Bioaccumulation of Heavy Metal in *Avicennia* sp. from Blanakan Riparian, Subang, West Java

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**Abstract.** The heavy metals from an aquatic environment can be absorbed, transported, and stored in mangrove tissues. This study aims to assess accumulations of Cu and Zn in the sediment, root, and stem of *Avicennia* sp. as affected by human activity in Blanakan riparian, West Java. *Avicennia* sp. root, stem, water, and sediment samples were collected from 2 stations located in Blanakan riparian. The concentrations of Cu and Zn in samples were measured using an atomic absorption spectrophotometer (AAS). Bioconcentration factor (BCF) and translocation factor (TF) equations were used to analyse the Cu and Zn accumulations in *Avicennia* sp. Based on the sediment quality guidelines, the sediment samples were not polluted for Cu (2.23–2.26 mg/kg) and moderately polluted for Zn (92.83–95.86 mg/kg). Moreover, the Cu and Zn in the water have BCF values of root ranging from 257.5–295 and 97.07–390.29, while BCF values of stem ranging between 590–990 and 90.23–330.21, respectively. Furthermore, the Cu and Zn in the sediment have BCF values of root ranging from 0.23–0.26 and 0.30–0.57, while BCF values of stem ranging between 0.53–0.88 and 0.30–0.48, respectively. In addition, the TF values ranged from 2.29–3.36 for Cu and 0.85–0.93 for Zn. To summarize, the root and stem of *Avicennia* sp. have the ability to translocate Cu from water and sediment in Blanakan riparian.

1. **Introduction**

Mangrove ecosystems are facing the threat of degradation of 52,000 hectares/year globally [1]. The mangrove forests in Indonesia degraded dramatically in 1980–2011 from 4.2 million hectares to 3.1 million hectares. The mangrove cover in the Blanakan village during the years 2005–2012 shows a decrease of about 5% per year. The high rate of mangrove degradation was caused by the conversion into settlements and fish ponds [2]. In fact, the mangrove vegetation has a number of important roles in the ecosystem.

Mangrove vegetation serves as a fish spawning spot, protecting the land from windstorm, abrasion, and the seawater intrusion [3]. The mangrove root system that deep and widely spread can filter, absorb, and accumulate heavy metal pollutants from the surrounding environment, thus the adverse effects of heavy metals contamination on ecosystems can be minimized [4, 5]. These capabilities made mangrove potentially can be used as a bioremediation agent [6, 7]. In addition, mangrove sediments are rich in organic and inorganic matters. Therefore, it can be used as indicators of heavy metal pollution [8].

Heavy metals are one of the most dangerous pollutants because they are accumulative, difficult to be degraded in aquatic environments, and can be passed to the organism tissue through the food chain. Eating fish that contaminated with heavy metals in a certain period can cause toxic effects to humans [5, 8], such as skin irritation and cancer [9]. Despite the fact that some heavy metals such as Cu and Zn...
classified as an essential micronutrient for plants, but it would be toxic if it exceeds a certain limit of the amount [7]. Mining activities, industry, agriculture, and the settlement allegedly produce waste that adds heavy metals inclusion into the water bodies [10].

Mangrove is one of the plant species that are tolerant of heavy metals through the dilution mechanism, which stores a lot of water in the tissue to dilute heavy metals concentration and minimized its toxicity. *Avicennia* sp. is a cosmopolitan mangrove species which is very common in Indonesia [11]. Correspondingly, this study aims to assess the accumulation of Cu and Zn in sediments, roots, and stems of *Avicennia* sp. as affected by human activities in Blanakan riparian, West Java.

2. **Methods**

2.1. **Study Area**

The study was conducted in June 2019 in Blanakan riparian, Subang, West Java. Mangrove area in Blanakan village stretches about 159 hectares [1]. The average rainfall is 222.92 mm per year, with an average rain of 10.5 days/month. The population is about 12,112 people, with densities reaching 940 people/km². The majority of people work as laborers and farmers. At least there are 67 industries operating in the Blanakan district [12]. Most industries are likely to dispose of waste throughout the watershed. Moreover, the heavy metal pollutants may have entered the water bodies due to the many sources of domestic waste on the riverbank.

Two stations were chosen based on their distance from the estuary. Station 1 was surrounded by fish ponds and closer towards the settlement (06°15'44.8"S, 107°39'52.1"E) while the station 2 was located closer to the estuary (06°14'30.5"S, 107°40'01.5"E) (Figure 1).

![Figure 1. The locations of 2 stations in this study](image)

2.2. **Water, Sediment, and Mangrove Samples Collection**

Samples of water, sediments, mangrove root and stem at diameter 10–30 cm were taken with 3 replicates at each station. The sediment samples were taken using Ekman grab. The water samples were taken directly using a plastic bottle (±250 ml each) and mangrove samples were taken using a cutting tool (±100 gr each). Collected samples were inserted into a zip lock bag and stored in a refrigerator.
2.3. Measurement and Analysis of Cu and Zn

The concentrations of Cu and Zn were measured using an Atomic Absorption Spectrophotometry (AAS), following the procedures as described in the literature [13]. Bioconcentration Factor (BCF) and Translocation Factor (TF) equations were used to analyze the Cu and Zn accumulations in *Avicennia* sp.:

\[
\text{BCF} = \frac{\text{concentration in the root or stem}}{\text{concentration in sediment or water}}
\]

\[
\text{TF} = \frac{\text{concentration in stem}}{\text{concentration in root}}
\]

BCF >1 was categorized as the accumulator, BCF=1 was categorized as indicator, and BCF <1 was categorized as excluder. In addition, TF >1 was categorized as phytoextraction mechanism or high mobility, while TF <1 was categorized as photostabilization [16]. The obtained data then tabulated and presented with graphics.

3. Results

3.1. Heavy Metal Concentrations

![Figure 2](image.png)

**Figure 2.** Cu and Zn in water (mg/l), sediment (mg/kg), root and stem (mg/kg) of *Avicennia* sp.

Based on the results, the Cu concentrations were <0.002 mg/L in the water, 0.257–2.23 mg/kg in the sediment, 0.515–0.59 mg/kg in the root, and 1.18–1.98 mg/kg in the stem. Meanwhile, the Zn contents were 0.14–0.283 mg/L in the water, 92.833–95.863 mg/kg in the sediment, 27.47–54.64 mg/kg in the root, and 25.535–46.23 mg/kg in the stem. Generally, the concentrations of both Cu and Zn were higher in station 1.

3.2. Bioconcentration Factor and Translocation Factor

| Station | Cu    | Zn    |
|---------|-------|-------|
|         | root  | stem  | root  | Stem  |
| 1       | 0.261 | 0.877 | 0.570 | 0.482 |
| 2       | 0.231 | 0.529 | 0.296 | 0.275 |
Table 2. BCF values of heavy metal from the water in *Avicennia* sp.

| Station | Cu | Zn |
|---------|----|----|
|         | root | stem | root | Stem |
| 1       | 295  | 990  | 390.286 | 330.214 |
| 2       | 257.5 | 590  | 97.067   | 90.230 |

Table 3. TF values from root to stem in *Avicennia* sp.

| Station | Cu    | Zn    |
|---------|-------|-------|
| 1       | 3.356 | 0.846 |
| 2       | 2.291 | 0.930 |

BCF of root and stem for both Cu and Zn from the sediment were all <1. Thus, *Avicennia* sp. can be categorized as excluder. Furthermore, TF values for Cu were >1, while TF for Zn was <1. Those results suggested that *Avicennia* sp. has a phytoextraction mechanism or high mobility for Cu, which can uptake Cu contaminants from soil then translocate it into the aboveground plant parts.

4. Discussion

Based on the water quality standard issued by the government of Indonesia (2001), the thresholds were 0.02 mg/L for Cu and 0.05 mg/L for Zn [14]. Therefore, the Cu concentrations in water samples were still below the threshold, but the Zn concentrations were above the threshold. Moreover, based on the sediment quality guidelines (SQG) [15], the sediment samples in this study were not polluted for Cu (2.23 to 2.26 mg/kg) and moderately polluted for Zn (92.83 to 95.86 mg/kg).

Table 4. Comparison of BCF and TF values of Cu from other locations.

| Species            | Range BCF | Range TF | Location | Reference |
|--------------------|-----------|----------|----------|-----------|
|                    | Root      | Stem     |          |           |
| *Avicennia* sp.    | 0.23–0.26 | 0.53–0.88| 2.29–3.36| Blanakan  |
|                    |           |          |          | riparian, |
|                    |           |          |          | Subang    |
| *Avicennia* alba   | 0.31–0.38 |          | 0.67–1.49| Wonorejo, |
|                    |           |          |          | Surabaya  |
| *Avicennia* sp.    | 0.10–1.29 | 0.28–1.59| 1.23–2.80| Blanakan  |
|                    |           |          |          | fishfarm, |
|                    |           |          |          | Subang    |
| *Avicennia* marina | 0.27–0.74 | 0.22–0.51| 0.43–0.83| Tapak,    |
|                    |           |          |          | Semarang  |
| *Avicennia* marina | 0.18–0.52 | 0.43–0.83| >1       | Red Sea,  |
|                    |           |          |          | Saudi     |
| *Avicennia* marina | 1.10–5.23 | 0.93–4.55| >1       | Arabia    |
| *Avicennia* marina | 0.38      | 0.20     |          | South     |
|                    |           |          |          | China     |

This study [16]
[13]
[17]
[18]
[15]
[19]
Table 5. Comparison of BCF and TF values of Zn from other locations.

| Species       | Range BCF | Range TF | Location                  | Reference |
|---------------|-----------|----------|---------------------------|-----------|
|               | Root      | Stem     |                           |           |
| *Avicennia sp.* | 0.30–0.57 | 0.28–0.48 | Blanakan riparian, Subang | This study |
| *Avicennia marina* | 0.95–1.53 | 0.52–0.78 | Muara Angke, Jakarta      | [17]      |
| *Avicennia sp.* | 0.23–0.25 | 0.01–0.53 | Blanakan Fishfarm, Subang | [13]      |
| *Avicennia marina* | 0.38–4.08 | 0.22–5.07 | Red Sea, Saudi Arabia     | [15]      |
| *Avicennia marina* | 0.16      | 0.06     | South China               |           |

According to Tables 4 and 5, BCF of *Avicennia sp.* has a majority value <1 for both Cu and Zn. Furthermore, the TF values for Cu in this study were higher compared to the other studies.

5. Conclusion
*Avicennia sp.* can potentially be used as phytoextractors because the root and stem of *Avicennia sp.* can translocate Cu from water and sediment in Blanakan riparian.

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