Heavy metals in marsh clam (*Polymesoda expansa*) and green mussel (*Perna viridis*) along the northwest coast of Sabah, Malaysia

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Abstract

Bivalves are known for their ability to accumulate contaminants such as heavy metals. This allows them to be widely used as bioindicator in monitoring of heavy metals in the marine environment. This study was conducted to determine the levels of heavy metals, namely Copper (Cu), Chromium (Cr), Nickel (Ni), Lead (Pb), Arsenic (As), Zinc (Zn) and Manganese (Mn) in marsh clams *(Polymesoda expansa)* and green mussels *(Perna viridis)* along the northwest coast of Sabah (Marudu Bay, Ambong Bay, and Mengkabong). The results showed that As (5.1 to 12.8 µg/g) and Mn (33.5 to 116.0 µg/g) concentrations in both marsh clams and green mussels collected from all the sampling stations along the northwest coast of Sabah were much higher than the permissible limit set by the Ministry of Health Malaysia and FAO/ WHO. Similarly, concentration of Zn (265.8 to 535.9 µg/g) in marsh clams from all the sampling areas and that of Cr (53.9 µg/g) in green mussel collected from Marudu Bay were also much higher than the permissible limits. The data also suggested that marsh clams accumulated higher Pb and Zn, whereas green mussels tend to contain higher concentrations of Cr, Cu and Ni. Since bivalves are an important protein source for the local population, a regular monitoring of all edible bivalve species should be conducted so that consumers can be advised about the toxicological and health risks due to consumption of bivalves.

Keywords: Heavy metals, Bivalves, Northwest coast, Sabah

Introduction

Bivalves are rich in omega-3 that can diminish cholesterol level and help in conditions causing coronary diseases, stroke and pre-mature birth (Daviglus et al*.,* 2002; Patterson 2002). They are also rich in protein, calcium, phosphorus, fluorine, and iodine, polyunsaturated and unsaturated fats, and insoluble vitamins which have hypocholesterolic impact against atherosclerosis or cardiovascular diseases (Ismail, 2005; Ikem and Egiebor, 2005). Despite these benefits, shellfishes could bring about negative effects to health (Tan and Ransangan, 2015). There has been rising evidence of heavy metal intoxication that leads to health risk (Jin et al*.,* 2011) such as weak immune system, mental retardation, organ damages as reviewed by previous studies (Kamaruzzaman et al*.,* 2011; Alluri et al*.,* 2007; Ismail and Rosniza, 1997; Gorell et al*.,* 1997).

Bivalves were known to feed on suspended particles in the water column which could be contaminated by various contaminants (including heavy metals) derived from either anthropogenic activities or natural emissions (Langston et al*.,* 1998). The main sources of heavy metal contamination in the natural environment are run-off from agricultural activities (Abdallah, 2008), municipal wastes from urban areas and sewage systems (Alexander and Young, 1976), leaching and dumps from residential and industrial areas (APHA, 1992), discharges from mining, manufacturing, and other industries byproducts that are highly toxic (Alexander and Young, 1976). Bivalves are known to filter between twenty and one hundred liters of surrounding waters a day.

In doing so, they accumulate natural or anthropogenic contaminants. Upon consumption, they present these harmful contaminants to the consumers (Richards, 1988; Lees, 2000; Robertson, 2007).

In recent years, interest in the benefits and risks of aquatic organisms to human health is growing tremendously (Domingo et al*.,* 2007; Mahaffey, 2004). Organizations such as the United Nation Environment Program (UNEP) and Food and Agriculture Organization (FAO) have emphasized the requirements to examine the substantial metal presence in nature (UNEP, 1996). Unfortunately, this is not always the case in Sabah, Malaysia. Hence, this study is aimed to evaluate the heavy metal contents in the two highly exploited marine bivalve species which are marsh clam (*Polymesoda expansa*) and green mussel (*Perna viridis*) along the northwest coast of Sabah.

Materials and Methods

Sample collection

Live specimens of marsh clam and green mussel were collected from Marudu Bay, Ambong Bay and Mengkabong River (Figure 1). While the marsh clam samples were collected from the natural population at the sampling sites by the help of fishermen, the green mussel samples were procured from the raft culture in Marudu Bay (6°36.135' N, 116°51.017' E), Ambong Bay (6°18'00.9"N 116°17'32.6"E), and Mengkabong River (6°08'23.1'' N, 116°08'31.1'' E). Thirty individuals (N=30) of marsh clam and green mussel were obtained from each site. These specimens were transported to laboratory in separate plastic containers.
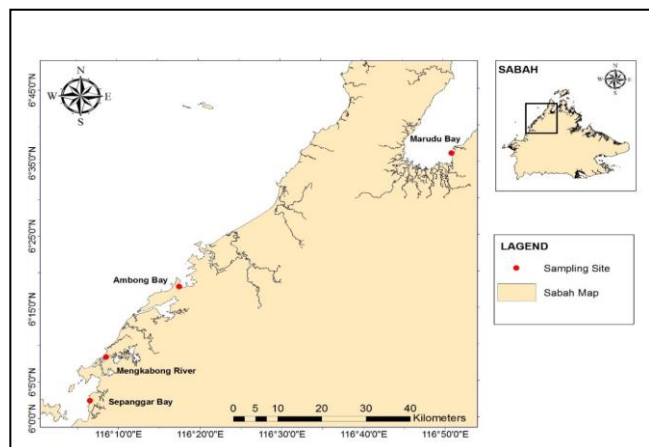
Figure 1. Map showing sampling sites of marsh clam and green mussel

Heavy metal analysis

Prior to analysis, the bivalve samples were cleaned with tap water to remove sediment and barnacles from the outer shell. Then, the soft tissues were retrieved and oven dried at 105 $^{\circ}$C for 24 hours (Mo and Neilson, 1994; Nurnadia et al., 2013; Meei-Fang et al., 2014). The dried tissues were then ground homogenously to powder form. The glassware used for the analysis was washed using 10% nitric acid (Sow et al., 2012).

Samples were digested following the technique used by Yap et al. (2004). This involved transfer of 0.3 g of the powdered tissue sample to a tube and its acid digestion using 3 ml concentrated nitric acid (HNO_3, GR, 65%, Merck). The samples were then placed in a hot block digester (Tecator Digestor Auto 8, FOSS), first at low temperature (80 $^{\circ}$C) for 1 hour before treatment at high temperature (180 $^{\circ}$C) for 3 hours for complete digestion. Each digestion batch included at least one blank sample to maintain accuracy (Yap et al., 2004; Sow et al., 2012).

Upon completion of sample digestion, the tubes were allowed to cool to room temperature before addition of 1.25 ml nitric acid (HNO3, GR, 65%, Merck) and 10 ml of double-distilled water. Subsequently, the solution was filtered using Whatman filter paper (No. 1001-110) and diluted to 30 ml using double-distilled water. The heavy metal contents were measured by using the Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), Perkin Elmer Optima 5300DV. For instrument recovery, Quality Control Standard 21 (Perkin Elmer Pure) was used as Standard Reference Material (SRM).

Statistical analysis

Concentrations of heavy metals were analyzed using the SPSS Windows Statistical Package (version 21). Prior to analyses, the variable (heavy metal concentration) was tested for normality and homogeneity of variances. One-way ANOVA was performed followed by Tukey multiple comparison tests (Tukey HSD) to make specific contrast in spatial variation of heavy metal concentrations. Tests were judged to be significant at $p < 0.05$ level.

An independent t-test was performed to compare the concentrations of heavy metals in marsh clam and green mussel samples. Results of the heavy metal concentrations were expressed in mean ± standard error (SE).

Results

Spatial variation of heavy metals in marsh clam and green mussel

The concentrations of heavy metals in marsh clam and green mussel from Marudu Bay, Ambong Bay, Mengkabong River and Sepanggar Bay are summarized in Tables 1 and 2. Concentration of lead (Pb) in Mengkabong River marsh clam and that in the green mussel in Marudu Bay and Ambong Bay was found below the detection limit. On the other hand, arsenic (As), manganese (Mn) and zinc (Zn) in marsh clams obtained from the three sampling sites exceeded the permissible limit. Same observation was noticed for Cr, Cu, As, Mn and Zn in green mussel that originated from these sampling sites.

It was also noticed that the concentration of Cu in marsh clam (27.73 µg/g) and green mussel (75.71 µg/g) was significantly higher ($p < 0.05$) in Marudu Bay than that in Ambong Bay and Mengkabong River. Significantly higher ($p < 0.05$) concentration of As in marsh clam (12.80 µg/g) and green mussel (9.73 µg/g) was observed in Mengkabong River. Marsh clam sourced from Ambong Bay accumulated significantly higher ($p < 0.05$) Cr (10.69 µg/g), Ni (8.90 µg/g) and Pb (5.48 µg/g) compared to those specimens which were procured from Marudu Bay and Mengkabong River.

Table 1. Concentrations of heavy metals in marsh clam collected from Marudu Bay, Ambong Bay, Mengkabong River and Sepanggar Bay

Bivalve	Heavy metals (µg/g)	Marudu Bay	Ambong Bay	Mengkabong River
Marsh clam	As	6.72±0.20 [a]	8.59±0.88 [b]	12.80±0.43 [c]
	Cr	6.55±0.72 [b]	10.69±0.55 [c]	1.45±0.33 [a]
	Cu	27.73±2.96 [c]	11.16±0.21 [a]	17.16±2.12 [b]
	Mn	116.0±12.7 [a]	33.49±4.66 [a]	91.73±13.1 [a]
	Ni	5.38±0.55 [b]	8.90±0.33 [c]	2.76±0.26 [a]
	Pb	2.90±1.23 [b]	5.48±0.03 [c]	b.d.l
	Zn	332.45±17.4 [ab]	265.8±16.2 [a]	535.8±45.2 [c]

Note: b.d.l = below detection limit

Table 2. Concentrations of heavy metals in green mussels collected from Marudu Bay, Ambong Bay, Mengkabong River and Sepanggar Bay

Bivalve	Heavy metals (µg/g)	Marudu Bay	Ambong Bay	Mengkabong River
Green Mussel	As	5.13±0.17 [a]	6.42±0.25 [b]	9.73±0.15 [d]
	Cr	53.89±17.0 [b]	11.13± 2.18 [a]	14.49±1.19 [a]
	Cu	75.71±6.28 [b]	12.39±2.68 [a]	12.87±0.74 [a]
	Mn	84.85±8.06 [a]	36.16±1.36 [a]	33.47±1.52 [a]
	Ni	32.18±9.69 [b]	11.23±1.36 [a]	10.92±0.64 [a]
	Pb	b.d.l	b.d.l	4.88±0.19 [b]
	Zn	66.39± 1.07 [a]	85.30±5.70 [a]	82.20±4.52 [a]

Note: b.d.l = below detection limit

Table 3. Mean concentration of heavy metals recorded in marsh clam and green mussel along the northwest coast of Sabah and the safe limit guidelines for heavy metals in food

Heavy metals ($\mu g/g$)	Bivalves		Safe limit guidelines		
	Marsh clam	Green mussel	MFR (1985)	FAO/WHO (1984)	FDA (1993)
As	9.12±0.18	7.45±0.15	1.0	0.1-5.0	-
Cr	6.07±0.32	20.72±4.20	-	13.0	-
Cu	16.6±0.98	27.02±2.18	30.0	10.0	-
Mn	138.1±13.6	117.0±13.5	-	5.4	-
Ni	5.71±0.25	14.74±2.38	-	-	80.0
Pb	2.31±0.32	1.04±0.14	2.0	2.0	-
Zn	377.1±14.5	153.5±8.58	100.0	150.0	-

Note: FAO: Food and Agriculture Organisation of the United Nations; WHO: World Health Organisation;
FDA: United States Food and Drug Administration; MFR: Malaysian Food Regulations

Discussion

Spatial variations in concentration of heavy metals

Results of this study revealed that the concentration of Cu in both marsh clam and green mussel collected from Marudu Bay were significantly higher ($p<0.05$) compared to that in Ambong Bay and Mengkabong River. According to Tan et al. (2016b), Marudu Bay is naturally rich in Zn (42.8 to 89.7 mg/kg) and Cu (56.3 to 115.8 mg/kg) which could contribute to the higher Cu accumulation in bivalves in Marudu Bay. In addition, the expansion of oil palm plantation around the bay has been reported to be one of the main factors contributing to heavy metal load in that area (Aris et al., 2014; Denil et al., 2017). Copper is included in the fertilizer used in oil palm agriculture for preventing Cu deficiency in the plant which causes mid-crown chlorosis in its leaflets (Ng, 2002). Hence, it leaches out from the fertilizer during rains and is carried by the run-off to the aquatic environment. Moreover, as an essential metal, it is not unusual that Cu would accumulate to some extent in an organism for taking part in physiological activities (Festa and Thiele, 2011).

Moreover, sewage and wastes from local villages and tourism activities such as those in Mengkabong Water Village and Mengkabong River Cruise could also contribute heavy metals to Mengkabong River. Furthermore, aquaculture that is being carried out in the vicinity of the sampling location could be a source of heavy metals but there is no scientific evidence to establish it. Apparently, these factors collectively account for significantly higher concentration of As in both marsh clam and green mussel as well as the concentration of Zn (in marsh clam) and Pb (in green mussel) collected from Mengkabong River. Concordant views have been expressed by Mansour et al. (2013) who provided reasons for linking increase in Pb load to tourism activities in Hurghada area, Egypt.

Study conducted by Saleh et al. (2011) claimed that, increase in coastal population has led to the clearing of natural mangrove for agriculture activities and human settlement. Hence, wastewater originating from municipal activites and farming could cause increase in Cr, Ni and Pb in marsh clam from Ambong Bay.

Spatial variation in heavy metals in the bivalve from different sites is obviously affected by anthropogenic activities of different nature and scale (Ferreira et al., 2004;

Yao et al., 2014). Sany et al. (2013) also reported wastewater discharge from the industries and domestic activities in the area. Earlier studies (Gorell et al., 1997; Ismail and Rosniza, 1997; Alluri et al., 2007; Kamaruzzaman et al., 2011) have identified steel industry, paint manufacturing and shipping activities as the possible sources of As, Mn, Zn and Cr in Malaysian waters. One of the main parameters influencing the heavy metal level in the marine environment is the sediment texture (Sany et al., 2013). Finer grain sediment has a larger surface area for heavy metal adsorption (Yao et al., 2015). Thus, the differences in sediment types in the sampling sites may also be responsible for spatial variation in heavy metal concentration in the two bivalve species. A number of physic-chemical factors such as water temperature, salinity and pH have also been shown to affect heavy metal bioavailability in water (Phillips et al., 2004; Li et al., 2013).

Heavy metal bioaccumulation in marsh clam and green mussel

Table 4 shows the comparison of heavy metal concentrations (As, Cr, Cu, Mn, Ni, Pb and Zn) in marsh clam and green mussel of the current study with the results published earlier in Malaysia. In marsh clam, Cu (16.60 $\mu g/g$) and Ni (5.71 $\mu g/g$) levels are within the range of 3.22- 36.0 $\mu g/g$ and 0.53-31.1 $\mu g/g$, respectively as reported by previous studies (Edward et al., 2009; Yap and Chew, 2011; Dabwan and Taufiq, 2016). Zn (377.1 $\mu g/g$) level was slightly higher than the concentration (368.0 $\mu g/g$) reported by Edward et al. (2009) for samples from Kg. Pasir Putih, Johor. This study found Pb content (2.31 $\mu g/g$) lower than the previous studies (6.9-10.03 $\mu g/g$) conducted by Edward et al. (2009) and Dabwan and Taufiq (2016). In green mussel, Pb level (1.04 $\mu g/g$) was comparable to the value of 1.12 $\mu g/g$ and 0.96 $\mu g/g$ reported by Ismail et al. (2000) and Abdullah et al., (2014), respectively. Copper was higher (2.26 to 20.1 $\mu g/g$) than that reported by previous studies (Ismail et al., 2000; Kamaruzzaman et al., 2011; Abdullah et al., 2014) but lower than that observed by Denil et al. (2017) in Marudu Bay (45.81 $\mu g/g$). The concentrations of Cr (20.27 $\mu g/g$), Mn (117.0 $\mu g/g$), Ni (14.74 $\mu g/g$) can be compared with the values documented earlier (Abdullah et al., 2014; Denil et al., 2017) which were 2.12 $\mu g/g$, 48.55 $\mu g/g$, 8.66 $\mu g/g$ and 16.52-129.0 $\mu g/g$ for Cr, Mn, Ni and Zn, respectively. Cr and Mn levels in marsh clam and As in green mussel were not examined before.

Table 4. Comparison of heavy metal concentrations in marsh clam and green mussel examined in this study and earlier investigations in Malaysia

Site	Species	µg/g (dry weight)							References
		As	*Cr*	*Cu*	*Mn*	*Ni*	*Pb*	*Zn*	
Current study		9.12	6.07	16.60	138.1	5.71	2.31	377.1	This study
Kuala Kemaman, Terengganu	Marsh clam *(Polymesoda expansa)*	-	-	15.9	-	-	6.9	12.8	Dabwan and Taufiq (2016)
Kg Pasir Putih, Johor		-	-	36.0	-	6.04	17.2	368.0	Edward et al. (2009)
Pantai Lido, Kelantan		-	-	4.34-27.2	-	2.82-31.1	-	-	Yap and Chew (2011)
Sg. Semerak, Kelantan		-	-	3.22-11.3	-	0.53-8.32	-	-	Yap and Chew (2011)
Current study		7.45	20.27	27.02	117.0	14.74	1.04	153.5	This study
Mengkabong, Sabah	Green mussel *(Perna viridis)*	-	2.12	2.36	-	-	1.12	16.52	Abdullah et al. (2014)
Kuala Penyu, Sabah		-	-	2.26	-	-	0.96	25.80	Ismail et al. (2000)
Tg. Batu, Marudu Bay, Sabah		-	-	45.81	48.55	8.66	-	46.72	Denil et al. (2017)
Peninsular Malaysia (West Coast)		-	-	7.76-20.1	-	-	2.51-8.76	75.1-129.0	Yap et al. (2004)
Pekan, Pahang		-	-	19.05	-	-	0.47	45.54	Kamaruzzaman et al. (2011)

Living organisms generally accumulate heavy metals in variable amounts in relation to their physiological and biochemical functions (Sikora et al., 1996), leading to differences in the profile of these substances in different bivalve species. Moreover, bivalves also have a poor ability to regulate heavy metals in their bodies, and the regulatory capacity might be different in different species (Hashmi et al., 2002a). Marsh clam is a benthic bivalve and is usually found buried in sediment. Many studies claimed that, sediment is the sink of various contaminants including heavy metals from the surface water (Ali et al., 2014). This could explain the significantly higher concentration of Pb and Zn in marsh clam compared to green mussel in the present investigation. However, previous study also outlined that the retention of metal elements in clam is influenced by the food composition. For example, Lee and Lee (2005) have found that metals associated with algal food are retained longer than those bound in the sediment as the crystalline lattice of sediment can strongly hold metal elements. Thus, the significantly lower concentrations of Cr, Cu and Ni in marsh clam of the current study might be attributed to this factor.

It was noted that different species of organisms can accumulate heavy metals at varied levels. Variations in heavy metal concentration in bivalves could be due to biological factors such as body size, growth, fitness, reproductive condition and genotypes (Waykar and Deshmuch, 2012). The same authors also noted that in closely-related species, the differences in biokinetic uptake, depuration rate and other physiological processes could contribute to the variations in the heavy metal concentration in tissues.

Implications of the present finding
1. Human consumption
Heavy metals are classified into three categories based on their toxicity: potentially toxic (examples, arsenic, cadmium, lead), probably essential (nickel) and essential (copper, zinc, manganese) (Salimullah et al., 2014). The essential metals can also produce toxic effect when intake is in excess or when ingested in low concentration over a long time period (Uluozlu et al., 2007). Various disorders following heavy metal exposure to aquatic organisms are seen as a threat to seafood industry. Through food chain, biomagnification of heavy metals in the organisms occurs and because of which organisms at higher trophic levels might experience far more intoxication (Chen et al., 2000).

In the current study, As and Mn in marsh clam and green mussel obtained from all the study sites exceeded the permissible limit and could pose health threat to consumers. Arsenic has been known to cause various types of skin cancers (Table 5) and its toxicity may lead to neurological and cognitive dysfunction as reviewed by Tyler and Allan (2014). Meanwhile, overexposure of Mn may lead to central nervous system disorder (Crossgrove and Zheng, 2004). The toxic effects of heavy metals to consumers manifesting in the form of mental disorders, organ damages and various types of cancers have been reviewed by many authors (eg. Gorell et al., 1997; Ismail and Rosniza, 1997; Alluri et al., 2007; Kamaruzzaman et al., 2011). Consumers are often unaware of the toxic effects associated with heavy metals as early symptoms of poisoning (headache, nausea and skin irritations) resemble with symptoms of other common

illnesses. Frequent consumption of bivalves can have prolonged exposure to heavy metals that can lead to chronic disorders such as various types of cancers, neurological complications and organ damages (Table 5). Thus, there is a necessity to address this matter in order to ensure the well-being of consumers.

Table 5. Sources and toxicological effects of selected heavy metals (Gorell et al., 1997; Ismail and Rosniza, 1997; Alluri et al., 2007; Kamaruzzaman et al., 2011)

Heavy metal	Sources	Effects
Copper (Cu)	Shipping activities, Pesticides and Insecticides	Mental disorders, anaemia, arthritis, hyperactivity, insomnia, enlargement of liver, heart problem and cystic fibrosis
Chromium (Cr)	Steel and textile industry	Respiratory problems, haemolysis, weakened immune systems, kidney and liver damage, lung cancer, pulmonary fibrosis
Nickel (Ni)	Electroplating, zinc base casting and storage battery industries	Dermatitis, headache, chest pain, rapid respiration, cancer of lungs, nose and bone
Lead (Pb)	Shipping activities, batteries and paints	Learning difficulties, mental retardation, kidney damage, birth defects, muscle weakness, degeneration of motor neurons
Arsenic (As)	Shipping activities	Skin cancer
Zinc (Zn)	Paint manufacturing and sewage	Electrolyte imbalance and lethargy
Manganese (Mn)	Paint manufacturing and pharmaceutical industries	Permanent neurological disorder

2. Fishery resources

A survey of literature reveals that the number of studies reporting heavy metal contamination in seafood, especially in bivalves, has been increasing (Yap et al., 2008; Lias et al., 2013; Dabwan and Taufiq, 2016). This coincides with the development of various industries which contribute to the deposition of pollutants, including heavy metals, in the marine natural environment.

As reviewed by Jezierska et al. (2009), waterborne heavy metals promote the production of low quality offspring in fish due to several disturbances such as hatching delay, and deformations. Often, there are cases of heavy mortality of newly hatched larvae linked to metal intoxication. This is in agreement with Rani et al. (2015) who noted that heavy metal contamination affects fish immune system which in turn, leads to decline in production due to reduced resilience of the fish to infectious diseases. Based on the results of the current study, the possibility of heavy metal contamination may exist due to concentration of some metals exceeding the safe limits. Thus, threat of heavy metal toxicity to the production of the bivalves in the study sites should be taken seriously. Observations made by Guzman-Garcia et al. (2009) in oyster (*Crassosstrea virginica*) where lesions in the digestive gland and damages to internal organs related to heavy metal exposure provide ample justification for seriousness of this matter.

3. Aquaculture

Heavy metal contamination of marine environment has many obvious implications for aquaculture. Water pumped from the sea into hatcheries or grow-out systems exposes the otherwise healthy stocks to metal contamination. Seed procured from natural environment for grow-out involved in the farming operations could carry the heavy metal residues present in the environment. Broodstock sourced from the wild for captive breeding and seed production in hatcheries may already be contaminated with heavy metals in the environment. Hussain and Mazid (1999) have observed that broodstock condition affects the quality of offspring. This can lead to mass mortality, slow growth, disease risk and production losses in aquaculture.

Since bivalves are filter-feeding organisms, the heavy metal poisoning associated with their consumption is more prominent compared to that of non-filter feeder organisms. Hence, in order to tackle this problem, depuration process of bivalves assumes importance. Due to an increasing number of publications on heavy metals in the marine environment and organisms in Malaysia (Hashmi et al., 2002a,b; Yap et al., 2008; Lias et al., 2013; Dabwan and Taufiq, 2016) there is a great deal of scientific data that provides a basis for taking measures for mitigating the heavy metal contamination and protecting public health.

Measures for controlling heavy metal contamination of bivalves for public health

Sabah is also popular for its seafood. The local community has traditionally depended on seafood as an important source of dietary protein. In fact, seafood has also emerged as a product of tourism importance, considering the increasing number of tourists patronizing seafood restaurants, especially those offering live seafood animals. Such food commodities that contribute to cultural lifestyles and to the local economy deserve more attention. Measures should, therefore, be taken to protect heavy mental contamination of bivalves and other seafood animals not just to protect the aquaculture and seafood industries but also consumer health. Some of the measures include: Controlling discharge from industries into the sea through effective enforcement and preventing disposal of waste from boats and ships. Successful enforcement in China of such measures has been reported by Hu et al. (2014). It can also achieved in Malaysia.

In addition, depuration process is a strategic approach of improving the food quality of shellfishes (Amiard et al., 2008). Depuration process before supplying bivalves to market helps in minimizing heavy metal contamination and food poisoning (El-Gamal, 2011). The consumers should also play their role by making use of awareness programs. According to Amiard et al. (2008), cooked shellfishes may reduce the bioaccessibility of metals to consumers due to protein degradation, and loss of weight and water which subsequently affect the metal level in the shellfish. In this connection, it is rather safer for consumers to choose well-cooked bivalves rather than the raw or half-cooked ones which some consumers are so fond of.

Conclusion

The present study shows the presence of heavy metals (As, Cr, Cu, Mn, Ni, Pb and Zn) in marsh clam and green mussel. The concentration varied among sampling sites. Levels of As, Cr, Cu, Mn, Ni, Pb and Zn in marsh clams and green mussels collected from the northwest coast of Sabah exceeded the permissible limits set by MFR (1985), FAO/WHO (1984) and FDA (1993). This finding suggests the need for regular monitoring of heavy metal level in bivalves and in other seafood animals, and taking measures to control this problem in the interest of health and well-being of consumers.

Acknowledgement

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