Analysis of The Heavy Metal Content (Cd and Zn) in Water, Sediment, Roots, and Leafs of *Sonnetaria* sp. in Badung River Estuary Area

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Abstract

The estuary area of the Tukad Badung river has the potential to experience heavy metal pollution because of its location for various domestic and industrial wastes also has dense shipping activities around it. This study aims to identify the heavy metal content of Cd and Zn in water, sediment, root, and leaf samples of *Sonnetaria* sp. that grows in the area. The results obtained from the analysis of the heavy metal content of Cd and Zn in water samples were 0.006 mg/L and 0.014 mg/L. The results of the analysis of heavy metal content of Cd and Zn in sediment samples were 0.406 mg/kg and 15.462 mg/kg, respectively. This shows that water and sediment samples are still below the applicable quality standards. The Bioaccumulation Factor (BCF) value shows that the roots and leaves of *Sonnetaria* sp. can accumulate heavy metal Cd by 0.034483 and 0.041872 and accumulate heavy metal Zn by 0.011059 and 0.016751. The calculation of Translocation Factor (TF) of Cd metal of 1.214286 and Zn of 1.51462 shows that *Sonnetaria* sp. belongs to the category of phytoextraction (TF>1). Based on the Igeo index, the estuary area of the Tukad Badung river is classified as unpolluted to moderately polluted by heavy metals Cd (Igeo: 0.436517) and not contaminated with Zn metals (Igeo: -2.76359).

Keywords: *bioaccumulation; heavy metals; Sonnetaria sp.; tukad badung*

1. Introduction

Mangrove forests are a type of forest that is located in tidal areas, such as on protected beaches, lagoons, or river estuaries (Khairunnisa et al., 2020). Mangroves act as a connecting area between land and sea which is important for the ecosystem, especially for aquatic populations. This plant is an important food source for aquatic organisms in coastal areas. In addition, its elongated root system has the ability to trap sediment and pollutants, such as heavy metal cotaminants (Pradit et al., 2018). Pollutants produced by various industries can enter river basins be carried to the marine environment. The high or low concentrations of heavy metals are affected by the input load of these substance into waters (Harlyan & Sari, 2015).

Badung River is one of the rivers that flows through Badung and Denpasar Regencies. The length of this river is around 22 km with its upstream located in Abiansemal Distric (Badung Regency) and flows towards Badung River estuary area (Benoa Bay) in Denpasar (Palgunadi & Purnama, 2022). Badung River estuary is the final disposal for various domestic and industrial wastes. This causes various contaminants trapped and accumulate in that area, including heavy metal contamination. The entry of heavy metal pollutant sources from textile also causes pollution in Badung River estuary. Apart from that, Benoa Bay also has dense shipping activity that potentially give some negative impacts on the surrounding waters (Sudarmawan et al., 2020). Based on this, mangrove plants in Badung river estuary area have the potential to absorb and accumulate inorganic pollutants, such as heavy metals in their tissues (Siaka et al., 2019).

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Several previous studies have discussed the bioaccumulation of heavy metals at Badung River estuary area. Marandi et al. (2018) found Pb and Cd accumulation in mullet fish caught in the Badung river estuary (Benoa Bay). Then, research by Siaka et al. (2018) found that the Pb and Cd content in sediments and pidada fruit (*Sonnetaria* alba) in this area had exceeded the threshold. Suprihatin et al. (2014) also found Cr and Zn metals contamination in the roots, stems, and leaves of *Rhizopora apiculata* at Badung River estuary area.

Heavy metal pollution is a serious problem. This has andgerous effects, even in small concentrations. Heavy metals have non-biodegradable properties, can cause bioaccumulation, and biomagnification (Kapahi & Sachdeva, 2019). If absorbed and accumulated in the human body, heavy metal pollutants can harm health (Santana et al., 2018). In addition, heavy metals that enter the water will be dispersed and suspended at the bottom of the water. This can cause ecological impacts that enandger the environment and surrounding organisms (Harlyan & Sari, 2015). Based on this, this research was carried out on analysis of the heavy metals Cd and Zn in water, sediment, roots, and leaves of *Sonnetaria* sp. in the Badung river estuary area to determine the concentration and level of Cd and Zn bioaccumulation in this area.

2. Research Methodology

2.1. Time and place of research

This research was carried out in the mangrove area at the Badung river estuary, Badung, Bali with one station to collect water, sediment, roots, and leaves of *Sonnetaria* sp. Research station was selected using a purposive method by considering ease access and representativeness of research location. Badung River and Mati River are areas that have highest spatial distribution of solids in the waters of Benoa Bay (Tanto et al., 2018). This area has sources of input pollutants that can harm coastal ecosystems. Analysis of water, sediments, roots, and mangrove leaves samples was carried out at the Balingtan Laboratory, Central Java.

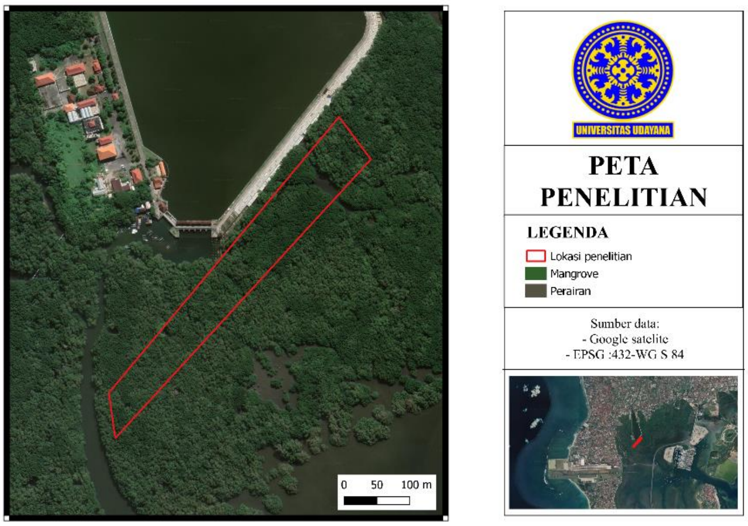

Figure 1. Research map

2.2. Tools and materials

The tools used in the research were cooling boxes, ziplock plastics, bottles, spatulas, knives, label, scales, GPS, and roll meters. The materials used were samples of water, sediment, roots, and leaves of *Sonnetaria* sp..

2.3. Sampling method

The research location was determined using a purposive sampling method considering ease access and representativeness of research location. Water samples were taken using bottles of 2 liters each. Water samples were taken and ensure there are no air bubbles. After that, the bottles are labelled. Surface sediment samples were taken using a spatula. Sediment samples were taken and put in a labeled ziplock plastic. Mangrove root samples were taken using a cutting tool with a length of 10-30 cm from the tip of the root, amounting to 500 grams. The samples that have been taken are then washed and put in a ziplock plastic that has been labeled. A sample of 500 grams of mangrove leaves was taken with the criteria of not being too old and not too young. The samples that have been taken are then put in a ziplock plastic that has been labeled. Heavy metal analysis was carried out at the Balingtan Laboratory, Central Java. The method used was Atomic Absorption Spectrophotometer (AAS) to determine the levels of the heavy metals Cd and Zn contained in each sample.

2.4. Data collection and processing data

2.4.1. BCF (*Bioaccumulation Concentration Factor*)

Bioaccumulation of the heavy metals Cd and Zn in roots and leaves of *Sonnetaria* sp. was analyzed using the Bioaccumulation Concentration Factor (BCF) which was calculated using the Ghosh & Singh formula in 2005 (Santana et al., 2018). The bioconcentration factor is obtained by comparing the concentration of Cd and Zn metals in mangroves with the concentration of Cd and Zn metals in sediment.

$$BCF = \frac{Kb\ (ppm)}{Cw\ (ppm)} \tag{1}$$

where, *BCF* is a bioconcentration analysis; *Kb* is the heavy metal content in mangroves; and *Cw* is the heavy metal content in sediment.

Baker in 1981 separated plant abilities based on BCF values into 3 groups, accumulators, excluders and indicators. Accumulator are plants that have the ability to accumulate heavy metals in high concentrations, even exceeding the concentration in the soil (BCF>1). Excluders prevent heavy metals from entering the top of the plant, but the roots have a high concentration of heavy metals (BCF<1). Meanwhile, indicator plants tolerate the presence of heavy metals by producing metal-binding compounds or changing the composition of metals in insensitive parts (BCF = 1) (Santana et al., 2018).

2.4.2. TF (*Translocation Factor*)

The ability of mangrove species to carry out the translocation process can be analyzed using the Translocation Factor (TF) with a formula by Baker in 1981. Plants with a TF>1 indicate their ability as metal accumulators, while TF<1 is an excluder (limiting) type of metal. This shows that plants with bioconcentration and translocation factors greater than one (TF and BCF>1) have the potential to be used as phytoremediation plants (Santana et al, 2018).

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

where, *TF* is a Translocation analysis.

2.4.3. Igeo (Geoaccumulation Index)

The condition of heavy metal contamination in sediment can be calculated using the geoaccumulation index (Igeo) equation developed by Muller in 1969 (Mulyaningsih & Suprapti, 2014). There are 7 levels of geoaccumulation index values to describe sediment quality. Igeo ≤ 0 not polluted, 0 < Igeo ≤ 1 not polluted to moderately polluted, 1 < Igeo ≤ 2, moderately polluted, 2 < Igeo ≤ 3 moderately polluted to heavily polluted, 3 < Igeo ≤ 4 heavily polluted, 4 < Igeo ≤ 5 heavily polluted to very heavily polluted and Igeo ≥ 6 very heavily polluted (Purbonegoro, 2022).

$$Igeo = log_2(\frac{Mc}{1.5 \times Bc}) \quad (3)$$

where, *Igeo* is a geoaccumulation index; *Mc* is the concentration of a heavy metal in sediment; *Bc* is the natural concentration of heavy metals (background value); and factor 1.5 is a correction factor for natural fluctuations related to lithospheric effects.

3. Results and Discussion

3.1. Cd and Zn Metal Content in Water and Sediment Samples

The results of measuring metal content of Cd and Zn in water samples in the Badung river estuary area were 0.006 mg/L and 0.014 mg/L, respectively. Meanwhile, according to Republic of Indonesia Government Regulation Number 22 of 2021 concerning the Implementation, Protection and Management of the Environment, the limit for Cd and Zn metal contamination in river water areas and similar areas is 0.01 mg/L and 0.05 mg/L respectively. Based on this, it can be concluded that the metal content of Cd and Zn in water samples obtained from the Tukad Badung river estuary area meets the applicable quality standards.

The results of measuring concentrations of Cd and Zn in sediment samples were 0.406 mg/kg and 15.462 mg/kg respectively. The Indonesian government has not yet established regulations governing maximum limits for metal contamination in aquatic sediments. Therefore, the Australian and New Zealand Environment and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMACANZ) (2000) quality standards were used. According to ANZECC/ARMACANZ regulations (2000), the quality standard values of Cd and Zn are divided into two categories, namely low (Cd: 1.5 mg/kg dry wet and Zn: 200 mg/kg dry wet) which indicates low and high toxicity effects (Cd: 10 mg/kg dry wet and Zn: 410 mg/kg dry wet) represent reference values for assessing the adverse effects experienced by half of the exposed population. Based on these quality standards, it can be concluded that the concentrations of Cd and Zn in sediment samples in the Tukad Badung river estuary area are still below the values set by the ANZECC/ARMACANZ quality standards.

The results of research on heavy metals in sediments are different from the results of research conducted by Siaka et al. (2019). This research found that the total content of the heavy metal Cd in the sediment at the Badung river estuary was in the range of 1.4849-7.0230 mg/kg, which indicates that the sediment in the area was polluted and exceeded the permissible limit. Meanwhile, research into the heavy metal Zn content in the area has not been found. Research by Harlyan & Sari (2015) found that the content of the heavy metal Zn in mangrove ecosystem sediments in Muara Sungai Porong, East Java was 0.5653 mg/kg, which shows that the area still meets the ANZECC/ARMACANZ (2000) sediment quality standards. In detail, the content of the heavy metals Cd and Zn in the water and sediment samples of the *Sonnetaria* sp. mangrove at Badung river can be seen in Table 1.

Table 1. Cd and Zn Metal Content in Water and Sediment Samples

No.	Sample type	Heavy metal	Concentration	Quality standards
1	Water	Cd	0.006 mg/L	0.01 mg/L
		Zn	0.014 mg/L	0.05 mg/L
2	Sediment	Cd	0.406 mg/kg dw	*Low*: 1.5 mg/kg dw *High*: 10 mg/kg dw
		Zn	15.462 mg/kg dw	*Low*: 200 mg/kg dw *High*: 410 mg/kg dw

3.2. Data on the content of heavy metals Cd and Zn in root and leaf samples of Sonnetaria sp.

Results of measurements of the heavy metal content Cd and Zn in root samples of *Sonnetaria* sp. respectively were 0.014 mg/L and 0.171 mg/L. Meanwhile, the results of measuring the content of heavy metals Cd and Zn in leaf samples of *Sonnetaria* sp. respectively were 0.017 mg/L and 0.259 mg/L. Research by Suprihatin et al. (2014) showed that the content of the heavy metal Zn in samples of Rhizopora apiculata mangrove roots and leaves in Badung river estuary was 19.4 ± 0.06 mg/kg and 38.72 ± 0.03 mg/kg. This shows differences in the abilities of *Sonnetaria* sp. with *Rhizophora apiculata* in absorbing Zn metal. Meanwhile, research regarding the content of the heavy metal Cd in samples of mangrove roots and leaves in the Tukad Badung river estuary area has not yet been found. In detail, the heavy metal content Cd and Zn in the *Sonnetaria* sp mangrove samples. can be seen in Table 2.

Table 2. Kandungan Logam Berat Cd and Zn pada Sampel Akar and Daun

***Sonnetaria* sp.**			
Roots Cd	Roots Zn	Leaves Cd	Leaves Zn
0.014	0.171	0.017	0.259

3.3. Bioconcentration Factor (BCF) and Translocation Factor (TF) of Heavy Metals Cd and Zn in the Sonnetaria sp.

The ability of plants to absorb heavy metals from the soil or substrate can be determined by calculating the BCF value. All results of BCF calculations on the roots and leaves of *Sonnetaria* sp. against the heavy metals Cd and Zn shows the ability of *Sonnetaria* sp as an excluder. According to Putri et al. (2023), excluder plants do not absorb heavy metals effectively, but bind metals in the root zone environment through deposition. The results of the BCF calculation are presented in Table 3.

Table 3. Bioconcentration Factor (BCF)

No	**Heavy metal**	**BCF**		**Category**
1	Cd	Akar	0.034483	*Excluder*
		Daun	0.041872	*Excluder*
2	Zn	Akar	0.011059	*Excluder*
		Daun	0.016751	*Excluder*

The translocation process of the heavy metal Zn from roots to leaves can be determined by carrying out TF analysis. All results of TF *Sonnetaria* sp. against the heavy metals Cd and Zn shows that *Sonnetaria* sp has a photoextraction mechanism. Photoextraction is a process carried out by plants to absorb heavy metals by the roots and then translocate them to the stems and leaves (Santana et al., 2018). The results of the TF calculation are presented in Table 4.

Table 4. Perhitungan Faktor Translokasi (TF)

No	**Heavy metal**	**TF**	**Mechanism**
1	Cd	1.214286	Photoextraction
2	Zn	1.51462	Photoextraction

3.5. Geoaccumulation Index Analysis (Igeo)

The results of the analysis of the Cd metal geoaccumulation index in the Badung river estuary area were classified as unpolluted to moderately polluted with a value of 0.436517 ($0 < Igeo \leq 1$) while the Zn metal geoaccumulation index was classified as not polluted with a value of -2.76359 (Igeo ≤ 0). Another research regarding the geoaccumulation index in the Tukad Badung river estuary area has not yet been found. Meanwhile, the results of research by Permana et al. (2022) showed that the highest content of the heavy metal Cd in Estuary Java sediments was 0.116 mg/kg. Meanwhile, research by Putri et al. (2022) found that the geoaccumulation index value of the heavy metal Zn in the sediment of the Musi River estuary had a value smaller than 0.

Table 5. Geoaccumulation Index Analysis (Igeo)

Geoaccumulation Index (Cd)	Classification	Geoaccumulation Index (Zn)	Classification
0.436517	Unpolluted to moderately polluted	-2.76359	Not polluted

4. Conclusion

Based on the results of analysis of the heavy metals Cd and Zn in *Sonnetaria* sp. in the Badung river estuary area, it can be concluded that the water and sediment samples tested still meet the applicable quality standards. Based on the BCF value, *Sonnetaria* sp. does not absorb heavy metals effectively. Meanwhile, based on the TF value, this plant has the ability to translocate heavy metals from the roots to the leaves. Then, based on the geoaccumulation index value, the area is classified as not polluted to moderately polluted by the heavy metal Cd and not polluted by Zn metal.

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Bibliography

ANZECC and ARMACANZ. (2000). *Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand*. Canberra, Australia: ANZECC and ARMACANZ.

Harlyan, L. I., & Sari, S. H. J. (2015). Konsentrasi Logam Berat Pb, Cu, and Zn pada Air and Sedimen Permukaan Ekosistam Mangrove di Muara Sungai Porong, Sidoarjo, Jawa Timur. *Jurnal Perikanan and Kelautan*, **20**(1), 52-60.

Kapahi, M., & Sachdeva, S. (2019). Bioremediation Options for Heavy Metal Pollution. *Journal of Health & Pollution*, **9**(24), 1-20.

Khairunnisa, C., Thamrin, E., & Prayogo, H. (2020). Keanekaragaman Jenis Vegetasi Mangrove di Desa Dusun Besar Kecamatan Pulau Maya Kabupaten Kayong Utara. *Jurnal Hutan Lestari*, **8**(2), 325-336.

Marandi, N. P. S., Restu, I. W., & Sari, A. H. W. (2018). Kandungan Logam Berat Timbal (Pb) and Kadmium (Cd) Pada Baand Air and Ikan di Perairan Teluk Benoa, Bali. *Current Trends in Aquatic Science*, **1**(1), 106–113.

Mulyaningsih, T. R., & Suprapti, S. (2015). Penaksiran Kontaminasi Logam Berat and Kualitas Sedimen Sungai Cimandur, Banten. *Jurnal Iptek Nuklir Ganendra*, **18**(1), 11-21.

Palgunadi, N. P. G. S., & Purnama, I. G. H. (2022). Bioakumulasi and Analisis Risiko Kesehatan Masyarakat dari Pencemaran Logam Berat Pb and Cd pada Ikan yang ditangkap di Tukad Badung, Denpasar. *Arc.Com.Health*, **9**(1), 33-49.

Republik Indonesia. (2021). *Peraturan Pemerintah Nomor 22 Tahun 2021 tentang Penyelenggaraan Perlindungan and Pengelolaan Lingkungan Hidup.* Jakarta, Indonesia: Pemerintah Republik Indonesia.

Permana, B., Rafii, A., & Eryati, R. (2022). Kandungan Logam Berat Timbal (Pb), Kadmium, (Cd), and Tembaga (Cu) pada Air and Sedimen di Muara Perairan Kecamatan Muawa Jawa Kabupaten Kutai Kertanegara. *Tropical Aquatic Sciences*, **1**(1), 62-68.

Pradit, S., Shazili, N. A. M., Pattaratumrong, M. S., Chotikarn, P., Kobkeatthawin, T., Yucharoen, M., & Towatana, P. (2018). Accumulation of Trace Metals in Mangrove Plant *Soneratia caseoralis* in Songkhla Lake, Thailand. *Applied Ecology and Environmental Research*, **16**(4), 4081-4095.

Purbonegoro, T. (2022). Penggunaan Indeks Pencemaran Logam Berat dalam Sedimen di Wilayah Pesisir: Studi Kasus Segara Anakan Cilacap Jawa Tengah. *Oseana,* **47**(1), 12-19.

Putri, W. A. E., Susanti, M. I., Rozirwan, Hendri, M., & Agustriani, F. (2022). Status Cemaran Logam Berat di Sedimen Muara Sungai Musi Sumatera Selatan. *Buletin Oseanografi Marina*, **11**(2), 177-184.

Santana, I K. Y. T., Julyantoro, P. G. S., & Wijayanti, N. P. P. (2018). Akumulasi Logam Berat Seng (Zn) pada Akar dan Daun Lamun Enhalus acoroides di Perairan Pantai Sanur, Bali. *Current Trends in Aquatic Science*, **1**(1), 47-56.

Siaka, I. M., Suprihatin, I. E., & Widari, N. K. D. S. (2019). Kandungan Logam Berat Total Pb and Cd dalam Sedimen and Buah Pedada (*Sonneratia alba*) di Muara Sungai Badung. *Jurnal Kimia (Journal of Chemistry*), **13**(1), 40-43.

Sudarmawan, A. R., Suteja, Y., & Widiastuti. (2020). Logam Berat Timbal (Pb) pada Air and Plankton di Teluk Benoa, Badung, Bali. *Journal of Marine and Aquatic Sciences*, **6**(1), 133-139.

Suprihatin, I. E., Manurung, M., and Mayangsari, D. (2014). Logam Kromium (Cr) and Seng (Zn) dalam Akar, Batang, dan Daun Tumbuhan Mangrove *Rhizophora apiculata* di Muara Sungai Badung. *Jurnal Kimia*, **8**(2), 178-182.

Tanto, A. T., Putra, A., Husrin, S., & Pranowo, W. S. (2018). *Reklamasi di Perairan Teluk Benoa Bali*. Jakarta, Indonesia: Amafrad Press.