

Purification of Batik Liquid Waste and Decrease of Pb and Cd Heavy Metal Content by Combination of Sargassum SP. Biomass and Alum

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Abstract

Batik liquid waste containing Pb and Cd heavy metals is a very dangerous waste and can cause cancer, reproductive disorders, bone fragility, kidney damage, damage to the immune system, anemia and death within 1-2 days. The purpose of this research was to determine the combination of Sargassum sp. and alum in the purification and decrease of Pb and Cd metal content in batik liquid waste. Waste was taken directly from home-based batik craftsmen in Sesemut-Wiradesa-Pekalongan. This research used a combination of Sargassum sp. and alum in the ratio of 1: 4, 2: 3, 1: 1, 3: 2, 4: 1 in 0.3 grams of total weight. Pb and Cd metals were analyzed by using an atomic absorption spectrophotometer (AAS) while the purity was measured by using UV-Vis spectrophotometry. The combination of Sargassum sp.: alum (1:4, 2:3, 1:1, 3:2, 4:1) could reduce the Pb and Cd metal content respectively in (83.1%; 98.7%), (77.0%; 99.1%), (82.4%; 99.5%), (76.5%; 99.3%), (80.1%; 99.2%). The best percentage decrease in absorbance was in the combination of 1: 4 (98.5%). This combination was proven to reduce Pb and Cd heavy metals and to purify batik liquid waste.

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INTRODUCTION

Batik is a typical Indonesian clothing that is currently very popular among local and foreign consumers. Suhendra (2009) states that batik entrepreneurs experienced an income increase of up to 50% after the announcement of national batik day on October 2, 2009. The increasing number of batik consumers force entrepreneurs to increase batik production. As a result, more waste is generated. On the other hand, there are still many batik industries that directly dispose of batik liquid waste around the environment. The author's direct interview with the batik

businessman in Sesemut-Wiradesa-Pekalongan Village shows that many people dispose of batik's liquid waste directly to the environment because they do not have a Wastewater Treatment Plant (IPAL).

Batik liquid waste contains many toxic and dangerous materials (B3). Purwaningsih (2008) states that the value of Chemical Oxygen Demand (COD) reaches 3039.7 mg/L and the color intensity of 185 CU in liquid waste of the batik industry. The problem that arises in addition to the high color intensity and the large COD value is the heavy metal content in the

liquid waste of the batik industry. Sudarja *et al.* (2011) state that batik industry liquid waste contains heavy metals such as lead (Pb), chromium (Cr), cadmium (Cd), mercury (Hg), and copper (Cu). Chronic poisoning Cd can cause reproductive gland damage, kidney damage, bone fragility, damage to the central nervous system, cancer, psychological disorders, and damage to the immune system (Agustina, 2010). Darmono (1995) states that Cd heavy metal can be buried in body tissues in which it has a long time to stay in the human body and even becomes permanent due to binding to a protein called metallothionein (MTN). Malaka (1994) states that Pb is toxic and easily accumulates in body organs causing anemia and decreased nerve conduction velocity. This is reinforced by Agustina (2010) who states that the heavy metal causes a fertility decrease in men, miscarriage, high blood pressure, severe anemia, intelligence reduction in children, and even death within 1-2 days.

Several technologies that have been found to reduce heavy metals in wastewater include technologies based on oxidation methods (Ahmet *et al.*, 2003), adsorption with coconut shell charcoal, coal, and photodegradation (Setyaningsih, 2007), photooxidation and ozonation (Tratnyek and Hoigne, 1991; Tratnyek *et al.*, 1994), electrolysis (Riyanto, 2010) and electrochemistry (Sheng and Peng, 1994). However, the use of photooxidation, electrolysis, ozonation, and bacterial biomass in wastewater treatment is considered inefficient because of the high cost of the materials used while the use of coal and coconut shell charcoal also has weaknesses due to the preparation and supply of complex materials and the difficulty of obtaining these materials.

Biomass *Sargassum sp.* has been declared to be able to absorb metal compounds Cr, Cd and Cu in liquid waste (Cossich *et al.*, 2002., Antunes *et al.*, 2003). Tahir *et al.* (2008) also suggest that *Sargassum sp.* can absorb

methylene blue in the textile industry liquid waste. Alum ($\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$) can reduce the intensity of colors, organic component, inorganic component, algae, bacteria, and suspended solids (Saryati *et al.*, 2002). Availability of *Sargassum sp.* Abundance in Indonesian coastal waters and the low cost of alum become one of the advantages of this research.

This research will be beneficial as a strong scientific foundation to help wastewater management of the batik industry, especially in Sesemut-Wiradesa-Pekalongan which still discharges the liquid waste of batik directly to the environment. The results of this research are expected to prevent dangerous diseases arising from heavy metals. Utilization of *Sargassum sp.* abundance in the beach can be a selling point by fishermen and considering that many industries in Indonesia do not have WWTP yet, this research is important to conduct.

RESEARCH METHODOLOGY

Instrumentation

Oven, shaker, 60 mesh size sieve, digital scale, glassware, micropipette, vacuum stove, AAS Shimadzu AA-7000, UV-vis spectrophotometer Shimadzu UV mini-1240.

Materials

Brown algae (*Sargassum sp.*), Alum, 0.1 M HCl, concentrated HNO_3 , aquades, aquabides, Pb 1000 ppm standard, Cd 1000 ppm standard, batik liquid waste of Sesemut-Wiradesa-Pekalongan.

Research Location

The making process of a combination of *Sargassum sp.* Biomass and alum, and AAS tests and UV-Vis spectrophotometry were conducted at the Faculty of Pharmacy, Universitas Muhammadiyah Surakarta.

Research Procedures

Sample destruction process

Batik liquid waste was taken as much as 50 mL and put in a 100 mL erlenmeyer, then

added 2.5 mL of concentrated HNO₃, stirred until homogeneous and boiled on an electric stove until the volume became 15 mL. The addition of concentrated HNO₃ and heating aimed as a metal oxidation process of Pb and Cd in the sample to form stable salt compounds. The solution was then added with 2.5 mL concentrated HNO₃ solution, stirred then erlenmeyer was covered with a watch glass, reheated until the solution turned clear. The solution was cooled in a 50 mL measuring flask and added a little aquabides to the limit of the measuring flask. Then the solution was filtered with filter paper and the waste was measured by Pb and Cd metal contamination using AAS (Figure 1).

Sargassum sp. and alum were weighed in the ratio of 1:4, 2:3, 1:1, 3:2, 4:1 in 0.3 grams. These comparisons were included in 50 mL batik liquid waste and stirred with a shaker for 20 minutes. The choice of a combined weight of 0.3 grams in 50 mL of sample was intended as the lowest level of alum in purifying the waste solution. The precipitate was separated from the liquid by filter paper. Then the filtrate was extracted as above and then the metal content was measured using AAS. Observation of color (visually and UV-Vis spectrophotometer) was conducted by taking 50 mL of the sample before and after being given a combination of Sargassum sp. biomass, and alum (Figure 1).

Research Flow Chart

The outline of this research is presented in figure 1.

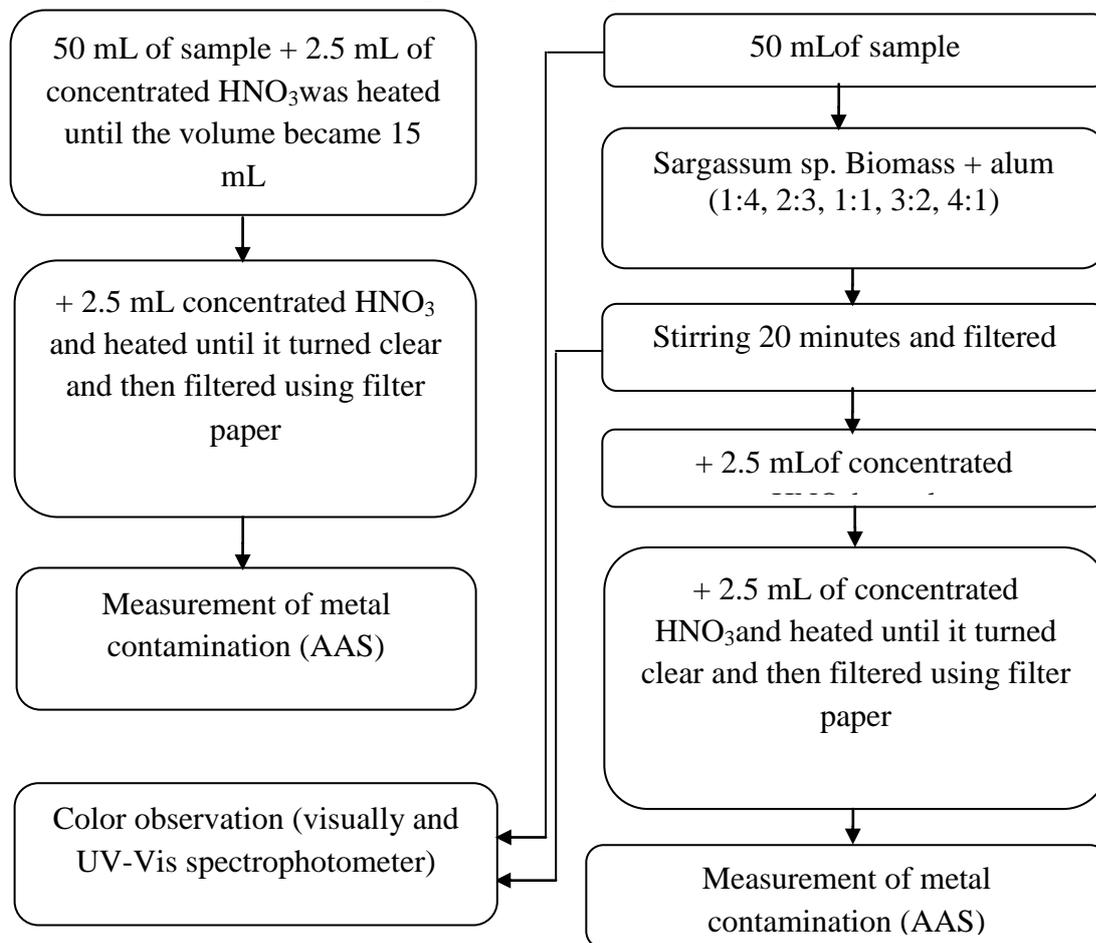


Figure 1. Research Flow Chart

Work Mechanism

a) Production of Sargassum sp. Biomass

Brown algae were sorted, then washed using distilled water and dried in an oven for 24 hours at 60 °C. It was continued by being mashed and sieved using a 60 mesh particle sieve. The 60 mesh of Sargassum sp. was then dried at 105 °C for 24 hours (Cossich

et al., 2002). The Sargassum sp. was then modified with HCl 0,1 N. HCl 0,1 N that serves as a solvent for the fucoxanthin pigment causing the brown color in the solution (Aryanti, 2011). Fukosantin (C₄₂H₅₈O₆) is a basic compound because it contains an OH functional group so that it dissolves in HCl 0,1 N.

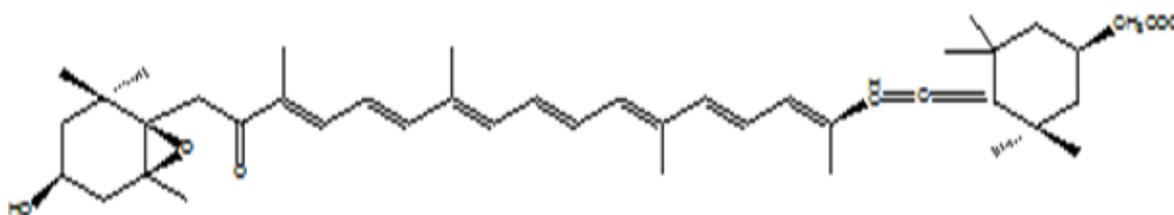


Figure 2. The structure of fucoxanthin on brown algae (Takaichi, 2011)

Dry Sargassum sp. weighed as much as 2.5 grams and it was mixed with HCl 0,1 N solution of 100 mL for 3 hours at room temperature. This modification was then filtered and washed with distilled water. After being clean, it was then dried in the oven for 24 hours at a temperature of 60°C. In the next step, the dry Sargassum sp. 0.1 m was added with HCl solution as much as 400 mL and then they were stirred for 3 hours at room temperature. It was continued by being filtered and washed with distilled water. After being clean, it was dried in the oven for 24 hours at a temperature of 60°C. Modification of Sargassum sp. biomass was stated to produce the clearest filtrate in managing wastewater in the fisheries home industry (Aryanti, 2011).

b) Analysis of Batik Production Liquid Waste

Batik liquid waste used in this research was taken from waste coloring from the home batik industry in Sesemut-Wiradesa-Pekalongan. Waste was taken during the day because at that time the waste taken was directly from the waste that was still new and not much contaminated. Waste was collected at

the temporary wastewater storage facility behind the production house. The temporary storage of wastewater was in the form of irregular perforated land with a volume capacity of ± 1000 Liters. Samples were taken from three areas with the same depth and put in a 3-liter glass bottle and then analyzed. The liquid waste analysis includes the analysis of color observations by using UV-Vis spectrophotometry, visuals, and analysis of metal contamination using AAS.

c) Determination of the Comparison of Adsorbents Used

Each of 0.3-gram combination of Sargassum sp. biomass, and alum (1:4, 2:3, 1:1, 3:2, 4:1) was put into a 100 mL glass beaker containing 50 mL of batik industry liquid waste. The compound was then stirred using a shaker for 20 minutes. The purpose of the stirring process was to have the time needed for metal binding by Sargassum sp. biomass through ion-exchange and also as a coagulation process of alum which ended in flocculation. Biomass was separated from the liquid, then liquid waste was analyzed by the color and metals contamination of Pb and Cd.

d) Procedure Analysis

Analysis of Metal Contamination by the Spectrophotometry Method

The sample was taken and found out the maximum wavelength by providing a wavelength range of 500-700 nm. The maximum wavelength was determined for the determination of sample absorption.

Analysis of Metal Contamination using AAS Method

The sample was carried out destructively. The sample was filtered using filter paper. AAS was ignited according to the procedure and then blank was done by using aquabides. The concentration series were analyzed from the smallest ones to the largest ones. Then a sample analysis was performed.

Making a Standard Curve

a) Making a standard curve was by determining the concentration series. The Pb metal standard concentration series were 0.25; 0.50; 1; 2; 4 ppm while the standard concentration of Cd metal was 0.0125; 0.025; 0.05; 0.1; 0.2 ppm.

b) Pipetting of standard stocking of Pb and Cd 1000 ppm metal stock was made to 50 ppm in 5 mL. 250 µL from 1000 ppm stock was pipetted and then put into 5 mL measuring flask and added aquabides to the lower meniscus limit.

c) The next step, 50 ppm stock was pipetted according to the Pb and Cd metal concentration series which was then put into a 5 mL measuring flask for Pb metal and 100 mL measuring flask for Cd metal. For the last stage,

it was added aquabides to the lower meniscus limit.

Data Analysis

Data obtained from UV-Vis spectrophotometer in the form of absorbance from the sample that is sought the percentage decrease using the formula:

$$\text{Sample} = \frac{\text{mean of initial sample uptake} - \text{treatment uptake}}{\text{mean of initial sample uptake}} \times 100\% \quad (1)$$

The percentage data of the decrease in sample uptake is statistically tested using t-test or Wilcoxon as an alternative if the data are not normal.

Absorption data from AAS is then calculated the Pb and Cd metal content determined based on standard curves, $y = bx + a$, then compare the metal content of Pb and Cd before and after treatment by calculating percentage decrease:

$$\text{Sample} = \frac{\text{mean of initial sample level} - \text{sample level}}{\text{mean of initial sample level}} \times 100\% \quad (2)$$

The percentage of data in sample level reduction is statistically tested using t-test or Wilcoxon as an alternative if the data are not normal.

RESULTS AND DISCUSSION

The preliminary test of the sample of written-batik liquid waste from Sesemut-Wiradesa-Pekalongan is an initial test to determine the content of heavy metals and color intensity. Initial test results from the sample without dilution show a dark green color with absorption of 0.667 and contains Pb and Cd metals (Table 1).

Table 1. The initial sample test results of batik liquid waste from Sesemut-Wiradesa-Pekalongan using UV-Vis and AAS spectrophotometers

Sample name	Parameter				
	λ_{max} (nm)	Color intensity (Abs [#])	Visual	Logam contamination (Abs [#])	Logam contamination (ppm)

				Pb	Cd	Pb	Cd
I*	608.5	0.667	Dark green	0.0178	0.4566	0.9862	3.2885
II*	608.5	0.667	Dark green	0.0177	0.4376	0.9813	3.1511
III*	608.5	0.667	Dark green	0.0183	0.4468	1.0106	3.2176

*Replication I, II, III of batik liquid waste without dilution
#Absorbance

Sample solution that has been mixed with Sargassum sp. and alum with a ratio of 1:4 (A), 2:3 (B), 1:1 (C), 3:2 (D), 4:1 (E) in 0.3 grams of the total weight is undergoing precipitation. Precipitating the solution will be completed and fast by stirring using a shaker. This occurs due to the ions coming from alum will collide more with colloids contained in batik liquid waste that cause instability in the colloids and will

form flocks that are easily deposited. Purifying observation is done by looking at the solution directly and measured using a UV-Vis spectrophotometer. The results of direct vision show that there is a significant change in color purify after giving a combination of Sargassum sp. biomass. and alum (Figure 3). This shows that alum can reduce color intensity.

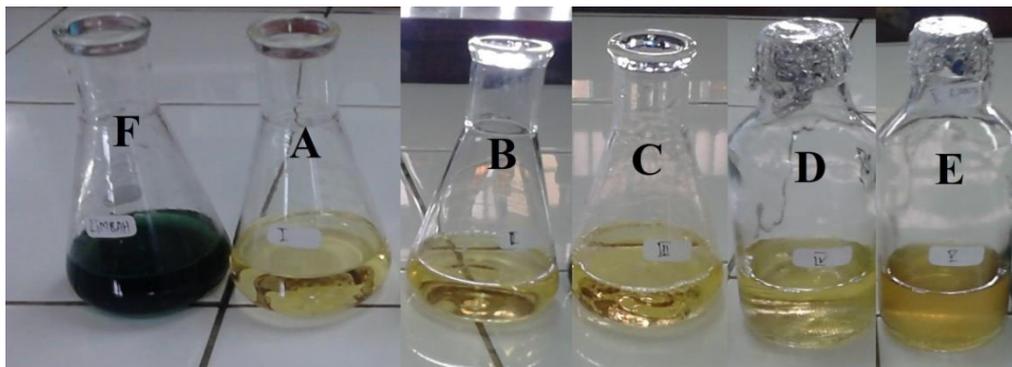


Figure 3. Batik liquid waste in Sesemut-Wiradesa-Pekalongan with a combination treatment of Sargassum sp. : alum A (1:4); B (2:3); C (1:1); D (3:2); E (4:1) and 3 times replication and pure sample (F). Stirring for 20 minutes and filtered using filter paper in which treatments A, B, C, D, E show clearer colors compared to the sample before treatment (F). among the treatment group, the samples do not show a significant clearing difference.

Measurement using a UV-Vis spectrophotometer shows that there is a significant decrease in the color intensity. The clearer the analyzed sample shows that the smaller the absorbance. The highest percentage decrease in intensity is in treatment A with 98.5% (Table 2, Figure 4).

Table 2. The results of the decrease in color intensity (absorbance) in batik liquid waste using a UV-Vis spectrophotometer (λ : 608.5 n: 3)

Treatment of <i>Sargassum</i> <i>msp.</i> : Alum	Color intensity (Abs [#])				Percentage decrease in color intensity (%)			
	I*	II*	III*	Mean \pm SD	I*	I*	III*	Mean \pm SD
Initial	0.66	0.66	0.66	0.667 \pm 0.0000	-	-	-	-
A	0.01	0.01	0.00	0.010 \pm 0.0010	98.4	98.	98.	98.5 \pm 0.15 ^{α}
B	0.01	0.01	0.01	0.010 \pm 0.0006	98.4	98.	98.	98.5 \pm 0.06
C	0.01	0.01	0.01	0.013 \pm 0.0010	98.2	98.	97.	98.1 \pm 0.15 ^{β}
D	0.01	0.01	0.01	0.018 \pm 0.0006	97.3	97.	97.	97.3 \pm 0.06
E	0.17	0.14	0.19	0.169 \pm 0.0276	74.4	79.	70.	74.7 \pm 4.11 ^{Ω}

* Replication I, II, III

Absorbance

^{α} Significantly different from E, but not significantly different from B and D

^{β} Significantly different from E, but not significantly different from A, B and D

^{Ω} Significantly different from A and C, but not significantly different from B and D

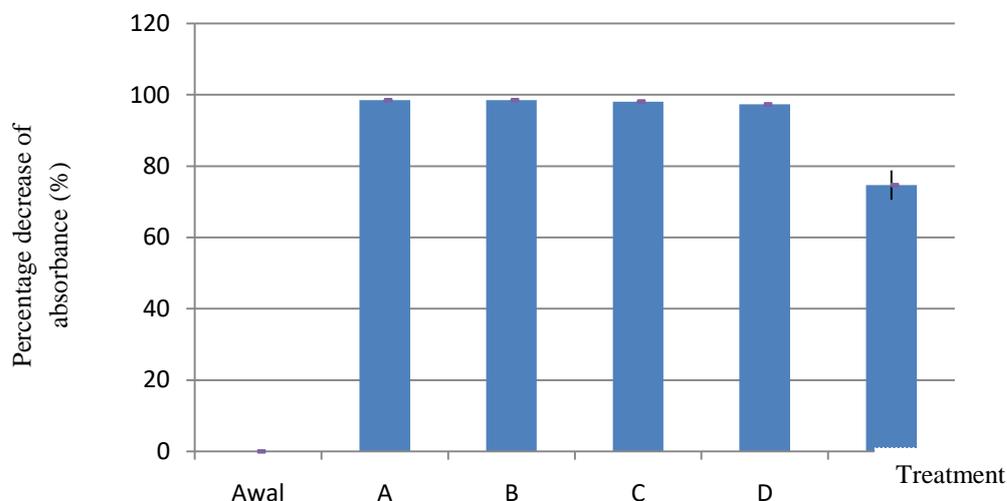


Figure 4. Diagram of percentage decrease of absorbance in color intensity in batik liquid waste by combination treatment of *Sargassum* sp.: alum A (1:4); B (2:3); C (1:1); D (3:2); E (4:1) and Initial (initial waste without treatment) (there is a significant decrease in color intensity

on the beginning of the sample and there was a significant difference between treatment groups)

The results of the percentage decrease in color intensity uptake in the test sample from

the highest to the lowest ones are the comparison of the *Sargassum* sp. biomass and alum combination respectively in A, B, C, D, and E. This means that the bigger the alum supply, the bigger the level of purification. Purification of waste by alum will be increased by the addition of polysaccharides (Saryati *et al.*, 2002). *Sargassum* sp. contains alginic compounds which are polysaccharides and

function as absorbents of heavy metals (Volesky *et al.*, 2003). So, the combination has complementary properties in the reduction of Pb and Cd metals and purification of batik liquid waste.

Observations on the percentage decrease in Pb metal show the highest decrease in Pb levels in treatment A, with the highest decrease in 83.1% (Table 3, Figure 4)

Table 3. The analysis results of Pb metal contamination in batik liquid waste using AAS

<i>Sargassum</i> m: alum (0,3 gram/50 mL)	Pb (ppm) Level				Percentage decrease of Pb level (%)			
	I*	II*	III*	Mean ± SD	I*	II*	III*	Mean ± SD
Initial	0,986 2	0,981 3	1,010 6	0,9927 ±0,01569	-	-	-	-
A	0,176 4	0,166 7	0,161 8	0,1683 ±0,00743	82, 2	83, 2	83, 7	83,1±0,7 5 ^a
B	0,220 3	0,244 7	0,220 3	0,2284 ±0,01408	77, 8	75, 4	77, 8	77,0±1,4 2
C	0,181 3	0,166 7	0,176 4	0,1748 ±0,00743	81, 7	83, 2	82, 2	82,4±0,7 5
D	0,225 2	0,259 4	0,215 5	0,2334 ±0,02306	77, 3	73, 9	78, 3	76,5±2,3 2 ^b
E	0,195 9	0,171 6	0,225 2	0,1976 ±0,02683	80, 3	82, 7	77, 3	80,1±2,7 0

* Replication I, II, III

^aSignificantly different from D, but not significantly different from B, C and E

^bSignificantly different from A, but not significantly different from B, C and E

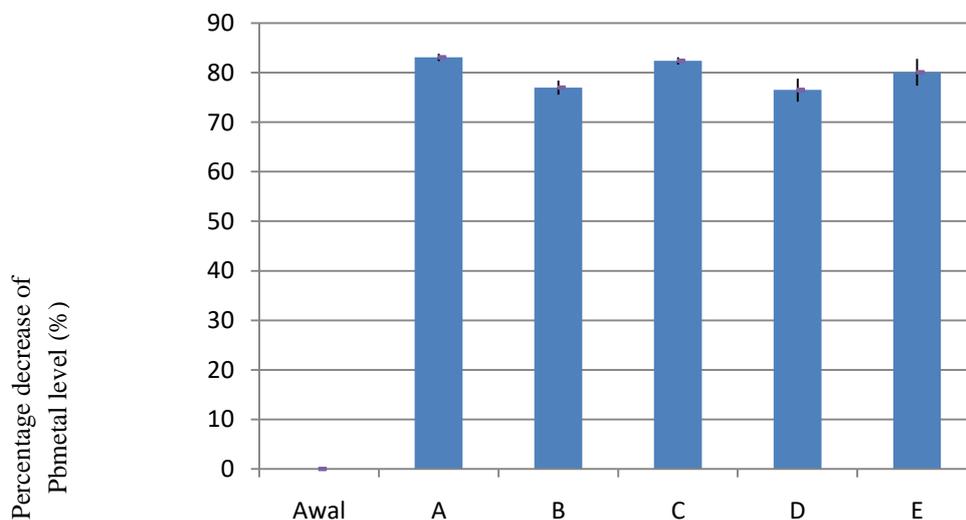


Figure 5. Diagram of Pb metal content decrease in batik liquid waste with a combination treatment of *Sargassum* sp. : alum A (1:4); B (2:3); C (1:1); D (3:2); E (4:1) and Initial (initial waste without

treatment) (there is a significant decrease in Pb metal content between all treatments on the initial sample and there was a significant difference between treatment groups)

Observation of the Cd metal shows the highest decrease in Cd levels in the Sargassum sp.: alum (1:1) treatment, with the highest decrease of 99.5% (Table 4, Figure 5).

Table 4. Analysis of Cd metal contamination in batik liquid waste using AAS

Sargassu m: alum (0,3 gram/50 mL)	Cd (ppm) Level				Percentage Decrease in Cd level (%)			
	I*	II*	III*	Mean ± SD	I*	II*	III*	Mean ± SD
Initial	3.288	3.151	3.217	3.2191 ± 0.06871	-	-	-	-
A	0.047	0.053	0.023	0.0414 ± 0.01614	98.5	98.3	99.3	98.7 ± 0.50 ^α
B	0.031	0.024	0.031	0.0292 ± 0.00397	99.0	99.2	99.0	99.1 ± 0.12
C	0.019	0.011	0.019	0.0169 ± 0.00456	99.4	99.6	99.4	99.5 ± 0.14 ^β
D	0.024	0.031	0.012	0.0227 ± 0.00954	99.2	99.0	99.6	99.3 ± 0.30
E	0.023	0.028	0.027	0.0265 ± 0.00303	99.3	99.1	99.1	99.2 ± 0.09 ^π

* Replikation I, II, III

^αSignificantly different with E, but not significantly different with B and D

^βSignificantly different with E, but not significantly different with A, B and D

^πSignificantly different with A and C, **tetapi tidak berbedasignifikandengan B and D**

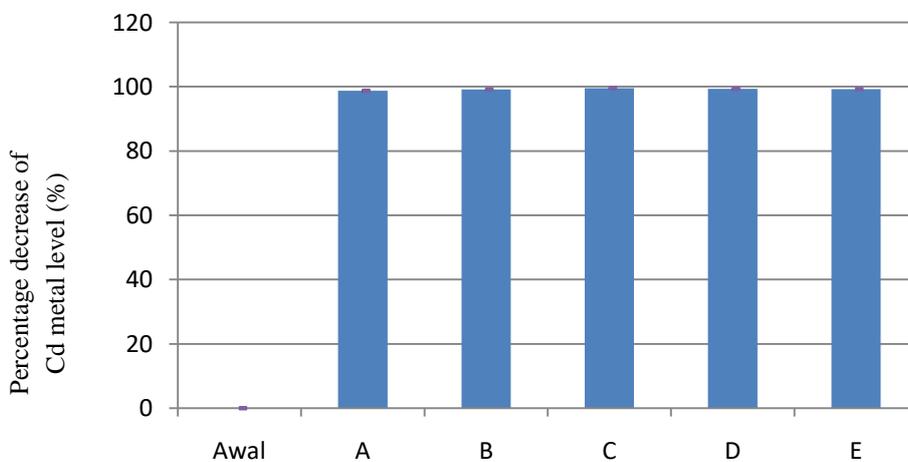


Figure 6. Diagram of percentage decrease of Cd metal level in batik liquid waste by a combination treatment of Sargassum sp.: alum

A (1:4); B (2:3); C (1 Treatment E (4:1) and Initial (initial waste without treatment) (there is a significant decrease in Cd metal level between

all treatment groups on the initial sample and there is a significant difference between treatment groups)

Overall results show a combination of Sargassum sp.: alum can purify the waste solution and reduce the Pb and Cd metal contamination. The decrease of Pb and Cd metals does not correlate with the ratio of Sargassum sp.: alum.

Alum has two stages in reducing the color intensity in this research including coagulation and flocculation. Coagulation is the instability of the solution in the presence of ions opposite to colliding colloidal particles due to the rapid stirring process between alum (coagulant) and liquid solution (Sianita and Nurchayati, 2009). The ions from alum will be free and collide with colloidal particles in batik liquid waste, resulting in instability in the solution. Alum with the chemical formula $(Al_2(SO_4)_3 \cdot 18H_2O)$ will ionize into Al^{3+} and $(SO_4)^{2-}$. The nature of this ion is unstable and will naturally stabilize itself by forming complex compounds. These ions will bind to colloidal particles in batik liquid waste so that flockshaving mass are formed. Due to high molecular weight in the presence of flocculation, the flocks will precipitate due to the earth's gravitational force so that the solution becomes clear.

Sargassum sp. has two adsorption mechanisms on the Pb and Cd metals including physical and chemical bonds. The former is physical adsorption with the formation of Van der Waals forces which depend on the distance between molecules. This bond is formed by the presence of different charges that attract each other which is the positive charge from Pb and Cd metals and the negative charge that comes from guluronate on the alginate that pulls each other. The latter is the exchange of divalent and monovalent ions such as Ca, Mg, K, and Na on the cell wall replaced by heavy metal ions (Figure 6). The Ca, Mg, K, and Na ions in

alginate are naturally derived from seawater (Figueira *et al.*, 1999).

Sargassum sp. has hydrophilic and carboxylic sides as active groups that will bind to heavy metals. The heavy metal bond to the carboxylate is stronger than the bond of Ca, Na, Mg, and K with the carboxylate resulting in ion-exchange. Alginates have an important role in the absorption of cations by their carboxylic groups. Heavy metals of 2^+ or 3^+ magnitude will be bound by carboxylic groups with ion exchange in an acidic condition (Figueira *et al.*, 1999). Alginates consist of manuronates and guluronates. Physical binding between the positive charge originating from the metal and the negative charge from the guluronate containing the carboxyl acid group will form a space that allows it to be entered by the metal so that the physical building of the egg box model is formed (Rees, 1972; Grant, G. T., *et al.*, 1973).

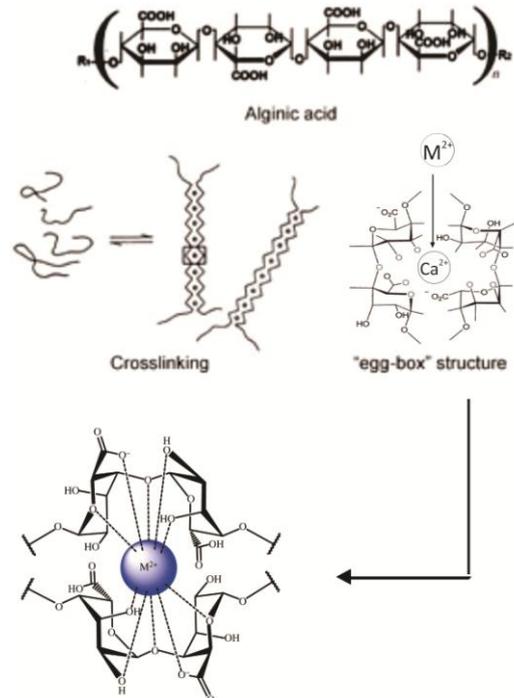


Figure 7. The mechanism of ion exchange reaction of adsorption of heavy metals (M^{2+}) replaces Ca^{2+} by alginate (Mun, 2010)

CONCLUSION

Based on the results, it can be concluded that *Sargassum* sp. biomass and alum formulation (1:4, 2:3, 1:1, 3:2, 4:1) can reduce the Pb and Cd metal content of (83.1%; 98.7%), (77.0 %; 99.1%), (82.4%; 99.5%), (76.5%; 99.3%), (80.1%; 99.2%) respectively. *Sargassum* sp. biomass and alum formulation (1:4) can reduce the highest color intensity at 98.5%.

SUGGESTION

1. Further research needs to analyze other metals, especially Ca, Na, K, and Mg.
2. It is necessary to analyze the effect of pH and temperature.

REFERENCES

1. Agustina, T., 2010, Kontaminasi Logam Berat pada Makanan dan dampaknya pada Kesehatan, *Teknubuga*, 2(2)
2. Ahmet, B., Ayfer, Y., Doris, L., Nese, N. & Antonius, K., 2003, Ozonation of high strength segregated effluents from a woolen textile dyeing and finishing plant, *Dyes and Pigments*, 58, 93-98
3. Antunes, W. M., Luna, A. S., Henriques, C. A. & Costa, A. C. A., 2003, An evaluation of copper biosorption by a brown seaweed under optimized condition, *Biotechnology J*, 6(3), 174-184
4. Arif, H. S., Wardana, L. D., Budiarti, G. I., Wardani, S. P. W., Wahyuni, A. S. & Edi, M. S., 2013, Kombinasi Biosorben *Sargassum* dan Arang Sekam Padi untuk Limbah Cair Industri Batik: Efisiensi Penggunaan Air pada Industri Batik dengan Strategi Regenerasi Air Limbah, *Journal of Waste Management Technology*, 16(1), 1410-9565
5. Aryanti, L., 2011, Pemanfaatan Rumput Laut *Sargassum* sp. Sebagai Adsorben Limbah Cair Industri Rumah Tangga Perikanan, *Tugas Akhir*, Bogor: Institute Pertanian Bogor
6. Artanti, R., Nursyamsi, D., & Jatmiko, S. Y., 2011, Penurunan Konsentrasi Kromium (Cr) dalam Limbah Cair *Electroplating* dengan Penggunaan Koagulan dan Adsorben, *Ecolab*, 5(2), 79-88
7. Cossich, E. S., Tavares, C. R. G. & Ravagnani, 2002, Biosorption of chromium (III) by *Sargassum* sp. biomass, *Biotechnology J*, 5, 133-140
8. Darmono, 1995, *Logam Dalam Sistem Biologi Makhluk Hidup*, UI-Press, Jakarta hal 109-114
9. Figueira, M. M., Volesky, B., & Mathieu, H. J., 1999, Instrumental Analysis Study of Iron Species Biosorption by *Sargassum* Biomass. *Environmental Science and Technology*, 33(11)
10. Grant, G. T., Morris, E. R., Rees, D. A., Smith, P. J. C., & Thom, D., 1973, Biological Interactions Between *Polysaccharides* and Divalent Cations: The Egg-Box Model, *Feb Letters*, 32 (1)
11. Malaka, T., 1994, *Biomonitoring Proceeding Simposium Pantauan Biologi dalam Proteksi Kesehatan Tenaga Kerja, Kedokteran Universitas Indonesia*, Jakarta
12. Mun, T. S., 2010, Development of Micro-Bioreactors for a More Efficient Fermentation Process to Produce Bio-Ethanol, *Tesis*, National University Of Singapore
13. Purwaningsih, I., 2008, *Pengolahan Limbah Cair Industri Batik Cv. Batik Indah Raradjonggrang Yogyakarta Dengan Metode Elektrokoagulasi Ditinjau Dari Parameter Chemical Oxygen Demand (COD) Dan Warna*, *Tugas Akhir*, Jogjakarta: Universitas Islam Indonesia
14. Rees, D. A., 1972, Shapely Polysaccharides the Eighth Colworth Medal Lecture, *Biochem. J.*, 126: 257-273
15. Riyanto, 2010, *Penemuan Teknik Baru Untuk Pengolahan Limbah Batik*, *Laporan Penelitian*, Yogyakarta: FMIPA, Universitas Islam Indonesia
16. Saryati, Sutisna, Sumarjo, Wildan, Z. L., Wahyudianingsih & Suprpti, S., 2002,

- Komposit Tawas
ArangAktifZeolitUntukMemperbaikiKualita
s Air, *JurnalSainsMateri Indonesia*, 4(1), 9-
15
17. Setyaningsih, H., 2007, PengolahanLimbah
Batik dengan Proses Kimia
danAdsorpsiKarbonAktif, Tesis, Universitas
Indonesia
<http://lontar.ui.ac.id/opac/themes/libri2/detail.jsp?id=81459&lokasi=lokal>
18. Sheng, H. & Peng, C.F., 1994, Treatment of
textile wastewater by electrochemical
method, *Wat. Res.*, 28, 277–282
19. Sudarja, Diharjo, K. &Caroko, N., 2011,
Pengaruh Grain Size
ArangAktifdariBahanLimbahIndustriSaguA
renterhadapPenyerapanPolutanLimbah
Batik, *JurnalIlmiahSemestaTeknika*, 14 (1),
86-93
20. Suhendra, 2009, Permintaan Batik
Melonjak,
[http://finance.detik.com/read/2009/03/14/152007/1099371/4/permintaan-batik-melonjak-50\(Diaksestanggal14Maret2009\)](http://finance.detik.com/read/2009/03/14/152007/1099371/4/permintaan-batik-melonjak-50(Diaksestanggal14Maret2009)).
21. Tahir, H., Sultan, M. &Jahanzeb, Q., 2008,
Removal of Basic Dye Methylene Blue By
UsingBioabsorbents*Ulva Lactuca*and
Sargassum, *African Journal of
Biotechnology*, 7 (15), 2649-2655
22. Takaichi, S. 2011. Carotenoid in Algae:
Distributions, Biosyntheses and Functions.
Mar. Drugs, 9, 1101-1118
23. Tratnyek, P. G. &Hoigne, J., 1991,
Oxidation of substituted phenols in the
environment: AQSAR analysis of rate
constants for reaction with singlet oxygen,
Environ. Sci. Technol., 25, 1596–1604
24. Tratnyek, P. G., Elovitz, M. S. &Colverson,
P., 1994, Photo Effects of Textile Dye
Wastewater: Sensitization of Single Oxygen
Formation, Oxidation of Phenols and
Toxicity to Bacteria, *Environ.
Toxico., Chem.*, 13, 27–33
25. Volesky, B., Weber, J., Park, J.M., 2003:
Continous-Flow Metal Biosorption in
Regenerable *Sargassum* Column, *Water
Research* 37, 297–306