Translocation Factor of Zinc (Zn) in Water and Sediment by Root and Stem of *Rhizophora* sp. at Blanakan Riparian, West Java

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**Abstract.** Mangroves are plants that can transport, absorb, and store heavy metals in the surrounding environment. This study aims to measure the capacity of *Rhizophora* sp. root and stem in transporting, absorbing, and storing Zn from water and sediment of Blanakan Riparian, West Java. *Rhizophora* sp. root, stem, water, and sediment samples were collected from 3 stations located on the Blanakan Riparian, West Java. Atomic Absorption Spectrophotometer was used to analyze the Zn contents from the samples. Likewise, Bioconcentration Factor (BCF) and Translocation Factor (TF) were used to calculate the Zn contents from water and sediment stored in root and stem. The results showed that the range of BCF of Zn in water and sediment in root were 108.214-284.204 and 0.254-0.271, respectively. Meanwhile, the range of BCF of Zn in water and sediment in the stem were 112.193-189.611 and 0.233-0.297. Furthermore, the range of TF of Zn in water and sediment were 0.667-1.036 and 0.917-1.095. To conclude, the root and stem of *Rhizophora* sp. can be used to translocate Zn contents from water and sediment at Blanakan Riparian, West Java.

1. **Introduction**

Mangroves are plants that can absorb, transport, and store toxic substances such as heavy metals in the mangrove environment. Mangroves can cope with toxic materials, including weakening the effect of poison through dilution, which was carried out by diluting the concentration of heavy metals in the tissue so mangroves can reduce the toxicity of the heavy metals [1]. In general, heavy metal accumulation occurs at the roots of mangroves with limited transportation to the other parts of plant organs such as stem and leaf. It shows that mangroves actively avoid the uptake of heavy metals [2].

Mangroves can accumulate heavy metals up to 1000 mg/kg [3]. Zinc (Zn) is one of the essential nutrients that is needed for plant growth and development. Zn plays a role in enzymatic reactions, enzyme activator on respiration process, and growth hormones, but Zn is highly toxic in plants if the amount is excessive [3, 4, 5]. Bioconcentration and translocation factors are values that can be used to determine the ability of mangroves to accumulate heavy metals [6]. Plants that have bioconcentration factor values and translocation factor values >1 can be used as bioaccumulators. Plants that have bioconcentration factor values >1 and translocation factors < 1 can be used as photo stabilizers, while plants that have bioconcentration factors <1 and translocation factors >1 can be used as phytoextractors [7].
Blanakan riparian in Subang District, West Java, is close to the river that used as transportation for ship and fishery activities. The river is also quite close to the settlement, so that there was a lot of human activity, which causes the Blanakan riparian is experiencing water pollution. Water pollution can come from wastes, fertilizers, pesticides, and detergents used as cleaning agents. *Rhizophora* sp. is one of the many mangroves found in Blanakan riparian that has functioned as a natural bioremediation agent. It because mangroves can naturally absorb heavy metals in nature such as Fe, Mn, Cr, Cu, Co, Ni, Pb, Zn, and Cd, and this function is called biosorption [8]. This study aims to measure the capacity of *Rhizophora* sp. root and stem in transporting, absorbing, and storing Zn from water and sediment of Blanakan riparian, West Java.

2. Methods

2.1 Study site
The Blanakan riparian is located in Subang district, West Java province. The station geo-coordinates were from upstream at lat: -6.277444, long: 107.6599 to downstream (river mouth) lat: -6.240083, long: 107.667472 (Figure 1). The width of the Blanakan riparian is varied from 60 m near the river mouth to 11 m in the upstream. In upstream, the river was surrounded by settlements and paddy field, in midstream was transition area from paddy field to fish pond and downstream was dominated by the fish pond and revegetated by mangrove.

![Figure 1. The locations of 3 stations in Blanakan river](image)

Samples were taken in June 2019 in stations 1, 2, and 3 (Figure 1). The method used in this study was random sampling by taking samples from 3 stations. In each station, three mangrove trees were sampled. Sediment samples were taken using Ekman Bottom Grab, and water samples were taken using plastic bottles, while mangrove samples were taken using a cutting knife. Mangrove parts taken for this study were roots and stems from *Rhizophora* sp.

2.2 Heavy metal analysis
Samples were prepared for analysis of the heavy metal content using an Analyst 800 atomic absorption spectrophotometer (AAS). First, roots and stems of *Rhizophora* sp. were cleaned and cut into small
pieces. Each plant and sediment samples were dried. Mangrove samples were dried in an oven with a temperature of 80°C, while the sediment samples were dried at 105°C. 0.5 grams of dried samples were then ground. The samples were destructed by the aqua regia (HCl:HNO$_3$ = 3:1). After destructing, mangrove samples were heated to 1 ml in volume, while sediment samples were supplemented with hydrofluoric acid (HF) and heated. Aquadest distilled water was added to each sample. Samples were filtered to a volume of 25 ml. A heavy metal analyzed in this study was zinc (Zn). Data of Zn concentration in water, sediments, and mangroves were used to calculate the bioconcentration and translocation factors [9]. The unit was stated in mg/kg

2.3 Bioconcentration and Translocation Factors

Bioconcentration Factor (BCF) from sediment were calculated based on the following formula:

$$BCF = \frac{\text{Concentration in mangrove organ}}{\text{Concentration in sediment}} \quad [9]$$

Bioconcentration Factor (BCF) from the water was calculated based on the following formula

$$BCF = \frac{\text{Concentration in mangrove organ}}{\text{Concentration in water}} \quad [9]$$

Translocation Factor (TF) were calculated based on the following formula

$$TF = \frac{BCF \text{ in stem}}{BCF \text{ in root}} \quad [9]$$

Both bioconcentration factors and translocation factors were ratios. The value was not stated in the unit.

3. Result

The content of zinc was measured from sediment, root, and stem of *Rhizopora* sp. The content of zinc was shown in Figure 2. While the bioconcentration factor and translocation factor of zinc were shown in Table 1 and Table 3.

![Figure 2](image-url) Average of Zn in water (mg/L), sediment (mg/kg), root and stem (mg/kg) of *Rhizophora* sp.

At station 1, mangroves were not found. The average of Zn in the roots of *Rhizophora* sp. at station 2 was 24.31 mg/kg, while at station 3 it was 25.18 mg/kg. The average of Zn in the stems of *Rhizophora* sp. at station 2 was 21.875 mg/kg and 22.555 mg/kg at station 3. The Zn in the water at station 1 was 0.28 mg/L, station 2 was 0.14 mg/L, and station 3 was 0.283 mg/L. While the Zn in sediment at station 1 was 90.846 mg/kg, station 2 was 97.332 mg/kg, and station 3 was 88.91 mg/kg (Figure 2).
Table 1. Average of Bioconcentration Factor of Zn in sediment, in roots and stems of *Rhizophora* sp.

| Station | Bioconcentration Factor |    |    |
|---------|-------------------------|----|----|
|         | Root (mg/kg)            | Stem (mg/kg) |
| 1       | -                       | -              |
| 2       | 0.254                   | 0.233          |
| 3       | 0.271                   | 0.297          |

The BCF (Table 1) value of Zn from sediment to root at station 2 was 0.254 mg/kg and 0.271 mg/kg at station 3. While the BCF value of Zn from sediment to stem at station 2 was 0.233 mg/kg and 0.297 mg/kg at station 3. It shows that from station 2 to station 3, there was an increase in BCF values from sediments to plant organs such as roots and stems.

Table 2. Average of Bioconcentration Factor of Zn in water, in roots and stems of *Rhizophora* sp.

| Station | Bioconcentration Factor |    |    |
|---------|-------------------------|----|----|
|         | Root (mg/kg)            | Stem (mg/kg) |
| 1       | -                       | -              |
| 2       | 284.204                 | 189.611        |
| 3       | 108.214                 | 112.193        |

The BCF (Table 2) value of Zn from water to the root was 284.204 mg/kg at station 2 and 108.214 mg/kg at station 3. While the BCF value of Zn from water to the stem was 189.611 mg/kg at station 2 and 112.193 mg/kg at station 3. From these figures, we know that the BCF value from water-root and water-stem has decreased from station 2 to station 3.

Table 3. Average of Translocation Factor of Zn in sediment and water of *Rhizophora* sp.

| Station | Translocation Factor |    |    |
|---------|----------------------|----|----|
|         | Water-root-stem (mg/kg) | Sediment-root-stem (mg/kg) |
| 1       | -                    | -              |
| 2       | 0.667                | 0.917          |
| 3       | 1.036                | 1.095          |

From the BCF values that have been obtained, it can be used to find out the TF value. TF values of Zn in water-root-stem for *Rhizophora* sp. at station 2 was 0.667 mg/kg (Table 3). Meanwhile, at station 3 it was 1.036 mg/kg. While, the TF values of Zn in sediment-root-stem for *Rhizophora* sp. at station 2 was 0.917 mg/kg and at station 3 was 1.095 mg/kg. From these data, it appears that the TF from station 2 to station 3 has increased.

4. Discussion

At station 1, mangroves were not found, especially *Rhizophora* sp. It was caused by the location, which is adjacent to the upstream. Upstream waters have low salinity, so this location is not suitable for mangroves. *Rhizophora mucronata* has the best growth in salinity of 7.50-15.0 ppt, with an average height increase of 2.48 cm [11].

Table 4. Bioconcentration Factor of sediment-to-root of Zn of *Rhizophora* sp. in comparison with other locations

| Species           | BCF     | Locations                  |
|-------------------|---------|----------------------------|
| *Rhizophora* sp.  | 0.254-0.271 | Blanakan river (this study) |
| *Rhizophora* sp.  | 0.34-1.95  | Blanakan Fish Farm [7]     |
| *Rhizophora mucronata* | 0.98       | Muara Angke [4]           |
Table 5. Bioconcentration Factor of sediment-to-stem of Zn of *Rhizophora* sp. in comparison with other locations

| Species                | BCF          | Locations                  |
|------------------------|--------------|----------------------------|
| *Rhizophora* sp.       | 0.233-0.297  | Blanakan river (this study) |
| *Rhizophora* sp.       | 0.11         | Blanakan Fish Farm [7]     |
| *Rhizophora mucronata* | 0.03-0.12    | Sungai Tallo, Makassar [10]|

Table 6. Translocation Factor of Zn of *Rhizophora* sp. in comparison with other locations

| Species                | TF            | Locations                  |
|------------------------|---------------|----------------------------|
| *Rhizophora* sp.       | 0.667-1.036 (water-root-stem) | Blanakan river (this study) |
|                        | 0.917-1.095 (sediment-root-stem) |                           |
| *Rhizophora* sp.       | 0.14-2.24     | Blanakan Fish Farm [7]     |
| *Rhizophora mucronata* | 0.86          | Muara Angke [4]            |

Based on Figure 2, it shows that the Zn in the root was greater than in the stem. It is caused by the accumulation of heavy metals occurs at the root. The heavy metal accumulation that occurs at the root will be carried to other tissues. Metal from roots to other plant parts such as stems and leaves was limited transported. This shows that mangroves actively avoid the uptake of heavy metals [4,12].

The Zn in water ranges from 0.14 to 0.283 mg/L. It shows that the water in the Blanakan river was in Class 4, in which Class 4 was a group of water that can be used to irrigate, plant, and other uses that require the same water quality as these uses. However, when considering the Zn content, the water from the river can still be used for drinking, because the amount of Zn is ≤ 5 mg/L [13]. To find out whether water can be used for drinking or not, we must look at the contents of other substances.

The Zn in sediment ranges from 88.91 to 97.332 mg/kg. Based on the Canadian Freshwater Sediment Guidelines, the Zn threshold in sediments is 123 mg/kg. While based on the Ontario Ministry of Environment Screening Level Guidelines, the Zn threshold in sediments is 120 mg/kg [14]. By comparing those two guidelines, the Zn in sediments in the Blanakan river was still below the threshold.

Based on Table 1-3, the differences in BCF and TF values obtained were not significant when compared with other locations (Table 4-6). From this study, the range of BCF in *Rhizophora* sp. for sediment-root-stem was 0.233-0.297 (Table 1) and the TF of *Rhizophora* sp. (Table 6) almost close to even more than 1. The TF for the water-root-stem was 1.036, and the TF for sediment-root-stem was 1.095. It shows that *Rhizophora* sp. can be used as zinc (Zn) phytoextractors. High BCF values in roots were supported by high metal concentrations in roots and low in sediments or water. This resulted in high BCF values in roots, while the low TF value of essential metals such as Zn indicates that mangroves use these essential metals for metabolic and growth activities [4].

5. Conclusion
Bioconcentration and translocation factors are values that can be used to determine the ability of mangroves to accumulate heavy metals. BCF values from sediments to plant organs such as roots and stems from station 2 to station 3 shows that BCF values were increasing. While BCF values from water to roots and stems have decreased from station 2 to station 3, respectively, TF value from station 2 to station 3 has increased. The *Rhizophora* sp. in this study can be considered as Zinc (Zn) phytoextractors since it has the BCF lower than 1 and the TF more than 1.

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References

[1] Supriantini E, Nuraini R A T and Dewi C P 2017 Daya Serap Mangrove Rhizophora sp. terhadap Logam Berat Timbal (Pb) di Perairan Mangrove Park, Pekalongan Jurnal Kelautan Tropis 20 16-24.
[2] Qari R and Ahmed S 2014 Heavy Metal Distribution in Avicennia marina from Sonmiani, Pakistan Coast Journal of Shipping and Ocean Engineering 4 38-42
[3] Hamzah F and Pancawati Y 2013 Fitoremediasi Logam Berat dengan Menggunakan Mangrove Ilmu Kelautan 18 203-12
[4] Hamzah F and Setiawan A 2010 Akumulasi Logam Berat Pb, Cu, dan Zn di Hutan Mangrove Muara Angke, Jakarta Utara Jurnal Ilmu dan Teknologi Kelautan 2 41-52
[5] Kutlu B and Mutlu E 2017 Growth and Bioaccumulation of Cadmium, Zinc, Lead, Copper in Dunaliella sp. Isolated from Homa Lagoon, Eastern Aegean Sea Indian Journal of Geo Marine Sciences 46 1162-9
[6] Handayani C O, Dewi T and Hidayah A 2018 Biokonsentrasi dan Translokasi Logam Berat Cd pada Tanaman Bawang Merah dengan Aplikasi Amelioran Jurnal Tanah dan Sumberdaya Lahan 5 841-5
[7] Takarina N D and Pin T G 2017 Bioconcentration Factor (BCF) and Translocation Factor (TF) of Heavy Metals in Mangrove Trees of Blanakan Fish Farm Makara Journal of Science 21 77-81
[8] Kairuddin, Yamin M and Syukur A 2018 Analisis Kandungan Logam Berat pada Tumbuhan Mangrove sebagai Bioindikator di Teluk Bima Jurnal Biologi Tropis 18 69-9
[9] Takarina N D and Pin T G 2015 Bioconcentration Factor and Translocation Factor of Copper (Cu) in Avicennia sp. at Rawameneng and Blanakan Ponds, Subang Regency, West Java, Indonesia International Journal of Marine Science 5 1-5
[10] David M, Liong S and Hala Y 2016 Fitoakumulasi Cd dan Zn dalam Tumbuhan Bakau Rhizophora mucronata di Sungai Tallo Makassar Available at: http://repository.unhas.ac.id/bitstream/handle/123456789/21857/M.%20David%20Artikel.pdf?sequence=1 accessed 5 August 2019
[11] Hutahaean E E, Kusmana C and Dewi H R 1999 Studi Kemampuan Tumbuh Anakan Mangrove Jenis Rhizophora pumbar, Bruguiera ginnorrhiza dan Avicennia marina pada Berbagai Tingkat Salinitas Jurnal Manajemen Hutan Tropika 5 77-85
[12] Kamaruzzaman B Y, Sharlinda M Z R, John B A and Waznah A S 2011 Accumulation and Distribution of Lead and Copper in Avicennia marina and Rhizophora apiculata from Balok Mangrove Forest, Pahang, Malaysia Sains Malaysiana 40 555-60
[13] Peraturan Pemerintah Republik Indonesia Nomor 82 Tahun 2001 tentang Pengelolaan Kualitas Air dan Pengendalian Pencemaran Air (Jakarta: Pemerintah Pusat)
[14] Burton G A 2002 Sediment Quality Criteria in Use Around the World Limnology 3 65-75