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Research Article

Ability of Mangrove Apple as Mercury Bioindicator

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ABSTRACT

The anthropogenic provide a negative impact on the surrounding environment. Mangrove species, such as *Sonneratia alba* able to get of anthropogenic activities, to accumulate the pollution of heavy metals. The aim of this study is to evaluate mercury accumulation in Mangrove Apple (*S. alba*) as mercury bioindicator. Samples were taken at Pari Island, Seribu Islands by purposive sampling. Mercury on the root, stem, leaf, and fruit samples of S. alba and from sediment was analyzed using Mercury Analyzer NIC type MA-3000. Data analysis were performed by paramectic test, bioconcentration factor (BCF), metal extraction ratio (MER) and translocation factors (TF). The results showed that the highest concentration of mercury in the Northern of Pari Island was found in the leaves and the lowest was in the fruit. The highest concentration of mercury in the Eastern of Pari Island was found in the leaves and lowest was in the fruit. The concentrations of mercury in the Eastern area higher the Northern area (significantly different). The accumulation of mercury mainly collected on the leaves with TF> 1, but the ability of *S. alba* trees absorb mercury in the environment showed a small value, namely BCF <1. The ability of *S. alba* in sediments, contaminated with mercury showed a high value on the leaves in the East Pari Island, but the fruit of *S. alba* both in the north and east of the Pari Island showed a small value. Mangrove apple leaves is potential bioindicator of mercury.

Keywords: *bioaccumulation, mercury, Sonneratia alba, Pari Island*

1. Introduction

Industrial activities have two different impacts, namely positive impacts of economic improvement and negative impacts of environmental degradation, which from the absence of good industrial waste management (Murphy and Gouldson 2000), such as the declining of water quality due to pollutants passing through the threshold (Li et al., 2016b; Rumisha et al., 2016). Mercury is a hazardous and toxic pollutant produced by anthropogenic activity (Polii and Sonya 2002; Sembel 2015), Mercury is a ubiquitous contaminant derived from urban and industrial sources that reaches many coastal areas worldwide, such has been observed in Jakarta Bay such as North Jakarta intregrated industrial area and shipping transportation line, also from 13 river runoff in Jakarta Bay. Mercury can accumulate through the food chain to give the effects of acute and chronic poisoning (Bose-O'Reilly et al., 2010; Hadi, 2013). The accumulation of mercury in the body of aquatic organisms will disrupt the enzymatic system (Simbolon et al., 2010).

Field et al (1998) declared mangrove provide a role in anthropogenic functions (i.e. management of sediments, maintenance of fisheries), biogeochemical functions (i.e. nutrient cycling, production) and ecological functions (i.e. spawning ground, feeding ground and habitat for marine and coastal organisms in different tropic levels). Mangrove forests as one of the natural resources have a very important role to overcome and at the same time potentially as an indicator of environmental pollution (Ontorael et al., 2012). Mangrove is very sensitive to environmental changes such as sea lever rise and marine pollution (Wibowo and Handayani, 2006), has the ability to accumulate mercury in waters (Machado et al., 2016), thus reducing the negative impact of pollutants on water (Setyawan and Winarno, 2006). The study of heavy metal pollution is mostly done on water, sediment, and fish as did Priyanto et al. (2008); Murtini et al. (2008); And Riani (2010). The study of heavy metal

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accumulation on mangrove among others was done by Supriyantin and Soenardjo (2015) which studied heavy metals of Pb and Cu on root and fruit of *Avicennia marina*; Setiawan (2013) conducting studies on the accumulation and distribution of heavy metals in mangrove vegetation in coastal waters of South Sulawesi; Hamzah and Setiawan (2010) who studied the concentrations of heavy metals Pb, Cu, and Zn in the mangrove ecosystem. Studies on bioaccumulation as well as mangrove potential as mercury bioindicators in mangroves, especially in Indonesia and especially in the type of *S. alba*, are still underway (Lewis et al., 2011; Sandilyan and Kathiresan, 2014).

The vulnerability of the Thousand Islands region will increase due to the increase of anthropogenic waste in Greater Jakarta (Jabodetabek) area (Purpaningsih, 2006; BPLHD DKI Jakarta, 2015), one of the ecosystems that will be affected is the mangrove ecosystem. Revitalization of mangrove functions by local residents in the area of Pari Island, Seribu Archipelago is underway, one of which is *S. alba*. Therefore, this study aims to determine the accumulation of mercury heavy metals in Mangrove Apple (*S. alba*) from Pari Island, Seribu Archipelago, Jakarta so that it can be known as a potential mercury bioindicator.

2. Materials and Methods

Sampling

Samples were taken in Pari Island, Seribu Archipelago at S.alba mangrove sites (Figure 1) with purposive sampling on the northern part of Pari Island, and the eastern part of Pari Island. The roots, stems, leaves, and fruits were taken from five sites of mangrove apple (3 sites in the north and 2 sites in the east), then we put into sterile plastic and in a box containing coolant with a temperature of 4-8°C (EPA Method 200.7, 200.8, and 200.9).

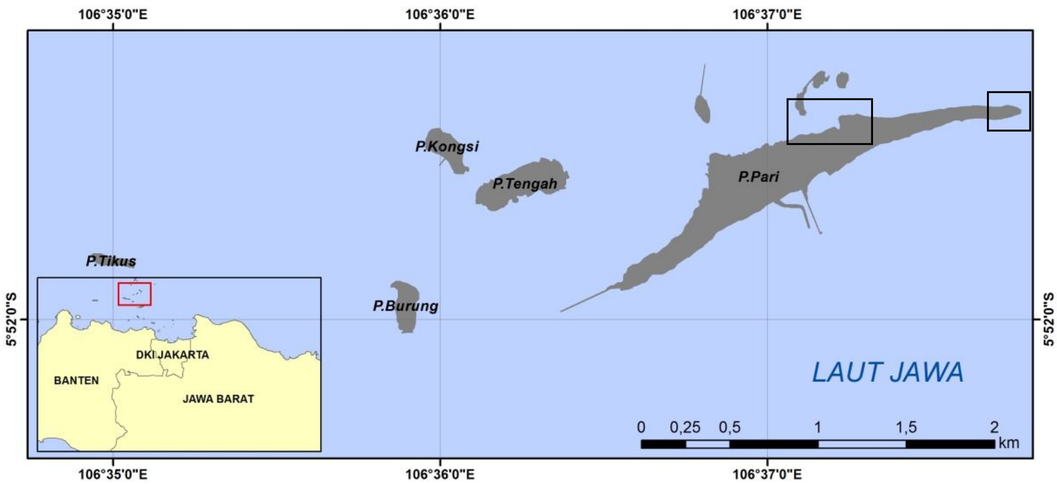

Figure 1. Sampling location

Analysis of mercury content

Mercury on *S. alba* and from sediment was analyzed using Mercury Analyzer NIC type MA-3000. The mercury analysis process is based on USEPA 7473 and ASTM D-6722-01, with the principle of thermal decomposition, amalgamation, and atom absorption (NIC, 2015). The root, stem, leaf, and fruit samples of *S. alba* were removed from other sediments and other impurities with double-distilled deionized water. After cleaning process, we put sample to sterile petri dish and started to weight it. Each part of *S. alba* was analyzed ten times repetition. The weighing process of the sample was carried out with an analytical instrument of the Denver Instrument type SI-234. 100-150 gr samples were placed in sterile Petri dishes and dried with Heraeus Instrument type T-12 oven at 60°C for 24 hours (SNI No 01-2354.6-2006). The dried sample was taken 20-30 mg and mashed with sterile mortar. As a quality control and quality assurance of mercury analyzer, standard measurement material was measured from National Institute of Standards and Technology No. 1515. The analysis of STM 1515 measured as a sample of 0.04614 mg/kg, still within the standard range of 0.044 ± 0.004 $mg.kg^{-1}$ (NIST 1993). The value indicates mercury analyzer by the method being in a valid and controlled condition.

Data analysis

The mean and standard deviation values of mercury in *S. alba* from mercury analyzer were discussed descriptively. Statistical parameter were used with parametric test with t-test and post hoc equality test of variance equality with Games-Howell test and Bonferroni test (Santoso, 2010a, 2010b; Triyanto et al., 2012) in RKWard version 0.6.5. The value of p-value used to show the real difference between variables <0.05 (Nichols and Holmes 2007; Sedgwick 2012).

Further data analysis were performed by calculating bioconcentration factor (BCF), metal extraction ratio (MER) and translocation factors (TF). Rezvani and Zaefarian (2011); Supriyantini and Soenardjo (2015) stated that BCF is a comparison analysis of metal concentrations in organs with metal concentrations in sediments, with high accumulation category (> 1mg.kg^{-1}) and low accumulation (<1mg.kg^{-1}). BCF is obtained by the formula:

$$\mathrm{BCF} = \frac{Cx}{Cs}$$

With :
Cx : The average concentrations of metals in root organs, stems, leaves, and fruit *S. alba* (mg.kg^{-1}dw);
Cs : Metal concentrations in sediments (mg.kg^{-1}dw).

MER represents the ratio of metal accumulation to organs and to sediments (Rezvani and Zaefarian, 2011). MER is obtained through the formula:

$$\mathrm{MER} = \frac{Cp \times Mp}{Cs \times Ms} \times 100$$

With:
Cp : the metal concentration in the organs (mg.kg^{-1}dw);
Mp : mass of organ sample (mg).
Cs : metal concentration in sediment (mg.kg^{-1}dw);
Ms : mass of sediment sample (mg).

TF is the ratio of metal concentrations between organs to analyze the effectiveness of inter-organ metallic translocation, TF> 1 values showed high effectiveness (Rezvani and Zaefarian, 2011). TF is obtained through the formula:

$$\mathrm{TF} = \frac{Cx}{Cy}$$

With:
Cx : the average metal concentration in the receiving organs (mg.kg^{-1}dw);
Cy : the average concentration of metal in the distributing organs (mg.kg^{-1}dw).

3. Result and discussion

Accumulation of mercury in S. alba organ

Based on the analysis, all the organs of *S. alba*, accumulate mercury (Table 1). The average concentration of mercury in the organ can be seen in Table 1. In general, the highest mercury accumulation is found in *S. alba* growing in the eastern part, with an average concentration of 0.0152 ± 0.0030 mg.kg^{-1}dw. In *S. alba* grown from the northern part of Pari Island, the average mercury concentration is 0.0086 ± 0.0015 mg.kg^{-1}dw.

The eastern area of Pari Island adjacent to Jakarta Bay is initial area affected by the mass of ocean currents carrying heavy metals mercury from anthropogenic activities, particularly industry, in Greater Jakarta thus causing a higher concentration of mercury in *S. alba* growing in the east. This is in accordance with the statement of Widiarti and Anggraini (2012) which states that part of Pari Island which is directly adjacent to the tube and waters of Jakarta Bay causes the condition of the waters in that location has a stronger current than the island side north of Pari Island. Purnawan et al. (2013) state the magnitude of ocean currents will affect the spread of mercury. Greenland and Hayes (1981) added, closer to the source of pollutants, the possibility of higher pollutant accumulation.

An analysis of the accumulation of mercury in organs was performed on root organ, stem, leaf, and fruit of *S. alba* (Table 1). The highest accumulation is in leaves, then on roots and stems. The lowest accumulation is found on *S. alba* mangroves. Based on further tests on each organ, there was a marked difference (p <0.05) in mercury accumulation as well as at both sampling sites. Compared with mercury concentrations in sediments, mercury concentrations in *S. alba* were lower.

Table 1. Mercury concentration in the sediment and on *S. alba* organ

Sample	Sampling location	Concentration ± SD ($mg.kg^{-1}dw$)
Sediment	North	0.0340
	East	0.0563
Root	North	0.0122 ± 0.0017 [a]
	East	0.0195 ± 0.0028 [b]
Stem	North	0.0081 ± 0.0017 [a]
	East	0.0101 ± 0.0013 [b]
Leaf	North	0.0124 ± 0.0010 [a]
	East	0.0272 ± 0.0020 [b]
Fruit	North	0.0017 ± 0.0003 [a]
	East	0.0038 ± 0.0009 [b]

Remark: [a] and [b] indicated significant different between mercury concentration on *S. alba* organ

The highest mercury accumulation on *S. alba* leaves grown in the east (0.0272 ± 0.0020 $mg.kg^{-1}dw$). The concentration of mercury (0.0124 ± 0.0010 $mg.kg^{-1}dw$) in *S. alba* leaves living in northern Pari Island is highest among other organs in the same individual. The results of this study based on Heriyanto and Subiandono (2011) which states the high accumulation of heavy metals (Hg, Pb, and Cu) on mangrove leaves. The accumulation of mercury in *S. alba* leaves occurs because the leaves have a synthesis function of organic matter and organs with the most active metabolic part (Ding et al., 2011). Ai and Banyo (2011) stated that plants will carry nutrients (including contaminants) to leaves, through xylem tissue and photosynthesis system (Dahlan 1986). Organic materials and pollutants, including heavy metals, entering from the sediments will be transported to the leaves through the transpiration stream and accumulate in the leaves (Ding et al., 2011).

At the root, the mercury concentration in the northern part is lower (0.0122 ± 0.0017 $mg.kg^{-1}dw$) than in the *S. alba* root grown in the east (0.0195 ± 0.0028 $mg.kg^{-1}dw$). Setiawan (2013) reported, direct interactions between mangrove root with sediment and water can accumulate mercury and make the roots as the highest mercury accumulators. Heriyanto and Subiandono (2011); Heriyanto and Suharti (2013) added from their research in mangrove area on Purwakarta and Sidoarjo, root system and root surface area of plants, including mangrove, make pollutants absorbed by tree roots, along with nutrients. Ding et al. (2011) added mangrove roots to absorb organic matter and pollutants such as heavy metals which will then be distributed to other organs through the xylem. Based on post-hoc (further test), there was no significant difference between mercury concentration at root and leaf, but significant difference in stem against root, leaf, and fruit; on leaves against stems and fruit.

The high accumulation of mercury in leaves and roots due to the toxic ion excretion process that is done through both organs. Roots has direct contact to the sediment and bring all nutrients through xylem and phloem to leaves which is the most metabolic part in mangrove, this process through ion exchange. Our hypotheses were similar with report from Andani and Purbayanti (1981), the ions can be drawn between the organs via the xylem tissue back to the parenchyma xylem, then released through the roots back to the sediments. This can be the reason for heavy metal accumulation in mangrove stems is lower than in leaves and mangrove roots, but higher than in fruit. Compared to other plant, Murat et al. (2004) mercury accumulation on *Myriophyllum spicatum* were higher in roots and leaves than in stem.

Table 2. Bioconcentration factors (BCF) and metal extraction ratio (MER) on *S. alba* in Pari Island

Organ	BCF		MER	
	North	East	North	East
Root	0.3588	0.3471	54.09	64.99
Stem	0.2388	0.1795	37.53	37.99
Leaf	0.3659	0.4831	54.13	99.93
Fruit	0.0491	0.0670	7.36	14.33

Table 3. *Translocation factors* (TF) on *S. alba* in Pari Island

TF North					TF East				
	Root	Stem	Leaf	Fruit		Root	Stem	Leaf	Fruit
Root	-	0.6656	1.0197	0.1369	Root	-	0.5169	1.3920	0.1929
Stem	-	-	1.5320	0.2057	Stem	-	-	2.6931	0.3733
Leaf	-	-	-	0.1342	Leaf	-	-	-	0.1386
Fruit	-	-	-	-	Fruit	-	-	-	-

Bioconcentration factors (BCF), metal extraction ratio (MER) and Translocation factors (TF) on S. alba in Pari Island

The value of BCF shows that the level of contaminants in organisms originating from the environment (Hamzah and Setiawan 2010). Based on the analysis, the BCF value of *S. alba* (Table 2) were low (<1). We thought, low BCF values correlated to mangrove roots function as a barrier and mangrove leaves could excrete salt and unused mineral. Low BCF indicates the low ability to bind and mercury ion exchange from the environment (Rezvani and Zaefarian 2011; Marchand et al. 2016). Our hypotheses supported report from Li et al (2016a) stated lower heavy metal BCF is an indicator that mangrove plant adopted exclusion strategy, and Lacerda et al (1993) added that root role to select metal accumulation and it has a metal tolerant ability, then Ding et al (2011) stated leaves role to excrete salt and mineral.

Hamzah and Setiawan (2010) which states the accumulation of metal can be seen by comparing the concentration between the tissues of mangrove plants. MER analysis in this study (Table 2) was performed to evaluate *S. alba* in its ability as an indicator of mercury contaminants from the environment on the organ, by comparing mercury concentration on roots, stem, leaves and fruits in north and east of Pari Island. The highest MER value in this study was obtained from *S. alba* leaves that grew in the eastern region of Pari Island (99.93%). This shows the ratio of extraction as well as the accumulation of mercury in the leaves approaching the mercury concentration in the sediments. The lowest MER value is in *S. alba* fruit in the northern region (7.36%) and in the east (14.33%). The MER value in this study is in accordance with the studies which show the metal extraction ratio will decrease with the increase of metal concentration in the environment on *Aeluropus littoralis* from Iranian saline habitats (Rezvani and Zaefarian 2011) and *Avicennia marina* in South China Sea mangrove forest (Li et al 2016a, 2016b).

The TF value describes the distribution of contaminants, including heavy metals, in every organ of an organism (Ding et al. 2011). Nutrients and contaminants present in the sediments are absorbed by *S. alba* through the roots and channeled to other organs such as stems, leaves, and fruit. The high TF (Table 3) value of leaves (TF> 1) shows the effectiveness of xylem tissue transport from root to a leaf (Zhao et al, 2006). Martuti et al. (2016) and Marchand et al. (2016) stated that mangroves have adaptations to overcome pollutants by accumulating contaminants on old tissues, such as old leaves or old leather, easly to remove; mangrove could save a lot of water to dilute the pollutant and harmful for their metabolism..

4. Conclusion

The highest accumulation of mercury in mangroves apple (*Sonneratia alba*) was found in eastern Pari Island which directly adjacent to the waters of Jakarta Bay. The highest accumulation of mercury was found on leaves, then on roots. Based on BCF, MER and TF, mangrove apple has the potential to be a bioindicator of mercury contaminants, especially on the leaves.

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