

Analysis of the Heavy Metal Content Cadmium (Cd) and Zinc (Zn) in Mangrove Trees *Rhizophora* sp. in Muara Tukad Badung, Bali

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Abstract

The mangrove ecosystem has higher productivity compared to other coastal ecosystems. They have the ability to biologically filter, bind, and accumulate substances. The accumulation of heavy metals in the environment poses serious problems, which is caused by continuous waste disposal. Heavy metals cannot be biologically or chemically degraded and will accumulate and be transported by water flow. Cd and Zn are heavy metals that can contaminate the environment if accumulated continuously. The aim of this research was to determine the Geoaccumulation Index, Bioaccumulation Concentration Factor, Translocation Factor, and the raw water quality standard with respect to the heavy metal content of Cadmium (Cd) and Zinc (Zn). Based on the method used, the analysis results can be concluded as follows: the geoaccumulation index analysis indicates an uncontaminated status ($I_{geo} \leq 0$). The bioaccumulation concentration factor values (BCF1 for Zn indicates phytoextraction, while the value of TF.

Keywords: *bioaccumulation; geoaccumulation; heavy metal; mangrove; waste disposal*

Abstrak

Ekosistem mangrove memiliki produktivitas yang lebih tinggi dibandingkan dengan ekosistem pesisir lainnya. Mereka memiliki kemampuan menyaring secara biologis, mengikat dan mengakumulasi. Akumulasi logam berat di lingkungan menyebabkan masalah yang serius, hal ini disebabkan oleh pembuangan limbah yang terus menerus. Logam berat tidak dapat terdegradasi secara biologis maupun kimiawi dan akan terakumulasi serta terangkut oleh aliran air. Cd dan Zn merupakan logam berat yang dapat mencemari lingkungan apabila terakumulasi secara terus-menerus. Tujuan penelitian ini dilakukan untuk mengetahui Indeks Geoakumulasi, Faktor Konsentrasi Bioakumulasi, Faktor translokasi dan kualitas baku mutu air sungai dengan kandungan logam berat kadmium (Cd) dan seng (Zn). Berdasarkan metode tersebut dapat disimpulkan hasil analisis indeks geoakumulasi berada pada status tidak terkontaminasi ($I_{geo} \leq 0$), nilai faktor konsentrasi bioakumulasi dengan rentang nilai BCF1 atau fitoekstraksi. Sedangkan nilai Cd yaitu $TF < 1$ atau fitostabilisasi.

Kata Kunci: *bioakumulasi; geoakumulasi; logam berat; mangrove; pembuangan limbah*

1. Introduction

Mangroves play an important role in coastal ecosystems, found between land and sea where sea tides occur (Al-Mur, 2021). Mangrove ecosystems have higher productivity compared to other coastal ecosystems. They have the ability to biologically filter, bind and accumulate (Khairudin et al., 2018). The mangrove ecosystem in Indonesia is spread from Sumatra to Papua. Mangroves grow in 124 tropical and

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sub-tropical countries. Covering an area of around 20 million hectares, Indonesia, Australia, Brazil, Nigeria and Mexico represent 48% of the total area of mangroves in the world. One of them *Rhizophora* sp. Mangrove ecosystems have high economic and ecological value (Lavieren et al., 2015). Mangrove areas have decreased in area from year to year. The decline in mangroves of 1-2% per year globally is a worrying trend. In developing countries, mangrove decline tends to be even higher (Carter et al., 2015). The decline in mangrove growth is caused by environmental damage due to human activities, including urbanization, industrial development and manufacturing which produces waste containing heavy metals (Marchanda et al., 2006). The accumulation of heavy metals in the environment causes serious problems, this is caused by continuous waste disposal. Pollution due to heavy metals can cause many problems, both temporary and prolonged (Sihotang et al., 2021). Heavy metals are toxic chemicals that can cause damage to aquatic organisms (Pratiwi, 2020). Heavy metals cannot be degraded biologically or chemically and will accumulate and be transported by water flows (Marchanda et al., 2006). Heavy metals can contribute to soil pollution. Heavy metals in the water will settle and accumulate in sediment, so that the heavy metal content in the sediment will increase (Robi et al., 2021). Cd and Zn are included in the heavy metal category which can pollute the environment if they are continuously deposited. The heavy metal Cd is a non-essential heavy metal whose benefits in the body are unknown, and Zn is an essential heavy metal because its presence is needed by the body in certain concentrations (Irrhamni et al., 2017). The continuous influx of Cd and Zn metals can pollute waters. Heavy metals can pollute waters which have an impact on water quality. Water is an important requirement for life. The amount of water is said to be constant, meaning it does not increase or decrease because water undergoes a hydrological cycle. Even though the amount of water does not decrease or increase, water quality will decrease over time due to human life (Rohmawati and Kustomo, 2020). The aim of this research was to determine the Geoaccumulation Index, Bioaccumulation Concentration Factor, Translocation Factor and river water quality standards containing the heavy metals cadmium (Cd) and zinc (Zn).

2. Research Method

2.1. Time and Place of Research

This research was carried out in March – July. Located in the Muara Tukad Badung area. Muara Tukad Badung is located at the southern end of the Badung river, which is the largest river in Bali. Muara Tukad Badung is located to the west of Denpasar city center.

2.2. Research Tools and Materials

2.2.1 Tools

The tools used in this research are, Cooling box, plastic ziplock, soil drill, spatula, knife, label paper, scales, GPS and roll meter.

2.2.2 Materials

The materials used in this research were samples of sediment, water, mangrove roots and leaves

2.3. Research Flow

The implementation of this research includes field observations, determining sampling points, preparing tools and materials, collecting data, laboratory testing, data analysis and compiling results.

2.4. Data Collection Method

2.4.1. Sediment Sampling

Sediment sampling was carried out using a soil drill at depths of 0-50 cm and 50-100 cm. Sediment samples were located at each data collection point, each transect measuring 10x10 was carried out 3 times. The sample is put in a labeled plastic bag.

2.4.2. Sampling in Mangrove Stands

Stands range in height from 3-5 m and have a diameter of 15-25 cm. The sample uses old mangroves because it is assumed that mangroves that are old enough can be used as environmental bioremediation. Sampling in mangrove stands (*Rhizophora* sp.) is divided into 2, namely, root sampling and leaf sampling. 500 grams of 10-30 cm long root samples were taken from tree roots that were in the substrate using a cutter and stored in labeled plastic. Leaf samples were taken by selecting 500 grams of mangrove leaves that were not too old and not too young and put them in labeled plastic.

2.5. Sample Analysis

2.5.1. Analysis of Heavy Metals in Sediments

The sediment samples were dried using an oven at 105°C, then 0.5 grams of the dried samples were heated. 8 ml of HNO₃ was added and dissolved in distilled water until the volume reached 100 ml then filtered using 0.45 µm filter paper. Samples were tested with an Atomic Absorption Spectrophotometer (AAS) to determine heavy metal levels.

2.5.2 Analysis of Heavy Metals in Roots and Leaves

Root and leaf samples were cleaned with fresh water then packed in aluminum foil then dried in the oven for 24 hours at a temperature of 70°C. The dried root and leaf samples were then ground and weighed, weighing 0.5 grams each. Extraction was carried out by adding 3 ml of concentrated H₂SO₄. The sample was transferred into a 25 ml measuring cup and distilled water was added until it reached a volume of 100 ml. The sample was filtered using 0.45 µm filter paper. Heavy metal levels were tested with Atomic Absorption Spectrophotometer (AAS).

2.6. Data Analysis

2.6.1. Geo-Accumulation Index (*I_{geo}*)

The geoaccumulation index can be used to determine the accumulation of heavy metals in sediment by comparing it to standard concentrations. Based on Rubio et al., (2000) and Roozbahani et al., (2015) the calculation of the geoaccumulation index is as follows:

$$I_{geo} = \log_2 \left[\frac{C_n}{1,5 B_n} \right]$$

Where:

C_n = Specific metal concentration (mg.kg⁻¹)

B_n = Background value (mg.kg⁻¹)

Table 1. Sediment Quality Criteria

Value	
0	Not contaminated

Value	
0-1	Not contaminated until contaminated light
1-2	Light to moderate contamination
2-3	Moderate to high contamination
3-4	Moderate to high contamination
4-5	High to extreme contamination
>5	Extreme contamination

2.6.2. Bioaccumulation Concentration Factor (BCF)

The content of heavy metals Cd and Zn in sediment, roots and leaves of mangroves is used to calculate the ability of roots and leaves to accumulate heavy metals through the bioconcentration factor (BCF) (MacFarlane et al., 2007).

$$BCF = \frac{K_b \text{ (ppm)}}{C_w \text{ (ppm)}}$$

Where:

BCFD = Bioconcentration analysis

Kb = Heavy metals content in mangrove

Cw = Heavy metals content in sediment

2.6.3. Translocation Factor (TF)

Translocation factor calculations were carried out to determine the ability of mangrove species to accumulate heavy metal so it can be said to be hyperaccumulator heavy metal. In addition, in TF calculations it can be seen the transfer of heavy metal accumulation from roots to shoots (MacFarlane et al., 2007). The equations are as follows:

$$TF = \frac{\text{Heavy metal in leaf}}{\text{Heavy metal in root}}$$

If most of the heavy metals are accumulated by the roots then the measurement value will show a TF value 1. Plants that have a TF value >1 are metal accumulators and TF1) have the potential to be used in phytoremediation. The higher the BCF value, the taller the plant will be phytoextraction.

3. Results and Discussion

It is very important to know the assessment of heavy metal concentrations in sediments, the accumulation of heavy metals in sediments will continue to increase naturally with relatively small increases. Solid or liquid waste sources can contribute to an increase in heavy metals in the aquatic environment (Pratikno et al., 2022). Based on the results of sampling and sample analysis, the measurement values for the accumulation of Cd and Zn in sediments in Muara Tukad Badung were obtained using Geo-Accumulation Index (Igeo) ranges from -0.57 mg.kg⁻¹ and 1.53 mg.kg⁻¹ as in table 2. This value range is in uncontaminated status (Igeo ≤ 0), therefore it is said that the sediment in the Tukad Badung Estuary is still in normal condition and safe for biota and the environment of the Tukad Badung Estuary.

Table 2. Analysis Result Geo-Accumulation Index (Igeo)

Cadmium (Cd)	-0.57
Zinc (Zn)	-1.53

Analysis results Bioaccumulation Concentration Factor(BCF) shows the ability of living organisms to accumulate heavy metals (Bioaccumulation) which is determined from the bioconcentration factor (BCF). The accumulation values of Cd and Zn in roots range between -0.57 ppm for Cadmium (Cd) and -1.53 ppm for Zinc (Zn) and the accumulation values in leaves range from 0.034 ppm for Cd and 0.011 ppm for Zn, which can be seen in table 3, The BCF value range <1 indicates that the plant effectively prevents Cd and Zn from entering the upper area of the plant, but the metal concentration around the root area is still high. Low concentrations of Cd and Zn can be caused by water currents and the rainy season (Supriyanti and Soenardjo, 2015).

Table 3. Analysis Result Bioaccumulation Concentration Factor (BCF)

	Root	Leaf
Cadmium (Cd)	0.039	0.034
Zinc (Zn)	0.010	0.011

The translocation factor is used to determine the translocation of Cd and Zn metal content. The translocation factor value is 0.88 ppm for cadmium (Cd) and 1.33 ppm for zinc (Zn). Based on the analysis results, the Zn value is $TF > 1$ or phytoextraction. Meanwhile, the Cd value, namely $TF < 1$ or phytostabilization, can be seen in table 4. Phytostabilization is a process carried out by plants to transform pollutants in the soil into non-toxic compounds without absorbing them first, the results of the transformation remain in the soil, because plants stabilize pollutants in the soil and therefore heavy metals become harmless. Phytoextraction is the absorption of contaminants or pollutants by plant roots and the translocation or accumulation of these compounds to plant parts such as roots, leaves and stems (Junriah and Alam, 2016).

Table 4. Analysis Result Translocation Factor (TF)

Cadmium (Cd)	0.88
Zinc (Zn)	1.13

The results of heavy metal data collection in the waters of Muara Tukad Badung showed a concentration of cadmium (Cd) of 0.006 mg/L and zinc (Zn) of 0.014 mg/L. based on Government Regulation no. 21 of 2021, attachment VI regarding river water quality standards and the like, states that the river water quality standard is dissolved Cd of no more than 0.01 mg/L. Meanwhile, Zn is in the range of 0.05 mg/L to 2 mg/L. Therefore, river water in Muara Tukad Badung is said to meet national river water quality standards. Based on research conducted by Susanti et al. (2014) Zn and Cd contamination in river bodies in Central Java is quite high because the waters in this area are a location for industrial waste to enter.

Table 5. Water Quality Data

Cadmium (Cd)	0.006
Zinc (Zn)	0.014

4. Conclusion

Value range Geo-Accumulation Index is in uncontaminated status ($I_{geo} \leq 0$) with a value range of -0.57 mg.kg^{-1} and 1.53 mg.kg^{-1} . Bioaccumulation Concentration Factor shows a range of BCF values <1 where Cd and Zn can prevent heavy metals from entering the top of the plant but will accumulate in the soil around the roots. The results of the translocation factor analysis showed that Zn $TF > 1$ or phytoextraction, while the Cd value was $TF < 1$ or phytostabilization. Cd can transform pollutants in soil into non-toxic compounds without absorbing them first. Zn can absorb contaminants or pollutants by plant roots and translocate or accumulate these compounds to plant parts such as roots, leaves and stems. Based on standard analysis results The quality of river water in Muara Tukad Badung meets national river water quality standards because the results of sample analysis do not exceed the quality standards for Cd and Zn content in river waters.

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