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Heavy Metal Concentration in Fishes from the Coastal Waters of Kapar and Mersing, Malaysia

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Abstract

Although fish is a significant source of protein, they are currently affected by rapid industrialization and mechanized agricultural activities, resulting in increased concentrations of heavy metals in fishes. Concentrations of heavy metals, namely, Cd, Cu, Mn, and Zn, were estimated in the muscle, liver, and gills of two commercially important marine fishes, namely, *Arius thalassinus* and *Johnius belangeri*. The fish samples were collected from Kapar and Mersing, which are the west and east coastal waters of Peninsular Malaysia, respectively. The results showed that the muscle had the lowest metal concentrations compared with the liver and gills. Among the estimated heavy metal concentrations, those of Zn and Cd were the highest and the lowest, respectively, for both species in muscle, liver and gills. Moreover, our results indicate that *A. thalassinus* has higher metal concentrations than *J. belangeri* in both areas. None of the values in the muscles exceeded the standard guideline values and hence would not pose any health hazard to consumers.

Keywords: Brackish water, heavy metals, *Arius thalassinus*, *Johnius belangeri*, risk factor.

Introduction

Rapid industrialization and economic development in Malaysia has resulted in increased water pollution in the coastal areas. This issue has been the focus of numerous studies. Pollutants deposited into water cause serious changes which in turn directly or indirectly affect the ecological balance of the environment, creating extensive damage and even mass mortality to the life and activities of aquatic organisms because of their high toxicity and accumulative behavior (Matta *et al*., 1999). Heavy metal contamination of the coastal environment continues to attract the attention of environmental researchers because of its increasing input to coastal waters, especially in developing countries. In fact, in recent decades, industrial and urban activities have contributed to the increase of heavy metal contamination in the marine environment and have directly influenced coastal ecosystems (Ong and Kamaruzzaman, 2009).

Heavy metals can enter the food web through direct consumption of water or organisms or through uptake processes and be potentially accumulated in edible fish (Paquin *et al*., 2003). For instance, metals such as Cu and Zn are essential for fish metabolism whereas others, such as Cd, have no established role in biological systems (Canli and Atli, 2003). These heavy metals may reach a toxic concentration level that can potentially destroy the ecological environment (Agusa *et al*., 2005, 2007; Hajeb *et al*., 2009). The rate at which this effect is pronounced greatly depends on the industrialization level and the use of mechanized agricultural activities as well as on uncontrolled urbanization along the coastal areas (Zheng *et al*., 2008). Subsequently, these anthropogenic activities have increased the release of harmful heavy metals into the aquatic environment (Agusa *et al*., 2005, 2007; Hajeb *et al*., 2009). The disposition of these toxic metals in Malaysian coastal areas has increased the uptake rate of those metals by aquatic organisms, such as fishes, consequently affecting humans through the food web (Agusa *et al*., 2005, 2007; Hajeb *et al*., 2009).

The intake rate of these heavy metals by humans through the consumption of fish causes serious health hazards (Puel *et al*., 1987; Luoma and Rainbow, 2008). The increased accumulation of heavy metal levels in the aquatic environment is disastrous to aquatic organisms and humans alike (Uluturhan and Kucuksezgin, 2007; Naji *et al*., 2010) and has been progressing in a number of countries, including Malaysia (Naji *et al*., 2010). As a result of the hazards associated with the consumption of heavy metals, their concentration in commercial fishes in Malaysia should be periodically examined to evaluate the possible risks associated with the consumption of contaminated fish (Cid *et al*., 2001).

Fish is a rich source of protein and is also a leading source of income in Malaysia (Agusa *et al*., 2007; Hajeb *et al*., 2009). Currently, fish is considered one of the most important foods to humans and is used in a variety of diets; it is a good source of digestible protein, vitamins, minerals, and polyunsaturated fatty acids (Carvalho *et al*., 2005) which support healthy living (Ikem and Egiebor, 2005). However, fishes are good indicators of heavy metal contamination in aquatic systems because they occupy different tropic levels and are of different sizes and ages (Burger *et al*., 2002). The heavy metal intakes by fish in a polluted aquatic environment vary depending on ecological requirements, metabolisms, and other factors, such as salinity, water pollution level, food, and sediments. Fish accumulates metals in its tissues through absorption, and humans can be exposed to these metals via the food web. The consumption of contaminated fish causes acute and chronic effects to humans (Nord *et al*., 2004). Although a number of studies have investigated heavy metal concentrations in fishes in other parts of Malaysia (Babji *et al*., 1979; Sivalingam and Sani, 1980; Law and Singh, 1991; Sin *et al*., 1991; Ismail *et al*., 1995; Yap *et al*., 2002, 2004; Agusa *et al*., 2005, 2007; Kamaruzzaman *et al*., 2010), no research has been conducted on Cd, Cu, Mn, and Zn concentration in commercially important marine fishes (*Arius thalassinus* and *Johnius belangeri*) in the coastal waters of Kapar and Mersing.

In the present study, the marine coastal waters in Kapar and Mersing were selected because of economic and strategic factors. Economically, Kapar is a potential breeding ground for fishes; strategically, many sources of pollution are found around this area, such as an electric power station which uses coal and discharges polluted pre-used water into the surrounding waters of Kapar (Mohamed *et al*., 2006). The wastage of agriculture, industrialization, and urbanization along the coasts of Kapar and Port Klang likewise adds to the volume of pollution to this area. In Mersing and the nearby offshore islands, such as Pulau Tioman, fishing is a key local industry. However, Mersing is less industrialized compared with Kapar; therefore, the sources of heavy metal accumulation could be limited to ship and boat transports.

The muscles of the fish collected from Kapar and Mersing were analyzed based on their metal intake in the liver, given that the tissue specializes in metal storage and detoxification (Kotze *et al*., 1999). The gills of the fish were analyzed because they are an uptake site of waterborne ions, where metal concentrations increase at the beginning of exposure before entering other parts of the body (Jezierska and Witeska, 2001). Cu and Cd were selected because of their close association with anthropogenic activities; Mn and Zn were chosen because of their abundance in marine organisms.

In the present study, the concentrations of heavy metals (i.e., Cd, Cu, Mn, and Zn) in the muscle, liver, and gills of two commercially important fishes, namely, *A. thalassinus* and *J. belangeri*, from the coastal waters of Kapar and Mersing were estimated. Moreover, the permissible limit of these heavy metals via fish consumption was discussed.

Materials and Methods

Reagents

All reagents used in the present study were of analytical grade and consisted of nitric acid (65% v/v) and hydrogen peroxide (30% v/v) (Merck, Darmstadt, Germany). Standard stock solutions of Cd, Cu, Mn, and Zn with concentrations of 1,000 mg/L were prepared by diluting 1 mL of each single element stock in the combination list to 100 mL with deionized distilled water that contains 1% (v/v) nitric acid. Prior to the experimental process, the apparatus was sterilized by soaking it for approximately 24 h in diluted nitric acid (10% v/v); afterwards, the apparatus was rinsed with deionized water.

Apparatus

This study used the PerkinElmer Elan 9000 inductively coupled plasma mass spectrometer (ICP-MS, USA). After calibrating the instrument by using standard solutions derived from commercial materials, the system was optimized based on the recommendation of the manufacturer. The analytical conditions for the analysis of heavy metals with the use of ICP-MS are described in Table 1.

Study Area

To understand the bioavailability of heavy metals and assess their potential impact on aquatic biota, fresh fish samples were collected directly from local fishermen in selected areas in Kapar near the Sultan Abdul Aziz electric power station on the west

Table 1. Operating parameters for the Inductively Coupled Plasma Mass Spectrometery

Parameters	Condition
RF Generator	40MHz
RF Power	1000 W
Spray Chamber	Ryton Scott
Nebulizer	Cross-Flow
Plasma gas flow	15.0 L/min
Auxiliary gas flow	1.0 L/min
Nebulizer gas flow	0.60 L/min
Sampler & skimmer cone	Nickel
Sweeps/Reading	20
Reading/Replicates	3

coast and Mersing on the east coast of Peninsular Malaysia (Figure 1) on December 2009.

Collection and Digestion of Fish Samples

The two selected species of fish examined in this study were a non-scaled fish (i.e., *A. thalassinus*) and a scaled fish (*J. belangeri*). The samples were collected directly from local fishermen and were kept in a cool box for metal analysis. The total length (cm) and weight (g) of both species were measured before dissection. The samples were dissected; the muscle, liver, and gills of the fishes were separated and dried in an oven at 80°C until constant weight was obtained. Afterwards, 0.5 g of the homogenized samples of muscle and gills as well as 0.1 g of liver were digested in triplicate with HNO_3 (65% v/v) and H_2O_2 (30% v/v) in Teflon vessels placed in a microwave oven digestive system (Start D Microwave Digestive System) using the microwave digestion program. Microwave digestion is used instead of classical methods because of its shorter time, less acid consumption, and ability to retain volatile compounds in the solutions (Gulmini *et al*., 1994; Krushevska *et al*., 1993). The residues were filtered by using a 0.45 µm Whitman filter paper and were then transferred to a 50 mL volumetric flask. Afterward, the residues were diluted to the same level with deionized water for muscle and gills and to 25 mL for liver. The dilution with deionized water for liver samples (25 mL) was less than that for muscle and gills samples (50 mL) because the amount of the digested liver samples (0.1 g) was less than that of the muscle and gill samples (0.5 g).

Chemical Analysis

Mn, Cu, Zn, and Cd concentrations were measured by using PerkinElmer Elan 9000 ICP-MS (USA) (Agusa *et al*., 2007; Kamaruzzaman *et al*., 2011). The results were expressed in micrograms of metal per gram of dry fish (µg/g dry weight).

Validation of Analytical Methods

The precision of the applied analytical method was validated through accurate analysis of the standard reference material (SRM2976, freeze-dried muscle tissue, National Institute of Standards and Technology, USA). All the analyses were carried out in triplicate. As presented in Table 2, the results obtained on the SRMs are consistent with the certified values for all metallic elements. The recovered values of all the metals ranged from 83% to 104% of the certified value.

Limit of Detection (LoD)

The instrument LoD was calculated as the concentration was associated with thrice the standard deviation of the background noise recorded on seven measurements of the procedural blank (Mendil *et al*., 2010). Table 2 shows the detection limit (µg/g) of the four heavy metals and the FDA-recommended health criteria concentrations (µg/g) of five metals in seafood (Swami *et al*., 2001).

Limit of Quantification (LoQ)

The instrument LoQ was calculated as the concentration was associated with 10 times the standard deviation of the background noise (Djedjibegovic *et al*., 2012). The methods LoD and LoQ were calculated in a similar way by using real sample digest with concentrations of metals in the range of one to five times the instrument LoD.

Figure1. Map showing the study areas. Black circle (●) denotes sampling site.

Statistical Analysis

One-way ANOVA was performed to test the differences between the two species, and Duncan test was used to determine the difference among stations. The *P*-value was considered statistically significant at $P<0.05$. The statistical analysis was performed by using SAS (Version 5.0, SAS Institute, Cary, NC, USA).

Results and Discussions

Heavy Metal Contents in Various Organs of Fish

The metal concentrations and the corresponding mean standard deviations (expressed as µg/g dry weight) were measured in the muscle, liver, and gills of the two species of fish from Kapar and Mersing, and the results are summarized in Tables 3 and 4, respectively. The mean length and weight of *A. thalassinus* ranged from 26 cm to 34 cm and from 230 g to 450 g, respectively; those for *J. belangeri* ranged from 20 cm to 22 cm and from 70 g to 100 g, respectively. The variance reveals that the mean concentrations of metals among the organs of each species were significantly different ($P<0.05$), except for Cd. Among all the studied elements, Zn had the highest concentrations in the three organs of the analyzed species from both areas. Furthermore, metal accumulation in liver and gills was higher than that in the muscle. This finding is in agreement with previous reports by Al-Yousuf *et al*. (2000), Canli and Atli (2003), and Monday and Nsikak (2007). However, Zn is essential micronutrients which comprises nearly 300 enzymes in marine organisms and is responsible for certain biological functions that require relatively higher Zn (Heath, 2000). Zn is also critical for aquatic organisms, including fishes; however, Zn becomes poisonous when it exceeds its maximum value. Many researchers have stated that dietary Zn is the

Table 2. Method detection limits of heavy metals, health-criteria levels (µg/g) and recovery of metals in the mussel tissue certified reference material (SRM2976)

Metals	Limit of Detection (µg/g)	*Health-criteria levels (µg/g)	Recovery (%)
Mn	0.94	_	095
Cu	0.26	120	104
Zn	1.40	480	084
Cd	0.02	004	083

*FDA recommended health-criteria concentrations (µg/g) (Swami *et al*., 2001)

Table 3. Metal levels in different organs of fish samples collected from Kapar, and metal permissible limits by different authorities.

	Species	Organ	Metal levels ± SD (µg g⁻¹ dry wt.)			
			Zn	Cu	Mn	Cd
	A.thalassinus	Muscle	20.54±1.15	1.21±0.14	0.62±0.07	0.058±0.01
		Liver	290.8±21.2	33.44±18	10.45±0.98	0.30±0.10
		Gills	498.2±13.0	2.17±0.11	79.08±5.10	0.05±0.02
	J. belangeri	Muscle	18.27±0.40	0.66±0.05	0.54±0.07	0.055±0.01
		Liver	51.55±1.90	7.87±0.42	5.09±0.54	0.58±0.04
		Gills	73.18±6.80	1.76±0.13	20.70±0.84	0.09±0.01
Authorities	FAO/WHO*		150	10	5.4	0.2
	MFR**		100	30	NP	1

* FAO/WHO (1984) / **Malaysian Food Regulation (MFR, 1985) / NP means no permissible limits in MFR

Table 4. Metal levels in different organs of fish samples collected from Mersing and metal permissible limits by different authorities.

	Species	Organ	Metal levels ± SD (µg g⁻¹ dry wt.)			
			Zn	Cu	Mn	Cd
	A.thalassinus	Muscle	30.21±9.60	1.56±0.12	0.92±0.07	0.027±0.01
		Liver	409.6±13.50	55.87±2.3	6.21±0.25	13.35±1.50
		Gills	739.6±43.50	3.60±0.24	28.24±1.80	0.08±0.02
	J. belangeri	Muscle	13.12±0.76	0.95±0.07	0.97±0.12	0.04±0.02
		Liver	56.30±1.30	13.50±0.6	5.69±0.12	0.47±0.20
		Gills	55.40±2.60	1.96±0.37	16.01±3.70	0.076±0.03
Authorities	FAO/WHO*		150	10	5.4	0.2
	MFR**		100	30	NP	1

* FAO/WHO (1984) / **Malaysian Food Regulation (MFR, 1985) / NP means no permissible limits in MFR

fundamental reason for increased Zn in marine fish (Xu and Wang, 2002).

For the fish samples from Kapar, the Zn concentrations in the muscles of *J. belangeri* and *A. thalassinus* were 18.27 µg/g and 20.54 µg/g, respectively, as shown in Table 3. Meanwhile, for the fish samples from Mersing, the Zn concentrations in the muscles of *J. belangeri* and *A. thalassinus* were 13.12 µg/g and 30.21 µg/g, as shown in Table 4. In addition, the Zn concentrations in the tissues of the fish samples from Mersing (east coast) were higher than those from Kapar (west coast); however, the concentrations varied significantly. For the fish samples from Kapar, the concentration of Zn in the livers of *J. belangeri* range from 51.55 µg/g in *J. belangeri* to 56.30 µg/g, whereas that of *A. thalassinus* ranged from 290.8 µg/g to 409.6 µg/g. Meanwhile, for the fish samples from Mersing, the Zn concentrations in the gills were 55.40 µg/g in *J. belangeri* and 739.2 µg/g in *A. thalassinus*, which indicates that the Zn concentration in the gills of these samples was higher than that in the liver. Moreover, high Zn concentrations were observed in the liver (409.6 µg/g) and gills (739.2 µg/g) of *A. thalassinus.* A similar study by Kamaruazzaman *et al.* (2010) on fishes from Pahang estuary indicated that the varying levels of heavy metals in different fish species could be the result of ecological needs, metabolism and feeding patterns (Yilmaz, 2003), and behavior and body size (Tuzen, 2003). The Zn concentrations reported in Malaysian marine fishes ranged from 15.40 µg/g to 60.10 µg/g and from 27.10 µg/g to 953.0 µg/g in the muscles and livers, respectively (Agusa *et al*., 2005). According to a study conducted in Langkawi Island, Malaysia, all fish species had higher Zn concentrations compared with other metals, and the Zn concentration in muscles ranges from 34.33 µg/g to 49.39 µg/g (Irwandi and Farida, 2009).

The Zn concentrations in the muscles of fish samples reported in the literature from other parts of the world, such as those of marine culture fishes collected from Hong Kong (20.1 µg/g to 68.3 µg/g, dry weight) (Wong *et al*., 2001) and those of different marine fish species captured from Tuzla Lagoon, Turkey (16.48 µg/g to 37.39 µg/g) (Dural *et al*., 2007), were higher than those reported in the present study. Moreover, the Zn concentrations in the livers and gills (61.5 µg/g to 174.1 µg/g and 75.4 µg/g to 116.2 µg/g, respectively) of marine culture fishes collected from Hong Kong (Wong *et al*., 2001) and those of different marine fish species captured from Tuzla Lagoon, Turkey (21.7 µg/g to 99.8 µg/g and 24.1 µg/g to 50.5 µg/g, respectively) (Dural *et al*., 2007) were higher than those found in *J. belangeri* in the current work; however, Zn concentrations in liver and gills of *A. thalassinus* were higher than its concentrations in the same organs of marine culture fishes collected from Hong Kong and (Wong *et al*., 2001) and from Northeast Mediterranean Sea (Canli and Atli, 2003). Furthermore, the Zn concentrations in the muscles of different marine fishes harvested from Aqaba Gulf, Red Sea, Jordan (10.61 µg/g to 21.38 µg/g, dry weight) (Ismail and Ahmed, 2008) were approximately similar to those reported in the present study.

Cu is an essential element that is carefully regulated by physiological mechanisms in most organisms (Erdoğrul and Ates, 2006). However, it poses potential hazards that endanger both animal and human health. Cu can be found in a natural environment and is essential for the normal growth and metabolism of all living organisms (Eisler, 1998). However, it becomes toxic at high concentrations. The proposed permissible daily dose of Cu for adults is 0.05 µg/g body weight (NRC, 1980) for a man with a body weight of 70 kg. Cu concentration in humans can increase by consuming contaminated fishes. In the present study, the Cu concentrations in the muscle of fishes from Kapar were 0.66 µg/g in *J. belangeri* and 1.21 µg/g in *A. thalassinus*; the Cu concentrations in the liver were 7.87 µg/g in *J. belangeri* and 33.44 µg/g in *A. thalassinus*; and the Cu concentrations in the gills were 1.76 µg/g in *J. belangeri* and 2.17 µg/g in *A. thalassinus.*

In Mersing, the mean Cu concentrations in the muscle were 0.95 µg/g in *J. belangeri* and 1.56 µg/g in *A. thalassinus;* the mean Cu concentrations in the liver were 13.50 µg/g in *J. belangeri* and 55.87 µg/g in *A. thalassinus*, and; the mean Cu concentrations in the gills were 1.76 µg/g in *J. belangeri* from Kapar and 3.60 µg/g in *A. thalassinus*. The Cu concentrations in the muscle and liver of fishes from Malaysian marine coastal waters were reportedly 0.86 µg/g to 3.48 µg/g and 2.62 µg/g to 29.0 µg/g, respectively (*Agusa et al*., 2005). The maximum permissible limit for Cu according to Malaysian Food Regulations (1985) and the Food and Agriculture Organization of the United Nations (FAO) (1984) was 30 µg/g and 10 µg/g, respectively (Table 4). The Cu concentrations reported in the present study are generally in agreement with those in the literature. However, our findings showed that mean Cu concentrations in the fish samples from Mersing were higher than those from Kapar. This result is in accordance with those reported by Agusa *et al*. (2005) on big-eye scads found in the east coast of Malaysia Peninsular. They found that the Zn and Cu concentrations in the big-eye scads from the east coast of Malaysia Peninsular were significantly higher than those in the fish samples from the west coast of Malaysia (Strait of Malacca). In the present study, the Cu concentrations in the muscle, liver, and gills of *A. thalassinus* and *J. belangeri* were lower than those found in a study on fishes collected from the Northeast Mediterranean Sea (i.e., from 2.19 µg/g to 4.41 µg/g, from 18.18 µg/g to 202.8 µg/g, and from 5.02 µg/g to 14.64 µg/g, respectively) (Canli and Atli, 2003). Meanwhile, the Cu concentrations in the muscle and liver of the fish samples in the current study were higher than those reported in a study on different marine fish species captured from Tuzla Lagoon, Turkey (i.e., from 0.26 µg/g to 0.82 µg/g and from 0.35 µg/g to 12.03 µg/g, respectively, (Dural *et al.*, 2007).

Mn is an essential element for both animals and plants, and Mn deficiency results in severe skeletal and reproductive abnormalities in mammals (Sivaperumal *et al*., 2007). For the fish samples from Kapar, the Mn concentrations in the muscle were 0.54 µg/g in *J. belangeri* and 0.97 µg/g in Mersing. The Mn concentrations in the liver of the fish samples from Kapar were 5.09 µg/g in *J. belangeri* and 10.45 µg/g in *A. thalassinus*, whereas those in the gills were 16.01 µg/g in *J. belangeri* from Mersing and 79.08 µg/g in *A. thalassinus* from Kapar. The Mn concentrations were lower in the muscle than in the liver and gills. According to previous literature, the Mn concentrations in the muscle of fish samples from marine coastal water in Malaysia ranged from 0.21 µg/g to 0.61 µg/g (Agusa *et al*., 2005), those in the liver of marine fishes from Turkish coastal waters ranged from 0.72 µg/g to 7.33 µg/g (Tepe *et al*., 2008), those in the liver of fishes from the Marmara, Aegean, and Mediterranean seas ranged from 0.55 µg/g to 5.40 µg/g (Turkmen *et al*., 2008), and those in the livers and gills of fishes from the Aqaba Gulf, Red Sea, Jordan, ranged from 3.41 µg/g to 5.55 µg/g and from 6.49 µg/g to 22.33 µg/g, respectively (Ismail and Ahmad, 2008); these Mn concentrations were lower than those in the present study. Meanwhile, the Mn concentrations in the liver of fishes from the marine coastal waters of Malaysia ranged from 0.69 µg/g to 12.30 µg/g (Agusa *et al*., 2005), those in the muscles of fishes found in Indian fish markets ranged from 0.14 µg/g to 3.36 µg/g (Sivaperumal *et al*., 2007), and those in the muscles of fish from the Aqaba Gulf, Red Sea, Jordan ranged from 0.93 µg/g to 1.03 µg/g (Ismail and Ahmad, 2008). Moreover, according to Kojadinovic *et al*. (2007), the Mn concentrations in the muscle (0.24 ± 0.23 µg/g) and liver (3.73 ± 0.72 µg/g) of swordfish as well as those in the same organs of yellowfin tuna (0.27 ± 0.11 µg/g and 5.16 ± 0.96 µg/g, respectively) collected from the northern part of the Mozambique Channel were higher than those reported in the present study. Meanwhile, the Mn concentrations in the muscle of fish samples from Langkawi Island, Malaysia ranged from 16.80 µg/g to 24.35 µg/g (Agusa *et al*., 2005), which is approximately similar with the findings of the current study.

High accumulation of heavy metals in the liver of fishes has likewise been reported in numerous studies (Honda *et al*., 1983; Agusa *et al*., 2005 and 2007); these studies suggested that the liver plays an important role in the metabolic processes of heavy metal in fishes. According to Kotze et al. (1999), among the different organs of fishes, the muscles are a primary part of metal intake, the liver is a tissue that specializes in metal storage and detoxification, and the gills are directly exposed to the surrounding environment. The high vulnerability of gills to toxic chemicals results primarily from the large surface area, which facilitates greater toxicant interaction and absorption and secondly due to the weaker detoxification system, which is not robust as that of the liver (Evans, 1987). Additionally, absorption of toxic chemicals through gills is rapid and therefore toxic response in gills is also rapid (Evans, 1987). Tables 3 and 4 shows that the permissible limit of heavy metals allowed in fish muscle from both sites were lower than the permissible safety levels for human consumption. Moreover, the finding presented in this study indicates that there are trends of higher Cu and Zn concentration in fishes from Mersing area (east coast) compared to Kapar (west coast). These results indicate that some sources of heavy metals contamination are present in the east side of the Peninsular Malaysia in spite of the relatively lower human activities.

Conclusion

Knowledge of heavy metal concentrations in fishes is important in order to regulate the consumption of fish. In this study, the highest metal concentrations were found in the liver and gills, while the muscle had less accumulation of heavy metals. The accumulation of metals in liver, gills and muscle was established and decreases in the order of Zn> Cu> Mn> Cd. The concentrations of Zn were the highest in all organs of two species from both study areas. Moreover, species from Mersing site have higher Zn and Cu concentrations than those from Kapar. The mean concentrations of heavy metals analyzed in the muscles of both species were lower than the maximum permitted concentrations recommended by FAO/WHO (1984), and Malaysian Food Regulation act (1985). The concentrations of these metals in muscle tissues of the samples were not risky to human health. These data provide a useful baseline to measure any future changes in local pollution.

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