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Chromium Accumulation by *Avicennia alba* Growing at Ecotourism Mangrove Forest in Surabaya, Indonesia

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ABSTRACT

The Ecotourism Mangrove Forest at Wonorejo in East Coast Surabaya area is one of large mangrove forests inside in the metropolitan city in Indonesia. There are many ecological values of the mangrove forest in most tropical countries such as sea fisheries, place of sea and coastal animals, sea and brackish water quality protecting the endangered mangrove coastlines and development of human life. The role of mangrove in increasing the sea and brackish water quality can be shown through many processes such as cycling of nutrients, particulate matter and some pollutants in water and sediment around the mangrove plants. One of the inorganic pollutants that can be removed by mangrove are heavy metals, such as chromium (Cr). The Wonorejo River is one of the rivers that receive the disposal of wastewater in Surabaya East Coast area. Large quantitites of wastewater from industries and households were released to this river. The concentration of Cr at the Wonorejo Estuary reached 0.0325 mg/L and 2.7761 mg/L in sediments. The purpose of this research was to determine the potency of Cr accumulation by *Avicennia alba* that was grown for ten years at Wonorejo Ecotourism Mangrove Forest. The sampling activities were conducted using a transect quadrat sampling method with a 10x10 m dimension. The sediment and mangrove root samples were extracted before being analysed using an atomic absorption spectrophotometer (AAS). The results showed that the Cr accumulation by roots of *A. alba* reached 25.4 ± 1.6 to 55.3 ± 1.1. The BCF value in *A. alba* were 0.32 ± 0.01 to 0.83 ± 0.5 with the concentration Cr in sediment were 60 ± 1.4 to 79.3 ± 1.1. *A. alba* showed potential as a moderate accumulator for Cr. In conclusion, *A. alba* can be considered for use in phyto-monitoring and phytoremediation of Cr in coastal areas.

Keywords: *Avicennia alba*, BCF, coastal area, chromium, mangrove forest, root, sediment

INTRODUCTION

Some heavy metals such as iron (Fe), chromium (Cr), copper (Cu) and zinc (Zn) are essential for the normal plant growth and development, being trace . However, they are also potentially toxic to the plant growth if the concentration of those heavy metals exceeds the normal concentration for plants (Asati et al., 2016). The increasing concentrations of Cr in some media such as air, fresh water, saline water or soil cause toxic effects on the metabolism of plants; thus, they inhibit the growth and development of plants leading to death in the worst case (Aydogan et al., 2017). Cr is needed for normal life processes; however it can be toxic to organisms at elevated concentrations at environment (Krishnani et al., 2004). Cr can affect the photosynthesis process of higher plants and trees through the processes of CO^2 fixation, electron transport, photophosphorylation and enzyme activities in plants (Asati et al., 2016). The activity of heavy metals in seawater is more toxic in the ionic form compared with the other form of the metal, such as organic heavy metal compounds (Viarengo, 1989).

The estuary water contains some polutants such as inorganic polutants from the sewage system, industrial effluents, domestic and agricultural wastewater. Those sources of polutants consists of varying hazardous chemicals, thus they can cause negative effects on aquatic organisms (Krishnani et al., 2004). Many anthropogenic activities such as the electroplating industry and leather tanning industry can cause the increasing of concentrations of Cr in estuary area (Krishnani et al., 2004). The Wonorejo River is one of the rivers that discharge into the East Coast area in Surabaya. The wastewater from industry and households is discharge to this river, so it can pollute the estuary area in Surabaya (BLH, 2012). The disposal of industrial waste, especially into the Wonorejo River was harmful to the environment because Cr could persist in that estuary. The concentration of Cr at the Wonorejo Estuary in 2007 reached 0.0325 mg/L and 2.7761 mg/L in sediments. The concentration of Cr at the Wonorejo estuary reached 0.418 mg/L, based on KepMenLH No. 51 (2004), indicating it was above the water quality standard for marine biota (0.005 mg/L).

Actually, the Wonorejo Mangrove forest was started by the local community with the first purpose of preventing the sea water abrasion. The Wonorejo Mangrove forest areas in Surabaya is 64.83 ha in the total area of 133.98 ha. Nowdays, the ecotourism Mangrove Forest at Wonorejo in East Coast Surabaya area is one of large mangrove forests inside in the metropolitan city in Indonesia. Ecotourism is a natural resources activity in the form of tourism that is aimed at education, research, and conservation of the natural environment. Besides, the main of purpose is to increase the local economy near the location (Murtini et al., 2018). Ecotourism can accommodate tourists to explore the natural and local culture as well as the environment. They can learn more about the natural wealth owing to the ecotourism. Additionally, the ecotourism activities can increase the income for nature conservation and local communities. Besides the function as an ecotourism, there are many ecological values of a mangrove forest in most tropical countries such as sea fisheries, habitat of animals, increasing of estuary water quality protecting endangered mangrove coastlines and human life. Mangroves play a role in increasing estuary water quality that can be shown through the cycling of nutrients, pollutants, and particulate matter at surrounding the mangrove. One of inorganic pollutants that can be removed by mangrove includes heavy metals such as Cr.

Avicennia marina is a mangrove species that has a high population in the Wonorejo Ecotourism Mangrove Forest area with 88% of the total mangrove population. Meanwhile, the population of *Avicennia alba* corresponds to 11% of the total population. This area was planted with mangroves 10 years ago. The aim of this reserach was to determine the potency of Cr accumulation by *Avicennia alba* that was grown for ten years at Wonorejo Ecotourism Mangrove Forest.

MATERIALS AND METHODS

Sampling Locations

The sampling activities were conducted using a Transect quadrat sampling method. This is a sampling method of a population with a sample plot approach that is on a line drawn through the ecosystem. The dimension of one quadrant was 10m x 10m. The sampling point determinations were conducted using a GPSmap 76CSx (Garmin, USA). Figure 1 shows the sampling location, while the coordinates were shown in Table 1.

Sampling of sediment and mangrove roots

The sampling activities were conducted at around 7.00 am. The sea water level was low enough at that time for sediment sampling. According to Usman & Mohamed's (2009) methods, the sediment sampling was carried out by random sampling at a depth of 0–30 cm. According to Abohassan (2013), the concentrations of heavy metal did not show the difference at the 5–20 cm depths. The root samplings were conducted using a manual drill. All the samples were stored in an icebox at 4°C; then, the samples were taken to the Environmental Remediation Laboratory, Department of Environmental Engineering, Institut Teknologi Sepuluh Nopember (ITS) for further analysis.

Analysis of Chromium in Sediment and Roots of Mangrove

First, all samples were prepared before being analysed by samples extracting. The Cr analysis in sediment and mangrove root was conducted using an atomic absorption spectrophotometer (AAS). The AAS was used to measure the concentration of Cr in the sediment and *A. alba* roots. The model of AAS instrument used was a Rayleigh WFX 210 (China). The AAS analysis was conducted in

Figure 1. Sampling Locations

Table 1. Coordinate of Sampling Locations

No	Sampling code	Coordinate of samplings
1	A21A	S = 07^{0}18’21,0” E = 112^{0}50’39,5”
2	A22A	S = 07^{0}18’21,1” E = 112^{0}50’39,4”
3	A21B	S = 07^{0}18’20,7” E = 112^{0}50’39,1”
4	A22B	S = 07^{0}18’20,7” E = 112^{0}50’39,0”
5	A21C	S = 07^{0}18’20,4” E = 112^{0}50’39,2”
6	A22C	S = 07^{0}18’20,5” E = 112^{0}50’39,1”
7	A21D	S = 07^{0}18’20,6” E = 112^{0}50’39,4”
8	A22D	S = 07^{0}18’20,6” E = 112^{0}50’39,42”
9	A21E	S = 07^{0}18’20,9” E = 112^{0}50’39,7”
10	A22E	S = 07^{0}18’20,9” E = 112^{0}50’39,8”

the Department of Chemical Engineering, ITS, at the Laboratory of Affiliation Team and Industry Consultation (TAKI).

The roots of *A. alba* were dried before extraction. The Cr extraction from roots of *A. alba* was conducted using a modified wet digestion method. The modified wet digestion method was carried out based on Titah et al. (2013). Meanwhile, the sediment extraction was performed with the EPA method 3050B (1996).

Bio-concentration Factor

The Bioconcentration Factor (BCF) or Biological Accumulation Coefficient (BAC) calculation (Bini et al. 1995) was used to gauge the ability of the plants to take up metal from the substrate (Idris et al., 2016). The determination for BAC was based on the following equation.

$$BCF = \frac{C_{roots}}{C_{media}} \tag{1}$$

RESULTS AND DISCUSSION

The average concentration of Cr in *A. alba* roots ranged from 25.4 ± 1.6 to 55.3 ± 1.1 mg/kg (Figure 2). This result showed that *A. alba* could take up Cr and accumulate it in their roots. On the basis of the previous study, the value of Cr in roots of *Avicennia marina* in mangove forest ranged from 28 mg/kg to 92.25 mg/kg (Pratikno et al., 2017). According to Peters et al. (1997), mangrove plants trend to uptake and than to accumulate heavy metals such as Cu, Zn, Pb, Fe, Mn and Cd is observed primarily in the root tissue, rather than in their foliage. This phenomenon occured in such mangrove species as *Avicennia spp*., *Rhizophora spp*. and *Kandelia spp*. The continuous accumulation of heavy metals and the filtration of heavy metals in roots of mangrove plants at a long period of time can cause higher heavy metal concentration in roots compared to the sediment (Abohassan, 2013). Heavy metals can be immobilized in root so the concentration of heavy metals is higher in roots than in other parts of plants. According to Basta et al. (2005), the mechanism of heavy metals involved immobilization in root, i.e. a bioavailable heavy metal fraction was sorbed at root surface, then the bioavailable metal moved across to the cellular membrane into root cells;

thus a heavy metal absorbed into roots was immobilized in the vacuole of the root.

The average concentration of Cr in the sediment near *A. alba* ranged from 60 ± 1.4 to 79.3 ± 1.1 mg/kg (Figure 2). According to the Canadian sediment quality guidelines, some concentrations of Cr at some sampling points were above the standard. The standard for Cr concentration based on those regulations was 52.3 mg/kg. It indicated contamination at those areas. This condition occurred due to the dicharge of wastewater from industry and households to this river, causing pollution at the estuary area. On the basis of our previous study, the average value of Cr concentration in the sediment in the surrounding of *A. marina* grown ranged from 47 mg/kg to 66.5 mg/kg (Pratikno et al., 2017). It was predicted that many other heavy metals are concentrated in the sediments of this area. According to Rachmawati et al. (2018), the concentrations of Cu were 4.13–36.95 ppm and Pb were 3.28 - 23.79 ppm. Sari et al. (2017) reported that certain concentrations of Hg and Cu were detected at Wonorejo coastal area.

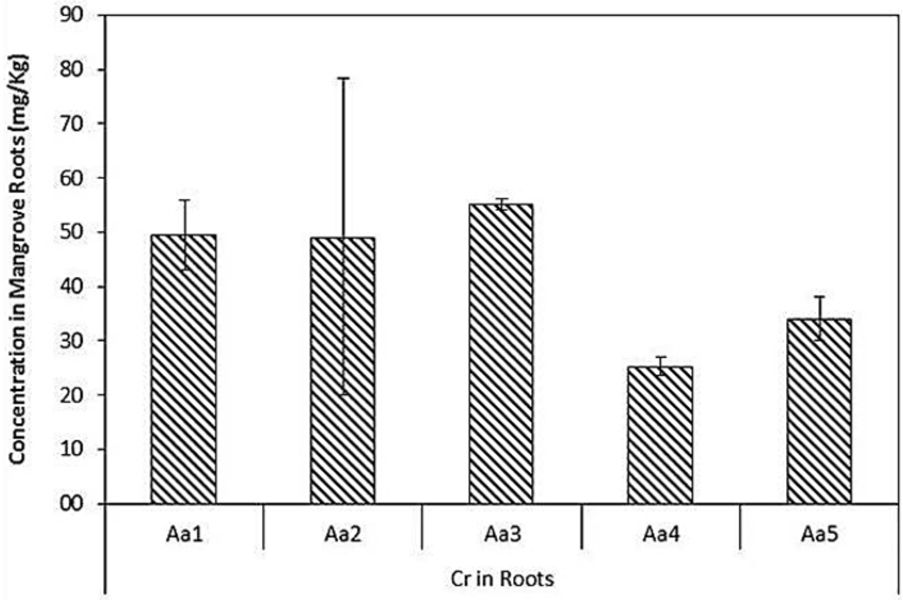

Figure 2. Concentration of Cr in Mangrove Root of *A. alba* (Aa = *Avicennia alba*)

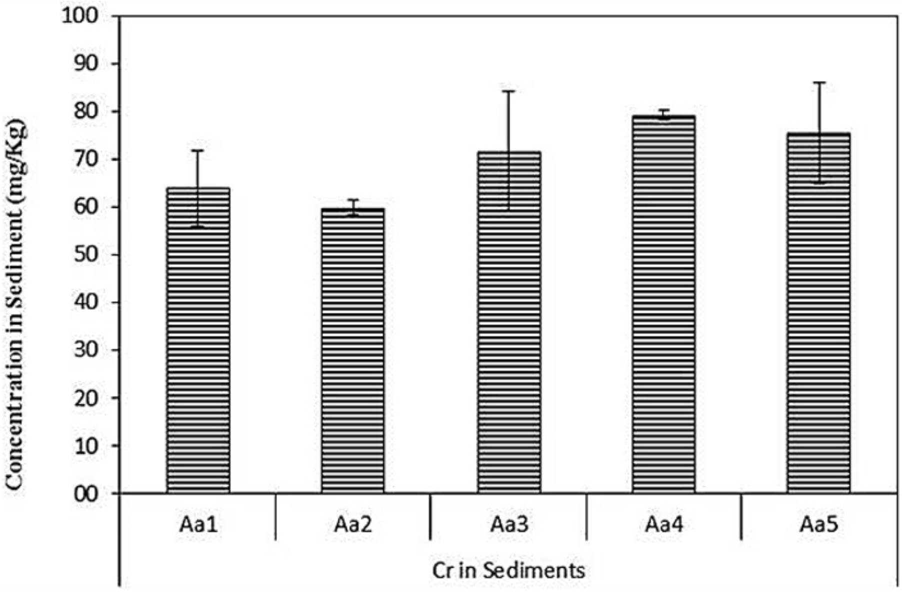

Figure 3. Concentration of Cr in Sediments (Aa = *Avicennia alba*)

The BCF value was calculated using equation 1. The BCF value in *A. alba* were 0.32 ± 0.01 to 0.83 ± 0.5. On the basis of the plant classification (Bini et al., 1995), *A. alba* showed potential as a moderate accumulator for Cr. This result indicates that *A. alba* was taken up Cr from sediment and *A. alba* was included as an accumulator plant for Cr. Rodríguez-Iruretagoiena et al. (2016) reported that *A. alba* showed a good accumulation potential because this plant can accumulate Al, Cd, Co, Cr, Cu, Ni, Mn and Zn. It was considered that *A. alba* constitutes an efficient accumulator plants. Some species accumulated metals in shoots; however, they cannot be classified as hyperaccumulators since the metal concentrations were not sufficiently high to fit the criteria for plants in a phytoextraction strategy, even those with TF > 1 and BCF > 1 such as *Thespesia populnea* for Ni and *Cyperus involucratus* for Cr.

On the basis of the data, the *A. alba* grown at Ecotourism Mangrove Forest, Wonorejo in East Coast Surabaya can take upCr from sediments and accumulate it in their roots. *A. alba* can control the concentration of Cr in the enviroment, especially in the sediments near those plants which grew by taking up and accumulating Cr. The Ecotourism Mangrove Forest, Wonorejo in East Coast Surabaya can be used for phyto-monitoring and phytoremediation of Cr, so that the negative effect of Cr on ogranisms and environment can be reducted.

CONCLUSION

The Cr accumulation by roots of *A. alba* reached 25.4 ± 1.6 to 55.3 ± 1.1. The BCF value in *A. alba* were 0.32 ± 0.01 to 0.83 ± 0.5 with the concentration Cr in sediment in the range from 60 ± 1.4 to 79.3 ± 1.1. *A. alba* showed potential as a moderate accumulator for Cr. In conclusion, *A. alba* can be considered for use in phyto-monitoring and phytoremediation of Cr in coastal areas.

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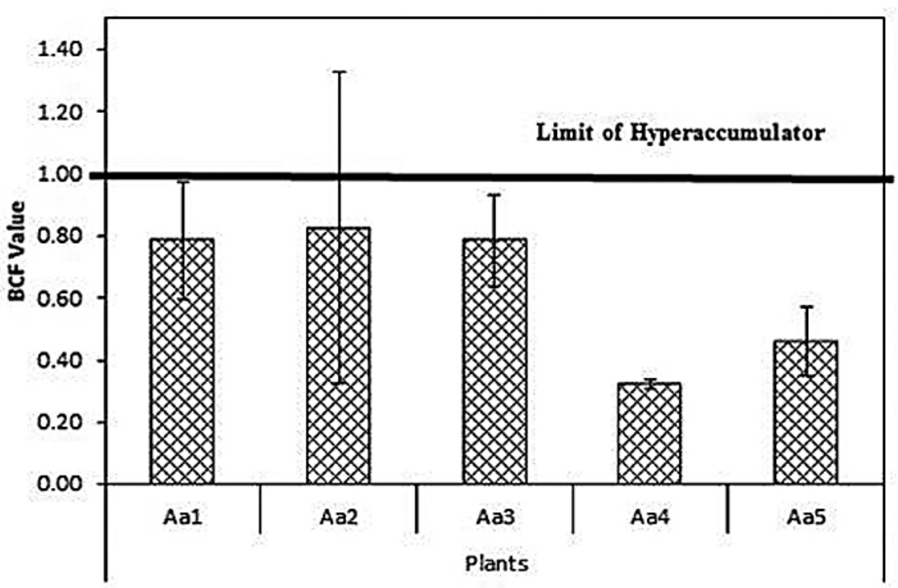

Figure 4. BCF Value, (Aa = *Avicennia alba*)

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