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Lead accumulation in White-Mangrove, *Avicenniaalba* (Blume), inhabiting densely industrial area of East Java, Indonesia

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Abstract

Coastal area of East Java Sea has long been threatened by industrial source pollution, mangrove conversion into shrimp culture, over fishing, destructive fishing, sedimentation, and coastal settlement. Heavy-metal is probably the most threat that directly influencing human health. This study was carried out in two coastal areas considered central to the threat, Kedawang and GunungAnyar. Lead concentration was measured in the water, sediments, and white-mangrove, *Avicenniaalba*. It showed that heavy-metal has been accumulated in the sediments. Root of mangrove tree can up take and bio-concentrating this lead heavy metal up to 5.74 mg kg^{-1} dry weight. The concentration in the leaves and seeds were significantly lower as it frequently exuviate, drop down, and regenerated. This metal concentration was higher than the allowable concentration (Ministerial Decree of State Environment No. 51 year 2004). Measures have to be taken in order to maintain coastal area healthy for human population.

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Introduction

As widely common in Southeast Asia (Burke *et al.*,2002), coastal area of East Java (part of Java Sea) was pervasively threatened due to industrial pollution and coastal development – it receives pollutants from two main rivers in Java, Solo and Brantas. Heavy metals are the most hazardous chemical compounds that always found to be far higher than the standard allowable concentration (Everaarts, 2003,Takarina*et al.*, 2012). These materials are concentrated in sediments (Atkinson *et al.*, 2007), various edible organisms, such as gastropod, fish (Takarina*et al.*, 2012,BasygitandTekin-Ozan, 2013) and plants such as mangroves (Casares*et al.*, 2014, Lawson, 2011,Mullai*et al.*, 2014,RezvaniandZaefarian, 2011).

Various species of wetland plants and mangroves are scientifically proved to be able to up take metal ions, translocation, and degrade it into non-hazardous compounds (Hamadouche*et al.*, 2012, Li *et al.*, 2014,Nirmal Kumar *et al.*, 2011, Weis and Weis, 2004). However, these functional vegetations have been cleared cut and converted into shrimp ponds (tambak system). As shrimp culture was boosting around the 1980s, new tambaks were developed along the coast of East Java, and consequently reducing the healthy population of mangrove forests (Hariati*et al.*, 1995). Initially, shrimp farming has significantly increased export and national earning. As tambaks growing mature, the production came down and finally collapse, leaving the open space unmanaged.

The concentration of some heavy metals was recently observed to be declining, particularly in the sediment near Jakarta Bay (Hosono*et al.*, 2011,Rinawati*et al.*, 2012). This was due to many strict environmental regulations being enacted recently and strictly implemented in the field (Hosono*et al.*, 2011). In case where nature is not optimally functioning as was before, such as reduced area of mangroves in East Java, the heavy metal pollution will remain in the coastal area. The research was aimed to monitor lead concentration in the water and sediment in two industrialized areas of East Java and to test phytoremediation capacity of white-mangrove, *Avicenniaalba* (Blume) that still left and dominating in the area.

Materials and methods

Sampling sites

The study was carried out at two heavy polluted cities in East Java, namely Kedawang (Pasuruan), and GunungAnyarlocated in the capital city of Surabaya (Fig. 1). Both sites are ± 80 km apart and receive the highest water pollution in the province. Samplings were done during almost the end of rainy season in March 2014, considering that most industries tended to dump their waste during rainy season. It was commonly understood among industries that waste would be diluted quickly when river is over-flooding. Bath areas are densely occupied for local settlements. GunungAnyar was more industrialized area, whereas Kedawang was more popular for shrimp and/or milkfish culture (tambak system).

Water quality

In-situ water quality parameters were monitored during the study – water temperature, salinity, pH, and Dissolved Oxygen. Water temperature and Dissolved Oxygen were measured using DO-meter (0.1 °C, and 0.01 mg l^{-1}, respectively). pH was measured using pH-meter (0.01 pH unit). All these water quality may influence the sequestration of released lead and its accumulation into sediment and mangrove plants.

Heavy Metal

Samples for Lead (Pb) heavy metal were collected from coastal water, sediment, roots, leaves, and seeds of white-mangrove, *Avicenniaalba* (Blume), the most dominated species in both areas. The roots were carefully cleared from sediments. All the samples were labeled, stored in cool box with ice, and transported directly to the laboratory.

The sediment samples were sieved and lead were extracted using procedures as explained in Rauret (1998). Samples of plant parts were thoroughly washed with deionized water to remove all dirt. It was then oven-dried at 70ºC for 48 hours. The dried plant tissues were digested in a mixture of nitric acid and perchloric acid. The lead concentration in the samples was determined using AAS (Atomic Absorption Spectrophotometry, Varian Spectra AA220) as explained in Soareset *al.* (1999).

Fig. 1. Map of sampling sites: A – Kedawang, Pasuruan, concentrated shrimp farms and settlements; B – GunungAnyar, Surabaya, intensive settlements after industry's area.

Data analysis

The data was analyzed using student't' test to detect if any significant differences of eachheavy metal exist between concentration in the water, sediments, and plant parts (roots, leaves, and seed). The *p*-values of less than 0.05were considered to indicate statistical significance. Lead concentration in sediment and root of mangrove plants were compared to measure bio-concentration rate.All statistical analysis was done using software SPSS v.16

Resultsand discussion

Water quality

Temperature and salinity were significantly different in both coastal areas (Table 1). However, pH and Dissolved Oxygen (DO) were almost in the same ranges. Lead release and sequestration rates are affected mainly by changes in overlaying water salinity, pH, and DO, apart from biological disturbance by such as benthic bivalve (Atkinson *et al.*, 2007). Decreased pH appeared to increase the sequestration rate of released lead. Water with low dissolved oxygen will lead to low sequestration rate of released lead. When temperature increased, it will increase lead absorption into sediment (Do andPark, 2011). The pattern appeared to be similar for increase in salinity.

Mean pH and Dissolved Oxygen were comparable in both coastal areas, Kedawang and GunungAnyar. Average temperature and salinity in Kedawang (Pasuruan) were found to be significantly higher than that in GunungAnyar (Table 1). However, measured lead in the coastal water of GunungAnyar was higher (Table 2). It indicated that estuary of GunungAnyarreceived much higher metal pollutants than Kedawang. Surabaya is considered to be the most polluted area from heavy metal compared with other areas in East Java (Susanti*et al.*, 2001).

Lead Concentration

Lead concentrations in the water (for both sites) were higher than the allowable concentration enacted under State Ministerial Decree of Environment No. 51 year 2004 (Table 2). Total numbers of industries, particularly in Surabaya, are increasing every year. Industries that produce waste of heavy-metals are not well recorded. In case the individual industry produces heavy-metal waste less than the allowable concentration, total concentration in the coastal areas will still high as the numbers of industries are increasing.

Table 1. Statistics of water quality parameters in both sites (Kedawang District Pasuruan, and GunungAnyar-Surabaya).

PARAMETER	N	STATISTICS	SAMPLING SITES	
			KEDAWANG	Gunung ANYAR
Temperature (°C)	5	Means	32.62[b]	27.91[a]
		Min-Max	32.2-33.2	25.0-32.6
		SD	0.421	3.146
		SE	0.188	1.407
Salinity (ppt)	5	Means	22.6[b]	7.5[a]
		Min-Max	16.0-26.0	1.0-12.5
		SD	3.9	4.3
		SE	1.8	1.9
pH	5	Means	7.2[a]	6.7[a]
		Min-Max	6.8-7.8	6.6-7.0
		SD	0.415	0.164
		SE	0.185	0.073
Dissolved Oxygen (mg l^{-1})	5	Means	6.8[a]	6.7[a]
		Min-Max	6.6-7.0	6.6-6.8
		SD	0.148	0.075
		SE	0.066	0.034

Remark:Different alphabetical code after the number (means) indicates statistical differences of means at α = 0.05.

Surabaya is capital city of East Java Province where industries and settlements are concentrated. Meanwhile, coastal land use in KedawangPasuruan is more concentrated for shrimp culture (tambaks) and settlements. The concentration of Lead heavy-metals in Surabaya were significantly higher than that in Pasuruan (Table 2). However, lead concentration in sediment and root of white-mangrove were higher than in the water for both sites. This indicates that heavy-metal, particularly Lead (Pb), has accumulated in sediment and plants as well.

The Lead concentration in the root of white-mangrove at Kedawang was statistically comparable with that in the sediment. So, mangrove plant couldabsorb and bio-accumulating lead from its surrounding environment. Lead concentration in root of mangrove plants at GunungAnyar was lower compared to that in the sediment. Up to certain level (± 5.74 mg kg^{-1} dry weight), mangrove plants may able to up take heavy-metal from the sediment. This metal is transported into barks, leaves and seeds (Hamadouche*et al.*, 2012, Khan *et al.*, 2013).

White-mangrove has the ability to transport Pb from their roots to leaves and seeds. The concentration in leaves and seeds were significantly lower than that accumulated in the root of the plants. Before accumulating lead in high concentration, leaves and seeds of mangrove will exuviate drop to the ground. Meanwhile, root will directly exposed in longer time with heavy-metals that accumulated in the sediment.

Plant damage.

Table 2. Lead concentration (mg l^{-1}) for between and within sites, measured at different target (water, sediment, and root, leaves, and seeds of white-mangrove).

	Lead concentration:				
	Water	Sediment	Roots	Leaves	Seeds
Between sites:					
Kedawang	0.15^a	2.81^a	2.99^a	0.26^a	0.25^a
GunungAnyar	0.34^b	7.38^b	5.74^b	0.65^b	0.43^a
Within sites:					
		Kedawang		GunungAnyar	
Lead in water (mg l^{-1})		0.15^a		0.34^a	
Lead in sediment (mg kg^{-1})		2.81^b		7.38^c	
Lead in roots (mg kg^{-1})		2.99^b		5.74^c	
Lead in leaves (mg kg^{-1})		0.26^a		0.65^a	
Lead in seeds (mg kg^{-1})		0.25^a		0.43^a	

Remark: Different alphabetical code after the number (means) indicates statistical differences of means at $\alpha = 0.05$.

It is not very clear yet on how heavy-metals are converted by aquatic plants into substances that less hazardous to human health. On average, mangrove leaves in Kedawang contain 0.26 mg kg^{-1} of Lead. This concentration was significantly lower than mangrove leaves in GunungAnyar, Surabaya (Table 2). Within this concentration range, it does not show damage of leave structure of mangrove in Kedawang. However, with higher Pb accumulation in the leaves (GunungAnyar Surabaya), it shows some damage of leave structure (Fig. 2). The damage is particularly concentrated on the upper epidermis of leave structure. Mesodermis and lower epidermis were remained comparable, indicating no significant damage.

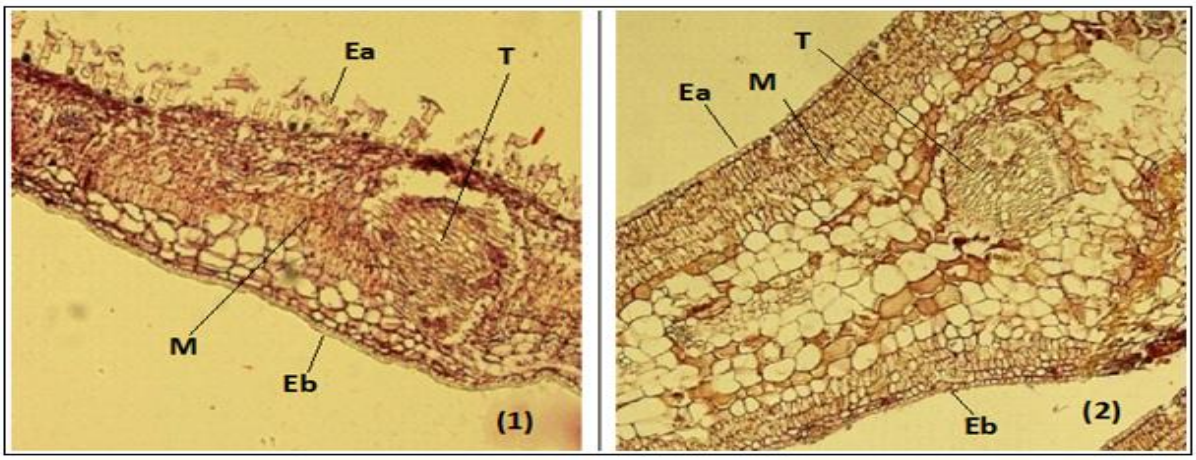

Fig. 2. Leave histological view of white-mangrove, *Avicenniaalba*, found in GunungAnyar-Surabaya (1) and Kedawang-Pasuruan (2). It shows the damage of upper epidermis for mangrove leaves in GunungAnyar, due to high lead accumulation. Remark: Ea = Upper Epidermis Layer; Eb = Lower Epidermis; M = mesodermis; T = Leave Bone.

Conclusion

This study proved high Lead concentration in the coastal water of East Java. Even in less industrialized areas, Kedawang, heavy-metal was still higher than the allowable concentration. Sediment and coastal plants were able to accumulate heavy-metal (Pb) more than 10 times the measured concentration in the water. Root was the most point where bio-accumulation was occurred as it directly exposed and longer contact with sediment. Leaves, those translocate high concentration of heavy-metal, showed significant damage, particularly in the upper epidermis of the leave.

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