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Original Paper

AN ASSESSMENT OF HEAVY METAL CONCENTRATIONS IN THE SCLERACTINIAN CORAL TISSUES OF KARIMUNJAWA ARCHIPELAGO, INDONESIA

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ABSTRACT

Karimunjawa archipelago, marine national park, has been considered to be a relatively pristine area that have more than 90 species of corals. This study was conducted to detect any concentrations heavy metal levels in the tissues of eight coral species. Based on life-forms, selected coral species are classified as massive (Porites lutea and Goniastrea retiformis), submassive (Galaxea fascicularis and Stylophora pistillata), foliaceous (Pavona decussata and Montipora foliosa) and branching/ramosa (Acropora aspera and Pocillopora damicornis). The concentration of heavy metals in the coral tissues were assessed using Atomic Absorption Spectrophotometer (AAS) technique. The present experimental results demonstrated that metal in coral tissues were no significant difference between sites. Concentration levels of five heavy metals were found to be in the order of Pb>Zn>Cr>Cd>Cu. Relating heavy metal concentrations to life-form corals, there were no significant differences of all the metals (except Pb), the highest concentration of Pb were found in foliaceous type of corals. The high level of Pb in foliaceous coral life-form (Pavona decussata and Montipora foliosa), indicating that these coral species are usefull as potential candidates of biomonitoring material for this metal. However, the use of corals as biomonitors should be considered carefully in biological and local environmental factors.

Keyword: coral tissue, coral life-form, heavy metals, Karimunjawa archipelago

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INTRODUCTION

Coral reef is a marine animal that widely regarded as pristine habitats which are not exposed to high heavy metal input (McConchie and Harriot, 1992; Anu, *et al.*, 2007). However, the increased coastal dwellers, terrestrial runoff, high and destructive fishing, sedimentation, and the release of pesticides and toxic trace metals to coastal waters are known to have an effect on corals in several parts of the world (Mitchelmore *et al.*, 2003; Muslim and Jones, 2003; Esslemont *et al.*, 2004; Ramos *et al.*, 2004; Orpin *et al.*, 2004). Contaminants, such as heavy metals, although noticed as a big

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concern that have never been closely monitored in coral reef ecosystems. This heavy metal contaminant is a serious problem because of their toxicity and their ability to accumulate in the corals (Islam and Tanaka, 2004; Sabdono, 2009). Therefore, an investigation of heavy metal concentration in corals should be part of any assesment and monitoring program in the coral reef ecosystem.

Karimunjawa mini archipelago, which forms a chain of 27 islands, represents several ecosystem types including lowland rain forest, seagrass and algae fields, coastal forests, mangrove forests, and coral reefs in the Java Sea, Indonesia. This archipelago is located in the north direction 90 kilometers from Semarang, Central Java (5^{o} 40' 39''– 5^{o} 55' 00'' LS dan 100 ^{o} 05' 57'' - 110^{o} 31'15'' BT). Only five of the 27 islands are inhabited. Kemujan and Menjangan Kecil were the islands choosen in this study represent inhabited and uninhabited regions, respectively. This archipelago has been considered to be a relatively unpolluted marine environment, since there is no evidence that heavy metals have reached concentrations in coral, water and sediment of Karimunjawa. Most Karimunjawa people's life rely on the coral reefs and its resources with the majority's job as fisherman, therefore it becomes important to assess the heavy metals on reefs since their effect will degrade coral ecosystems. Coral reef degradation was found to affect the fish abundance. Furthermore, Java coastal waters was reported to contaminate by heavy metals (Booij *et al.,* 2001; Takarina *et al.*,, 2004). Guzman and Jimenez (1992) stated that the metals are probably transported and distributed by currents through the entire region, even to pristine offshore reefs.

Heavy metal pollution assessment in marine ecosystems has usually involved analysis in several species of marine fauna (molluscs, barnacles, mussel, oysters), sediments and water (Esslemont, 2000; David, 2002; Usero *et al.*, 2005; Edinger *et al.*, 2007). In some previous studies this approach is satisfactory, however in some regions acceptable sentinel organisms are insufficiently rare or restricted in their distribution. As a result, the collection and analyses of adequate samples is costly and time consuming. In these situation, it would be better to have an alternative indicator organism available. Corals fulfill all the accepted criteria of a suitable biomonitoring organism. The most plentiful and readily sampled sentinel organisms in Karimunjawa are the corals themselves. The Karimunjawa's corals are a mixture of fringing, barrier, and patch with bottom depths ranging from 5 to 30 meters. They have an incredible wealth of 51 genera and more than 90 species of corals.

Corals have some benefits over the use of mollusk, fish or mussels, as sentinel organisms for monitoring metal pollution, such as ease of sampling, low impact on the target pollution, wide distribution of target organisms and lack of target organism mobility (McConchie and Harriot, 1992). Many studies have been concerned with the determination of heavy metal concentration in the skeleton and tissue of corals (Hanna and Muir, 1990; Guzman and Jimenez 1992; McConchie and Harriot, 1992; Esslemont, 2000[b]; Mitchelmore *et al.*, 2003). The results of their studies suggest that metal concentrations in tissues were relative higher than that of in skeletal parts of coral. In addition to unpolluted sites, metal loads in skeletal coral are too low to be used as biomonitor. The specific purposes of this study were to compare heavy metal concentrations in the coral organic tissues between sampling sites, to differ metal loads among life-form corals and to evaluate the possibility of scleractinian corals for

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monitoring some heavy metal pollution in Karimunjawa islands.

MATERIALS AND METHODS

Sample Collection

Sampling sites were located on Kemujan Island and Menjangan Kecil Island, Karimunjawa Archipelago (S $06^0 34'$ 44.1" , E 110^0 37' 47.4"), Java Sea. The Kemujan is inhabited island that considered have nearly anthropogenic metal input, whereas Menjangan Kecil is uninhabited island. However, with respect to heavy metals, this entire area is pristine and metal concentration in coral from both of them must reveal very little differences in environmental metal concentrations. (**Fig. 1**) shows the sampling sites. Specimens of the corals for this analyses were collected randomly during rainy season of 2008 (October) by scuba diving at depths of 3 to 5 m, broken away with chisel and hammer and placed in plastic bag submerged in sea water. Upon collection coral fragments were put into sterile plastic bags (Whirl-Pak, Nasco, USA) and immediately brought to our laboratory with dry-ice.

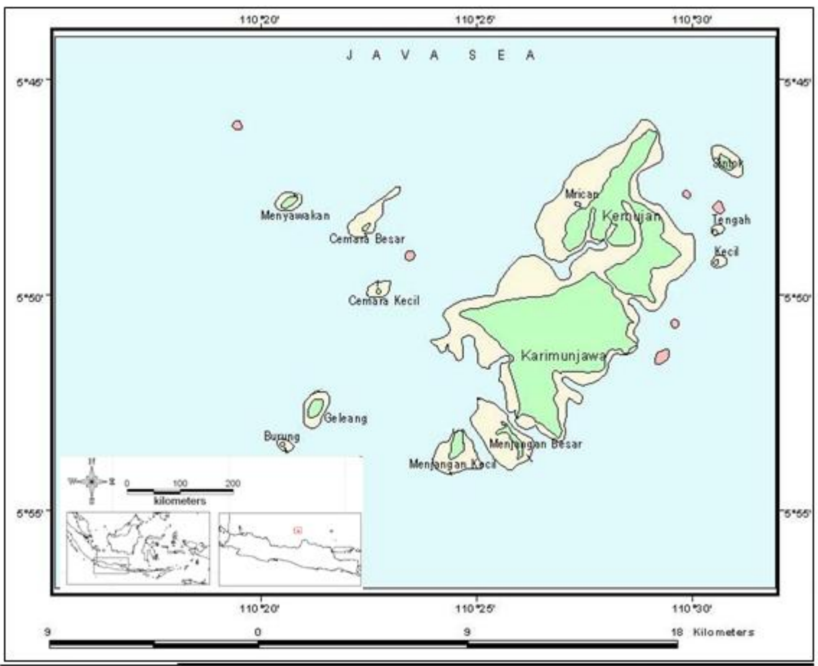

Fig1. Sampling site of Karimunjawa Archipelago

Coral cover and Oceanography parameters

Spatial distributions of hard corals on the reef rim were determined along four randomly placed line transects. The line transect method (Dartnall and Jones, 1986) was used for reef assessment with slightly modification in the present study. The 50 m long measuring tape was placed at both sides depending on coral sampel location, and the lengths of live coral transecting the tape were recorded. Oceanographic parameters such as temperature, salinity, turbidity, conductivity,

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pH and dissolved oxygen concentration were measured by using Water Quality Checker, produced by Horiba Co. Ltd, Japan. Wave Recorder produced by Sountex, USA was used to measure current speed and orientation.

Sample preparation

In laboratory, corals were washed with sterile water to free from visible biotic and abiotic contaminants, dried in room temperature and weighed. Each sample consisted of a part colony (± 200 g). The tissue material in the washed and dried samples was separated from the coral skeleton by the Water Pik method recommended by Johannes and Wiebe (1970). Coral tissue was blasted from the skeleton using Water Pik. Specimens tissue was removed within large polyethylene bags to prevent loss by splattering. The resulting fragmented tissue suspended in water and was poured into a beaker glass. This material was used for chemical analysis after homogenized and centrifugated.

Metal analyses

The collected specimens were digested a mixture of HF, HNO_3 and $HClO_4$ acids (Chester *et al.*, 1994). After the complete digestion, each sample was diluted to 50 ml and the trace metals were determined as $\mu g\ g^{-1}$ using AAS technique (PE-3110) (Sabdono, 2009). The measurements accuracy was checked by applying two replicates in each sample.

Statistical analyses

Concentrations of trace metals in tissue of the eight coral species were subjected to 2 way ANOVA for testing the significance of the difference in the concentrations between sampling sites, between coral life-form and interactive effects site specifity for coral life-form.

RESULTS AND DISCUSSION

A total of 4 transects were made on reefs with dense coral cover. From a data set of 4 transects, percentage coral cover averaged 48,4 % with range from 38-62 %. It is obvious that a 50 m transect did not represent the reef in terms of species diversity. It can only reflect the species composition and coral cover at certain location. Based on measured percentage coral cover, the status of coral sampling sites was classified in moderate to good conditions. Low variation existed among some oceanographic parameter in both sampling sites **(Table 1).**

Table 1. Oceanographic parameters of sampling site

Sampling Site	Oceanographic parameters: :						
	Current ($m\ s^{-1}$)	Turbidity	Salinity ($^0/_{00}$)	Conductivity (mhos cm^{-1})	DO (mg L^{-1})	Temp ^{o}C	pH
Kemujan	0.031	0	29.6	6.10	3.28	29.90	7.67
Menjangan Kecil	0.012	0	29.8	6.15	3.38	29.90	7.67
Mean±Sd	0.021±0.01	0	29.7±0.05	6.12±0.02	3.32±0.02	29.9±0.0	7.28±0.0

Heavy metal concentrations in the tissue parts of the coral species *Porites lutea*, *Goniastrea retiformis*, *Galaxea fascicularis, Stylophora pistillata*, *Pavona decussata*, *Montipora foliosa*, *Acropora aspera* and *Pocillopora damicornis* from two different sites were shown in Table 1. Result for the mean of heavy metals in the coral tissues were Cd 20.01±2.70 mg kg^{-1}, Pb 142.50±42.57 mg kg^{-1}, Cu 4.62±1.52 mg kg^{-1}, Zn 31.58±9.29 mg kg^{-1} and Cr 29.25±5.14 mg kg^{-1}. Coral species *M. foliosa* recorded the highest concentrations of lead. The high level of Pb in corals indicated that these species are a potential biomonitoring material for this metal.

Metal concentration in coral tissue was slightly elevated at the Kemujan Island, however analyses using two-way ANOVA showed that all the metals were no significant differences between those sites. The detection of slightly differences metal concentrations in coral from Kemujan and Menjangan Kecil Island suggest that scleractinian corals may have a potential use in pollution monitoring programs, the difference will be more significant especially when applied between polluted and unpolluted sites. The slightly elevated metal concentrations in Kemujan Island is probably related to the assorted metallic litter dumped from boat or household. This island is surrounded by harbour, shipyard, high density of settlements and high intensity of agricultural activities. The increase in the heavy metals in coral may reflect the environmental factors besides the anthropogenic impacts (Shen *et al.*, 1987; Esslemont *et al.*, 2000). In a previous study, carried out in Jepara coastal waters, Java Sea, the lead levels in total corals of *G. fascicularis* was determined. The mean Pb levels of coral was estimated as 58.01±6.03 mg kg^{-1} (Sabdono, 2009). The anomaly was in the case of lead level in this study was determined two-fold higher than the previous results (polluted site). It was surprised since the finding of many authors reported that coral metal concentrations in polluted site showed higher than that of unpolluted site (Hanna and Muir, 1990; Guzman and Jimenez, 1992; Esslemont, 2000[a]; Reichelt-Brushett and McOrist, 2003 and Mitchelmore *et al.*, 2003). The exception was the study conducted by McConchie and Harriot (1992) reported that Cd concentration in coral tissue in the pristine site was higher than that of polluted site. No explanation could be offered, only they suggested that careful considerations must be given to ways of distinguishing between anthropogenic pollution and natural influences.

Relating trace metal concentrations with coral life-forms, the highest concentrations of all the heavy metals were noted for the foliaceous life-form corals (**Fig. 2**). For Cadmium, Copper, Chrom and Zinc, the two-ways factorial ANOVA indicated that sampel site, coral-life-forms and interaction between these factors were no significant differences. For Lead, however, the two factorial ANOVA demonstrated that coral life-forms were significant (p=0.002), the highest concentration of Pb were found in foliaceous type of corals.

The element Pb accumulation coral life-form pattern was in the order foliaceous>massive>submassive>branching/ramose. Similarly, the order for species wise metal accumulation was *M. foliosa>P. decussata>P. damicornis>S. pistillata>G. retiformis>P. lutea>G. fascicularis>A. aspera*. However, the one-way ANOVA for all the metals showed that species was not a significant factor.

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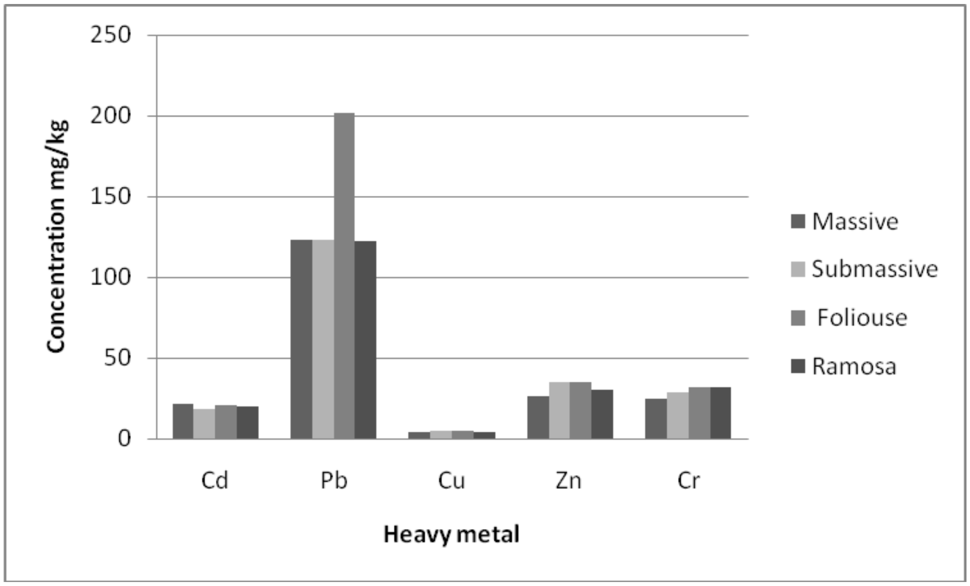

Fig 2. Heavy metal in coral life-forms

Table 2. Mean heavy metal concentrations (mg kg^{-1})in coral tissues from two sampling sites

Coral species	Kemujan Island					Menjangan Kecil Island				
	Cd	**Pb**	**Cu**	**Zn**	**Cr**	**Cd**	**Pb**	**Cu**	**Zn**	**Cr**
P. lutea	19.3	122	4.0	21.5	19	22.2	122	<3.0	9.4	27
G. retiformis	21.3	112	6.9	37.5	22	22.5	137	3.7	37.1	30
G. fascicularis	15.8	120	5.6	37.4	29	14.5	116	4.5	34.9	30
S. pistillata	20.9	120	3.7	34.1	30	20.9	135	4.3	32.4	29
P. decussata	21.6	257	<3.0	29.0	35	22.2	143	7.8	24.9	34
M. foliosa	23.0	202	6.7	53.5	25	16.8	205	4.1	33.0	32
A. aspera	17.1	97	5.1	26.9	23	19.0	123	<3.0	29.4	33
P. damicornis	19.9	150	<3.0	35.5	39	23.2	119	5.5	28.8	31
Mean	**19.86**	**147.5**	**4.33**	**34.43**	**27.75**	**20.16**	**137.5**	**4.15**	**28.74**	**30.75**
SD	**2.4**	**54.69**	**2.29**	**9.54**	**6.82**	**3.12**	**28.9**	**2.01**	**8.69**	**2.25**

Comparisons with previous study, this experimental results are different from Anu *et al.*, (2007) who concluded that Lead showed highest concentration within the branching coral life-form. The causes of different concentration of heavy metals in those coral life-forms are probably because of the difference of biological and local environmental factors, such as, mucus production (Reichelt-Brushett and McOrist, 2003), sedimentation, variation in metal tolerance levels, the amount of zooxanthellae and the influence of different reproductive

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states of corals (Esslemont, 2000[b]; Esslemont, *et al.*, 2000; Reichelt-Brushett and Harrison, 2000). The enrichment of lead can take place in adsorption on the outer surface. Corals absorb metals across their surface's tissue, then metals are suspended or floating in the surrounding water will be absorbed. The amount of metal present in the environment will influence metal accumulation in corals. This study suggested that *M. foliosa* and *P. decussata* (foliaceaous) seem to have potential organisms for monitoring Pb in coral reef ecosystems of Karimunjawa.

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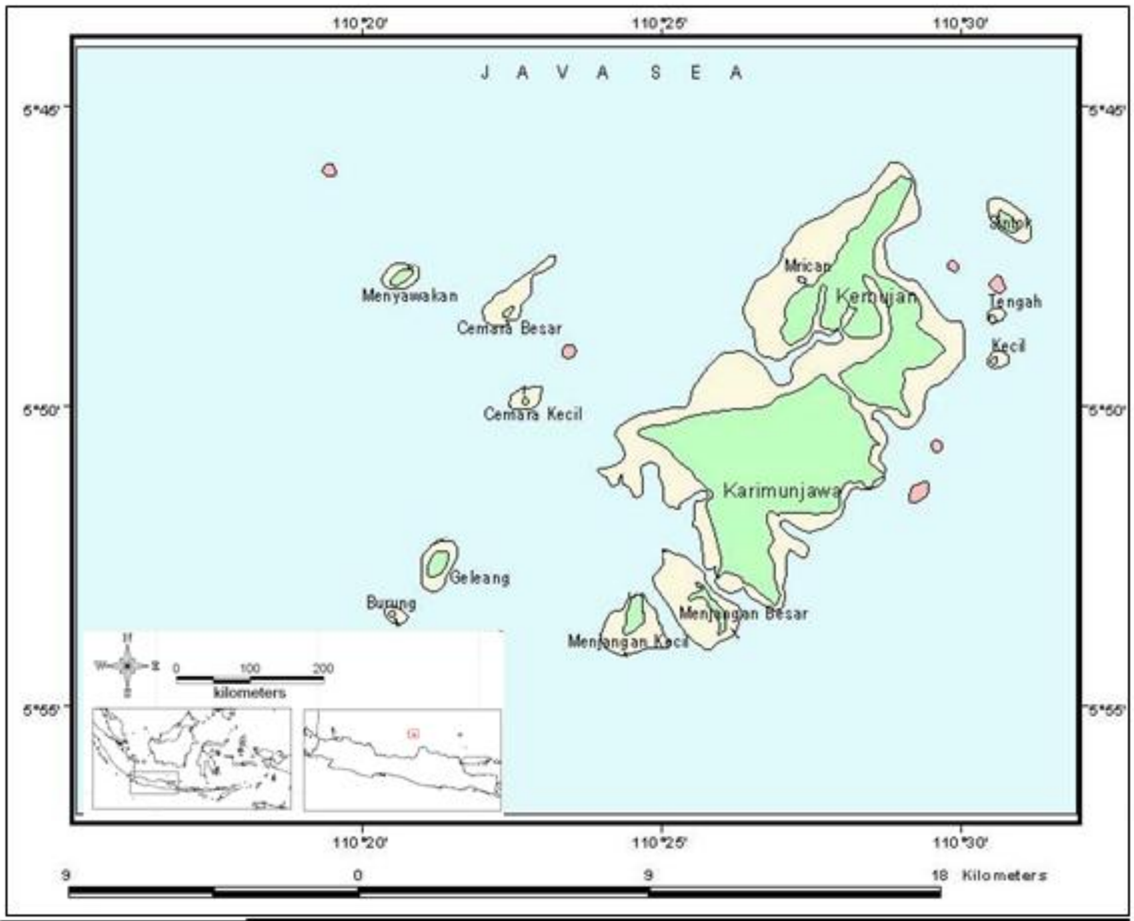

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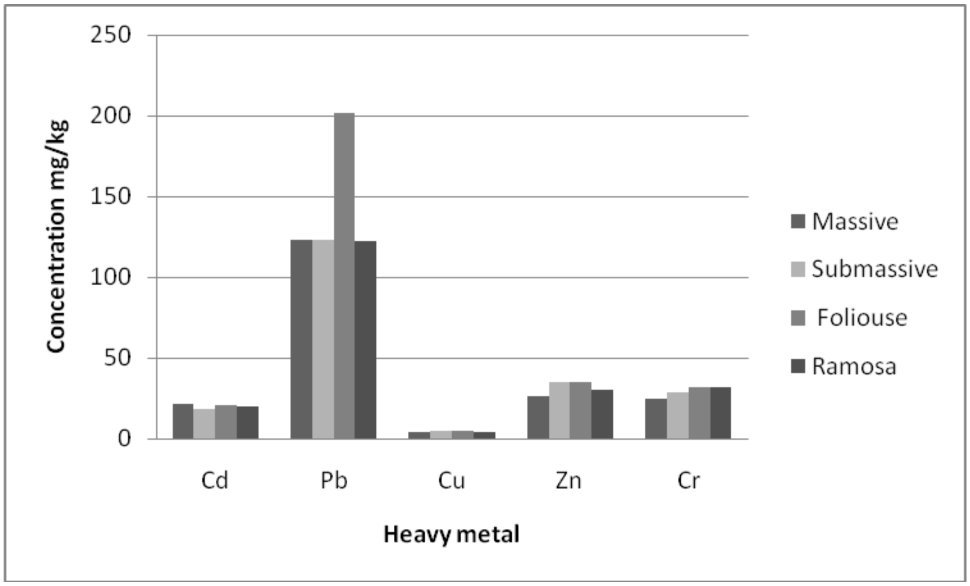

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