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#20673 Review

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Authors	Umi Baroroh, Adang Firmansyah, Deni Deni, Lina Maudyawati, Ahmad Zainuddin (https://journal.uinjkt.ac.id/index.php/valensi/user/email?redirectUrl=https%3A%2F%2Fjournal.uinjkt.ac.id%2Findex.php%2Fvalensi%2Fauthor%2FsubmissionReview%2F20673&to%5B%5D=%22Umi%20Baroroh%22%20%3 Cost%20Adsorbent&articleId=20673)
Title	Dyes Removal from Wastewater by Coral Reef Waste as a Low-Cost Adsorbent
Section	Jurnal Kimia VALENSI, Volume 8, No. 1, May 2022
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#20673 Summary

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Author comments	Dear Editor I hope you are in good health during this pandemic. The highlight of this article is the use of natural material waste (coral reef) to absorb dyes. Only a few studies material can be a novelty in adsorb dyes. I hope this article meets your journal, so we can publish it here. Thank you in advance
Abstract Views	0

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Title and Abstract

Title Dyes Removal from Wastewater by Coral Reef Waste as a Low-Cost Adsorbent

Abstract

Despite the positive impact of the rapid industrial growth in Indonesia, it has caused several problems. The non-biodegradable pollutant, such as reactive dyes that result from the textile industry, is harmful to the environment and human health. This contaminating agent should be removed from the waste before being disposed to the surrounding ecosystem. Adsorption is one of the simple and low-cost techniques to eliminate dye from the effluent. Waste from coral reefs is interesting to be explored as a dye-removing adsorbent because it is abundant in nature, cheap, and reusable. Therefore, this study aims to determine the adsorption performance of coral reef waste in removing several dyes, i.e., methylene blue (MB), remazol brilliant blue (RBB), disperse orange (DO), and vinyl sulfone (VS) from wastewater. The adsorption capacity was determined to evaluate the effectiveness of coral reef waste in removing the dyes at the isotherm model. Adsorption capacity and isotherm model were used to evaluate the effectiveness of this natural adsorbent. Based on the percentage removal and coefficient distribution value, the removal selectivity of RBB was the best, followed by DO, VS, and MB, respectively. In conclusion, coral reef waste is promising to be developed as a low-cost adsorbent for removing dyes from wastewater.

Indexing

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Dear Editor in Chief of

Jurnal Kimia Valensi,

Manuscript ID 20673

We would like to thank the Editor and Reviewer of Jurnal Kimia Valensi to review our manuscript, entitled " Dyes Removal from Wastewater by Coral Reef Waste as a Low-Cost Adsorbent". We really appreciate all the comments and suggestions. We have revised our manuscript based on suggestions that highlighted by the reviewers.

Please allow us to explain and clarify the revision:

No.	Comment	Answer	Location of Revision in Revised Manuscript
Reviewer B			
1	the title: coral reef waste. however, there is no information about coral waste. and, the coral photo looks very beautiful.	We update the sentences in 4th paragraph by "Nevertheless, only 5.2% coral reef in Indonesia consider in health condition …."	The fourth paragraph of 1. Introduction
2	The coral reef powder was activated using chemical and physical methods. This powder was impregnated [Ma1] with NaOH 2N at 100˚C for 120 minutes. The pellets were neutralized to reach the neutral pH and dried at 60˚C and then dried[Ma2] at 700˚C for 6 hours. [Ma1]treated [Ma2]calcined	We update the words as reviewer suggested.	The first paragraph of 2.1
3	3.1 Characterization[Ma1] of Adsorbent [Ma1]pls add the IR n XRD of the sample (before n after treatment with NaOH solution.	We understood reviewer's concern. However, we cannot add the IR and XRD due to the limited access into the lab because of the pandemic.	
4	It was known that the coral reef comprises calcium	We update and add sentences to make this clear	The fourth paragraph of 1. Introduction

	carbonate and produces about 4 kilograms of $CaCO_3$ per square meter per year[Ma1] (Giyanto et al., 2017). [Ma1]not clear.		
5	mean[Ma1] 0.18 41.20 0.08 [Ma1]no need. it is generally accepted that different initial concentrations of adsorbate will be get different adsorbent performance	We have removed the mean.	Table 2
6	3.1 Equilibrium Adsorption Isotherm The Langmuir and Freundlich [Ma1] adsorption isotherms model was used to analyze the concentrations of the dye for the interpretation of equilibrium isotherm data. Generally, the interaction of [Ma1]the author should apply these models to the data, and see the fit one. in addition, about the data, it looks fluctuation with very low R^2. Therefore, it is suggested to repeat the experiment to get good data.	We understood reviewer's concern. However, same as comment no. 3 we cannot re-conduct the experiment due to the limited access into the lab because of the pandemic.	
7	After the adsorption experiment, the particles look tidier and uniform, flatten, and there were holes between one particle to particles. Indicating[Ma1] dye binds	We used SEM to monitor and evaluate the changes in the surface structure of coral reef before and after experiment. To make this clear, we remove the last sentence.	Last sentence of 3.4

	in the surface of particles. [Ma1]can we monitor the molecular bonding using SEM? as I know, SEM is only for surface morphology. We can use infrared to monitor the functional group for chemical bonding.		
Reviewer C			
1	Please also add the physicochemical properties of coral reef so that it has scientific reason that coral reef has potential to be used as good adsorbent	We have added new sentences	The fourth paragraph of 1.Introduction
2	To whom does author refer this procedure of experiment? This procedure suitable with chemical activation approach. How about the physical one that author mention in previous sentence?	Yes, the sentence is suitable for chemical activation and the next sentences is for physical activation. We have revised and cleared the sentences	2.1 Preparation and Characterization of Adsorbent In 5^{th} -7^{th} line
3	Why use different concentration of each dyes? Please add some reference or maybe government regulations related to the threshold for each dyes in water	Thank for your comment. In this study, we just want to know the ability of coral to adsorb dye. Since it was the preliminary study of our research we just focus to the ability of coral. In the next study we will consider it	
4	Please also add some physical and chemical properties reason for this series	We have added the sentences	The next sentence
5	Please refer the equation 4 in this sentence	We have revised this sentence	Last sentence in the first paragraph of 3.3
6	Please refer the equation 5&6 in this sentence	We have revised this sentence	The second paragraph of 3.3
7	Before we compare the constant value in each model, please make sure that all data are fit with the model (R2 > 0.98), if not the data not fit therefore all	We revised the sentence	The third paragraph of 3.3

	constant value couldn't be compare to each other.		
8	Please consider to use the significant figure's rule	We have revised it	Table 3
9	Please use scatter type for data not scatter+line Please also add for Langmuir model in Figure 3.	We have changed the chart type Figure 2 describes about the Langmuir model while figure 3 describes the SEM results	Figure 2
10	Why there is a hole when there is an additional compound attached? The adsorbate should filled the hole or pore, right?	Based on Langmuir equation model, the RBB has a higher b and Kb value therefore the dye might be bind on the surface of particle and thus create holes between particles.	The next sentences
11	Please also add some literature to compare the result.	We remove this sentence to make this clear	The last sentence of 3.4

Our manuscript describes about the potential of coral reef waste or coral-like adsorbent to remove some dyes. There are not a lot of information about coral reef waste as adsorbent. In addition, the unhealthy or waste of coral reef is plentiful. Whereas this material can be used to adsorb dyes. Further development is needed to know the effectiveness of this material and the utilize of coral-like adsorbent from natural material. We were updated and paraphrase the sentences according to reviewer's comments. However, we did not add the IR and XRD or re-conduct the experiment due to the limited access into the lab because of pandemic. We hope that the current manuscript meets the quality required to be published in your respected journal.

Thank you in advance.

Regards

Umi Baroroh
Indonesian School of Pharmacy

Dyes Removal from Wastewater by Coral Reef Waste as a Low-Cost Adsorbent

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Abstract

Despite the positive impact of the rapid industrial growth in Indonesia, it has caused several problems. The non-biodegradable pollutant, such as reactive dyes that resulted from the textile industry is harmful to the environment and human health. This contaminating agent should be removed from the waste before disposed to the surrounding ecosystem. Adsorption is one of the simple and low-cost techniques to eliminate dye from the effluent. Waste of coral reef is interesting to be explored as a dye-removing adsorbent because it is abundant in nature, cheap, and reusable. For this reason, we aimed to study the adsorption performance of coral reef waste in removing several dyes, i.e., methylene blue (MB), remazol brilliant blue (RBB), disperse orange (DO), and vinyl sulfone (VS) from wastewater. The adsorption capacity was determined to evaluate the effectiveness of coral reef waste in removing the dyes at the isotherm model. Adsorption capacity and isotherm model were used to evaluate the effectiveness of this natural adsorbent. Based on the percentage removal and coefficient distribution value, the removal selectivity of RBB was the best, followed by DO, VS, and MB, respectively. In conclusion, coral reef waste is promising to be developed as a low-cost adsorbent for removing dyes from wastewater.

Keywords: adsorption, coral reef, dyes, wastewater, low-cost adsorbent

1. INTRODUCTION

Textile industry in Indonesia has been growing rapidly. In general, this industry uses dyes as an agent of coloring (Khodaie *et al.*, 2013). During the dyeing process, about 10-15% of the dyes are missed from fabric and could pollute the water (Murugesan *et al.*, 2007). The existence of very small quantities of dyes (less than 1 ppm) in water is highly evident and unwanted (Robinson *et al.*, 2001). Dyes are inert and challenging to be biodegraded and decolorized when thrown into the waste stream. Hence, the existence of dyes in streams and rivers denote water pollution (Dulman & Cucu-Man, 2009).

Reactive dyes are widely used worldwide in industry, especially in textile, and could bind covalently with the fiber. These dyes are carcinogenic, harmful, and toxic to the organism (Ahmad *et al.*, 2014). They also carry a danger to aquatic organisms (O'Neill *et al.*, 1999). One of the most commonly

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used dye water, methylene blue, is used for cotton and wood (El-Ashtoukhy & Fouad, 2015). It has some negative effects on human being such as respiratory disorders, and can cause diarrhea, gastritis, vomiting, and nausea (Chcn *et al*, 1999). Remazol brilliant blue (RBB) is also widely used in the textile industry. It is one of the examples of reactive dye, which has the characteristics of light color, low energy consumption dyeing process, and high solubility in water (Baskaralingam *et al.*, 2007). This reactive dye is highly carcinogenic and possesses toxicity to the organism. In vitro study of anthraquinone from RBB indicated its toxicity by inhibiting the mitochondrial adenine nucleotide translocation and oxidative phosphorylation. In addition, most of the dyes inhibited mitochondrial [14C]adenosine diphosphate uptake in a partially competitive-noncompetitive manner (Chcn *et al.*, 1999). Therefore, to keep the environment the removal of such dyes from wastewater is needed.

Several treatments such as precipitation, adsorption, flocculation, coagulation, reverse osmosis, sedimentation, electrochemical techniques, ozonization, membrane filtration, fungal degradation, and photodegradation have successfully conducted to remove the dyes (Bhatt *et al.*, 2012). Treatment with adsorption was found to be simple and cost-effective compare to other treatments. Some advantages of using this method are relatively easy to degrade, can be used to remove different types of coloring, and also can use natural material as an alternative low-cost adsorbent (Crini, 2006; Ho & McKay, 2003).

Lately, the development of cheaper and effective adsorbents has been studied. Some materials, including natural materials, biosorbents, and waste materials from industry and agriculture have been proposed by several workers as low-cost adsorbents (Crini, 2006). Indonesia has a lot of natural sources, especially from the sea. More than 70% of area is filled by sea and can be explored. The coral reef is abundant and potential to be used as an adsorbent (Giyanto *et al.*, 2017). The coral reef contains calcium carbonate and can use to reduce environmental pollution. Additionally, this material hopefully can be utilized as an effective adsorbent with high capacity. Hence, a small amount of adsorbent could adsorb dyes effectively and easy to be degraded. Some experiments had been reported that eggshells and coral powder can be used to immobilize heavy metals as an alternative to $CaCO_3$ (Ahmad *et al.*, 2012). However, the use of coral reef to remove dyes from wastewater still unknown.

In this preliminary study, we applied coral reef waste adsorbent to remove several dyes from aqueous solutions. Methylene blue (MB), remazol brilliant blue (RBB), disperse orange (DO), and vinyl sulfone (VS) were used in this experiment. The adsorption was evaluated based on the Langmuir and Freundlich adsorption isotherm models, the removal percentage, and adsorption capacity. The interaction of coral reef with dye was recognized by scanning electron microscopy (SEM). This study hoped that knowing the potency of the coral reef would provide novel insight into the alternative adsorbent.

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2. RESEARCH METHODS

2.1 Preparation and Characterization of Adsorbent

Coral reef waste of *Goniopora columna* (Figure 1.) was collected from Rancabuaya beach, Garut, West Java, Indonesia. The impurities were removed by washing the coral reef several times with distilled water and then this coral reef was crushed mechanically using a grinder. This material was then passed through a mesh no. 100 to get a homogeneous particle size. The coral reef powder was activated using chemical and physical methods. This powder was impregnated with NaOH 2N at 100˚C for 120 minutes. The pellets were neutralized to reach the neutral pH and dried at 60˚C and then dried at 700˚C for 6 hours. SEM (JEOL® JSM-6510A) analysis was used to monitor the surface structure before and after sorption.

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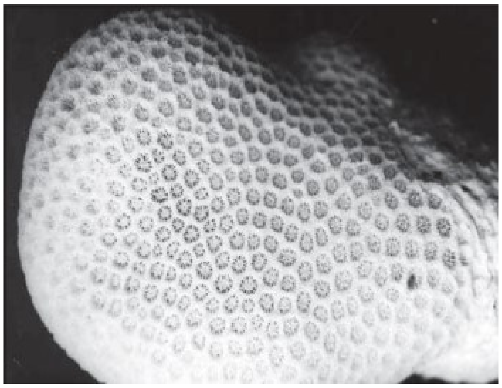
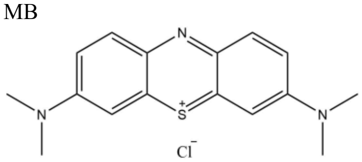
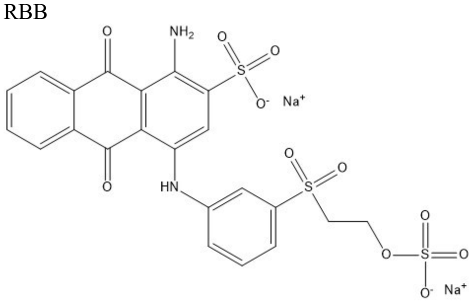
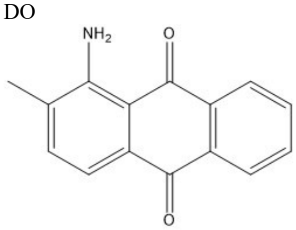
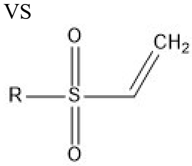


Figure 1. Coral reef of *Goniopora columna.*

2.2 Preparation of Stock and Dye Solutions

Four dyes were used in this study, i.e. MB, RBB, DO, and VS. The chemical structures and their properties are shown in Table 1.

Table 1. Chemical structures and the properties of dyes

Compound	**Molecular weight**	**Melting point**	**Solubility in water**
MB  $C_{16}H_{18}ClN_3S$	319.9 g/mol	100-110 ˚C	43,600 mg/L at 25 ˚C
RBB  $C_{22}H_{16}N_2Na_2O_{11}S_3$	626.5 g/mol	305 ˚C	10 – 50 mg/mL at 21 ˚C
DO  $C_{15}H_{11}NO_2$	237.25 g/mol	205.5 ˚C	0.332 mg/L at 25 ˚C
VS  $C_4H_6O_2S$	118.16 g/mol	-26 ˚C	100 mg/mL at 17 ˚C

The stock solution was prepared by dissolving 0.01 g of each dye powder into 100 mL distilled water to reach the final concentration of 100 mg/L dye solution. Five different initial concentrations of each dye were prepared by dilution of stock solution.

2.3 Samples Analysis

UV-visible spectrophotometer (Thermo Scientific® type Genesys 10S UV-visible) was used to determine the concentration of the adsorbates. The maximum wavelength of MB, RBB, DO, and VS were 649, 590, 445, and 635 nm, respectively. To confirm the homogeneity and linearity over the concentration range used in this study, calibration curves for these dyes' concentrations were measured and produced.

2.4 Adsorption Experiment

The adsorption of MB, RBB, DO, and VS onto coral reef were studied at room temperature at different initial concentrations. The initial dye concentrations were set at 6, 5, 4, 3, and 2 mg/L for MB; 100, 90, 80, 70, and 60 mg/L for RBB; 60, 50, 40, 30, and 20 mg/L for DO; and 90, 80, 70, 60, and 50 mg/L for VS. For the adsorption experiments, 1.0 g of adsorbent and 100 mL of each initial dye solution was mixed in 250 mL Erlenmeyer flask on a thermal shaker at 25°C with the velocity of 500 rpm. After 120 minutes, the suspensions were filtered and the concentrations of the dye remaining in the supernatant were analyzed using a UV-visible spectrophotometer.

2.5 Adsorption Capacity

The adsorption capacity was calculated by measure the amount of dye adsorbed per unit mass of adsorbent (q_e in milligrams of dyes per gram of adsorbent) using the expression:

$$q_e = \frac{C_o - C_e}{m} \ x \ V \qquad (1)$$

C_o is the initial dye concentration (mg/L), C_e is the equilibrium dye concentration (mg/L), m is the amount of the adsorbent used (g), and V is the volume of aqueous phase (L). The removal efficiency of dyes by adsorbent is examined in percentage as follow in equation (2), while the coefficient distribution is calculated using equation (3):

$$Removal\ efficiency = \frac{C_o - C_e}{C_o} \ x \ 100 \qquad (2)$$

$$K_d = \frac{q_e}{C_e} \qquad (3)$$

2.6 Adsorption Isotherm Model

The Langmuir and Freundlich adsorption isotherm models were used to the experimental data for the uptake of MB, RBB, DO, and VS by the coral reef waste. The expression of the Langmuir isotherm model is:

$$q_e = \frac{kC_e b}{(1 + kC_e)} \qquad (4)$$

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C_e is the equilibrium solution phase concentration (mg/L), q_e is the equilibrium solid phase concentration (mg/g), k is the enthalpy-related constant, and b is the Langmuir isotherm sorption capacity (/mg). Plotting C_e/q vs C_e gives Langmuir isotherm, where *1/b* is the slope and *1/kb* is the intercept.

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The Freundlich isotherm model is expressed in equations (5) and (6) in their non-linear and linear forms, respectively

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$$q_e = kf C_e^{1/n} \qquad (5)$$

$$Log\ q_e = Log\ kf + \left(\frac{1}{n}\right) Log\ C_e \qquad (6)$$

q_e and C_e were described previously, k*f* is the sorption capacity constant and *n* is the intensity constant. Plotting $Log\ q_e$ vs $Log\ C_e$ gives Freundlich isotherm, where the slope is the value of *1/n* and intercept is equal to $Log\ kf$.

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3. RESULTS AND DISCUSSION

3.1 Characterization of Adsorbent

It was known that the coral reef comprises calcium carbonate and produces about 4 kilograms of $CaCO_3$ per square meter per year (Giyanto *et al*., 2017). In addition, Ahmad *et al*. (2012) also found from FT-IR analysis that coral spectra appear centered between 1450 and 1500 cm^{-1} and these bands match to the v3 (asymmetric stretching of carbonate) mode (Ho & McKay, 2003). Coral reef produces $CaCO_3$ from the polyp part as forming the skeleton. This compound is required to protect the ecosystem (Ahmad *et al*., 2012). In general, calcium carbonate exists in amorphous and three polymorphs, namely calcite, vaterite, and aragonite. The calcite is thermodynamically the most stable at ambient conditions (Smith & Kinsey, 1976). The ion of Ca^{2+} and CO_3^{2-} play a crucial agent to adsorb the dyes. The charge of dyes gives an ionic interaction on the surface of $CaCO_3$. Zhao and Gao, (2010) also reported that $CaCO_3$ could be used to remove acidic pink res B (APRB) dye solution (Shaw *et al.*, 2015).

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3.2 Analysis of Percentage Removal of Dyes

This analysis was used to know the percentage of removal of different dyes to the adsorbent. Five initial and final concentrations were measured to evaluate the adsorption capacity. The list is shown in Table 2. For MB, the percentage removal decreased as the initial concentration decrease and the average removal was the lowest than the other dyes. VS also had similar results with MB, the percentage removal decreased as the initial concentration decrease, but it has a better average percentage removal value. In contrast, RBB and DO had different results. The percentage removal increased as the initial concentration decrease. Although for DO at an initial concentration of 20 mg/L the removal percentage decreased. It was suggested because the optimum concentration was between 30-40 mg/L. The most interesting thing is for RBB. The removal percentage was the highest and had a similar value in all different concentrations. It was indicated that this adsorbent is good for RBB treatment. RBB is an anionic dye since it has an anthraquinone group (Lazim *et al.*, 2015). The chemical structure of RBB consists of more reactive atoms than the others. It is suspected to be the reason that RBB could bind to the surface of the adsorbent.

Table 2. The amount of removal percentage and the coefficient distribution for each added dye concentration.

	Initial conc. (mg L^{-1})	**qe (mg/g)**	**Removal (%)**	**Kd (L g^{-1})**
Methylene blue	6	0.30	49.50	0.10
	5	0.26	52.60	0.11
	4	0.20	49.75	0.10
	3	0.11	37.67	0.06
	2	0.03	16.50	0.02
	mean	0.18	41.20	0.08
Remazol brilliant blue	100	9.11	91.05	1.02
	90	8.23	91.41	1.06
	80	7.34	91.80	1.12
	70	6.50	92.84	1.30
	60	5.58	92.95	1.32
	mean	7.35	92.01	1.16
Disperse orange	60	3.94	65.67	0.19
	50	3.67	73.46	0.28
	40	3.27	81.83	0.45
	30	2.41	80.23	0.41

	20	1.53	76.35	0.32
	mean	2.97	75.51	0.33
Vinyl sulfone	90	6.71	74.6	0.29
	80	5.73	71.61	0.25
	70	4.86	69.39	0.23
	60	4.04	67.38	0.21
	50	3.13	62.58	0.17
	Mean	4.89	69.11	0.23

To compare the efficiencies of the dyes, the distribution coefficient (Kd) values were analyzed. The distribution coefficient is used to compare the adsorption capacities of different dyes under the same experimental conditions. The ratio of dye concentration in the solid phase to that in the equilibrium solution after a specified reaction time was stated in the Kd value (Ahmad *et al.*, 2012). A high value of Kd shows high solid-phase retention through adsorption and chemical reactions. Nevertheless, a small value of Kd denotes that a high number of dyes remained in the solution. As shown in Table 2, the Kd value is comparable to that of removal efficiency. The highest value comes to RBB with an average of 1.16.

Based on the percentage removal and coefficient distribution value, the selectivity of dye sorption onto coral reef was found to be RBB > DO > VS > MB.

3.3 Equilibrium Adsorption Isotherm

The Langmuir and Freundlich adsorption isotherms model was used to analyze the concentrations of the dye for the interpretation of equilibrium isotherm data. Generally, the interaction of adsorbents and adsorbate is described in adsorption isotherm and thus is critical in optimizing the use of adsorbents. The Langmuir adsorption has been used successfully for many adsorption processes of monolayer adsorption that assumes the adsorption occurs at specific homogeneous sites within the adsorbent (Bulut & Aydin, 2006). In the Langmuir equation, the b value is the Langmuir constant related to the affinity of the binding site, while Kb represents a partial limiting adsorption capacity when the surface is fully covered with dye molecules which assists in the comparison of adsorption performance (Hui *et al.,* 2005).

To explain the heterogeneous systems, the empirical equation of Freundlich isotherm is used. From this equation, Kf and n values are roughly an indication of the adsorption capacity of the adsorbent and the adsorption intensity, respectively. Kf is a Freundlich constant that shows the strength of the relationship

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between adsorbate and adsorbent, while the n value is an indication of adsorption favorability. The value of n in the range of 1 to 10 generally represents good adsorption (Vadivelan & Vasanth Kumar, 2005).

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Table 3 shows the value of Langmuir and Freundlich adsorption isotherm. The b value of RBB is the highest followed by DO. It was indicated that the affinity of RBB is stronger than DO and the lowest affinity was reached to VS. It worth to note that the RBB has a higher b and Kb value, supported by the R^2 that indicated RBB follows the Langmuir model adsorption. Hence, from this model the thread of dye sorption was RBB > DO > VS > MB. The equilibrium isotherm curves in Figure 2. was plotted between the amount of dye adsorb from the dye single solution against the equilibrium concentration. The results showed that different types of dye give different types of adsorption. In addition, the n and Kf value of RBB from the Freundlich model is higher than others. It was indicated that coral reef has good sorption to RBB in both model adsorption isotherm.

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Table 3. The parameter used in Langmuir and Freundlich model

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Dyes	Langmuir model			Freundlich model		
	b (mg^{-1})	kb ($mg\ g^{-1}$)	R^2	n	kf	R^2
Methylene blue	-0.0492	0.01567202	0.3746	0.31	0.01228	0.6899
Remazol brilliant blue	19.49318	1.86741363	0.9716	1.60	2.303563	0.9899
Disperse orange	6.042296	0.62119518	0.8348	1.82	0.843335	0.7346
Vinyl sulfone	-2.0141	0.06678242	0.8984	0.31	0.000241	0.9502

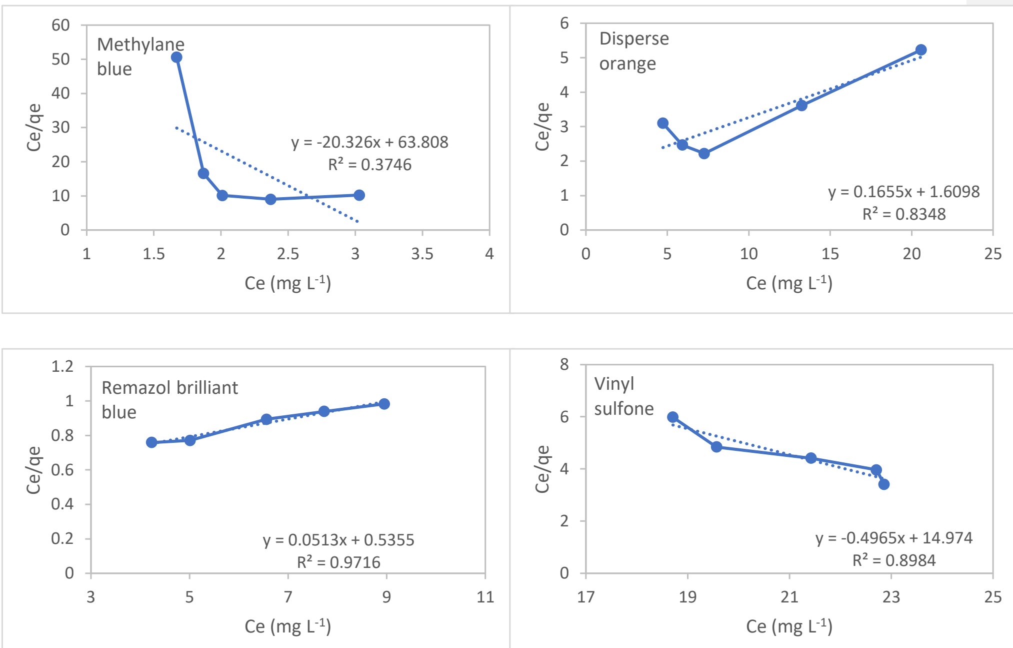

Figure 2. Langmuir sorption isotherms of dyes onto coral reef.

3.4 Mechanism of Adsorption Process

In this study, SEM analysis was used to monitor the changes in the surface structure of coral reef after the experiments. Figure 3 shows the surface structure before and after the adsorption experiment with RBB. It was shown that there were any changes in SEM analysis indicating that something happens with the adsorbent. After the adsorption experiment, the particles look tidier and uniform, flatten, and there were holes between one particle to particles. Indicating dye binds in the surface of particles.

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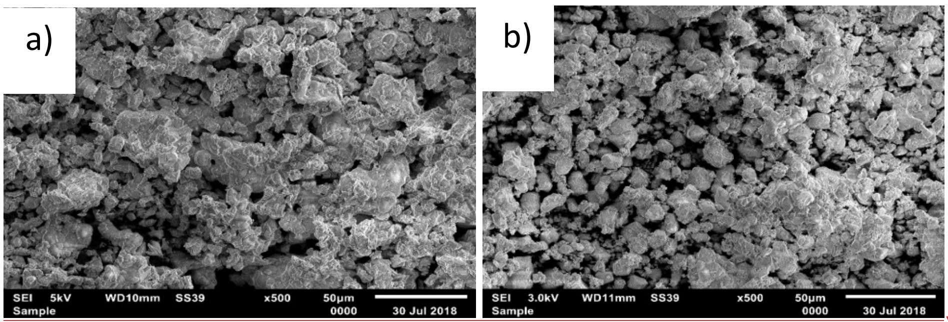

Figure 3. SEM analysis of *G. columna* before (a) and after adsorbing Remazol brilliant blue (b).

4. CONCLUSION

Coral reef waste was used to remove some dyes solutions as a low-cost adsorbent. Based on percentage removal and coefficient distribution value, the selectivity sequence of dye adsorption onto coral reef occurred in the following order: RBB > DO > VS > MB. The high content of minerals is a major component of this adsorbent. Future studies are needed to evaluate the effectiveness of this adsorbent as well as some factors affecting it including, pH, temperature, reaction time, and adsorbent dose. These results indicated the potential usefulness of coral reef waste as a low-cost adsorbent especially for the removal of RBB from the environment.

ACKNOWLEDGMENT

We want to thank the Indonesian School of Pharmacy and Hazanah Foundation, Bandung, Indonesia for their support of this work.

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