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Comparison of Zinc (Zn) and Cadmium (Cd) Levels in *Rhizophora Mangrove Species mucronata* in Muara Tukad Badung, Bali

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Abstract

Mangrove forests are an ecosystem that has an important role and function for the environment. Mangrove forests have ecosystems that are very beneficial to humans directly or indirectly. Apart from that, the mangrove ecosystem also has other important functions, namely as a catcher of sediment and as a prevention of erosion and as a soil stabilizer in estuary areas. Data collection was carried out in March using several methods, namely BCF, TF, and Igeo. Sampling was carried out using the Rhizopora type of mangrove mucronata at 3 different stations. The heavy metals tested in this study were zinc (Zn) and cadmium (Cd). In the highest sediment values for Zn and Cd were 15.516 and 0.532 respectively. In water, the highest levels for Zn and Cd are 0.020 and 0.006 respectively. The highest BCF root values for Zn and Cd are 0.00896 and 0.0609 respectively. The highest leaf BCF values for Zn and Cd are 0.02417 and 0.04487 respectively. The highest TF values for Zn and Cd are 2.68784 and 0.92857 respectively. The Igeo value for Zn is in the unpolluted category and CD is in the slightly polluted category.

Keywords : *Rhizopora mucronata ; bioaccumulation factors; factor translocation ; geoaccumulation index; Zn ; CDs*

1. Introduction

Mangrove forests have a very important role and function for the environment. As a buffer area between marine ecosystems and land ecosystems, mangrove forests act as a residence (habitat) for several biota and microorganisms. Indonesia is one of several countries in the world that has the largest mangrove forests , which is around 25% of the total mangroves in the world (17 million hectares), which is around 4.25 million hectares. One of the mangrove forests in Indonesia is in Bali Province, namely the Great Forest Park (Lestari, 2018).

Mangroves have an ecosystem that benefits humans directly and indirectly, namely in the socio-economic aspects of the surrounding population. Apart from that, mangroves also have an important function as sediment traps and as preventing erosion as well as stabilizing landforms in estuary areas. Mangroves have a root system that has the ability to absorb and utilize heavy metals in sediments (Riyanti et al., 2019; Harnani & Titah, 2017).

The use of coastal areas by humans cannot be separated from the resulting negative impacts. Direct waste disposal causes coastal areas to be polluted by residential activities, shipping, tourism, industry, aquaculture and fisheries in liquid or solid form. One of the wastes that causes pollution in the environment is heavy metals (Samosir et al., 2023). Heavy metals can harm the body because they are unable to block

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the performance of enzymes, thereby disrupting the body's metabolic processes, causing cancer, and treatment (Pratiwi, 2020).

According to research from Sudarmawan et al. (2020), in the waters of Benoa Bay there is a heavy metal called Lead (Pb) ranging from 0.001 - 0.053 mg / L and in plankton it is found at higher levels ranging from 0.001 - 9.287 mg/Kg. This value has exceeded the standard threshold set by MNLH (2004) of 0.008 mg/L. Benoa Bay is directly connected to Tukad Badung. According to research conducted by Palgunadi & Purnama (2022), tilapia fish caught in Tukad Badung contain the heavy metal Pb with an average of 0.2539 ppm and 0.2437 ppm. Both values have exceeded the maximum limit for Pb metal in fish which is regulated in BPOM Regulation No. 23 of 2017.

Rhizopora mucronata is one of the mangrove species that has the ability to accumulate heavy metals. This ability can make mangroves an indicator in assessing the level of heavy metal pollution in coastal areas (Supriyanti & Soenardjo , 2015). Heavy metals will be absorbed by the root tip epididymis and enter the mangrove body in the form of ions (Song, 2016; Yulaeni et al., 2022).

2. Research Methods

2.1. Time and location of activities

This research was conducted in March 2023 at the Tukad Badung estuary, Badung Regency, Bali. The research location is divided into three stations at the Tukad Badung estuary. As in Figure 1. The contributor to the heavy metal Cd in Tukad Badung comes from the rapid development of the textile industry to achieve production targets and dispose of waste directly into the river without considering the pollution that has been done (Mahendra et al., 2015). The heavy metal Zn in Tukad Badung comes from mixed metal activities, galvanizing, paint, batteries and rubber which are directly or indirectly related to port activities or population activities (Santana et al., 2018).

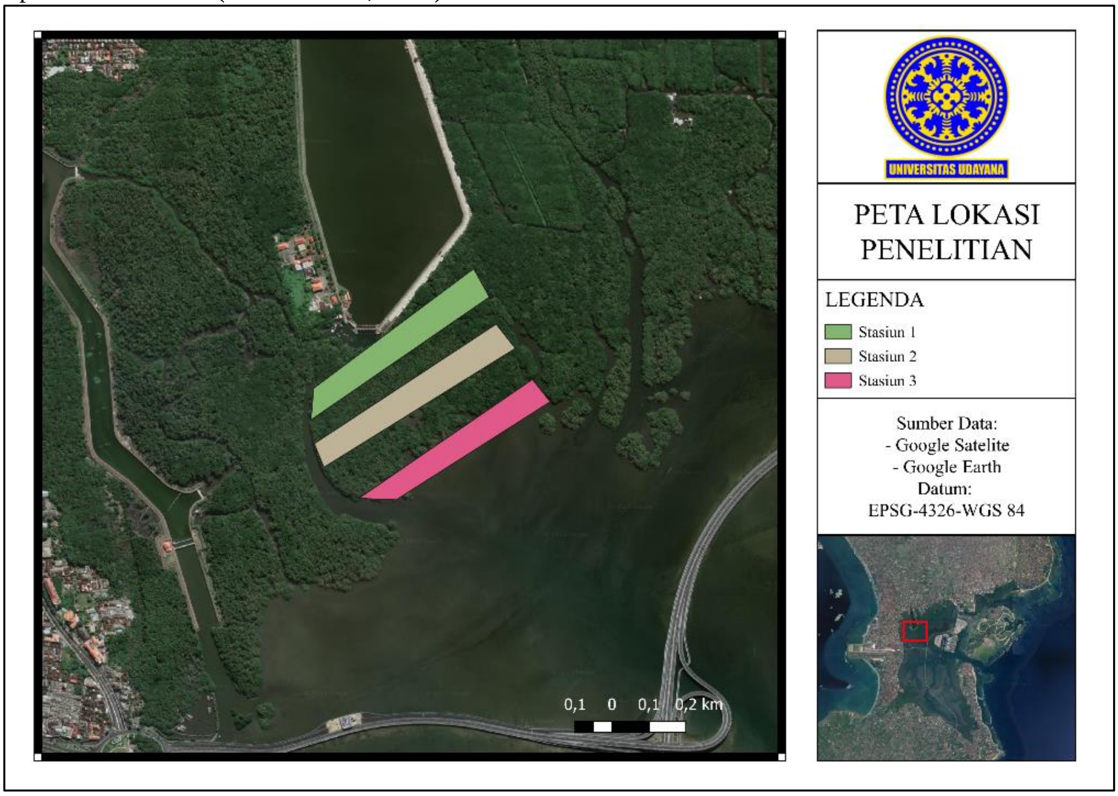

Figure 1. Sampling location map

2.2. Tools and materials

The tools used in this research were box coolers, plastic ziplock, soil drill, spatula, knife, label paper, scales, Global Positioning System (GPS), and roll meter. The materials used in this research were water samples, sediment, roots and leaves of mangrove.

2.3. Data collection method

2.3.1. Sediment sampling

Sediment sampling was carried out using a soil drill at depths of 0-50 cm and 50-100 cm. Sediment samples were taken at each data collection point, each transect measuring (10 m x10 m) was carried out one time. Then, the sample is put in a plastic bag and labeled.

2.3.2. Air sampling

Air samples were taken at half depth 3 (three) times at each station. Samples taken at each station were ± 500 ml and then put into a PE bottle and 10 drops of HNO_3 were added. The sample bottle is placed in cold box filled with blue ice packs (Suryani et al., 2018).

2.3.3. Taking samples in mangrove stands

a. Root sampling

Root samples were taken using flat cutting tools (knife and *cutter*) ± 10-30 cm long 10-30 cm from the root tip 500 grams. The samples that have been obtained are then washed and put into plastic samples that have been labeled.

b. Leaf sampling

Leaf samples are taken by selecting leaves that are not too old and not too young. Leaf samples were taken from the bottom as much as 500 grams. The leaf samples are then put into plastic samples that have been labeled.

2.4. Data analysis

2.4.1. Calculation of Bioconcentration Factor (BCF)

The aim of the BCF calculation is to determine the heavy metal content in organisms originating from the environment which is calculated according to the BCF formula (Mahmiah et al., 2023).

$$BCF = \frac{Heavy\ metal\ content\ in\ mangroves}{Heavy\ metal\ content\ in\ sediment} \tag{1}$$

According to Baker (1981) in Awaliyah et al. (2018), plants are able to accumulate their share of heavy metals into 3 (three) categories, namely BCF > 1 = Accumulator, BCF < 1 = *Excluder,* BCF = 1 = Indicator.

2.4.2. Translocation Factor (TF) Calculation

The heavy metal translocation factor aims to calculate the translocation process of heavy metals from roots to leaves (Puspita et al., 2013).

$$TF = \frac{Heavy\ metal\ in\ leaves}{Heavy\ metal\ in\ roots} \tag{2}$$

The TF value indicates the status of the plant, if TF > 1 = phytoextraction and TF < 1 = phytostabilization (Awaliyah et al., 2018).

2.4.3. *Geo-Accumulated* Calculations (Igeo)

Geoaccumulation index aims to determine the accumulation of heavy metals in sediment by comparing standard concentrations.

$$Igeo = log^2 \left[\frac{Cn}{1.5\ Bn}\right]$$

where, *Igeo* is a geoaccumulation index; *Cn* is the specific heavy metal concentration (mg.kg^{-1}); *Bc* is the background value (mg.kg^{-1}); and factor 1.5 is a correction factor for natural fluctuations related to lithospheric effects.

Based on Ahmad (2013), there are criteria for levels of contamination and metal contamination which are presented in full in Table 1.

Table 1. Contamination and contamination level criteria.

Igeo	Information
Igeo <0	Not polluted
0 < Igeo < 1	Lightly polluted
1 < Igeo < 2	Moderately polluted
2 < Igeo < 3	Quite badly polluted
3 < Igeo < 4	Seriously polluted
4 < Igeo < 5	Extremely badly polluted
Igeo > 5	The pollution was extremely serious

3. Results and Discussion

3.1. Comparison of heavy metal levels in sediments

A river is a naturally formed channel that is able to accommodate and channel air rain from the highlands to the lower plains and ultimately empties into a lake or ocean. Generally, river flows will transport materials originating from the erosion process. As time goes by, the materials carried by river currents will experience sedimentation so that the river becomes shallow due to the sedimentation process (Sembiring, 2014). Sedimentation in river flows is able to prevent heavy metal substances from starting to dissolve and will also settle in the sediment until the heavy substances and sediment bind together (David et al., 2016). The highest levels of the heavy metals Zn and Cd were at station 1 respectively at 15,516 ppm and 0.532 ppm followed by station 2 at 15,468 ppm and 0.372 ppm and the lowest at station 3 at 15,403 ppm and 0.312 ppm (Table 2).

Table 2 . Levels of heavy metals Zn and Cd in sediment at the third station.

Heavy metals in sediment	Station		
	1	2	3
Zn	15,516	15,468	15,403
CD	0.532	0.372	0.312

The levels of the two heavy metals at the third station were still within the safe limits of quality standards for heavy metal substances in sediment (Table 3). The high levels of both heavy metals at station 1 were caused by the location of station 1 close to the river mouth. Generally, differences in heavy metal levels at each station occur due to various processes over time, namely physics, biology and chemistry. Physical processes are thought to be very influential processes because of the mixing and settling processes which are influenced by current speed and water depth (Maslukah, 2013). The heavy metals Zn and Cd experience increased sedimentation caused by several natural factors, such as rock and anthropogenic weathering (Patty et al., 2018). The anthropogenic sources in question are the use of fertilizer and household waste (Syahminan et al., 2015).

Table 3 . Quality status of heavy metal levels in sediment (Permanawati et al., 2013)

Heavy metal	Unit	Concentration (ppm)	Measurement results				Detection limit (ppm)	CATCH* (ppm)	Score**
			max	minute	std	average			
Zn	ppm	95,800 - 333,000	333,000	95,800	79,711	167,240	0.01	410	0
CD	ppm	0.012 - 0.750	0.750	0.012	0.201	0.257	0.00001	5.1	0

*Threshold value according to Sediment Quality Standard WAC 173-204-320

**Determination of quality status according to KEP-115/MENLH/2003

3.2. Comparison of heavy metal levels in water

The highest levels of the heavy metal Zn were at station 1 at 0.020 ppm followed by station 3 at 0.011 ppm and the lowest at station 2 at 0.10 ppm. If you look at the river water quality standards as in the table, the levels of the heavy metal Zn are below the quality standard threshold so the air can be categorized as not polluted. The heavy metal Cd in river water was highest at stations 1 and 2. Cd levels at both stations were 0.006 and the lowest were at station 3 at 0.005. Based on the quality standards set by the government, the levels of heavy metal C at the third station are below the threshold so it can be concluded that the river water is not polluted (Table 4).

Table 4 . Levels of heavy metals Zn and Cd in the water.

Heavy metals in the air	Station			River Water Quality Standards*
	1	2	3	
Zn	0.020	0.010	0.011	0.05
CD	0.006	0.006	0.005	0.01

* Class II water quality standards based on Republic of Indonesia Government Regulation no. 22 of 2021 attachment VI

The heavy metal Zn is a heavy metal which is generally used as a material for batteries, plastics, rubber, soaps, as well as cosmetics and deodorants. Zn can be very dangerous if consumed in large amounts, such as vomiting, diarrhea, fever, extreme fatigue, anemia and reproductive disorders (Rahmadani et al., 2015). Based on research from Santana et al. (2018), Zn in waters comes from a mixture of metals, galvanizing , paint, batteries and rubber which is directly or indirectly related to port activities or population activities.

The heavy metal Cd contained in river water comes from the processing of materials using pigments or colors and waste from the textile industry. CdS and CdSeS compounds are widely used as dyes (Emilia et al., 2013). The heavy metal Cd has a very high risk to blood vessels. If humans are exposed to Cd over a long period of time, it will accumulate in the liver and kidneys (Lukmanulhakim et al., 2023).

3.3. Bioaccumulation Factors (BCF) in Rhizophora roots and leaves mucronata

Before being translocated into plant tissue, heavy metals from the air accumulate in sediment (Hamzah & Pancawati, 2013). The accumulation of heavy metals from sediment to the roots can be seen from the root BCF value. The high root BCF value for heavy metals is supported by the high concentration of all metals in the roots and the low concentration in the sediment so that it is able to produce high BCF values.

The highest root BCF value for the heavy metal Zn was at station 1 at 0.00896, while the highest root BCF value for the heavy metal Cd was at station 3 at 0.0609 (Table 5).

Table 5 . Bioaccumulation Factors (BCF) in *Rhizophora mucronata*

Station	BCF Root		BCF Leaf	
	Zn	CD	Zn	CD
1	0.00896	0.03571	0.02417	0.03195
2	0.00705	0.03763	0.01034	0.03495
3	0.00377	0.0609	0.00409	0.04487

This is in accordance with the Zn content in the sediment at station 1 which is the highest among the other stations but is different from the Cd sediment which is the lowest among the other stations. If we look at the BCF indicator put forward by Baker (1981), where BCF < 1 = *Excluder* , then BCF roots for both heavy metals including *excuders* . *Excluders* is a plant that can effectively prevent heavy metals from entering the upper area but the concentration of heavy metals around the root area is still relatively high (Santana et al., 2018).

leaf BCF for the heavy metal Zn was at station 1 at 0.02417, followed by station 2 at 0.01034 and station 3 as the smallest leaf BCF at 0.00409. The leaf BCF for the heavy metal Zn at the third station is higher than the root BCF for the heavy metal Zn at the third station (table 3). This is different from the analysis results from Amin, et al. (2019), where the BCF of the roots is higher than the BCF of the leaves because the position of the roots interacts directly with sediment which has a high Zn concentration. The leaf BCF for the heavy metal Cd was highest at station 3 at 0.04487 followed by station 2 at 0.03495 and station 3 which was the lowest at 0.03195. The leaf BCF value for the heavy metal Cd is smaller than the root BCF value for the heavy metal Cd . This is caused by the same reasons as the heavy metal Zn , namely the roots interact directly with sediment which has a high concentration of Zn (Hamzah & Pancawati, 2013).

3.4. Rhizophora root and leaf translocation factors mucronata

Translocation Factor (TF) is used to determine the translocation of heavy metals Zn and Cd from the roots to other parts of the plant using the Baker (1981) formula. The highest TF value for the heavy metal Zn was at station 1 at 2.68784 followed by station 2 at 1.46789 and station 3 with the lowest value at 1.08621. This is in accordance with the results that the root BCF value for Zn is smaller than the leaf BCF for Zn because the TF value is very high so that heavy levels of Zn metal are translocated from the roots and accumulated in the leaves. The highest TF value for the heavy metal Cd was at station 2 at 0.92857 followed by station 1 at 0.89474 and station 3 with the lowest value at 0.73684 (Table 6).

Table 6 . Translocation Facts (TF) in *Rhizophora mucronata*

T.F	Station		
	1	2	3
Zn	2.68784	1.46789	1.08621
CD	0.89474	0.92857	0.73684

This result is one of the factors that the root BCF value for Cd is higher than the leaf BCF for Cd because the TF value is low so that little heavy metals are translocated from the roots and little is also accumulated by the leaves. Differences in TF values at each station are influenced by several factors other than environmental factors, such as metal concentration in sediment, type of metal, level of plant tolerance to metal, age of the plant, and temperature in the plant's environment (Nafie et al., 2019). Based on Baker (1981), the TF value for both heavy metals at the third station was assessed as phytostabilization .

Phytostabilization is the ability of plants to excrete or secrete certain chemical compounds to demobilize heavy metals in the root area (Caroline & Moa, 2015).

3.5. Geoaccumulation index analysis of Zn and Cd

Geoaccumulation Index aims to determine the level of heavy metal contamination accumulated in sediments (Alahabadi & Malvandi, 2018; Woo *et al*., 2014). The geoaccumulation index for the heavy metal Zn at the third station is below 0 (table 7). According to Ahmad (2013), if I_{geo} is smaller than 0, then the sediment is included in the criteria for not being contaminated with Zn metal . This is different from the geoaccumulation index for the heavy metal Cd where the results at the third station are between 0 and 1. Based on these results, the sediment is lightly polluted by Cd . In general, the heavy metal Cd comes from waste products from processing pigments or dyes which are thrown directly into rivers without proper waste processing (Emilia et al., 2013).

Table 7 . Geoaccumulation index analysis Zn and Cd

Igeo	Station		
	1	`2	3
Zn	-2.75856	-276303	-276911
CD	0.82646	0.31034	0.05658

4. Conclusion

Mangrove forests have a very important role and function for the environment which is very beneficial for humans directly and indirectly, namely in the socio-economic aspects of the surrounding population. Apart from that, mangroves also have an important function as sediment traps and as preventing erosion as well as stabilizing landforms in estuary areas. *Rhizopora mucronata* At 3 stations in the Tukad Badung estuary there were different levels of heavy metals in the sediment, air and parts of the mangrove plant , namely roots and leaves. In the highest sediment levels for Zn and Cd were 15,516 and 0.532 respectively. In the highest air levels for Zn and Cd were 0.020 and 0.006. The highest root BCF values for Zn and Cd were 0.00896 and 0.0609. The highest leaf BCF values for Zn and Cd were 0.02417 and 0.04487. The highest TF values for Zn and Cd were 2.68784 and 0.92857. Value I_{geo} Zn is in the unpolluted category and Cd is in the lightly polluted category. Based on BCF values of roots and leaves on the third station, *Rhizophora mucronata* does not enter the bioaccumulator for heavy metals Zn and Cd .

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