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Assessment of Heavy Metal in Self-caught Saltwater Fish from Port Dickson Coastal Water, Malaysia

(Penilaian Logam Berat bagi Ikan Air Masin yang Ditangkap dari Perairan Port Dickson, Malaysia

SARVA MANGALA PRAVEENA* & CARYN LIEW SUET LIN

ABSTRACT

Freshwater fish has been studied and reported numerously. However, little attention has been made and limited studies available on local marine fish in Malaysia. Thus, in this study, concentrations of heavy metals (Cd, Cr, Pb and Cu) were studied in four major local marine fish Megalaspis cordyla *(hardtail scad),* Rastrelliger kanagurta *(Indian mackerel),* Selaroides leptolepis *(yellowstripe scad) and* Sardinella fimbriata *(fringescale sardinella). The study was also intended to estimate potential health risk assessment from these heavy metals to the consumption of fish and assess maximum allowable fish consumption rate. The range of heavy metal concentrations were 0.053-0.096 mg/kg for Cd, 1.16-2.34 mg/kg for Cr, 8.34-12.44 mg/kg for Pb and 1.40-3.21 mg/kg for Cu in four major self-caught saltwater fish. Heavy metal levels of Cd and Cu in the local marine fish from Port Dickson are below the limit enforced by Food Regulations (1985) while the levels of Cr and Pb have exceeded the limit. Potential health risks associated with Cd, Cr, Cu and Pb were assessed based on target hazard quotients. HQ values calculated for Cd, Cr and Cu were less than 1, thus indicate that no adverse effects while HQ values for Pb exceeded 1 for all the fish species assessed with the exception of* Megalaspis *spp. and* Sardinella *spp. Cr was the highest while Pb concentrations were the lowest in all the studied fish samples for maximum allowable fish consumption rate. A long term monitoring program is crucial to be done in coastal areas with high consumption of local marine fish along Port Dickson to obtain real consumption rates and other cofounders factors in local population.*

Keywords: Fish; health risks; heavy metal; marine

ABSTRAK

Ikan air tawar telah banyak dikaji dan dilaporkan. Akan tetapi sedikit tumpuan diberikan kepada ikan air masin tempatan. Oleh itu, penyelidikan ini mengkaji kepekatan logam berat (Cd, Cr, Pb dan Cu) dalam empat ikan air masin utama seperti Megalaspis cordyla *(cencaru),* Rastrelliger kanagurta *(ikan kembung),* Selaroides leptolepis *(selayang jalur kuning) dan* Sardinella fimbriata *(fringescale sardinella). Kajian ini juga bertujuan untuk menganggarkan potensi penilaian risiko kesihatan daripada logam berat kepada penggunaan ikan dan menilai kadar pemakanan ikan maksimum. Julat kepekatan logam berat adalah 0,053-0,096 mg/kg bagi Cd, 1,16-2,34 mg/kg bagi Cr, 8,34-12,44 mg/kg bagi Pb dan 1,40-3,21 mg/kg bagi Cu dalam empat ikan air masin utama yang ditangkap sendiri. Tahap logam berat Cd dan Cu dalam ikan air masin dari Port Dickson adalah di bawah had yang dikuatkuasakan oleh Peraturan-peraturan Makanan (1985) manakala tahap Cr dan Pb telah melebihi had tersebut. Potensi risiko kesihatan yang berkaitan dengan Cd, Cr, Cu dan Pb dinilai berdasarkan nisbah mudarat (HQ) yang ditetapkan. Nilai HQ yang dikira bagi Cd, Cr dan Cu adalah kurang daripada 1, sekaligus menunjukkan bahawa tiada kesan buruk manakala nilai HQ untuk Pb melebihi 1 untuk semua spesies ikan yang dinilai kecuali* Megalaspis *spp. dan* Sardinella *spp. Cr adalah yang tertinggi manakala kepekatan Pb adalah yang paling rendah dalam semua sampel ikan yang dikaji untuk dibenarkan bagi kadar pemakanan ikan maksimum. Satu program pemantauan jangka panjang adalah penting di kawasan pantai melibatkan ikan air masin di sepanjang perairan Port Dickson untuk mendapatkan kadar penggunaan sebenar serta faktor tambahan yang mempengaruhi kesihatan penduduk tempatan.*

Kata kunci: Ikan; logam berat; marin; risiko kesihatan

INTRODUCTION

Fish is often at the top and major part of aquatic food chain (Oyoo-Okoth et al. 2010; Taweel et al. 2013). As a crucial constituent of the human diet, fish contains high protein content with the presence of omega-3 fatty acids, fats and vitamins with several minerals (Taweel et al. 2013). Prolong consumption of contaminated fish with heavy metal could pose significant health risks. This is because fish can represent a major dangerous source of certain heavy metal (Bogut 1997; Zhuang et al. 2013). Fish have a tendency to accumulate heavy metal in a manner depending on their position in the food chain and their feeding habits. Top predators (piscivores fish) and species with high lipid contents have been shown to be the most sensitive indicators of environmental contamination with lipophilic compounds (Dusek et al. 2005; Fathi et al. 2012). The advantages of fish as bioindicators are they are long-lived and integrate fluctuations of pollutants over time, making a continuous monitoring of the presence of pollutants possible while also allowing for a spatial integration of pollutant data and they are easily sampled (Fathi et al. 2012).

Numerous investigations and monitorings have been carried out on heavy metal concentration in fish particularly in the last decade (Bogut 1997; Burger & Gochfeld 2005; Zhuang et al. 2013). However, most of the numerous investigations and monitoring were carried out in local marine fish (especially freshwater fish). However according to Burger and Gochfeld (2005), little attention has been directed towards local marine fish. People who eat local marine fish including freshwater fish make decisions about where to fish, the type to eat and the quantity to eat. There has been considerable attention in the media devoted to benefits, data and possible health risk information on local freshwater fish (Burger et al. 2013). Thus, focusing on limited information on local marine fish is necessary. This is because the public who consume local marine fish needs to know information on fish they ate and address concerns about health risks from consuming these types of fishes.

Port Dickson has become an area with major economic and domestic tourism destination (Praveena et al. 2011). Straits of Malacca have received a large of waste loadings from municipal, industrial, agricultural and shipping discharges (Chua et al. 1997). As Port Dickson facing the Straits of Malacca, Port Dickson sea received heavy metal pollution due to growth in tourism, shipping, small industries and urbanization (Schwartz 2005; Thanapalasingam 2005). Kadaruddin (1997) has stressed out that there are eighty two wastewater pipe lines discharge wastewater including sewage from hotels and houses directly into the sea in northern part of Port Dickson. These discharges lead to degradation of the marine water quality causing significant negative impacts on marine ecosystem in water and sediment quality and coral reefs in particular. On top of that, majority of the coastal waters were polluted by suspended solids, *E. coli* and oil and grease. The levels of heavy metal have also exceeded the Marine Water Quality Criteria and Standards (Department of Environment 2006). According to Gopinath et al. (2000) and Law et al. (1990), daily crude and refined oil handlings at the terminals, port as well as transportation of heavy maritime tanker in the Straits of Malacca would undoubtedly impacted on the water quality of Port Dickson coastal waters. Impacts of holiday maker activities, shipping, oil tankers, refineries, land reclaiming activities, coastal zone management construction and insufficient sewage water treatment are the most pressing environmental problems that have caused deterioration of water quality in Port Dickson (Law et al. 2002). Fishing is one of the major activities in Port Dickson. Coastal water of Port Dickson located on the western coast of Peninsular Malaysia is a potential fish breeding ground. To date, varied levels of heavy metal in fish samples in Malaysia were reported from various collection sites (Fathi et al. 2012; Hajeb et al. 2009; Irwandi & Farida 2009; Kamaruzzaman et al. 2010). However, there is a scarcity of reports on this similar study in literature for local marine fish.

Bearing this in mind, a study was arranged to investigate heavy metal in local marine fish in Port Dickson. The present study was designed to determine heavy metal concentrations (Cadmium (Cd), Chromium (Cr), Lead (Pb) and Copper (Cu)) in local marine fish from Port Dickson coastal water. The study was also intended to estimate potential health risk assessment from these heavy metals to the consumption of fish and assess safe dietary intake of these metals and fish. The output of this study will provide vital quantitative information on health risk and maximum allowable fish consumption rate. This quantitative information will also minimize potential health risk in population especially those who consume local marine fish in coastal areas.

Materials and Methods

Questionnaire

The questionnaire was used to determine the socio demographic information, fish consumption information and health effects of exposure to heavy metals. Each participant that fulfilled the inclusion criteria was interviewed using questionnaire as a guide. The inclusion criterion for respondents was adult above 18 years old residing in Port Dickson consuming fish caught directly from the water of Port Dickson. The questionnaire contains information such as age, body weight, duration of residence and fish consumption (frequency and quantity of consumption). The participants were also asked to list down the local marine fish species most consumed. The questionnaire used was subjected to face validation to ensure its validity. The questionnaire was tested with Cronbach's Alpha Test to ensure its reliability with coefficient (alpha) of 0.70.

Sampling Locations

Port Dickson coastal water was selected for the collection of most consumed caught local marine fish species which obtained from questionnaire survey. The most consumed caught local marine fish species are *Megalaspis cordyla* (Linnaeus 1758), *Rastrelliger kanagurta* (Cuvier 1816), *Selaroides leptolepis* (Cuvier 1833) and *Sardinella fimbriata* (Valenciennes 1847). Local names for these fish are *Megalaspis* spp (hardtail scad), *Rastrelliger* spp (Indian mackerel), *Selaroides* spp (yellowstripe scad) and *Sardinella* spp (fringescale sardinella). The fish species were purchased directly from local fishermen when they are back from fishing activities from Port Dickson coastal water (Figure 1). Total weight and fork length of each captured local marine fish were measured to the nearest millimeter and gram, respectively, before dissection and analysis. The fish weight ranged from 48 to 240 g and the fish fork lengths were between 13 and 27 cm. The fish were washed using deionized water, kept in polyethylene bags and labelled. The fish were stored in ice box (-4°C) and immediately transported to the laboratory for further analysis.

SAMPLE PREPARATION AND ANALYSIS

The local marine fish samples were thawed to room temperature. The fish samples were beheaded; organs were removed; washed and filleted using sterilized stainless steel dissecting equipments. The fillets were dried in the oven at 90°C until constant weight was achieved. Before digestion, the dried samples were grinded and homogenized using porcelain mortar and pestle. A total of 1 g of the dried fish samples was digested with 10 mL of concentrated nitric acid (25%) as applied by Agusa et al. (2005), Ahmad et al. (2007) and Irwandi and Farida (2009). The mixture was heated at 40°C for one day. The residue was filtered with Whatman filter paper (0.45 μm) and diluted with nitric acid (0.25 M) to 25 mL. Analysis of metals (Cd, Cr, Pb, Cu) in samples was performed using flame atomic absorption spectrophotometer (F-AAS).

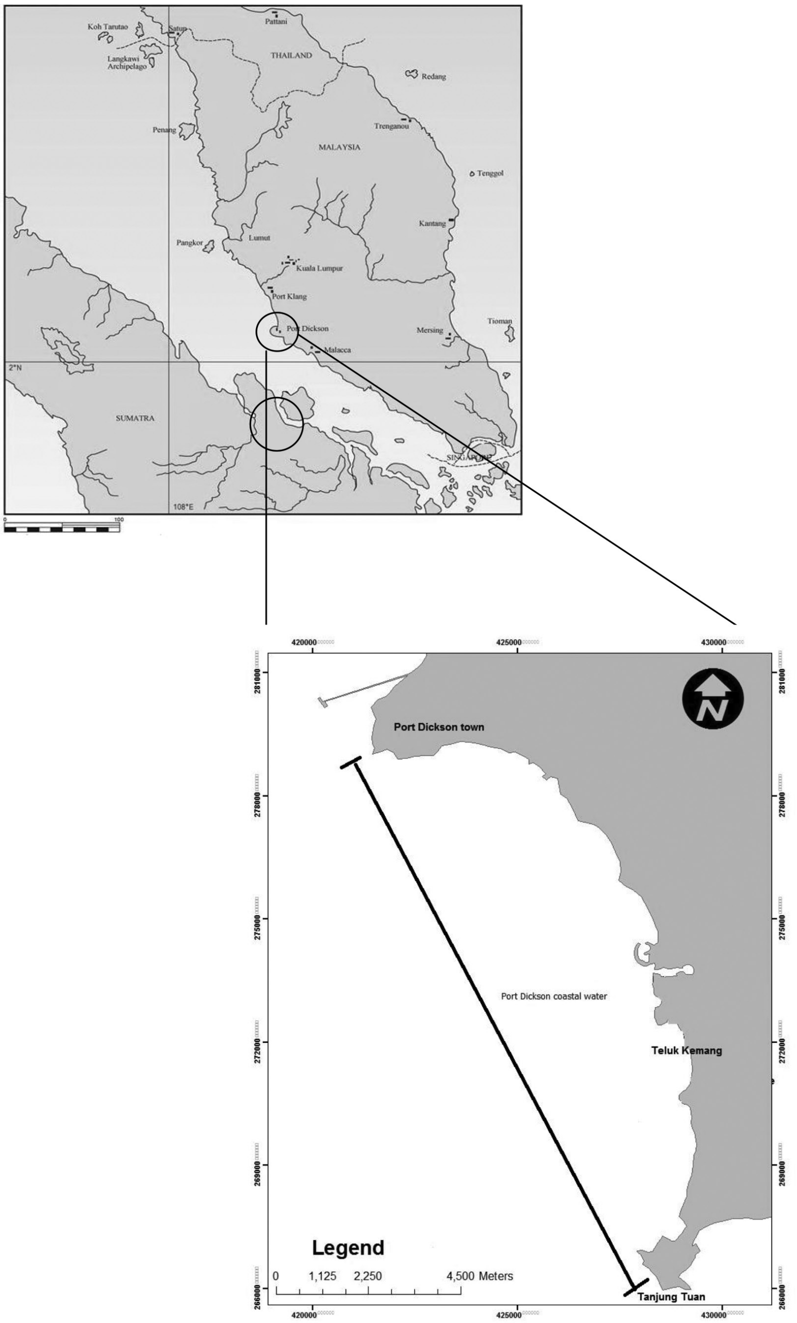

FIGURE 1. Study area showing Port Dickson coastal water

QUALITY CONTROL

The questionnaire used in this study was modified from guidance for identifying populations at risk from mercury exposure developed by WHO United Nations Environment Programme (UNEP) for heavy metal health risk assessment. The questionnaire was pre-tested among population that had similar characteristics with the study population. To ensure the analysis was performed correctly, triplicate of local marine fish samples were analyzed. A series of standard solutions was prepared from standard stock solution (1000 mg/L) to obtain the calibration curve. All reagents used in the study were of analytical grade. Deionized water was used throughout the study. All the glassware and plastic apparatus were soaked overnight in diluted nitric acid (10%) and rinsed with deionized water before using.

DATA ANALYSIS

Descriptive statistics was performed to obtained mean, maximum and minimum values using SPSS for windows (version 20) software. Potential health risk assessment estimation was adapted from Wang et al. (2005). This method had been used by various studies in assessing health risks of heavy metals to the general public through food consumption via Hazard Quotient values (Harmanescu et al. 2011; Wang et al. 2005). Safe dietary intake and maximum allowable fish consumption rate estimations were adapted from Taweel et al. (2013) using reference dose, body weight and measured concentration of heavy metal in edible portion of fish (fillet) values. One-way analysis of variance (ANOVA) was performed to test the effect of local marine species and heavy metal concentration.

ESTIMATION OF POTENTIAL HEALTH RISK ASSESSMENT

Fish is an important food source in Southeast Asia including Malaysia. Heavy metal intake via fish is a great concern as potential human health risk. In the estimation of potential health risk assessment, heavy metal data from fish samples were used. Hazard Quotients is a complex parameter used in estimation of potential health risks associated with long term exposure to chemical pollutants including heavy metal (Harmanescu et al. 2011). The following equation (1) was used in the estimation of potential health risk assessment adapted from Wang et al. (2005):

$$\text{Hazard Quotient (HQ)} = \frac{E_F E_D F_{IR} C}{R_{FD} W_{AB} T_A} \times 10^{-3}, \quad (1)$$

where E_F is the exposure frequency (from 365 days/year for people who eat fish seven times); E_D is the exposure duration (74.26 years, equivalent to average lifetime based on World Bank (2012); F_{IR} is the Food ingestion rate (160 g/person/day) (FAO 2005); C is the metal concentration in food (µg/day); R_{FD} is the Oral reference dose (mg/kg/day); W_{AB} is the body weight of each participant (61.85 kg obtained from questionnaire output) and T_A is the averaging exposure time for non-carcinogens (365 days × E_D).

The oral reference doses (RFD) for the heavy metals assessed in this study according to US EPA were as follow:

Cadmium: 1×10^{-3} mg/kg/day;
Chromium: 1.5 mg/kg/day;
Lead: 0.004 mg/kg/day and Copper: 4×10^{-2} mg/kg/day.

ESTIMATION OF MAXIMUM ALLOWABLE FISH CONSUMPTION RATE

For estimation of safe dietary intake, (2) was used and the results were expressed in kilogram of fish per day. Assumption that there are no other sources of Cd, Cr, Pb and Cu exist in the local people diet, safe dietary was calculated using (2). The safe dietary intake results indicated allowable fish consumption rate of the studied fishes. These safe dietary intake values were multiplied by seven to obtain a safe weekly intake and converted to maximum safe number of monthly fish meals using (3) applied by Moreau et al. (2007).

$$CR_{lim} = (RfD \text{ X } BW/C_m) \times 7, \quad (2)$$

where CR_{lim} is the maximum safe daily consumption rate of the fish samples (kg/day); RfD is the reference dose for each heavy metal (mg/kg/day); BW is the body weight (kg) and C_m is the measured concentration of heavy metal in fillet fish (mg/kg).

$$CR_{mm} = (CR_{lim} \times T_{ap})/MS,$$

where CR_{mm} is the maximum allowable fish consumption rate (meals/month); CR_{lim} is the maximum safe daily consumption rate of the fish samples (kg/week); T_{ap} is the average time period in a month (4.3 week/month) and MS is the meal size, 227 g for adults and 114 g for children (USEPA 2000).

RESULTS AND DISCUSSION

QUESTIONNAIRE OUTPUT

The questionnaire was used to extract information such as age, body weight, duration of residence, fish consumption (frequency and quantity of consumption) and list of local marine fish species most consumed. Ninety nine people participated in this study with (40/99) male and (59/99) female. The age range for total respondents is 18 to 59 years old with the mean age of 36.68. Weight of the respondents is within the range of 45 to 86 kg with the mean weight of 61.85 kg. The range for duration of residence in Port Dickson among the respondents is 1 to 59 years with the mean duration of 13.64 years. For fish consumption, out of 99 respondents, 67 respondents consumed fish daily. The remaining 32 respondents consumed fish sometimes (a meal per several days). The most consumed caught local marine fish species are hardtail scad, Indian mackerel, yellowstripe scad and fringescale sardinella which purchased directly from local fishermen once they are back from fishing activities from Port Dickson coastal water.

CONCENTRATIONS OF HEAVY METAL IN LOCAL MARINE FISH SAMPLES

The highest concentration of Cd was observed in *Sardinella* spp (0.096±0.069 mg/kg) and lowest in *Megalaspis* spp (0.053±0.024 mg/kg) as in Table 1. Cr and Pb concentrations were not detected in *Megalaspis* spp. The level of Cr was highest in *Selaroides* spp (2.34±0.13 mg/kg), while the level of Pb was highest in *Rastrelliger* spp (12.44±1.66 µg/g). For Cu, the highest level was observed in *Sardinella* spp (3.21±0.91 µg/g) and lowest in *Megalaspis* spp (1.40±0.75 µg/g). Further details of the level of heavy metal in different fish species are in Table 1. The heavy metal in each studied fish species was compared with Permissible limits of Malaysian Food Regulations (1985) and FAO/WHO (1999). The levels were low and did not exceed the regulatory limit stated in Malaysian Food Regulations (1985).

ATSDR (2003) reported that Cd level in marine ecosystem is only in trace amount. Similarly, findings from local studies on coastal water fish reported lower range of Cd level in fish. Agusa et al. (2005) reported that the range of Cd mean concentration in Port Dickson was from 0.0042 to 0.010 mg/kg. Another study conducted in the Straits of Malacca reported that the range of Cd mean concentration was from 0.006 to 0.03 mg/kg (Alina et al. 2012). Based on the findings of this study, it was observed that the level of Cd in fish increased compared with the study done by Agusa et al. (2005). This could be an indicator of the pollution status in coastal water of Port Dickson. Cr was present in all of the analysed fish samples except in *Megalaspis* spp. Cr level was the highest in *Selaroides* spp with mean concentration value of 2.34 mg/kg, followed by *Sardinella* spp (1.42 mg/kg) and *Rastrelliger* spp (1.16 mg/kg). Cr levels were high and exceeded regulatory limit stated in the Malaysian Food Regulations (1985). There are limited local studies performed to determine the Cr concentration in local marine fish in Malaysia. A study by Agusa et al. (2005) reported that Cr level in fish from coastal water of Port Dickson was within the range 0.31 and 0.71 mg/kg. The findings from present study also showed an increment in Cr levels in fish samples from coastal water of Port Dickson. The range of mean concentration of Pb in the samples is 8.34 to 12.44 mg/kg. The highest concentration of Pb is in *Rastrelliger* spp (12.44 mg/kg) followed by *Selaroides* spp (10.18 mg/kg) and *Sardinella fimbriata* (8.34 mg/kg). Pb levels in all the fish species assessed (except *Megalaspis* spp*)* have exceeded regulatory limit of the Malaysian Food Regulations (1985). A study by Agusa et al. (2005) on fish from Port Dickson reported a Pb range from 0.027 to 0.054 mg/kg.

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TABLE 1. Heavy metal level recorded as means ± standard deviation (SD) in samples (n=12)

Common name	Mean values for level of heavy metal (mg/kg)			
	Cd	Cr	Pb	Cu
Megalaspis cordyla	0.05±0.02	ND	ND	1.40±0.75
Rastrelliger kanagurta	0.09±0.04	1.16±0.06	12.44±1.66	2.15±0.29
Selaroides leptolepis	0.07±0.04	2.34±0.13	10.18±1.60	2.46±0.48
Sardinella fimbriata	0.10±0.07	1.42±0.06	8.34±0.28	3.21±0.91
p values	<0.05	<0.05	<0.05	<0.05
Permissible limit (Malaysia)*	1	1	2	30
Permissible limits (FAO/WHO)**	0.1	-	0.2	3.0

* Malaysian Food Regulation (1985)
**FAO/WHO (1999)
ND= not detectable
p values are significant at the 0.05 level

(3.21 mg/kg) followed by *Selaroides* spp (2.46 mg/kg), *Rastrelliger* spp (2.15 mg/kg) and *Megalaspis* spp (1.40 mg/kg). Cu levels in all the fish samples did not exceed regulatory limit stated in the Malaysian Food Regulations (1985). Cu levels in most of the fish species assessed are consistent with the study conducted in coastal water of Pahang reported with mean Cu concentration of 2.88 mg/kg (Kamaruzzaman et al. 2010). The present study also found that Cu levels in local marine fish from Port Dickson have increased compared with Agusa et al. (2005) which reported mean Cu level of 1.96 mg/kg. Cu level was the highest in *Sardinella* spp (3.21 mg/kg) followed by *Selaroides* spp (2.46 mg/kg), *Rastrelliger* spp (2.15 mg/kg) and *Megalaspis* spp (1.40 mg/kg). Cu levels in all the fish samples did not exceed regulatory limit stated of the Malaysian Food Regulations (1985). Cu level in most of the fish species analyzed is consistent with the study conducted in coastal water of Pahang by Kamaruzzaman et al. (2010) with mean Cu concentration of 2.88 mg/kg. The present study has showed that Cu in local marine fish from Port Dickson has increased compared with findings by Agusa et al. (2005) which reported mean Cu level of 1.96 mg/kg.

Among all the heavy metal assessed, Pb was present in the highest level in all of the fish species followed by Cr, Cu and Cd. This is due to the high transfer factor of Pb compared with other heavy metal. According to Abdel-Baki et al. (2011), transfer factor for Pb from water to muscle of fish was highest followed by Cr, Cu and Cd. This indicated that bioaccumulation of Pb from water to muscle of fish is greater compared to other metals. Abdel-Baki et al. (2011) have showed that transfer factor was the highest for Pb compared with other heavy metal in fish species. Besides transfer factor, there are several factors that could affect the bio-accumulation of heavy metal in fish. The factors include water temperature, seasonal variation and body size of marine organism (Ray 1984). Accumulation of heavy metal in fish is also related with water temperature (Maimon et al. 2012). For example, Ray (1984) reported that Cd accumulation increases with gradual rise of water temperature. Carvalho et al. (2004) reported that accumulation of Cu increases with decreasing of temperature. This reflects the difference of heavy metal level in different fish species. Seasonal variation time include changes in temperature, it also plays a role in accumulation by affecting the temperature of water and also the body size of the marine organism. Other properties of water that can affect heavy metal accumulation in fish are water hardness, salinity and pH of water (Jezierska & Maágorzata 2006). Besides, concentration of heavy metal in local marine fish is dependent on size, weight and age of the marine organisms. Several studies conducted on fish from local coastal water found positive correlations between level of heavy metal in fish and the weight and fork length of fish (Fathi et al. 2012; Kamaruzzaman et al. 2010, 2008). Other factors that can affect the level of heavy metal in fish are sex of fish, sex biological cycle, behaviour and feeding habits, nutrient availability and habitats (Maimon et al. 2012).

POTENTIAL HEALTH RISK ASSESSMENT OUTPUT

If HQ more than 1 is obtained, potential health risk is related to the studied heavy metal (Taweel et al. 2013). The mean values of HQ calculated for Cd, Cr and Cu were below 1 for all fish species assessed, thus consumption of fish from study area poses no adverse effects of Cd, Cr and Cu (Table 2). Similarly, local study conducted by Agusa et al. (2005) which addressed health risk assessment of heavy metal via fish consumption also reported that the daily intake for Cd, Cr and Cu did not exceed the guidelines set by EPA. However, the mean HQ values of Pb exceeded 1 with mean HQ values of 2.75 and 2.73 through ingestion of *Rastrelliger kanagurta* and *Selaroides leptolepis*, respectively. This indicates possible adverse health effects associated with Pb through prolong consumption of fish.

The estimation of safe dietary intake (CR_{lim}) and maximum allowable fish consumption rate (CR_{mm}) are shown in Table 3. The Cr concentrations in all studied fish samples (except for *Megalaspis* spp) resulted in the highest maximum allowable fish consumption rates compared with other studied heavy metal. On the other hand, Pb concentrations were the lowest in all the studied fish samples (except for *Megalaspis* spp).

It is important to note that HQ must be used with caution. USEPA (1997) stresses that HQ value greater than 1 does not necessarily mean that adverse effects will occur. Apart from local marine fish, there are many other sources of heavy metal exposures such as from crops grown in contaminated land, contaminated drinking water and cigarette smoke (Department of Environment 2012; Zhuang et al. 2009). All these sources even in small amount could contribute to significant health risks of heavy metal in our daily life. Ngo et al. (2012) reported that the current WHO standard for Cd in rice (0.4 mg/kg rice) is unacceptable due to frequent consumption of large amount of rice in Vietnam. Thus, health risks should be estimated with cautious by taking into account frequency of exposure, the duration of exposure and individual characteristics such as body weight.

Due to the presence of heavy metal in different fish species, human consumers may ingest heavy metal with potential to cause adverse health effects. The specific consumption limit safe dietary intake and maximum allowable fish consumption indicated that it would be appropriate to minimize the weekly meals of the analyzed fish species, reduce the risk to fish consumers and avoid the chronic systemic effects due to studied heavy metal content. Therefore, the estimation limits of safe dietary intake and maximum allowable fish consumption will provide consumers with specific information (related to site, species and size) regarding the maximum amount of fish that can safely be consumed.

TABLE 2. Estimation of potential health risk and HQ values for caught saltwater fish species

Fish species	Mean values for HQ of heavy metal			
	Cd	Cr	Pb	Cu
Megalaspis cordyla	0.15±0.13	ND	ND	0.10±0.08
Rastrelliger kanagurta	0.08±0.07	$6.8\times10^{-4} \pm 6.0\times10^{-4}$	2.75±2.42	0.05±0.04
Selaroides leptolepis	0.07±0.08	$1.67 \times10^{-3} \pm 1.92\times10^{-3}$	2.73±3.13	0.07±0.08
Sardinella fimbriata	0.03±0.02	$3.03 \times10^{-4} \pm 5.05\times10^{-4}$	0.67±1.11	0.03±0.04

TABLE 3. Estimation of safe dietary intake (CR_{lim}) and maximum allowable fish consumption rate (CR_{mm}) for studied heavy metal in fish samples

Fish sample	Heavy metal	Mean concentration (mg/kg)	RfD (mg/kg/d)	Estimation of safe dietary intake, CR_{lim} (kg/week)	Maximum allowable fish consumption rate, CR_{mm} (meals/month)
Megalaspis cordyla	Cd	0.05	1×10^{-3}	37.23	0.16
	Cr	ND	1.5	ND	ND
	Pb	ND	0.004	ND	ND
	Cu	1.40	4×10^{-2}	53.19	0.23
Rastrelliger kanagurta	Cd	0.09	1×10^{-3}	20.69	0.09
	Cr	1.16	1.5	2407.35	10.61
	Pb	12.4	0.004	0.60	0.003
	Cu	2.15	4×10^{-2}	34.64	0.15
Selaroides leptolepis	Cd	0.07	1×10^{-3}	26.60	0.12
	Cr	2.34	1.5	1193.39	5.26
	Pb	10.18	0.004	0.73	0.003
	Cu	2.46	4×10^{-2}	30.27	0.13
Sardinella fimbriata	Cd	0.10	1×10^{-3}	18.62	0.08
	Cr	1.42	1.5	1966.57	8.66
	Pb	8.34	0.004	0.89	0.004
	Cu	3.21	4×10^{-2}	23.20	0.10

CONCLUSION

In conclusion, the range of heavy metal concentrations were 0.053-0.096 mg/kg for Cd, 1.16-2.34 mg/kg for Cr, 8.34-12.44 mg/kg for Pb and 1.40-3.21 mg/kg for Cu in four major local marine fish *Megalaspis* spp (hardtail scad), *Rastrelliger* spp (Indian mackerel), *Selaroides* spp (yellowstripe scad) and *Sardinella* spp (fringescale sardinella). All the studied heavy metal concentrations in fish samples have increased compared with previous studies done in Port Dickson coastal water. Heavy metal levels of Cd and Cu in the local marine fish from Port Dickson are below the limit enforced by the Malaysian Food Regulations (1985). However, the levels of Cr and Pb have exceeded the limit enforced by the Malaysian Food Regulations (1985). The HQ values calculated for Cd, Cr and Cu are less than 1, thus indicated that no adverse effects caused by Cd, Cr and Cu are expected as a result of consumption of fish from Port Dickson. However, moderate consumption of fish is recommended as the HQ values for Pb exceeded 1 for all the fish species assessed with the exception of *Megalaspis* spp and *Sardinella* spp. The maximum allowable fish consumption rate based on Cr was the highest while Pb concentrations were the lowest in all the studied fish samples (except for *Megalaspis* spp). This study has provide an important inputs on health risk and maximum allowable fish consumption rate. These inputs are crucial to provide information for minimizing the potential health risk in population especially those who consume local marine fish in coastal areas. A long term monitoring program is crucial to be done in coastal areas with high consumption of local marine fish along Port Dickson and the Straits of Malacca to obtain the actual consumption rates and other cofounders factors in local population. This is to understand the actual possibilities to develop health risk on consuming local marine fish. Furthermore, heavy metal that showed HQ more than 1 should be analysed further in terms of its speciation to make risk factor calculations specific ratio between inorganic and organic forms.

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Department of Environmental and Occupational Health
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
43400 Serdang, Selangor Darul Ehsan
Malaysia

*Corresponding author; email: smpraveena@gmail.com

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