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Translocation and Elimination of Cu in *Avicennia marina*

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ABSTRACT

Heavy metal pollution is a big problem in the aquaculture sector. Phytoremediation is one of the innovative approach to clean up the polluted water. The purpose of this research was to study the translocation of heavy metal (Cu), and its elimination using the mangrove plant, *Avicennia marina*. The study was conducted in Tapak Tugurejo, a coastal area in the northern part of Semarang City, Indonesia, where the water was polluted by heavy metals discharge (Cu) from industries nearby, at the upstream of the Tapak River. Samples of *A. marina* parts (roots, leaves, litter), sediment and water were collected and analysed to determine total Cu concentration. Results showed the plants of *A. marina* has the ability to translocate Cu metal in their tissues, respectively Cu concentrations in litter > leaf > root. Therefore, litter has the ability to eliminate metals in the environment through the defoliation process. The results also showed that Concentration Factor (CF) of Cu between water and sediment was 500.5 to 897.7, while the Bio Concentration Factor (BCF) between sediment and roots was in the range of 0.03 to 0.13. The Translocation Factor (TF) in roots and leaves ranged between 0.4 and 1.1. Hence, translocation of Cu metals was evident in the roots and leaves of *A. marina*, and the absorbed Cu was then eliminated via the litter .

Keywords: *Avicennia marina*, elimination, Cu, translocation, litter

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INTRODUCTION

Mangrove ecosystem plays an important role in coastal areas. Mangrove swamps not only protect the environment against erosion and t strong winds they also have the ability to absorb metals present in the coastal area. The mangrove roots are a natural filter of pollutants as they

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trap sediment and particles carried by downstream current to the ocean (Kumar et al., 2011). Kr'bek et al. (2011) studied the role of mangroves as the bioaccumulator of heavy metals. MacFarland & Burchett (2000) and MacFarlane et al. (2007) found a strong linear relationship between metals contained in the sediments with those in the tissues of mangrove plants (roots). This shows that the plants have the natural ability to accumulate contaminated sediments.

Avicennia marina is one of the mangrove species which is prevalent in the north coast of Java. Hastuti et al. (2013) argued that *A. marina* is a mangrove species that dominate the coastal areas of Semarang and Demak, Indonesia.

According to Usman et al. (2013) *A. marina* has the potential to accumulate Cu from sediment, as shown by high Cu accumulation in roots and leaves with Bio Concentration Factor (BCF) and Translocation Factor (TF) values > 1. Einollahipeer et al. (2013) showed that tissues of roots, stems and leaves of *A. marina* can be used as a good bio-indicator of Cu, with a BCF value of 0.60. Based on its BCF value, *A. marina* has potential to phytoremediate heavy metals (Lotfinasabasl & Gunale, 2012).

It is in at the roots of mangrove plants that heavy metal is concentrated (Tam & Wong, 1996).Mobility and solubility of metal also affect accumulation of heavy metals in plants. According to Sinha (1999) the ability of plants to accumulate heavy metals is as follows i.e. Mn>Cr>Cu> Cd>Pb. The ability to accumulate heavy metals differs from one species to the other. Heavy metal concentration in roots, branches and leaves of a plant species also differ.

It is assumed that the litter also contain considerable amount of trace metals. In addition, the litter may pose the danger of bringing the accumulated metal back into the waters. This topic however, has not been explored in depth by scholars. Therefore, the aim of this paper is to discuss heavy metal accumulation in litter, and their translocation in the roots, leaves and litters of *A. marina*.

MATERIALS AND METHODS

Study area

This research was conducted in Tapak Tugurejo, a coastal area of Semarang city, Indonesia. The area (110°17'15 " to 110°22'4" E and 6°56'13 " to 6°59'14" S) is filled with by mangrove vegetation. Tambak Aji factory is situated at the headwater of Tapak river which passes through the Tapak Tugurejo area. The pollutants from the factory is channelled to the Tapak River directly affecting Tapak Tugurejo area (Marjanto, 2005).

Sampling and sample preparation

The study examined heavy metal (Cu) concentration in water, sediments and the mangrove plant, *A. marina*, namely its roots, leaf, and litter for a period of 12 weeks (January-March) with two-week interval. 1 mol. L^{-1} HNO_3 solution was used to wash the glass tubes for at least 12 hours and then

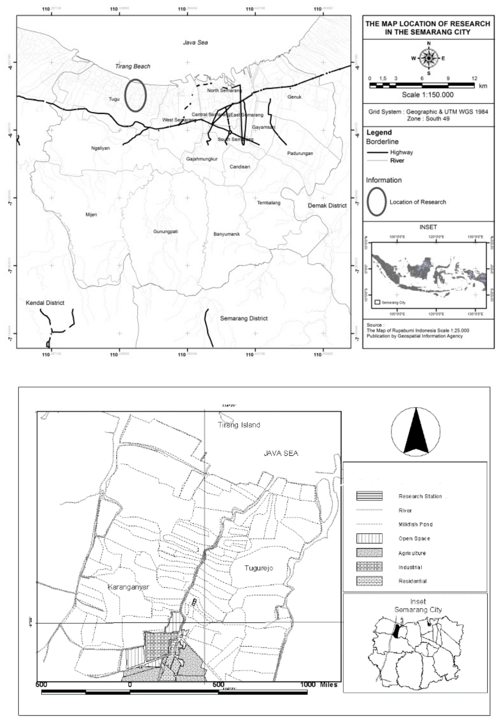

Figure 1. The Map of Tapak Region of Tugurejo, Semarang, Indonesia

rinsed 5 times thoroughly with deionised water. Each sample was replicated 8 times to guarantee the accuracy of results. Samples of *A. marina* were taken from young leaves where most Cu are accumulated Martuti & Irsadi (2014). The submerged roots were cut and litter was collected using a net trap. The water samples were collected in 150 ml polyethylene cans while the sediments were taken from. 1 cm, 5 cm and 15 cm depths respectively before they were mixed thoroughly.

Water samples were filtered with 0.45 mm Whatman GF/C filters to separate suspended particulate matter. A 0.5% (v/v) of HNO_3 was added to the filtered water for the precipitation of samples. The sediments were left to dry at room temperature for at least three days. The dried solid sample then pulverized and sieved through a 1 mm stainless steel mesh. The roots were rinsed repeatedly with de-ionised water to remove dirt before they were cut to smaller pieces and dried at 110°C for 24 hours. They were later ground into fine powder. The same method was used for the leaves and litter. Strong acids were used to oxidise the organic matter and sediments, which will release metallic elements (Blekeer, 2007). About 100 mg of dry sample of grinded roots was put in a destruction tube to which 2 ml of 4.1 (v/v) HNO_3 :37% Concentrated HCL was added to the mixture and left for 15 minutes before it was placed in an oven set at 140°C for seven hours. About 8ml of de-ionised water was added to the digested sample in the destruction tube and was swirled repeatedly. The mixture was then poured into the polystyrene tube and stored at 4°C. All the samples, water, sediments and *A. marina* (leaves, roots, and litter), were analysed using atomic absorption spectrophotometer (Plus 932, Australia) to measure the concentration of Cu.

The concentration of metals in roots, leaves, and litter were measured in order to determine the translocation of Cu in the mangrove plant. The ratio of Cu concentration in the sediment to Cu in the water was expressed as the Concentration Factor (CF). Likewise, the ratio of Cu in the sediments to Cu in the roots was expressed as the Bio Concentration Factor (BCF). The ratio of Cu concentration in the leaves to Cu in the roots was expressed as the Translocation Factor (TF).

RESULTS AND DISCUSSION

The presence of dissolved metals in seawater and sediments depends on the quality of the water. Increased activity in the water environment would lead to rising concentration of heavy metals. Results of laboratory analysis of the Cu are shown in Table 1. Copper was present in the pond in Tapak Tugurejo region, Semarang City, Indonesia.

Table 1
Cu concentration in water and sediment and the Concentration Factor (CF)

Week	Concentration*		
	Water (mg/L)	Sediment (mg/kg)	CF
0	0.05 ± 0.008	25.03 ± 4.77	500.5
2	0.03 ± 0.005	19.65 ± 2.23	577.9
4	0.03 ± 0.005	18.00 ± 4.80	720.0
6	0.02 ± 0.007	20.65 ± 3.52	897.7
8	0.03 ± 0.007	17.20 ± 3.97	521.2
10	0.02 ± 0.005	16.09 ± 3.41	670.4
12	0.03 ± 0.004	15.20 ± 1.77	524.2

*All values are mean ± standard deviation

Concentration of Cu ranged between (0.02 ± 0.005) and (0.05 ± 0.008) mg / L (Table 1). All the Cu concentration values exceeded the maximum permissible level for marine biota of 0.008 mg / L set by the Indonesian Ministry of Environment, i.e. the Decree of the Minister of Environment of Indonesia Number 51 Year 2004 on Standard Quality of Sea Water.

The Cu contamination happened in Tapak area most probably because it was located in the downstream of the Tapak River. The ponds are also vulnerable to metal pollution since they were connected to the mangrove ecosystem in the estuary of Tapak River. Chaiyara et al. (2013) contends argued that the presence of metal concentrations in water and sediment in an area depends on the presence of human activity in the upstream, such as mining, industrial, and residential.

The concentration of Cu in the sediment ranged between (15.20 ± 1.77) and (25.03 ± 4.77) mg/kg with CF of 500.5–897.7 (Table 1). Typically, there is high Cu concentration in pond sediment. This demonstrates the ability of pond sediment to accumulate Cu from the water. Sany et al. (2012) confirmed a close link between the concentration of heavy metals in sediments and those in water. Chaiyara et al. (2013) explained that the water dilution process resulted in higher concentration of Cu in sediment compared with the water layers. Sediment is important for mangrove ecosystems because of its ability to store heavy metals from the environment. The presence of heavy metal in the sediment is highly dependent on the contamination level of the water (Abohassan, 2013).

Measurements of Cu in *A. marina* from milkfish pond showed the presence of the metal in the roots, leaves, and litter as shown in Figure 2. The concentration of Cu in the roots ranged between 0.87 ± 0.32 mg/kg and 2.21 ± 0.99 mg/kg. The leaves of *A. marina* were able to accumulate Cu between 0.88 ± 0.18 mg/kg and 2.70 ± 0.34 mg/kg. Litter in the *A. marina* which is the result of defoliation of the mangrove plant showed Cu between 2.35 ± 0.54 mg/kg and 5.72 ± 1.74 mg/kg.

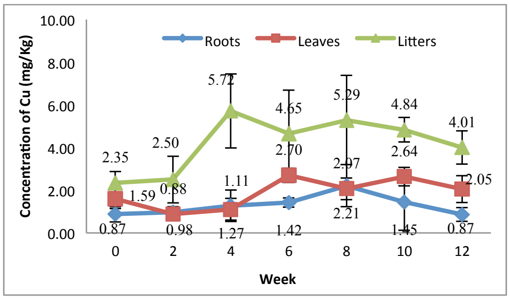

Figure 2. Cu Concentrations in Roots, Leaves, and litter in *A. marina* (all values are mean + standard deviation)

It can be seen from Figure 2 that the concentrations of Cu varied between plant tissues of *A. marina*. The highest concentration was found in the litter followed by leaves and roots respectively. On the other hand, the concentrations of Cu in all plant tissues tended to increase between 0 and fourth week and declined on the 8th week.

The BCF calculation between the root *A. marina* and pond sediment showed

Table 2
BCF and TF of Cu in A. marina

Week	BCF	TF
0	0.04	0.5
2	0.05	1.1
4	0.07	1.1
6	0.07	0.5
8	0.13	1. 1
10	0.09	0.6
12	0.06	0.4

ranged between 0.04 and 0.13 (Table 2). This small value was due to the low value of Cu concentration in sediment. Higher BCF value is associated with higher value of Cu concentration in sediment. The difference between this study and McFarlane (2002) could be explained by the difference of concentrations in the sediment. Most likely, the absorption of Cu by the root is proportional to the concentration of Cu in the sediment following first order kinetics. The breathing roots *A. marina* are on the surface of the sediment and parts of the root are above water a form of adaptation of plants on tidal conditions. Generally, the plants absorb elements through the roots, either from sediments or water, and then translocate the metal to other parts of plant and localise or accumulate it in certain tissues (Hardiani, 2009). The process of evapotranspiration process is a mechanism whereby contaminants transfer from the roots to the shoots of plants (Tangahu et al., 2011)

The ability of *A. marina* in accumulating Cu is influenced by the presence of metal in the water and sediment. Defew et al. (2004) described the presence of heavy metals in the aquatic environment which experience precipitation, dilution and dispersion, which are absorbed by the organisms living therein. The findings of this study confirm those of previous studies on concentration of heavy metal in mangrove habitat which followed a decreasingly consecutive order, i.e. sediments>root>stem>leaf>fruit>seawater (Saifullah et al., 2004).

Table 2 shows metal transfer (TF) from roots to leaves ranged between 0.4 and 1.1. This demonstrates the potential of *A. marina* as a bio accumulator. The root of *A. marina* plays an effective role to transfer Cu to the stem tissues and leaves with a TF value of 1.47 (Einollahipeer et al., 2013). The results of this study are consistent with those of Lotfinasabasl and Gunale (2012), that higher concentration of heavy metals is accumulated in the leaves than in the root of *A. marina*. The high concentration of metals is found in the leaves because after metal penetrates the root's endodermis, metal or other extraneous substance is transported on transpiration system to the top of the plant through transporting tissues (xylem and phloem) to other parts of the plant (Priyanto & Prayitno, 2007).

Elevated Cu concentration in the leaves of *A. marina* leaves is due to their ability to accumulate metal. According to Parvaresh et al. (2011), the leaf is one of several tissues of mangrove plants which is able to accumulate metal. In addition, Nazli & Hashim (2010) argued that not only the roots but also leaves of the mangrove have the ability to accumulate heavy metals. The ability of the roots and leaves of mangrove to accumulate heavy metals is relatively higher compared with other plant species. Kamaruzzaman et al. (2011) stated that the presence of Cu in plant tissue is also expedient for its growth, particularly in leaf tissue where the process of photosynthesis occurs. Findings of this study are consistent with those of Martuti & Irsadi (2014) that the young leaves of *A. marina* have a higher Cu metal content than the old ones. However, their study did not measure the Cu content in litter. Therefore, the findings of this study is important. Further research is needed to explain why Cu content in litter is higher than in the old leaves.

The relatively high concentration of copper in the *A. marina* litter is a product of adaptation whereby the plant defends itself against contaminated environments by excreting copper through the leaves, which will then be discarded through defoliation. As confirmed by Barutu et al. (2014), the amount of accumulated metal in the leaves is the result of localisation by the plant, which concentrates metal in the organs of both intracellular and extracellular, such as the leaves. The process is a form of active plant excretion through the gland in the canopy. Meanwhile, passive mechanism includes the accumulation in the leaves as indicated by defoliation of old leaves.

Excretion is an important plant mechanism when dealing with environmental toxicity. Excretion is actively conducted via gland in the crown and passively through the accumulation of old leaves followed by litter discharge (Fitter & Hay, 1992). According to Lotfinasabasl & Gunale (2012), litter can restore metal to the environment. Abohassan (2013) substantiated that litter is able to release <3.5% of the absorbed metal back to the environment. This condition is almost identical when the plants have high saline concentration; the mechanism by which *A. marina* survives is by excreting the salt through defoliation. MacFarlane & Burchett (2000) confirmed that the metals Zn and Cu found in the tissues of plants will be excreted through the salt gland on the lower surface of leaves.

Metal excretion process through plant litter indicates that metal accumulated will be returned to the environment. Restoring metals into the environment through litter is an adaptation mechanism of plants under extreme environmental conditions. Saenger & McConchie (2004) stated that litter can return heavy metals into the environment in a bioavailable form and the amount of metal released is relatively low. As the litter usually spreads in relatively large area due to winds or waves, the release of metal from the litter to the environment is expected to be relatively low.

CONCLUSION

Heavy metal (Cu) accumulation has been discussed extensively in this paper. Its accumulation in parts of *A. marina* has been found to be more than ten-fold higher than that in water, while the accumulation in sediment is the highest, with minimum CF of 500. The translocation of Cu in the roots, leaves and litter in *A. marina* indicated by the value of BCF and TF in the range of 0.04-0.13 and 0.4-1.1 respectively.

The results showed that Cu was translocated in the ionic form of Cu from the roots to the leaves of *A. marina*, and later eliminated through the litter. The highest concentration of Cu in *A. marina* was found in its litter, followed by leaves and roots. Although litter may release the accumulated heavy metals into the environment in a bioavailable form, the amount of metal released is relatively low due to the large spread of its fall. Thus *A. marin*a is important for reducing heavy metal (Cu) concentration in the environment.

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