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Analysis of Cadmium (Cd) Heavy Metal on Sediment and Mangrove Leaves *Avicennia marina* at Mangrove Ecotourism Wonorejo, Surabaya

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Abstract. Mangrove plants have the ability to accumulate heavy metals and help reduce the level of concentration of contaminants in the water. Sediments and *Avicennia marina* leaves potentially become indicators of heavy metal content of cadmium in an area. The content of heavy metal cadmium in Mangrove Ecotourism Wonorejo, Surabaya is not known for certain. Based on the environmental quality standard guidelines according to Decree of Minister of Environment Number: KEP-MEN LH No.51/MENKLH/2004, cadmium threshold for biota is 0.001 ppm. Cadmium threshold in sediment refers to the Canadian Council of Ministers for the Environment (CCME) at 0.7 ppm. The purpose of this research is to learn the cadmium heavy metal content on soil sediments and mangrove leaves of *Avicennia marina* in Jagir and Aftur rivers in Mangrove Ecotourism Wonorejo Area. The research method used was descriptive method with field survey and sampling then testing by Atomic Absorption Spektrophotometry (AAS). The supporting parameters observed in this study are pH, temperature, and salinity. The results of Atomic Absorption Spektrophotometry (AAS) show that in Jagir River Mangrove Ecotourism Surabaya Area, the highest content of cadmium (Cd) heavy metal in sediment and *Avicennia marina* leaves is 1.025 ppm and 0.602 ppm respectively. The content of cadmium (Cd) heavy metal is highest in the sediments and *Avicennia marina* leaves in the Aftur River Mangrove Ecotourism Wonorejo Surabaya area at 1.003 ppm and 0.622 ppm respectively. Coefficient of sediment correlation and *Avicennia marina* leaves in Jagir river equals to 0.932 and in Aftur river is at 0.929. The shape of the sediment correlation and *Avicennia marina* leaves is positive with a very strong correlation relationship.

Keywords. sediment, *Avicennia marina* leaves, cadmium, atomic absorption spektrophotometry, correlation.

1. Introduction

Surabaya is a metropolitan city that is close to the coast and has a mangrove ecotourism area with an area of around 648,453 ha. The area of mangrove forests continues to decrease because of the conversion and exploitation of mangrove forests into ponds and residential areas. The mangrove species found in the Wonorejo mangrove ecotourism in Surabaya are *Avicennia marina*, *Avicennia alba*, *Rhizophora stylosa*, *Rhizophora mucronata*, and *Rizophora apiculata*



(Prasetya, 2011). The most commonly found mangrove species in Wonorejo mangrove ecotourism is *Avicennia marina* because it has the most extensive life tolerance (Poedjirahajoe, 2017).

Cadmium (Cd) has the characteristics of silvery white, heat resistance and corrosion resistance. Cadmium (Cd) is widely used for electrolysis, paint, textile, enamel and plastic industries (Azhar, 2012). Cadmium heavy metals are harmful to humans for a long time because they can accumulate in the body, especially the liver and kidneys. The heavy metal content that accumulates in water and sediment enters the food chain system and affects the life of the organism (Meador, 2005).

Heavy metals entering the aquatic environment experience precipitation, dilution and dispersion. Parvaresh et al. (2010), states that besides being able to accumulate in sediments, heavy metals can accumulate in the mangrove structure. The ability of mangroves to accumulate heavy metals is very good. The highest part of the mangrove that can accumulate cadmium metal is found in the leaves (Kumar et al., 2010).

Mangrove sediments and leaves have the potential to be indicators of cadmium heavy metal content in an area. The heavy metal content of cadmium in Mangrove Ecotourism Wonorejo, Surabaya is not known for certain. Based on environmental quality guidelines according to the Decree of the Minister of Environment Number: KEP-MEN LH No.51/MenKLH/2004, the cadmium threshold for biota is 0.001 ppm. Whereas, the threshold value of cadmium in the sediments in Indonesia has not yet been regulated specifically to be used as references. In this study, an assessment of cadmium threshold in sediments refers to the Canadian Council of Ministers for the Environment (CCME), which is 0.7 ppm.

Based on these problems, the researchers were interested in examining the content of cadmium heavy metal in sediments and leaves of *Avicennia marina* on the Jagir river and the Aftur river of Mangrove Ecotourism Area in Wonorejo, Surabaya.

1.1. Problem Statements

- Has the content of cadmium heavy metal in mangrove sediments of *Avicennia marina* in Jagir river and Aftur river in Mangrove Ecotourism Area Wonorejo exceeded the safe threshold?
- Has the content of cadmium heavy metal in mangrove leaves of *Avicennia marina* in Jagir river and Aftur river in Mangrove Ecotourism Area Wonorejo exceeded the safe threshold?

1.2. Purposes of the Study

- To determine the content of cadmium heavy metals in the *Avicennia marina* mangrove sediments on Jagir river and Aftur river in Mangrove Ecotourism Area Wonorejo.
- To find out the content of cadmium heavy metals in the *Avicennia marina* mangrove leaves on Jagir river and Aftur river in Mangrove Ecotourism Area Wonorejo.

1.3. Benefit

This study is expected to provide information about the content of cadmium heavy metals in sediments and mangrove leaves of *Avicennia marina* in Mangrove Ecotourism Wonorejo, Surabaya.

2. Research methodology

2.1. Place and time

This research activity was carried out in Jagir river and Aftur river in Mangrove Ecotourism Area Wonorejo, Surabaya. This study took place from January to March 2018.

2.2. Research tools

The research tools used in this study were Ekman grab, 1000 gr plastic, label paper, GPS, black plastic bags, scales, digital cameras, icebox, knives, pH meters, thermometers and refractometers.

2.3. Research materials

The materials used in this study were leaf samples and sediment of mangrove soil obtained from the Mangrove Ecotourism Wonorejo, Surabaya

2.4. Research methods

The research method is used to solve a problem that can be done by collecting data through observation, surveys, or through experiments (Kusriningrum, 2010). The research method used in this research was descriptive method, which is a method intended to describe the situation or event through fact finding with the right interpretation. Judging from the type of problem investigated and the techniques used in researching, the descriptive method used was the method of field survey with sampling.

2.5. Work Procedures

Samples were taken from the Mangrove Ecotourism Wonorejo. The samples taken in this study were soil sediments and mangrove leaves. Soil sediments and mangrove leaves were taken directly based on the sampling area group, starting from Aftur river flow and Jagir river flow of Mangrove Ecotourism Wonorejo. Samples at each point were taken randomly.

Sediment sampling was carried out at high tide due to stirring, so that the concentration value would be greater than at low tide (Pradipta, 2013). Sediment samples were collected using Ekman grab at random depth between 0-20 cm (Siaka, 2008). The collected sediment samples were then weighed as much as ± 50 gr and put in a plastic and given a sign. Samples that have been marked are stored on the icebox to keep it safe from damage.

Leaves samples were collected manually by picking at each point. Leaves samples taken were young mangrove leaves with an average mangrove height of 5 m. The obtained leaves samples are then weighed ± 50 gr and put in plastic and marked. Samples that have been marked are stored on the icebox to keep it safe from damage.

Each place was sampled 6 times. Samples were taken then analyzed in the Nutrition Lab of the Public Health Faculty of Universitas Surabaya to find out the amount of cadmium heavy metal content in the sample. The content of heavy metal cadmium was measured using Atomic Absorption Spectrophotometry (AAS).

3. Result and discussion

3.1. The content of Cadmium (Cd) in sediments

The implementation of sediment sampling was carried out on March 10, 2018 when the tide was running which affected the heavy metal content of the sediment at 09:00 – 12:00 WIB (West Indonesia Time). Sediment sampling was carried out 6 times at each location using Ekman grab with a difference in taking distance of about 500 meters at each location point. Sediment samples were taken as much as ± 50 gr then tested in the laboratory using the AAS method. Data on cadmium content taken from the Mangrove Ecotourism Wonorejo, Surabaya can be seen in Table 1.

Table 1. Result of Cadmium (Cd) content test on the sediment

Sample Code (Jagir river)	Cd (ppm)	Sample Code (Aftur river)	Cd (ppm)
A ₁	1.025	B ₁	1.003
A ₂	0.775	B ₂	0.850
A ₃	0.538	B ₃	0.725
A ₄	0.463	B ₄	0.450

Based on the research conducted in Jagir river and Aftur River in the Mangrove Ecotourism Wonorejo, Surabaya, data on the differences in the content of heavy metal cadmium in sediment samples were obtained. Test results for cadmium content in sediment samples taken from the two regions range from 0.450 to 1.025 ppm.

3.2. The content of Cadmium (Cd) in *Avicennia marina* leaves

Data on cadmium content taken from the Mangrove Ecotourism Wonorejo, Surabaya can be seen in Table 2.

Table 2. Result of Cadmium (Cd) content test on the *Avicennia marina* leaves.

Sample Code (Jagir river)	Cd (ppm)	Sample Code (Aftur river)	Cd (ppm)
A ₁	0.602	B ₁	0.622
A ₂	0.596	B ₂	0.574
A ₃	0.548	B ₃	0.534
A ₄	0.524	B ₄	0.518

The test results of cadmium content in *Avicennia marina* leaf samples taken from Jagir river and Aftur river in Mangrove Ecotourism Wonorejo, Surabaya range from 0.518 to 0.622 ppm. The highest cadmium content in the two rivers lies in B1 (0.622 ppm), while the lowest cadmium content is on B4 (0.518 ppm).

3.3. Correlation of Cadmium content in sediments and *Avicennia marina* leaves

The linear correlation test of cadmium content in sediment and *Avicennia marina* leaf samples taken from Jagir river and Aftur river in the Mangrove Ecotourism Wonorejo, Surabaya ranges from 0.932 to 0.929. Comparison of the correlation coefficients taken from the Mangrove Ecotourism Wonorejo, Surabaya can be seen in Table 3.

Table 3. Result of Correlation Test of Cadmium content test on sediment and *Avicennia marina* leaf.

No	Correlation coefficients of cadmium content in sediment and <i>Avicennia marina</i> leaf	
	Jagir river	Aftur river
1	0.932	0.929

3.4. Parameter of Water Quality

There are no significant differences in the value of environmental parameters of each point from the Jagir river and the Aftur river of the Wonorejo Mangrove Ecotourism Area in Surabaya. The results of measurements of pH, temperature and salinity environmental parameters used as supporting factors for each point can be seen in Table 4 and Table 5.

Table 4. Environmental parameter data (pH, temperature and salinity) of Jagir river.

Sample Code	pH	Temperature (°C)	Salinity
A ₁	6.6	28	32
A ₂	6.8	28	32
A ₃	6.8	28	33
A ₄	7	29	34

Table 5. Environmental parameter data (pH, temperature and salinity) of Aftur river.

Sample Code	pH	Temperature (°C)	Salinity
B ₁	6,6	28	32
B ₂	6,6	28	32
B ₃	6,6	28	34
B ₄	6,8	29	35

3.5. Discussion

Pollution of heavy metals that enter the river waters will dissolve in water and accumulate in the sediment. Accumulation of heavy metals will increase every time depending on the conditions

of the aquatic environment (Wulan et al., 2013). Heavy metals can move from the environment to organisms and from one organism to another through the food chain (Yalcin et al., 2008). Heavy metals have an easy nature to bind organic matter and settle in the bottom of the water and unite with sediments so that the levels of heavy metals in sediments are higher than in water (Woro, 2011). Organic matter easily binds to heavy metals because it has a carboxyl group (OH) that is able to bind free heavy metal cations such as cadmium (Cd^{2+}), so that cations are exchanged and form bonds.

The particle size has an important role in the high content of cadmium in sediments. Cadmium content will increase with the finer grain size of the sediment. Subtle sedimentary particles have a large surface area with ion densities that are more stable to bind metals than larger sedimentary particles (Sahara, 2009). Siaka (2008) stated that the highest heavy metal content was found in sediments in the form of mud, clay, muddy sand and a mixture of the three compared to those in the form of pure sand. Sediment types in the mangrove area of Wonorejo are mud (Prasetya, 2011). The mud has a smooth sedimentary size that has good ability to bind metals in sediments. The high percentage of sludge content tends to contain high metals. This causes the concentration of cadmium in the sediments at both points of location to be high, because the type of mud sediment can bind metals longer due to the electrochemical attraction between particles of sediment and metal particles.

Avicennia marina has endurance in absorbing metals. Based on physiological mechanisms, the *Avicennia marina* actively reduces the absorption of metals when metal concentrations in sediments are high (MacFarlane et al., 2003). Absorption is still done, but in limited quantities. This is in accordance with the conditions at all stations where the concentration of metal cadmium in leaves is lower than the concentration of metal cadmium sedimented in almost all stations. Therefore from the concentration of cadmium in sediments can also influence the high and low concentrations of cadmium in the leaves.

The heavy metal content of cadmium on the *Avicennia marina* leaves, which is lower than the initial location point – final location of sampling, shows the function of mangroves as a reduction in heavy metal pollution. *Avicennia marina* has a mechanism to deal with high pollutant concentrations by means of amelioration and tolerance. Amelioration is to minimize the effect of toxins that can be done by localizing toxins in certain organs while tolerance is on mangrove vegetation by developing a metabolic system that can function at toxic concentrations. This mechanism causes the concentration of pollutants in the *Avicennia marina* waters to be reduced (Kusumastuti, 2009).

Based on the results of research on the Jagir river in Wonorejo Mangrove Ecotourism Area in Surabaya, the correlation coefficient on sediments and leaves is 0.932. Meanwhile, the results of research on the Aftur River Wonorejo Mangrove Ecotourism Area in Surabaya show that the correlation coefficient on sediments and leaves is 0.929. The content of cadmium in sediments and leaves has a positive correlation with a very strong variable relationship.

pH affects the concentration of cadmium content that accumulates in the sediment. Setiawan (2015) stated that the lower the pH, the higher the accumulated heavy metal content. The Jagir river pH ranges from 6.6-7 while Aftur river pH ranges from 6.6-6.8. Jagir river shows a higher pH range compared to that of Aftur river so that the solubility of cadmium in sediments in the Jagir river is lower than Aftur river's. The increase in pH causes Cd^{2+} ions to tend to shift from reacting with carbonate ions (CO_3^{2-}) to reacting with hydroxide ions (OH^-). Emilia (2013) claimed that the increase in pH can reduce the solubility of metals in water, because the increase in pH causes metals to bind to particles in the waters and experience deposition. Deposition is when heavy metals are difficult to dissolve in water because they are in the form of suspended particles.

Water temperature affects the solubility of heavy metals that accumulate into the sediment. At Jagir river and Aftur river, the temperature is 28-29°C. The cadmium content in Jagir river and Aftur river is low at high temperatures. This is not in accordance with Waykar et al. (2012) who believed that increasing water temperature tends to increase the accumulation of heavy metals. This can be a result of the content of cadmium being reduced by mangrove plants, so

that at the research point which experienced temperature increase, cadmium content has been reduced.

Water salinity affects the solubility of heavy metals found in waters. In the Jagir river, salinity ranges from 32-34 ppt while in Aftur river, salinity ranges from 32-35 ppt. The Jagir river shows a lower salinity range compared to that of Aftur river, making the solubility of cadmium in the *Avicennia marina* leaves on the Jagir river higher than that of Aftur river. This is in accordance with the Mukhtasor (2007) study, which stated that the higher the salinity value, the lower the concentration of heavy metals in the waters.

4. Conclusion

- The highest cadmium content in sediments in Jagir river is 1.025 ppm while in Aftur river the highest cadmium content is 1.003 ppm. The content of cadmium in sediments has exceeded the safe threshold value of 0.7 ppm (CCME, 1999).
- The highest cadmium content in the *Avicennia marina* leaf in Jagir river is 0.602 ppm while in the Aftur river, the highest content of cadmium in *Avicennia marina* leaves is 0.622 ppm. Cadmium content in leaves has exceeded the safe threshold of 0.001 ppm (KEP-MEN LH No.51/MenKLH/2004).

5. Suggestion

This research can be used as a reference for further research because it has been known that the content of cadmium in sediments and leaves of *Avicennia marina* in the Wonorejo Mangrove Ecotourism Area of Surabaya has exceeded the safe threshold. This certainly affects humans, especially the surrounding community since the area is a maritime tourist spot.

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