

# Heavy Metal Concentrations in Fishes from Juru River, Estimation of the Health Risk

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Received: 1 October 2013 / Accepted: 23 December 2014 / Published online: 7 January 2015  
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**Abstract** This study examined the concentration of heavy metals in 13 fish species. The results indicated that shellfish species (clams) have the highest metal concentrations, followed by demersal and pelagic fishes. The mean concentration of metals in clams are Zn  $88.74 \pm 11.98$   $\mu\text{g/g}$ , Cu  $4.96 \pm 1.06$   $\mu\text{g/g}$ , Pb  $1.22 \pm 0.19$   $\mu\text{g/g}$ , Cd  $0.34 \pm 0.04$   $\mu\text{g/g}$  dry wt. basis, whereas the same measure in fish tissues was  $58.04 \pm 18.51$ ,  $2.47 \pm 1.21$ ,  $0.58 \pm 0.27$  and  $0.17 \pm 0.08$   $\mu\text{g/g}$  dry wt. basis. The concentrations of heavy metals in clams and fish tissues were still lower than the maximum allowable concentrations as suggested by the Malaysian Food Act (1983) and are considered safe for local human consumption.

**Keywords** Metals · Juru River · Hazard Quotient · Feeding habitats

Fish are the main supply of protein besides meat and poultry products and contribute to a large percentage of dietary protein globally. In most Asian countries, especially in south-east Asia like Thailand, Indonesia and Malaysia, fish is consumed as the main dish of the diet. Fish is particularly valuable for providing food with nutritional value in the form of protein, and minerals such as calcium, phosphorus, iron and copper. In addition, consumption of fatty fish is recommended by nutritionists as a means of preventing cardiovascular diseases (Domingo et al. 2007). Heavy metals are serious pollutants in our natural environment due to

their toxicity, persistence and bioaccumulation problems (Balachandran and Lalu 2005). In freshwater systems, fish is one of the aquatic products humans consume, and also provide a good indicator of trace element pollution. Copper and zinc are essential elements for growth and development and their uptake from the environment is regulated according to nutritional demand through homeostatic control (Couture and Rajotte 2003). However, Cu and Zn become toxic at concentrations above the limits of homeostatic control (McKim and Eaton 1978). Cadmium and lead are non-essential heavy metals that do not have dedicated regulatory mechanisms (Viarengo 1989) and are therefore more toxic to organisms. Some previous studies (Lim and Kiu 1995; DOE 2005) at various periods indicate that the Juru River Basin is grossly polluted by domestic wastes and discharges from pig farms. The objectives of this study are to determine the distribution of selected heavy metal concentrations (lead (Pb), zinc (Zn), cadmium (Cd) and nickel (Ni)) in 13 species of fish from the Juru River, Malaysia in based on living habitats, to estimate the health risk from these heavy metals related to the consumption of the edible parts (muscles) of fish and also to assess the safe dietary intake of these metals.

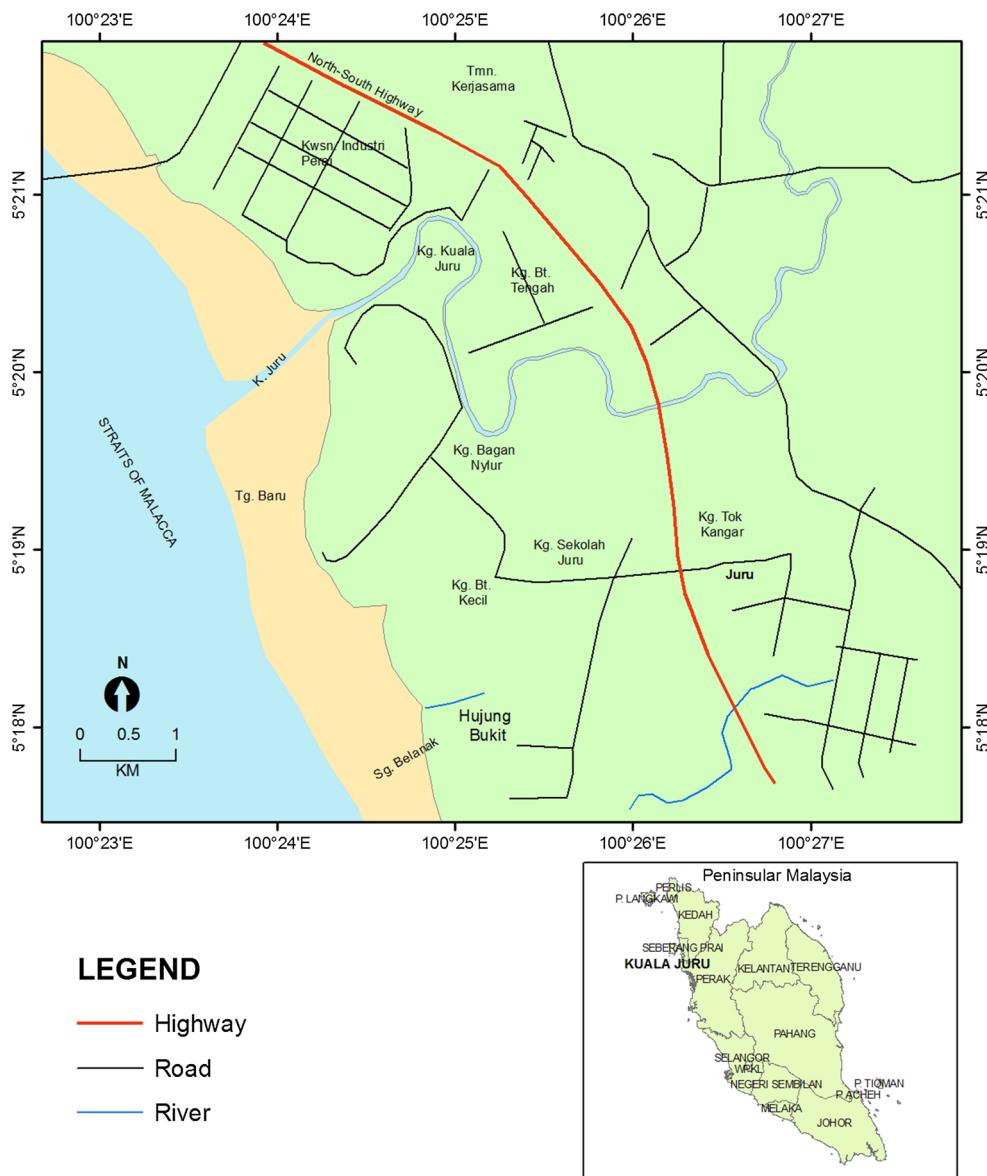
## Materials and Methods

The Juru River originates from the Bukit Mertajan hills located at  $05^{\circ}22$  N latitude and  $100^{\circ} 28$  E longitude, Penang in the north-eastern part of Malaysia (Fig. 1) and drains approximately 7.95 km long. The Juru River receives water from several small tributaries that flow through urban settings that are grossly polluted with industrial, agriculture and domestic wastes which are discharged directly into these rivers. Besides high levels of

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**Fig. 1** Map of the Juru River and sampling stations



**LEGEND**

- Highway
- Road
- River

organic loadings, these wastes are also contaminated with heavy metals (Lim and Kiu 1995).

Fish were randomly caught using the gill net and cast net. In the laboratory, the frozen samples were thawed at room temperature and dissected using stainless steel scalpels for analysis. Only tissues without bone were selected for extraction. Approximately 10 g of fish tissues of each sample were dried in an oven at 60°C for 2 days until dry weight was obtained (Nussey et al. 2000). The dry tissue samples were extracted with concentrated nitric acid (HNO<sub>3</sub>, 70 %) followed by perchlorid acid (HClO<sub>4</sub>) and digestion was done on the hot plate (Agemian et al. 1980). After extraction sample mixtures (of yellowish-colour) were then filtered through 0.45 µm pore size and filtrates were then analyzed using inductively coupled plasma (ICP) model Perkin Elmer/Elan 9000. The Operational parameter

**Table 1** Operational parameter settings used for the ELAN 9000 Perkin Elmer

Characteristics	Instrument condition
RF generator	40 MHz
RF power	1000 W
Spray chamber	Ryton scott
Nebulizer	Cross-flow
Plasma gas flow	15.0 L/min
Auxiliary gas flow	L/min
Nebulizer gas flow	0.60 L/min
Sampler and skimmer cone	Nickel

setting used for ELAN 9000 Perkin Elmer is given in Table 1 and shows the Operational parameter settings used for the ELAN 9000 Perkin Elmer. One-way analysis of

variance (ANOVA) was performed on all experimental data, and means were compared using Tukey's test with SPSS for Windows (version 18) software.

The confidence level was  $p < 0.05$ . The detection limits for the studied elements were 0.00004<sup>d</sup> mg/kg for Pb, 0.0003<sup>d</sup> mg/kg for Zn, 0.00009<sup>d</sup> mg/kg for Cd and 0.0002<sup>c</sup> mg/kg for Cu; where d means run on ELAN DRC in DRC mode in a class-100 clean room using PT cones and quartz sample introduction system, c means run on ELAN DRC in standard mode in a class-100 clean room using PT cones and the quartz sample introduction system. For comparison purposes, a reference site at Lake Chini, Pahang was chosen because this site has low concentrations of metals in fish.

For the quality assurance purpose in fish, standard reference materials were analysed prior to the analysis. The lobster sample (TORT-2) (National Research Council Canada) was used to confirm the recovery of digestion and analysis. Percentage of recoveries ( $n = 5$  for each metal) for certified and measured concentrations of those metals was satisfactory, with the recoveries being 80 for nickel, 90 for zinc, 96 for cadmium and 85 for copper. All experimental data were analysed using ANOVA, while the means of the two sampling times were compared using Tukey's test.

#### Assessment of Human Health Risk

The daily intake of an element from food consumption is dependent on the element concentration in food and amount of food consumed. Statistics have shown that the average age Malaysian consumes 160 g/day/person of marine fish daily (FAO 2009). From a human health perspective it is important to assess whether the metals pose a risk, especially in regions where fish can be a cheap and readily available source of protein. Oral reference doses (RfDs) of Pb 2 mg/kg body wt./day, Zn 300 mg/kg body wt./day, Cd 0.5 mg/kg body wt./day, Cu 40 mg/kg body wt./day have been published by the Joint FAO/WHO Expert Committee on Food Additives (JECFA 2003).

The following equation was used to estimate risk:

$$HQ = (FIR \times C) / (RfD \times WAB)$$

where HQ is chemical-specific Hazard Quotient (unitless); FIR is the fish ingestion rate (fish: 160 g/day/person) (FAO 2009); C is the metal concentration in the muscle of fishes (edible fish part) (mg/g); RfD is the oral reference dose (JECFA 2003); WAB is the average body weight (64 kg; the reference weights were derived from numerous local Malaysian studies (Lim et al. 2000). If the Hazard Quotient  $> 1.00$ , there is a potential risk related to the studied metal. Calculations of health risk from fish consumption for the non-carcinogenic metals (Pb, Zn, Cd and Cu) are shown in

Table 4. This calculation was made by assuming that the maximum studied fish consumption is seven times per week.

Calculation of the allowable daily consumption ( $CR_{lim}$ )

$$CR_{lim} = RfD \times BW / C_m$$

where  $CR_{lim}$  is the maximum safe daily consumption rate of fish (kg/day); RfD is reference dose for each heavy metal (mg/kg/day); BW is average consumer body weight (kg); and  $C_m$  is measured concentration of chemical in the edible part of fish (mg/kg). The RfD is determined by the US EPA and is an estimate of the daily intake of a contaminant over a lifetime that would not be expected to cause adverse health effects (US EPA 2000). The results of the calculation of the allowable studied fish consumption rates (kg/day) showed that the Pb, Zn, Cd and Cu-based allowable consumption rate of *Anadara granosa* from the Juru River was the lowest (0.47, 1.00, 0.46 and 2.10 kg/day, respectively). The allowable consumption rate of Cd and Cu was on the top in *Megalops cyprinoides* (3.20 and 8.83 kg/day respectively). Zinc in the *Lobotes surinamensis* fish species was associated with the highest allowable consumption rate of 3.89 kg/day, as shown in Table 2.

#### Results and Discussion

Details of 13 species of fish analysed in this study are given in Table 3, showing concentrations of four heavy metals, Pb, Cu, Zn and Cd, in the tissue of thirteen fish species from Juru River during two sampling occasions (December 2009 and April 2010); it reveals that the ranking order of mean concentration of the heavy metals in the fish tissues were Zn (64.86)  $>$  Cu (3.03)  $>$  Pb (0.72)  $>$  Cd (0.21)

**Table 2** Maximum allowable fish consumption rate (kg/day) for Pb, Zn, Cd and Cu in 13 fish muscle (edible part)

Fishes	Pb	Zn	Cd	Cu
<i>Plotosus canius</i>	1.28	2.14	1.07	5.33
<i>Valamugil cunnesius</i>	1.83	1.45	1.07	6.40
<i>Sillago chondropus</i>	2.13	1.18	0.64	8.26
<i>Psammoperca waigiensis</i>	0.58	2.55	0.80	2.98
<i>Oreochromis niloticus</i>	0.98	1.93	0.80	7.76
<i>Anadara granosa</i>	0.47	1.00	0.46	2.10
<i>Perna viridis</i>	0.56	1.09	0.53	3.08
<i>Cynoglossus bilineatus</i>	0.58	1.11	0.53	3.51
<i>Megalops cyprinoides</i>	1.60	1.39	3.20	8.83
<i>Lobotes surinamensis</i>	0.67	3.89	1.60	6.40
<i>platycephalus indicus</i>	1.07	1.26	3.20	3.76
<i>Nemapteryx caelatus</i>	1.16	1.78	1.07	2.27
<i>Oreochromis mossambicus</i>	1.60	1.51	1.60	7.53

(mean;  $\mu\text{g/g}$  dry weight) respectively. Zinc was detected in the range from 19.4 to 115, Cu from 1.24 to 6.89, Pb from 0.26 to 1.65, and Cd from 0.07 to 0.43  $\mu\text{g/g}$  on a dry wt. basis. Metal accumulation in the tissues of fish varies according to the rates of uptake, storage and elimination (Kalay and Canli 2000). This means that metals which have high uptake and low elimination rates in tissues of fish are expected to be accumulated to higher levels (Kalay and Canli 2000). According to living habitats the mean concentration of metals in shellfish species are (Zn 88.74  $\mu\text{g/g}$ , Cu 4.96  $\mu\text{g/g}$ , Pb 1.22  $\mu\text{g/g}$ , Cd 0.34  $\mu\text{g/g}$  dry wt. basis.), whereas in demersal fish tissues the value are 61.37, 2.80, 0.57 and 0.19  $\mu\text{g/g}$  on a dry wt. basis, respectively. The mean metals concentration in pelagic fish tissues are (Zn 49.70  $\mu\text{g/g}$ , Cu 1.66  $\mu\text{g/g}$ , Pb 0.60  $\mu\text{g/g}$ , Cd 0.13  $\mu\text{g/g}$  on a

dry wt. basis.). There are many factors that influence the rate of accumulation such as locality, type of food and living habitats (Boscolo et al. 2007). The *Anadara granosa* (cockle) accumulated the highest of all metals followed by *Perna viridis* (clam); this could be due to the fact that the habitat of *Anadara granosa* (cockles) that are living at the bottom of sea, in close proximity to the sediment where various kinds of hazardous and toxic substances are accumulated (Kamaruzzaman et al. 2011). According to Boscolo et al. (2007), bivalve mollusc species had a high capacity and propensity to concentrate pollutants. All studied metals varied significantly at ( $p < 0.05$ ) in demersal, pelagic and shellfish species. This is in agreement with Gale et al. (2004) who reported that Cu and Pb concentrations in muscle of bottom-feeding fish were higher than top-feeding fish. Sediment is well known to act as a sink for metal deposition and these metals are easily taken by demersal and shellfish fishes compared to the pelagic species. Similar results were obtained by Romeo et al. (1999) who pointed out that Cd concentration in tissues of pelagic fish species are lower than benthic fish species. All species of fish studied in this study were commercially consumed by people. Concentration of the metals in the reference site was 0.09  $\mu\text{g/g}$  dry weight for Pb, 0.92  $\mu\text{g/g}$  dry weight for Zn, 0.05  $\mu\text{g/g}$  dry weight for Cd, 0.09  $\mu\text{g/g}$  dry weight for Cu which were much lower than the results of this study. The metal concentrations in fish and clam tissues in this study were found to be lower than the maximum allowable concentration as listed in the Malaysian Food Act and is considered safe for local consumption. The Hazard Quotient (HQ) values of Pb, Zn, Cd and Cu in *Anadara granosa* (cockle) were the highest at 1.25, 0.76, 1.80 and 0.36 respectively, whereas the lowest HQ for Pb, Zn, Cd and Cu were observed in *Sillago*

**Table 3** Species of fish, numbers and trophic status from two sampling occasions

Fish species	n	Trophic status	Habitat
<i>Plotosus canius</i>	5	Carnivores	Demersal
<i>Valamugil gunnesius</i>	7	Omnivores	Demersal
<i>Sillago chondropus</i>	6	Carnivores	Demersal
<i>Psammoperca waigiensis</i>	8	Carnivores	Demersal
<i>Oreochromis niloticus</i>	9	Herbivores	Pelagic
<i>Anadara granosa</i>	25	Omnivores	Shellfish
<i>Perna viridis</i>	20	Omnivores	Shellfish
<i>Cynoglossus bilineatus</i>	4	Carnivores	Demersal
<i>Megalops cyprinoides</i>	6	Carnivores	Pelagic
<i>Lobotes surinamensis</i>	5	Carnivores	Pelagic
<i>Platycephalus indicus</i>	4	Carnivores	Demersal
<i>Nemapteryx caelatus</i>	5	Carnivores	Demersal
<i>Oreochromis mossambicus</i>	6	Omnivores	Pelagic

**Table 4** Mean concentrations and health risk estimates for Pb, Zn, Cd and Cu consumption from selected fish species in Juru River

Fishes	Mean Pb Conc. ( $\mu\text{g/g}$ )	HQ	Mean Zn Conc. ( $\mu\text{g/g}$ )	HQ	Mean Cd Conc. ( $\mu\text{g/g}$ )	HQ	Mean Cu Conc. ( $\mu\text{g/g}$ )	HQ
<i>Plotosus canius</i>	0.50 $\pm$ 0.08	0.62	43.03 $\pm$ 7.51	0.35	0.15 $\pm$ 0.01	0.75	2.34 $\pm$ 0.41	0.14
<i>Valamugil gunnesius</i>	0.35 $\pm$ 0.06	0.43	63.40 $\pm$ 1.11	0.52	0.15 $\pm$ 0.02	0.75	1.95 $\pm$ 0.21	0.11
<i>Sillago chondropus</i>	0.32 $\pm$ 0.05	0.40	78.47 $\pm$ 14.42	0.65	0.28 $\pm$ 0.05	1.4	1.52 $\pm$ 0.17	0.09
<i>Psammoperca waigiensis</i>	1.06 $\pm$ 0.04	1.25	36.23 $\pm$ 7.26	0.30	0.22 $\pm$ 0.05	1.1	4.15 $\pm$ 0.05	0.25
<i>Oreochromis niloticus</i>	0.67 $\pm$ 0.15	0.83	47.70 $\pm$ 2.95	0.39	0.22 $\pm$ 0.03	1.1	1.63 $\pm$ 0.21	0.10
<i>Anadara granosa</i>	1.34 $\pm$ 0.22	1.25	92.53 $\pm$ 12.29	0.76	0.37 $\pm$ 0.04	1.8	5.89 $\pm$ 0.62	0.36
<i>Perna viridis</i>	1.11 $\pm$ 0.07	1.25	84.95 $\pm$ 11.40	0.70	0.32 $\pm$ 0.02	1.6	4.03 $\pm$ 0.16	0.25
<i>Cynoglossus bilineatus</i>	1.07 $\pm$ 0.32	1.25	82.70 $\pm$ 0.166	0.68	0.30 $\pm$ 0.00	1.5	3.51 $\pm$ 0.26	0.21
<i>Megalops cyprinoides</i>	0.40 $\pm$ 0.02	0.50	66.17 $\pm$ 10.78	0.55	0.09 $\pm$ 0.01	0.45	1.42 $\pm$ 0.20	0.08
<i>Lobotes surinamensis</i>	0.92 $\pm$ 0.08	1.15	23.73 $\pm$ 5.56	0.19	0.10 $\pm$ 0.01	0.50	1.92 $\pm$ 0.15	0.11
<i>Platycephalus indicus</i>	0.62 $\pm$ 0.04	0.77	73.23 $\pm$ 4.85	0.60	0.08 $\pm$ 0.01	0.40	3.30 $\pm$ 0.12	0.20
<i>Nemapteryx caelatus</i>	0.57 $\pm$ 0.04	0.71	51.77 $\pm$ 4.39	0.42	0.18 $\pm$ 0.03	0.90	5.44 $\pm$ 1.03	0.33
<i>Oreochromis mossambicus</i>	0.41 $\pm$ 0.04	0.51	61.20 $\pm$ 4.48	0.50	0.10 $\pm$ 0.01	0.50	1.66 $\pm$ 0.34	0.10

*chondropus*, *Lobotes surinamensis*, *Platycephalus indicus* and *Megalops cyprinoides* at 0.40, 0.19, 0.40 and 0.08 respectively (Table 4). In all studied fish the Hazard Quotient is lower than 1.00 except for Pb and Cd in some fish species which means that consuming fishes from the Juru River could pose a health risk to the natives for these two metals. If the Hazard Quotient >1.00, there is a potential risk related to the studied metal. For maximum allowable fish consumption rates, the studied heavy metals in 13 fish species in the Juru River showed that there would not be expected to be any cause for negative health effects for humans.

## Conclusion

This study has identified the level of heavy metals such as Pb, Zn, Cd and Cu in fish and shellfish caught along the Juru River. All metals were present in all samples but values obtained were below permitted limits set by the Food Act 1983. In all studied fish the Hazard Quotient is lower than 1.00 except for Pb and Cd in some fish species which means that consuming fishes from the Juru River could pose a health risk to the natives for these two metals. If the Hazard Quotient >1.00, there is a potential risk related to the studied metal.

**Acknowledgments** We would like to acknowledge the Faculty of Science and Technology, National University of Malaysia and the Ministry of High Education in Libya for financial support and also the laboratory assistants for sampling and analysing the fish samples.

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