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Heavy Metal (Pb) in the *Rhizophora apiculata* Mangrove in Asahan, North Sumatera, Indonesia

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ABSTRACT

Mangroves have an ability in environmental conditions, i.e., in the sediment, and organs. This research was carried out to assess the Pb absorption rate (sediment and mangrove parts of *R. apiculata*) in the eastern coast of Asahan, North Sumatra. The results showed that Pb content increased in the sediment, but it significantly decreased in leaves. The highest Pb content was in the sediment > roots > fruits > stem bark > leaves. The PCA results of factor loading showed that in the sediment (0.98), roots (0.98), fruits (0.98), stem bark (0.74) and leaves (0.98). The bioaccumulation factor (BAF) and translocation factor (TF) were < 1 indicating that *R. apiculata* has a capability of heavy metal absorption, especially Pb. Pb had a positive correlation in the sediment and roots.

Keywords: *Mangrove, Rhizophoraceae, Asahan Regency, Pb*

1. INTRODUCTION

Mangrove forest is an ecosystem that can be found in tropical areas such as Indonesia. Asahan Regency is an area located in North Sumatra where the coastal mangrove species of *R. apiculata* can be found in the east coast of Asahan. *Rhizophora apiculata* mangrove is a Rhizophoraceae mangrove which is often used for the coastal rehabilitation such as *R. mucronata* and *R. stylosa* mangroves [1]. The existence of mangrove ecosystems can provide various functions including breeding and reproduction areas as well as foraging for various types of biota [2-5] coastal protection, support for fisheries resources, and carbon absorption [6]. Mangrove forest can be nutrients source [7], a source of metabolites such as tannins [8], amino acid [9], protein and carbohydrate [10-11]. In general, mangroves have the potential for productivity and decomposition rates that support sustainable ecosystems. The mangrove area is an ideal place for human activities such as housing, industrial, and recreational development, so that they cause various problems such as heavy metal pollutions. Anthropogenic activity can impact the heavy metal content in the intertidal zone [12].

Heavy metals can cause pollutants to the environment and organisms. Heavy metals have an impact on the aquatic environment which accumulates in habitats and soils [13- 14]. Heavy metal pollution in the mangrove environment can have negative effects on ecological health [15]. The heavy metals can be used for monitoring and evaluation of the mangrove ecosystem conditions in the sediment [16].

Heavy metals such as lead (Pb) have very toxic properties and have an effect on ecological systems [17]. Heavy metals has a high bioavailability and activity so that it can interfere with metabolism which leads to poor growth and lower biomass [18]. Developed researches on heavy metals in mangrove ecosystems include tolerance of mangroves to heavy metals [15], response of young mangroves [19], bioaccumulation in the sediment [20], and distribution in the sediment [21]. Therefore, this study focused more on the rate of absorption in the sediment to the mangrove plant parts (roots, stems, leaves, stem bark, and fruits). This research was carried out to assess the Pb absorption rate (sediment and mangrove parts of *R. apiculata*) in the eastern coast of Asahan, North Sumatra.

2. MATERIALS AND METHODS

2.1 Time and Area

Data collection was carried out in Asahan East Coast, Asahan Regency, North Sumatra from March to August 2020 (Figure 1).

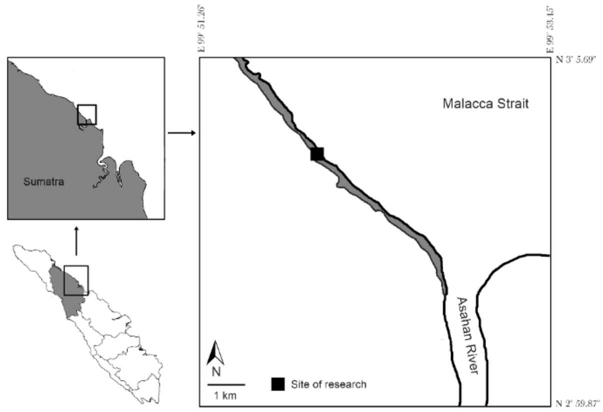

Figure 1 Research location in the east coast of Asahan, Asahan Regency, North Sumatra

2.2 Sample collection and preparation Sediment

Sediment were collected from March to August 2020 at a depth of ±15 cm. Sampling was conducted with two replications in a 10 cm transect. Mangrove sediment was collected using a pipe. Plastic bags were used to pack samples and stored at low temperature (4° C) prior to sample preparation in the laboratory. The samples were dried in an electric oven at 45° C for 72 hours. The dry sample was then pounded into a small grain size of a homogeneous mixture using a mortar and pestle and sieved through 0.25 mm to remove organic matters. The homogeneous powder samples were used to the heavy metal analysis.

Mangrove organs (leaves, fruit, stems, bark, roots)

The mangrove sample was collected from east coast of Asahan. The specimens of mangrove species samples (roots, stems, leaves, bark, and fruits) were identified at the Aquaculture Study Program, Asahan University, North Sumatra. The mangrove parts (leaves, roots,flowers) in *R. apiculata* were separated and dried from sunlight. The mangrove parts were dried, crushed and filtered. The replication samples were three (3) samples for analysis of heavy metal Pb.

Analysis of heavy metal Pb

Around 0.5-1.5 grams of solid sample or 0.5-1.5 mL of liquid sample were carefully weighed into a vessel. HNO_3 was added 10 mL and let stand for 15 minutes. The vessel was closed and the destruction in a microwave digester was performed with the following program: ramp to 150°C for 10 minutes and hold at 150°C for 15 minutes. The result of digestion was cooled, then it was put in a 50 mL volumetric flask. The vessel was quantitatively rinsed with aquabidest, and the rinsed result was combined with the destruction result in a 50 mL volumetric flask. 0.4 mL internal standard mixture of In, Bi 10 mg/L was added. The sample was dilute with aquabidest until the mark then was homogenized. The solution was filtered with a 0.20 μm RC/GHP filter. Sample solution intensity in the ICP MS system was measured. Pb analyte was using the internal standard Bi. The intensity of the standard series solution, sample solution, and blank solution was measured using ICP MS.

Biological risk assessment

The evaluation of the risks used Biological risk assessment from the vegetation. The biaccumulation factor (BAF) showed the ratio of metal content in environment and organs (roots, bark, stems, leaves and fruits) of mangroves (Arumugam et al. 2018). Bioaccumulation factor (BAF) and translocation factor (TF) can be estimated the phytoremediation of plants. BAF is the ratio between metal concentrations in certain tissues (roots, shoots, stem bark, branches and leaves) and concentrations in the surrounding environment.

BCF = Root concentration / concentration (sediment)

TF = Concentration (leaves, stems, bark and branches) / concentration in roots.

2.3 Statistical analysis

Principal component analysis (PCA) used XL Stat 2019 to evaluate the relationships of the sample. After the PCA application, the varimax normalized rotation was applied to minimize the variance of factor loading within the variables for each factor.

3. RESULTS AND DISCUSSION

3.1 Pb contents in the roots and sediment

Figure 1 shows the differences in Pb contents found in the roots and sediment. Pb content in the sediment (9.06 ± 0.05 mg/kg) was higher than roots (0.77 ± 0 mg/kg) of *R. apiculata* mangrove. In general, the Pb was accumulated in the sediment.

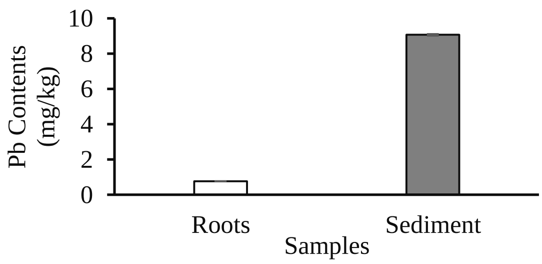

Figure 1 The difference in Pb content (mg/kg) in the roots and sediment of *R. apiculata* in the East Coast of Asahan, Asahan Regency, North Sumatra.

Based on Abdullah et al. [22] the Pb content of *R. apiculata* in the roots was 0.22 mg/kg. The mangrove *R. apiculata* in the east coast of Asahan was better in absorbing Pb. Furthermore, mangrove sediment can function as primary storage containers and secondary sources for heavy metals [12, 23]. The absorption process of heavy metals after being absorbed by mangrove plants acts as an important filter for heavy metals [24-25]. Pb showed more dominant in the roots. Harlyan et al. [26] that Pb absorption (roots) showed higher than leaves. The concentration of heavy metals (Pb) in the roots showed a high concentration due to the influence of the finer sediment size which causes a higher accumulation of heavy metals. Pb in the sediment varied with different seasons, ranging from Pb (0.43-17.49) mg/kg [27].

Table 1 Pb contents in the parts (bark, leaves and fruits) of *R. apiculata* mangrove in Asahan East Coast, Asahan Regency, North Sumatra

No	Mangrove section	Pb (mg/kg)
1	Stem Bark	0.00025 ± 0
2	Leaf	0.00035 ± 0
3	Fruit	0.00035 ± 0

Table 1 shows the Pb contents in various parts of the *R. apiculata* mangrove. The Pb content was higher of leaves = fruits than stem. This result is in agreement with a research Abdullah et al. [22] showed a smaller content compared to the bark of 0.31 mg/kg and leaves of 0.08 mg/kg. The Pb accumulation in *R. apiculata* in the east coast of Asahan showed the normal concentration range (5.0-10.0 mg/kg) [28]. This study also showed that the heavy metal of Pb varied due to the geographical location and mangrove species. Plant species, plant component types, tissue physiological age, and seasons also influence the heavy metal accumulation [29], [30]. The higher concentrations of heavy metals in the mangrove tissue indicate that the ability of mangroves to act as a phytoremediation agent. Analuddin et al. [31] added that this function is urgent to protect and to maintain the marine coastal zone in order to maintain marine biodiversity hotspots. Ganeshkumar et al [27] also reported that in the plant tissue, heavy metal concentrations (Pb) ranged from 6.20 to 26.57 mg/kg. Abdullah et al. [22] reported that the Pb content was roots (0.22 ± 0.13 mg/kg), tem bark (0.11 ± 0.06 mg/kg), and leaves (0.08 ± 0.04 mg/kg).

The BCF and TF values of heavy metal Pb in the east coast of Asahan are various parts of the mangrove plant (Table 2). The BAF value < 1 indicates that mangrove parts rapidly utilize Pb with active metabolisms. In addition, the metal bioaccumulation factor (BAF) is also estimated to divide the concentration of metal in each mangrove species by the concentration of each metal in the sediment [32]. The TF value of *R. apiculata* showed a higher value compared to the bark. Agoramoorthy et al [33] reported that translocation factor of heavy metal Pb in mangrove tissue was estimated by dividing heavy metal concentrations in leaves compared to those in stems. Marchand et al. [34] showed that there were differences in the concentration of heavy metals found in the leaves and bark.

Table 2 BCF and TF of heavy metal Pb in mangrove *R. apiculata* in Asahan East Coast, North Sumatra

No	BCF parameter	BCF value	TF parameter	TF value
1	Root	0.0800	-	-
2	Stem Bark	0.0003	Stem bark	0.0004
3	Leaf	0.0004	Leaf	0.0005
4	Fruit	0.0004	Fruit	0.0005

Note: BCF (concentration of bioaccumulation factor), TF (translocation factor)

3.2 PCA analysis regarding the relationship of Pb absorption in the sediment and mangrove organs

Figure 3 shows the relationship between Pb contents in the sediment and mangrove organ tissues using PCA. The PCA analysis results showed that there are 2 factors, i.e., F1 93.86% and F2 6.24% with a total of 100%.

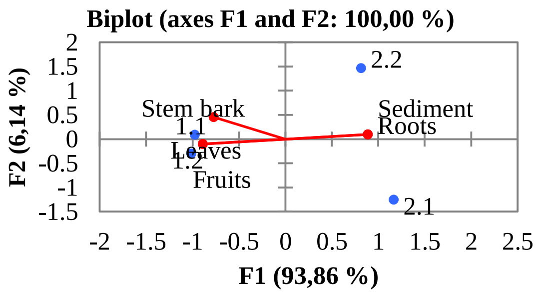

Figure 3 Relationship between Pb contents in the sediment and mangrove tissues in the east coast of Asahan, North Sumatra, Indonesia

Correlations between variables and factors show that sediment and roots have a positive relationship. This means that the higher levels of heavy metals in the sediment resulted higher absorption by mangrove roots. Study by Analuddin et al. [31] revealed that the higher concentration of Pb contamination in the roots of most mangrove species could act as a barrier to translocated heavy metals. The results could be useful for the recovery of Pb contamination in coastal areas, for example by planting different mangrove species.

The PCA results also showed the correlation between variables and factors that the roots and stem bark, leaves and fruits had a negative relationship. The higher Pb content and absorption by roots caused lower absorption by stem bark and fruit tissues. Wang et al. [35] showed that roots play a role in immobilizing heavy metals because mangroves have a mechanism that restricts heavy metal transport up and out of sensitive tissues. Concentrations of non-essential elements were recorded at a low range from 0.01 to 0.03 mg/kg for Cd and 0.08 to 0.35 mg/kg for Pb [22]. The abundance of Cd can be reflected in the natural environment background. The accumulation of Pb in *R. apiculata* in this study was in the range of normal concentrations below 5 mg/kg [28]. Usman et al. [36] suggested that the low Pb concentration was caused by reactions with clays, and organic matters, which resulted in low Pb solubility.

4. CONCLUSION

Mangroves have the ability to absorb heavy metal Pb. The highest Pb content was found in the sediment. However, the highest part of the *R. apiculata* mangrove plant was found in the roots. Sediment and roots had a positive relationship, meaning that the higher heavy metal content in the high sediment caused high absorption by mangrove roots, while the absorptions of heavy metal Pb in the bark, leaves and fruits were low.

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