Bioconcentration Factor (BCF) and Translocation Factor (TF) of Heavy Metals in Mangrove Trees of Blanakan Fish Farm

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Bioconcentration Factor (BCF) and Translocation Factor (TF) of Heavy Metals in Mangrove Trees of Blanakan Fish Farm

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Abstract

In the mangroves of Blanakan, Indonesia, silvofishery practices may play a role in maintaining the environmental quality of ponds. Mangroves are known as pollutant traps since their root systems absorb and accumulate materials. Heavy metals are pollutants that often contaminate aquatic environment like ponds. The bioconcentration factor can be used to evaluate the content of heavy metals in organisms, while the translocation factor can be used to measure the amount of heavy metals transferred form one organ to another. The aim of this study was to determine the bioconcentration factor and the translocation factor of heavy metals (Pb, Cu, and Zn) in mangrove trees (Avicennia and Rhizopora) at the Blanakan ponds. Samples of mangrove trees from 3 stations, were cut using a knife, and samples of sediments were collected using Ekman Bottom Grab sampler. Samples were then prepared for heavy metal content analysis using the Shimadzu 6300 atomic absorption spectrophotometer. The bioconcentration and translocation factors were calculated using formulas; the bioconcentration factor was calculated as the content of heavy metals in trees divided by the content of heavy metals in sediments. Results showed that the bioconcentration factor of Cu was higher than 1 in the roots, stems and leaves of Avicennia trees and of Zn was higher than 1 in the roots of Rhizopora trees at station 1. Translocation factors higher than 1 were mostly found in Avicennia (Cu) and Rhizopora (Pb) trees. Mangrove trees with translocation values of greater than 1 for one or more heavy metals can be considered as strong accumulators of the corresponding metals.

Keywords: bioconcentration factor, heavy metals, mangroves, ponds, translocation factor

Abstrak

Tanaman Mangrove di Blanakan, Indonesia, merupakan praktek silvofishery yang berperan dalam menjaga kualitas lingkungan tambak. Mangrove diketahui sebagai perangkap pencemar karena sistem akarnya menyerap dan mengakumulasi materi. Logam berat adalah pencemar yang seringkali mengontaminasi lingkungan perairan seperti tambak. Faktor biokonsentrasi dapat digunakan untuk mengevaluasi kandungan logam berat dalam organisme, sedangkan faktor translokasi dapat digunakan untuk mengukur jumlah logam berat yang dipindahkan dari satu organ ke yang lain. Tujuan penelitian ini adalah untuk menentukan faktor biokonsentrasi dan faktor translokasi logam berat (Cu, Pb, Zn) pada tanaman mangroves (Avicennia dan Rhizopora) di tambak Blanakan. Sampel tanaman mangrove dari 3 stasiun, dipotong menggunakan pisau dan sampel sedimen dikumpulkan menggunakan Ekman Bottom Grab sampler. Sampel kemudian dipreparasi untuk analisis kandungan logam berat menggunakan Shimadzu 6300 atomic absorption spectrophotometer. Faktor biokonsentrasi dan translokasi dihitung menggunakan formula; faktor biokonsentrasi dihitung dengan kandungan logam berat pada tanaman dibagi kandungan logam berat pada sedimen. Hasil menunjukkan bahwa faktor biokonsentrasi Cu lebih dari 1 pada akar, batang dan daun tanaman Avicennia dan faktor biokonsentrasi Zn lebih dari 1 pada akar tanaman Rhizopora di stasiun 1. Faktor translokasi lebih dari 1 ditemukan pada tanaman Avicennia (Cu) dan Rhizopora (Pb). Tanaman mangrove dengan faktor translokasi lebih dari 1 untuk satu logam berat atau lebih dapat dipertimbangkan sebagai akumulator kuat logam terkait.

Keywords: bioconcentration factor, heavy metals, mangroves, ponds, translocation factor
Introduction

High levels of pollution in ponds can affect cultured animals and their production due to economical activities. The health of individuals that consume products from these systems, such as fish, could also be negatively impacted [1]. The impact could be more severe if contaminants are hazardous substances, such as heavy metals. Metals such as copper (Cu), lead (Pb), and zinc (Zn) are common contaminants encountered in aquatic environments.

Material in the water column often ends up in the sediment, where deposits of organic and inorganic materials can be found. In ponds or fish farms, sediment provides a natural food supply called klekap, which is mostly consumed by milkfish [2]. Based on research at ponds in Gresik, lead content in the sediment was lower than its content in the water [3].

Mangroves also play an important role in reducing the levels of pollutants (heavy metals) in the environment. Mangrove plants have the ability to absorb heavy metals through their root system and store them in their tissues [4]. Zinc content in the roots of mangroves at Muara Angke, Jakarta, was higher than in the leaves, sediment, and water [5]. Another study found that the distribution of copper was higher in stems and roots of mangrove plants, mercury in leaves and stems, and lead in roots and leaves [6]. Mangrove within area 0-500 m to Cilamaya River tend to have highest metals concentration [6].

The bioconcentration factor is a calculated value that indicates the ability of plants to remove metal compounds from the soil/substrate. Meanwhile, the translocation factor is a value that indicates the ability of the compound to be transferred from plant roots to other organs [7].

Plants that have bioconcentration and translocation factors >1 can be used as bioaccumulators [8]. Bioconcentration values >2 are considered to be high values [7]. Plants can be used as phytostabilizers if they have bioconcentration factors >1 and translocation factors <1 and as phytoextractors if they have bio-concentration factors <1 and translocation factors >1 [9].

Based on Nugrahanto’s et al (2014) and Siahaan’s et al (2013) species Rhizophora mucronata, showed variation in the lead concentration and have bioconcentration and translocation factors <1 [10,11]. On the other hand, bioconcentration and translocation factors >1 were found in Avicennia marina [8]. The aim of this study was to determine the bioconcentration and translocation factors of heavy metals (Pb, Cu, and Zn) in mangroves (Avicennia sp. and Rhizophora sp.) at the Blanakan ponds.

Figure 1. Location of Sampling Stations
Materials and Methods

Study site. The study was conducted in the village ponds of Blanakan, District Blanakan, Subang, Indonesia. Silvofishery is practiced in this area. These ponds are the result of a replanting and rehabilitation project carried out by the Perum Perhutani Unit III in West Java 20 years ago. There are 4 types of ponds in the village of Blanakan: open ponds, intercropping ponds, embankment ponds, and forestry ponds [12]. Blanakan village has an area of 980.46 hectares. The boundaries of this village are Java Sea to the north, Ciasem Biru to the south, Langensari village to the east, and Jaya Mukti and Rawamekar villages to the west. The daily average temperature of the region is 32 °C, with an average humidity of 32%. Rainfall is about 2,800 mm/year; the wet season lasts 180 days/year [12].

In this study, three sampling stations of mangrove area and sediments were established (Figure 1). The stations were located in intercropping ponds. Each station represented one pond. Field sampling. Sampling was performed twice in August 2015 based on purposive sampling. Samples were taken from mangroves and sediments. Based on observations, mangrove trees in this area belong to Avicennia sp. and Rhizophora sp. Samples (two individuals from each pond) of mangrove tree roots, stems, and leaves were cut using a knife. Sediments (100 g from each pond) were taken using an Ekman Bottom Grab sampler and a plastic spatula. Samples were then put into a clean plastic bags and stored in a cooler box.

Heavy metals analysis. The mangrove samples (roots, stems, and leaves) were cleaned and cut into small pieces. The mangrove samples were dried in the oven at 80 °C, while the sediment samples were dried at 105 °C. Dry samples were ground. Then, 0.5 g of dry mangrove samples was digested by the aqua regia method (HCl:HNO₃ = 3:1) and heated until achieving a volume of 1 ml. For the sediment, 0.5 g of dry samples was digested using the aqua regia method, then supplemented with hydrofluoric acid (HF) and heated. Aqua Dest distilled water was then added to each sample; samples were filtered until obtaining a volume of 25 ml. The resulting filtrate was submitted to heavy metal analysis using the Shimadzu AAS 6300 atomic absorption spectrophotometer [13]. Metals analyzed were copper (Cu), lead (Pb), and zinc (Zn). Data on heavy metal concentrations from both sediments (54 readings) and mangrove trees (90 readings) were used to calculate the bioconcentration and translocation factors.

Bioconcentration and translocation factors. The calculation of the bioconcentration factor (BCF) and the translocation factor (TF) were performed to assess whether plants could be categorized as accumulators, as follows [7]:

\[
\text{BCF} = \frac{\text{concentration in mangrove organ}}{\text{concentration in sediment}}
\]  \hspace{1cm} (1)

\[
\text{TF} = \frac{\text{BCF of stem or leaf}}{\text{BCF of root}}
\]

Data on the bioconcentration and translocation factors were tabulated using Windows Excel and are presented in table format.

Result and Discussion

In the research area, mangrove trees of Avicennia sp. and Rhizophora sp. were found at all stations, while Rhizophora sp. was only found at stations 1 and 3. The bioconcentration factors of heavy metals in Avicennia sp. are shown in Table 1. Based on this table, bioconcentration factors of greater than 1 can be found for Cu in roots, stems, and leaves of Avicennia sp. Meanwhile, for Pb and Zn, mostly concentrations of less than 50% were absorbed from the sediments of mangroves.

Bioconcentration factors of heavy metals in Rhizophora sp. are shown in Table 2. Based on this table, bioconcentration factors greater than 1 can be found for Zn in roots. More than 50% accumulation was found for Cu in roots (0.64) and for Zn in leaves (0.76), and the remaining concentrations were below 50%.

The translocation factors of heavy metals in Avicennia sp. can be seen in Table 3. As observed in this table, translocation factors greater than 1 are mostly observed for Cu and Zn. The highest translocation factors for all metals, Pb, Cu, and Zn, were found for root-stem translocation, with values of 1.09, 2.80, and 2.12, respectively. This finding indicates that this mangrove tree is capable of translocating metals from the roots to the stems rather than to leaves.

The translocation factors of heavy metals in Rhizophora sp. can be seen in Table 4. Based on this table, the greatest translocation factors are observed for Pb and Zn for root-leaf translocation at 1.48 and 2.24, respectively. Therefore, this mangrove tree translocated Cu and Zn from roots to leaves rather than from roots to stems.

Heavy metals are commonly found in roots and leaves [11]. The process of heavy metal binding in plants occurs via the mechanisms of heavy metal accumulation and tolerance. Mangrove roots can thus contribute to the prevention of heavy metal accumulation in the surrounding environment; high concentrations of heavy metal contaminants in sediments may be stored/extracted by the tissues and leaves of trees [14].
The translocation factors for heavy metals in plants should be more than one in order to be considered as bioaccumulators [11]. Hyperaccumulator plants can accumulate high concentrations of heavy metals at the tissue surface (above ground) when found in their natural habitat [15]. *Avicennia* sp. had the highest metal leaf-root translocation factor for Pb at 1.58 [5]. Metal translocation of the essential metals (Cu and Zn) from roots to leaves was lower compared with the non-essential metal (Pb) [5]. The low translocation factors of the essential metals could indicate that mangroves use both these metals for metabolic activity and growth, while the mobility of the non-essential metal from roots to leaves is comparably higher. In leaves, Pb is toxic, especially for the plant functions of photosynthesis and the synthesis of chlorophyll and antioxidant enzymes. Sometimes, the roots can prevent the transport of non-essential metals, so metals accumulate in the roots [16]. Root-leaf and root-stem translocation values of more than 1 showed that metal concentration in leaves or stems was higher than in roots. It seems that roots have a greater ability to absorb rather than accumulate the studied heavy metals. The translocation of materials in plants occurs via the vascular system, or the xylem tissue. Its main function is to transport water, although heavy metals could also potentially be transported from roots to leaves. Moreover, the speed of heavy metal translocation may be influenced by the systems responsible for capillary action in plants.

The existence of mangroves are important, as mangroves provide habitats for fisheries. The ability of mangroves to accumulate heavy metals from sediments can improve the quality of environments [17]. Furthermore, mangrove trees can remediate ponds affected by heavy metal pollution and reduce any negative effects on human health and the organisms inhabiting the ponds [18].

### Table 1. Bioconcentration Factors of Heavy Metals in *Avicennia* sp.

| Station | Pb | Cu | Zn |
|---------|----|----|----|
|         | Root | Stem | Leaves | Root | Stem | Leaves | Root | Stem | Leaves |
| 1       | 0.42 | 0.29 | 0.35 | 1.29 | 1.59 | 1.14 | 0.23 | 0.01 | 0.27 |
| 2       | 0.35 | 0.38 | 0.31 | 0.25 | 0.38 | 0.31 | 0.29 | 0.18 | 0.36 |
| 3       | 0.18 | 0.16 | 0.02 | 0.10 | 0.28 | 0.23 | 0.25 | 0.53 | 0.43 |

### Table 2. Bioconcentration Factors of Heavy Metals in *Rhizophora* sp.

| Station | Pb | Cu | Zn |
|---------|----|----|----|
|         | Root | Stem | Leaves | Root | Stem | Leaves | Root | Stem | Leaves |
| 1       | 0.21 | 0.13 | 0.31 | 0.64 | 0.21 | 0.50 | 1.95 | -    | 0.27 |
| 3       | 0.24 | 0.26 | 0.21 | 0.38 | 0.31 | 0.13 | 0.34 | 0.11 | 0.76 |

### Table 3. Translocation Factors of Heavy Metals in *Avicennia* sp.

| Station | Pb | Cu | Zn |
|---------|----|----|----|
|         | Root - Stem | Root - Leaf | Root - Stem | Root - Leaf | Root - Stem | Root - Leaf |
| 1       | 0.69 | 0.83 | 1.23 | 0.88 | 0.04 | 1.17 |
| 2       | 1.09 | 0.89 | 1.52 | 1.24 | 0.62 | 1.24 |
| 3       | 0.89 | 0.11 | 2.80 | 2.30 | 2.12 | 0.04 |

### Table 4. Translocation Factors of Heavy Metals in *Rhizophora* sp.

| Station | Pb | Cu | Zn |
|---------|----|----|----|
|         | Root - Stem | Root - Leaf | Root - Stem | Root - Leaf | Root - Stem | Root - Leaf |
| 1       | 0.62 | 1.48 | 0.33 | 0.78 | -    | 0.14 |
| 3       | 1.08 | 0.88 | 0.82 | 0.34 | 0.32 | 2.24 |
Conclusion

Rhizophora sp. showed potential as zinc (Zn) bioaccumulators and lead (Pb) phytoextractors. Other mangrove species, Avicennia sp. demonstrated potential as copper (Cu) bioaccumulators as well as phytoextractors of lead (Pb) and zinc (Zn).

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