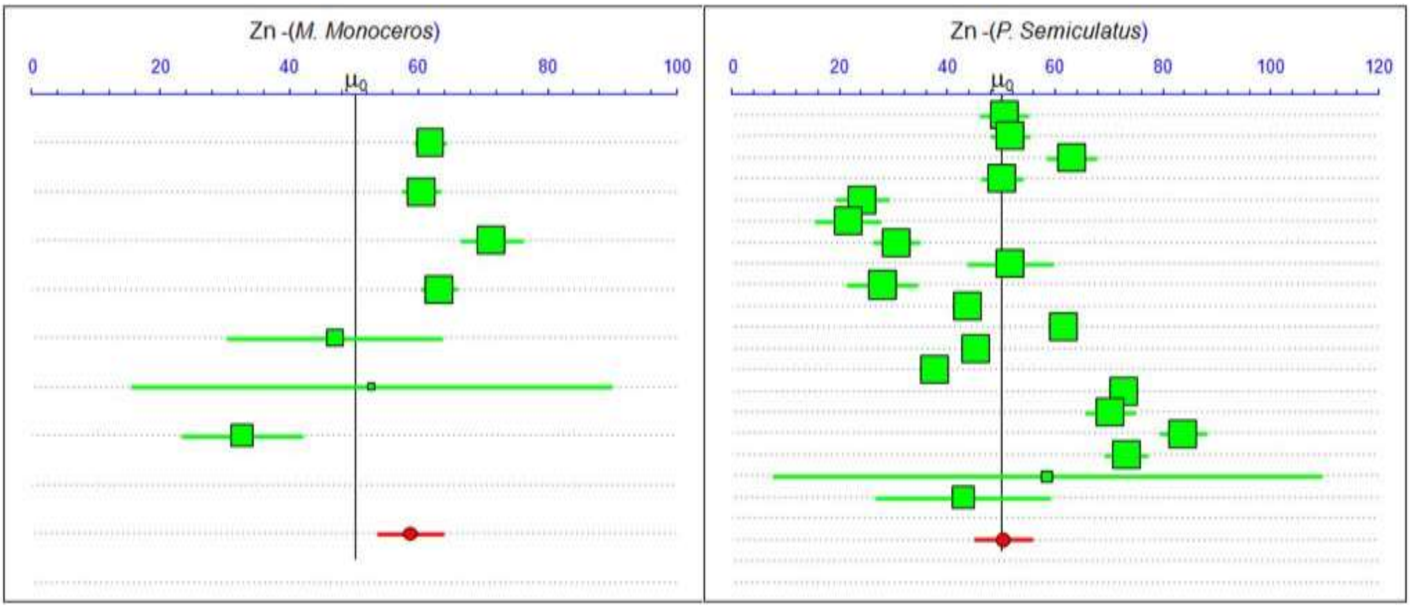

Figure 2. Squares with horizontal bars show mean and their confidant limits for each of studies on Zn accumulation in *M. monoceros and P. semiculcatus* in accordance with Table 4 and Table 5, respectively. Circles locate on the bottom show resulted from meta-analyses. μ_0 point on the top horizontal exes shows testing of Null hypothesis against the referenced value at 5% significance level (Ho: μ_0 ≤50 mg kg^{-1} Zn).

Şekil 2. Yatay çubuklar üzerindeki kareler, sırasıyla Tablo 4 ve Tablo 5'ye göre *M. monoceros* ve *P. semiculcatus*'ta *Zn birikiminin ortalama ve bunların güven sınır limitlerini göstermektedir. Alt kısımda bulunan daireler meta-analizin sonucudur. Üstte yatay eksen üzerindeki μ_0 noktası,% 5 anlamlılık düzeyinde (Ho: μ_0 ≤50 mg kg^{-1} Zn) referans değerine karşı sıfır hipotezinin test edildiğini gösterir.*

High concentrations of Pb in the marine environment have been reported to occur from various sources such as emissions from wastewater and industries, emissions from leaded gasoline powered vehicles, smoke and dust emissions from coal and gas-fired power plants, roofers and paints and rust inhibitors. Studies have demonstrated that lead contamination of foodstuffs is caused by soldered seams of cans and soldered lids of condensed milk cans, metal lids of wine bottles and lead pipes used in drinking water systems (Badr et al., 2009; Frignani et al., 1997). Yılmaz et al. (2007) reported that seasonal lead concentrations in the muscles of shrimp (*P. semisulcatus*) caught from Iskenderun Bay were between 0.2 and 0.6 µg g^{-1}. Turan et al. (2009) investigated the toxic metal concentrations in various fish species and reported that the average lead level was 0.426 µg g^{-1} in *M. merlangus* muscle captured from the Mediterranean and 0.426 µg g-1 in the *M. merlangus* muscle captured. They also reported that it was 0.502 µg g^{-1} in the Black Sea. Sivaperumal et al. (2007) reported that the lead levels in the muscles of different shrimp species were 0.61 mg kg^{-1} by wet weight.

In the present study, meta-analyses of lead accumulation in *P. semiculcatus* (a high heterogeneity among studies with I-square = 99.982%) and *M. monoceros* (I-square = 94.281%) yielded a very strong significant difference (μ_0>2 mg kg^{-1} Pb***) (Table 6-Table 7 and Figure 3). These values were found to be above the acceptable limit (2.0 ppm) stipulated by WHO (2005) and (2 mg kg^{-1}) FAO (2007) for consumption in shrimp. In addition, the Pb concentration in the studied shrimp was above the risk international standards (median 2.0 µg g^{-1} vs. 0.5-10.0 wet weight) given by the United Nations Food and Agriculture Organization Reference Dose (risk-based); United States Environmental Protection Agency (USEPA, 2015). This is confirmed by the study of Al Farraj et al (2013), who stated that this type of domestic transport causes a significant increase in the level of pollution. Lead concentrations in the edible parts of the body in invertebrate samples obtained different stations in the bay have been studied by many researchers. Lead levels of the *Penaeus semisulcatus* muscle have been reported by many researchers and the values obtained can be listed as follows; Kargın et al. (2001) (5.7±0.58-8.5±0.96 dw), Çoğun et al. (2005) (15.4±1.44-28.6±2.15 dw), Yılmaz and Yılmaz (2007) (0.2±0.1- 0.6±0.2 ww for female fish) and Kaymacı (2011) (n.d.-1.035±0.516 ww). *Sepia officinalis*, *Monodon taturbinata* and *Spondylus spinosis*, Duysak et al. (2013) (1.74±0.36 ww for female fish), Duysak and Ersoy (2014) (1.44±0.32-90.8±2.61 dw) and Türkmen et al. (2006) (4.63-352 dw).

Mean Pb levels in *Litopenaeus vannamei* and *Panulirus homarus* were higher than the FAO/WHO guideline limit, but lower than the FAO/WHO guideline limit in *Metapenaeus affinis* and *Fenneropenaeus indicus* (FAO/WHO, 2004, 2006).

Average As levels in *Panulirus homarus* and *Penaeus semisulcatus* were found to be higher than the FAO/WHO guideline limit (FAO/WHO, 2004, 2006). The average Pb in *Aristaeo morphafoliacea* living in the Mediterranean and *Penaeus kerathurus* (Izmir Bay) was 0.43±0.01 (Olgunoğlu et al., 2015) and 0.37 - 0.86 mg kg^{-1} dw. (Dokmeci et al., 2014); This was similar to our study, but Pb (0.51-2.12 mg kg^{-1} dw) levels were found to be higher in *Parapenaeus longirostris* (Türkmen, 2012) living in Tekirdağ, on the Marmara Sea Coast, compared to the levels of our study. However, depending on the technological developments, some values in the water change depending on the time. For example, the development of heavy industry or the increase of factories.

Copper is an essential element in human metabolism, and it is estimated that adults need 2.0 mg of copper per day. In human blood, there is 0.8 mg Cu^{++} ions per liter. It plays an important role in the release of tissue iron for erythrocyte formation, bone, central nervous system and connective tissue development. In case of excessive intake, inflammation of the mucosa, vascular diseases, liver and kidney diseases and central nervous system irritations with depression can be seen (Jenkins, 1989). Although copper is a widely used metal, when it is not removed from the body, it causes Wilson's disease, which is characterized by the accumulation of toxic levels of

Table 6. Mean and Standard deviation-Sd with their sample size (n) and confidant intervals (95%) of the studies on Pb accumulation in *M. monoceros* and tested referenced value (μ_0) ≤2 mg kg^{-1} Pb, α = 0.05) with their weighting (%) in meta-analysis

Çizelge 6. *M. monoceros* için Pb birikiminin ortalama ve standart sapma, örnek büyüklüğü, güven aralığı, referans değerleri ((μ_0) ≤2 mg kg^{-1} Pb α = 0.05) ve ağırlık yüzdesi (%).

	M. Monoceros			**C. interval (95 %)**		**(μ_0) ≤2 mg kg^{-1}**	
References	**Mean (Pb)**	**Sd**	**n**	**Lower L.**	**Upper L.**	**Sig. (α = 0.05)**	**weighting (%)**
Kargın et al. 2001	11.300	2.720	10	9.355	13.245	(>μ_0)***	15.542
Kargın et al. 2001	10.300	2.973	10	8.174	12.426	(>μ_0)***	15.457
Kargın et al. 2001	21.600	3.542	10	19.066	24.134	(>μ_0)***	15.244
Kargın et al. 2001	12.100	2.909	10	10.019	14.181	(>μ_0)***	15.479
Kaymacı, 2011	3.785	26.099	106	-1.241	8.811	ns	12.780
Kaymacı, 2011	4.005	26.820	106	-1.160	9.170	ns	12.638
Kaymacı, 2011	4.970	25.688	106	0.023	9.917	ns	12.861
Meta-Analysis	**10.143**	**4.090**	**358**	**6.179**	**14.107**	**(>μ_0)*** **	

Table 7. Mean and Standard deviation-Sd with their sample size (n) and confidant intervals (95 %) of the studies on Pb accumulation in *P. semiculcatus* and tested referenced value (μ_0) ≤2 mg kg^{-1} Pb, α = 0.05) with their weighting (%) in meta-analysis.

Çizelge 7. *P. semiculcatus* için Pb birikiminin ortalama ve standart sapma, örnek boyutu, güven aralığı, referans değerleri ((μ0) ≤2 mg kg^{-1} Pb, α = 0.05) ve ağırlık yüzdesi (%).

	P. Semiculcatus			C. interval (95 %)		(μ_0) ≤2 mg kg^{-1}	
References	Mean (Pb)	Sd	n	Lower L	Upper L	Sig. (α = 0.05)	Weighting (%)
Çoğun et al. 2006	15.400	7.343	26	12.434	18.366	(>μ_0)***	5.550
Çoğun et al. 2006	16.200	4.946	26	14.202	18.198	(>μ_0)***	5.561
Çoğun et al. 2006	28.600	10.963	26	24.172	33.028	(>μ_0)***	5.524
Çoğun et al. 2006	16.500	8.974	26	12.875	20.125	(>μ_0)***	5.539
Aytekin et al. 2019	1.000	0.500	15	0.723	1.277	ns	5.571
Aytekin et al. 2019	3.000	1.000	15	2.446	3.554	(>μ_0)**	5.570
Aytekin et al. 2019	2.000	1.000	15	1.446	2.554	ns	5.570
Aytekin et al. 2019	1.000	0.500	15	0.723	1.277	ns	5.571
Kargın et al. 2001	4.015	23.279	108	-0.426	8.456	ns	5.520
Kargın et al. 2001	5.175	26.812	108	0.060	10.290	ns	5.504
Kargın et al. 2001	25.030	1.850	10	23.707	26.353	(>μ_0)***	5.567
Kargın et al. 2001	62.750	0.580	10	62.335	63.165	(>μ_0)***	5.570
Kaymacı, 2011	49.780	4.400	10	46.632	52.928	(>μ_0)***	5.551
Kaymacı, 2011	22.180	0.620	10	21.736	22.624	(>μ_0)***	5.570
Meta-Analysis	**6.300**	**2.024**	**10**	**4.852**	**7.748**	**(>μ_0)*** **	

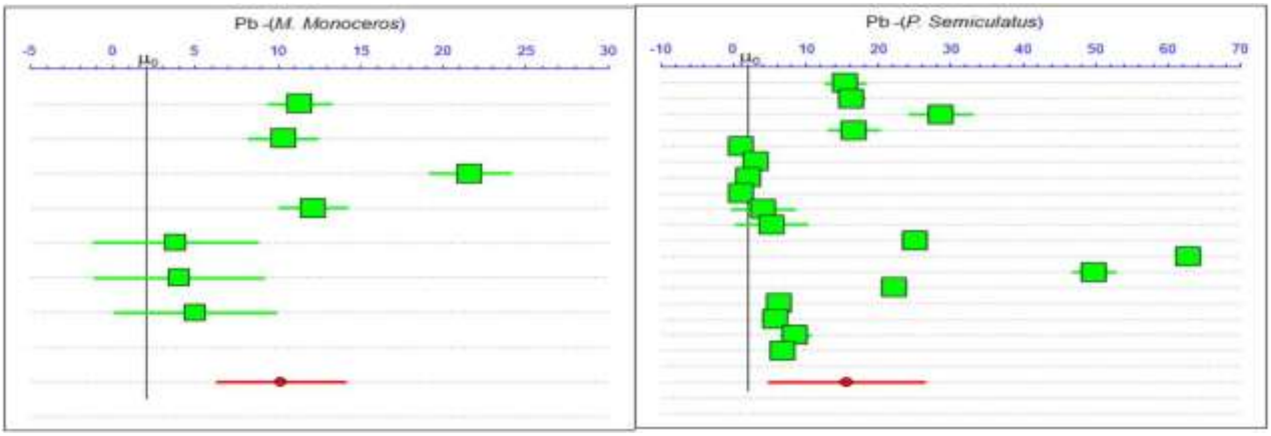

Figure 3. Squares with horizontal bars show mean and their confidant limits for each of studies on Pb accumulation in *M. monoceros and P. semiculcatus* in accordance with Table 6 and Table 7, respectively. Circles locate on the bottom show resulted from meta-analyses. μ_0 point on the top horizontal exes shows testing of Null hypothesis against the referenced value at 5% significance level (Ho: μ_0 ≤2 mg kg^{-1} Pb).

Şekil 3. Yatay çubuklar üzerindeki kareler, sırasıyla Tablo 6 ve Tablo 7'ye göre *M. monoceros* ve *P. semiculcatus*'ta Pb birikiminin ortalama ve bunların güven sınır limitlerini göstermektedir. Alt kısımda bulunan daireler meta-analizin sonucudur. Üstte yatay eksen üzerindeki μ_0 noktası, %5 anlamlılık düzeyinde (Ho: μ_0 ≤2 mg kg^{-1} Pb) referans değerine karşı sıfır hipotezinin test edildiğini gösterir.

copper in many organs, tissues, especially liver, brain and eyes. The initial steps of copper absorption and transport to the liver are normal, causing the absorbed copper not to enter the circulation in the form of ceruloplasmin, and its excretion into bile is markedly reduced. Copper in excess of certain concentrations is toxic to crustaceans because it affects several important physiological and biological functions at the molecular and cellular level. Copper is known to cause toxic liver damage with its rapid accumulation in the liver. Copper damages cellular microanatomy and the ultrastructure of organelles, including mitochondria, endoplasmic reticulum, and the nuclear membrane (Frías-Espericueta et al., 2003; Yang et al., 2008). Generally, in a patient who reaches the age of five, copper unrelated to ceruloplasmin spreads into the circulation and undergoes hemolysis and causes pathological changes in areas such as the brain, cornea, kidneys, bone joints, and parathyroids. Meanwhile, the urine excretion of copper increases significantly. Wilson's disease manifests with mild or severe changes in the liver. These changes are mild or moderate fatty changes, acute hepatitis, chronic hepatitis and cirrhosis, respectively (Yang et al., 2008).

Copper (Cu) has been reported to be one of the heavy metals most frequently occurring in industrial wastewater (Pamukoğlu and Kargı, 2007). Copper enters aquatic ecosystems via wastes in ionic form or complexes organic and inorganic ligands and they can accumulate in tissues. Copper plays a biologically important role in the growth and life of most aquatic organisms. However, it can become toxic to marine organisms if it exceeds a certain threshold (Kennish, 1992). Copper's entry into the marine environment; It comes from different sources, including mining, smelting, domestic and industrial activities, and algaecides and antifouling paints on boat hulls (Fabrizio, 2012). Copper is highly toxic in aquatic environments and has effects on fish, invertebrates, and amphibians, and all three groups are equally sensitive to chronic toxicity (USEPA, 2015). Crustaceans such as shrimp, lobster and crab need Cu especially as it acts as oxygen carrier in their blood (Fredrick and Ravichandran, 2012). Everaarts and Nieuwenhuize (1995) found that because many crustaceans use Cu in a blood pigment, Cu concentrations in crustaceans can increase (60 and 140 µg g^{-1}) compared to other groups (polykets and mollusks). In this study, the Cu level was above (µ0 20 mg kg^{-1}). These values were found above the allowable limit for shrimp set by FAO (1992) (20 ppm) and WHO (1998) and (10 ppm). The toxicity of copper at high concentrations is due to its coagulating effect on cellular proteins and interfering with respiratory processes; Copper in low concentrations causes degenerative changes in certain tissues and inhibits the Glutathione balance.

In contrast to a high heterogeneity among the Cu accumulation studies on *M. monoceros* (I-square = 89.245%), meta-analyses showed a non-significance difference against the referenced level ($\mu_0 \leq 20$ mg kg^{-1} Cu). However, meta-analyses of cupper accumulation in *P. semiculcatus* showed both high heterogeneity among studies (I-square = 99.630%) and a very strong significant difference against the referenced level ($\mu_0 \leq 20$ mg kg^{-1} Cu***) (Table 8 and Table 9 and Figure 4).Other studies also showed accumulation of Cu was over standard limit values. Kaya and Türkoğlu (2017) observed that arsenic levels in shrimp were found to be above all the legal limit values. Yilmaz et al. (2018) indicated that domestic wastewater and industrial activities in the region need to be monitor in future perspective. Some differences between the results of the studies conducted in this region are thought to be due to many reasons such as sample size, duration of study, poor evaluation of the results, and lack of analysis results. This situation emerges as a situation that should be examined well in terms of human health. Since these shrimps are used in the human diets. Since the early 2000s, concentrations of heavy metals entering the Iskenderun Gulf have rapidly accumulated due to rapid local population and industrial development. This study indicates potential contamination of shrimp samples with metals in the different locations of Iskenderun bay which may indicate that the Cu effluents contributed to high levels of these metals in aquatic environments.

Zinc, an essential element, is found in human cells, tissues and organs. Although it is abundant as a mineral, it is present in air, soil, water and all foods. Usage areas of zinc; coating processes of iron and other metals, dry cell batteries, alloy manufacturing,

Table 8. Mean and Standard deviation-Sd with their sample size (n) and confidant intervals (95%) of the studies on Cu accumulation in *M. monoceros* and tested referenced value (μ_0) ≤20 mg kg^{-1} Cu, α = 0.05) with their weighting (%) in meta-analysis.

Çizelge 8. *M. monoceros* için Cu birikiminin ortalama ve standart sapma, örnek büyüklüğü, güven aralığı, referans değerleri ((µ0) ≤20 mg kg^{-1} Cu^{+++}, α = 0.05) ve ağırlık yüzdesi (%).

	M. Monoceros			**C. interval (95 %)**		**(μ_0) ≤20 mg kg^{-1}**	
References	**Mean (Cu)**	**Sd**	**n**	**Lower L.**	**Upper L.**	**Sig. (α = 0.05)**	**Weighting (%)**
Kargın et al. 2001	22.100	3.637	10	19.499	24.701	ns	21.189
Kargın et al. 2001	20.600	3.289	10	18.247	22.953	ns	21.441
Kargın et al. 2001	30.700	3.605	10	28.121	33.279	(>μ_0)***	21.213
Kargın et al. 2001	22.500	3.320	10	20.125	24.875	(>μ_0)*	21.419
Kaymacı, 2011	40.155	150.316	106	11.206	69.104	ns	1.871
Kaymacı, 2011	34.610	264.598	106	-16.348	85.568	ns	0.640
Kaymacı, 2011	15.100	41.646	106	7.080	23.120	ns	12.227
Meta-Analysis	23.250	4.348	358	19.164	27.337	ns	

Table 9. Mean and Standard deviation-Sd with their sample size (n) and confidant intervals (95 %) of the studies on Cu accumulation in *P. semiculatus* and tested referenced value (μ_0) ≤20 mg kg^{-1} Cu,α = 0.05) with their weighting (%) in meta-analysis.

Çizelge 9. *P. semiculcatus* için Cu birikiminin ortalama ve standart sapma, örnek büyüklüğü, güven aralığı, referans değerleri ((μ_0) ≤20 mg kg^{-1} Cu, α = 0.05) ve ağırlık yüzdesi (%).

	P. Semiculcatus			C. interval (95 %)		(μ_0) ≤20 mg kg^{-1}	
References	**Mean (Cu)**	**Sd**	**n**	**Lower L.**	**Upper L.**	**Sig. (α = 0.05)**	**Weighting (%)**
Çoğun et al. 2006	27.90	10.912	26	23.493	32.307	(>μ_0)**	5.593
Çoğun et al. 2006	28.80	6.323	26	26.246	31.354	(>μ_0)***	5.658
Çoğun et al. 2006	41.90	13.410	26	36.483	47.317	(>μ_0)***	5.544
Çoğun et al. 2006	30.40	6.527	26	27.764	33.036	(>μ_0)***	5.656
Aytekin et al. 2019	87.50	8.000	15	83.070	91.930	(>μ_0)***	5.600
Aytekin et al. 2019	127	38.000	15	105.956	148.044	(>μ_0)***	4.148
Aytekin et al. 2019	74.5	3.500	15	72.562	76.438	(>μ_0)***	5.674
Aytekin et al. 2019	212	27.500	15	196.771	227.229	(>μ_0)***	4.763
Kargın et al. 2001	34.24	11.990	5	19.352	49.128	ns	5.122
Kargın et al. 2001	28.50	3.850	10	25.746	31.254	(>μ_0)***	5.659
Kargın et al. 2001	34.23	1.180	10	33.386	35.074	(>μ_0)***	5.689
Kargın et al. 2001	26.44	1.430	10	25.417	27.463	(>μ_0)***	5.687
Kaymacı, 2011	19.35	1.290	10	18.427	20.273	ns	5.688
Kaymacı, 2011	31.20	5.439	10	27.309	35.091	(>μ_0)***	5.628
Meta-Analysis	49.689	14.719	421	27.204	32.996	(>μ_0)***	

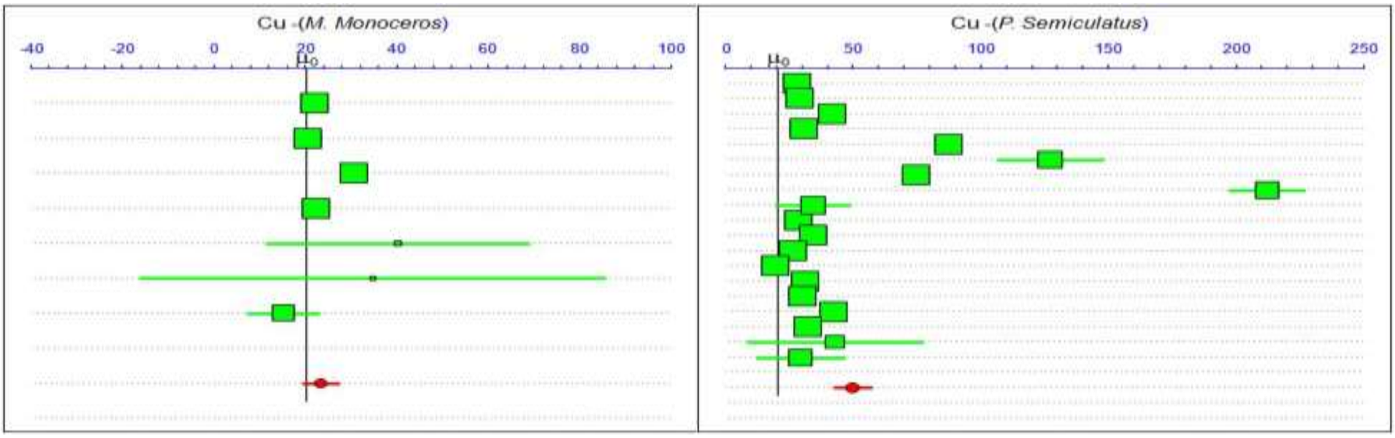

Figure 4. Squares with horizontal bars show mean and their confidant limits for each of studies on Cu accumulation in *M. monoceros and P. semiculcatus* in accordance with Table 8 and Table 9, respectively. Circles locate on the bottom show resulted from meta-analyses. μ_0 point on the top horizontal exes shows testing of Null hypothesis against the referenced value at 5 % significance level (Ho: μ_0 ≤20 mg kg^{-1} Cu).

Şekil 4. Yatay çubuklar üzerindeki kareler, sırasıyla Tablo 8 ve Tablo 9'a göre M. monoceros ve P. semiculcatus'ta Cu birikiminin ortalama ve bunların güven sınır limitlerini göstermektedir. Alt kısımda bulunan daireler meta-analizin sonucudur. Üstte yatay eksen üzerindeki μ_0 noktası,% 5 anlamlılık düzeyinde (Ho: μ_0 ≤20 mg kg^{-1} Cu) referans değerine karşı sıfır hipotezinin test edildiğini gösterir.

white paint production, ceramics, rubber industry, fertilizers, and some cosmetic and health fields (ATSDR, 2003). Approximately 90% of the zinc in the soil is used in plant growth. In addition, aquatic organisms also accumulate zinc. Zinc accumulates most in the prostate, kidney, muscle and liver. Insufficient intake of zinc, which causes various damages in living things when taken at high levels, negatively affects more than 200 enzymes (ATSDR, 2003). Zinc is essential for various metabolic processes in the human body, such as development, skin integrity and function, egg maturation, immune power, wound healing and carbohydrate, fat, protein, nucleic acid synthesis or degradation. It acts as a co-enzyme component for more than 70 metalloenzyme functions such as alcohol dehydrogenase, carbonic anhydrase and carboxypeptidase. It must be present in water and feed in small amounts (Roohani et al., 2012). Studies conducted in the aquatic environment revealed that zinc can be harmful not only in high concentrations but also in low concentrations if exposed for a long time. Zinc deficiency negatively affects growth in young people, weakens the immune system, and also prevents the development of babies in pregnant women. Approximately 90% of the zinc in the human body is found in bones and muscles. Problems such as excessive zinc intake in humans, decreased appetite and immune system activity, delayed healing of wounds, and increased cholesterol together with excessive skin sensitivity have been identified (ATSDR, 2003).

Zinc is a naturally abundant element found in agriculture, food waste, pesticide production, and antifouling paints as a common contaminant. Zinc plays an important role as an important trace element in all living systems (Merian, 1991). However, it is a USEPA (United States Environmental Protection Agency) priority pollutant (Keith and Telliard, 1979). High concentration of zinc in water is particularly toxic to many species of algae, crustaceans, and salmon (Leland and Kuwabara, 1985) and has strong effects on macro invertebrates such as molluscs, crustaceans, odonates, and ephemera (Gore and Bryant, 1986).

In the current study high heterogeneity among the studies on Zn accumulation in *P. semiculcatus* (I-square = 99.088 %) and *M. monoceros* (I-square = 90.387 %) were observed. Despite that high heterogeneity, meta-analysis showed that zinc accumulation on *P. semiculcatus* was not statistically important ($\mu0 \leq 50$ mg kg^{-1}). Half of the studies on *M. monoceros* were statistically important ($\mu0 > 50$ mg kg^{-1} Zn***), and meta-analysis yielded a moderate significant result on zinc accumulation in that species ($\mu0 > 50$ mg kg^{-1} Zn **). On the other hand, Sadiq et al. (1982) noted that the entire body Zn of the Persian Gulf was 148 ppm / dry shrimp. This value is significantly higher than the level achieved in the current study. In another study of the green tiger shrimp northwest of the Persian Gulf, Pourang et al. (2005) recorded the highest mean Zn concentration (43.39 ppm / fresh weight) in the hepatopancreas. They found that the Zn levels in the exoskeleton and muscle were 8.56 and 8.98 ppm / wet weight, respectively. However, for *M. monoceros* the Zn concentrations in these studies were above the risk international standards (40-100 with a median wet weight of 50) given by the United Nations Food and Agriculture Organization Reference Dose (risk-based); United States Environmental Protection Agency (USEPA, 2015). Zn levels in this study are below the maximum limits for *P. semiculcatus* (FAO, 1992) and seafood (100 ppm) (WHO, 1998).

Aytekin et al. (2019) stated that metal concentrations are lower in muscles than gills, liver shows higher values. They also indicated that there were significant accumulation of Cd and Pb in edible tissues of *P. semiculcatus*. Other studies also showed accumulation of Cd and Cu was over standard limit values. Kaya and Türkoğlu (2017) observed that arsenic levels in shrimp were found to be above all the legal limit values. Yilmaz et al. (2017) indicated that domestic wastewater and industrial activities in the region need to be monitor in future perspective. Can et al. (2020) indicate that the Target Hazard Quotients (THQ) and Total Target Hazard Quotients (TTHQ) values based on muscle for Cr, Cu, Fe, Mn and Zn were not exceeded 1.00 for some fish species. Some differences between the results of the studies conducted in this region are thought to be due to many reasons such as sample size, duration of study, poor evaluation of the results, and lack of analysis results. This situation emerges as a situation that should be examined well in terms of human health. Since these shrimps are used in the human diets. Since the early 2000s, concentrations of heavy metals entering the Iskenderun Gulf have rapidly accumulated due to rapid local population and industrial development. This study indicates potential contamination of shrimp samples with metals in the different locations of Iskenderun bay which may indicate that the Cd, Pb and Cu effluents contributed to high levels of these metals in aquatic environments. Literature values indicated that almost 43%shellfish contained exceeding limit of Cd in the edible parts of shellfish and may cause potential health risk.

Although high concentrations of all metal ions pose a threat to human health, some metal ions are required at low concentrations in order to maintain metabolic activity in the body. Therefore, the levels of heavy metal ions in food and water consumed by humans are important. In all sampled, Cd, Zn, Pb and Cu levels were determined in the muscle tissue or other part of animal, which is the consumable part of the shrimp and these levels were determined at not acceptable levels for human consumption (Cd: 0.050 mg kg^{-1} according to the Turkish Food Codex, 2011). Cu: 20.0 mg kg^{-1}; Pb: 0.30 mg kg^{-1}; Zn: 50.0 mg kg^{-1}) (Joint FAO/WHO, 2011). According to FAO (1992), these values are 0.5 mg kg^{-1} for Cd and Pb; it is 30.0 mg kg^{-1} for Cu and Zn. The daily tolerable amount of heavy metals for an individual with a body weight of 60 kg was determined by the FAO/WHO as 60 mg for Zn, 3 mg for Cu, 214 µg for Pb, and no value for Cd was reported (Joint FAO/WHO, 2011).

These results can be expected due to existing systems, industrialization and urbanization in the bay. The main marine industry structures of the Iskenderun Bay are ports and piers and filling facilities. These are BOTAŞ Petrol Terminal and Toros Fertilizer Terminal in Ceyhan; BOTAŞ Petroleum Terminal, TPAO Pier, Aygaz LPG Filling Facilities and Pier and Mobile Oil Filling Facilities and Pier in Dörtyol; Gübretaş Fertilizer Pier and Ekinciler Iron and Steel Industry Pier in Sarıseki Organized Industrial Zone (OİE); İskenderun Highway Asphalt Facilities Pier, Petrol Ofisi Filling Facilities and Pier, Shell Liquid Cargo Filling Facilities. In addition, urbanization is mostly concentrated in Botaş and İskenderun locations. Looking at the current system, two main types of circulation are seen in the Bay. During the summer months, the water coming from the Syrian coast enters the Gulf from close to Karataş, and two recesses are formed, one in the inside clockwise and the outside in anticlockwise direction. This surface circulation pattern is also visually observed from large collections of plastic materials at the centers of the gyres. Ceyhan river inputs are carried inland by the westerly winds that prevail in summer. The cellular circulatory system in the bay begins to deteriorate in autumn. In winter, open sea waters enter the bay near Akıncı Burnu and proceed along the south coast towards the innermost areas. The waters eventually curl counterclockwise and leave the bay near the Karataş region.

CONCLUSION

In this study heavy metal accumulations in two economically important shrimp species were evaluated in terms of health risk to human based on previous studies from İskenderun Bay by a series of meta-analyses. Findings would be very important for mainly consumer, authorities, and fishing industry, etc., and a summary of the major findings were represented in Table 10. Cd, Pb and Cu metals for *P. semiculcatus* were detected above except Zinc was below the values recommended by FAO and WHO. Also, Pb and Zn metals for *M. monoceros* were observed above the values recommended by FAO and WHO. Although, the results do not seem to be good, but (i) detrimental impacts of heavy metals on human health become apparent only when long-term consumption of contaminated crustaceans occurs, (ii) much more well-organized studies (with more samples, suitable sampling strategy, etc.,) are needed to make a ultimate decision on whether the contents of these considered heavy metals in the these two shrimp species were exceeded or not the reference points.

Table 10. Meta-analysis results showing the accumulation exceeding status (based on legal limits) of Cd, Pb, Cu and Zn on the edible part of two shrimp species.
Çizelge 10. *İki karides türünün yenilebilir kısmında Cd, Pb, Cu ve Zn'nin birikme durumunu (yasal sınırlara göre) gösteren meta analiz sonuçları.*

Metals (mg kg^{-1})	***Metapenaeus monoceros***	***Peneaus semiculcatus***
Cd	not exceed	exceed
Pb	exceed	exceed
Cu	not exceed	exceed
Zn	exceed	not exceed

Statement of Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical statement

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed by the authors.

Authorship Contribution Statement

The contribution of the authors is equal

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