RESEARCH ARTICLE

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Public health risk assessments associated with heavy metal levels in panga fish fillets imported from Vietnam

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Abstract

Pangasius hypophthalmus (panga fish) is farmed in the Mekong River (Vietnam), which is known as a polluted river, and exported to many countries. The present study aimed to determine heavy metal levels in frozen panga fillets imported from Vietnam as well as the risks of heavy metals to human health. Panga fillets belonging to four brands were bought from three supermarkets in Adana city, Turkey, and heavy metals (As, Cd, Hg, Pb, Ni, Cu, Mn and Co) were analyzed. To analyze the potential risks to human health, EWI (estimated weekly intake), THQ (target hazard quotient), and CR (lifetime cancer risk) values were calculated to assess the potential risks to consumer health of the metal content in panga fillets. The health risk assessment values were calculated for children and adults according to the frequency of consumption once, three and seven times a week. The results revealed that the presence of heavy metals in the studied panga fillets was below permissible limits indicated by WHO (World Health Organization), EPA (United States Environmental Protection Agency) and TKB (Turkish Fisheries Laws and Regulations). The EWI, THQ or ∑THQ and CR values were below PTWI (provisional tolerable weekly intake), 1 and 10^{-5}, respectively. Remarkably, the highest values of the EWI/PTWI ratio and THQs were found for children.

Keywords: Metal toxicity, *Pangasius hypophthalmus*, Consumer health risks, Cancer risks

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INTRODUCTION

Human health is firmly related to diet quality (Korkmaz et al., 2019). Fish meat, which has high protein levels and low calories (Copat et al., 2013), is one of the most important food sources for the human diet. Moreover, fish meat has important specialities, such as reducing cardiovascular disease risks and promoting the nervous system, thanks to ingredients such as polyunsaturated fatty acids and particularly omega-3 fatty acids (Herrera-Herrera et al., 2019). A healthy diet that contains amino acids, vitamins, fatty acids, etc. must not contain deleterious substances, such as heavy metals (Fair et al. 2018; Korkmaz et al., 2019).

Metals are elements that exist in low concentration ranges and are found in a balance in nature (Simionov et al., 2019). Their balance in nature changes with the degree of human intervention, and their amounts may reach a dangerous level for living. Heavy metals are specifically spread to the environment through industrial production, iron and steel production and mining(Jayanthi et al., 2019); thus, their concentrations in the environment and concentration levels depend on increased risks. Toxic substances that are released into the water columns affect aquatic organisms and accumulate in their bodies (Maanan, 2008). This accumulation reaches humans with the consumption of aquatic organisms and could adversely affect human health.

Cadmium (Cd) is known for its mobility and high toxicity among metals. One feature of cadmium is its ability to replace and behave similarly to calcium. This ability has been accepted as a reason to enter the human body and accumulate to a high level in several organs (Kubier et al., 2019). Lead (Pb) is an element that is used in various fields and exists naturally on Earth's crust. Lead is classified as cancerogenic; moreover, it affects organs and systems in humans (Başaran, 2022). Mercury (Hg) is a metal found in nature in various forms, such as inorganic mercury and metallic mercury. It has toxic effects and enters the body easily through mucous membranes and the lung. Mercury damages the gut and kidney. Acute exposure to elemental mercury vapor can lead to fatal pneumonitis (Bernhoft, 2012). Arsenic (As) is one of the most toxic compounds exposed to the natural environment. It is used to manufacture pesticides, insecticides and various products. The main concern of being exposed to arsenic is its potential for cancerogenic effects (Ratnaike, 2003). Nickel (Ni) is an element that exists in nature. It is used in various industrial fields and thus spreads to the environment. Nickel can accumulate in different forms in the body, but the way that it is metabolized is not clear (Denkhaus & Salnikow, 2002). Copper (Cu) exists in nature and is needed in mammalian nutrition. The important part of the copper intake is supplied from drinking water. Copper, although it is an essential metal, is thought to be associated with various neurological disorders in the event of high intake. (Stern et al., 2007). Manganese (Mn) is one of the most abundant elements on Earth (Chen et al., 2018).

It is an essential metal that plays vital roles in nervous system function, energy metabolism, immunological functions and hormone functions (Santamaria, 2008). Cobalt (Co) is a trace element that exists on Earth and shows high similarity with iron and nickel in the case of chemical properties. Cobalt is necessary for physiological function in the body and plays a vital role (Leyssens et al., 2017).

Studies particularly show that fish are quite sensitive to toxic substances in the water (Alibabić et al., 2007; Copat et al., 2013). Pollutants may accumulate in fish bodies because fish are the last step of the aquatic food chain. Thus, fish are a very important bioindicator for metal pollution in the aquatic environment (Authman, 2015).

Panga fish (P. hypophthalmus, Sauvage 1878) live and are cultured in Southeast Asia, particularly in the Mekong River, Vietnam. Fillets of this species have the increasing demand by consumers due to their taste and lower price (Ruiz-de-Cenzano et al., 2013). The aquaculture of panga fish has evolved from rural activity to commercial business over time(Orban et al., 2008). Moreover, the Mekong delta and river were stated to be polluted by pesticides, sewage treatment plants, and human-made pollutants. As a downside to these, panga was indicated to affect these pollutants (Rodríguez et al., 2018).

Frozen fillets of panga have a growing demand for consumption in Turkey; thus, imported panga fillets are sold in markets countrywide. In the present study, the levels of arsenic, cadmium, mercury, lead, nickel, copper, manganese, and cobalt in panga fillets were examined. Furthermore, to predict possible risks to consumer health, estimated weekly intake (EWI), target hazard quotient (THQ), and lifetime cancer risk (CR) were calculated for one, three and seven days/week consumption in adults and children. This study is important to analyze the potential health risks of imported panga fillets that are distributed from Vietnam to the world.

MATERIALS AND METHODS

Sample Collection

Samples of frozen panga fillet were selected in supermarkets (three supermarkets, four brands) located in Adana, a city located in the Eastern Mediterranean region of Turkey. Samples were grouped as G1, G2, G3 and G4. Each group represents one brand. Four packs were purchased for each brand. Three fish fillets for each pack were analysed (n=12 for one brand). As a result, the present study was carried out with 48 fillets in total. Fish samples were weighed, homogenized and then stored at -20 °C until analyses.

Metal Analysis

The weights of fillets belonging to groups are given in Table 1. The method of (Agah et al., 2009) was modified and implemented as follows. Sample extraction was performed by taking 0.5 g from homogenized muscle tissues. Then, 2 ml H2O2 (Merck) and 5 ml HNO3 (Merck) were added to the weighed (0.5 g) samples in a tube, and the samples were burned with a microwave oven (CEM Mars 5) for 1 h at 180-190 °C. After acid digestion, the final volume of the samples was brought up to 20 ml with distilled water and then filtered with a 0.2 µm glass microfibre (Whatman). Samples were analyzed without extra dilution. The obtained data were multiplied by the dilution factor coefficient (20 / 0.5 = 40). The metal contents of the samples were given as µg / g wet weight.

Device Conditions

All analyses were carried out by ICP-MS (Perkin Elmer Nexion 2000P) in Cukurova University Central Research Laboratory. The recoveries of metals were in the range of

94 - 100.1 %. The operating conditions of the device were as follows: RF power 1600 W, plasma gas flow rate 15 L min -1, auxiliary gas flow1.2 L min -1, nebulizer gas flow 0.97, and carrier gas flow 5.3 min -1.

Health risk estimation

To determine potential risks related to the consumption of panga fillets, EWI (estimated weekly intake), THQ (target hazard quotient) and CR (lifetime cancer risk) values were calculated according to consumption frequencies of one, three and seven times a week. Potential risk calculations were made separately for adults and children and based on data provided by (US EPA, 2000) and (US EPA, 2019), respectively. The average body weight and lifetimes were assumed to be 70 kg and 70 years for adults and 32 kg and 7 years for children. The calculation was performed using the formulae below.

In contrast to other metals, the majority of arsenic consists of the nontoxic organic form (Arsenobetaine) (Castro-González & Méndez-Armenta 2008). Thus, for calculating the risk factors of As, its inorganic toxic form was assumed to be 3 % of the total concentration (Andaloro et al., 2012; EFSA, 2009; Kosker, 2020).

EWI, THQ and CR were calculated with the formulas [(CM × IR) / BW] (US EPA 2000),[(EF × ED × IR × CM) / (RfD × BW × AT)]× 10^{-3} (US EPA, 2019) and [(EF × ED × IR × CM × CsF) / (BW × AT)] × 10^{-3} (US EPA, 2019), respectively. In EWI calculations, CM defines the yearly average concentration of metal (µg / g) in muscle tissue, IR defines 1-, 3- and 5-day / person / week consumption rates (FAO, 2017) and BW defines consumer body weight.

In Turkey, fish consumption is 16.82 g / person / day (Kosker, 2020). The consumption frequencies (one, three and seven times a week) were compared to PTWI (provisional tolerable weekly intake). PTWI is based on body weight (mg / kg BW), and its mean describes the estimated amount of a substance that can be taken weekly for a lifetime without health risks.

THQ (target hazard quotient) indicates the ratio between the reference dose (RfD) of metals and the exposure rate to them. The THQ value demonstrates the noncarcinogenic risks of metals. In THQ calculations, EF demonstrates the frequency of exposure (one, three and seven times a week; 52, 156 and 365 days per year), and ED shows the exposure period (70 years was used for adults, while seven years was used for children). IR indicates the amount of consumption, and CM indicates the yearly average concentration of metal (μg/g) in the tissues. RfD states the oral reference doses for metals, and RfD values for Cd, Pb, Hg, As, Ni, Cu, Mn and Co are given as 1×10^{-3}, 4×10^{-3}, 1×10^{-4}, 3×10^{-4}, 2×10^{-3}, 0.04, 0.14, and 3×10^{-4}, respectively (Mwakalapa et al., 2019; US EPA, 2019). BW indicates body weight (70 kg for adults and 32 kg for children). AT represents the noncarcinogenic average period (356 days / year × ED). THQ and TTHQ values (total THQ values of all elements) > 1 indicate possible risks of health issues in addition to cancer in consumers.

CR (lifelong cancer risk) gives the individual cancer risk exposed to metal pollution through consumption. Its calculation was performed according to (US EPA, 2019). High carcinogenic risk is mentioned in the case of CR values above 10^{-5}. Another value that is used in CR calculation is CsF (cancer slope factor). The CsF values for Cd, Pb, Hg and As are 6.3, 8.5 × 10^{-3}, 1.5 and 1.5, respectively.

Statistical Analyses

All experiments were carried out in triplicate, and the results are reported as the mean ± standard deviation. SPSS 20.0 software was used to perform all statistical analyses. The experimental data were checked with Levene's test to assess the equality of variances. Intergroup differences in data were evaluated using one-way ANO-

Table 1. Fillet weights (g) and mean and standart deviation of metal levels in edible muscle fillet of Panga (mg/kg)

	G1	G2	G3	G4
	The average weights of fillets (mean ± std. deviation)			
	256.50±25.82	191±28.85	188.25±14.58	254.12±31.14
	Metal levels (mg / kg)			
Cd	$4.6\times10^{-3}\pm7.1\times10^{-4a}$	$6\times10^{-3}\pm5.4\times10^{-4a}$	$4.4\times10^{-3}\pm1.6\times10^{-3a}$	4.9x10-3$\pm2\times10^{-3a}$
Pb	0.17 ± 0.05^{a}	0.13 ± 0.03^{a}	0.14 ± 0.04^{a}	0.12 ± 0.04^{a}
Hg	$1.7\times10^{-2}\pm1.1\times10^{-3a}$	$2.9\times10^{-3}\pm1.2\times10^{-3b}$	$1.8\times10^{-2}\pm1.7\times10^{-3a}$	$1.6\times10^{-2}\pm2.5\times10^{-3a}$
As	$1.3\times10^{-2}\pm3\times10^{-3ab}$	$1.2\times10^{-2}\pm2.4\times10$-^{3b}	$1.6\times10^{-2}\pm3.8\times10^{-3a}$	$1.3\times10^{-2}\pm2.3\times10^{-3ab}$
Ni	0.17 ± 0.03^{a}	0.10 ± 0.02^{b}	0.10 ± 0.03^{b}	0.11 ± 0.03^{b}
Cu	0.23 ± 0.05^{a}	0.16 ± 0.01^{a}	0.20 ± 0.08^{a}	0.22 ± 0.09^{a}
Mn	0.18 ± 0.04^{ab}	0.17 ± 0.03^{ab}	0.20 ± 0.04^{a}	0.14 ± 0.02^{b}
Co	6.3×10^{-3a}	$5.2\times10^{-3}\pm1.3\times10^{-3a}$	$5.2\times10^{-3}\pm2.1\times10^{-3a}$	$5\times10^{-3}\pm7\times10^{-4a}$

Values in the same line with different superscripts are statistically different (P < 0.05).

VA with Duncan's and Games-Howell posthoc tests. The level of significance was determined as $P < 0.05$.

RESULTS AND DISCUSSION

Fillet weights and metal levels (mg/kg) in panga fillets are listed in Table 1. The group variances of metals excluding Cu were homogenous. The total accumulations of heavy metals were found to be Cu > Mn > Pb > Ni > Hg ≃ As > Co > Cd. The intergroup differences in Cd, Pb, Co and Cu were not significant ($P > 0.05$). Hg levels in G2 were significantly lower than those in the other groups ($P < 0.05$). TheMn and As levels of G3 were significantly higher than those of G4 and G2, respectively. Ni levels in G1 were significantly higher than those in the other groups. Differences other than those mentioned above were not statistically significant.

Elementel Composition

Cadmium

Cadmium is nonessential and very toxic to organisms and the environment (Stancheva et al., 2010). Cadmium is implicated in carcinogenic diseases (Rakib et al., 2021). Permissible amounts of cadmium in fish are 0.05, 1.4 and 0.5 mg/kg according to Turkish Fisheries Laws and Regulations (TKB) (Köker et al., 2021), EPA (EPA, 1989) and WHO (WHO, 1989), respectively. In the present study, the cadmium levels of the groups were found to be close to each other, and moreover, their levels were found tobe quite low and below the indicated limits (Table 1). Similar to the present study, quite low cadmium amounts from varied fish species' muscles were shown in different countries, such as Bangladesh, Italy, Turkey and Spain (Töre et al., 2021; Varol et al., 2019). In another study carried out with panga fillets, the Cd amount was found to be in the range of 0.01–0.03 µg / g ww (Dambrosio et al., 2016). Molognoni et al. (2016) reported that the amounts of cadmium in panga fillets imported from different regions of Vietnam (Dong Thap & Can Tho) differ, and the results from the Can Tho region were found to be closer to the results we obtained.

Lead

Lead, as an important contaminant, naturally occurs in the environment. It is also considered a neurotoxic agent that affects the rates of survival and growth in vertebrates (Rakib et al., 2021). It moves in nature due to atmospheric convection (Bosch et al., 2016). Permissible amounts of lead in fish are 0.3 and 0.5 mg / kg according to TKB (Köker et al., 2021) and WHO (WHO, 1989), respectively. In the present study, the differences in lead levels of the groups were not significant ($P > 0.05$), and all of them were found to be below the indicated limits. Hajrić et al. (2022) reported that the average Pb levels were 0.004 mg / kg in trout and 0.007 mg / kg in carp in Bosna-Herzegovina. Pb levels were found to be in the range of 0.0025 - 0.0156 mg / kg in different parts of China (Li et al., 2022). Heavy metal pollution was reported to vary according to seasons from different fish species and regions of India. Furthermore, Pb levels were reported in the average range of 0.088 and 0.135 mg / kg (Pandion et al., 2022). In our study, although it was not significant, the results of G1 were found to be higher than those of the others. This case may be based on regional differences.

Mercury

Mercury is a heavy metal that does not naturally exist in living organisms (Köker et al., 2021), and it is mentioned to affect the human neurological system (Rakib et al., 2021). Permissible amounts of mercury in fish are0.5 and 0.5 mg / kg according to TKB (Köker et al., 2021) and WHO (WHO, 1989), respectively. In the present study, the results were below the indicated limits, but the G2 data were significantly lower than those in the other groups ($P < 0.05$). The region where the fish in group 2 are cultured may be further away from the region that is contaminated with mercury. Botwe (2021) indicated that Hg levels in different fish were found to be at the average of 0.11 ± 0.01 mg / kg, and Hajrić et al. (2022) pointed out that the average Hg levels were 0.081 and 0.052 mg / kg in trout and carp, respectively. These values are much higher than those of G1, G2, G3 and G4 in the present study. In a similar study, the average levels of mercury were found to be 0.20 ± 0.20, 0.27 ± 0.19, 0.19 ± 0.16, 0.18 ± 0.22 and 0.16 ± 0.18 mg / kg in muscles of P. Hypophthalmus (Rodríguez et al., 2018). These results are quite above the results of the present study but below limits. This difference may be based on environmental pollution of aquaculture regions or from the way the fish is obtained: fishing or aquaculture.

Arsenic

The inorganic forms of As show the highest toxicity, and various organisms have been shown to be affected by As toxicity (Kumari et al., 2017). Absorption of As is quite high, and its distribution affects the whole body, including the placenta (EFSA, 2009). The European Food Safety Authority (EFSA) reported that limits of As should be reevaluated because of its harmful effects on health (EFSA, 2009); moreover, TKB defined its limit as 1 mg/kg for consumable fish meat (Köker et al., 2021). In the present study, the average As levels were $1.3 \times 10^{-2} \pm 3 \times 10^{-3}$, $1.2 \times 10^{-2} \pm 2.4 \times 10^{-3}$, $1.6 \times 10^{-2} \pm 3.8 \times 10^{-3}$ and $1.3 \times 10^{-2} \pm 2.3 \times 10^{-3}$ mg / kg in G1, G2, G3 and G4, respectively. The difference between G3 and G2 was significant ($P < 0.05$). Although there are some significant differences, all results were below the legal limits. Töre et al. (2021) reported similar results for As from Capoeta trutta and Carassius gibelio species in the Tigris River in Turkey. Furthermore, heavy metal pollution was reported to change by season, and in a study, the highest As levels in pikeperch were found in spring (Dehghani et al., 2022).

Nickel

Chronic exposure to nickel compounds has negative effects on human health. Nickel is thought to be one of the causes of contact dermatitis, allergic reactions and cancer (Duda-Chodak & Blaszczyk, 2008). Furthermore, nickel is linked to the potential to lead to lung fibrosis and heart and kidney diseases (Denkhaus & Salnikow, 2002). In the present study, the average nickel level of G1 was 0.17 ± 0.03 mg / kg, which was significantly higher than those in the other groups. The permissible daily dose of nickel is 1.46 mg / kg according to EPA (Alibabić et al., 2007; EPA, 1980). The results obtained are below the permissible limits. Alibabić et al. (2007) reported that the average concentration of nickel was 0.15 mg / kg in Salmonidae species. This value is higher than those in G2, G3 and G4 when compared to the present study.Łuszczek-Trojnar et al. (2015) stated the high nickel levels (the average level of 5.2 ± 1.2 mg / kg) from frozen pangasius fillets in Poland. This is quite higher than those from our study. Another study conducted with panga fillets imported from Vietnam indicated that the nickel level was below the detectable limit (Duarte et al., 2019). Aquaculture regions and exposure times to metals might be thought to be important in this difference.

Copper

Copper status in the body, both deficiency and excess, can affect health cases. Copper is associated with neurological disorders, including Alzheimer's disease and prion diseases (Stern et al., 2007). The permissible limits of copper are higher than those of many metals; its limits are 54 and 30 mg / kg for EPA (1989) and WHO (1989), respectively (Köker et al., 2021). Copper was the only metal whose results were not homogeneous, and the difference among groups was not significant ($P > 0.05$). G1 had the highest average level of 0.23 ± 0.05 mg / kg, which was well below the specified limits. Many studies have shown that copper levels found in fish muscle are below permissible limits (Molognoni et al., 2016; Mortuza & Al-Misned, 2015; Pragnya et al., 2020). Copper deficiency and excess can lead to health problems (Stern et al., 2007). Its permissible limits are quite high compared to many other metals since humans also need copper. Studies on the accumulation of copper in fish meat show that its accumulation is mostly far from posing a threat to humans.

Manganese

The brain is accepted to be the main target of manganese toxicity because manganese-related toxicity leads to neurological disorders. Moreover, manganese has important roles in immune and antioxidative responses, development, reproduction and energy metabolism in humans (Chen et al., 2018). The WHO reported that the daily requirement of manganese was suggested to be in the range of 2 to 9 mg in the human diet (Łuszczek-Trojnar et al., 2015), and its permissible limit is 1 µg / g (Töre et al., 2021). In the present study, the results of all groups were found to be below permissible limits; furthermore, the manganese levels of G3 were found to be significantly higher than those of G4 ($P < 0.05$). Łuszczek-Trojnar et al. (2015) stated that manganese levels were reported to have an average level of 0.3 ± 0.02 mg / kg in pangasius fillets that came from Asia to Poland markets. This level was lower than those found in Alaska pollock, rainbow trout and tilapia. Elnimr (2011) indicated quite low levels of manganese (0.08 µg / g) in P. hypophthalmus when compared to the present study.

Cobalt

Cobalt, as an essential metal, plays a vital role in biochemical processes and shows toxic effects in the case of intake above a certain concentration (Zaynab et al., 2022). Moreover, cobalt is a necessary metal for B12 vitamin function (Leyssens et al., 2017). Cobalt shows a tendency to accumulate in the liver, and it is kept at a minimum in muscle tissue (Jayanthi et al., 2019). In the present study, there were no significant differences among groups, and the highest level was found in G1, with an average level of 6.3×10^{-3} mg / kg, while the levels of cobalt in the other groups were very close to each other. Pragnya et al. (2020) stated that cobalt was below the detectable limits in P. hypophthalmus, and they interpreted that fish came from fishing rather than aquaculture. The maximum permissible limit of cobalt is defined as 1.5mg / kg by the WHO (Jayanthi et al., 2019). The results we found were quite below the limit explained.

Health risk assessment of metals

Metal and metalloid accumulation in the marine environment can affect marine species as well as humans who consume these species. Although muscle tissue in marine species contains lower metal concentrations than other tissues (Solgi & Beigzadeh-Shahraki, 2019), it may pose a risk depending on the amount consumed. Therefore, EWI (Table 2), THQ (Table 3) and CR (Table 4) were calculated to assess health risks based on panga fillet consumption. To understand the risk effects of metals and metalloids on children and adult consumers, all calculations were made for the consumption of 1, 3 and 7 days per week. PTWI values were used as reference values (safe levels) of heavy metals for making a comparison with EWI levels. In the present study, the EWI values of all samples were much lower than the PTWI values (Table 2).

For the samples studied, the consumption of panga fillets does not pose a risk to consumers regarding the heavy metals studied. Because the limit value is not determined for cobalt (Solgi & Beigzadeh-Shahraki, 2019), its PTWI has not been set, but its value of maximum tolerable daily intake (MTDI) was indicated as 100 µg / kg body weight (Kukusamude et al., 2021). According to the data above, the MTDI of cobalt was calculated as 7 mg / kg and 3.2 mg / kg for adults and children, respectively. The cobalt data in the present study were found tobe quite below the MTDI calculated.

The highest values of the EWI / PTWI ratio excluding Mn were found for children and in G2. They were found tobe 0,002857, 0,0256, 0,0175, 0,004, 0,018, and 0,007 for Cd, Pb, Hg, As, Ni and Cu, respectively. The highest EWI / PTWI ratios of Mn were found for children and in G4 at 0,004151 and 0,003882 for males and females, respectively. Soegianto et al. (2020) indicated that in the tissues of Anadara granosa (L., 1758), the EWIs of Pb and Cu were found to be below the PTWI values, but the EWI of Cr was

Table 2. Estimated weekly intake (EWI; µg / kg BW) for each analyzed metals

EWI		Day	Cd	Pb	Hg	As	Ni	Cu	Mn	Co
G1	Adult	7	0,01	0,29	0,03	0,02	0,29	0,40	0,31	0,01
		3	0,00	0,13	0,01	0,01	0,12	0,17	0,13	0,00
		1	0,00	0,04	0,00	0,00	0,04	0,06	0,04	0,00
	Children	7	0,02	0,64	0,07	0,05	0,63	0,88	0,69	0,02
		3	0,01	0,28	0,03	0,02	0,27	0,38	0,29	0,01
		1	0,00	0,09	0,01	0,01	0,09	0,13	0,10	0,00
G2	Adult	7	0,01	0,23	0,00	0,02	0,17	0,28	0,29	0,01
		3	0,00	0,10	0,00	0,01	0,07	0,12	0,13	0,00
		1	0,00	0,03	0,00	0,00	0,02	0,04	0,04	0,00
	Children	7	0,02	0,50	0,01	0,04	0,37	0,62	0,64	0,02
		3	0,01	0,21	0,00	0,02	0,16	0,27	0,28	0,01
		1	0,00	0,07	0,00	0,01	0,05	0,09	0,09	0,00
G3	Adult	7	0,01	0,24	0,03	0,03	0,17	0,35	0,34	0,01
		3	0,00	0,10	0,01	0,01	0,07	0,15	0,15	0,00
		1	0,00	0,03	0,00	0,00	0,02	0,05	0,05	0,00
	Children	7	0,02	0,53	0,07	0,06	0,37	0,77	0,75	0,02
		3	0,01	0,23	0,03	0,03	0,16	0,33	0,32	0,01
		1	0,00	0,08	0,01	0,01	0,05	0,11	0,11	0,00
G4	Adult	7	0,01	0,21	0,03	0,02	0,20	0,39	0,23	0,01
		3	0,00	0,09	0,01	0,01	0,08	0,17	0,10	0,00
		1	0,00	0,03	0,00	0,00	0,03	0,06	0,03	0,00
	Children	7	0,02	0,46	0,06	0,05	0,43	0,85	0,51	0,02
		3	0,01	0,20	0,03	0,02	0,18	0,36	0,22	0,01
		1	0,00	0,07	0,01	0,01	0,06	0,12	0,07	0,00
PTWI values (µ / kg)			7	25	4	15	35	125	180.7 (male) 193.2 (female)	
			(FAO/ WHO)* (Arvay et al., 2015)	(Solgi et al., 2019)	(Solgi et al., 2019)	(Kosker, 2020)	(Kukusamude et al., 2021)	(Kosker, 2020)	(Kukusamude et al., 2021)	

* The Joint FAO/WHO Expert Committee on Food Additives, FAO: The Food and Agriculture Organization of the United Nations

found to be higher than its PTWI. Similarly, the EWIs of Cd, Pb, Hg and As were below recommended PTWI values (Özden & Erkan, 2016).

THQ is accepted as an indicator to determine potential risks to consumer health (Kosker, 2020). THQ or total THQ values of metals > 1 indicate that the metal intake level is ≥ RfD. THQ or ∑THQ indicates that the metal content in food may cause various health problems for consumers (Kosker, 2020). In the present study, THQ and ∑THQ values were below reference value 1. The calculated THQ values for children were higher than those for adults in G1, G3 and G4. These results show that the panga fillets studied do not pose a health risk for either adult or children consumers in terms of heavy metals. Özden and Erkan (2016) reported THQ values of < 1 in fish studied but also a total THQ value of > 1 in female fish. Similarly, muscle samples of five fish species were reported to have no potential health risk in terms of the intake of toxic metals (Varol & Sünbül, 2018).

The CR value is used to calculate the cancer risk of metals in food for consumers. The CR value must be above 10^{-5} to mention a health risk. CR calculations were made based on (US EPA, 2019). In the present study, all results were found to be below the reference value of 10^{-5}. Among the CR values calculated for children, CRs of Hg in the G1, G3 and G4 groups and CRs of Cd in all groups were detected at closer levels to 10^{-5} when compared to others.

CONCLUSIONS

In this study, panga fish fillets of four different brands were examined in terms of toxic metal accumulation and risks to human health. According to the results, fillets were suitable for heavy metal consumption, but other pollutants, such as organochlorine pesticides or polychlorinated biphenyls, may also be risk factors for consumers, and these kinds of pollutants must be researched. For food safety, all potential pollutants must be researched considering legal limits. However, regular

Table 3. Target hazard quotient (THQ), total target hazard quotient (TTHQ) for metals

THQ		Day	Cd	Pb	Hg	As	Ni	Mn	∑THQ
G1	Adult	7	0,00	0,01	0,01	0,01	0,01	0,00	0,04
		3	0,00	0,00	0,01	0,00	0,01	0,00	0,02
		1	0,00	0,00	0,00	0,00	0,00	0,00	0,01
	Children	7	0,00	0,02	0,02	0,02	0,03	0,00	0,08
		3	0,00	0,01	0,01	0,01	0,02	0,00	0,05
		1	0,00	0,00	0,00	0,11	0,01	0,00	0,12
G2	Adult	7	0,00	0,01	0,00	0,01	0,01	0,00	0,02
		3	0,00	0,00	0,00	0,00	0,01	0,00	0,01
		1	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Children	7	0,00	0,01	0,00	0,01	0,02	0,00	0,05
		3	0,00	0,01	0,00	0,01	0,01	0,00	0,03
		1	0,00	0,00	0,00	0,09	0,00	0,00	0,10
G3	Adult	7	0,00	0,01	0,01	0,01	0,01	0,00	0,03
		3	0,00	0,00	0,01	0,00	0,01	0,00	0,01
		1	0,00	0,00	0,00	0,00	0,00	0,00	0,01
	Children	7	0,00	0,01	0,02	0,02	0,02	0,00	0,07
		3	0,00	0,01	0,01	0,01	0,01	0,00	0,04
		1	0,00	0,00	0,00	0,13	0,00	0,00	0,14
G4	Adult	7	0,00	0,01	0,01	0,01	0,01	0,00	0,03
		3	0,00	0,00	0,01	0,00	0,01	0,00	0,01
		1	0,00	0,00	0,00	0,00	0,00	0,00	0,01
	Children	7	0,00	0,01	0,02	0,02	0,02	0,00	0,07
		3	0,00	0,01	0,01	0,01	0,01	0,00	0,04
		1	0,00	0,00	0,00	0,11	0,00	0,00	0,12

Table 4. Target carcinogenic risk (CR) for Cd, Pb, Hg and As

CR		Day	Cd	Pb	Hg	As
G1	Adult	7	5.07E-06	2.55E-07	4.55E-06	3.39E-06
		3	3.04E-06	1.53E-07	2.73E-06	2.03E-06
		1	1.01E-06	5.1E-08	9.11E-07	6.78E-07
	Children	7	1.11E-05	5.57E-07	4.55E-05	7.42E-06
		3	6.65E-06	3.34E-07	5.98E-06	4.45E-06
		1	2.22E-06	1.11E-07	1.99E-06	1.48E-06
G2	Adult	7	6.61E-06	1.96E-07	7.56E-07	3.01E-06
		3	3.96E-06	1.18E-07	4.54E-07	1.8E-06
		1	1.32E-06	3.93E-08	1.51E-07	6.01E-07
	Children	7	1.45E-05	4.29E-07	7.56E-06	6.58E-06
		3	8.67E-06	2.58E-07	9.92E-07	3.95E-06
		1	2.89E-06	8.59E-08	3.31E-07	1.32E-06
G3	Adult	7	4.94E-06	2.1E-07	4.73E-06	4.32E-06
		3	2.96E-06	1.26E-07	2.84E-06	2.59E-06
		1	9.87E-07	4.19E-08	9.45E-07	8.64E-07
	Children	7	1.08E-05	4.58E-07	4.73E-05	9.45E-06
		3	6.48E-06	2.75E-07	6.2E-06	5.67E-06
		1	2.16E-06	9.17E-08	2.07E-06	1.89E-06
G4	Adult	7	5.4E-06	1.81E-07	4.09E-06	3.4E-06
		3	3.24E-06	1.09E-07	2.46E-06	2.04E-06
		1	1.08E-06	3.62E-08	8.19E-07	6.8E-07
	Children	7	1.18E-05	3.96E-07	4.09E-05	7.43E-06
		3	7.09E-06	2.37E-07	5.37E-06	4.46E-06
		1	2.36E-06	7.92E-08	1.79E-06	1.49E-06

monitoring of the metal content of seafood products exported to many countries is important for consumer health.

COMPLIANCE WITH ETHICAL STANDARTS

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions

All authors contributed to the study's conception and design. Sample collection and burning process were carried out by Serdar Kilercioglu and Ece Evliyaoglu, also the health risk calculations were made by Ali Riza Kosker. Moreover, all authors have contributed to the writing phase.

Ethical approval

Ethics committee approval is not required.

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Data availability

All data generated or analysed during this study are included in this published article.

Consent to Publish

All authors exist in the present study approve to publish this manuscript. Furthermore, there is no other one who has rights to this manuscript.

REFERENCES

Agah, H., Leermakers, M., Elskens, M., Fatemi, S. M. R. & Baeyens, W. (2009). Accumulation of trace metals in the muscle and liver tissues of five fish species from the Persian Gulf. Environmental Monitoring and Assessment, 157(1–4), 499–514. [CrossRef]

Alibabić, V., Vahčić, N. & Bajramović, M. (2007). Bioaccumulation of Metals in Fish of Salmonidae Family and the Impact on Fish Meat Quality. Environmental Monitoring and Assessment, 131(1–3), 349–364. [CrossRef]

Andaloro, F., Romeo, T., Renzi, M., Guerranti, C., Perra, G., Consoli, P., Perzia, P. & Focardi, S. E. (2012). Alteration of potential harmful elements levels in sediments and biota from the central Mediterranean Sea (Aeolian Archipelago) following an episode of intense volcanic activity. Environmental

Monitoring and Assessment, 184(7), 4035–4047. [CrossRef]
Árvay, J., Tomáš, J., Hauptvogl, M., Massányi, P., Harangozo, Ľ., Tóth, T., Stanovic, R., Bryndzova, S. & Bumbalová, M. (2015). Human exposure to heavy metals and possible public health risks via consumption of wild edible mushrooms from Slovak Paradise National Park, Slovakia. Journal of Environmental Science and Health, Part B, 50(11), 833-843.
Authman, M. M. (2015). Use of Fish as Bio-indicator of the Effects of Heavy Metals Pollution. Journal of Aquaculture Research & Development, 6(4), 1–13. [CrossRef]
Başaran, B. (2022). An assessment of heavy metal level in infant formula on the market in Turkey and the hazard index. Journal of Food Composition and Analysis, 105, 104258. [CrossRef]
Bernhoft, R. A. (2012). Mercury Toxicity and Treatment: A Review of the Literature. Journal of Environmental and Public Health, 2012, 1–10. [CrossRef] DOI: https://doi.org/10.1155/2012/460508
Bosch, A. C., O'Neill, B., Sigge, G. O., Kerwath, S. E. & Hoffman, L. C. (2016). Heavy metals in marine fish meat and consumer health: a review. Journal of the Science of Food and Agriculture, 96(1), 32–48. [CrossRef]
Botwe, B. O. (2021). Heavy metal concentrations in five fish species from the Gulf of Guinea and their human health implications. Regional Studies in Marine Science, 44, 101763. [CrossRef]
Castro-González, M. I. & Méndez-Armenta, M. (2008). Heavy metals: Implications associated to fish consumption. Environmental Toxicology and Pharmacology, 26(3), 263–271.
Chen, P., Bornhorst, J. & Aschner, M. A. (2018). Manganese metabolism in humans. Frontiers in Bioscience, 1655–1679.
Copat, C., Arena, G., Fiore, M., Ledda, C., Fallico, R., Sciacca, S. & Ferrante, M. (2013). Heavy metals concentrations in fish and shellfish from eastern Mediterranean Sea: Consumption advisories. Food and Chemical Toxicology, 53, 33–37. [CrossRef]
Dambrosio, A., Normanno, G., Storelli, A., Barone, G., Ioanna, F., Errico, L., Centoducati, G. & Storelli, M. M. (2016). Aspects of Vietnamese Sutchi Catfish (Pangasius Hypophthalmus) Frozen Fillet Quality: Microbiological Profile and Chemical Residues. Journal of Food Safety, 36(4), 532–536. [CrossRef]
Dehghani, A., Roohi, A. A. & Dehghani, A. (2022). Trophic transfer, bioaccumulation, and health risk assessment of heavy metals in Aras River: case study—Amphipoda- zander – human. Environmental Science and Pollution Research, 1–10. [CrossRef]
Denkhaus, E. & Salnikow, K. (2002). Nickel essentiality, toxicity, and carcinogenicity. Critical Reviews in Oncology/Hematology, 42(1), 35–56. [CrossRef]
Duarte, G. S. C., Takemoto, R. M., Yamaguchi, M. U., Matos, L. S. & Pavanelli, G. C. (2019). Evaluation of the concentration of heavy metals in fillets of Pangasius hypophthalmus (Sauvage, 1878), Panga, imported from Vietnam. Int J Dev Res, 9(10), 30181–30186.
Duda-Chodak, A. & Blaszczyk, U. (2008). The impact of nickel on human health. Journal of Elementology, 13(4), 685–693.
EFSA (2009). Scientific opinion on arsenic in food, CONTAM (EFSA Panel on Contaminants in the Food Chain). EFSA Journal, 7(10), 1351.
Elnimr, T. (2011). Evaluation of some heavy metals in Pangasius hypothalmus and Tilapia nilotica and the role of acetic acid in lowering their levels. International Journal of Fisheries and Aquaculture, 3(8), 151–157.
EPA (US Environmental Protection Agency) (1980). Ambient water quality criteria document for nickel EPA-440/4-80-060, NTIS PB 81-117715. Cincinnati: OH-US Environmental Criteria and Assessment Office (ECAO).
EPA (US Environmental Protection Agency) (1989). Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish: A Guidance Manual.
Fair, P. A., White, N. D., Wolf, B., Arnott, S. A., Kannan, K., Karthikraj, R. & Vena, J. E. (2018). Persistent organic pollutants in fish from Charleston Harbor and tributaries, South Carolina, United States: A risk assessment. Environmental Research, 167, 598–613. [CrossRef]
FAO (Food Administration Organization) (2017). Food Balance Sheets.
Hajrić, D., Smajlović, M., Antunović, B., Smajlović, A., Alagić, D., Tahirović, D., Brenjo, D., Clanjak-Kudra, E., Djedjibegovic, J., Porobic, A. & Poljak, V. (2022). Risk assessment of heavy metal exposure via consumption of fish and fish products from the retail market in Bosnia and Herzegovina. Food Control, 133, 108631. [CrossRef]
Herrera-Herrera, C., Fuentes-Gandara, F., Zambrano-Arévalo, A., Higuita, F. B., Hernández, J. P. & Marrugo-Negrete, J. (2019). Health Risks Associated with Heavy Metals in Imported Fish in a Coastal City in Colombia. Biological Trace Element Research, 190(2), 526–534. [CrossRef]
Jayanthi, R., Rao, V. A., Babu, R. N., Sivakumar, T., Sriram, P. & Abraham, R. J. J. 2019. Analysis of essential heavy metals in ready-to-eat chicken meat products of Chennai city. Journal of Entomology and Zoology Studies, 7(3), 427–432.
Köker, L., Aydın, F., Gaygusuz, Ö., Akçaalan, R., Çamur, D., İlter, H., Ayoğlu, N. F., Topbaş, M. & Albay, M. (2021). Heavy Metal Concentrations in Trachurus Mediterraneus and Merlangius Merlangus Captured from Marmara Sea, Turkey and Associated Health Risks. Environmental Management, 67(3), 522–531. [CrossRef]
Korkmaz, C., Ay, Ö., Ersoysal, Y., Köroğlu, M. A. & Erdem, C. (2019). Heavy metal levels in muscle tissues of some fish species caught from north-east Mediterranean: Evaluation of their effects on human health. Journal of Food Composition and Analysis, 81, 1–9. [CrossRef]
Kosker, A. R. (2020). Metal and fatty acid levels of some commercially important marine species from the northeastern Mediterranean: benefits and health risk estimation. Environmental Monitoring and Assessment, 192(6), 1–16.
Kubier, A., Wilkin, R. T. & Pichler, T. (2019). Cadmium in soils and groundwater: A review. Applied Geochemistry, 108,

104388. [CrossRef]

Kukusamude, C., Sricharoen, P., Limchoowong, N. & Kongsri, S. (2021). Heavy metals and probabilistic risk assessment via rice consumption in Thailand. Food Chemistry, 334, 127402. [CrossRef]

Kumari, B., Kumar, V., Sinha, A. K., Ahsan, J., Ghosh, A. K., Wang, H. & DeBoeck, G. (2017). Toxicology of arsenic in fish and aquatic systems. Environmental Chemistry Letters, 15(1), 43–64. [CrossRef]

Leyssens, L., Vinck, B., Van Der Straeten, C., Wuyts, F. & Maes, L. (2017). Cobalt toxicity in humans—A review of the potential sources and systemic health effects. Toxicology, 387, 43–56. [CrossRef]

Li, Y., Wang, X., Du, H, Xiao, G. & Guo, L. (2022). Heavy metal accumulation and health risk assessment of crayfish in the middle and lower reaches of Yangtze River during 2015–2017. Environmental Monitoring and Assessment, 194(1), 24. [CrossRef]

Łuszczek-Trojnar, E., Błoniarz, P., Winiarski, B., Drąg-Kozak, E. & Popek, W. (2015). Comparison of cadmium, zinc, manganese and nickel concentrations in fillets of selected species of food fish. Scientific Annals of the Polish Society of Animal Production, 11, 75–84.

Maanan, M. (2008). Heavy metal concentrations in marine molluscs from the Moroccan coastal region. Environmental Pollution, 153(1), 176–183. [CrossRef]

Molognoni, L., Vitali, L., Ploêncio, L. A., Santos, J. N. & Daguer, H. (2016). Determining the arsenic, cadmium, lead, copper and chromium contents by atomic absorption spectrometry in Pangasius fillets from Vietnam. Journal of the Science of Food and Agriculture, 96(9), 3109–3113. [CrossRef]

Mortuza, M. G. & Al-Misned, F. A. (2015). Trace elements and heavy metals in five cultured and captured fishes from Rajshahi City, Bangladesh. Biomedical Sciences Today, 1, 1–9.

Mwakalapa, E. B., Simukoko, C. K., Mmochi, A. J., Mdegela, R. H., Berg, V., Bjorge Müller, M. H., Lyche, J. L. & Polder, A. (2019). Heavy metals in farmed and wild milkfish (Chanos chanos) and wild mullet (Mugil cephalus) along the coasts of Tanzania and associated health risk for humans and fish. Chemosphere, 224, 176–186. [CrossRef]

Orban, E., Nevigato, T., Lena, G. D., Masci, M., Casini, I., Gambelli, L. & Caproni, R. (2008). New trends in the seafood market. Sutchi catfish (Pangasius hypophthalmus) fillets from Vietnam: Nutritional quality and safety aspects. Food Chemistry, 110(2), 383–389. [CrossRef]

Özden, Ö. & Erkan, N. (2016). Evaluation of Risk Characterization for Mercury, Cadmium, Lead and Arsenic Associated with Seafood Consumption in Turkey. Exposure and Health, 8(1), 43–52. [CrossRef]

Pandion, K., Khalith, S. B. M., Ravindran, B., Chandrasekaran, M., Rajagopal, R., Alfarhan, A., Chang, S. W., Ayyamperumal, R., Mukherjee, A. & Arunachalam, K. D. (2022). Potential health risk caused by heavy metal associated with seafood consumption around coastal area. Environmental Pollution, 294, 118553. [CrossRef]

Pragnya, M., Dinesh, K. S., Solomon Raju, A. J. & Murthy, L. N. (2020). Bioaccumulation of heavy metals in different organs of Labeo rohita, Pangasius hypophthalmus, and Katsuwonus pelamis from Visakhapatnam, India. Marine Pollution Bulletin, 157, 111326. [CrossRef]

Rakib, M. R. J., Jolly, Y. N., Enyoh, C. E., Khandaker, M. U., Hossain, M. B., Akther, S., Alsubaie, A., Almalki, A. S. A., Bradley, D. A. (2021). Levels and health risk assessment of heavy metals in dried fish consumed in Bangladesh. Scientific Reports, 11(1), 14642. [CrossRef]

Ratnaike, R. N. (2003). Acute and chronic arsenic toxicity. Postgraduate Medical Journal, 79(933), 391–396. [CrossRef]

Rodríguez, M., Gutiérrez, Á. J., Rodríguez, N., Rubio, C., Paz, S., Martín, V., Revert, C. & Hardisson, A. (2018). Assessment of mercury content in Panga (Pangasius hypophthalmus). Chemosphere, 196, 53–57. [CrossRef]

Ruiz-de-Cenzano, M., Beser, U., Cervera, M. L., & de la Guardia, M. 2013. Fast determination of fish mineral profile. Application to Vietnamese panga fish. Ecotoxicology and Environmental Safety, 95, 195–201. [CrossRef]

Santamaria, A. B. (2008). Manganese exposure, essentiality & toxicity. Indian Journal of Medical Research, 128(4), 484–500.

Simionov, I. A., Cristea, V., Petrea, S. M. & Sirbu, E. B. (2019). Evaluation Of Heavy Metals Concentration Dynamics in Fish From The Black Sea Coastal Area: An Overview. Environmental Engineering and Management Journal, 18(5), 1097–1110. [CrossRef]

Soegianto, A., Putranto, T. W. C., Lutfi, W., Almirani, F. N., Hidayat, A. R., Muhammad, A., Firdaus, R. A., Rahmadhani, Y. S., Fadila, D. A. N. & Hidayati, D. (2020). Concentrations of Metals in Tissues of Cockle Anadara granosa (Linnaeus, 1758) from East Java Coast, Indonesia, and Potential Risks to Human Health. International Journal of Food Science, 2020, 1–9. [CrossRef]

Solgi, E. & Beigzadeh-Shahraki, F. (2019). Accumulation and Human Health Risk of Heavy Metals in Cultured Rainbow Trout (Oncorhynchus mykiss) Form Different Fish Farms of Eight Cities of Chaharmahal and Bakhtiari Province, Iran. Thalassas: An International Journal of Marine Sciences, 35(1), 305–317. [CrossRef]

Stancheva, M., Peycheva, K. & Makedonski, L. (2010). Assessment of heavy metal distribution in muscle, skin and gills of two fish species from the Black Sea, Bulgaria. Scientific Works of the University of Plovdiv, LVII(part 2), 41.

Stern, B. R., Solioz, M., Krewski, D., Aggett, P., Aw T-C, Baker, S., Crump, K., Dourson, M., Haber, L., Hertzberg, R., Keen, C., Meek, B., Rudenko, L., Schoeny, R., Slob, W. & Starr, T. (2007). Copper and Human Health: Biochemistry, Genetics, and Strategies for Modeling Dose-response Relationships. Journal of Toxicology and Environmental Health, Part B, 10(3), 157–222. [CrossRef]

Töre, Y., Ustaoğlu, F., Tepe, Y. & Kalipci, E. (2021). Levels of toxic metals in edible fish species of the Tigris River (Turkey); Threat to public health. Ecological Indicators, 123, 107361.

[CrossRef]

US EPA (2000). Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume II. Risk Assessment and Fish Consumption Limits.

US EPA (2019). Regional screening levels (RSLs) – equations. Retrieved from https://www.epa.gov/risk/regional-screening-levels-rsls-equations

Varol, M., Kaya, G. K. & Sünbül, M. R. (2019). Evaluation of health risks from exposure to arsenic and heavy metals through consumption of ten fish species. Environmental Science and Pollution Research, 26(32), 33311–33320. [CrossRef]

Varol, M. & Sünbül, M. R. (2018). Multiple approaches to assess human health risks from carcinogenic and non-carcinogenic metals via consumption of five fish species from a large reservoir in Turkey. Science of The Total Environment, 633, 684–694. [CrossRef]

WHO (1989). Evaluation of certain food additives and the contaminants mercury, lead and cadmium.

Zaynab, M., Al-Yahyai, R., Ameen, A., Sharif, Y., Ali, L., Fatima, M., Khan, K. A. & Li, S. (2022). Health and environmental effects of heavy metals. Journal of King Saud University - Science, 34(1), 101653. [CrossRef]