Concentration of heavy metals lead (Pb) and cadmium (Cd) in water, sediment and seagrass *Thalassia hemprichii* in Ambon Island waters

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Abstract. Seagrasses have a high bioaccumulation capacity because they interact directly with the water column through the leaves and with sediment through the roots and rhizomes. Therefore they can be used as good bioindicator. The aims of this study were to analyze the heavy metal concentration of Pb and Cd in sea water and sediment as well as on the organs of *Thalassia hemprichii* including roots, rhizomes and leaves, potentially as phytoremediator agent. Samples were taken from two coastal waters in Ambon Island, namely Suli and Poka waters. The heavy metal content of Pb and Cd was analyzed in water, sediment and seagrass organ using Atomic Absorption Spectrophotometer. The results showed that the concentrations of Pb and Cd were higher in sediments (0.135 to 0.309 ppm/Pb and 0.107 to 0.190 ppm/Cd) than in water (0.013 to 0.084 ppm/Pb and 0.032 to 0.071 ppm/Cd). The highest metal concentration of Pb and Cd was detected at the roots of 0.579 ppm (Pb) and 0.363 ppm (Cd), then on leaves with values of 0.451 ppm (Pb) and 0.275 ppm (Cd). The concentrations of Pb and Cd were higher in seagrass than in water and sediments indicating that seagrass *T. hemprichii* has a good accumulator capability, indicated by a bioconcentration factor (BCF) value greater than 1 and potentially as a phytoremediator agent of heavy metals Pb and Cd.
Key Words: seagrass, sediment, bioaccumulation, phytoremediator, heavy metals.

Introduction. Heavy metals are one of the harmful contaminants that interfere with human health (Palar 2008). Heavy metal pollution in marine waters come from industrial, agricultural and residential waste disposal. In addition, human activities that potentially contribute heavy metals to the sea are ship transport activities, ship repair, motor vehicle fumes and domestic waste (Male et al 2014). Some of the heavy metals resulting from such activities are lead (Pb) and cadmium (Cd).

Heavy metal pollution into the aquatic environment will accumulate in the sediment and may increase over time, depending on the environmental conditions of these waters (Wulan et al 2013). Such heavy metals will also be absorbed by living organisms through biological processes and eventually accumulate in their bodies. The content of heavy metals that accumulate in seawater and sediment will enter into the food chain system and affect the lives of the organisms (Said et al 2009). The impacts of metal pollution of Pb, Cd and mercury (Hg) have been studied in several waters in Indonesia, one of which is in the waters of Jakarta Bay that has exceeded the thresholds of water and marine biota resulting in mass mortality in fish (Yatim et al 1979 cited in Rochyatun & Rozak 2007).

Seagrasses are marine angiosperms that are found to grow and develop in shallow waters, areas that have always been inundated or exposed when subsided to the substrate of sand, muddy sand, and corals (Dahuri 2003). The seagrasses existence causes these ecosystems to be affected by various activities in coastal areas. The species *Thalassia hemprichii* is one of the dominant species on the Ambon island, being capable of absorbing and accumulating heavy metals on parts of its body (Tupan et al 2014). A number of studies have been conducted to determine the accumulation of heavy metals in seagrasses, where seagrasses are able to absorb and accumulate heavy metals in leaves (Lewis et al 2007; Herawati 2008; Sugiyanto et al 2016) and at roots (Ambo Rappe 2008; Llagostera et al 2011; Tupan et al 2014; Male et al 2014). The presence of heavy metal content on the parts of the seagrass organ proved the response of seagrass to the heavy metal pollutants as well as evidence of absorption and accumulation of heavy metals to the seagrass organs. The present study was conducted in order to determine the heavy metal concentration of lead (Pb) and cadmium (Cd) in the organs of *T. hemprichii* seagrass and on water and sediment, where *T. hemprichii* has a potential as a phytoremediator agent, which is useful for monitoring and control of marine pollution in Ambon Island.

Material and Method

Study site and sampling. This research was conducted in April 2017 on the coastal waters of Tanjung Tiram, Poka and the coastal waters of Suli, Ambon Island, Indonesia (Figure 1). Seagrass sampling at each study site was conducted on two study stations representing muddy sand substrate (St 1) and mixed sand and coral fragment (St 2) substrate. Data were collected by using transect line method. *T. hemprichii* is extracted in a 1 x 1 m square plot perpendicular to the coastline on the front, middle and back. There were three replications at each station and data were compiled before analysis. The seagrass samples were then washed out of the sediment and the attaching organism. Then, the seagrass was separated into the roots, rhizomes and leaves and placed in a plastic bag respectively to be brought to the environmental laboratory, Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang, Indonesia. Water and sediment sampling was also conducted in the same place as seagrass sampling. Water quality parameters measured were temperature, pH, salinity and dissolved oxygen. Temperature and salinity were measured using conductivity temperature depth (CTD) Pelican 1550 case. pH and dissolved oxygen were measured using Hanna HI 98196 Multiparameter (pH/DO) Probe.

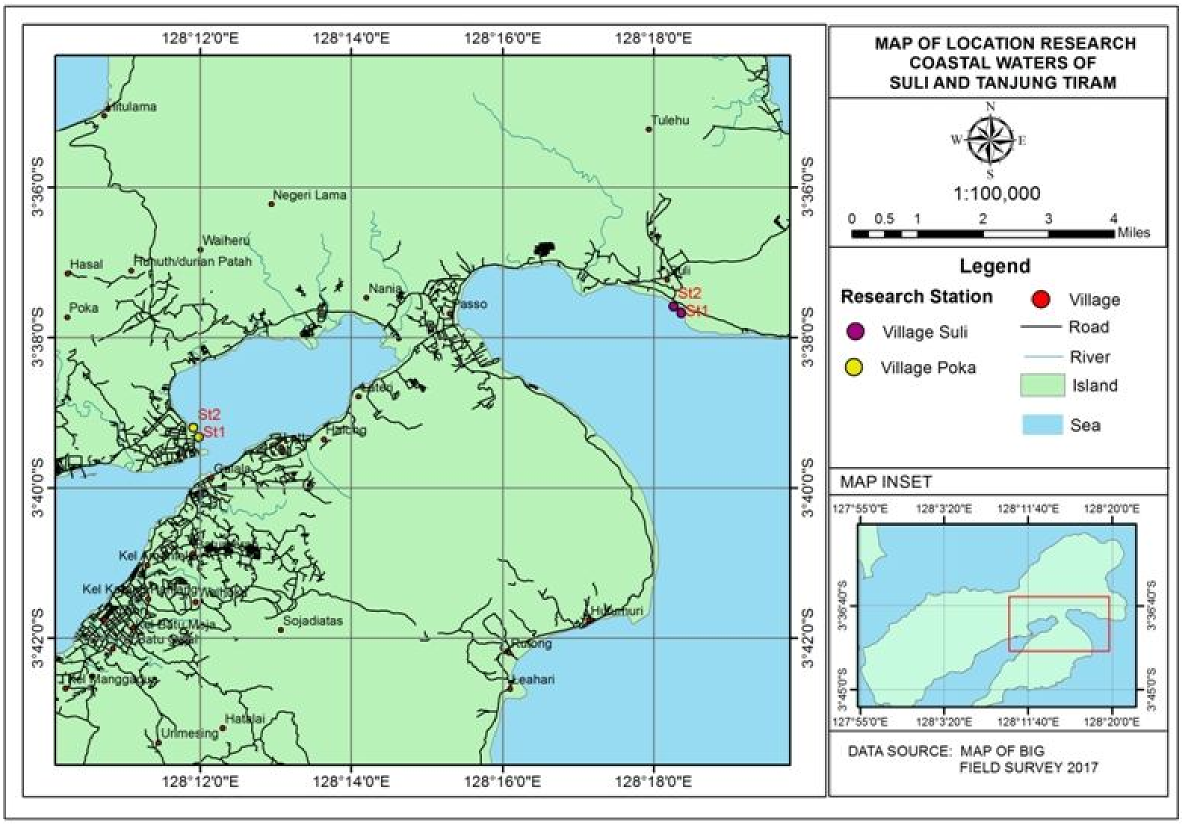

Figure 1. Map of location research

Analysis of heavy metal content. Analysis of heavy metal content in seawater was done by adding concentrated HNO_3 as much as 5 mL and heated, then added aquades and shaken until homogenous then analyzed using atomic absorption spectrophotometer (AAS) at 283.3 nm wavelength. Sediment and seagrass samples were dried at 105^{o}C for 5 hours and then cooled in desiccator for 30 minutes. The smoothed sample was then dissolved as much as 1 g with HNO_2 M and filtered using whatman filter paper Grade 1: 11 µm (medium flow filter paper). Samples were then added aquades up to 50 mL volume and ready to be analyzed using AAS at 283.3 nm wavelength.

Data analysis

Bioconcentration factor (BCF). Bioconcentration factors were analyzed based on metal concentrations in sediments and on tissues of seagrass above and below the substrate (Lewis et al 2007). BCF analysis was performed to determine the accumulated level of heavy metals Pb and Cd on roots and leaves of *T. hemprichii* seagrass.

$$BCF = \frac{\text{Concentration in seagrass tissue } (\mu g.g^{-1}DW)}{\text{Concentration in vegetated sediment } (\mu g.g^{-1}DW)}$$

Translocation factor (TF). The translocation factor in each metal was analyzed by dividing the concentration of metal in the leaves by the concentration of metal in the roots.

$$TF = \frac{\text{Concentration in seagrass leaves } (mg.kg^{-1})}{\text{Concentration in seagrass roots/rhizomes } (mg.kg^{-1})}$$

Phytoremediation. Phytoremediation was analyzed by reducing the value of BCF with TF value (Yoon et al 2006)

$$FTD = BCF - TF$$

Results and Discussion

The heavy metal concentration of Pb and Cd in water and sediment. The results of the analysis of heavy metal concentration of lead (Pb) and cadmium (Cd) on water and sediments at Tanjung Tiram, Poka and Suli locations are presented in Figure 2. The concentration of Pb of seawater in Poka ranged from 0.053±0.03 to 0.084±0.03 ppm, Suli ranged from 0.013±0.01 to 0.060±0.01 ppm. The lowest average Pb concentration was found in Suli waters, station 2 (substrate of sand and mixed coral) and the highest was in Poka waters, station 1 (muddy sand substrate). The similar result was also found in Cd concentration. The highest concentration of Cd was found in Poka waters, station 1 of 0.071±0.01 ppm and the lowest was in Suli waters, station 2, which was 0.032±0.01 ppm.

Higher concentrations of Pb and Cd were found in Poka waters than in Suli waters. This was due to some activities on coastal area such as waste from power station, runoff from land, settlement, boat transportation routes. Poka waters are included in the waters of Teluk Ambon Dalam which have high utilization activities mainly as sea transportation routes for ships entering and exiting Ambon Bay, as well as waste and corrosion discharges from ships placed in the waters of Ambon Bay.

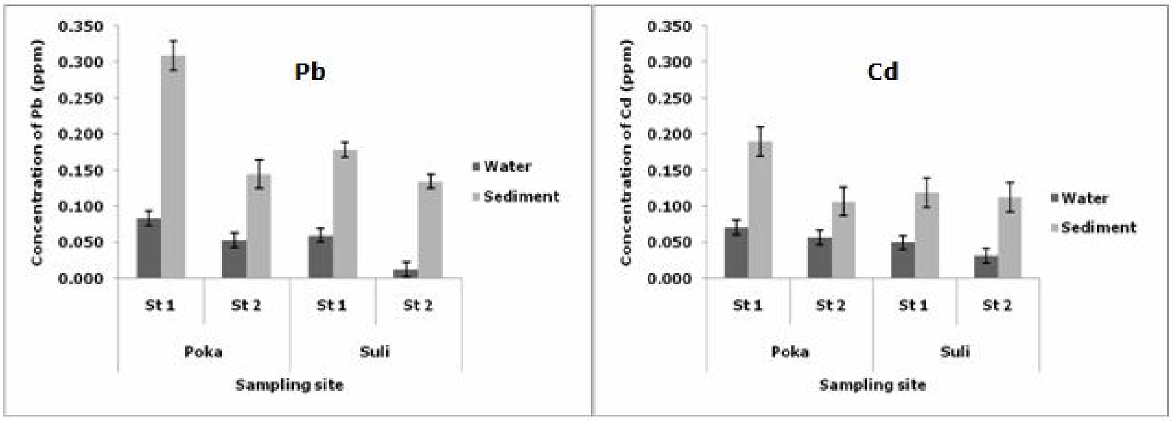

Figure 2. Concentration of lead (Pb) and Cadmium (Cd) in water and sediment in Poka and Suli Waters

Visually, the waters of Suli seem clean, but have been contaminated with both Pb and Cd. The pollution is allegedly derived from the anthropogenic activities such as washing activities, domestic waste and docked of fishing boat. According to Bryan (1976) and Wittmann (1979) cited in Connell & Miller (1984), there were some input sources came into environment. The natural heavy metals came into the marine environment from rivers and erosion. Erosion was caused by wave and glacier activity. It was also from the deep ocean, including metals released by deep volcanic activity in the sea; metals released from the shore or sediments by chemical processes; inputs that extend beyond the coastal land environment, and metals transported in the atmosphere as dust particles or as aerosols as well as materials produced by glacier erosion in the polar regions and transported by floating ice. While the source came from human such activities on land such as mining activities, household waste, urban flow and waste and industrial waste. In addition, the activities on the sea comes from the ballast water of ships and metal mining in the sea. The concentration of Pb and Cd in sea water has exceeded the Standard value for marine biota of 0.008 ppm for Pb and 0.001 ppm for Cd (KMNLH No 51 Year 2004).

Heavy metals that are in the water column difficult dilut so that over time will come down to the bottom and settle in the sediment. This is supported by an alkaline pH value, where the metal will be difficult to dissolve and settle in the bottom of the water (Rochyatun & Rozak 2007). In addition, temperature can also affect the heavy metal content in a waters (Rochyatun & Rozak 2007). Sea water temperature will affect the toxicity of heavy metals including Pb and Cd. The higher the temperature the heavy metal toxicity against the organism will be higher. High temperatures cause low metal solubility so that the metal will settle at the bottom of the waters and unite with the sediments will then accumulate in plants. Water temperature during the study was obtained at Poka ranging from 29 to 32^{o}C and Suli ranged from 30 to 32^{o}C. This temperature range is still in accordance with the normal sea water temperature ranging from 25.6 to 32.3^{o}C and still at the optimum temperature for seagrass growth ranging from 28 to 30^{o}C (Zieman 1975). Therefore, it can be said that the temperature range would affect the toxicity of metal in the seagrass.

The content of Pb in the sediment ranged from 0.084±0.06 (Suli) to 2.090±0.01 ppm (Poka) and the Cd content ranged from 0.541±0.02 (Suli) to 1.195±0.03 ppm (Poka). Higher Pb and Cd content was found in Poka waters than in Suli waters. High metal content in the waters will be deposited and accumulated in the sediment. Thus, the high metal content in Poka waters causes the metal content was also high in the sediment of these waters. The value of metal content in this sediment was higher than that of Pb in water. This difference was because most of the heavy metals that enter the waters are generally deposited in the sediments. This was supported by a factor of acidity degree (pH) that was alkaline and normal temperature range resulted in insoluble Pb and deposited on sediments (Rochyatun & Rozak 2007).

The absorption capacity of metals is closely related to particle size and surface area of absorption, so that the concentration of metal in the sediment is usually influenced by the particle size in the sediment, which the finer the grain size, the higher metal binding capacity in the water (Wilson et al 1985 cited in Wilson 1988). Station 1, in Poka and Suli waters has a higher metal content than station 2 and has smaller or finer grain size, resulting in higher absorption capacity and metal binding ability.

The accumulation of lead (Pb) and cadmium (Cd) on T. hemprichii seagrass. The results of the analysis of Pb and Cd content on parts of *T. hemprichii* seagrass at Tanjung Tiram, Poka and Suli sites are presented in Figure 3.

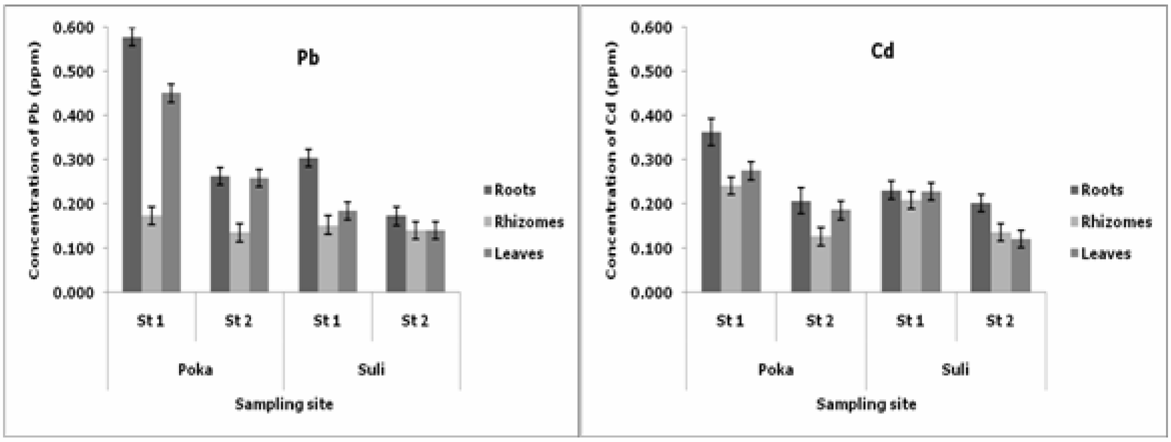

Figure 3. Concentration of lead (Pb) and Cadmium (Cd) in roots, rhizomes and leaves of *T. hemprichii* in Poka and Suli waters.

The concentration of Pb and Cd in the seagrass parts of the plants was higher at Poka than that in Suli. The roots had the highest metal content compared to rhizome and leaves. According to Lakitan (2007) that plant roots can absorb metals in the form of ions diffusely in the soil solution or passively carried by the groundwater flow with the nutrients entering with the water flow, where these root cells generally contain more ionic concentrations high from the surrounding medium, so that water diffusion events containing Pb and Cd can take place. Other processes that assist the accumulation of Pb and Cd in the roots are the result of root suction on water and ions in the sediments (Brooks 1997 cited in Herawati 2008). Furthermore, Guilizzoni (1991) adds that aquatic plants have a well developed transport system, so it can translocate ions through xylem and phloem basipetal or acropetal. Other seagrass parts such as leaf, is also a place of absorption of nutrients through the water column but the leaves do not have stomata but thin cuticles. The cuticle serves to absorb nutrients, although in less amounts than is absorbed by the roots (Tomasick et al 1997). As a consequence of accumulation of heavy metal in the part of seagrass, the exoderm and endoderm tissue (at the root) would be thickening as well as on the cuticle and epidermis (at the leaves) (Tupan & Azrianingsih 2016).

Bioconcentration and translocation factors of Pb and Cd in T. hemprichii seagrass. The bioconcentration factor (BCF) of Pb and Cd in seagrass *T. hemprichii* is shown in Table 1. BCF was used to analyze the ability of *T. hemprichii* in accumulating in roots and leaves the Pb and Cd from the sediment. The average value of BCF obtained is more than 1 and the BCF value at the root is higher than the leaves of both Pb and Cd. This value proves that *T. hemprichii* tends to absorb and accumulate heavy metals primarily at the root and indicate that this seagrass species is a good metal accumulator. Baker & Brooks (1989) stated that plants are able to accumulate heavy metals up to > 1000 mg kg^{-1} and are known as hyperacumulators. Whereas if the value of BCF > 1 is known as plant accumulator (Baker 1981).

Table 1
The value of BCF roots and leaves *T. hemprichii* to heavy metals Pb and Cd in Poka and Suli waters

Tissues	*Station*	*Poka*		*Suli*	
		Pb	*Cd*	*Pb*	*Cd*
Roots	St 1	1.874	1.911	1.698	1.941
	St 2	1.814	1.935	1.281	1.212
	Mean	1.844±0.042	1.923±0.017	1.490±0.295	1.577±0.515
Leaves	St 1	1.460	1.447	1.028	1.916
	St 2	1.786	1.738	1.044	1.071
	Mean	1.623±0.231	1.593±0.206	1.036±0.012	1.493±0.598

Translocation factor (TF) analysis was used to measure the ability of plants in moving metals from root to all parts of plant. The metal translocation is calculated between the ratio of metal concentrations in the leaves and at the roots. Based on the result of the analysis, the average value of TF for Pb and Cd is close to 1 or < 1 (Table 2). This indicates that *T. hemprichii* has a phytostabilizing mechanism. The TF value < 1 indicates that plants have phytostabilization ability (Baker (1981). This low TF value is possible because the roots often have a metal transport termination system leading to the leaves causing the accumulation of metal in the root (Yoon et al 2006).

Table 2
TF value of *T. hemprichii* to heavy metals Pb and Cd in Poka and Suli waters

Station	*Poka*		*Suli*	
	Pb	*Cd*	*Pb*	*Cd*
St 1	0.779	0.758	0.605	0.987
St 2	0.985	0.899	0.815	0.883
Mean	0.882±0.146	0.828±0.100	0.710±0.148	0.935±0.073

Plants could be used as media to reduce pollutant content specifically on reducing metal movement in sediment. This was done by using phytoremediation (Ma et al 2006). Phytoremediation analysis (FTD) is the difference between BCF and TF. FTD will be maximized if BCF is high and TF is low (Yoon et al 2006). FTD values can be seen in Table 3. The mean FTD value of Pb at the roots for both sites ranges from 0.780±0.443 to 0.962±0.188, and in leaves ranges from 0.326±0.137 to 0.741±0.085. The mean FTD value of Cd at roots for both sites ranged from 0.642±0.442 to 1.094±0.083 and in leaves ranged from 0.558±0.524 to 0.765±0.106. These values are not much different between Pb and Cd, so it can be concluded that seagrass *T. hemprichii* can remediate both Pb and Cd in a waters.

Table 3
FTD value of heavy metals Pb and Cd on roots and leaves of *T. hemprichii* seagrass in Poka and Suli waters

Tissues	*Station*	*Poka*		*Suli*	
		Pb	*Cd*	*Pb*	*Cd*
Roots	St 1	1.095	1.153	1.093	0.954
	St 2	0.829	1.036	0.466	0.329
	Mean	0.962±0.188	1.094±0.083	0.780±0.443	0.642±0.442
Leaves	St 1	0.681	0.690	0.423	0.929
	St 2	0.801	0.840	0.229	0.188
	Mean	0.741±0.085	0.765±0.106	0.326±0.137	0.558±0.524

Conclusions. The content of Pb and Cd in sediments was higher than that of water columns in both Poka and Suli waters. The content of Pb and Cd was higher at Poka than Suli both in the water column and the sediment

The accumulation of Pb and Cd in *T. hemprichii* was higher at Poka than Suli. The accumulation of the two heavy metals was consistently higher at the root followed by the leaves and rhizome (root > leaf > rhizome). Seagrass *T. hemprichii* has the capability of being an accumulator and potentially as a phytoremidiator of Pb and Cd in marine waters.

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References

Ambo Rappe R., 2008 Heavy metals accumulation and possible translocation in seagrass, *Zostera capricorni* Aschers. Torani 18(2):136-147.

Baker A. J. M., 1981 Accumulators and excluders - strategies in the response of plants to heavy metals. Journal of Plant Nutrition 3(1-4):643-654.

Baker A. J. M., Brooks R. R., 1989 Terrestrial higher plants which hyperaccumulate metallic elements - a review of their distribution, ecology, and phytochemistry. Biorecovery 1:81-126.

Connell D. W., Miller G. J., 1984 Chemistry and ecotoxicology of pollution. Wiley, New York, 464 pp.

Dahuri R., 2003 [Marine biodiversity. Sustainable development asset of Indonesia]. Gramedia Pustaka Utama, Jakarta, pp. 38-52. [in Indonesian]

Guilizzoni P., 1991 The role of heavy metals and toxic materials in the physiological ecology of submersed macrophytes. Aquatic Botany 41:87-109.

Herawati E. Y., 2008 [Seagrass (*Cymodocea rotundata*, *Thalassia hemprichii* and *Enhalus acoroides*) as a bioindicator of lead heavy metal (Pb) in East Java coastal water]. PhD thesis, Ilmu Pertanian, Program Pascasarjana, UB Malang, 226 pp. [in Indonesian]

Lakitan B., 2007 [The basic of plant physiology]. PT Raja Grafindo Persada, Jakarta, 203 pp. [in Indonesian]

Lewis M. A., Dantin D. D., Chancy C. A., Abel K. C., Lewis C. G., 2007 Florida seagrass habitat evaluation: a comparative survey for chemical quality. Environmental Pollution 146:206-218.

Llagostera I., Perez M., Romero R., 2011 Trace metal content in the seagrass *Cymodocea nodosa*: differential accumulation in plant organs. Aquatic Botany 95:124-128.

Ma L. Q., Komar K. M., Tu C., Zhang W., Cai Y., Kennelley E. D., 2006 A fern that hyperaccumulates arsenic. Nature 409:579.

Male Y. T., Sunarti, Nunumete N., 2014 [Analisys of lead (Pb) and chromium (Cr) content in the root of seagrass (*Enhalus acoroides*) in water of Waai and Tulehu village central Maluku regency]. Ind J Chem Res1:65-71. [in Indonesian]

Menteri Negara Lingkungan Hidup, 2004 [Decree of State Minister of Environment Number: 51 Year 2004 about quality standard of sea water]. Kementerian Lingkungan Hidup, Jakarta, pp. 1489-1498. [in Indonesian]

Palar H., 2008 [Pollution and heavy metal toxicology]. PT Rineka Cipta, Jakarta, 152 pp. [in Indonesian]

Rochyatun E., Rozak A., 2007 [Monitoring of heavy metal content in sediments in the waters of Jakarta Bay]. Makara, Sains 11(1):28-36. [in Indonesian]

Said I., Jalaludin M. N., Upe A., Wahab A. W., 2009 [Determination of heavy metal Cr and Pb concentrations in estuary sediment of Matangpondo River Palu]. Jurnal Chemica 10(2):40-47. [in Indonesian]

Sugiyanto R. A. N., Yona D., Kasitowati R. D., 2016 [Analysis of heavy metal content of lead (Pb) and cadmium (Cd) on seagrass *Enhalus acoroides* as phytoremediation agent at Paciran beach, Lamongan]. Prosiding Seminar Nasional Perikanan dan Kelautan VI Fakultas Perikanan dan Ilmu Kelautan, Universitas Brawijaya, Malang, pp. 449-455. [in Indonesian]

Tomascik T., Mah A. J., Nontji A., Moosa M. K., 1997 The ecology of the Indonesian seas. Vol VIII, Part II. Periplus edition (HK) Ltd. Singapore, pp. 829-900.

Tupan C. I., Herawati E. Y., Arfiati D., Aulanni'am, 2014 Profile of lead (Pb) heavy metal in water, sediment and seagrass (Thalassia hemprichii) in Ambon Island, Maluku, Indonesia. Journal of Biodiversity and Environmental Sciences 5(4):65-73.

Tupan C. I., Azrianingsih R., 2016 Accumulation and deposition of lead heavy metal in the tissues of roots, rhizomes and leaves of seagrass *Thalassia hemprichii* (Monocotyledoneae, Hydrocharitaceae). AACL Bioflux 9(3):580-589

Willson J. G., 1988 The biology of estuarine management. St. Edmundsbury Press Ltd., Suffolk, Great Britain, 204 pp.

Wulan S. P., Thamrin, Amin B., 2013 [Concentration, distribution and correlation between heavy metals of Pb, Cr and Zn in water and sediments on Siak River waters near the harbor of Indah Kiat Pulp and Paper Corporation, Perawang - Riau Province]. Pusat Penelitian Lingkungan Hidup, Universitas Riau, 21 pp. [in Indonesian]

Yoon J., Cao X., Zhou X., Ma L. Q., 2006 Accumulation of Pb, Cu and Zn in native plants growing on a contaminated Florida site. Science of the Total Environment 368(2-3):456-464.

Zieman J. C., 1975 Seasonal variation of turtle grass, *Thalassia testudinum* König, with reference to temperature and salinity effects. Aquatic Botany 1(2):107-123.

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