Metals Accumulation in Muscle Tissues and Digestive Contents of *Periglypta reticulata* (Kerang Geton) from Lancang Island, Jakarta

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Abstract: *The concentration of nineteen metals (Hg, As, Cd, Co, Cr, Cu, Fe, Li, Mg, Mn, Mo, Ni, Pb, Se, Sr, Ti, Tl, V, and Zn) were determined in muscle tissues and digestive contents of* Periglypta reticulata *(Kerang Geton), collected from Lancang Island part of Seribu Islands, Jakarta. An interaction between toxic and essential metal in a clam is also studied. The results showed high concentrations of As (4.56), V (1.20), and Zn (4.91) mg/kg wet weight in muscle tissues and As (7.16), Ti (2.53), and Zn (8.68) mg/kg wet weight in digestive contents. Average concentrations of metals in muscle tissues and digestive contents were below regulation limit from permissible standard National Agency of Drug and Food Control except for Arsenic (As). The average concentration of metals in muscle tissues was significantly ($P < 0.05$) lower than in digestive contents except As, Co, Cr, Mg, and Tl, respectively. Toxic metals (Pb, Hg, Cd, and As) showed a strong correlation with several essential metals so that these metals can be a threat to the main function of a particular metal. The present study showed digestive contents could accumulate in higher metals; therefore, we suggested removing it before consuming this clam.*

Keywords: Periglypta reticulata*; heavy metals; Lancang Island*

INTRODUCTION

Heavy metals contamination is one of the complex problems in an aquatic environment and raising concern over their potential in the risk of human health [1]. Some heavy metals (Co, Cr, Cu, Fe, Mn, Mo, Ni, Se, Zn) are essential elements for the organism being constituents of several key enzymes and playing important roles in various oxidation-reduction reactions [2]. However, an excess amount of metals may produce cellular and tissue damage [3]. Metals such as Hg, Pb, Cd, and As have no established biological functions and are considered as non-essential and potentially toxic at relatively low concentrations [4]. The heavy metals concentration may be attributed to sewage and agricultural drainage. Besides, the corrosion of the ship's hull coating and antifouling paints at the ship can cause a high concentration of copper in the lake [5].

Marine bivalves could accumulate metals presented at undetectable levels from environmental to very high concentrations in tissues [6]. Bivalves are known to feed on suspended particles in the water column, which could be contaminated by various contaminants derived from either anthropogenic activities or natural emissions [7]. The primary source of heavy metals contamination in the natural environment is the run-off from agricultural activities [8]. Bivalves are known to filter between twenty and one hundred litters of surrounding waters a day. In doing so, they accumulate natural or anthropogenic contaminants [9].

Furthermore, since the bivalves have high nutritional and economic values, eating bivalves contain high concentrations of heavy metals is dangerous and threats to human health [10]. The present study was aimed to investigate the concentration of toxic metals (As, Pb, Cd, and Hg) and essential metals (Co, Cr, Cu, Fe, Li, Mg, Mn, Mo, Ni, Se, Sr, Ti, Tl, V, and Zn) in muscle tissues and digestive content of *Periglypta reticulata* from Lancang Island, part of Seribu Islands, Jakarta. The other goal was to study the interaction between toxic and essential metals in the clam. Lancang Island located 30 km North-West from Jakarta Bay and 9 km from Cisadane estuary in Tangerang. Jakarta Bay receives enormous amounts of municipal discharges from the Jakarta metropolis [11] that caused marine pollution with various pollutants, especially heavy metals.

■ EXPERIMENTAL SECTION

Materials

Periglypta reticulata were purchased from fisherman in Lancang Island and directly placed in a zip-lock plastic bag and freeze until further analysis. All reagents used were analytical-reagents grade. The solutions were prepared using ultra-pure water (Milli-Q), Nitric acid (65% HNO_3 Suprapur, Merck), HCl 37% (Merck), Hg standard solution 1.000 mg/L (Merck) and L-Cysteine (Nacalai Tesque Inc. Japan).

Instrumentation

Caliper and analytical balance (Sartorius BP 210 S) were used for morphometric analysis. Dried samples were prepared using oven (Heraeus Instrument), petri dish, spatula, mortar, and pestle. ICP-OES 7400 Thermo and Mercury Analyzer NIC MA-3000 were used for concentrations analysis.

Procedure

Sample collection

In the laboratory, bivalves were cleaned to remove dirt attached to the bivalve and were separated from muscle tissues and digestive contents. Morphometric analysis of the total weight of the wet tissues was measured with Sartorius analytical balance, while the length and width of bivalves were measured with a digital caliper. Samples were dried in an oven at 60 °C for 24 h for heavy metals analysis. Moisture contents of muscle tissues and digestive contents were measured with oven-dried at 105 °C for 24 h [12]. Muscle tissues (MT) and digestive contents (DC) were ground into a fine powder with mortar and pestle for the subsequent analysis.

Metal analysis

Three replicates of dried MT and DC samples were individually weighed approximately 10–20 mg directly in the sample boat and analyzed with mercury analyzer for total mercury concentration. The modified method from USEPA 3051a for total metals analysis was utilizing a mixture of concentrated HNO_3 and HCl and a microwave oven [13]. In brief, the mixture of acid (9 mL HNO_3 and 3 mL HCl) was drop-added into 0.5 g of samples then the mixture was heated using microwave oven CEM MARS 5 Express at 185 °C for 15 min and hold for 30 min. Then the solution was filtered using Whatman filter paper No. 41, and the filtrate was diluted to 25 mL using deionized water. Three replicates of dried MT and DC samples were also applied for a non-Hg measurement. The samples were measured using ICP-OES 7400 Thermo for metals analysis.

Data analysis

Statistical correlation analysis was based on IBM SPSS Statistics 22. Pearson's correlation coefficient analysis was used to determine the significant relationship between metal accumulation in muscle tissues and digestive contents with two-tailed p-value < 0.05 and p-value < 0.01 were considered significant. All graphical plot was based on the R program.

■ RESULTS AND DISCUSSION

Details of metals concentration MT and DC in *P. reticulata* are shown in Fig. 1 and Fig. 2. Bivalves (n = 10 individual samples) collected in this study displayed similar-sized of 8.00±0.53 cm (Length) × 8.65±0.85 cm (Width). The average wet weights of total tissues were 32.40±8.83 g, and the moisture content for MT and DC were 81.38% and 75.64%, respectively. Concentrations of As, Co, Cr, Mg, and Tl were not statistically significantly different between MT and DC. Concentrations of toxic metals (Hg, Pb, and Cd) except As were lower than the permissible limit from *Badan Pengawas Obat dan Makanan* or National Agency of

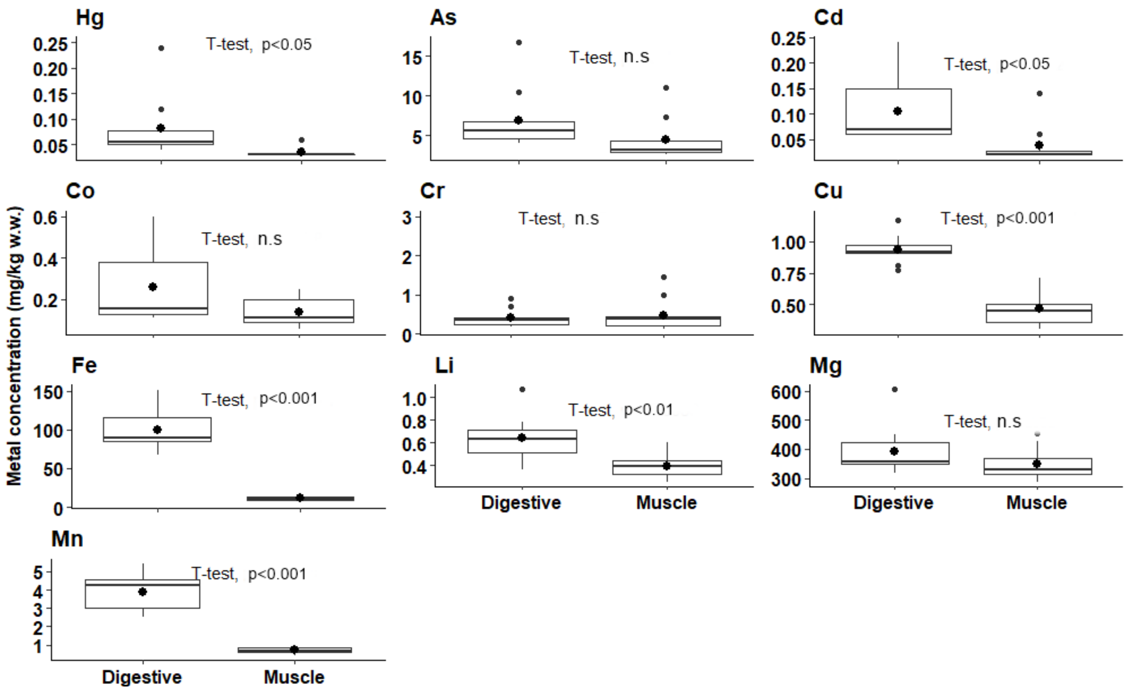

Fig 1. Metals concentrations (mg/kg w.w.) in digestive contents and muscle tissues of *P. reticulata* ("•" represents mean value)

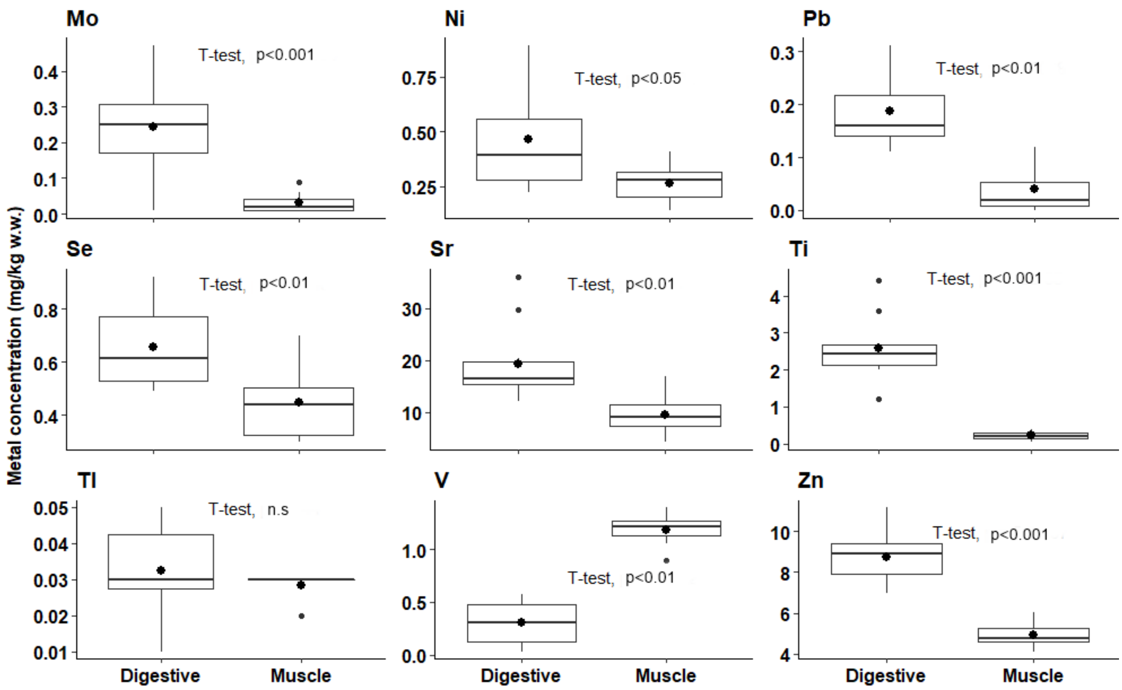

Fig 2. Metals concentrations (mg/kg w.w.) in digestive contents and muscle tissues of *P. reticulata*("•" represents mean value)

Drug and Food Control (NADFC) in muscle tissues and digestive contents. Concentrations of As, Co, Cr, Mg and Tl in MT and DC were 2.58–11.04 (4.41±2.71) and 4.03–16.74 (6.93±3.93); 0.06–0.25 (0.14±0.07) and 0.11–0.60 (0.26±0.18); 0.14–1.45 (0.49±0.42) and 0.18–0.90 (0.41±0.23); 288.86–454.28 (349.70±53.58) and 318.90–

605.27 (393.56±85.98); 0.06–0.37 (0.22±0.11) and 0.014–0.053 (0.033±0.014) mg/kg w.w., respectively. In this study, the concentration of Arsenic (As) in MT and DC (2.58–11.04 (4.41±2.71) and 4.03–16.74 (6.93±3.93) mg/kg w.w. were higher compared to study that reported by Copat et al. [14] in *Donax trunculus* from Catalina Gulf, Italia (1.53 mg/kg w.w.), Sivaperumal et al. [15] in *Villorita cyprinoides* from Cochin area, India (0.69 mg/kg w.w.), Lei at el. [16] in *Mactra chinensis* from Shanghai (0.20 mg/kg d.w.) and Li et al. [17] in *Mactra veneriformis* from Bohai Bay, China (1.44–2.51 mg/kg w.w.). These facts showed an As enrichment in *P. reticulata* that was not fully understood because of sediment, as the main factor, was not examined in this study. Enrichment As could be attributed to the natural and anthropogenic sources. Natural sources mostly related to phosphate deposits and anthropogenic As can be driven As-rich pesticides in the past and phosphorite processing activities [17].

Concentrations of Hg, Cd, and Ni were statistically significant ($p < 0.05$); Li, Pb, Se, Sr, and V statistically significant ($p < 0.01$) different between MT and DC. Concentrations of Cu, Fe, Mn, Mo, Ti, and Zn were statistically highly significant ($p < 0.001$) different between MT and DC in *P. reticulata*. Copper, iron, manganese, molybdenum, and zinc were known as cofactors of many enzymes that play an important role in aquatic organisms [17]. Iron is an essential element for biological function, but in excess, it is related to heart disease, cancer, and impaired insulin sensitivity [18]. Mn is an essential micronutrient for many biochemical reactions in living beings [19]. Zinc has generally been considered to be non-toxic and a minor nutrient required for growth and development [20].

Accumulation of heavy metals in marine mollusks can be affected by many factors, including endogenous and exogenous factors. Endogenous factors such as body size, growth, fitness, reproductive condition and genotypes [21], the differences in biokinetic uptake, depuration rate, and other physiological processes could contribute to the variations in the heavy metal concentration in tissues [22]. Meanwhile, the exogenous factors could be salinity, metal bioavailability [23], alkalinity, and others [19].

Table 1. Pearson correlation R between metals concentration (mg/kg w.w.) in muscle tissues of *P. reticulata*

Element	Hg	As	Cd	Co	Cr	Cu	Fe	Li	Mg	Mn	Mo	Ni
Hg		**0.783**[a]		**0.431**		-0.252		**0.480**	-0.351	**0.440**	-0.202	**0.652**[b]
As				**0.648**[b]					**-0.466**	0.255	0.323	**0.603**
Cd					**0.425**	**0.440**	**0.585**		-0.294	**-0.446**	**0.475**	-0.231
Co						**-0.441**		0.370		0.358	0.350	**0.761**[b]
Cr						**0.769**[a]	**0.684**[b]		-0.257		0.234	
Cu								-0.286	**-0.509**	-0.299	**0.409**	**-0.479**
Fe								**0.448**				0.263
Li									**0.495**	0.382	**-0.472**	**0.575**
Mg											-0.314	
Mn											**-0.466**	**0.716**[b]
Mo												
Ni												
Pb												
Se												
Sr												
Ti												
Tl												
V												
Zn												

Table 1. Pearson correlation R between metals concentration (mg/kg w.w.) in muscle tissues of *P. reticulata* (*Continued*)

Element	Pb	Se	Sr	Ti	Tl	V	Zn
Hg			-0.297		0.279		**-0.537**
As	-0.260						
Cd	-0.201	**0.674**[b]			-0.353		
Co						**0.430**	
Cr	-0.224	**0.427**		0.329	**-0.627**		-0.212
Cu	**-0.423**	**0.512**		**0.416**	**-0.737**[b]		
Fe		0.246			-0.305		
Li		**-0.511**	**-0.512**		**0.406**		
Mg	0.355	**-0.565**		-0.334	0.398		**0.424**
Mn				0.201		-0.204	**-0.439**
Mo	-0.370	**0.477**	0.354		**0.719**[b]	**0.625**	**0.449**
Ni	0.225	-0.337				-0.206	-0.237
Pb		**-0.480**			**0.416**	**-0.716**[b]	
Se			**0.500**		**-0.603**	**0.400**	-0.344
Sr				0.216	**-0.536**	0.287	
Ti					**-0.417**	-0.334	
Tl						**-0.404**	
V							**0.417**
Zn							

Only meaningful |R| > 0.2 correlation is shown; Bold is significant correlation value of > 0.4
[a] Correlation is significant at the 0.01 level (2-tailed); [b] Correlation is significant at the 0.05 level (2-tailed)

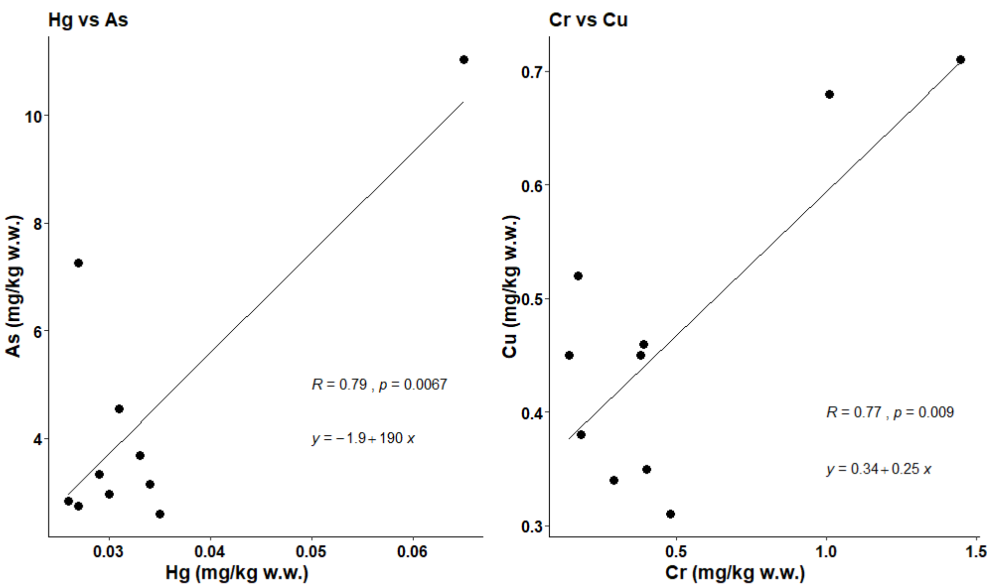

Fig 3. Elemental relationship in the muscle tissues of *P. reticulata* (wet weight)

Pearson correlation between metals in muscle tissues in *P. reticulata* showed in Table 1 and a significantly positive linear correlation ($p < 0.05$) were observed between concentrations of some metals (As-Co, Cr-Fe, Hg-Ni, Co-Ni, Mn-Ni, Cd-Se, Mo-Tl) and significantly negative linear correlation ($p < 0.05$) (Cu-Tl and Pb-V). A significant positive correlation ($p < 0.01$) between Hg-As ($r^2 = 0.79$) and Cr-Cu ($r^2 = 0.77$) is shown in Fig. 3.

Table 2. Pearson correlation R between metals concentration (mg/kg w.w.) in digestive contents of *P. reticulata*

Element	Hg	As	Cd	Co	Cr	Cu	Fe	Li	Mg	Mn	Mo
Hg											
As	**0.976[a]**										
Cd	**0.895[a]**	**0.895[a]**									
Co	**0.676[b]**	**0.684[b]**	**0.923[a]**								
Cr			0.226	0.350							
Cu	**-0.411**	**-0.529**	-0.255								
Fe			0.298	**0.431**	0.622	**0.601**					
Li	0.202		**0.411**	**0.534**	0.319	**0.459**	**0.813[a]**				
Mg		-0.220	0.209	**0.487**		**0.631**	**0.686[b]**	**0.701[b]**			
Mn	**-0.575**	**-0.574**	-0.374		0.373	**0.477**	**0.605**	**0.547**	0.388		
Mo	**0.477**	**0.478**	**0.724[b]**	**0.770[a]**			**0.480**	**0.509**	**0.443**		
Ni	**0.716[b]**	**0.701[b]**	**0.910[a]**	**0.969[a]**	0.272		0.395	**0.558**	**0.500**	-0.222	**0.753[b]**
Pb	**0.411**	**0.420**	**0.707[b]**	**0.793[a]**	**0.546**	0.223	**0.654[b]**	**0.500**	**0.475**		**0.606**
Se	**0.534**	**0.577**	**0.594**	**0.618**		**-0.556**		0.255			**0.660[b]**
Sr	**0.709[b]**	**0.656[b]**	**0.741[b]**	**0.735**	0.360	-0.236	**0.424**	**0.628**	0.337		**0.426**
Ti	-0.207	-0.294		-0.257		**0.733[b]**	**0.560**	0.226		**0.404**	
Tl	-0.293	**-0.408**		0.218		**0.499**	0.355		**0.775[b]**		
V	**0.467**	**0.554**	**0.525**	**0.578**	**0.614**	**-0.998[a]**		-0.288	-0.824	-0.331	**0.910**
Zn	-0.285	-0.283		0.286	0.277	**0.675[b]**	**0.705[b]**	**0.683[b]**	**0.653[b]**	**0.681[b]**	0.387

Table 2. Pearson correlation R between metals concentration (mg/kg w.w.) in digestive contents of *P. reticulata* (*Continued*)

Element	Ni	Pb	Se	Sr	Ti	Tl	V	Zn
Hg								
As								
Cd								
Co								
Cr								
Cu								
Fe								
Li								
Mg								
Mn								
Mo								
Ni								
Pb	**0.663[b]**							
Se	**0.690[b]**							
Sr	**0.806[a]**	0.395	**0.606**					
Ti	-0.330	0.270	**-0.575**	-0.334				
Tl		0.338	-0.236					
V	**0.567**		**0.987[b]**	0.251	**-0.660**	-0.891		
Zn		**0.604**			**0.507**	0.330	**-0.624**	

Only meaningful |R| > 0.2 correlation is shown; Bold is significant correlation value of > 0.4

[a] Correlation is significant at the 0.01 level (2-tailed); [b] Correlation is significant at the 0.05 level (2-tailed)

Pearson correlation between metals in digestive contents in *P. reticulata* showed in Table 2 and a significantly positive linear correlation ($p < 0.05$) were observed between concentrations of some metals (Hg-Co,

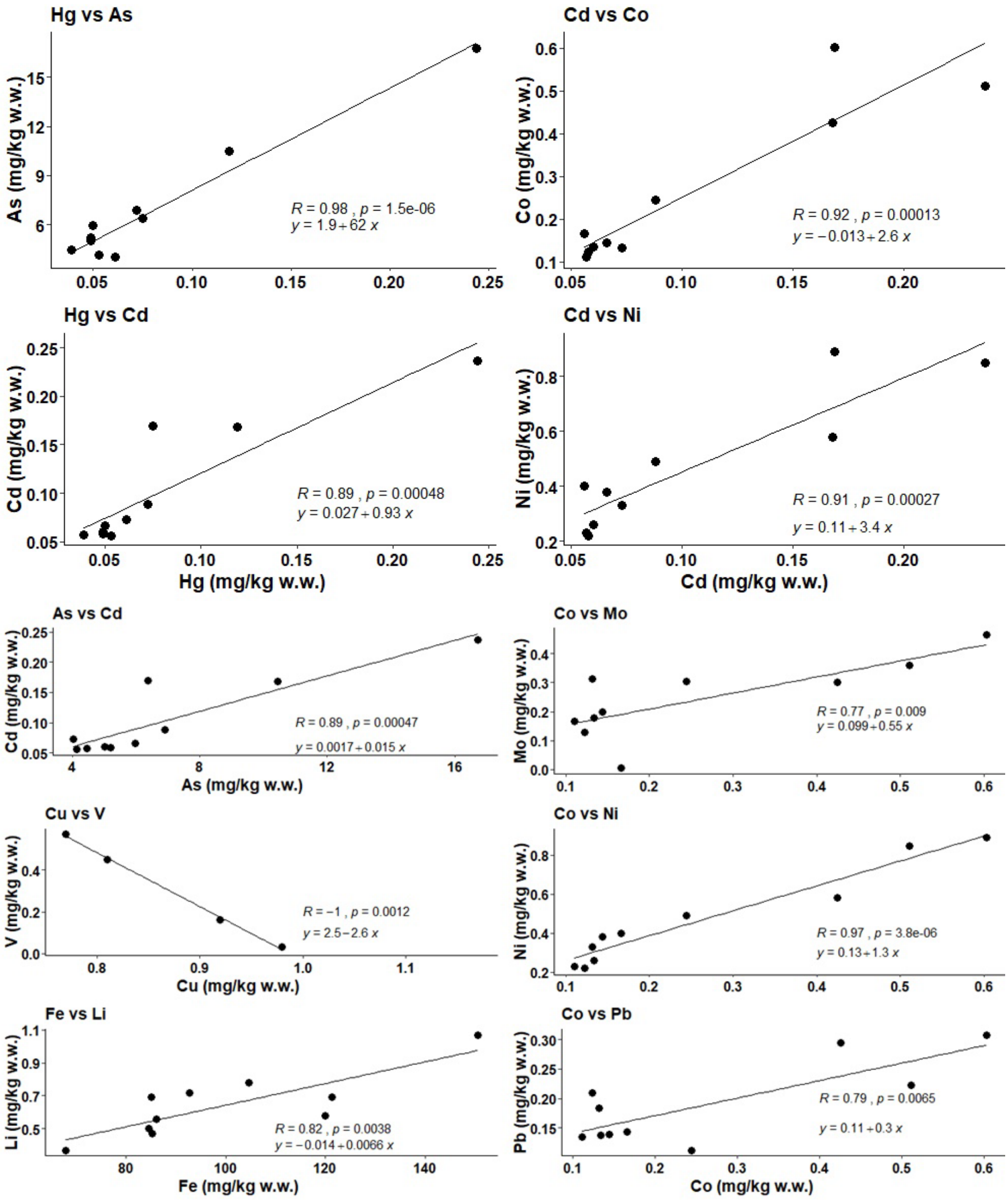

Fig 4. Elemental relationship in the digestive contents of *P. reticulata* (wet weight)

Hg-Ni, Hg-Sr, As-Co, As-Ni, As-Sr, Cd-Mo, Cd-Pb, Cd-Sr, Cu-Ti, Cu-Zn, Fe-Mg, Fe-Pb, Fe-Zn, Li-Mg, Li-Zn, Mg-Tl, Mg-Zn, Mn-Zn, Mo-Ni, Mo-Se, Ni-Pb, Ni-Se, and Se-V). A significantly positive linear correlation ($p < 0.01$) between Hg-As ($r^2 = 0.98$), Hg-Cd ($r^2 = 0.89$), Cd-Co ($r^2 = 0.92$), Cd-Ni ($r^2 = 0.91$), As-Cd ($r^2 = 0.89$), Co-Mo ($r^2 = 0.77$), Co-Ni ($r^2 = 0.97$), Fe-Li ($r^2 = 0.82$) Co-Pb ($r^2 = 0.79$) and significantly negative correlation ($p < 0.01$) for Cu-V ($r^2 = -1$) are shown in Fig. 4. Copper and Titanium showed a positive correlation in the digestive contents of *P. reticulata.* Therefore, it indicated that these metals sources come from slow corrosion of anti-fouling coating paint in a boat [24]. Concentrations of heavy metals *P. reticulata* from Lancang Island compared to the previously reported from around the world and guidelines (NADFC, ANZFC, and JECFA/WHO) were shown in Table. 3.

In the digestive content, Cd as a toxic element was positively correlated with the most of essential metals, Mo,

Table 3. Comparison of heavy metal concentrations in muscle tissue and digestive contents of *P. reticulata* from Lancang Island and *Veniridae* clams in other area (metal concentration in mg/kg; dry weight (d.w.) or wet weight (w.w.) basis; bold indicated exceeding maximum limit from NADFC 2018)

Site	Species		Year	Hg	As	Cd	Co	Cr	Cu	Fe	Li	Mg	Mn	Mo
Lancang Island, Indonesia	*Periglypta reticulata (muscle)*	w.w.	2018	0.03	**4.41**	0.04	0.14	0.49	0.47	11.59	0.39	349.70	0.71	0.03
	P. reticulata (digestive)	w.w.	2018	0.08	**6.93**	0.10	0.26	0.41	0.94	99.87	0.64	393.56	3.91	0.24
Catania Gulf	*D. trunculus* (composite)	w.w.	2012		1.53	0.01		0.25					4.26	
Cochin Area	*Villorita crypinoides* (composite)	w.w.	2011			0.34		0.26	1.4					
Shanghai	*Mactra chinensis* (composite)	d.w.	2008		0.20	0.03		0.10					5.18	
Bohai Bay	*Mactra veneriformis* (soft tissue)	w.w.	2008		1.44	0.27	0.55	1.37	2.34				23.95	0.12
Parit Jawa, Johor	*Polymesoda erosa* (total tissue)	d.w.	2009			3.26			14.1	790				
Parit Jawa, Johor	*Polymesoda erosa* (foot)	d.w.	2009			1.47			3.77	110				
Parit Jawa, Johor	*Polymesoda erosa* (gill)	d.w.					1.46		12.8	1088				
Telok Mas, Mallaca	*Polymesoda erosa* (total tissue)	d.w.	2009			4.23	2.96		15.7	1111				
Telok Mas, Mallaca	*Polymesoda erosa* (foot)	d.w.	2009				0.253		1.80		93.5			
Telok Mas, Mallaca	*Polymesoda erosa* (gill)	d.w.	2009				2.86		8.81	1620				
Coast of New Celedonia	*Gafrarium tumidum* (soft tissue)	w.w.	2008	0.42										
Coast of New Celedonia	*Periglypta chemnitzi* (soft tissue)	w.w.	2008	0.4										
Astamudi Lagoon	*Villorita cyprinoides* (soft tissue)	d.w.	2017			0.08	0.87	3.57	17.73	69.23		574.99	5.16	
Catania Fish Market	*D. trunculus* (composite)	w.w.	2013		1.52	0.005		0.24					4.25	
Marudu Bay	*Polymesoda expansa (soft tissue)*	d.w.	2017		9.12			6.07	16.6				138.1	
Rias of Pontevedra (A1)	*Dosiona exoleta* (soft tissue)	d.w.	2006			0.29			8.67					
(A2)		d.w.				0.25			9.13					
(A4)		d.w.				0.75			16.10					
Kuala Kemaman, Terengganu,	*Polymesoda expansa*	d.w.	2016											
Coastline of India	*Polymesoda aerosa*	d.w.	2013											
Tanjung Lumpur, Malaysia	*Polymesoda expansa (soft tissue)*	d.w.	2017											
	NADFC (2018)	w.w.	2018	0.50	0.25	0.10								
	ANZFC	w.w.	2000	0.5	1	2								
	JECFA/WHO	w.w.	2016	0.5		2								

Table 3. Comparison of heavy metal concentrations in muscle tissue and digestive contents of *P. reticulata* from Lancang Island and *Veniridae* clams in other area (metal concentration in mg/kg; dry weight (d.w.) or wet weight (w.w.) basis; bold indicated exceeding maximum limit from NADFC 2018) (*Continued*)

Site	Species		Year	Ni	Pb	Sb	Se	Sr	Ti	Tl	V	Zn	Ref.
Lancang Island, Indonesia	*Periglypta reticulata (muscle)*	w.w.	2018	0.26	0.04	nd	0.44	9.45	0.22	0.03	1.19	4.93	This study
	P. reticulata (digestive)	w.w.	2018	0.46	0.19	nd	0.66	19.26	2.57	0.03	0.30	8.76	This study
Catania Gulf	*D. trunculus* (composite)	w.w.	2012	0.33	0.07								[14]
Cochin Area	*Villorita crypinoides* (composite)	w.w.	2011	0.34	0.68							40	[26]
Shanghai	*Mactra chinensis* (composite)	d.w.	2008		0.13							14.8	[16]
Bohai Bay	*Mactra veneriformis* (soft tissue)	w.w.	2008	1.00	0.37	0.04	1.26					11.57	[17]
Parit Jawa, Johor	*Polymesoda erosa* (total tissue)	d.w.	2009	5.07	17.9							67.1	[27]
Parit Jawa, Johor	*Polymesoda erosa* (foot)	d.w.	2009		2.18							92.1	[27]
Parit Jawa, Johor	*Polymesoda erosa* (gill)	d.w.			2.56							263	[27]
Telok Mas, Mallaca	*Polymesoda erosa* (total tissue)	d.w.	2009	4.29	6.80							343	[27]
Telok Mas, Mallaca	*Polymesoda erosa* (foot)	d.w.	2009		0.937							105	[27]
Telok Mas, Mallaca	*Polymesoda erosa* (gill)	d.w.	2009		6.51							263	[27]
Coast of New Celedonia	*Gafrarium tumidum* (soft tissue)	w.w.	2008										[28]
Coast of New Celedonia	*Periglypta chemnitzi* (soft tissue)	w.w.	2008										[28]
Astamudi Lagoon	*Villorita cyprinoides* (soft tissue)	d.w.	2017	2.42	1.46							76.79	[29]
Catania Fish Market	*D. trunculus* (composite)	w.w.	2013	0.32	0.07							7.62	[14]
Marudu Bay	*Polymesoda expansa (soft tissue)*	d.w.	2017	5.71	2.31							377.1	[22]
Rias of Pontevedra (A1)	*Dosiona exoleta* (soft tissue)	d.w.	2006		4.65							203	[30]
(A2)		d.w.			2.45							176	[30]
(A4)		d.w.			7.89							301	[30]
Kuala Kemaman, Terengganu,	*Polymesoda expansa*	d.w.	2016		6.9				15.9			12.8	[34]
Coastline of India	*Polymesoda aerosa*	d.w.	2013	14	1.1							91.7	[35]
Tanjung Lumpur, Malaysia	*Polymesoda expansa (soft tissue)*	d.w.	2017		1.94							269	[36]
	NADFC (2018)	w.w.	2018		0.20								[31]
	ANZFC	w.w.	2000		2								[32]
	JECFA/WHO	w.w.	2016										[33]

Sr, Pb ($p < 0.05$) and As, Co, Ni ($p < 0.01$). Cd had only a significant correlation with Se in the muscle ($p < 0.05$), whereas Pb was negatively correlated with V in muscle but had a strong correlation between essential metals, Fe, Ni ($p < 0.05$) and Co ($p < 0.01$) in digestive. Arsenic had strong correlations with Co, Ni, Sr ($p < 0.05$), and Cd in digestive but only had a positive correlation with Co in muscle. Mercury (Hg) also had a strong association with Co, Ni, Sr ($p < 0.05$) and with As and Cd ($p < 0.01$) in digestive but only strongly influenced As in muscle. Alonso et al. reported that there was a significant correlation between metal and essential metal, for example, Cd and was positively associated with most of the essential metals analyzed in the digestive, the organ that accumulates in higher concentrations, compared to muscle [25]. These interactions probably indicate that essential metals for homeostatic mechanisms in organisms, to regulate mineral balance in the body, could be interfered with or competed with toxic elements. This fact would bring a threat to the normal function of metal in the body. So, monitoring of toxic metals in the main compartment like sediment that transfers metals into marine organisms should be done regularly and intensively [26].

CONCLUSION

This study investigated the concentrations of nineteen metals in muscle tissues and digestive contents of *P. reticulata* from Lancang Island, part of Seribu Islands. Concentrations of total Arsenic in muscle and digestive were found to exceed permissible limit from the National Agency of Drug and Food Control. Cadmium, Lead, and Mercury have shown under the permissible limit in muscle tissues and digestive contents, but Cd and Pb in the digestive contents should be a concern because it nearly reaches permissible limit from NADFC. Toxic metals (Pb, Hg, Cd, and As) showed strong correlations with several essential metals, so monitoring for particular metals must be done intensively. Because of the high accumulation in digestive content, the elimination of this part was suggested when consuming this clam to reduce bioaccumulation of heavy metals in the human body.

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AUTHOR CONTRIBUTION

S as main contributor responsible for on data analysis, and drafted the manuscript. RP and ZP executed sampling and drafted the manuscript, while NS performed laboratory analysis.

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