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Research Article

Bioconcentration Factor of *Avicennia marina* (Forsk.) and *Rhizophora mucronata* (Lamk.) Inhabiting Coastal Area of Semarang City on Cadmium

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ABSTRACT
Mangrove plants are expected to act as bioaccumulators for heavy metals in coastal areas. One of the heavy metals with great potential risk to the environment is Cadmium (Cd). This research aimed to study the concentration of Cd in the sediment, water, and mangrove organs, as well as to analyse the bioconcentration factor of mangrove plants in the coastal area of Semarang City. This research was carried out through an experimental survey. The survey was conducted based on specific environmental criteria, which were considered as experiment setting, including the growing location and mangrove species. The growing locations include the shore and pond areas, while the mangrove species studied were Avicennia marina and Rhizophora mucronata. The parameters analyzed were Cd levels in root, leaves, water and sediment. Samples of Cd were taken from leaves and roots, as well as from water and sediment under mangrove stands growing in the shore and pond areas. These samples were then analyzed using the Atomic Absorbtion Spectrophotometer (AAS) method. The data were analyzed using ANOVA, followed by further testing using DMRT. The results suggested that Cd accumulation was much higher in the pond area, both in the water and sediment. Additionally, Cd concentration in mangrove organs showed similar behaviour. Bioconcentration factor analysis suggests that A. marina and R. mucronata are potential bioaccumulator of Cd, based on BCF values greater than 1, with indices reaching up to 20.333 for A. marina and 24.866 for R. mucronata.

Keywords: *Bioaccumulation; Bioconcentration Factor; Cadmium; Mangrove.*

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Introduction

Mangrove plants are known as persistent species in coastal areas. Mangroves play an important role in tropical and subtropical coasts by exporting organic matter to support a variety of organisms. Mangrove can survive environmental dynamics due to their capability to overcome environmental pressures [1–3]. One of these capabilities is maintaining the level of chemical compounds such as heavy metals in their organs [4].

Coastal areas where mangrove vegetation grows are vulnerable, especially to chemical pollutants [5], [6]. This vulnerability is even greater if industries exist in the upstream areas [7]. Due to industrial activities, there is a possibility of greater pollutant concentration caused by waste discharge [8]. Pollution refers to a condition in which the environment has deteriorated from its initial state. The use and discharge of chemical agents, such as heavy metals, resulting from anthropogenic activities, affect the normal variation and distribution pattern of heavy metals [6].

Heavy metals are one of the potential sources of environment pollution that can be dangerous to living organisms [9]. Typically, pollutants produced from upstream areas accumulate in estuaries, and are further released into the ocean. However, due to the hydrodynamic processes in estuaries, accumulation is more likely, leading to increased pollutant concentration. Unfortunately, the release rate of pollutants in non-vegetated estuaries is uncontrolled, which increases the ecotoxicology potential for marine organisms [10].

Cd is one of the heavy metals with a great potential risk to the environment due to its high accumulation rate in sediment [11]. Accumulation of Cd in the human body could cause various health problems, such as diarrhea, stomach pains, bone fractures, damage to the central nervous system and immune system, as well as the development of carcinogenic cells [12]. Unfortunately, there are various sources of Cd related to human activities, such as fertilizer, batteries, pigments, plastics, etc [13]. Therefore, Cd is likely to be available in the environment and become a threat to human health. Thus, proper mitigation is needed to reduce the potential risks.

The availability of heavy metals in the environment could be reduced by the utilization of bioaccumulator plants. Typically, plants act as phytoremediator for pollutants such as heavy metals [14]. Mangrove ecosystems, which exist in coastal areas, serve as natural control for pollutant release [15]. Due to mangrove rooting, a pollutant trapping process occurs, along with sedimentation [16]. Mangrove plants then absorb minerals from the sediment, including pollutants such as heavy metals [17]. The absorbed minerals would either be accumulated or released back into the environment through mechanisms such as leaf littering [18]. Due to tidal activities, mangrove ecosystems undergo frequent inundation, which serves as a mechanism to release minerals from coastal and estuarine areas into the marine ecosystem [19].

Due to active absorption, mangrove plants accumulate pollutants in their organs up to a specific limit [20]. Plants' capability to absorb and accumulate pollutants is considered a beneficial feature to the environment [21]. The reduction in pollutant availability is expected due to this ecological role of plants. The bioconcentration factor is used to describe plants' capability to absorb and accumulate heavy metals in the organs [22]. Even though most plants are able to absorb pollutants, this capability varies between species [23]. However, some species can accumulate pollutants at levels higher than the concentrations available in the environment, which is considered to indicate lipophilic or hydrophilic potential [22].

As inhabitants of coastal areas, mangroves are exposed to various kinds of pollutants [24]. Fortunately, mangroves are known for their ability to cope with various environmental stresses, such as heavy metal pollutants [25], [26]. Moreover, mangroves are also suggested to be potential phytoremediators of heavy metal pollutants in the coastal area. Mangrove plants can absorb and accumulate heavy metals at levels higher than their availability in the environment [27].

A plant's capability in absorbing heavy metals is measured by bioconcentration factor (BCF). The bioconcentration factor is the ratio of heavy metals accumulated in a plant's organ to their availability in the plant's growing media [22]. Plants with bioaccumulation potential are expected to have BCF>1, which indicates that their accumulation capacity is higher than the heavy metal's availability in the environment.

There have been studies related to the BCF of heavy metals in mangroves, such as Takarina's research [62], on the bioconcentration factor of Pb, Cu, and Zn in mangrove trees and Maharani's study [63] on the bioconcentration factor of Pb and Cu in *Avicennia marina*. Both studies, however, focused on only one type of coastal environment. The novelty of this research lies in its use of two types of coastal environments, such as shore and pond. In this study, the heavy metal Cd was observed in two mangrove species, namely *Avicennia marina* and *Rhizophora mucronata* across these two environmets (shore and pond).

The coastal ecosystem in Semarang City is an area vulnerable to pollutant exposure. Fortunately, the presence of the mangrove ecosystem is beneficial for controlling pollutant distribution. However, the accumulation of pollutants, especially heavy metals, is a consequence that could lead to their build-up in mangrove plants [4], [28]. Areas located near industrial zones are particularly susceptible to heavy metal pollution [7]. In addition to industrial areas, urban areas also serve as potential sources of heavy metal pollution [29].

Due to the variation in environmental settings, the bioconcentration factor of plants may differ by location. Currently, there is limited information about heavy metal pollution in the coastal area of Semarang City, including the bioconcentration factor of mangrove inhabiting the region. This research aimed to study the concentration of Cd in sediment, water, and mangrove organs, as well as to analyze the bioconcentration factor of two mangrove species across two different growing locations (shore and pond) in the coastal area of Semarang City.

Materials and Methods

Materials

The research was conducted through an experimental survey. The survey was carried out under specified environment criteria that could be considered as experiment setting, including the growing locations and mangrove species. Sampling locations included the coastal (shore) area and pond area, which were selected due to their distinct environment characteristics. The mangrove species studied were *A. marina* and *R. mucronata* from the same location, chosen due to their widespread presence in both growing locations. The heavy metal observed in this research was Cadmium (Cd). Environmental samples of heavy metal were taken from sediment and water under mangrove stands, while its bioconcentration in mangrove plants was analyzed from two organs, roots and leaves.

Methods

Sampling procedure

In this study, three sampling points were selected for each coastal environment (shore and pond). A 500 cc sediment sample was collected from the soil surface to a depth of 30 cm. Sediment samples were stored in plastic bags without preservation. Water samples, totaling 500 cc were taken from standing water under mangrove stands. These water samples were stored in glass bottles and preserved using HCl before being transported to the laboratory for analysis.

Samples of mangrove roots were taken from mangrove plants located in the coastal area of semarang city (shore and pond). Mangrove plants from two species (*A. marina* and *R. mucronata*) were randomly selected, with the criteria that they were of the same size and in the sapling phase. The roots used in this research were secondary roots, which extend horizontally and spread away from the tree. A total of 200 g of root samples were collected and stored in plastic bags in a chiller box.

Leaf samples were collected from the first to third leaves from the apical bud, taken from several branches. A total of 50 g of leaf samples were gathered and stored in a chiller box for preservation. All samples were then transported to the laboratory for analysis.

Cadmium Analysis using the *AAS Method*

Leaf and root samples were cut into smaller pieces and dried in an oven at 60 °C for 3 to 4 days, then blended into powder. Five grams of the powdered sample were heated in a furnace at 600-650 ºC for 4 hours. After heating, 10 mL of HNO_3 was added to the sample, followed by distilled water (aquadest) to make a total volume of 50 mL. The liquid sample was then heated on a hot plate until boiling and left for 10 minutes to cool to the temperature. The liquid was filtered using filter paper into an Erlenmeyer flask. Distilled water was added to the filtrate until the total volume reached 50 mL, and the mixture was blended using a vortex mixer. The same procedure was applied to sediment and water samples.

The AAS testing was performed by measuring the absorption spectrum of the samples at a wavelength of 228,8 nm. The calibration process used a Cd standard curve with concentration of 0, 0.2, 0.4, 0.6, 0.8, 1 ppm. The actual concentration of Cd was calculated using the following formula (eq.1).

$$K\ actual = \frac{K\ AAS\left(\frac{mg}{L}\right) x\ Solvent\ Vol\ (L)}{Sample\ weight\ (mg)} \quad \text{...} \quad (1)$$

Explanation:

K actual	: The actual Cd concentration
K AAS	: AAS results for the samples
Solvent Vol	: Volume of solvent used (L)
Weight sample	: Weight of the sample used (mg)

Bioconcentration Factor (BCF)

The bioconcentration factor (BCF) is the ratio of heavy metals accumulated in plant organs to their availability in the growing environment. BCF was calculated using the following formula (eq.2).

$$BCF\ Cd = \frac{Cd\ on\ organ}{Cd\ \ on\ sediment\ or\ water} \quad \text{...} \quad (2)$$

Where Cd on organ is the Cd concentration in leaf or root and Cd on sediment or water is the Cd concentration in sediment or water. The following criteria must be considered if BCF<1 implies that mangrove is an exluder; BCF=1 implies that mangrove is an indicator; and BCF >1 implies that mangrove is an accumulator (1<BCF<10) and can also being a hyper-accumulator (BCF>10) [61].

Statistical analysis

Statistical analysis was performed to analyse the significance of the concentration differences of Cd between locations, organs, and species as well as the bioconcentration factor between species and locations. Statistical analysis was performed with factorial ANOVA with 95% confidence interval and further testing using DMRT.

Results and Discussion

Based on the analysis result, Cd was found in mangrove organs such as leaf and root, as well as the environment such as sediment and water with varying concentrations between components. In order to further understand the pattern of Cd distribution, Cd concentration in this study were divided into two groups, namely in the environments and mangrove organs. Cd actual was obtained from sample Cd times solvent volume divided by sample weight. Meanwhile sample Cd was obtained from calibrating absorption spectrum with Cd standard curve. In the water, the concentration of Cd did not differ significantly between species nor growing location. Cd in the sediment showed significantly higher concentration than in the water. Cd concentration in the sediment in the other side showed different rates of accumulation. Table 1 shows complete analysis result of Cd concentration in the environment.

Refer to Table 1, Cd accumulation *(eq 1)* in the pond was much higher than in the shore area. Cd concentration in the water was <0.025 mg.L^{-1}, while in the sediment, the concentration was >0.09 mg.kg^{-1}. Statistical analysis also showed that accumulation of Cd under *Rhizophora mucronata* was higher than under *Avicennia marina*. Statistical analysis resulted F value of 4,621.67 (P=0.000). The finding suggests that Cd concentration in the sediment is higher than in the water. Similar result was found by Salem *et al* [30], that heavy metals concentration in the sediment is typically higher than in the water, where the result showed average concentration of Cd in the pond sediment was 0.51^{-1}.67 mg.kg^{-1} and 0.0105-0.0125 mg.L^{-1} in the water. Research by Wang *et al* [47], showed similar pattern where Cd concentration in the sediment comprises up to 1.15 mg.kg^{-1} while its concentration in the water was only up to 0.002 mg.L^{-1}. This condition is related to the different characteristic of respective component. Wetland sediment typically act as sink for heavy metals [31]. Therefore, the concentration is expected to be higher.

Table 1. Concentration of Cd content in sediment and water

Environments	Mangrove Species and Growing Location			
	Avicennia marina		*Rhizophora mucronata*	
	Shore	Pond	Shore	Pond
Sediment (mg.kg^{-1})	0.110 — 0.127	1.078 — 1.103	0.093 — 0.152	1.205 — 1.23
	0.119 ± 0.009^{b}	1.09 ± 0.013^{c}	0.125 ± 0.03^{b}	1.216 ± 0.013^{d}
Water (mg.L^{-1})	0.010 — 0.023	0.012 — 0.013	0.008 — 0.020	0.01 — 0.013
	0.016 ± 0.007^{a}	0.012 ± 0.001^{a}	0.015 ± 0.006^{a}	0.011 ± 0.002^{a}

Note: different letters on the same row indicate significant difference.

Heavy metal concentration in the environment is mostly related to solids, either dissolved or suspended [8]. Although sometimes heavy metals are also found in liquid compounds, the fraction is typically low [32]. Heavy metals in the water is typically bound to fine sediment [33], which make its availability lower than in the soil/sediment. Another factor that makes heavy metal availability in the water low is water movement. Water tends to always move from one place to another and doesn't stay still which make it impossible for heavy metals to accumulate intensively. Therefore, there would not be much fluctuation of heavy metals in the water [34]. However, in certain environment setting such as pond, the movement of the water is limited, making the concentration of heavy metals to increase. Therefore, the concentration of heavy metals in the water is strongly related to the movement (flow) of water. Stronger flow would likely lower the concentration of heavy metals in the water and vice versa. For example, Cd concentration was only 0.001-0.024 mg.L^{-1} in the Kali River [35] while in observation in the Port Klang which is a more open water, showed a lower concentration with range of only between 0.33^{-1}.07 µg.L^{-1} [36].

High concentration of heavy metals in the mangrove ecosystem is an indication of its capability to capture fine solids, both suspended and dissolved [37]. Heavy metals in the water is typically bound by solids [38]. Since sediment is constructed of solids, therefore it is logical that the concentration of heavy metals is much higher. Solids, especially suspended solids, is a proxy for heavy metal transport in the water [39]. Fluctuation of heavy metals in the sediment is also related to water dynamics, such as tidal and flow. Active water movement would eventually reduce heavy metal concentration in the sediment [40].

Heavy metals in the sediment is originally transported by water from various locations [41]. Solids in the water would likely be suspended which then accumulates in the mangrove sediment [28], [42]. Thus, the concentration of heavy metals would increase over time [43], [44]. In the wetlands where inundation frequently occurs, the accumulation should be higher since wetlands would receive supplies of solids from the surrounding water [45]. In the mangrove area, the potential of sedimentation is much higher due to the trapping mechanism of mangrove root [46]. This is proven by the much higher concentration of Cd in the sediment than in the water.

Higher accumulation of Cd was also observed in the pond area than in the shore area. This finding is typical and had been showed in previous research. This is related to the hydrology of the environment setting. In the pond are, water flow is limited, resulting in a calmer water. As the impact, solids dissolved in the water have better chance to get suspended [48]. Furthermore, the sediment in pond area contains a lot of clay material which is usually absorb more metals. Clay material, which is rich in organic matter, is highly able to bind metals. Heavy metals, like Cd, have a high capacity to form chelates with organic compounds [66].

Refer to the finding of this research, higher concentration of Cd in the environment showed further impact on the accumulation level in mangrove organs. Refer to the result, mangroves that grow in the pond has significantly higher Cd concentration than those in the shore area. This indicates that more availability of heavy metals increases its chance to be absorbed by plants [49]. High concentration of heavy metals also causes no different accumulation level between organs.

Analysis of Cd concentration in mangrove organs was focused on leaf and root. Cd concentration was varied by mangrove species and growing location (table 2). Mangroves that grow in the pond accumulated more Cd in the organs regardless the parts, such as leaf and root. Typically, mangroves that grow in the shore area accumulate <0.1 mg.kg^{-1} of Cd in its organs, while mangroves that grow in the pond area accumulate >0.2 mg.kg^{-1} of Cd. Refer to the result, Cd concentration in the leaf of mangrove growing in the shore area were significantly lower than in the root of the same location. In the meantime, Cd concentration in the leaf mangroves growing in the pond area was significantly higher than in the root of mangroves growing in the shore area. However, Cd concentration between leaf and root of mangroves growing in the pond area did not show significant difference. Statistical analysis resulted F value of 280.09 (P=0.000).

Table 2. Concentration of Cd content in mangrove organs

Mangrove Parts	**Mangrove Species and Growing Location**			
	Avicennia marina		***Rhizophora mucronata***	
	Shore	**Pond**	**Shore**	**Pond**
Leaf (mg.kg^{-1})	0.004 – 0.008	0.221 – 0.230	0.003 – 0.009	0.224 – 0.241
	0.007 ± 0.002^{a}	0.227 ± 0.005^{c}	0.006 ± 0.003^{a}	0.233 ± 0.009^{c}
Root (mg.kg^{-1})	0.049 – 0.073	0.202 – 0.244	0.055 – 0.088	0.239 – 0.242
	0.061 ± 0.012^{b}	0.222 ± 0.021^{c}	0.072 ± 0.017^{b}	0.241 ± 0.002^{c}

Note: different letters on the same row indicate significant difference.

Refer to the Cd concentration in mangrove organs, it could be suggested that mangrove that grow in the pond had saturated Cd content. Therefore, the absorbed Cd was distributed in its organs. A research by Shah *et al* [49], showed that the distribution of heavy metal in plant's organ would have slight differences under saturated environment. Some plant species is known to have such ability in order to avoid toxicity [50]. This ability also exists in most mangrove species [51].

Absorption of heavy metals by plants would be followed by the distribution to various organs. However, the accumulation rate between organs would typically be different [49]. However, under saturated concentration in the environment, plants would likely have high translocation factor which causes the concentration between organs to have slight differences.

Saturated Cd content in mangrove growing in the pond was confirmed by its content in mangrove growing in the shore area. In any condition, the Cd concentration in mangrove growing in the shore area was much lower than those growing in the pond area. Moreover, mangroves either *A. marina* or *R. mucronata* showed significantly higher Cd concentration in the root than in the leaf. Therefore, it could be suggested that under non saturated condition, Cd would be preferably accumulated in the root than in the leaf. Analuddin *et al* [23], showed different level of bioaccumulation factor in mangrove. Typically, root would have highest accumulation level compared to other parts such as stem and leaf.

Table 3. Bioconcentration factor of Cd in mangrove organs

BCF	Mangrove Species and Growing Location			
	Avicennia marina		***Rhizophora mucronata***	
	Shore	**Pond**	**Shore**	**Pond**
Root/Sediment	0.386 ─ 0.603 0.515 ± 0.114[a]	0.185 ─ 0.221 0.204 ± 0.018[a]	0.554 ─ 0.591 0.575 ± 0.019[a]	0.196 ─ 0.199 0.198 ± 0.002[a]
Leaf/Sediment	0.036 ─ 0.066 0.055 ± 0.016[a]	0.201 ─ 0.214 0.208 ± 0.007[a]	0.032 ─ 0.059 0.043 ± 0.014[a]	0.182 ─ 0.200 0.192 ± 0.009[a]
Root/Water	3.063 ─ 6.100 4.112 ± 1.722[b]	15.265 ─ 20.333 18.098 ± 2.586[c]	4.235 ─ 6.875 5.170 ± 1.479[b]	18.577 ─ 24.619 22.145 ± 3.166[d]
Leaf/Water	0.348 ─ 0.500 0.416 ± 0.077[a]	17.348 ─ 19.525 18.441 ± 1.088[c]	0.294 ─ 0.450 0.373 ± 0.078[a]	17.231 ─ 24.866 21.523 ± 3.905[d]

Note: different letters on the same row indicate significant difference.

Based on the concentration of Cd obtained from mangrove organs and the environment, bioconcentration factor (BCF) *(eq 2)* was analysed. Refer to the analysis result, the BCF of Cd in *A. marina* was between 0.036─20.333, while in *R. mucronata* was between 0.0032─24.866. typically, the BCF of Cd in mangroves growing in ponds were higher than those in the shore area. Notably, the BCF range for mangroves in the shore area was between 0.0326─6.875, while in the pond area the range was between 0.182─24.866. Detailed result on the BCF analysis of Cd *(eq 2)* in mangrove plants is presented in Table 3.

Refer to Table 3, both *Avicennia* and *Rhizophora* are bioaccumulator for Cd. Average concentration of Cd in the root of mangrove growing in the shore area was >4 of its concentration in the water. A greater ratio was even found in the root and leaf of mangrove growing in the shore area. Average concentration of Cd in *A. marina* root and leaf was >18 of its concentration in the water, while in *R. mucronata* the average concentration was >20 of its concentration in the water. However, comparison of Cd concentration in mangrove organs to its concentration in the sediment showed a lower ratio with only <0.60. Statistical analysis showed that there was significant difference of bioconcentration factor. Statistical analysis with ANOVA showed the F value of 94.67 (P=0.000).

The finding suggested that mangroves are potential bioaccumulator for heavy metals. Mangrove plants accumulate multiple times greater heavy metal concentration than its availability in the water. The potential of mangrove as bioaccumulator was also showed by Analuddin *et al* [23], in various mangrove species such as *Xylocarpus granatum*, *Sonneratia alba*, *Rhizophora apiculata*, *Bruguiera gymnorrhiza*, *Bruguiera parviflora*, *Ceriops tagal* and *Lumnitzera racemosa*. Another finding by Maldonado-Roman *et al* [27], found BCF index for Cd in various mangrove species in the polluted wetland of the north coast of Puerto Rico ranging from 1.8─27.

Bioconcentration factor of mangrove could be the impact of heavy metal's concentration in the sediment. Greater concentration of heavy metals in the sediment provides higher chance of mangrove to absorb it. This suggestion is supported by the data obtained in the research. Mangrove that grows in the shore area typically has higher concentration of Cd in its root than in the leaf. This is related to the absorption mechanism of heavy metals which typically occurred through root [52]. Thus, if the concentration of heavy metals in the sediment is low, its availability in plants would likely be lower [53]. This suggested is appropriate to the finding of Souza *et al* [54], that showed heavy metal concentration in the root fluctuates along with its concentration in the soil accordingly.

Refer to the finding of the research, the *Rhizophora* tends have higher BCF than *Avicennia* although the difference was not statistically significant. The difference in plant's capacity in accumulating heavy metals is typically related to its physiological factors. Different plant species has different ability in absorbing and accumulating heavy metals in its organ [49]. Plants typically have different internal structure that enable it to cope different environmental conditions [55], [56]. Robin *et al* [57] suggested that the permeability of root system is a factor that influence heavy metals absorption in mangrove. Refer to MacFarlane & Burchett [20], mangrove would stop absorbing, accumulating and transporting heavy metals under saturated condition. Other mechanisms were explained by Sruthi *et al* [26], such as the deployment of enzymatic and non-enzymatic antioxidants, production of osmoprotectants and chelation of metal binding molecules such as metallothioneins and phytochelatins.

Avicennia marina and *Rhizophora mucronata* are effective bioaccumulators. Mangroves play an important role in reducing the levels of pollutants (heavy metals) in the environment. Mangrove plants have the ability to absorb heavy metals through their root system and store them in their tissues [60─62]. Based on physiological mechanisms, mangroves *Avicennia marina* and *Rhizophora mucronata* actively absorp heavy metals when the concentration of heavy metals in sediments is high. The process of entering Cd heavy metals into plants is in the form of Cd cation. Cd metal absorption is carried out by the root tip, occurs in the root epidermis. The ions move towards xylem, through the cytoplasmic system (simplas) moving from cell to cell. The absorption process then takes place through two processes, which are ionized directly into the meristem cells of the leaf, then immobilized ions are absorbed on the old leaves cells to be aborted later. The process of taking heavy metals in mangroves is also done by passive transport system. Passive transport systems are those transported by physical forces, namely high to low concentrations that occur in cells. After being absorbed by roots, heavy metals would be translocated to all parts of the plant, especially the leaf and stem [63], [67].

High concentration of Cd in the pond area shows its threat to the environment. Environment enriched with heavy metal pollutants would likely lead to ecotoxicological risk [58]. Available heavy metals would enter aquatic organism through food chains [59]. For example, Malik and Maurya [35] found that the concentration of Cd in *Puntius ticto* and *Heteropneustis fossilis* was between 19.25–22.40 mg.g^{-1} and 29.6–45.4 mg.g^{-1} respectively. The concentration was much higher than the availability of Cd in the environment which only 1–24 mg.L^{-1} in the water and 0.11–2.28 mg.g^{-1} in the sediment. Research by Hastuti, *et al* [64] said that Cd heavy metal, which is a toxic element, could be entered the human body throgh the food chain phenomena. Cd would be absorbed by an aquatic animal or plant, which would be consumed by human. Various symptoms caused by Cd toxicity include kidney damage, osteoporosis, cardiovascular diseases, hypertension, diabetes, modification of several organs, infertility, and many others [65].

Conclusions

The availability of Cd in the coastal area of Semarang City varies between water and sediment by a lot. Cd concentration in the water was between 0.010–0.023 mg.L^{-1}, compared to its concentration in the sediment which was ranging from 0.110^{-1}.230 mg.kg^{-1}. Especially in the sediment, the concentration of Cd in the pond area was higher by multiple times than in the shore area. Similar pattern was found in mangrove organs which range from 0.202–0.244 mg.kg^{-1} in the pond area and only 0.003–0.088 mg.kg^{-1} in the shore area. Bioconcentration factor (BCF) showed the potential of *Avicennia marina* and *Rhizophora mucronata* as bioaccumulator of Cd, shown by its high BCF toward Cd concentration in the water in the pond area, comprising the index up to 20.333 for *A. marina* and 24.866 for *R. mucronata*.

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Conflict of Interest

We declare that there is no conflict of interest.

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