Preliminary study of lead and mercury concentrations in seven commercial seafood at Lombok Island, Indonesia

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Abstract. Fish and other marine biota such as shrimp and shellfish are important foods besides agricultural products coming from the mainland. Lombok Island - West Nusa Tenggara has large and diverse fishery resources. In addition, Lombok has mineral resources, an example of these being the gold that is mined both traditionally and using modern technology. These mining activities can impact not only the surrounding environment, but also far away coastal areas due to river run off. This study aims to examine the heavy metal contamination level in seven consumed biotas at Lombok Island. Sampling was conducted at the Fish Auction Market (Tempat Pelelangan Ikan - TPI) Tanjung Luar from 25 to 30 September 2015. Samples were identified before measurement and weighting. Sample analysis for lead (Pb) and mercury (Hg) concentrations use APHA method, 2012, 4500-N-C and APHA, 2012, 4500-P-E respectively. The results show that lead (Pb) content was detected in *Anadara* sp. and pearl lobster ranging from 0 to 2.25 mg/kg, with an average of 0.4 mg/kg. The content of lead in *Anadara* sp. and pearl lobster is beyond the safe level for consumption according to SNI 7387:2009 (Indonesia Reference Threshold). Mercury is detected in three biotas: *Anadara* sp., *Mugil* sp. and crab with a range of 0.002-0.06 mg/kg and can be categorized at safe levels to be consumed.
Key Words: consumption biota, heavy metals, Lombok Island, Tanjung Luar.

Introduction. Fish and other marine biota such as shrimp and shellfish are important foods besides agricultural land products. These marine products contain proteins, vitamins, minerals and fats, which are very important for metabolic processes. Malesa-Ciećwierz & Usydus (2015) found that some popular fish in Poland markets are good sources of vitamin D. Taurine an amino acid forming protein in fish, useful for brain cell development and nervous system (Wu & Prentice 2010; Ripps & Shen 2012). In addition, other nutrients that also contribute in forming brain cells are docosahexanoic acid (DHA), eicosapentanoic acid (EPA) and omega 3 fatty acids (Susanto & Fahmi 2012). Fish also contain several essential minerals for humans, such as iron (Fe), potassium (K), sodium (Na), zinc (Zn), calcium (Ca), magnesium (Mg) and selenium (Susanto & Fahmi 2012; Mulyaningsih 2014). Furthermore, Mulyaningsih (2014) observed that seawater fish have higher concentration of calcium and selenium than freshwater fish. Some minerals in shellfish (Fe, Zn and copper-Cu) are two times higher compared to fish, whereas shrimp contains more Ca than fish (Susanto & Fahmi 2012).

Besides having high nutritional value, fish and other marine biota are prone to heavy metal contamination. Therefore, fish can be used as bioindicators for environmental contaminations (Green & Planchart 2017; Keshavarzi et al 2018; Łuczyńska et al 2018). Fish can absorb heavy metals in contaminated water through gills, skin and digestive tract.

Some heavy metals are essential for living organisms. However, heavy metals can cause health risks when exceeding the optimum range, if consumed by humans (WHO 1996; Agustina 2014; Skalnaya & Skalny 2018). Heavy metal accumulation in fish can cause a number of disorders. Mercury (Hg), cadmium (Cd) and lead (Pb) can cause disturbances in nerve function and development. Moreover, heavy metals can cause hatching delay, deformities and mortality in fish (Sfakianakis et al 2015). Cancer risks can be related to exposure or consumption of heavy metal contaminated seafood (Bonsignore et al 2018).

Lombok Island has diverse natural resources. It has beaches important for tourism, coastal areas with mineral mining resources, such as gold, and high biological resources such as fish, shellfish and coral reefs (Yulius et al 2018). Based on data from Environmental Center of West Nusa Tenggara Province in 2013, the island has hundreds of gold mines operated both traditionally and using modern technology (Astiti & Sugianti 2014). These anthropogenic activities affect not only the surrounding environment, but also the coastal areas due to river run off. Therefore, several actions are needed to manage, develop and utilize these resources, considering environmental sustainability (Rustam et al 2016). The purpose of this study is to analyze the concentration of heavy metals in several seafood at Lombok Island.

Material and Method

Study sites. Samples were collected on 25-30 September 2015 at a Fish Auction Market (Tempat Pelelangan Ikan – TPI) Tanjung Luar, East Lombok. The GPS coordinates of Lombok are 8°46'37.87" S and 116°31'1.12" E (Figure 1). TPI Tanjung Luar is the largest fish landing place and fish auction market on Lombok Island. Starting there, captured biota is usually sold in traditional markets throughout Lombok.
Samples collected were economically important marine biota, mullet fish (*Mugil* sp.), grouper (*Ephinephelus* sp.), goatfish (*Parupeneus* sp.), yellow banded sweetlips fish (*Plectorhinchus* sp.), Ark shell (*Anadara* sp.), lobster (*Portunidae* sp.) and pearl lobster (*Panulirus* sp.). The number of samples varied from 1 to 10 individuals. Samples were measured and weighed after visual identification, using a fish introduction guidebook (Anonymous 2004).

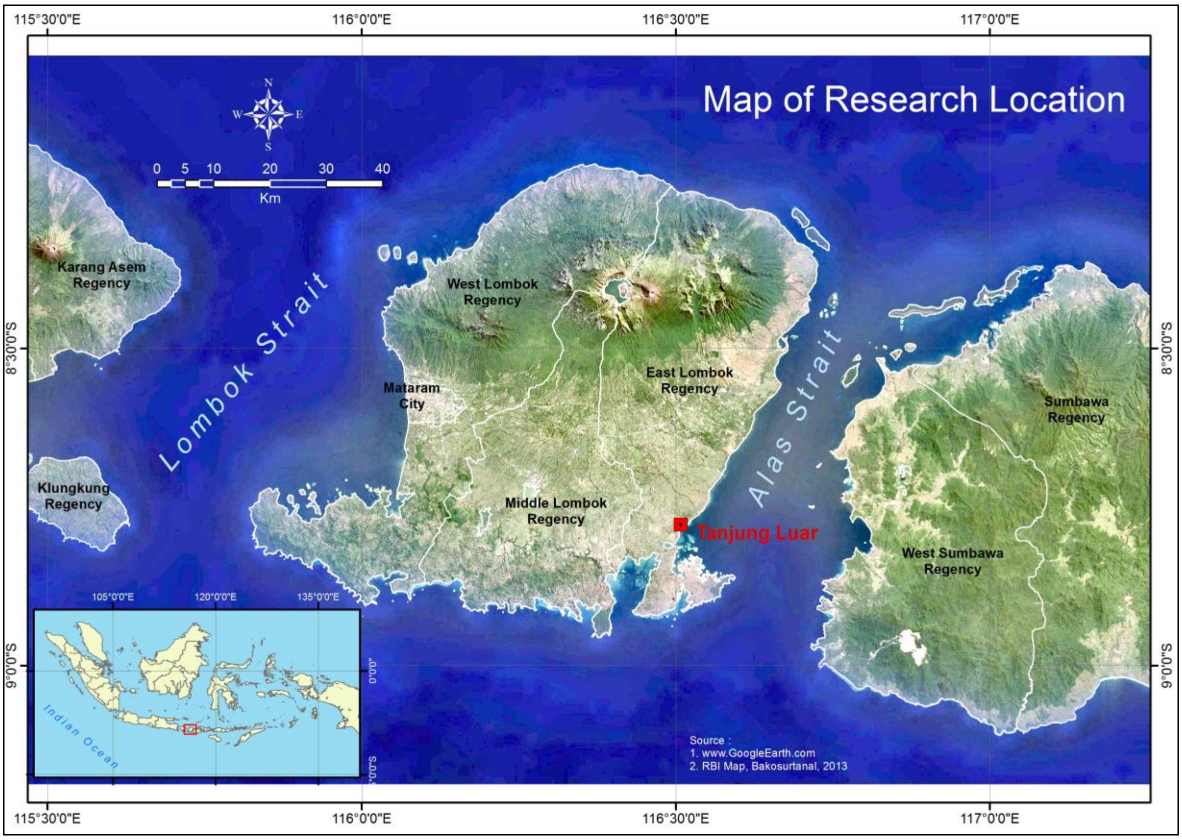

Figure 1. Tanjung Luar Fish Auction Market.

Sample Analysis. Several steps were followed in this study. After being purchased from the market, samples were weighed by 0.01 accuracy digital scale. Fish were measured morphometrically using common ruler. Total and standard length of fish were determined. 20 g of edible part (meat) were taken from each sample and placed in a -7^{o}C freezer for further laboratory analysis. The analysis of Pb and Hg was carried out in Proling-Bogor Agricultural University (IPB) laboratory. Lead (Pb) analysis implied APHA, 2012, 4500-N-C method with 0.23 detection limit, whereas for mercury (Hg) APHA, 2012, 4500-P-E method was used with a 0.004 detection limit.

The maximum limits of metal concentrations (As, Cd, Hg, Sn and Pb) in agricultural production materials, livestock and fisheries which are used for food consumption is regulated in Indonesia (SNI 7387:2009). The maximum limit of Pb and Hg in food from marine biota are presented in table 1.

Table 1

Maximum standard of heavy metals concentration in food (source: SNI 7387:2009)

Biota	*Hg (mg/kg)*	*Pb (mg/kg)*
Fish and processed fish	0.5	0.3
Shellfish	1.0	1.5
Crustaceans (Crab)	1.0	0.5

Maximum consumption limit for contaminated seafood was calculated according to the following formula (USEPA 2000):

$$CR_{lim} = \frac{RfD \times BW}{Cm} \text{ kg/day}$$

Where: CRlim - maximum consumption limit (kg/day); RfD - reference oral dose (mg/kg day); RfD for lead (Pb) = 4×10^{-3} (Bonsignore et al 2018); BW- body weight (kg); Cm - heavy metal concentration in fish (mg/kg). The consumption limit was calculated according to the infant age group (average body weight of 15 kg) and adult age group (average body weight of 50 kg) (Prastyo et al 2017).

Results and Discussion

Biota Sample Size. The life stage determination of fish, mainly in juvenile or adult phase, can be done by using the length and weight of the fish. The length and weight of the samples are presented in table 2. Several researches on fish size and life stage have been conducted until now. A study in Cilacap Donan River found that the length of *Mugil* sp. in juvenile phase is within an interval of 12.5-23.3 cm (Prastyo et al 2017). Likewise, the length of juvenile to adult stages of *Mugil* sp. from Ujung-Kulon National Park in Banten is 3.055-15.054 cm (Wahyudewantoro & Haryono 2013). According to Kotellat (1993) in Wahyudewantoro & Haryono (2013), adult mullets are 40 cm long. Espino-Barr et al (2016) reported that mullet (*Mugil cephalus*) in Central Mexican Pacific Coast reach first marturity at the length of 30 cm and age of 3.4 years. Mullet *Mugil liza* in Brazilian Bay reaches total sexual maturity at a total length of 55 cm for males and 57 cm for females (Albieri & Araújo 2010). Based on that categorization, the mullet samples were concluded to be in the juvenile stage since the total length ranges from 17-24 cm (average 20 cm).

The size of the *Ephinephelus* sp. in this study reached commercial size. According to Mayunar (1996), the proper size for consumption of live groupers is between 300-1500 g. However, grouper with a size of 0.5-1 kg has a relatively high price, since there is a high market demand (Purba 1990).

Table 2

Length and weight of sample biota

Type	*Sample Number (n)*	*Average Total Length (cm)*	*Average weight (gr)*
Ark shell (*Anadara* sp.)	10	-	49.66
Pearl Lobster (*Panulirus* sp.)	1	29	530
Mullet (*Mugil* sp.)	3	20	101.67
Lobster (*Portunidae* sp.)	3	77.33	230
Grouper (*Ephinephelus* sp.)	2	29.5	470
Goatfish (*Parupeneus* sp.)	2	21.5	165
Sweetlips fish (*Plectorhinchus* sp.)	1	22.5	195

Heavy Metal Concentration. Heavy metal concentrations for Pb and Hg are presented in figures 2 and 3, respectively. Lead is detected in *Anadara* sp. and *Panulirus* sp., whereas no lead was detected in fish. Lead concentration in *Anadara* sp. varies from 0 to 8.63 mg/kg with an average of 1.74±0.895 mg/kg. Moreover, Pb concentration in *Panulirus* sp. is 2.25 mg/kg.

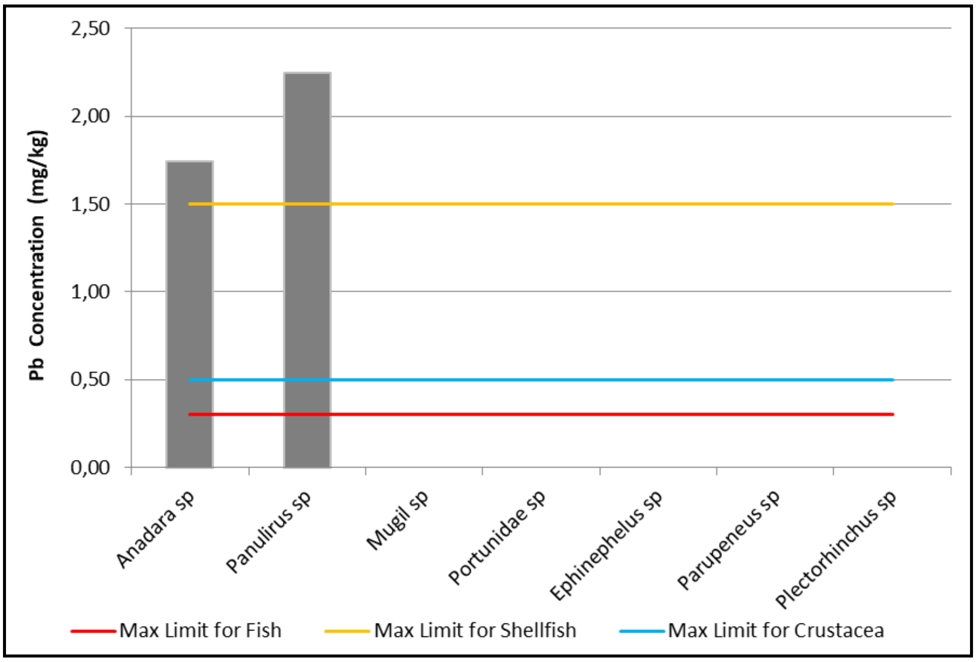

Figure 2. Lead (Pb) concentration in seafood from Lombok Island, Indonesia.

Mercury was detected in three species, namely *Anadara* sp., *Mugil* sp. and *Portunidae* sp. (Figure 3). The average concentration of each species ranges from 0.002-0.06 mg/kg. The lowest concentration was found in *Portunidae* sp., whereas the highest concentration was determined in mullet fish. In *Anadara* sp., mercury was detected in seven shellfish out of ten analyzed shellfish, within an interval of 0.015-0.073 mg/kg, with an average of 0.027 mg/kg.

The results indicate that the concentration of heavy metals differ between the two heavy metals (Pb and Hg) and among the fish species. Metal accumulation in marine organisms is dependent on several factors that can be divided in two main groups: abiotic and biotic. Abiotic factors are salinity, temperature, pH, metal types and their interaction with other metals. Biotic factors related to species and individual physiological traits are mainly feeding behavior, migration patterns and food chain level (ILA 2019; Suami et al 2018; Yi et al 2017; Storelli et al 2005).

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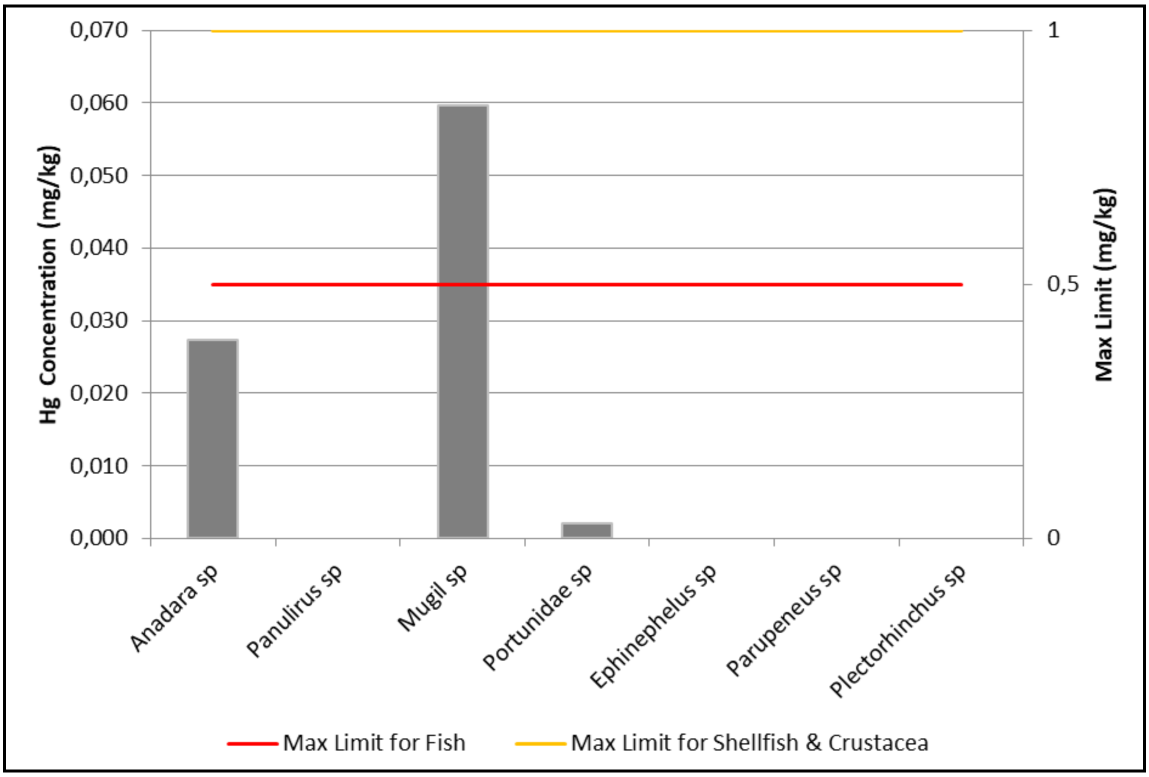

Figure 3. Mercury (Hg) concentration in seafood from Lombok Island, Indonesia.

Interestingly, the highest Hg concentration is found in *Mugil* sp. This condition might be related to the size and life stage of the fish. Canli & Atli (2003) showed that the bigger the size the lower the concentration of heavy metal in fish tissue. Therefore, juveniles tend to have a higher heavy metal concentration compared to adults. High accumulation of Hg in *Mugil* sp. is also influenced by their feeding habits as herbivores. Lasut (2009) showed that in controlled environment, the highest Hg biotransfer happens between phytoplankton and herbivores.

Comparing the concentration in the samples, especially in *Anadara* sp., Pb concentration is higher than Hg. High concentrations of Pb are also detected in *Anadara* sp. collected from Labuhan Tereng coastal waters in West Lombok (Handayani et al 2016). Lead in shellfish is accumulated more significantly than in fish (ILA 2019), due to the feeding behavior of shellfish as filter feeders. Inputs of waste containing Pb from land to waterways in the ocean can increase the possibility of heavy metal accumulation in marine biota tissue. Sources of Pb can be both natural and anthropogenic. Soil weathering, forest fires and volcanoes are the main natural sources of Pb contamination (ILA 2019). According to EU CSR report on 2016, almost 50% of lead sources in water come from household activities, whereas the other are from sewage systems (21%), waste management (15%), industry (13%) and traffic (5%) (ILA 2019).

Food Safety Limits. Heavy metal concentrations (Pb and Hg) in Lombok island commercial seafood is relatively lower compared to seafood from other areas based on several research results in Indonesia (Table 4). Pb was identified in *Isognomon* *ephippium* and *Crassostrea* sp. at East Flores, considerable low Pb concentrations were detected in Jakarta Bay and no Pb was detected in fish and shrimp from North Halmahera (Indriana et al 2011; Simange 2011; Wahyuningsih et al 2015). In contrast, seafood from North Halmahera contains higher mercury levels compared to the two other locations. Ati et al (2010) reported a high lead contamination in *Perna viridis* from Jakarta Bay.

Table 3

Lead and mercury concentrations in marine biota from Indonesia

Location/ Waters	*Fish Species*	*Sample tissue*	*Pb (mg/kg)*	*Hg (mg/kg)*	*Source*
Kao Bay North Halmahera	Red snapper	Heart Meat	- -	0.13-0.38 0.06-0.19	Simange 2011
	Mullet fish	Heart Meat	- -	0.16-0.36 0.05-0.25	
	White Shrimp	Meat	-	0.02	
	Goatfish (*Upeneus* sp.)	Heart Meat	- -	0.45-0.51 0.03-0.04	
Jakarta Bay	Black Pomfret (*Stromateus niger*)	Meat	<0.042	0.05-0.207	Wahyuningsih et al 2015
	Petek Fish (*Leiognatus dussumieri*)	Meat	<0.042	<0.003-0.003	
	Mackerel (*Scomber neglectus*)	Meat	<0.042	<0,003- 0,110	
	Crab	-	<0.042	<0,003-0,017	
	White shrimp (*Penaeus marguiensis*)	-	<0.051	<0.003- 0.033	
	Mantis Shrimp (*Oratosquilla* sp.)	-	<0.042	0.161- 0.293	
East Flores	*Isognomon ephippium*	Meat	0.26	-	Indriana et al 2011
	Crassostrea sp.	Meat	0.15	-	
Jakarta Bay	*Perna viridis*	Meat	38.7-50.1	< 0.02– 0.11	Ati et al 2010

In accordance with SNI 7387:2009, the maximum safety standard of food for lead concentrations in shellfish is 1.5 mg/kg (Table 5). The average value of Pb concentration measured in *Anadara* sp. is 1.74±0.89 mg/kg, which means it has exceeded the food safety limit. This situation also occurs in *Panulirus* sp. (2.25 mg/kg).

Compared to the maximum safety value of food for mercury, the concentration of all biota is still far below the limit. The maximum value of mercury in fish is 1 mg/kg while for shellfish and crustacean is 0.5 mg/kg. The maximum mercury concentration is 0.06 mg/kg, found in mullet fish.

Table 4 shows the maximum concentration limit for mercury and lead in seafood throughout the world. In comparison to other countries, Hongkong aplies a high value of lead, followed by Australia. However, many countries, including Indonesia, have comparable maximum permissible limits both for lead and mercury. Therefore, seafood from Lombok Island is safe based on some standards, regarding mercury concentrations. In contrast, *Panulirus* sp. exceed the standards (excepting Hongkong).

***Maximum Consumption for Anadara* sp**. Due to the high concentration of Pb in *Anadara* sp. that exceeds the food safety standard, the maximum consumption limit for *Anadara* sp. was calculated according to age groups. Maximum consumption of *Anadara* sp. for children is 0.034 kg/d, whereas for adults is 0.115 kg/d. Therefore, maximum consumption in a month should not exceed 1 kg for children and 3.4 kg for adults.

Table 4

Maximum permissible limits (MPL) of Pb and Hg in seafood

Country / Organization	*Heavy Metal (mg/kg)*		*Reference*
	Pb	*Hg*	
FAO (1983)	0.5	0.5	Bosch et al 2016; Korkmaz et al 2017
Hongkong	7.2	-	Putri et al 2016
Australia	1.8	0.5	Putri et al 2016
European regulation	0.5	-	Putri et al 2016
South Africa Dept. Of Health (DOH)	0.5	1	Bosch et al 2016
Commission regulation	0.3	-	EC No. 1881/2006; Bosch et al 2016
Commission regulation	-	0.5	EC No. 629/2008; Bosch et al 2016

Hajeb et al (2014) reviewed the occurrence, binding and reduction of heavy metals. In general, there are two ways to reduce heavy metal concentrations in contaminated seafood, which are food processing methods and application of chemical reagents as chelating agents. For the first, Hajeb et al (2014) argue that heavy metal concentrations in food depend on cooking conditions (time, temperature and medium) that allow heavy metals to be transferred to the oil or water used during cooking. The second treatment uses chemicals to bind heavy metals, so the concentration will be reduced, as acid can remove mercury bound in fish proteins. In addition, acid can also lower lead concentrations in fish, by weakening protein-metal bounds and emulsifying fat where mercury bonded besides proteins (Saputri et al 2015; Solihah et al 2016).

Table 5

Average Hg and Pb concentration aligned with consumption feasibility level (source: SNI 7387: 2009)

Biota	Average (±SE) Hg concentration (mg/kg)	Hg Threshold (mg/kg)			Average (±SE) Pb Concentration (mg/kg)	Pb threshold (mg/kg)		
		Shellfish	Crustaceans	Fish		Shellfish	Crustaceans	Fish
Anadara sp.	0.03±0.01	1	1	0.5	1.74±0.89	1.5	0.5	0.3
Mugil sp.	0.06±0.02	1	1	0.5	-	-	-	-
Panulirus sp.	-	-	-	-	2.25	1.5	0.5	0.3
Portunidae sp.	0.002	1	1	0.5	-	-	-	-

Conclusions. Mullet fish (*Mugil* sp.), grouper (*Ephinephelus* sp.), goatfish (*Parupeneus* sp.), yellow banded sweetlips fish (*Plectorhinchus* sp.), ark shell (*Anadara* sp.), lobster (*Portunidae* sp.) and pearl lobster (*Panulirus* sp.) are economic important seafood sampled at the Lombok Fish Auction Market. Lead and mercury were detected in four species (*Anadara* sp., *Mugil* sp., *Portunidae* sp., *Panulirus* sp.). The results show that the concentration of heavy metals differ between the two heavy metals (Pb and Hg) and among the fish species. These seafoods are relatively safe to consume, as only low concentrations of heavy metals were detected in their meat. Yet consumption of shellfish (*Anadara* sp.) should be considered not to exceed the maximum consumption limit since the concentration of lead detected is above the Indonesian threshold for food.

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