Uptake and Accumulation of Zinc by Grey Mangrove at Wonorejo Mangrove Forest, Surabaya, Indonesia

Harmin Sulistiyaning Titah[1*], *Herman* Pratikno[2], *Uridna* Marwah Luthansa[1]

[1]Department of Environmental Engineering, Faculty of Civil, Planning and Geo Engineering, Institut Teknologi Sepuluh Nopember, Keputih, Sukolilo, 60111 Surabaya, Indonesia
[2]Department of Ocean Engineering, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember, Keputih, Sukolilo, 60111 Surabaya, Indonesia

Abstract. Heavy metals have non-biodegradable, toxic and accumulative properties in the environment. Heavy metals that enter water bodies will be carried by the flow towards the coast. Zinc (Zn) is one of the metals found polluting the waters in the city of Surabaya, Indonesia. One of the efforts to overcome this problem is the use of mangroves as phytoremediation agents. The purpose of the study was to determine the ability of *Avicennia marina* (Forssk.) Vierh in the Wonorejo Ecoforest to accumulate Zn by determining the bioconcentration factor (BCF) and the translocation factor (TF). Determination of the sampling points of this study using the transect method. Samples were taken in the form roots, stems, and leaves of mangrove plants and those were analyzed for Zn concentration using an atomic absorption spectrophotometer (AAS). Based on the result, *A. marina* showed the immobilized of Zn in root due to the BCF value was higher than 1. In conclusion, *A. marina* have potential to be phytoremediation plants in coastal area.

Keywords: *Avicennia marina* (Forssk.) Vierh, heavy metal polution, phytoremediation, white mangrove

1 Introduction

The increasing of industries has both positive and negative impacts. The positive impact resulting from industrial activities is the creation of many jobs, while the negative impact is a decreasing of environmental quality due to waste disposal. Industrial waste is a serious problem in the era of industrial industrialization [1]. Every industrial activity will produce various kinds of waste. The type of waste varies depend on the type of activity. According to Nasir and Saputro [2], industrial waste treatment must start from the beginning of the process untill the end, because if it is not conducted properly, it will have a fatal impact on the environment and human survival. According to Yudo [3], industrial waste is generally

* Coresponding Author: harminsulis@gmail.com

disposed of into rivers without any treatment, so that it can cause a decreasing in the quality of water bodies.

The coastal zone has a high potential for heavy metal accumulation because it is directly adjacent to land and sea [1]. Heavy metal pollution in coastal areas is caused by agricultural runoff, industrial and domestic waste, chemical spills, ship fuel, WWTP effluent, mining and domestic waste [4]. According to Tchounwou *et al.*, heavy metals such as mercury (Hg), lead (Pb), arsenic (As), cadmium (Cd), chromium (Cr), zinc (Zn) and nickel (Ni) are inorganic materials that often cause serious water problems. The heavy metal waste enters water bodies and then settles in river estuary sediments [6]. The continuous deposition of heavy metals will cause environmental pollution because of the accumulative and toxic properties of metals [6]. One of the efforts to overcome heavy metal pollution in estuary dan coastal areas is phytoremediation using mangrove plants. Mangroves are plants that can live in areas with high salinity [7]. Several studies have proven that mangrove plants can accumulate heavy metals that pollute the environment [8]. The estuary of the Wonorejo river has the potential to accumulate heavy metals due to this location is passed by industries and domestic areas [9]. The aim of this study was to determine the ability of *Avicennia marina* (Forssk.) Vierh that grown at Wonorejo Mangrove Forest to uptake and accumulate of Zn.

2 Materials and methods

2.1 Location sampling

The location of the study was at the Wonorejo Mangrove Ecoforest area, in Surabaya, Indonesia. Based on the consideration of mangrove thickness, the determination of sampling stations was observed visually, using the google earth application, with easy road access and safety to reach the study location. The research station was divided into three regions, namely A Station (7° 18'19.75" South Latitude and 112° 50'39.4" East Longitude), B Station (7° 18'20.19" South Latitude and 112° 50'40." East Longitude), and C Station (7° 18'21.90" South Latitude and 112° 50'40.56" East Longitude). The location of this research was also shown in Figure 1. Based on observation, *A. marina* was founded at B dan C station. The codes of sampling locations of *A. marina* were SBP3 *A. marina*, SCP1 *A. marina*, SCP2 *A. marina* and SCP3 *A. marina*.

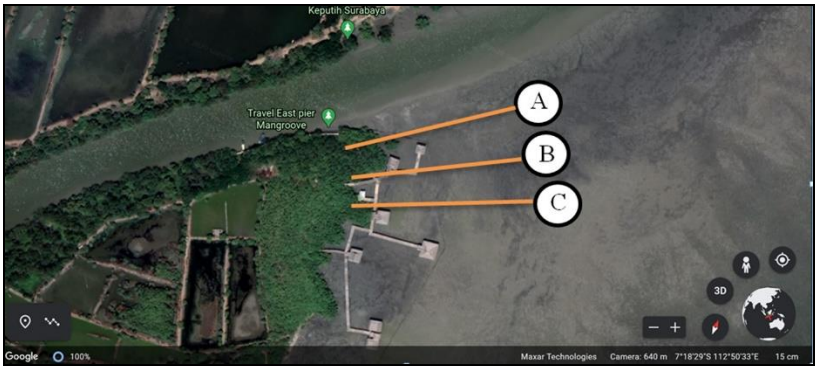

Fig. 1. Location of study.

2.2 Determination of BCF (bioconcentration factor) and TF (translocation factor)

The results of the analysis of the concentrations contained in the environment and mangrove plants, were used to calculate the values of BCF (bioconcentration factor) and TF (translocation factor). The BCF and TF were used to determine the heavy metals' accumulation and translocation abilities, in parts of the mangroves. The Bio-concentration factor (BCF) or biological accumulation coefficient (BAC) calculation [10] was used to determine the plants' ability to extract metal from the substrate [11]. Equation (1) shows BAC determination

$$BCF = \frac{[Zn\ in\ roots]}{[Zn\ in\ media]} \quad (1)$$

The BCF determination results were used to classify plants that are in hyperaccumulator, as shown in Table 1 based on Bini *et al*. [10].

Table 1. Category of BCF value

Category	Range
High accumulator / hyperaccumulator plants	1 to10
Moderate accumulator plants	0.1 to 1
Low accumulator plants	0.01 to 0.1
Non accumulator plants	< 0.01

The TF value was determined using Equation 2 [11, 12].

$$TF = \frac{[Zn\ in\ Stems]}{[Zn\ in\ roots]} \quad (2)$$

3 Results and discussions

3.1 The concentration of Zn in sediments

The results of the analysis of Zn in sediments was shown in Figure 2. The concentration of Zn were 56.7 mg kg^{-1}, 45.8 mg kg^{-1}, 62.5 mg kg^{-1} and 59.6 mg kg^{-1} at code location of SBP3 *A. marina*, SCP1 *A. marina*, SCP2 *A. marina* and SCP3 *A. marina*, respective. Indonesia does not have quality stones for sediments in coastal areas, so the sediment quality standards used in this study refer to the Environmental Protection Agency (EPA) Sediment Quality, Australian and New Zealand Environment and Conservation Council (Anzecc/Armcanz Guidelines) and the Canadian Council of Ministers. of Environment (CCME). The quality standards used in this study for Zn sediments came from America, Australia and Canada. The American quality standard for Zn sediment is > 2 mg kg^{-1}, Australia 410 mg kg^{-1} and Canada 315 mg kg^{-1}. Based on Figure 2, all sediments in this study have exceeded the quality standard threshold according to the sediment quality reference from America due to concentrations of Zn in the sediment were greater than 2 mg kg^{-1}. However, based on the Australian and Canadian quality standards, concentration of Zn in the sediment in the estuary were still below the quality standard.

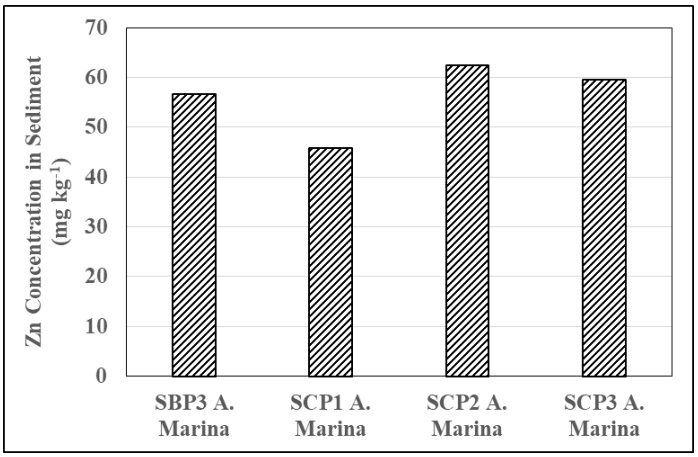

Fig. 2. Zn concentration in sediment.

3.2 Mangrove ability to remediate heavy metal Zn by determining BCF and TF

Mangrove plants were used as phytoremediation agents, due to being able to accumulate heavy metals around them naturally, which was also referred to as biosorption. Mangroves also filter, catch, and bind pollution within the environment, in the form of excess sediment, garbage, and other household wastes, which contributed greatly to improving water quality [14].

Figure 2 showed concentration of Zn in mangrove roots, stems and leaves of *A. marina* at B and C Station. The Zn concentration in the roots of *A. marina* at B Station was high (82.3 mg kg^{-1}). The results showed that Zn in mangrove roots at station of C had a range of 52.2 mg kg^{-1} to 93.3 mg kg^{-1}. The highest average Zn concentration in the mangrove roots of station C was found in the mangrove type of *A. marina*. *A. marina* was able to absorb the highest Zn metal compared to other types of mangroves. Concentration of Zn in stems of *A. marina* were 51.2 mg kg^{-1} till 101.3 mg kg^{-1} at B dan C Station. Concentration of Zn in leaves of *A. marina* were 37.6 mg kg^{-1} till 138.3 mg kg^{-1}. According to research by Amin [7], Avicennia mangroves have a higher accumulation capacity than other mangrove species. *A. marina* prevents the entry of heavy metals into other tissues so that the concentration of heavy metals in the roots is higher.

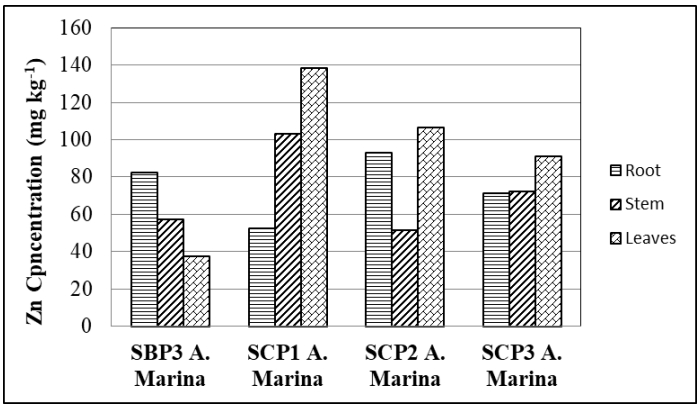

Fig. 3. Concentration of Zn in mangrove roots, stems and leaves of *A. marina*

The BCF value were calculated using equation 1. The BCF value in *A. marina* were 1.14 till 1.49. Figure 4 showed the BCF value of *A. marina*. Based on the classify which plants [10], *A. marina* showed potential as a hyperaccumulator for Zn. This result indicates that A. marina was taken up Zn from sediment and *A. marina* was included as a hyperaccumulator plant for Zn. It considered that *A. marina* was an efficient hyperaccumulator plants. However, according to Meeinkuirt *et al.* [15], *A. marina* was a phytoremediator plants for Zn, Cr, and Pb; and *Rhizophora mucronata* Lam. for Cu and Zn. *A. marina* showed the immobilized of Zn in root due to the BCF value was higher than 1.

Figure 5 showed the TF value of *A. marina*. The TF showed the all of value did not excess 1, it indicated that the process of phytoremediation was phytostabilization. Some species accumulated metals in shoots; however, they cannot be classified as hyperaccumulators since metal concentrations were not sufficiently high to fit the criteria for plants in a phytoextraction strategy, even those with TF > 1 and BCF > 1.

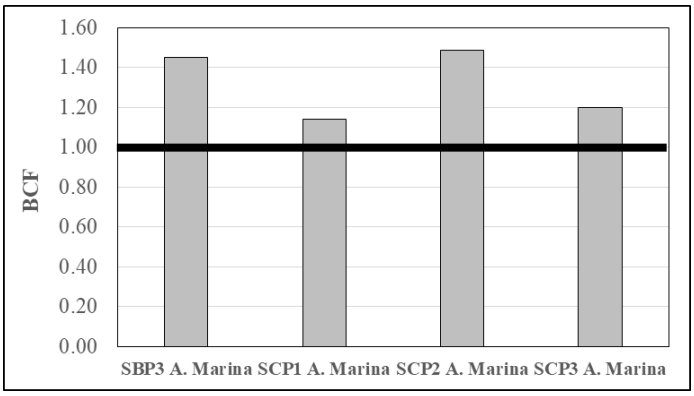

Fig. 4. BCF Value or Bioconcentration Factor on *A. marina*

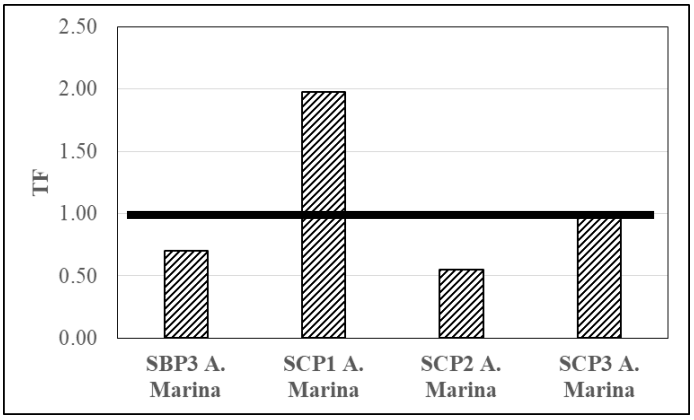

Fig. 5. TF value or translocation factor on *A. marina*

4 Conclusions

The Zn accumulation by roots of *A. marina* reached 52.2 mg kg^{-1} till 93.0 mg kg^{-1}. The BCF value in *A. marina* were 1.14 till 1.49 with the concentration Zn in sediment were 52.2 mg kg^{-1} to 93.3 mg kg^{-1}. *A. marina* showed potential as a hyperaccumulator for Zn. However, the TF showed the most of value did not excess 1, it indicated that the process of

phytoremediation was phytostabilization. In conclusion, *A. marina* can be considered for use in phytomonitoring and phytoremediation of Zn in coastal areas.

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