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ABSORPTION OF CADMIUM (CD) IN *AVICENNIA MARINA* (FORSK.) VIERH. AND *RHIZOPHORA APICULATA* BLUME MANGROVES IN THE EAST COAST OF SUMATRA, INDONESIA

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ABSTRACT

Mangroves of *R. apiculata* and *A. marina* have the ability and capability to absorb or bioaccumulate heavy metals. The purpose of this study was to determine and compare bioaccumulation of heavy metal Cd in *A. marina* and *R. apiculata* in the sediment and mangrove organ tissues. This research was conducted from March to August 2020 in the East Coast of Sumatra, Asahan Regency. Data analysis was carried out at the Aquaculture Study Program, Asahan University. The statistical analysis was performed using Principal Component Analysis (PCA) to examine the relationships and comparisons. The results showed that the Cd content in the mangrove sediment of *A. marina* was 0.05 ± 0 mg/kg) and *R. apiculata* was 0.03 ± 0 mg/kg.
***Keywords*: Concentration, sediment, leaves, correlation.

Introduction

Asahan Regency is located in the eastern coastal area of North Sumatra which has mangrove ecosystems. In coastal areas, there is a very complex interaction between freshwater and seawater due to tidal activities. The types of mangroves which can be found are *Rhizophora apiculata* and *Avicennia marina*. The mangrove *Avicennia marina* is found in this area with advantages of its wide life tolerance to different climates, tidal conditions and various salinities (Maguier *et al*., 2000; Ariyanto *et al*., 2018a), wide distribution among all mangroves (Tomlinson, 2016) and it is found at the very edge of the coast *Rhizhopra apiculata* has a high survival rate and can be used for coastal rehabilitation (Komiyama *et al*., 1996); good response to salinity levels (Saddhe & Kumar, 2019), an able to respond to heavy metals (Nguyen *et al*., 2017). Therefore, the mangroves *Rhizophora apiculata* and *Avicennia marina* provide annual productivity (Ariyanto *et al*., 2018b;Ariyanto *et al*., 2019a), metabolite contents (Ariyanto *et al*., 2018c) and carbon stock storage (Sianturi & Choesin, 2018; Wiarta *et al*., 2019), as habitats for organisms (Ariyanto *et al*., 2018d) Ariyanto *et al*., 2020), sources of food (Ariyanto, 2019), sources of protein and carbohydrate (Ariyanto *et al*., 2019b) and element content (Ariyanto *et al*., 2019c;Ningsih *et al*., 2020).

Anthropogenic activities include agricultural runoff, industrial waste originating from urban waste, mining, port activities, etc. causing the mangrove ecosystem to be constantly experiencing stability and survival problems. These activities more or less resulted in the entry of various types of released pollutants. Heavy metals contamination can be found in water, soil, plants, and even foodstuffs (Alharbi *et al*. 2019). Vane & Lister, (2009) mentioned that heavy metals are the pollutants with the most serious toxicity, persistence, and bioaccumulation. The presence of heavy metals contamination in the environment by accumulating in the sediment and organisms can eventually enter the food chain, thereby affecting human well-being (Doanlar & Atmaca, 2011; Wang *et al*., 2013). The heavy metal cadmium (Cd) is known to be a toxic metal with very little or no nutritional value (Feng *et al*., 2017). Cadmium (Cd) has characteristics and benefits for human life, including for electrolysis, paint, textile and plastic industries. The disadvantage of the heavy metal cadmium can harm humans and accumulate in the body, especially the liver and kidneys. The purpose of this study was to determine and compare bioaccumulation of heavy metal Cd in *A. Marina* and *R. apiculata* mangroves in Asahan East Coast, Sumatra, Indonesia.

Materials and Methods

Research Location and Time

This research was conducted in Asahan East Coast, Asahan Regency, North Sumatra from March to August 2020 (Figure 1). The mangrove part samples (roots, stems, leaves, bark, and fruits) of mangrove specimens were identified at the Aquaculture Study Program, Asahan University, North Sumatra.

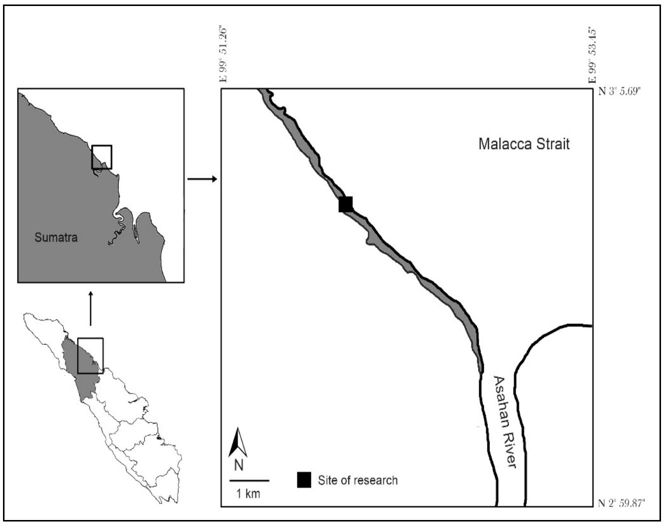

Fig. 1. Research location in the East Coast of Sumatra, Indonesia

Collection of mangrove samples

The ability of mangroves (*A. marina* and *R. apiculata*) to accumulate and translocate heavy metals in different compartments was investigated. Samples were selected for the collection of sediment and different compartments (leaves, branches and roots) of *A. marina* and and *R. apiculata*.

Collection of mangrove sediment samples

Sediment samples were taken using a PVC pipe with a diameter of 20 cm and a length of 15 cm. The first 2 cm of the sediment sample was removed to avoid contamination of the sample with detritus. The samples were stored in a container and kept in a cooler bag for transport to the laboratory. Samples were collected together. Taking into account each size of the three study areas, 8 samples at site A, 8 samples at site B, and 24 samples at site C were collected.

Analysis of heavy metal Cd

Around 0.5-1.5 grams of solid sample or 0.5-1.5 mL of liquid sample were carefully weighed into a vessel. 10 mL of concentrated HNO_3 was added and let stand for 15 minutes. The vessel was closed and the destruction in a microwave digester was performed with the following program: ramp to 150°C for 10 minutes and hold at 150°C for 15 minutes. The result of digestion was cooled, then it was put in a 50 mL volumetric flask. The vessel was quantitatively rinsed with aquabidest, and the rinsed result was combined with the destruction result in a 50 mL volumetric flask. 0.4 mL internal standard mixture of In, Bi 10 mg/L was added. The sample was diluted with aquabidest until the mark then was homogenized. The solution was filtered with a 0.20 µm RC/GHP filter. The intensity of the sample solution in the ICP MS system was measured. Cd 111 analyte was using the internal standard Bi. The intensity of the standard series solution, sample solution, and blank solution was measured using the ICP MS.

Bio-concentration and translocation factors

In the current study, the bio-concentration factor (BCF) of the heavy metals was calculated by the following equation (Usman *et al*., 2012):

BCF (leaves, bark, roots, fruits) = C leaves, bark, roots, fruits / C sediment

where C leaves, C bark and C roots are the metal concentrations in leaves, bark and roots, respectively, and C sediment are the heavy metal concentrations in the sediment

The translocation factor (TF) of the heavy metals was calculated by the following equation:

TF (leaves, bark, roots, fruits) = C (leaves, bark, fruits) / C roots

Statistical analysis

Correlation matrix and principal component analysis (PCA) were conducted using XL Stat 2019 to evaluate the relationships between the investigated variables in the sample. PCA was performed on original data sets (without weights or standardization). After the PCA application, the varimax normalized rotation was applied to minimize the variance of factor loading within the variables for each factor.

Results and Discussion

Table 1 shows Cd contents (mg/kg) of mangroves *A. Marina* and *R. apiculata*. The results showed that the Cd content in the mangrove sediment of *A. marina* was 0.05 ± 0 mg/kg and *R. apiculata* was 0.03 ± 0 mg/kg. The Cd content in the roots of mangrove *A. marina* was 0.04 ± 0 mg/kg, while the highest tissue parts with the lowest content were in the leaves and roots of 0.0005 ± 0 mg/kg, and the same Cd content was found in the stems and leaves of 0.0005 mg/kg.

Table 1 : Cd content (mg/kg) in the sediment and parts of the mangrove tissues of *A. marina* and *R. apiculata* in Asahan East Coast, North Sumatra

Mangroves	Source	Sediment	Roots	Bark	Leaves	Fruits
A. marina	Research data	0.05±0	0.04±0	0.0005±0	0.0005±0	0.02±0
	(Kamaruzzaman *et al*. 2011;	-	0.60±0.12	0.00±0.00	0.10±0.01	-
	Wang *et al*., 2013)	-	0.15±0.01	-	0.09±0.1	-
			4.05	1.83	5.71	
R. apiculata	Research	0.03 ±0	0.0005±0	0.00011±0	0.0005±0	0.0005±0
	(Abdullah *et al*., 2018)	-	0.02±0.01	0.01±0.01	-	0.01±0.006
	(Kumar, *et al*., 2011)	-	4.05	1.83	5.71	-

The results showed that Cd content in the sediment was higher than in the mangrove organ parts. This is in accordance with a research Zabetoglou *et al*., (2002) revealed that the concentration of heavy metals in the sediment usually exceeds the content that is around it. Mangroves have the ability to accumulate heavy metals and help reduce the level of contaminant concentrations in the sediment. Sediments and mangrove of *A. marina* have the potential to be indicators of heavy metal cadmium compared to mangrove of *R. apiculata*. Several researchers have reported the importance of mangrove ecosystems in trapping and storing heavy metals in the sediment and plant tissues (Keshavarz *et al*., 2012; Chakraborty *et al*., 2016). Mangrove of *A. marina* also has a large contribution to the absorption of heavy metals (Usman *et al*., 2012). Abohassan (2013) reported similar results in the absorption of heavy metals with this study, in which the absorption of mangrove stems ranked second after the sediment in *A. marina*. The highest heavy metal bioaccumulations observed in mangrove *A. marina* were sediment > stems > fruits > leaves = root, respectively; while in *R. apiculata* were sediment > stems = fruits = leaves > roots. Maximum concentrations of Cd exceeding the threshold for toxic effects indicate a hazardous risk to organisms in the sediment. Ganeshkumar *et al*., (2019) also reported on the existence of different seasonal variations of heavy metal concentrations in plant tissue ranging from 0.10 to 0.62 (Cd) mg/kg.

Table 2 shows that the mangroves of *A. marina* and *R. apiculata* at the study sites has BCF value > 1 ranging from 0.01 - 0.8 in *A. marina* and 0.0037 - 0.017 in *R. apiculata*. The TF value of the two mangroves was TF <1 of 0.0125 in *A. marina* and 0.22 - 1 in *R. apiculata*, respectively. The results of this study indicated that the mangroves of *A. marina* and *R. apiculata* can be developed as phytoremediation agents because they are able to absorb and transfer heavy metals from the environment to other body tissues. (Alharbi *et al*., 2019) also reported that BCF and TF values greater than 1.0 indicate acute contamination.

Table 2 : BCF and TF of *A. marina* and *R. apiculata* mangroves in Asahan East Coast, North Sumatera

BCF	*A. marina*	*R. apiculata*	TF	*A. marina*	*R. apiculata*
Roots	0.8	0.004			
Stem Bark	0.01	0.0037	Stems bark	0.0125	0.22
Leaves	0.01	0.017	Leaves	0.0125	1
Fruits	0.4	0.017	Fruits	0.0125	1

PCA analysis

PCA analysis in Figure 2 shows the relationship between Cd contents in the sediment and mangrove organ tissues of *A. marina* and *R. apiculata*. The PCA analysis results showed that there are 2 factors, i.e., F1 of 74.49% and F2 of 23.30% with a total of 97.79%. The correlation relationship shows the relationship between the sediment and roots, bark, leaves and fruits.

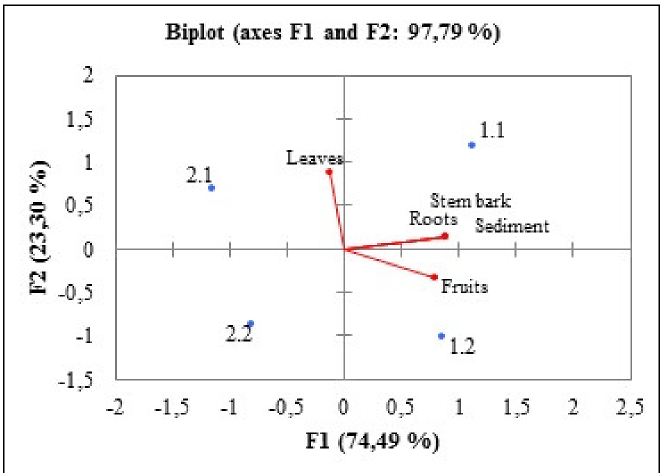

Fig. 2 : PCA analysis showing the relationship between absorption ability of Cd in *A. marina* and *R. apiculata* mangroves in the East Coast of Asahan, North Sumatra, Indonesia.

Correlations between variables and factors showed that the sediment and roots had a positive relationship, meaning that the higher levels of heavy metal Cd in the sediment caused high absorption of mangrove roots found in both *A. marina* and *R. apiculata* mangroves. Based on the PCA results, the absorption of heavy metal Cd was sediment (0.98), roots (0.98), bark (0.98), leaves 0.98) and fruits (0.89) showing that the sediment and organ tissues had a high ability to absorb heavy metals. Mangroves of *R. apiculata* and *A. marina* have the ability and capability to absorb or bioaccumulate heavy metals. Comparison of *A. marina* and *R. apiculata* mangroves showed that *R. apiculata* were better able to absorb than *A. marina* species. Bakshi *et al*., (2017) reported that mangroves have the ability to develop different adaptive features, such as morphological, anatomical and physiological features. Geomorphology (deposition and mixing between the lagoon and the sea, causing sedimentation and hydrodynamics at tides) is a factor that causes the concentration of heavy metals (Agah *et al*., 2016).

Sediment contaminations that enter the food chain with its accumulation properties produce a wide variety of adverse effects on animals and humans (Luevano & Damodaran, 2014). Sediment distribution of heavy metals is influenced by the mineralogy and chemical composition of the suspended material, anthropogenic influences, and in situ processes such as deposition, absorption, and enrichment in organisms (Jain *et al*., 2005). Heavy metal contamination from an ecological view causes pollution indexes such as geo-accumulation, contamination factors and pollution indexes, potential ecological risks, potential toxicity response indexes and biological concentration factors (Alharbi *et al*., 2019). Garcia *et al*., (2018) stated that *A. schaueriana* accumulated more Cd in roots compared to shoots, achieving a 75% higher value in roots. A similar concentration of Cd was also observed in *A. marina* (Dai *et al*., 2017). Cheng *et al*., (2014) reported that mangroves under heavy metal stress tend to develop strategies to accumulate heavy metals in roots and avoid its transport to shoots, such as lignification. In general, the Cd content in the mangrove ecosystem can be absorbed with high mobility so that it has an influence on mangrove growth and development such as photosynthetic metabolic processes (Gonzalez-mendoza & Zapata-perez, 2007) and changes of the primary and secondary metabolic compound productions, stomatal movement, gene expression and enzyme functions (Liu *et al*., 2010). In addition, the influence of heavy metals can cause transpiration into leaves (Sandilyan & Kathiresan, 2014).

Conclusion

The highest absorption of Cd in the sediment and organ tissues of *A. marina* and *R. apiculata* mangroves was found in the sediment and roots. The bioconcentration factor for these plants was less than 1 and cannot be categorized as a hyper accumulator, considering the plant physiology which enables them to maintain high heavy metal contents in the sediment.

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References

Abdullah, F.; Shaari, H.; Satyanarayana, B.; Wan Mohd Khalik, W.M.A. and Mohd. Jaafar, M.Z. (2018). Macro, micro, and non-essential elements in different parts of Rhizophora apiculata, Malaysian J. Anal. Sci., 22(4): 570–578.

Abohassan, R. (2013). Phenotypic and Genotypic Correlation Coefficients for Some Yield and Fiber Quality Traits of Segregating Populations (F 2 , F 3 and F 4) in Egyptian Cotton Crosses," JKAU Met., Env. Arid L. Agric. Sci, 24(1): 35–53.

Agah, H.; Saleh, A.; Bastami, K.D. and Fumani, N.S. (2016). Ecological risk, source and preliminary assessment of metals in the surface sediments of Chabahar Bay, Oman Sea," Mar. Pollut. Bull.; 107(1): 383–388.

Alharbi, O.M.L.; Khattab, R.A.; Ali, I.; Binnaser, Y.S. and Aqeel, A. (2019). Assessment of heavy metals contamination in the sediments and mangroves (Avicennia marina) at Yanbu coast, Red Sea, Saudi Arabia. Mar. Pollut. Bull.; 149: 110669.

Ariyanto, D.; Bengen, D.G.; Prartono, T. and Wardiatno, Y. (2018a) Distribution of Batillaria Zonalis (Mollusca: Gastropoda) on Avicennia Marina (Forsk.) Vierh in The Coast of Banggi, Rembang, Central Java. Omni-Akuatika, 14(3): 10–17.

Ariyanto, D.; Bengen, D.G.; Prartono, T. and Wardiatno, Y. (2018b). Productivity and CNP availability in *Rhizophora apiculata* Blume and *Avicennia marina* (Forssk.) Vierh . at Banggi Coast , Central Java – Indonesia. AES Bioflux, 10(3): 137–146.

Ariyanto, D.; Bengen, D.G.; Prartono, T. and Wardiatno, Y. (2018d). Short Communication: The relationship between content of particular metabolites of fallen mangrove leaves and the rate at which the leaves decompose over time. Biodiversitas, 19(3): 780-785.

Ariyanto, D.; Bengen, D.G.; Prartono, T. and Wardiatno, Y. (2018d). The association of *Cassidula nucleus* (Gmelin 1791) and *Cassidula angulifera* (petit 1841) with mangrove in banggi coast, Central Java, Indonesia. AACL Bioflux.; 11(2): 348–361.

Ariyanto, D. (2019). Food Preference on Telescopium telescopium (Mollusca: Gastropoda) Based on Food Sources In Mangrove," Plant Archives.; 19(1): 913–916.

Ariyanto, D.; Bengen, D.G.; Prartono, T. and Wardiatno, Y. (2019a). The physicochemical factors and litter dynamics (*Rhizophora mucronata* lam. and *Rhizophora stylosa* griff) of replanted Mangroves, Rembang, Central Java, Indonesia. Environ. Nat. Resour. J.; 17(4): 11–19.

Ariyanto, D.; Gunawan, H.; Puspitasari, D.; Ningsih, S.S.; Jayanegara, A. and Hamim (2019b). Identification of the chemical profile of Rhizophora mucronata mangrove green leaves from the eastern coast Of Asahan, North Sumatra, Indonesia.; Plant Archives.; 19(2): 4045–4049.

Ariyanto, D.; Gunawan, H.; Puspitasari, D.; Ningsih, S.S.; Jayanegara, A. and Hamim, H. (2019c). The differences of the elements content in Rhizophora mucronata leaves from Asahan Regency, North Sumatra, Indonesia. Polish J. Nat. Sci.; 34(4): 481–491

Ariyanto, D.; Bengen, D.G.; Prartono, T. and Wardiatno, Y. (2020) Distribution and abundance of Cerithideopsilla djadjariensis (Martin 1899) (potamididae) on Avicennia marina in Rembang, Central Java, Indonesia. Egypt. J. Aquat. Biol. Fish.; 24(3): 323–332.

Bakshi, M.; Ram, S.S. and Ghosh, S. (2017). Micro-spatial variation of elemental distribution in estuarine sediment and their accumulation in mangroves of Indian Sundarban. Env. Monit Assess, 189(221): 1–15.

Chakraborty, P.; Ramteke, D.; Gadi, S.D. and Bardhan, P. (2016). Linkage between speciation of Cd in mangrove sediment and its bioaccumulation in total soft tissue of oyster from the west coast of India. Mar. Pollut. Bull.; 106 (1–2): 274–282.

Cheng, H. *et al*. (2014). Metal (Pb, Zn and Cu) uptake and tolerance by mangroves in relation to root anatomy and lignification/suberization. Tree Physiol.; 34(6): 646–656.

Dai, M.; Lu, H.; Liua, W.; Jia, H.; Hong, H.; Liu, J. and Yan, C. (2017). Phosphorus mediation of cadmium stress in two mangrove seedlings. Ecotoxicol. Environ. Saf.; 139: 272–279,

Doanlar, Z.B. and Atmaca, M. (2011). Influence of airborne pollution on Cd, Zn, Pb, Cu, and Al accumulation and physiological parameters of plant leaves in Antakya (Turkey). Water. Air. Soil Pollut.; 214: 509–523.

Feng, J.; Zhu, X.; Wu, H.; Ning, C. and Lin, G. (2017). Distribution and ecological risk assessment of heavy metals in surface sediments of a typical restored mangrove–aquaculture wetland in Shenzhen, China. Mar. Pollut. Bull.; 124(2):1033–1039.

Ganeshkumar, A.; Arun, G.; Vinothkumar, S. and Rajaram, R. (2019) Bioaccumulation and translocation efficacy of heavy metals by Rhizophora mucronata from tropical mangrove ecosystem, Southeast coast of India. Ecohydrol. Hydrobiol.; 19(1): 66–74.

Garcia, J.S.; Dalmolin, Â.C.; Cortez, P.A.; Barbeira, P.S.; Mangabeira, P.A.O. and França, M.G.C. (2018). Short-term cadmium exposure induces gas exchanges, morphological and ultrastructural disturbances in mangrove Avicennia schaueriana young plants. Mar. Pollut. Bull.; 131: 122–129.

Gonzalez-mendoza, D. and Zapata-perez, O. (2007). Multiple Effects of Cadmium on the Photosynthetic Apparatus of *Avicennia germinans* L. as Probed by OJIP Chlorophyll

Fluorescence. J. Biosci.; 62(34): 265–272.

Jain, C.K.; Singhal, D.C. and Sharma, M.K. (2005) Metal pollution assessment of sediment and water in the River Hindon, India. Environ. Monit. Assess.; 105(1–3): 193–207.

Kamaruzzaman, B.Y.; Rina Sharlinda, M.Z.; Akbar John, B. and Siti Waznah, A. (2011). Accumulation and distribution of lead and copper in Avicennia marina and Rhizophora apiculata from Balok mangrove forest, Pahang, Malaysia. Sains Malaysiana.; 40(6): 555–560.

Keshavarz, M.; Mohammadikia, D.; Gharibpour, F. and Dabbagh, A.-R. (2012). Accumulation of Heavy Metals (Pb, Cd, V) in Sediment, roots and leaves of Mangrove species in Sirik Creek along the Sea Coasts of Oman, Iran. J. Life Sci. Biomed. 16(4): 88–91.

Komiyama, A.; Santiean, T.; Higo, M.; Patanaponpaiboon, P.; Kongsangchai, J. and Ogino, K. (1996). Microtopography, soil hardness and survival of mangrove (*Rhizophora apiculata* BL.) seedlings planted in an abandoned tin-mining area. For. Ecol. Manage.; 81: 243–248.

Kumar, I.N.; Sajish, P.R.; Kumar, R.N.; Basil, G. and Shailendra, V. (2011). An Assessment of the Accumulation Potential of Pb, Zn and Cd by Avicennia marina (Forssk.) Vierh. in Vamleshwar Mangroves, Gujarat, India. Not. Sci. Biol.; 3(1): 36–40.

Liu N.; Lin, Z.; Lin, G.; Song, L.; Chen, S.; Mo, H. and Peng, C. (2010). Lead and cadmium induced alterations of cellular functions in leaves of *Alocasia macrorrhiza* L. Schott, Ecotoxicol. Environ. Saf.; 73: 1238–1245.

Luevano, J. and Damodaran, C. (2014). A review of molecular events of cadmium-induced carcinogenesis. J. Environ. Pathol. Toxicol. Oncol.; 33(3): 183–194.

Maguier, T.; Sanger, P.; Baverstocks, P. and Henry, R. (2000). Microsatellite analysis of genetic structure in the mangrove species *Avicennia marina* (Forsk.) Vierh . (Avicenniaceae). Mol. Ecol.; 9 : 1853–1862.

Nguyen, K.L.; Nguyen, H.A.; Richter, O.; Pham, M.T. and Nguyen, V.P. (2017). Science of the Total Environment Ecophysiological responses of young mangrove species *Rhizophora apiculata* (Blume) to different chromium contaminated environments. Sci. Total Environ.; 574: 369–380.

Ningsih, S.S.; Ariyanto, D.; Puspitasari, D.; Jayanegara, A.; Hamim, H. and Gunawan, H. (2020). The amino acid contents in mangrove Rhizophora mucronata leaves in Asahan, North Sumatra, Indonesia. E3S Web Conf.; 151(01047): 1–3.

Saddhe, A.A. and Kumar, K. (2019). Molecular cloning, expression analysis, and heterologous characterization of a novel sodium/hydrogen exchanger from a mangrove plant, Rhizophora apiculata. Plant Gene.; 19: 100192.

Sandilyan, S. and Kathiresan, K. (2014). Decline of mangroves - A threat of heavy metal poisoning in Asia. Ocean Coast. Manag.; 102: 161–168.

Sianturi, R. and Choesin, D.N. (2018) Vegetation Structure And Carbon Stock In The Mangrove Community Of Payumb Coast , Merauke Regency, Papua. E3S Web of Conferences.; 12: 9–13.

Tomlinson, P.B. (2016). The Botany of Mangroves.

Usman, A.R.A.; Lee, S.S.; Awad, Y.M.; Lim, K.J.; Yang, J.E. and Ok, Y.S. (2012). Soil pollution assessment and identification of hyperaccumulating plants in chromated copper arsenate (CCA) contaminated sites, Korea. Chemosphere.; 87: 872–878.

Vane, C.H.; Jones, D.G. and Lister, T.R. (2009). Mercury contamination in surface sediments and sediment cores of the Mersey Estuary. Mar. Pollut. Bull.; 58(6): 940–946..

Wang, Y.; Qiu, Q.; Xin, G.; Yang, Z.; Zheng, J.; Ye, Z. and Li, S. (2013). Heavy metal contamination in a vulnerable mangrove swamp in South China. Environ. Monit. Assess.; 185:5775–5787.

Wiarta, R.; Indrayani, Y.; Mulia, F. and Astiani, D.W.I. (2019). Short Communication: Carbon sequestration by young Rhizophora apiculata plants in Kubu Raya District , West Kalimantan , Indonesia. Biodiversitas.; 20(2): 311–315.

Zabetoglou, K.; Voutsa, D. and Samara, C. (2002).Toxicity and heavy metal contamination of surficial sediments from the Bay of Thessaloniki (Northwestern Aegean Sea) Greece. Chemosphere, 49(1):17–26.