Potency of *Acanthus ilicifolius* as phytoremediation agent against copper pollution in Jagir River estuary, Wonorejo Village, Surabaya, Indonesia

[1]Salmana Wahwakhi, [2]Cecep Kusmana, [3]Dyah Iswantini

[1] Study Program of Natural Resource and Environmental Management, Post Graduate Program of Bogor Agricultural University, Bogor, Indonesia; [2] Department of Silviculture, Faculty of Forestry, Bogor Agricultural University (IPB), Bogor, Indonesia; [3] Department of Chemistry, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University (IPB), Bogor, Indonesia. Corresponding author: C. Kusmana, ckmangrove@gmail.com

Abstract. Estuary of the River Jagir is a gathering place of various pollutants from human activity in Surabaya. To reduce the various pollutants in the area, it can use phytoremediation technique with mangrove ecosystem. Nowadays, many mangroves can be utilized as phytoremediation agents; however its utilization is still limited on the tree-type which needs a long time to grow. In using mangroves for phytoremediation agents, *Acanthus ilicifolius* that thrives in the estuary of the River Jagir can be utilized. It is thrived in the Jagir River estuary and known as herbaceous plants which its growth process does not require a long time. This study aimed to analyze potency of *A. ilicifolius* plant as phytoremediation agents for Cu. Applications of AAS (Atomic Absorption Spectrophotometric) was used in this study. The results at the study site revealed Cu in water at station 1 of <0.004 mg L^{-1}, meanwhile at station 2 and station 3 was 0.05 mg L^{-1}. Cu in sediments has an average of 44.73 mg L^{-1}; in roots has an average of 20.68 mg L^{-1}; in stem has an average of 8.51 mg L^{-1}; and in leaves has an average of 5.75 mg L^{-1}. Results showed that *A. ilicifolius* can be used as phytoremediation agent for Cu and it has the best potential at the root within a fitostabilization mechanism. As for the conservation of *A. ilicifolius*, can be used “in situ” and “ex-situ” cultivation.

Key Words: bio-concentration factor, conservation, mangrove, phytotechnology, translocation factor.

Introduction. Currently, water pollution is such a serious damage which shows very diverse symptoms. One of the pollutants that become the concern and the center attention in various circles of society because of its toxic nature are heavy metals. Mills et al (1985) in his observations explained that Cu, Pb, and Zn are the three most dominant metals in waters. As for the mentioned three metals, the toxicity of Cu through LC_{50} for 96 hours indicates that Cu is more toxic than Pb and Zn for aquatic organisms and its toxicity value resides after Hg metal (Palar 2012).

Coastal areas are vulnerable toward pollution because the area is a place for toxic materials gathered, produced from human activities on land and oceans. Wonorejo Village, Rungkut Sub-district, Surabaya City, is one of the coastal areas in Indonesia which is the estuary of Jagir River. It is known as a disposal place of toxic materials such as Cu. In 2016, the concentration of Cu is in the second ranks after the Pb which is 51.62 mg L^{-1} found in the sediment at the estuary of the Jagir River. The Cu concentration was higher when compared with the Fitriyah et al (2013) study at the same location of 41.9 mg L^{-1}. As the Cu concentration is high in the region, it should be reduced immediately as they may endanger the survival of aquatic organisms. The remediation methods can be used as an effort to reduce the concentration of Cu.

Remediation is an action which can be applied to restore a contaminated area. One of the remediation techniques is phytoremediation which is known to be cost-efficient in its application in the environment and has the advantage of its aesthetic value

(Purwani 2010). Phytoremediation is the utilization of green plants for the waste removal and waste control, especially for the hazardous waste like the heavy metals (McCutcheon & Jergensen 2008). The mangrove ecosystem is a coastal ecosystem that has been known to reduce pollutants and be used as a phytoremediation plant in coastal areas. *Avicennia marina, Ceriops tagal, Rhizophora apiculata, R. mucronata*, and *Sonneratia caseolaris* are some species of mangrove ecosystems that can be utilized for phytoremediation (Handayani 2006; Kamaruzzaman et al 2009; Hamzah & Setiawan 2010; Heriyanto & Subiandono 2011; Hamzah & Pancawati 2013). Whereas, those species still focus on the utilization of mangroves, especially in tree species which application takes a long time to grow.

A. ilicifolius is one of the mangrove species belonging to herbaceous plants. Its growth is relatively fast and it is also easy to be cultivated in the coastal areas. In addition, the merit of *A. ilicifolius* in coastal areas have not been widely known and explored yet, especially about their environmental benefits. According to Irawanto et al (2015), *A. ilicifolius* is known to be used as a phytotechnology plant. Phytotechnology is a concept that utilizes the role of plants as a natural technology to solve the environmental problems. Plants that belong to phytotechnology can be developed for phytoremediation actions. Based on the explanation above, this research aims to determine the potential of *A. ilicifolius* plant as a Cu phytoremediation agent at the Jagir River estuary, Wonorejo Village.

Material and Method

Description of the study sites. This research was conducted at the estuary of the Jagir River, Wonorejo Village, Surabaya, East Java, Indonesia (Figure 1) in November 2016. Geographically, the estuary of the Jagir River is located between 7°18'21.73" and 7°18'20.12" S as well 112°49'14.30" and 112°50'35.81" E. Based on Monographic Data from July-September (2014), Wonorejo Village is situated at 2.5 m above sea level, while the rainfall is 13,300 mm $year^{-1}$ and the average air temperature reaches $32^{o}C$. The northern boundary of Wonorejo is Wonokromo River or well known as Jagir River, the east of Madura Strait, the south of Medokanayu, and the west of Penjaringansari Village.

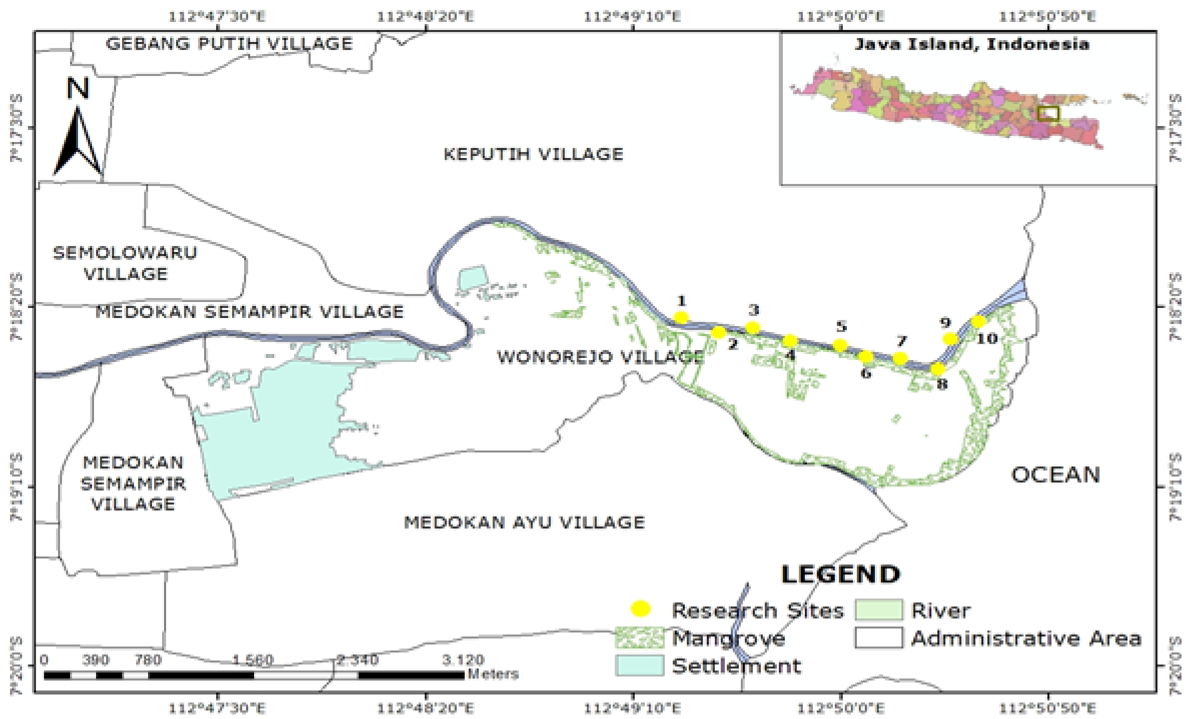

Figure 1. Research sites at estuary of the Jagir River, Wonorejo Village, Surabaya, Indonesia.

Methods. There were 10 stations for taking the samples with a distance between each station around ±300 m. At each location directly measurements were carried out and samples were taken for laboratory analysis. The direct measurements includes environmental parameters such as temperature, pH, salinity, and DO (dissolved oxygen). Concerning the measurement of the environmental parameters there were 3 repetitions with an interval of ±10 minutes at each station.

Beside the direct measurements, there were harvested several samples at the study sites for analysis in the laboratory that are water sampling, sediments, and plant parts *A. ilicifolius* (roots, stems, and leaves). Water sampling was performed by inserting a water sampler at half of water depth calculated for the total depth of the estuary of Jagir River (Roosmini et al 2010). The retrieval has been done as much as 3 times repetition which is then composed. After composting, the next was adding the sample with 3 mL of HNO_3 solution for 1 L (APHA / AWWA / WEF Standard Methods 20th ed 2001) and then the samples were analyzed in the laboratory. The sediment sampling was taken by using ekman grab with at depth of 0-10 cm at each station with 3 repetitions in different places. Next, the samples were composited and were analyzed in the laboratory. Sampling of *A. Ilicifolius* plant parts was done by harvesting plants randomly at each station which then was separated in root, stems, and leaves. The parts of the plant that has been separated were then taken to the laboratory for further analysis.

Data analysis. The data obtained was compared with the predefined quality standard. There are three quality standards used in this study, which are: Government Regulation Number 82 of 2001 on Water Quality Management and Water Pollution Control, Decree of the Minister of Environment Number 51 of 2004 concerning Water Quality Standard Appendix II (Marine Tourism) and Appendix III (Marine Biota), and ANZECC (Australian and New Zealand Guidelines for Fresh and Marine Water Quality) Volume 1 Year 2000. In addition, for the comparison with the established quality standard, the phytoremediation calculations were performed on *A. ilicifolius* plants.

There are three steps to get phytoremediation value from *A. ilicifolius* plants in phytoremediation calculation. The first stage is the calculation of BCF (Bio-Concentration Factor) with the formula (Machado et al 2002):

$$\text{BCF} = \frac{\text{[Heavy Metal Cu] Plants}}{\text{[Heavy Metal Cu] Sediment}} \qquad (1)$$

According to Remesicova & Kiraly (2016), there are three categories on the calculation of BCF, those are accumulator (BCF>1), indicator (BCF = 1), and excluder (BCF<1). The next step is the calculation of TF (Translocation Factor) which has the formula (MacFarlane et al 2007):

$$\text{TF} = \frac{\text{[Heavy Metal Cu] Stem or Leaf}}{\text{[Heavy Metal Cu] Root}} \qquad (2)$$

Majid et al (2014) explains that the value of TF obtained from equation 2 can determine the mechanisms occurring in *A. ilicifolius* plants. The first is the phitoextraction mechanism. It is classified if the value of TF>1. The second is the phytostabilization mechanism. It is classified as phytostabilization if the value of TF<1. The last stage is phytoremediation calculation. It is obtained from the difference between BCF value and TF value. Phytoremediation will be maximal if the BCF value is higher than the value of TF (Chaney et al 1995). The formula for phytoremediation can is:

$$\text{Phytoremediation} = \text{BCF} - \text{TF} \qquad (3)$$

Results

Environmental parameter. The results of the environmental parameters measurements including temperature, pH, salinity, and DO (Table 1) at the estuary of the Jagir River in Wonorejo show that the average temperature ranges between 30.2°C and 30.6°C while the pH ranges from 7.4 to 7.8. The average salinity ranges from 1.0 to 2.7 g L^{-1} and the DO was in the range of 2.6 and 4.4 mg L^{-1}.

Table 1
The environmental parameters at the estuary of the River Jagir, Wonorejo Village, Surabaya, Indonesia

Station	*Environmental Parameters*			
	Temperature (°C)	*pH*	*Salinity (gr L^{-1})*	*DO (mg L^{-1})*
1	30.3 ± 0.39	7.5 ± 0.12	1.0 ± 0.00	2.6 ± 0.12*
2	30.2 ± 0.14	7.4 ± 0.25	1.3 ± 0.47	3.0 ± 0.12*
3	30.3 ± 0.14	7.6 ± 0.29	1.0 ± 0.00	2.8 ± 0.19*
4	30.3 ± 0.16	7.6 ± 0.14	1.7 ± 0.47	3.0 ± 0.05*
5	30.3 ± 0.08	7.5 ± 0.05	1.0 ± 0.00	3.5 ± 0.17*
6	30.6 ± 0.09	7.6 ± 0.09	2.0 ± 0.00	2.8 ± 0.08*
7	30.3 ± 0.08	7.6 ± 0.14	1.3 ± 0.47	3.7 ± 0.17*
8	30.4 ± 0.05	7.7 ± 0.17	2.7 ± 0.47	3.2 ± 0.25*
9	30.5 ± 0.00	7.7 ± 0.09	2.3 ± 0.47	3.4 ± 0.40*
10	30.2 ± 0.05	7.8 ± 0.38	2.3 ± 0.47	4.4 ± 0.05*
Average	30.3 ± 0.12	7.6 ± 0.17	1.7 ± 0.47	3.2 ± 0.16*

*: Not in accordance with the quality standard of Ministerial Decree Number 51 of 2004 Appendix II and Appendix III.

Cu heavy metal concentrations. The result of Cu analysis (Table 2) showed that the Cu composition at estuary of the Jagir River is in a poor condition for biota living. However, the sediment concentration of Cu metals condition was relatively normal or below the quality standard at 44.73 mg L^{-1}. The Cu concentrations of *A. ilcifolius* plant showed a concentration metal in the roots ranging from 12.00 to 29.63 mg L^{-1}, the stem section between 3.1 to 12.87 mg L^{-1}, and the leaf ranged from 3.41 to 7,26 mg L^{-1}.

Table 2
Cu metal concentration of water, sediment, roots, stems, and leaves *A. ilcifolius* at the estuary of Jagir River, Wonorejo Village, Surabaya, Indonesia

Station	*Cu concentration (mg L^{-1})*				
	Water	*Sediment*	*Root*	*Stem*	*Leaf*
1		35.65	29.63	7.37	3.41
2	-	41.36	20.54	5.84	3.97
3		46.88	12.00	3.81	5.08
4		43.92	12.79	11.50	6.63
5	0.05*	49.08	15.97	9.89	6.98
6		42.54	26.35	11.39	7.26
7		45.37	21.64	9.31	6.22
8		48.96	21.36	6.45	4.14
9	0.05*	46.46	28.87	12.87	7.12
10		47.10	15.67	6.72	6.76
Average	-	44.73	20.28	8.51	5.75

-: not detected; *: exceeding the quality standard of Government Regulation Number 82 of 2001 and Ministerial Decree Number 51 of 2004 Appendix III.

The potency of A. ilicifolius as a Cu phytoremediation plant. The value of BCF and TF of the *A. ilcifolius* plant may indicate the potential as a phytoremediation plant. The calculation results of BCF, TF, and phytoremediation (Table 3) for Cu at the of Jagir River estuary, Wonorejo Village, Surabaya, showed that *A. ilcifolius* plant has a potency to become a phytoremediation plant. The best potential of it is in the root with an average phytoremediation value of 0.17 at the study site.

Table 3

The potency of *A. ilcifolius* as phytoremediation of Cu at the estuary of Jagir River, Wonorejo Village, Surabaya, Indonesia

Station	*BCF*		*TF*	*Phytoremediation*	
	Root	*Leaf*		*Root*	*Leaf*
1	0.83	0.10	0.11	0.72	-0.02
2	0.50	0.10	0.19	0.30	-0.10
3	0.28	0.11	0.39	-0.11	-0.28
4	0.31	0.15	0.48	-0.17	-0.33
5	0.33	0.14	0.44	-0.11	-0.29
6	0.62	0.17	0.28	0.34	-0.10
7	0.48	0.14	0.29	0.19	-0.15
8	0.44	0.08	0.19	0.24	-0.11
9	0.62	0.15	0.25	0.37	-0.09
10	0.33	0.14	0.43	-0.10	-0.29
Average	0.47	0.13	0.31	0.17	-0.18

BCF: Bio-Concentration Factor; TF: Translocation Factor.

Discussion

The waters quality of the Jagir River estuary. Temperature, salinity, pH, and DO are some environmental parameters that may affect the quality of water, the presence of heavy metals, and the living organisms in aquatic environments. Temperature is a very important physical factor since temperature can affect the life processes. The temperature of Jagir River estuary, Wonorejo (Table 1) is still relatively normal when it is compared with the predetermined quality standard, in which the average temperature is 30.3^{o}C. Naturally, the temperatures in Indonesian water ranges from 28 to 32^{o}C (Rustam & Prabawa 2015). According to the research conducted by Fitriyah et al (2013) in March to April 2013 in Jagir River, the water temperature was of 30^{o}C. Meanwhile, Hadiputra & Damayanti (2013) researches conducted in May, showed a water temperature at that location ranging from 27 to 31^{o}C. In March to June 2015, Sari et al (2017) noted that the temperature at the estuary of Jagir River ranged from 29.91 to 31.82^{o}C. The temperature is not much different if it is compared with the existing research. The water temperature can change over time. Some of the things that may affect the temperature are rainfall, wind speed, evaporation, solar intensity, air temperature, and humidity (Sanusi & Putranto 2009). Moreover, the temperature will also affect the toxicity of heavy metals. As the temperature increases, the toxicity of heavy metals will be higher (Hutagalung 1984).

The pH level at the estuary of the Jagir River has an average of 7.6 (Table 1) and is categorized in the highly productive waters (7.5 to 8.5). If it is compared with the existing quality standards, the waters at the estuary of the River Jagir will be still normal. The research conducted by Hadiputra & Damayanti (2013) from March to May 2013, revealed that the pH was in the range of 6.8 to 8. Meanwhile, Wahwakhi et al (2015) reported a pH of the Jagir River estuary of 8.37. From those studies, it is concluded that the pH from the last few years was in the range of 6.8-8.37, which is considered a normal condition. The pH difference in the recent years can be affected by several factors such as photosynthetic activity and respiration of living organisms from the water (Izzati 2008). The toxicity of heavy metals is also influenced by the magnitude of pH (Palar 2012). The lower is the pH of the water, the heavy metal toxicity will be higher (Deri et al 2013). In addition, besides effecting on heavy metals, pH changing will also have an impact on mangrove growth. Thus, the water will be less productive and not suitable for mangrove growth at pH 5.5 to 6.5 and >8.5.

Concerning the salinity, the average value of the Jagir River estuary (Table 1) was 1.7 g L^{-1}. In general, the water of the Jagir River estuary belongs to oligohaline or brackish waters (0.21 to 1.84 gr L^{-1}) (Roberts 2012). From the natural salinity point of view, salinity between 5 to 35 gr L^{-1} (Rangkuti & Tarigan 2014), such as the water of River Jagir estuary is under natural salinity. However, when it is compared with the predetermined quality standard, the salinity condition is still normal, especially for mangrove growth. A study conducted by Sari et al (2017) from March to June 2015 showed that salinity at the estuary of Jagir River was higher (5.26-11.95 gr L^{-1}). This salinity difference occurs since there are freshwater and seawater inputs that may affect the amount of salinity at the estuary of Jagir River. Salinity is influenced by several factors such as rainfall, river water input, evaporation, and water circulation (Kalangi et al 2013). In heavy metals, decreased salinity causes heavy metals to be found more in free ions which would cause heavy metals to enter the biota more easily (Syakti et al 2012). Moreover, the effect on plants in case of salinity changes is that plant growth will be impaired (Keliat et al 2016).

The next environmental parameter is DO. The average magnitude of DO at the estuary of Jagir River (Table 1) is 3.2 mg L^{-1}. The quantity of DO is below the standard of predefined quality. Low DO concentrations can occur due to the high activity of aquatic biota at the Jagir River estuary. According to Muzaki et al (2012) in a mud-proof environment, since the substrate at the Jagir River estuary is mud, it tends to have a lower DO concentration when compared to other substrates such as on sand substrate. If it is compared with the research of Fitriyah et al (2013) with the amount of DO 4.55 mg L^{-1}, then the amount of DO is not much different. The factors that affect the DO are the mixing of water masses, waste in the waters, the process of respiration and photosynthesis (Nontji 2005). The low water DO concentration can cause stress of aquatic biota so as to increase the respiration. Thus, it can increase the respiration in biota. It will increase bio concentration and toxicity of heavy metals in the biota (Syakti et al 2012). In water, DO is used by aquatic organisms and mangroves for the respiration (Patty et al 2015).

Cu concentration in the estuary environment of Jagir River. Cu in estuary environment can be present in the waters, sediments, and living organisms. The study subject of the present study is *A. ilicifolius*. The presence of high concentrations Cu in waters can be a threat to aquatic organisms. This is because dissolved heavy metals will be more easily absorbed by aquatic organisms. When it is compared to the quality standard of Government Regulation Number 82 of 2001 and Ministerial Decree Number 51 of 2004 Appendix III for biota, Cu at estuary of Jagir River at station two and three (Table 3) of 0.05 mg L^{-1} has exceeded the standard quality limit. A previous research upon Jagir River estuary conducted by Sari et al (2017) showed that Cu concentration was higher, 0.071 to 0.091 mg L^{-1}. The concentration of Cu in the waters of the Jagir River estuary is actually lower than that of Sari et al (2017) but still relatively categorized as high when compared with the applicable quality standards in Indonesia. The differences between high and low concentrations of Cu can be affected by waste disposal, waste treatment before entering the waters, as well as by seasons (Purnomo & Muchyiddin 2007). Maslukah (2013) adds that the presence of heavy metals in the estuary is influenced by dilution and sedimentation processes whose processes are influenced by the flow speed and water depth.

The presence of Cu in sediments can be used as an indicator for pollution because the sediment is a sink site (Arifin & Fadhlina 2009). Overall, the Cu concentrations in sediment (Table 2) have an average of 44.73 mg L^{-1}. Based on the standard of ANZECC (Australian and New Zealand Guidelines for Fresh and Marine Water Quality), Cu concentrations at the research sites are still relatively low. Since the State of Indonesia still does not have a standard quality for heavy metals, the ANZECC is used as a quality standard. The research conducted by Mulyadi et al (2009) in sedimentary waters of the Wonorejo River or Jagir River in 2009, revealed that the Cu concentrations reached an average of 3.19 mg L^{-1}. The reported Cu concentration was much lower compared to the averagethe present study. It happens because of the increasing presence of human activity whit daily Cu use such as materials for biocides so widely used for pesticides, pipe-making materials, catalysts in the chemical industry, as a means of making kitchen appliances, and good conductors so widely used for cables (Rompas 2010). Haeruddin et al (2005) states that metal concentrations in sediments typically reach 3-5 times higher values than those which can recorded in water. The heavy metals present in the waters will be removed from the aquatic bodies through several processes such as precipitation, adsorption and absorption by aquatic organisms (Makmur et al 2013).

In Cu accumulation, the root of *A. ilicifolius* is able to accumulate the highest amount (Table 3) with an average of 20.69 mg L^{-1} and the smallest Cu accumulation was found in the leaf with an average of 5.75 mg L^{-1}. The high concentration of Cu in the roots is occurred due to the location of the roots which is close to the sediment. In addition, the high concentration of Cu at the roots causes a lower concentration in the leaves. It happens since Cu is firstly used by roots and stems before it reaches to the leaves. Moreover, Cu is a micro nutrient for plants. The research conducted by Pahalawattaarachchi et al (2009) in *R. mucronata* concerning Cu accumulation also shows that the concentration of Cu in roots is higher than that of leaves. Plants require Cu metal to be used as a micro nutrient that has several functions as an enzyme which increase the formation of vitamin A, very important at the beginning of the growth because if from the beginning the plant has Cu deficiency it will have pale and dry leaves so that the process of photosynthesis is disturbed and can cause death of plants (Sudarmi 2013). The presence of Cu in a plant must have a threshold value so that it does not interfere with its physiological function. According to Heriyanto & Subiandono (2011), Cu concentration of 1 mg L^{-1} can interfere in the process of a plant such as photosynthesis and respiration process.

The potency of phytoremediation of Cu metal at A. ilcifolius of Jagir River estuary. The phytoremediation value of a plant is obtained from the difference between its BCF and TF values. The average of BCF values in the root and the leaf of *A. ilicifolius* sections at Jagir River estuary (Table 3) were 0.47 and 0.13, respectively. The high value of BCF is found at the root rather than leaves; this proves that the best accumulation of *A. ilicifolius* lies at its root. There are three categories of plants, concerning the absorption of pollutants; namely accumulators, indicators, excluders (Baker 1981). As for the value of BCF in roots and leaves of *A. ilicifolius* indicate that the plant belongs to the excluder category. Excluder plants are those that restrict the removal or transport of metals through their roots by depositing the metal (Mogopodi et al 2011). The value of a BCF in plants can be influenced by several factors such as species, metal type, and environmental conditions (Lotfinasabasl & Gunale 2012).

The TF values found in *A. ilicifolius* at the estuary of Jagir River (Table 3) had an average of 0.31. Thus, the mechanism occurring in *A. ilicifolius* is classified in the as phytostabilizatior category by Majid et al (2014). Phytostabilization is a mechanism that reduces the mobility and bioavailability of pollutants such as heavy metals in the environment to prevent their migration in the food chain (Ali et al 2013). The mechanism of phytostabilization is able to occur through several processes such as sorption, complexion, precipitation, or reduced metal valence. This mechanism can be used on Cu, Zn, Pb, Cd, As, and Cr metals (Henry 2000). There are several advantages and disadvantages to this mechanism. The advantages are 1) the land taking is not needed; 2) it is cheaper cost and less disruptive than other mechanisms because this mechanism makes heavy metals immobile in the environment; 3) it can improve the restoration of ecosystem; and 4) the disposal of biomass or hazardous materials is not necessary. However, the lack of this mechanism are 1) the contamination are persisted; 2) this mechanism is only a temporary measure; 3) the uptake of plants against the metal to the top of the soil should be avoided as there can be biomagnification through the food chain; 4) vegetation requires extensive fertilization; and 5) the direct contaminated root must be monitored (EPA 2000). According to MacFarlane et al (2003) mangroves have a special physiological mechanism that actively reduces the absorption of heavy metals when metals on the substrate are in high concentrations.

The next steps after knowing the value of BCF and TF of *A. ilicifolius* is phytoremediation calculations. The average of the phytoremediation value (Table 3) obtained in the present study at the roots was 0.17 and in the leaves -0.18. According to Yoon et al (2006), a plant that has the good potential as phytoremediation agent is that which has a higher BCF value compared to the TF value. As for the phytoremediation, the best part of *A. ilicifolius* concerning the Cu is the root with its mechanism of phytostabilization. This mechanism is used to reduce the movement of pollutants so that pollutants cannot migrate freely. This mechanism result a medium to low contaminated environment (Hamzah & Setiawan 2010). Susana & Suswati (2013) states that a successful phytoremediation is not only affected by the ability to accumulate the high pollutants, but it must also have a large biomass. Up to now, phytoremediation technology is continuously in the perfection stage because there are some disadvantages such as the time required and the possibility of contamination the food chain with heavy metals (Moenir 2010).

Conservation of A. ilicifolius plants at the estuary of the Jagir River. In the utilization of *A. ilicifolius* as phytoremediation agent, the sustainable utilization is required to do for maintaining the existence the species at Jagir River estuary. Thus, preserving *A. ilicifolius* at the estuary of the River Jagir can be done by conserving the plant itself. The conservation of *A. ilicifolius* in the research location is possible using two ways that are by "ex situ" or by "in situ". Ex situ conservation is performed by cultivating the *A. ilicifolius* outside of its habitat. The aims of conducting the cultivation in outside is to make the *A. ilicifolius* become a genetic resource. Afterwards, that genetic resource can ensure the sustainability of the resources of *A. ilicifolius* and can be planted on contaminated areas of Cu but still have the same ecological properties like in the study sites. According to Irawanto et al (2015), *A. ilicifolius* can grow in clusters and are found mostly along the edges of estuaries, marshy lands, and mangrove forests that grow close to the shore. *A. ilicifolius* is a true mangrove that is also commonly found along the fresh water. This plant can grow on all types of soil especially in muddy areas in the edge of the river. The growing zones are in the middle zone up to the upper zone that reaches the estuary. This plant can grow on the shade of other plants until it is fully opened. *A. ilicifolius* will prefer to grow in the areas where the water input is hihger. According to Joshi & Ghose (2003), *A. ilicifolius* is relatively insensitive towards the salinity changes.

In the in situ conservation, the utilization of *A. ilicifolius* in the study site requires the existence of harvesting governance of *A. ilicifolius* and for its utilization is directed to the sustainable harvesting. Therefore, the existence of sustainable *A. ilicifolius* management in the site is needed. While in this purpose, there is no data available about the proper age for harvesting *A. ilicifolius*. If data on the appropriate age for harvesting *A. ilicifolius* are available, the harvesting cycle can be determined so as not to result in the destruction of the *A. ilicifolius* ecosystem at the study site. Currently, the available data is still time and growth of *A. ilicifolius*. According to Irawanto et al (2015), by vegetative way (cuttings) *A. ilicifolius* can grow ±30 cm high within 3 months and by generative way (seed) can grow ±20 cm high within 6 months.

Conclusions. Concerning the environmental parameters located at the estuary of the Jagir River, Wonorejo Village, Surabaya the temperature has an average of 30.3^{o}C, the average pH of 7.6, the average recorded salinity was 1.7 gr L^{-1}, and the average DO 3.2 mg L^{-1}. The concentration of Cu in the waters of Jagir River at station one is <0.004 mg L^{-1} whereas in stations two and three have the same 0.05 mg L^{-1}. The Cu concentrations of *A. ilicifolius* roots, stems, and leaves have a mean of 20.68 mg L^{-1}, 8.51 mg L^{-1}, and 5.75 mg L^{-1}, respectively. The potential of phytoremediation of Cu in *A. ilicifolius* plants in the roots is 0.17 and in leaves is -0.18. This value indicates that *A. ilicifolius* can be used as phytoremediation agents with the best potential found at the root with a fitostabilisation mechanism. At the study site, conservation of *A. Ilicifolius* can be performed through "in situ" and "exsitu" cultivation.

Acknowledgements. We thank the Agriculture Official of Surabaya that has given permission to do research at estuary of Jagir River, Wonorejo Village, Surabaya. We also thank the field workers who helped in sampling.

References

Ali H., Khan E., Sajad M. A., 2013 Phytoremediation of heavy metals-concepts and applications. Chemosphere 91:869-88.

Arifin Z., Fadhlina D., 2009 Heavy metal fractionation of Pb, Cd, Cu, and Zn in sediments and bioavailability for biota in Bay Waters of Jakarta. Marine Science 14(1):27-32.

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.

Chaney R., Li Y. M., Green C., 1995 Potential use of metal hyperaccumulators. Mining Environmental Management 3:9-11.

Deri, Emiyarti, Afu L. O. A., 2013. Heavy metal accumulation of lead (Pb) of mangrove *Avicennia marina* roots in Kendari Bay. Journal of Mina Laut Indonesia 1(1):38-48.

Fitriyah A. W., Utomo Y., Kusumaningrum I. K., 2013 [Analysis of copper content (Cu) at water and sediment in Surabaya River]. [In Indonesian]. Available on-line at: http://jurnal-online.um.ac.id/data/artikel/artikel532103F06B3FD068E81050F2C917DD70.pdf

Hadiputra M. A., Damayanti A., 2013 The potential study of makrozoobentos as a bioindicator polluting of copper heavy metal (Cu) in the area mangrove Wonorejo ecosystem, east coast Surabaya. Proceeding XVIIIth National Technology Management Symposium, Surabaya, pp. 1-8.

Haeruddin, Sanusi H. S., Soedharma D., Supriyono E., Boer M., 2005 Distribution of metal in sediment at Wakak-Plumbon Estuary, Semarang, Central Java. Aquatic Sciences and Fisheries Indonesia 12(2):113-119.

Hamzah F., Pancawati Y., 2013 Phytoremidiation of heavy metals using mangroves. Marine Science 18(4):203-212.

Hamzah F., Setiawan A., 2010 Accumulation of heavy metals Pb, Cu, and Zn in the mangrove forest of Muara Angke, North Jakarta. Tropical Marine Science and Technology 2(2):41-52.

Handayani T., 2006 Bioaccumulation of heavy metals in mangrove *Rhizophora mucronata* and *Avicennia marina* at estuary of Angke Jakarta. Journal of Environmental Engineering 7(3):266-270.

Henry J. R., 2000 [An overview of the phytoremediation of lead and mercury]. National Network of Environmental Management Studies, Washington, United State.

Heriyanto N. M., Subiandono E., 2011 Absorption of heavy metal pollutants (Hg, Pb and Cu) by mangrove species. Forest Research and Nature Conservation 8(2):177-188.

Hutagalung H. P., 1984 [Heavy metals in the marine environment]. Pewarta Oseana, Jakarta, Indonesia. [In Indonesian].

Irawanto R., Ayiyanti E. E., Hendrian R., 2015 Seaholly (*Acanthus ilicifolius*): Seed, germination and uses. Proceeding National Indonesian Biodiversity Community 1(5):1011-1018.

Izzati M., 2008 [Changes in dissolved oxygen concentration and pond water pH after addition of seaweed *Sargasssum plagyophyllum* and extracts]. Diponegoro University, Faculty of Science and Mathematics, Department of Biology, Anatomi Fisiologi, XVI(2):60-69. [In Indonesian].

Joshi H., Ghose M., 2003 Forest structure and species distribution along soil salinity and pH gradient in mangrove swamps of the Sundarbans. Tropical Ecology 44(2):197-206.

Kalangi P. N. I., Mandagi A., Masengi K. W. A., Luasunanung A., Pangalila F. P. T., Iwata M., 2013 Distribution of temperature and salinity in Manado Bay. Tropical of Fisheries and Marine 9(2):71-75.

Kamaruzzaman B. Y., Ong M. C., Jalal K. C. A., Shahbudin S., Nor O. M., 2009 Accumulation of lead and copper in *Rhizophora apiculata* from Setiu Mangrove Forest, Terengganu, Malaysia. Journal of Environmental Biology 30(5):821-824.

Keliat D. A., Basyuni M., Utomo B., 2016 [Effect of salinity on the growth and root development in mangrove *Rhizophora apiculata* blume seedlings]. Peronema Forestry Science Journal 5(4), pp. 1-12. [In Indonesian].

Lotfinasabasl S., Gunale V. R., 2012 Studies on heavy metals bioaccumulation potential of mangrove species, *Avicennia marina*. International Journal of Engineering Science and Technology 4(10):4411-4421.
MacFarlane G. R., Koller E. C., Blomberg S. P., 2007 Accumulation and partitioning of heavy metals in mangroves: a synthesis of field-based studies. Chemosphere 69:1454-1464.
MacFarlane G. R., Pulkownik A., Burchett M. D., 2003 Accumulation and distribution of heavy metals in the grey mangrove, *Avicennia marina* (Forsk.) Vierh.: biological indication potential. Environmental Pollution 123:139-151.
Machado W., Silva-Filho E. V., Oliveira R. R., Lacerda L. D., 2002 Trace metal retention in mangrove ecosystems in Guanabara Bay, SE Brazil. Marine Pollution Bulletin 44:1277-1280.
Majid S. N., Khwakaram A. I., Rasul G. A. M., Ahmed Z. H., 2014 Bioaccumulation, enrichment and translocation factors of some heavy metals in *Typha angustifolia* and *Phragmites australis* species growing along Qalyasan stream in Sulaimani city. Journal of Zankoy Sulaimani-Part A 16:93-109.
Makmur R., Emiyarti, Afu L. O. A., 2013 Heavy metal accumulation of lead (Pb) on sediment in mangrove area of Kendari Bay. Mina Laut Indonesia 2(6):47-58.
Maslukah L., 2013 Relationship between heavy metals concentrations Pb, Cd, Cu, Zn with organic materials and grain size in sediment in estuary of Banjir Kanal Barat, Semarang. Marina Oceanographic Bulletin 2:55-52.
McCutcheon S. C., Jergensen S. E., 2008 Phytoremediation. Ecological Engineering 2751-2766.
Mills W. B., Porcella D. B., Ungs M. J., Gherini S. A., Summers K. V., Mok L., Rupp G. L., Bowie G. L., Haith D. A., 1985 A screening procedure for toxic and conventional pollutants in surface and ground water-part i. U.S. Environmental Protection Agency, Athens, Georgia.
Moenir M., 2010 Phytoremediation study as an alternative to heavy metal restoration of the soil. Journal of Industrial Pollution Prevention Technology Research 1(2):115-123.
Mogopodi D., Mosetlha K., Nkoane B., Mmatli E., Torto N., Abegaz B., 2011 analytical strategies towards the study of metallophytes plants growing in Cu-Ni mining areas in Botswana. In: Handbook of phytoremediation. Golubev I. A. (ed), pp. 495-527.
Mulyadi E., Laksmono R., Aprianti D., 2009 Mangrove function as control of heavy metal pollutants. Journal of Environmental Engineering Sciences 1:33-40.
Muzaki F. K., Saptarini D., Kuswytasari N. D., Sulisetyono A., 2012 [Exploring Mangrove Surabaya]. ITS Pr, Surabaya, Indonesia. [In Indonesian].
Nontji A., 2005 [Marine archipelago]. Djambatan, Jakarta, Indonesia. [In Indonesian].
Pahalawattaarachchi V., Purushothaman C. S., Vennila A., 2009 Metal phytoremediation potential of *Rhizophora mucronata* (Lam.). Indian Journal of Marine Sciences 38(2):178-183.
Palar H., 2012 [Heavy metal pollution and toxicology]. PT. Rineka Cipta, Jakarta, Indonesia. [In Indonesian].
Patty S. I., Arfah H., Abdul M. S., 2015 [Nutrients (phosphate, nitrate), dissolved oxygen, and ph and they relation to productivity of Jikumerasa Waters, Buru Island]. Journal of Coastal and Tropical Seas 1(1):43-50. [In Indonesian].
Purnomo T., Muchyiddin, 2007 Lead content analysis (Pb) on milkfish (*Chanos chanos* Forsk.) in ponds of Gresik District. Neptune 14(1):68-77.
Purwani J., 2010 [Remediation of soil by using plant accumulator heavy metal akar wangi (*Vetiveria zizanioides* L.)]. pp. 287-303. Available on-line at: https://www.scribd.com/doc/155471441/Remediasi-Tanah-Dengan-Menggunakan-Tanaman-Akumulator Logam-Berat-Akar-Wangi. [In Indonesian].
Rangkuti D. Y. U., Tarigan A. P. M., 2014 Study of physical characteristics of Batang Natal River Estuary of Mandailing Natal, pp. 1-9. [In Indonesian]. Available on-line at: http://download.portalgaruda.org/article.php?article=141632&val=4146&title=STUDI%20KARAKTERISTIK%20FISIK%20MUARA%20SUNGAI%20BATANG%20NATAL%20KABUPATEN%20MANDAILING%20NATAL

Remesicova E., Kiraly A., 2016 Heavy metal contamination of mine area and their uptake by plants (tailing Pond Sedem Zien, Slovakia). Proceeding 1st Environmental Technology and Innovations Symposium, Ho Chi Minh, pp. 37-42.
Roberts R. J., 2012 Fish Pathology. Blackweel Publishing Ltd, Washington, United State America.
Rompas R. M., 2010 [Marine toxicology]. PT. Walaw Bengkulen, Jakarta, Indonesia. [In Indonesian].
Rosmini D., Andarani P., Nastiti A., 2010 Heavy metals (Cu and Cr) pollution from textile industry in surface water and sediment (Case study: Cikijing River, West Java, Indonesia). The 8th International Symposium on Southeast Asian Water Environment, October 24th-26th, 2010, Phuket, Thailand, 12 pp.
Rustam A., Prabawa F. Y., 2015 Quality of waters in Punai Coast and Tambak Coast of East Belitung. Segara 11(1):75-84.
Sanusi H. S., Putranto S., 2009 [Marine chemicals & pollution]. IPB Pr, Bogor, Indonesia. [in Indonesian].
Sari S. H. J., Kirana J. F. A., Guntur, 2017 Heavy metal content analysis Hg and Cu dissolved in Coastal of Wonorejo, East Coast Surabaya. Journal of Geography Education 22(1):1-9.
Sudarmi, 2013 The importance of micro nutrients for plant growth. Widyatama 22(2):178-183.
Susana R., Suswati D., 2013 Cadmium bioaccumulation and distribution in root and shoot of 3 crops of Brassicaceae: implication for phytoremediation. Human and Environmental Journal 20(2):221-228.
Syakti A. D., Hidayati N. V., Siregar A. S., 2012 [Sea pollution agent]. IPB Pr, Bogor, Indonesia. [In Indonesian].
Wahwakhi S., Iranawati F., Pratiwi D. C., 2015 Phytoremediation technology *Avicennia alba* in reducing plumbum at the Wonorejo Village, Surabaya. Proceeding Vth National Fisheries and Marine Symposium, Malang, pp. 464-471.
Yoon J., Cao X., Zhou Q., Ma L. Q., 2006 Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida Site. Science of the Total Environment 368:456-464.
*** ANZECC (Australian and New Zealand Environment and Conservation Council), 2000 [Australian and New Zealand Guidelines for fresh and marine water quality]. National Water Quality Management Strategy, Australian and New Zealand.
*** APHA (American Public Health Association), AWWA (American Water Works Association), WEF (Water Environment Federation), 2001 [Standard methods for the examination of water and wastewater 20th edition]. American Public Health Association, Washington DC.
*** Decree of the Minister of Environment, 2004 [Decree of the minister of environment of the republic of Indonesia number 51 of 2004 regarding the quality standard of sea water]. Minister of Environment, Jakarta, Indonesia. [In Indonesian].
*** EPA (Environmental Protection Agency), 2000 [Introduction to phytoremediation]. National Risk Management Research Laboratory, Cincinnati, Ohio.
*** Government Regulation, 2001 [Government regulation of the republic of Indonesia number 82 of 2001 regarding management of water quality and control of water pollution]. Government Regulation, Jakarta, Indonesia. [In Indonesian].
*** Monographic, 2014 Monographic data of Wonorejo Village report 2014. Surabaya, Indonesia, 7 pp.

Received: 05 August 2017. Accepted: 30 September 2017. Published online: 13 October 2017.
Authors:
Salmana Wahwakhi, Post Graduate Program of Bogor Agricultural University, Study Program of Natural Resource and Environmental Management, Indonesia, Bogor 16680, e-mail: salmanawahwakhi@gmail.com
Cecep Kusmana, Bogor Agricultural University (IPB), Faculty of Forestry, Department of Silviculture, Indonesia, Bogor 16680, e-mail: ckmangrove@gmail.com
Dyah Iswantini, Bogor Agricultural University (IPB), Faculty of Mathematics and Natural Sciences, Department of Chemistry, Indonesia, Bogor 16680, e-mail: dyahprado@yahoo.co.id

How to cite this article:
Wahwakhi S., Kusmana C., Iswantini D., 2017 Potency of *Acanthus ilicifolius* as phytoremediation agent against copper pollution in Jagir River estuary, Wonorejo Village, Surabaya, Indonesia. AACL Bioflux 10(5):1186-1197.