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REVIEW

MANGROVES AS INDICATORS OF HEAVY METAL POLLUTION IN WATERS

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ABSTRACT
The ability of mangroves to absorb and store heavy metals in their tissues has received much study. Mangroves have been used to lower heavy metals in the aquatic environment because of their capacity to do so. Mangroves have also been utilized for biomonitoring of pollution from heavy metals. Mangroves have been regarded as a quick, efficient, and affordable way of biomonitoring aquatic ecosystems. The mangrove is an organism with the capacity to absorb heavy metal contaminants and act as a trap for fine pollutants. However, further study and analysis are required to perfect this technology for widespread application. This essay aims to outline the potential use of mangroves as a biomonitoring and bioindicator tool in mangrove studies in the future.

Keywords: Mangroves, Biomonitoring, Bioindicators, Heavy Metals, Phytoremediation

INTRODUCTION
The rapid rate of industrial growth as well as human activities from the agricultural sector and household waste contribute to the supply of waste that will adversely affect water bodies (rivers and seas), causing environmental degradation and pollution (**Owa, 2014; Devi *et al*., 2018).** Waste in a body of water will continue to accumulate if not handled properly and can cause contamination of organisms in a body of water commonly called water pollution **(Devi et al., 2018).**

Aquatic pollution is the condition of the entry of unwanted pollutants into water and changes the quality of water in terms of taste, color and odor **(Alrumman *et al*., 2016; Haseena *et al*., 2017).** Water pollution can be harmful to the environment, organisms and humans. Briggs (2003) suggests that water pollution is caused by the entry or inclusion of living things, substances, energy and/or other components into the environment by human activities so that water quality decreases to a certain level which causes it to no longer function in accordance with its designation. Pollution in a body of water is usually caused by a pollutant that enters usually in the form of waste.

Waste that enters the waters consists of organic and inorganic waste (**Aprilia *et al*., 2013**). Organic waste sources come from agricultural activities and urban wastewater such as nitrogen and phosphorus compounds can accumulate in large quantities. These pollutants can cause eutrophication in waters **(Trikoilidou *et al*., 2016).** Inorganic pollutants in waters can be non-degradable heavy metals such as chromium (Cr), cadmium (Cd), mercury (Hg) and lead (Pb) (Dissanayake and Chandrajith, 2009; **Nagajyoti *et al*., 2010).**

Heavy metal pollution in the estuarine sector is the result of inland inputs, mining, activities such as shipping and dredging and anthropogenic inputs **(Chakraborty *et al*., 2014).** These wastes will accumulate in sediments as well as aquatic organisms in them **(Sharif *et al*., 2017)**. Therefore, it is necessary to monitor the quality of a body of water that is indicated to have pollutants in it, one of which uses biological methods by observing organisms that grow around these waters, one of which is mangrove plants.

BIOMONITORING
Biomonitoring is the use of living organisms as biological indicators in response to environmental conditions to determine the quality of waters based on the presence and number of living things in the area **(Dar *et al*., 2017; Ramakrishnan, 2003)**. Biomonitoring is carried out to monitor environmental conditions due to pollutants entering the waters as a form of control and to determine the level of pollution. **Dar *et al*. (2017)** suggested that species as indicators in the biomonitoring system are organisms that can accurately show the condition of an environment or commonly referred to as bioindicators.

One of the aquatic biota that is directly affected and can be used as a bioindicator of metal pollution in the waters is mangrove plants. Mangroves that grow in river estuaries are a shelter for wastes carried by river flow **(Kamaruzzaman *et al.,* 2009)**. Mangroves have the ability to absorb organic and non-organic materials from the environment into the body through the cell membrane. Despite the input of many sources of pollutants, mangroves have a high tolerance to heavy metals **(Defew *et al*., 2005)**. Thus, mangroves can accumulate heavy metals in the sediments of their environment **(Kamaruzzaman *et al.,* 2011).**

MANGROVES AS BIOINDICATORS OF POLLUTION

Mangroves have a role as a collection point for pollutants from urban activities that are carried by river flow to the estuary **(Cheng *et al*., 2010).** Solid and liquid wastes dissolved in river water are carried by the current to the estuary and the open sea. Mangrove forest areas will become waste accumulation areas, especially if pollutants entering the estuary environment exceed the natural purification ability of water. Mangroves are high level plants in coastal areas that can function to absorb organic and non-organic materials so that they can be used as bioindicators of heavy metals (**MacFarlane *et al*., 2000)**. Mangroves have the ability to absorb and store heavy metals in body tissues such as leaves, stems and roots that are carried in sediments, some of these nutrient sources are needed to carry out metabolic processes.

Mangroves have the ability to accumulate and absorb heavy metals in the environment **(Zhang *et al.,* 2007).** Mangroves of several species such as *A. marina*, *R. mucronata*, and *B. gymnorrhiza* have the ability to absorb heavy metals effectively **(Yan *et al.,* 2010; Shete *et al*., 2007; Zhang *et al*., 2007;).** However, Avicennia species are thought to have higher resistance to some metals than other mangrove species **(Yan *et al*., 2010).** *Avicennia marina* was found to accumulate Cu, Pb and Zn in root tissues at levels similar to or higher than surrounding sediment concentrations. Cu and Zn showed movement throughout the plant, accumulating in leaf tissue at levels approximately 10% of the root. It can be said that the roots of *Avicennia marina* serve as biological indicators of Cu, Pb, and Zn exposure in the environment (**MacFarlane, 2003).**

Based on research conducted by **Deri *et al*. (2013),** it is known that *Avicennia marina* plants are able to accumulate heavy metal lead (Pb) in the roots. According to **Amin (2001)**, it is suggested that metals will be absorbed by the roots together with other nutrients which are then circulated to other parts. Absorbed heavy metals such as Cu and Pb will accumulate in the root organs and also in the leaves, both young and old leaves. From the research of **Deri *et al*. (2013)**, it can be seen that the amount of heavy metal lead (Pb) levels in the roots and water column showed a significant difference where the amount of accumulated heavy metal lead (Pb) in the roots of *Avicennia marina* mangrove is greater than in the water around the mangrove area. Lead (Pb) levels in the water ranged from 0.001×10^{-3} - 0.092×10^{-3} mg/L while the range of heavy metal levels of lead (Pb) in mangrove roots was 0.005 - 0.023 mg/L. Based on research conducted by Mulyadi, the average copper (Cu) content in sediments is 3,186 mg/lt while the average copper (Cu) content in the roots of api-api trees is 5,602 mg/lt. This shows that *Avicennia marina* plants have the ability to absorb heavy metals from the aquatic environment.

MECHANISM OF METAL UPTAKE

The accumulation process depends on the metal element, mangrove species and environmental conditions. Lead metal was selectively concentrated in mangrove bark and wood while zinc and copper reached the highest concentration in young leaves. Bioaccumulation coefficients of heavy metals were found in the following order Cu > Zn > Al > Co, Cr > Fe > Mn > Mg in *Avicennia marina* **(Kannan *et al.,* 2016)**. The uptake of heavy metals by mangrove tree roots is influenced by the root system and the surface area of the roots. Each type of mangrove has a different ability to absorb metals depending on the species and metals absorbed (**Yan *et al.,* 2010).**

Heavy metals that enter the aquatic environment will undergo a process of precipitation, dilution and dispersion, then absorbed by organisms living in these waters **(Defew, *et al*., 2005).** A study of the effects of sewage discharges on mangrove communities in Darwin Australia suggested that mangrove trees have a high capacity to accept sewage loads without damage to their growth. Nora F.Y Tam and Yuk Shan Wong have conducted a study on the accumulation and distribution of heavy metals in mangroves, which found that heavy metal content was more prevalent in the roots. In both sediments and plants, heavy metal concentrations increased as the amount of water discharged increased. The ability to retain heavy metals depends on plant age and biomass production (**Tam and Yao, 1998).**

Plant nutrient absorption is influenced by solution concentration, valence age, temperature and metabolic rate. In addition, the speed of absorption of elements is also influenced by the thickness of the cuticle layer and the status of nutrients in plants **(Keshavarz *et al*., 2011).** The speed of absorption of elements generally decreases with increasing plant age and when the temperature is low, the ability to absorb nutrients by plants will also decrease because plant metabolism runs slower **(Tao *et al.,* 2008).**

HEAVY METAL ACCUMULATION IN MANGROVE TISSUE

Roots. The root level *Avicennia marina* can accumulate heavy metals such as Pb, Cu, Zn, Fe, Hg and Cd **(Kannan *et al.,* 2016).** Roots accumulate more Pb and Cu than other parts of the plant body (followed by leaves and bark) in the second species **(Kamaruzzaman and Sharlinda, 2011).** The absorption ability of heavy metals in mangroves also depends on the type of heavy metal itself. The most highly absorbed heavy metals are of the Zn type **(Chakraborty *et al.,* 2014),** followed by heavy metals of the Pb type **(Einollahipeer, et al., 2013)**, and Cd (**Gupta and Chakrabarti, 2013)**. This is because the concentrations of heavy metals Zn, Pb, and Cd tend to be homogeneous.

Keshavarz et al. (2011), stated that the roots can absorb heavy metals in mangrove ecosystems depending on the season, salinity, and absorption rate in mangrove plants themselves. Then the results of research on the sea coast of Oman industrial activities can also affect the level of heavy metal pollution in mangrove sediments so that heavy metals will accumulate in mangrove roots.

Metals that enter the plant body depend on the absorption capacity of the roots. Plant roots in the soil absorb ions from media that contain not only essential nutrient ions but also a number of non-essential ions and organic compounds **(Cheng *et al*., 2010).** These metals can contact the root surface in three ways, namely: 1) by diffusion in the soil solution, 2) passively carried by soil water flow and 3) because the roots grow towards the metal's position in the soil matrix. After contact with the roots, fat-soluble metals will penetrate the cell membrane and accumulate in other cells and tissues **(Ayu *et al*., 2007).**

Stems. Heavy metals in addition to the root tissue can also be absorbed in mangrove stems. Heavy metals are absorbed in mangroves such as Zn, Cu, and Pb. Where Zn is a type of metal that absorbed the highest concentration of 74.61 ppm then Cu at 30.23 ppm and Pb metal at around 8.92 ppm (**Chakraborti *et al*., 2014).** The process of entry of heavy metal elements into plant tissues can be through the xylem to all parts of the body to the leaves. The stem as a transportation route will transport water and metals that dissolve in it to be translocated to the top of the plant. The process of plant metabolism from roots to leaves and vice versa will cause metals to accumulate in the stem **(Ayu *et al*., 2007).**

Leaves. The amount of Pb metal accumulation in mangrove leaves is an effort made by plants in the accumulate of metals concentrated in one particular organ **(Yan *et al*., 2010).** The entry of heavy metals in the leaves is by way of attachment of metal particles on the leaves and into the tissue through the stomata with the help of current. In addition, Zn is also absorbed by the leaves with a value of 35.04 ppm, and Cu at 19.85 ppm **(Chakraborti *et al*., 2014).** Metals that have entered the plant through the roots will be distributed to the leaves. In the leaves, the metal will be stored in old leaves that will eventually die and fall, so that the concentration will decrease in plants.

Leaves are the main organ in the photosynthesis process, so the presence of these metals will interfere with normal enzyme function. Therefore, countermeasures are carried out in the leaves by weakening the toxic effect through dilution, namely by storing a lot of water to dilute the concentration of heavy metals in their body tissues, thereby reducing the toxicity of these metals. Dilution by storing water in the leaves is usually followed by leaf thickening (succulence) **(Ayu *et al*., 2007)**. **MacFarlane *et al.* (2007)** said, that metals tend to accumulate in the roots equal to the concentration in the adjacent sediment, while the metal concentration in the leaves is half of the roots or lower. Metal content in leaves is one-tenth or less of the concentration in the sediment.

CONCLUSION

Mangroves and their sediments have important ecological value as they can act as natural sinks for heavy metals due to the high capacity of these organisms to absorb such metals from tidal and riverine waters and other sources. Mangrove species can be used as bioindicators for heavy metal pollution and contamination due to their heavy metal accumulation capacity in their roots, stems and leaves, however, mangrove root tissue is the most commonly used bioindicator for heavy metal pollution due to its high uptake reliability and accuracy.

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We are grateful that we were able to complete our brief essay on the risks that heavy metals represent to mangroves as a bioindicator in aquatic ecosystems. One of the most crucial ecological benefits comes from plants that can absorb heavy metals. Many species, including fish, mollusks, and plants, collect heavy metal. Future research on heavy metal exposure from aquatic environments is something we plan to do.

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