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FOCUS AND SCOPE

Jurnal Riset Teknologi Pencegahan Pencemaran Industri (Research Journal of Industrial Pollution Prevention Technology) seeks to promote and disseminate original research as well as review, related to following area:

Environmental Technology : within the area of air pollution technology, wastewater treatment technology, and management of solid waste and harzardous toxic substance.

Process Technology and Simulation : technology and/or simulation in industrial production process aims to minimize waste and environmental degradation.

Design Engineering : device engineering to improve process efficiency, measurement accuracy and to detect pollutant.

Material Fabrication : environmental friendly material fabrication as subtitution material for industry.

Energy Conservation : process engineering/ technology/ conservation of resources for energy generation.

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PREFACE

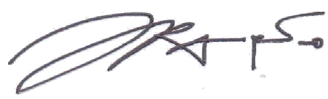
Alhamdulillah Robbie 'Alamin, Journal of Industrial Pollution Prevention Technology (JRTPPI) again will publish scientific articles, especially in the field of environmental technology for volume 9 no 1. Our high appreciation is directed to the authors, editorial board, structural officials of BBTPPI who have actively participated so as to maintain consistency of quality and punctuality of our periodic publications.

This edition of the issue is particularly different from previous editions, where all the articles are published in full-text English. This change is an attempt of the editorial board to improve the author's performance in delivering the results of their researches. Articles in full-text English are more likely to be read by broader audience so that it will increase the number of citations. This policy is also applied in order to actualize our hope of being a globally indexed international journal.

The articles contained in this edition consist of three important groups, namely: the use of natural materials, engineering tools for material quality analysis resulting in waste reduction and biotech waste treatment technology. The five manuscripts accepted and published in this edition are from LIPI, BBTPPI, and Baristand. The duration of submission, review, and editing of the manuscripts ranged from 4-7 months.

Hopefully, these scientific articles may be new source of knowledge and experience for readers from academic, researcher, industry, and society at large. We realize that nothing is perfect until the improvement of all parties involved is continuously done.

Semarang, May 2018



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ABSTRACT

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Rika Wulandari[1], Dwi Siswanta[2] ([1]Resesarch and Standardization Industry Pontianak, [2]Department Kimia, FMIPA Universitas Gadjah Mada Yogyakarta)

Adsorption of sodium dodecylbenzene sulfonate (DBS) by c-3,4-di-methoxyphenylcalix[4]resorcinarene triphenylphosphonium chloride

Jurnal Riset Teknologi Pencegahan Pencemaran Industri, May 2018, Vol. 9, No. 1, p. 1-8, 8 ill, 2 tab, 18 ref

Surfactants have been widely used in many industries, one of them is sodium dodecylbenzene sulfonate (DBS) which is a major component used in the manufacture of detergents and considered as toxic material. Various methods have been undertaken to reduce DBS content in water. One of them is adsorption, which is known as the most effective and environmentally friendly method so far. Our previous study has successfully synthesized an adsorbent C–3,4–dimethoxyphenylcalix [4] resorcinarene triphenylphosphonium chloride (CRP). The aim of this study is to investigate the adsorption of DBS by CRP. Adsorption studies were carried out using the batch methods at different acidity, contact time, and initial DBS concentration and analyzed using UV–Visible, FTIR, and SEM–EDX spectrophotometer. The results showed the optimum condition of DBS adsorption was at pH 8, contact time 120 min, and DBS concentration 40 mg/L. The maximum capacity for the adsorption process was 12.93 mg/g. The rate of adsorption was found to follow the pseudo second–order kinetic model and the Langmuir adsorption isotherm. The mechanism was a chemisorption that occur in monolayer ($\Delta G°$ ads = –24.87 kJ/mol).

(Author)

Keywords : adsorption, sodium dodecylbenzene sulfonate, c–3,4–dimethoxy–phenylcalix[4]resorcinarene triphenylphosphonium chloride, chemisorption

Ikha Rasti Julia Sari, Januar Arif Fathurrahman, Farida Crisnaningtyas, Moch. Syarif Romadhon (Center of Industrial Pollution Prevention Technology, Semarang)

FWHM dimensional analysis from scattered light intensity profile for dry rubber content determination in natural rubber

Jurnal Riset Teknologi Pencegahan Pencemaran Industri, May 2018, Vol. 9, No. 1, p. 9-14, 6 ill, 14 ref

Dry Rubber Content (DRC) describes a rubber particle percentage in natural rubber latex. In this paper, the relation between forward light scattering profiles of natural latex and rubber contents is reported for dry rubber content latex. The profile, characterized by Full Width at Half Maximum (FWHM), is increasing linearly with respect to rubber content. The measurement was performed immediately after latex being tapped with necessary addition of ammonia. This addition was meant to prevent latex coagulation. There is a high linear correlation between DRC and FWHM of both domains: one and two dimension. This is indicated by correlation factor r^2 which are higher than 0.9 for both of domains and sufficient in DRC determination.

(Author)

Keywords : natural latex, light scattering, dry rubber content, full width at half maximum

Bekti Marlena, Rustiana Yuliasni, Sartamtomo, Agung Budiarto, Syarifa Arum, Misbachul Moenir, Cholid Syahroni (Center of Industrial Pollution Prevention Technology, Semarang)

Removal of ammonia on catfish processing wastewater using horizontal sub-surface flow constructed wetland (HSSFCW)

Jurnal Riset Teknologi Pencegahan Pencemaran Industri, May 2018, Vol. 9, No. 1, p. 15-21, 3 ill, 1 tab, 30 ref

The performance of Horizontal Sub-Surface Flow Constructed Wetland (HSSFCW) to remove high ammonia content in catfish processing wastewater was investigated. A rectangular HSSFCW with 6 m long, 3 m wide,1 m deep and divided into 3 compartments was used. Gravel beds were used as media. *Canna sp*, *Heliconia sp*., and *Papirus sp*. were planted with plant density 10 plants per m^2. The result showed that removal of ammonia, nitrite and nitrate respectively reached 99.34%, 98.73%, and 99.99%. Residual ammonia concentration can be minimized by improving oxygen transfer rate and lessening organic matter in the system.

(Author)

Keywords : horizontal sub-surface flow constructed wetland, ammonia removal, catfish processing wastewater

Muhammad Amin*, Kusno Isnugroho, Yusup Hendronursito (Research Unit For Mineral Processing – Indonesian Institute of Sciences)

Utilization of blast furnace solid waste (slag) as cement substitution material on mortar manufacture

Jurnal Riset Teknologi Pencegahan Pencemaran Industri, May 2018, Vol. 9, No. 1, p. 22-28, 7 ill, 3 tab, 12 ref

Slag is defined as a waste material produced from iron ore smelting process in blast furnace. The slag was derived from Research Center for Mineral Technology located in Tanjung Bintang Lampung Selatan with particle size of 80,100, and 120 mesh. The percentages of slag used as cement substitution were 10%, 20%, and 30% from total volume. Test pieces was made by compressing all mixture material in 50 x 50 x 50 mm cubical mortar mold. Physical test of mortars, such as : porosity test, density test and compressive strength test were performed. Based on physical test of samples, it was shown that the higher ratio of slag used in cement substitution gives higher mortar porosity. Substitution of 10% slag with size of 100 mesh produced the porosity of 3.45%, while the substitution 20% and 30% slag with the same size, produced 5.08% and 5.76% porosity, compared with the standard of mortar which was 5.12%. The compressive strength test with 10% slag substitution was 19.3 Mpa, while 20% substitute slag gave the compressive strength of 19.1 Mpa and 30% substitute slag has compressive strength value of 18.7 Mpa. The standard mortar is 17.2 Mpa. However, beside of slag substitution ratio, the slag particle size also affected the compressive strength and porosity. Based on the results explained, the substitution of slag as a substitute for cement in mortar strength was still above the mortar standard.

(Author)

Keywords : slag, substitution, cement, physical test, compressive strength, material

Novarina Irnaning Handayani, Nanik Indah Setianingsih*, Misbachul Moenir (Center of Industrial Pollution Prevention Technology, Semarang)

Performance of immobilized-selected microorganisms in the biodegradation of textile wastewater

Jurnal Riset Teknologi Pencegahan Pencemaran Industri, May 2018, Vol. 9, No. 1, p. 29-37, 6 ill, 2 tab, 12 ref

Wastewater from textile industry contains of variation of pollutants within certain concentrations. To protect the environment and water bodies, polluted wastewater must be treated before it can be discharged into the environment. Anaerobic biological treatment has been used as technology in textile wastewater treatment. Several factors that affect the performance of conventional anaerobic treatment need to be addressed in order to improve the efficiency of this technology, including the utilization of a consortium consists of selected microorganisms acts as inoculums. These inoculums are expected to improve the textile wastewater biodegradation performance. In this study selected microorganisms in the form of immobilized and free cells were used. The performance of selected microorganisms was conducted by comparing the pollutants removal efficiency of immobilized, free cells and conventional sludge. Results show that selected-immobilized microorganisms achieved the best performance due to its stability and its highest efficiency in removing pollutants. Mean while microorganisms in the form of free cells had the lowest performance due to its sensitivity towards environmental conditions and having low mechanical strength of biomass. Immobilized cells succesfully treated wastewater from textile industry, with removal of suspended solid reached to 93.78%. In addition, for parameter oil & grease, BOD_5 and COD, the removal efficiency was 99.13%, 81.,54% and 64.94% respectively. However, the system could not sufficiently remove ammonia due to the anaerobic condition instead of aerobic condition in the reactor.

(Author)

Keywords: biodegradation, immobilized cells, waste water, textile industry

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Removal of ammonia on catfish processing wastewater using horizontal sub-surface flow constructed wetland (HSSFCW)

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ABSTRACT

The performance of Horizontal Sub-Surface Flow Constructed Wetland (HSSFCW) to remove high ammonia content in catfish processing wastewater was investigated. A rectangular HSSFCW with 6 m long, 3 m wide,1 m deep and divided into 3 compartments was used. Gravel beds were used as media. *Canna sp*, *Heliconia sp.*, and *Papirus sp.* were planted with plant density 10 plants per m^2. The result showed that removal of ammonia, nitrite and nitrate respectively reached 99.34%, 98.73%, and 99.99%. Residual ammonia concentration can be minimized by improving oxygen transfer rate and lessening organic matter in the system.

1. INTRODUCTION

Small scale industry of catfish processing is one of the emerging small scale industries in Indonesia, increasing in production yield from 39.66% to 67.74% in 2010, with Boyolali, Central Java as one of industrial center area (Triyanti and Shafitri, 2012). Due to its processes, fish processing industries consume large amount of water especially for cleaning and sanitation (Chowdhury et al., 2010), and the wastewater mainly contains variety of organic pollutants, such as lipid, grease, protein, colloidal particles and particulates (Gonzalez, 1996).High ammonia concentration is also observed due to high blood and slime passive content in wastewater streams. The ammonia concentration normally ranges from 0.7 mg/L to 69.7 mg/L (Fremp, 1994). High ammonia and nitrate discharge in water stream can cause eutrophication (Norton, 2014).

Due to its low cost and relatively easy maintenance, constructed wetland (CW) has been applied as post treatment in many small-scale industrial wastewater treatment plants (Iamchaturapatr et al., 2007). It is typically used after biological treatment for nutrient removal to meet the minimum effluent standard (Moenir et al., 2014) and specifically used as tertiary/post treatment in treating high ammonia content in industrial wastewater (Sun and Austin, 2007). Ammonia removal efficiency in a CW ranges between 25 – 85% (Crites, 1988).

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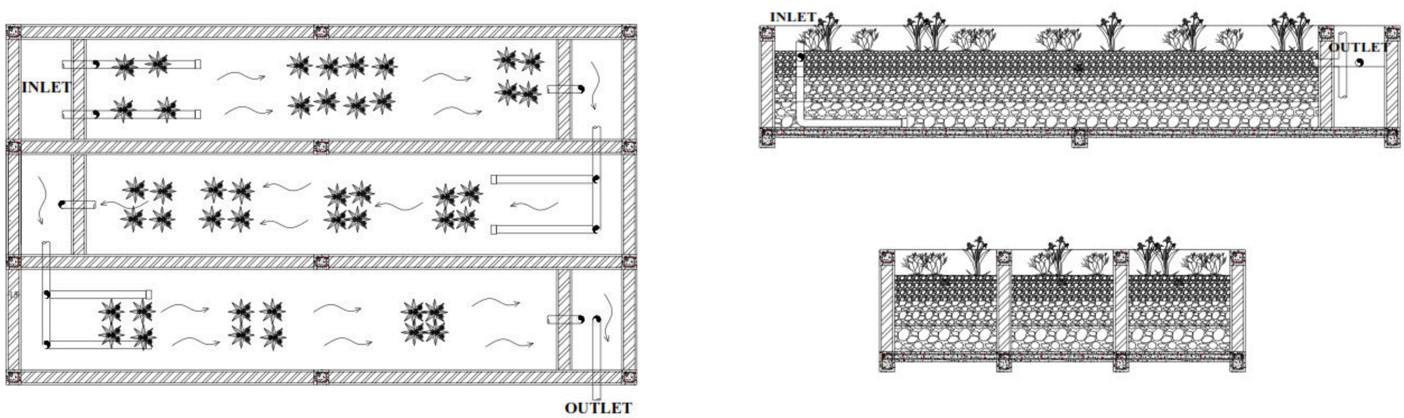
CW is described as engineered wetlands, contains of saturated or unsaturated substrates, a large biomass of plants, and a large variety of microbial communities, such as nitrifying and denitrifying bacteria (Vymazal, 2014). In theory, many emergent plants could be used for CW. However, in reality, only a limited number of species has been used so far (Vymazal, 2011). In the tropical area, local plants such as *Cyperus papyrus* (Wu et al., 2015; Kyambadde et al., 2004), *Heliconia* and *Canna* (Calheiros et al., 2007; Sohsalam et al., 2008), *Thypa latifolia* (Ciria et al., 2005; Gersberg et al., 1986; Kyambadde et al., 2004) are preferably used. Large variety of microbial communities play major role in the degradation of organic nitrogen, which involve ammonification, nitrification and denitrification mechanisms (Lee et al., 2009). Horizontal Sub-Surface Flow Constructed Wetland (HSSFCW) was selected to achieve higher nitrogen removal. HSSFCW is an engineered contructed wetland with hybrid system, involving a horizontal flow of wastewater feed with the emphasize of waste water level below the surface (Vymazal, 2014).

The performance of combination UASB-wetland technology for catfish processing WWTP had already been studied by Marlena et al. (2017), but this study focused only on the reactor design and the performance of the reactor was only calculated based on COD removal. Due to the fact that ammonia removal efficiency was higher than COD removal, this paper emphasize about nitrogen removal in HSSFCW to treat catfish wastewater.

2. MATERIAL AND METHODS

2.1 Material

Wetland used in this study was a rectangular HSSFCW with 6 m long, 3 m wide and 1 m deep. HSSFCW was divided into 3 compartments. Each compartment was filled with gravels to form filter bed. Filter bed was 0.75 m deep, contained of small size gravel (D = 0.5 – 1 cm) 0.25 m deep at the top layer, medium size gravel (D = 1 – 3 cm) 0.25 m deep at the middle layer and big size gravel (D = 3 – 7 cm) 0.25 m deep at the bottom layer. The water level was maintained at 0.7 m deep. The first compartment was planted with *Papyrus sp*, while the second was planted with *Canna sp.* and the third was planted with *Heliconia sp*. Plant density was arranged 10 plants per m^2.



(a) (b)

Figure 1. Constructed Wetland top view(a); side view (b)

2.2 Method

The performance of combination UASB-wetland technology WWTP has been applied in catfish processing industry (Marlena et al. 2017).The wastewater flowed from the outlet of Upflow Anaerobic Sludge Blanket (UASB) reactor into the filter bed via 3-inch polyethylene pipe by gravity. Inlet pipe was embedded at the bottom of filter bed, while the outlet was embedded at the top layer of filter bed. The treated wastewater flowed vertically up, from the bottom to the top layer, then collected in the outlet chamber. The HSSFCW was fed intermittently with flow rate 1 m^3/day, during 2 months operational period (May-June 2017). The outlet was then recirculated back (with ratio outlet : recycle = 2:1) to the first compartment using recirculating submersible pump (Aquila P 3900; 43 Watt; H_{max} = 3.9 m; Q_{max} = 2500 L/hour). Recirculating pump was controlled by automatic water level.

Water samples from inlet and outlet of the constructed wetland were collected and periodically submitted to BBTPPI Semarang testing laboratory, and analyzed using the methodology described in Standard Methods (SM) for the Examination of Water and Wastewater (Eaton et al., 2012) for the following parameters: nitrate (NO_3-N, SM-4500-NO_3), ammonia-nitrogen (NH_4^+-N, SM-4500-NH_3), nitrite (SM-4500-NO_2), alkalinity (SM-2320-alkalinity B), and dissolve oxygen (DO) was measured using SM-4500-O-C. Parameters ammonia, nitrate, nitrite, alkalinity were measured using Thermo Scientific Gallery Automated Photometry instrument, while dissolved oxygen was measured using Brand Digital Burette. Parameters collected on-site including temperature and pH was measured using a pH meter (Krisbow KW06-744).

3. RESULTS AND DISSCUSSION

3.1 Removal of ammonia, nitrite and nitrate in the HSSFCW

The removal efficiency of ammonia, nitrite and nitrate in HSSFCW is calculated, meanwhile, the total N concentration is derived from the summation of ammonia, nitrite, and nitrate concentration. The results of the removal efficiency are shown in table 1.

Table 1. shows that the concentration of all parameters such as ammonia, nitrite, nitrate and total nitrogen (TN) are high, which is dominated by the ammonia concentration. The removal of ammonia, nitrite, nitrate and TN respectively are 66.89 - 99.34%, 26.69 - 98.73%, 35.65 - 99.99% and 59.99 - 99.22%. Those removal efficiencies are higher compared to Vymazal (2001) and Prayitno (2014). Vymazal (2001) reported that ammonia removal efficiency could reach 48.3% and nitrate removal was 38.5%, meanwhile Prayitno (2014) reported 83.67% ammonia reduction. However, the residual ammonia higher concentration than nitrite and nitrate indicated possibility of the nitrification role as limiting step in ammonia removal, which will be discussed further.

3.2 The effect of Alkalinity, Dissolved Oxygen, C/N ratio on nitrification-denitrification process in HSSFCW.

Ammonia (NH_3-N), nitrite (NO_2^-N), and nitrate (NO_3^-N) removal, alkalinity consumption, and dissolved oxygen (DO) in HSSFCW were monitored and the results are shown in figure 1. Ammonia, nitrite and nitrate removal and alkalinity consumption were calculated from the subtractions of inlet concentration by outlet concentration, while DO was calculated based on DO concentrations in the wetland.

The figure 2. shows that nitrite and nitrate removal are correlated with DO and alkalinity consumption. Nitrite and nitrate removal increase when DO and alkalinity consumption in the system increase, and vice versa. Nitrification is the biological formation of NO_2^-N and NO_3^-N from NH_4^+. Oxidation of NH_4^+ releases H^+ and drops the pH, while adequate alkalinity is consumed to maintain a neutral pH. Theoretically, 7.14 mg/L alkalinity (as $CaCO_3$) is consumed for each mg/L ammonia nitrogen, and 1.98 mol of H^+ is released (Kadlec and Knight, 1996). In this experiment, ratio of alkalinity to $NH_4^+$is ± 4.5:1 mg/L, which is lower than the theoretical stoichiometric calculation written in equation 1.

$$NH_4^+ + 1.83\ O_2 + 0.98\ HCO_3^- \rightarrow 0.021\ C_5H_7NO_2 + 1.04\ H_2O + 0.98\ NO_3^- + 1.88\ H_2CO_3 \quad \text{(eq1)}$$

Table 1. Performance of ammonia, nitrite and nitrate in HSSFCW

No.	SAMPLE	Unit	Ammonia	Nitrite	Nitrate	Total Nitrogen(TN)
1	Inlet 1	mg/L	55.4	27.27	30.12	112.79
	Outlet 1	mg/L	7.013	6.26	5.377	18.56
	Removal 1	%	87.34	77.04	82.15	83.46
2	Inlet 2	mg/L	50.2	30.11	33.11	113.42
	Outlet 2	mg/L	7.7	7.42	0.014	15.13
	Removal 2	%	84.66	75.35	99.96	86.66
3	Inlet 3	mg/L	46.8	24.34	26.29	97.43
	Outlet 3	mg/L	15.25	0.82	0.624	16.69
	Removal 3	%	67.41	96.63	97.63	82.87
4	Inlet 4	mg/L	49	23.95	27.81	100.76
	Outlet 4	mg/L	15.3	15.34	9.676	40.32
	Removal 4	%	68.77	35.95	65.21	59.99
5	Inlet 5	mg/L	51.9	4.72	5.75	62.36
	Outlet 5	mg/L	16.3	3.46	3.7	23.46
	Removal 5	%	68.59	26.69	35.65	62.38
6	Inlet 6	mg/L	52.4	12.21	9.464	74.07
	Outlet 6	mg/L	17.35	7.55	4.337	29.24
	Removal 6	%	66.89	38.16	54.17	60.52
7	Inlet 7	mg/L	19.4	32.89	31.2	83.49
	Outlet 7	mg/L	1.12	5.65	0.044	6.814
	Removal 7	%	94.23	82.82	99.86	91.84
8	Inlet 8	mg/L	55.3	57.56	27.97	140.83
	Outlet 8	mg/L	0.365	0.73	0.001	1.096
	Removal 8	%	99.34	98.73	99.99	99.22

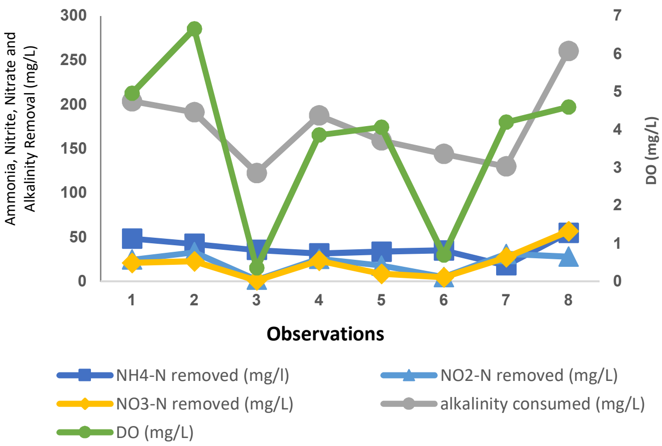


Figure 2. Ammonia, nitrite, and nitrate removal in correlation with consumption of alkalinity and DO.

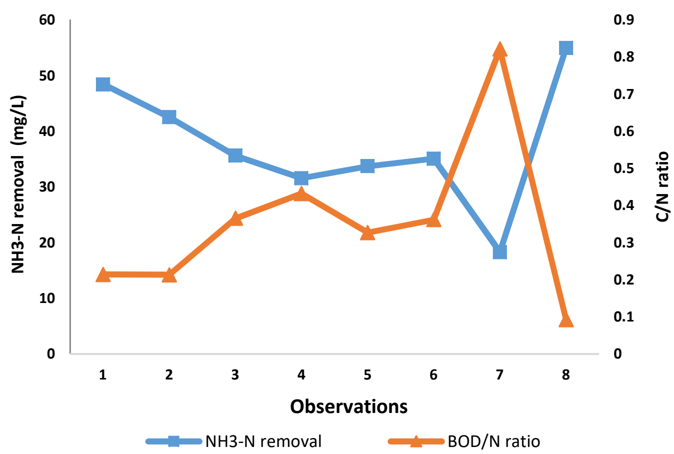


Figure 3. Correlation of Ammonia removal and C/N ratio

A complete NH_4^+ oxidation requires 4.2 – 4.5 mg O_2/mg N (Brix, 1987). In HSSFCW oxygen supply is provided by macrophyte, via roots oxygen release. Root oxygen release rates from a number of submerged aquatic plants are reported to be in the range of 0.5 to 5.2 g m^{-2}/day (Sand-Jensen et al., 1982; Kemp and Murray, 1986; Caffrey and Kemp, 1991), specifically according to Bavor et al. (1988), oxygen released by phragmites species was estimated around 0.8 g O_2/m^2 in gravel media. While in this reactor, DO concentrations in the bulk water to support growth of Ammonia Oxidation Bacteria (AOB) could not be calculated precisely due to lack of data. However, the data shoes that if residual DO in the effluent is below 1 mg/L (fig. 1), then nitrite and nitrate removal would be decreased. This result agrees with the theory that nitrification reaction occurs in aerobic condition, when DO level drops to <1 mg/L nitrification significantly decrease (Hammer and Knight, 1994). The evidence of low oxygen transfer rate in our system also shown in Figure 3.

Figure 3. shows the correlation of ammonia removal with C/N ratio. C/N ratio was calculated based on the ratio of organic carbon (as BOD) versus ammonia concentration in the inlet. It shows that ammonia removal decreased as ratio C/N in the inlet increased. AOB is autotrophic bacteria which able to consume carbon solely from CO_2 or bicarbonate present in the wastewater under sufficient aerobic condition. However, under oxygen limitation, ammonia removal process is organic carbon limited. Meaning that the presence of high amount of organic carbon (expressed as BOD) limits nitrification process, thus also limits ammonia removal. This is due to the fact that autotroph AOB has much lower respiration rates than heterotroph bacteria (Lee et al., 2009). Hence, significant nitrification performed by AOB does not occur before substantial BOD reduction performed by heterotrophs. It is indication of competition for O_2 between nitrifying bacteria and heterotrophy bacteria which affect nitrification process in the system. The result in this study is similar to the result of (Fan et al.,2013) study, who also performed their study under oxygen limited condition.

4. CONCLUSION

HSSFCW can remove ammonia content in catfish processing wastewater. Removal of ammonia, nitrite, nitrate and TN respectively are 66.89 - 99.34%, 26.69 - 98.73%, 35.65 - 99.99% and 59.99 - 99.22%. Nitrification acts as limiting step in ammonia removal. Hence, to maximize ammonia removal in HSSFCW system, enhancement of nitrification process by increasing oxygen transfer rate and by reducing the amount of organic matter in the system, can give a significant results. Higher oxygen transfer can be achieved by installing an aeration pump or by effluent recycling, while reducing organic matter can be done by optimizing organic removal in the UASB reactor.

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Performance of immobilized-selected microorganisms in the biodegradation of textile wastewater

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ABSTRACT

Wastewater from textile industry contains of variation of pollutants within certain concentrations. To protect the environment and water bodies, polluted wastewater must be treated before it can be discharged into the environment. Anaerobic biological treatment has been used as technology in textile wastewater treatment. Several factors that affect the performance of conventional anaerobic treatment need to be addressed in order to improve the efficiency of this technology, including the utilization of a consortium consists of selected microorganisms acts as inoculums. These inoculums are expected to improve the textile wastewater biodegradation performance. In this study selected microorganisms in the form of immobilized and free cells were used. The performance of selected microorganisms was conducted by comparing the pollutants removal efficiency of immobilized, free cells and conventional sludge. Results show that selected-immobilized microorganisms achieved the best performance due to its stability and its highest efficiency in removing pollutants. Mean while microorganisms in the form of free cells had the lowest performance due to its sensitivity towards environmental conditions and having low mechanical strength of biomass. Immobilized cells succesfully treated wastewater from textile industry, with removal of suspended solid reached to 93.78%. In addition, for parameter oil & grease, BOD_5 and COD, the removal efficiency was 99.13%, 81.,54% and 64.94% respectively. However, the system could not sufficiently remove ammonia due to the anaerobic condition instead of aerobic condition in the reactor.

1. INTRODUCTION

Water is abundantly required in the production process of textile industries. Residue of materials in the production process is generally discharged in the form of wastewater. Having negative impact to environment, wastewater must be treated. Anaerobic wastewater treatment is one of the biological treatment methods for treating wastewater containing of high organic pollutant. Goel (2010) had performed anaerobic condition to treat wastewater from staining process in the textile industry.

Factor affecting pollutant degradation in anaerobic condition is the availability of appropriate microorganisms. In addition, other external factors such as pH, alkalinity, temperature and nutrients are also influencing anaerobic degradation process. In conventional anaerobic treatment, sludge was used as source of inoculum to treat textile wastewater. Acclimatization process of conventional

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anaerobic treatment takes a long time and the low efficiency of pollutant removal needs to be improved. In order to increase the performance of wastewater treatment, a selected microorganisms can become one of alternatives. Selected microorganisms in the form of isolates found via isolation stage and have passed the ability test to degrade the pollutants in textile industry wastewater that contains amylum, cellulose, oil, and dye (Handayani et al., 2016).

Some researchers reported that performance of biological wastewater treatment systems can be upgraded by using inoculum in the form of immobilized cells. Han, T. & Shim (2016) used immobilized cells to improve the performance of biological system reactors in degradation of textile waste water from staining process. Immobilized cells was also used to degrade the azo type of staining waste water (Tan, L.N, & Xu, 2014). In addition Wang et al. (2007) successfully treated carbazole, a toxic pollutant with an aromatic polycyclic structure with immobilized cells

Immobilization is a technique of maintaining microorganisms to stay in the matrix in order to increase the efficiency of the desired microorganism performance (Thirumarimurugan, 2016). There are several methods of Immobilization cells, one of them is adsorption. Adsorption is the simplest and the most passive immobilization method, in which the cells are adsorbed into the inert pores of media (Cláudia et al., 2013). According to Górecka. E (2011) the used media for immobilization should be adapted to local availability, having a stable and non-toxic matrix and does not affect the structure and activities of cell.

Matrixs commonly used for passive surface immobilization include soil, peat, activated carbon, coke, plastic media, celite and glass beads (J.Wilson, 2017). In this study, peat soil was selected as cell immobilization media due to its availability and affordability. Lee et al. (2010) had used peat soil as cell immobilization media to degrade petroleum waste, and proved that it was the best matrix because of its highest cellular adsorption capacity.

This research aimed to study the performance of selected microorganisms in the form of immobilized and free cells to degrade pollutant in textile industry waste water compared with conventional sludge.

2. MATERIALS AND METHODS

2.1. Materials

The inoculum sources used in this research were selected isolates bacteria (Handayani et al., 2016) and sludge derived from textile wastewater equalization tank. Wastewater used in the experiment derived from Dan Liris textile industry in Pekalongan Central Java. Dried peat soil derived from the bottom of Rawapening Lake was used as matrix of immobilization. Aquadest and nutrient broth were used as media of free cells. Nutrient broth and chemical compounds used for analysis were p.a grade (Oxoid and Merck). pH meter used was Krisbow (KW0600744) Reactor used in the experiment was made of acrylic, with volume of 5 L and run with upflow system by using peristaltic pump (Cole-Parmer Masterflex Brand, easy load L/S type, model 7518-62).

2.2. Methods

Preparation of inoculums

Inoculum in this research were divided into three types namely immobilized cells, free cells, and conventional sludge. Immobilization in peat soil media was carried out by inserting a starter (consortium bacteria in liquid form of nutrient broth media) into peat soil media in a ratio of 1: 1 (1 kg of peat soil mixed with 1 liter starter). The mixture was incubated in room temperature and monitored in storage up to four weeks. During incubation process, the samples of mixture were taken five times to analyze the number of active bacteria in total plate count and pH measurements. Free cells was a consortium of bacteria inoculated in nutrient broth media only, while conventional sludge was derived from waste water equalization tank of textile industry.

Performance test of inoculums

The Performance of three types inoculums were observed in laboratory scale. The experiment was carried out in upflow anaerobic reactor with volume of 5 L. 20% of Inoculum was added in reactor then fed with wastewater from textile industry in upflow system using peristaltic pump.

The experiment was divided in two phases, the first was acclimatization phase and the second was continuous phase. In the acclimatization phase, wastewater with COD concentration range of 500-1300 mg/L was fed into reactor in batch system, and then circulated up to get optimum level of pollutant degradation. Pollutant degradation was observed based on COD reduction.

During continuous phase, COD concentration range was 500-1900 mg/L, with hydraulic retention time (HRT) was determined in 24 hours. Inlet and outlet samples of reactors were taken regularly to be analyzed. In steady state condition, when the highest pollutant degradation was achieved, then sample was taken to be analyzed in complete parameters such as: COD, Total suspended solid, BOD_5, Phenol, Chrom, Ammonia, Oil and grease. Furthermore, microbial identification was also carried out in order to know the species of microorganisms used as inoculum.

3. RESULT AND DISCUSSION

During incubation process of inoculum preparation, both immobilized and free cells, were analyzed on total plate count (TPC) and pH. TPC method is the nearest estimation method to determine whether bacteria in both immobilized and free cell inoculum live and grow or not.

It can be seen from table 1 that, up to 28 days of storage time, the living cells in both immobilized and free cells are more than $1.0x10^7$ CFU/ml, then it can be concluded that both inoculums are ready to be applied in the wastewater treatment process. After 28 days, TPC number of free cells is more stable than immobilized cells because during incubation period, free cells were incubated in refrigerator with temperature of 4-6^{o}C, while immobilized cells were incubated a room temperature. But in general, TPC number of immobilized cells is not different significantly compared to free cells.

Visual observation on the 28th day of immobilized cells shows biofilm formation on the surface of peat soil, which might be indication of inoculum adsorption in to the surface of peat soil matrix. As explained by Kilonzo & Bergougnou (2012), cell immobilization by adsorption is influenced by several factors including age and cell surface structure, composition and pH of the media, as well as the structure and size of the media pores. Furthermore, although strength level of cell immobilization with adsorption process is relatively weak, it is still able to bind the cell efficiently.

pH during incubation process was observed and the value can be seen in figure 1.

Table 1. Result of total plate count analysis

Time of incubation (days)	TPC of immobilized cells (CFU/mL)	TPC of free celsl (CFU/mL)
1	7.6×10^8	5.1×10^8
5	4.0×10^8	8.3×10^8
14	4.8×10^7	2.4×10^7
21	2.6×10^7	2.3×10^7
28	1.1×10^7	6.2×10^7

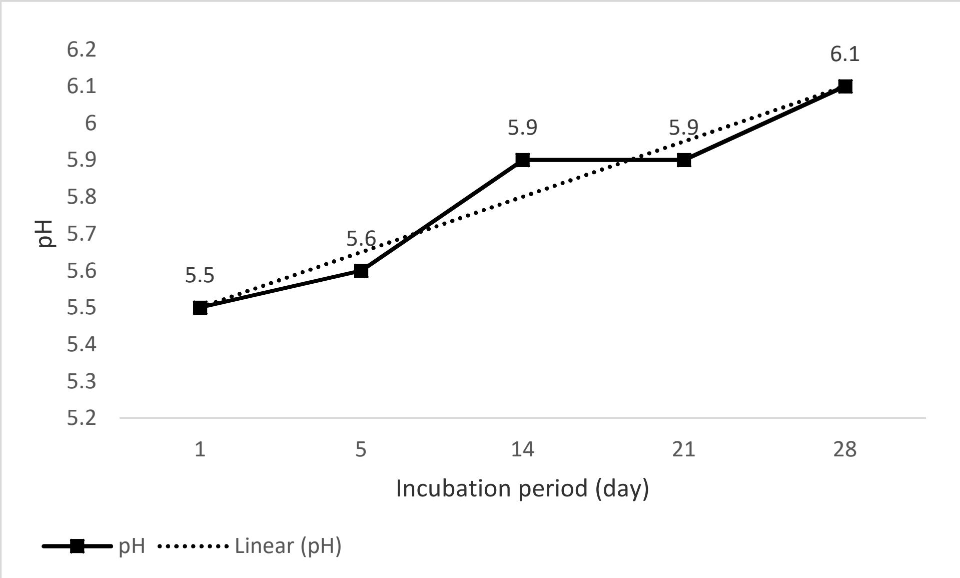

Figure 1. pH of immobilized cell during incubation process

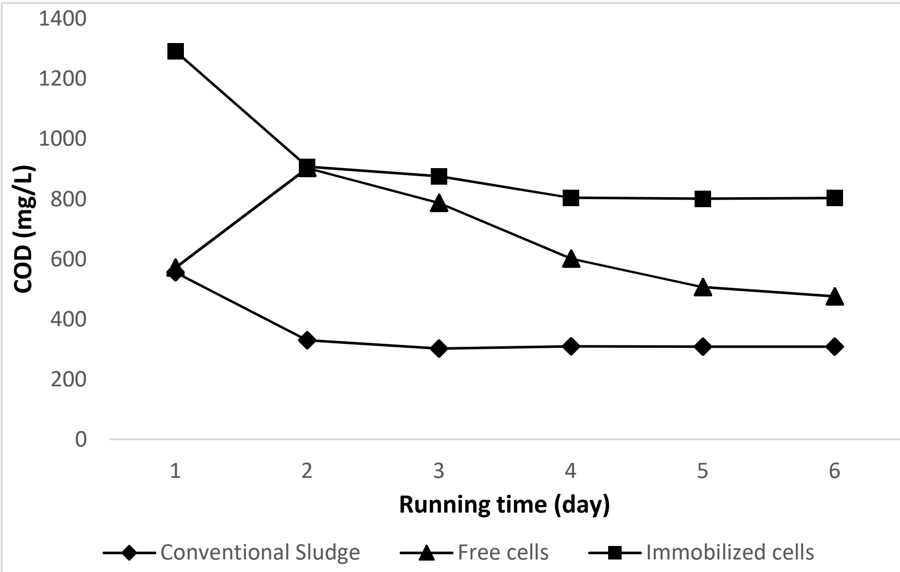

Figure 2. Pollutant degradation at acclimatization phase

Figure 1 shows that, pH of immobilized cells tend to increase during the incubation period, and has reached neutral range on the 28th day. Contrast with TPC analysis results (table 1) that shows a tendency of the longer incubation period of immobilized cell the lower number of TPC.

Some researchers reported that immobilized cells are able to tolerate the change in pH of medium than free cells (Linardi, 2001; Nigam, 2000). Chen et al.(2007) reported pH would have a significat on microbial activities and a neutral environment is suggested to obtain higher pollutant degradation rate with immobilized cells. Thus, in this research the immobilized cells were incubated untill pH reached on the neutral range to anticipate stress of cells because wastewater pH used in the experiment were higher than 6.5.

The results of wastewater treatment experiment during the acclimatization period can be seen in Figure 2.

During acclimatization process, a maximum point of pollutant degradation of three inoculum types are reached after day 4 of the experiment, indicated by decrease of COD concentration significantly . This result is almost similar to the report of Mostafa et al.(2015), that has the highest degradation rate after 4-6 days using similar immobilized and free cells. It can be seen in figure 2 treatment with immobilized cell and conventional sludge perform more stable condition process. Percentage of degradation pollutant by using immobilized cell is 38.07%, mean while free cells and conventional sludge reach on 16.73% and 44.49% respectively.

Figure 2 also shows that free cells get the lowest performance in degrading pollutant, even on the second day COD effluent slightly rise, which can be an indication of the occurance of death cells washed out, contribute to the increase of COD level in the effluent. Supported by some researchers, inoculum in free cells suspension having higher sensitivity to environmental conditions than immobilized cells. Reported that, pH and temperature affect on longlive of free cells suspension. In this research, pH of wastewater were 8 to 8.5 indication of alkali condition and reactors were operated at room temperature. According to Chen et al. (2007), if the ambient is higher than the optimal temperature, thermal death of the cells might occur, and removal rates would decrease. However, Murakami-nitta et al.(2003) observed that a free cell system was more sensitive to temperature change than immobilized cells, and immobilization increased the thermal stability of the cells.

The performance of inoculums in continuous phase are showed in figure 3, 4 and 5.

Conventional sludge in waste water treatment experiment perform stable condition during the experiment shows a trend of COD outlet and percentage of COD removal. Average of COD removal with conventional sludge in the experiment is 29.29%.

Running experiment period of free cells inoculum was shorter than conventional sludge and immobilized cells due to the death of cells presumption. In visual observation in the free cells outlet, some layers is found and different odor is also smell, which can be indication of washed out dead cells. Reported by Godjevargova et al.(2004), free cells on waste water treatment tend to washed out because of having low mechanical strength of biomass.

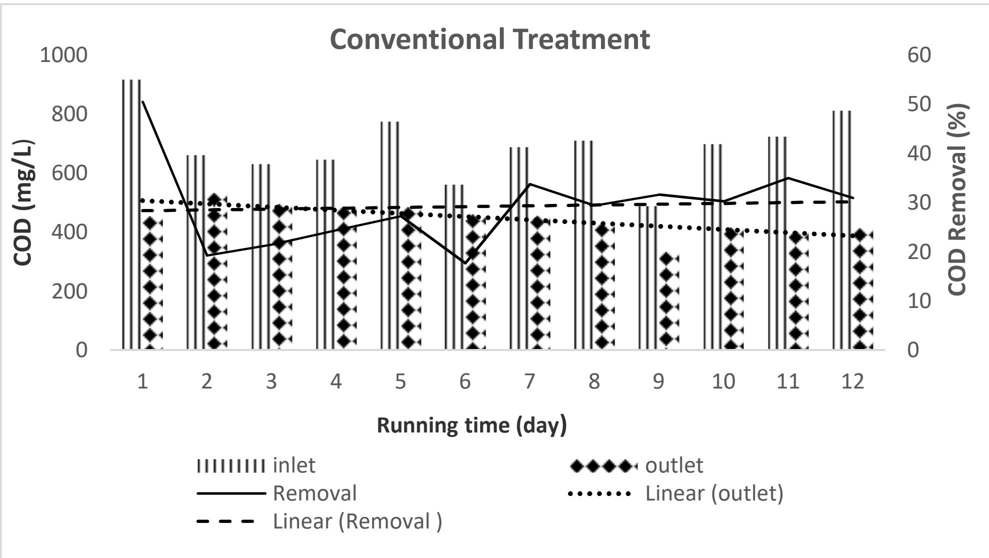

Figure 3. Performance of conventional sludge

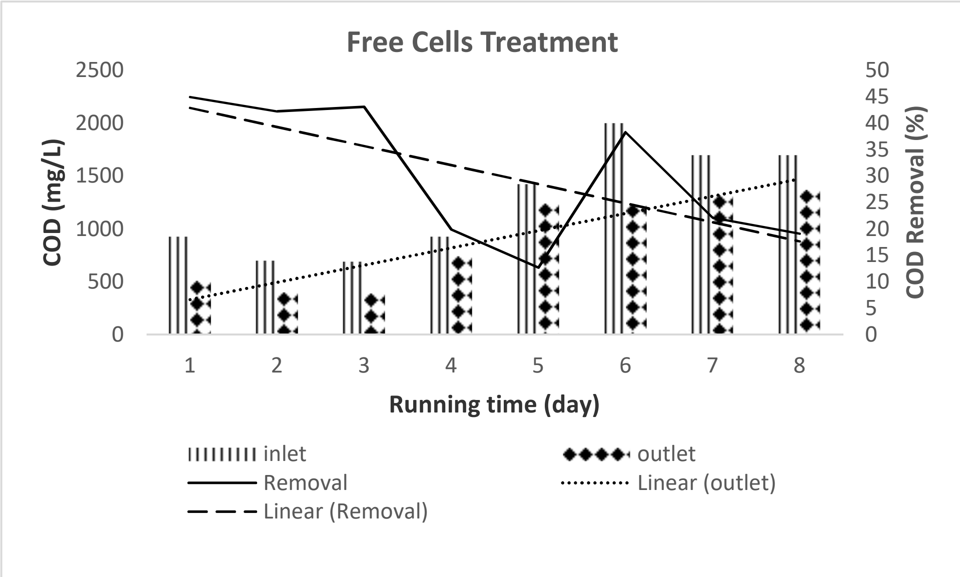

Figure 4. Performance of free cells suspension

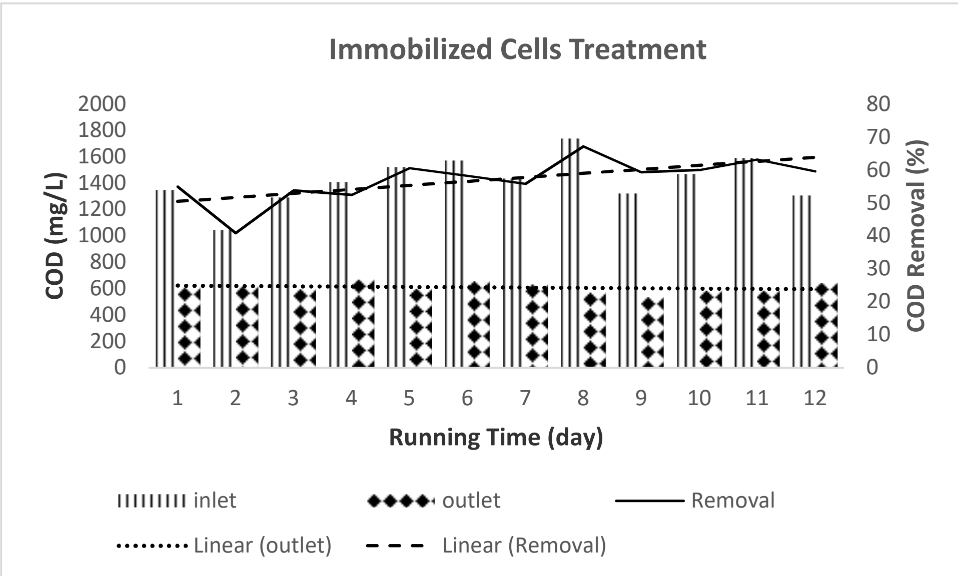

Figure 5. Performance of Immobilized Cells

In contrary with conventional sludge, COD removal of free cells treatment decline, that can be seen in figure 4. trend of COD removal percentage tend to decrease, on the contrary COD outlet sample tend to increase. As Reported by researcher, the use of native biomass (such as bacteria, yeast fungi and algae) for degradation pollutant in freely suspended state has a limitation, owing to their inherent disadvantages such as small particle size, possible clogging, and washed out potentially (Mostafa et al., 2015). Free supension cells also could not tolerate the toxicity pollutant at high levels (Chen et al., 2007; Godjevargova et al., 2004).

Performance of wastewater treatment using immobilized cells illustrates in figure 5.

Immobilized cells treatment gives a stable condition in wastewater treatment, which can be seen in figure 5 percentage of COD removal tend to slightly incline. Average of COD removal with immobilized cells in the experiment reach on 56.90%. This result agrees with some researchers, that immobilized cells has higher stability and better performance than conventional sludge and free cells, Immobilization of whole cells for the degradation pollutant in wastewater provides stability, because of high activity, yield and good operational. Moreover, the cell mass also can be separated from bulk liquid for possible reuse (Lan, G.& Jinbao, 2009). When immobilized microbial cells are used, the efficacy of biodegradation is often improved. Wang et al.(2007) reported that immobilized cells can increase biodegradation rate through a higher cell loading at high dilution rate without washed out.

Based on visual observation, the appearance of immobilized cells outlet sampel is clearer than appearance of sampel from conventional sudge and free cells treatment. As supported by a research, saying that the matrix in immobilized cells also served as barriers that may separate the microorganisms from the effluent and minimize the discharge of high molecular weight biodegraded products (Allabashi et al., 2007).

In order to evaluate the performance of three inoculums in treating waste water, percentage of COD removal has been compared and illustrated in figure 6.

At continuous phase, as can be seen on figure 6, immobilized cells and conventional sludge perform more stable condition than free cells. However, the highest ability of pollutant degradation is achieved by immobilized cells. COD removal percentage of Immobilized cells is also higher than conventional sludge, while the free cells COD removal tend to decrease.

This result is consistent with the statement of Cláudia *et al.*(2013) that immobilized cells have performance in degrading pollutants higher than conventional sludge. This is because immobilized cells have metabolic activity and stronger resistance to toxic chemical components. Immobilization through the adsorption process leads to direct contact between waste and microbes. This process brings microbial cells to the surface of porous media followed by cell adhesion and the formation of colonies on the media. This condition will expand the contact area between microbial cells and wastewater to allow for higher level of pollutant degradation (Kilonzo and Bergougnou, 2012). Kuo & Shu, (2004) also reported that the matrix as carrier of immobilized cells would provide a high specific surface area for microbial growth and also provide a shelter for bacteria that encountered chemical toxicity. The aforementioned reasons support the result of this experiment that immobilized cells perform more stable activity and higher in degrading pollutants than conventional sludge and free cells.

The other advantages of using immobilized cells reported some researchers are no obvious loss of cell activity was observed over the four consecutive uses of the immobilized cells (Chen *et al.*, 2007). Murakami-nitta *et al.*(2003) also reported that the number of viable cells increased after reuse. This suggests that, the activity of the immobilized cells can be maintained, and immobilized cells could use pollutant as carbon source throughout pollutant degradation experiments.

At steady state condition, treatment with immobilized cells perform degradation pollutant in complete parameter showed in Table 2.

Can be seen in table 2 almost all kind of pollutants succesfully treated by immobilized cells. Degradation of pollutant in the form of total suspended solid and oil & grease reached more than 90%. In wastewater treatment process, utilization of immobilized cells could improve pollutant degradability due to microbial activity enhacement. The presence of matrix inside immobilized cells also has a function as a barrier that able to minimize the discharge of suspended molecule to the effluent, so that removal of suspended solid pollutant could be improved.

Oil and grease, generally in the form of complex compounds and have a large molecular weight, was succesfully treated with immobilized cells up to 99.13%. This result agrees with the result of some researchers (Lan et al., 2009 ; Nisola et al., 2009 ; Mostafa et al., 2015) which showed that immobilized cells succesfully treated fat, oil and grease (FOG) in wastewater and was able to sustain the required FOG and COD removals even at highly fluctuating influent concentrations.

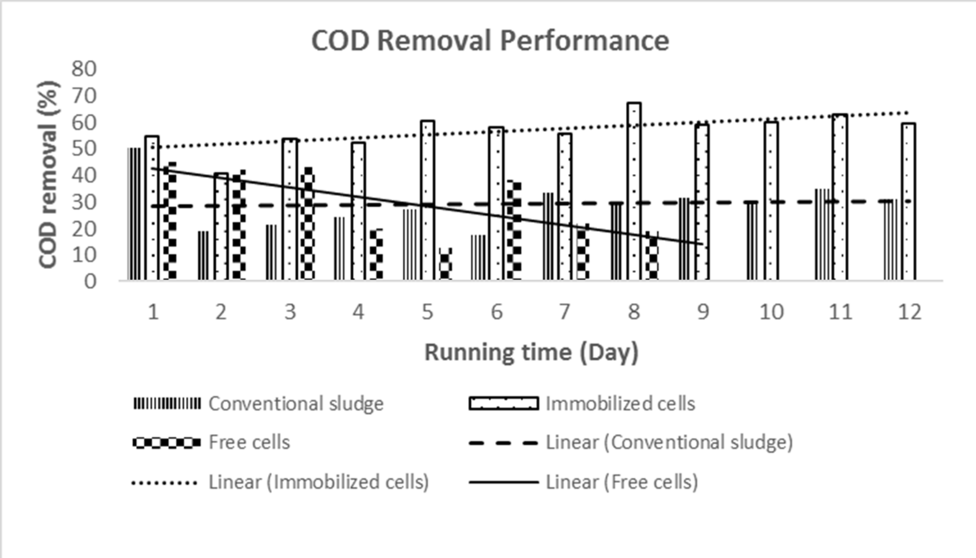

Figure 6. Comparison of COD removal performance

Table 2. Analysis result in complete parameter treated by immobilized cells

No	Parameter	Inlet	Outlet	% Degradation
1	Total suspended solid (mg/L)	660	41	93,78
2	BOD5 (mg/L)	316,1	58,33	81,54
3	COD (mg/L)	1510	529,3	64,94
4	Penol total (mg/L)	<0,01	<0,01	#
5	Khrom total (Cr) (mg/L)	<0,01	<0,01	#
6	Oil and grease (mg/L)	81,0	0,7	99,13
7	Amonia total (NH3-N) (mg/L)	8,60	7,05	18,02

BOD_5 is also succesfully treated, indicating that microorganisms have a highly biodegradation activity. Immobilized cells have a better metabolic activity and stronger resistance to toxic chemical components than conventional sludge and free cells, then pollutant in the waste water could be degraded in to sources of energy to support microbial growth.

Ammonia has not been succesfully treated in this experiment. This result does not mean that immobilized cells could not treat ammonia in wastewater treatment, this result because of the system used in the experiment was anaerobic condition. Understood that, ammonia only will be succesfully treated in aerobic condition (Oh, 2003 ; Show et al., 2012). Meanwhile, application of immobilized cells in waste water treatment containing ammonia pollutant also showed good results in aerobic condition (Dong et al., 2017 ; Taylor et al., 2015 ; Dong et al., 2014).

The identification of species of selected microorganisms are shown in Table 3. The species identification analysis gives 8 of dominant species microorganisms used in the experiment.

Total of eight species were combined as consortium in degrading wastewater. Both of all species having ability in degrading kind of pollutants organic carbon, oil and grease, also dye (Handayani et al., 2016). But, in the experiment of wastewater treatment, consortium in the form of immobilized cells having better performance and stability than in the form of free cells.

Table 3. Species of inoculums

No	Species	No	Species
1	Corynebacterium *variabile*	5	Brevundimonas *diminuta*
2	Bacillus *cereus*	6	Bacillus *amyloliquefaciens*
3	Bacillus *sp*	7	Pseudomonas *otitidis*
4	Bacillus *subtilis*	8	Rhodococcus *ruber*

4. CONCLUSION

Results obtained from this study indicate that, in the form of immobilized cells, inoculum perform higher efficiency and stability in degrading pollutant of waste water than in the form of free cells and conventional sludge. Free cells having the lowest performance and stability in waste water treatment, due to its sensitivity to environmental condition. Immobilized cells succesfully treat wastewater from textile industry, with removal of total suspended solid parameter reaches on 93.78% while for oil & grease, BOD_5 and COD, removal reach on 99.13%, 81.54% and 64.94% respectively. Pollutant in the form of amonia has not been succesfully treated with immobilized cells in the anaerobic condition. Results from this study provide us with insight into the characteristics of pollutant biodegradation in textile industry waste water treatment using immobilized cells as inoculum in the anaerobic condition.

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Utilization of blast furnace solid waste (Slag) as cement substitution material on mortar manufacture

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ABSTRACT

Slag is defined as a waste material produced from iron ore smelting process in blast furnace. The slag was derived from Research Center for Mineral Technology located in Tanjung Bintang Lampung Selatan with particle size of 80,100, and 120 mesh. The percentages of slag used as cement substitution were 10%, 20%, and 30% from total volume. Test pieces was made by compressing all mixture material in 50 x 50 x 50 mm cubical mortar mold. Physical test of mortars, such as : porosity test, density test and compressive strength test were performed. Based on physical test of samples, it was shown that the higher ratio of slag used in cement substitution gives higher mortar porosity. Substitution of 10% slag with size of 100 mesh produced the porosity of 3.45%, while the substitution 20% and 30% slag with the same size, produced 5.08% and 5.76% porosity, compared with the standard of mortar which was 5.12%. The compressive strength test with 10% slag substitution was 19.3 Mpa, while 20% substitute slag gave the compressive strength of 19.1 Mpa and 30% substitute slag has compressive strength value of 18.7 Mpa. The standard mortar is 17.2 Mpa. However, beside of slag substitution ratio, the slag particle size also affected the compressive strength and porosity. Based on the results explained, the substitution of slag as a substitute for cement in mortar strength was still above the mortar standard.

1. INTRODUCTION

Many Researches about concretes or mortar have been done to improve the strength of concrete in terms of material aspects. Most of these studies focused with material substitution derived from industrial waste, whether rough or smooth aggregates, act as binder material or additive materials to increase the adhesive quality of concrete. One of the example is slag. Slags are produced from smelting of iron ore wastes that have almost the same physical characteristic as nature sand. The aim of this research study was to see the impact of adding slag from iron smelting waste to the cement mixture ingredients to improve concrete's strength. According to Antoni (2007), slag is defined as waste material derived from iron smelting process, where the process is using furnace, with addition of fuel burning, and ashes blown in the air. In metal casting process, iron ore or iron scrap is melted with a combination of limestone, dolomite or chalk. Steel manufactures begin with the reduction of steel impurities ion, i.g aluminums, silicon, and phosphor. To eliminate steel impurities, limestones rich in calcium ions were needed. Slag, which is made out of the mixture of aluminum, silicon, and phosphor, reacted at temperature of 1600 ^{0}C to form a liquid, then cooled to form crystal. Slags can be used as cement mixture and as aggregate substitution (Antoni,

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2007). Slag was side product made from smelting steel, which come from oxidation colonies in melting conditions, then separated from steel liquid phase throughout the smelting process in blast furnace (Josephson et al., 1997). Slags are generally formed as lumps and need preparation in application. Slags usually are used for road material, concrete aggregate, as a cement raw material because having pozzolan character (Lewis, 1982 ; Mitsufuji et al., 2000). There is a maximum limit of slag application for cement using copper slag over of 15 % caused decrease of compressive strength. The effective ratio of copper slag used is at 28 ages with 15 % variation and increasingly smooth of slag grain increase the contribution to concrete quality (Muhammad, 2015). Slags from blast furnace waste were made into mortar with dimension of 5 x 5 x 5 cm, with cement and sand ratio of 4:1. Slags used as cement substitution in mortar had variation of volume 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 75%, and 100%, respectively. Utilization of steel slags as cement substitution or mix materials should be not over than 20 % of volume (Nofrizon, 2009). Other added material are water, aggregate or cement. The function of this material is to change the characteristic of mortar or cement in pasta to comply with certain conditions or economical reason like energy saving (Nawy,1996).

Mortar is a mixture of cement, water, and sand with different compositions. As a binding material, mortar must have standard fluidity. The standard fluidity is useful to determine of mortar strength on wall plastering, so it can withstand the compression force and can not be destroyed (Mulyono, 2003).

2. METHODS

2.1 Materials and Tools

The materials used for this research were slags from blast furnace (Research unit for mineral workshop), sands, cement, and water. While the tools used were grinding ball mill, meshing 80 mesh, 100 mesh, 120 mesh and 50 x 50 x 50 mm cubical mortar mould, measuring cups, and compression strength test equipment.

The primary data gathered during experiment were physical test data, including compressive, porosity dan density test. The samples were soaking for 3 days prior the tests performance.

2.2 Procedure

The composition of raw materials used for this research was originated from the Research Unit for Mineral processing. The chemical composition of slags can be seen in Table 1.

Table 1. The Composition of Raw Material

Size of Sample	% weigh		
	Sands	Cements	Slags
Standard	60	40	-
Slag Mesh 80	60	30	10
	60	20	20
	60	10	30
Slag Mesh 100	60	30	10
	60	20	20
	60	10	30
Slag Mesh 120	60	30	10
	60	20	20
	60	10	30

The physical test performances:

- Compressive strength test

Standard test method for compressive strength of cylinder concrete specimens was referred to ASTM C39M-01. This test method is conducted by applying a compressive axial load to specimen with a surface area (mm^2) and force (N) which was within a prescribed range until failure occurs. Compressive strength of the specimen calculated by dividing the maximum load attained during the test by the cross-sectional area of specimen. The shape of specimen was cubic with size and certain age (SNI 03-6825-2002, 2002)

Compressive strength $\left({}^{Kg}/_{Cm^2} \text{ atau Mpa}\right) = \sigma m$

$$\sigma m = {}^{PMax}/_{A} \quad (1)$$

Where σm the compressive strength of mortar (Mpa) was, $PMax$ was the maximum compressive force (Newton), and A was the sectional area of specimen (mm^2).

- Porosity test

Porosity test testing methods was referred to ASTM C231-97, with the principle of submersion the specimen during 24 hours. Porosity was ratio of porous in the specimen. The porous usually contains of water or air which were interconnected and named mortar capiler. The mortar capiler would be remain even though the water had evaporated so this capiler reduced density of mortar. The increase of porous directly parallel with porosity value. As porosity has an effect to the decresed of mortar strength (Murdock and Brook, 1990).

$$\text{Porosty } (\%) = \frac{W_2 - W_1}{W_1} \times 100\ \% \qquad (2)$$

Where W_1 was dry weight (gr), W_2 was weigth after absorb water saturated (gr)

- Density

Density was defined as weight on volume unit of materials devided by weight of water in the same volume

$$\text{Density} \left({}^{gr}/_{cm^2}\right) = \frac{m}{V} \qquad (3)$$

Where m was mass of specimen, V was water volume

The research methodology was firstly study literature, then doing laboratory experimental. Literature studies were used for finding relevant references with this research. In laboratory experiments, samples preparations were done by making of mortar with the addition of blast furnace slag as a cement substitute with the size of specimen are 50w x 50h x 50l mm. The data were collected by conducting physical test, which are compressive strength, porosity and density tests. The procedure to make mortar was by initially refining slag of blast furnace with grinding ball mill, then meshing it to make slags with particle size of 80 mesh, 100 mesh, and 120 mesh. Afterwards, slags were weighing to produce mortar with composition ratio of 10%, 20%, 30%, and 40 % slags (calculated based on cement weights), and then added 60% of sand. All the ingredients then mixed and stirred in the mixer while water was added until pasta was formed. The pasta then molded with a size of 50 x 50 x 50 mm, left for one night, then the mortar was removed from models and submerged in water for three days.

3. RESULT AND DISCUSSION

Raw material slag from blast furnace and micro structure scanning with SEM can be seen in Figure1 and Figure 2

Based on Figure 1, it can be described that the slags from blast furnace have smooth surface and glasslike structure, but the characteristic is brittle and fragile. The formation of slags is reaction resulted from limestone and iron ore that consist of many impurities such as oxide, and the function of limestone as flux is to help catalytic and binding reaction by chemical and eliminate the impurities like silica. In this reaction, iron oxide reduces to be iron dioxide, oxidation carbon to be carbon dioxide, and impurities to be slag like glass which separated and released.

Figure 2 explain the SEM scanning of the slag from blast furnace. It showed that the crystal structures are dominated by calcite which has irregular cubic form, covered by fine grained quartz distribution, porous surface and smooth like glass [11]. The Chemical composition of slag is presented in Table 2.

Table 2. Chemical Composition of Slag

NO	Component	Composition (%)
1	CaO	40.23%
2	SiO_2	28.45%
3	MgO	4,28%
4	Al_2O_3	5.67%
5	Fe_2O_3	0.54%
6	Mn O	0.63%
7	TiO_2	0.55%
8	SO_3	0.26%

Figure 1. Slag from Blast Furnace Waste Type Glass

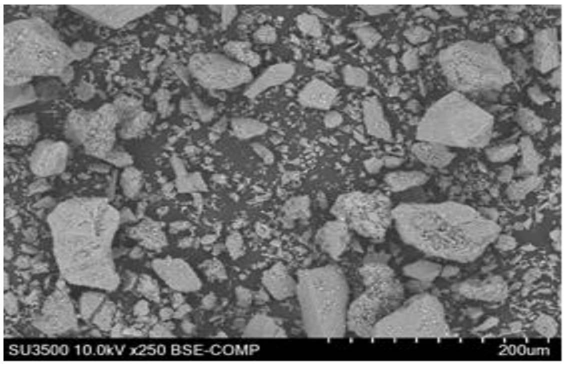

Figure 2. SEM Of Slag (250 X)

Table 3. Physical Test Result

Size of Samples	Cement Subtitutes (%)	Physical Tests		
		Porosity (%)	Compressive strength (MPa)	Density (gr/cm^3)
Standard	w/o Slags	5.12	17.20	1.78
Slag Mesh 80	10	6.53	16.65	1.70
	20	6.06	16.30	1.67
	30	11.41	15.04	1.55
Slag Mesh 100	10	3.45	19.29	2.32
	20	5.08	19.13	2.26
	30	5.76	18.71	2.11
Slag Mesh 120	10	3.33	19.70	2.40
	20	3.55	19.20	2.31
	30	5.62	18.83	2.15

Based on the chemical analysis from slag, the chemical compositions of slag are dominated by limestone, silica, magnesium, and alumina. This slags are formed from iron ore impurities, when the iron ore is melting in blast furnace at temperature of 1600 °C , reacted with calcium from limestone then added in melting process. Limestone acts as a flux which is needed for binding of impurities from iron ore, such as silica oxide, mangan, alumina, and sulfur. These bonds formed lumps named slags. Slags composition are dominated of silica, calcium, and alumina, make slag suitable to be utilized as cement substitution material because they have characteristic of pozzolan. Mixture of slag and cement would be more hydrated. Formation reactions of slags are written as follows:

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

$SiO2(s) + CaO(s) \rightarrow CaSiO3(l)$

$Al_2O_3(s) + CaO(s) \rightarrow Ca(AlO_2)_2(l)$

$P_2O_5(s) + 3CaO(s) \rightarrow Ca_3(PO_4)_2$

- Physical test of mortar to find of physical strength of mortar.

The tests include compressive strength test, porosity test, and density test. The physical tests results based on the composition of slag and cement can be seen in Table 3.

The result of compressive strength of mortar in each percentage composition of cement with size variation after submergence for 3 days. The samples for compressive strength test and the equipment of compressive strength can be seen in Figure 3 dan Figure 4.

The result of compressive strength test can be seen in Figure 5.

Slag composition of 10% with size of 80 mesh, give the compressive strength value of 16.65 Mpa, while the 100 mesh had the biggest compressive strength value of 19.29 Mpa, and the 120 mesh give compressive strength value of 19.70 Mpa. The compressive strength of 20% slag substitution with 80 mesh is 16.30 Mpa, and for size 120 Mesh, the compressive strength is 19.20 Mpa. The compressive strength for 30% slag substitution size 80 mesh is 15.40 Mpa, while for 100 mesh, the compressive strength is 18.71 Mpa and for 120 mesh, the compressive strength is 18.73 Mpa.

Figure 3. The Samples for Compressive Strength Test

Figure 4. Compressive Strength Machine

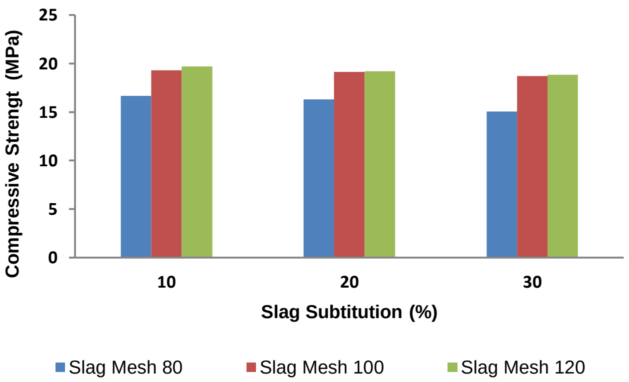

Figure 5. Slag Mesh Variation Vs Compressive Strength

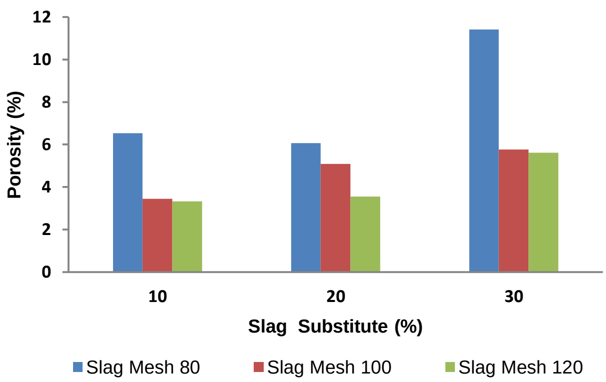

Figure 6. Porosity Test Result

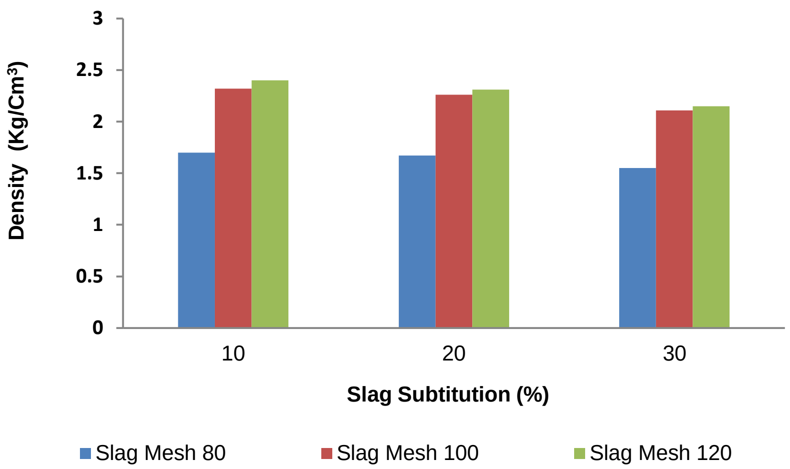

Figure 7. Density Test Result

Based on the compressive strength test result, the values are influenced by particle size of slag. Compressive strength value with particle size of 80 mesh is higher than 100 mesh and 120 mesh is slightly higher than 100 mesh. Referring to these results, it can be concluded that hydration process of cement and slag with higher size would have longer reaction than the fine grain slag. The hydration process start from outside of cement grain which has smoother grained particles of cement and slag, then hydration process goes faster and make the particles timing bind become shorter resulting in more rapid mortar strength. (Widojoko, 2010). Furthermore, slag chemical characteristics also have influence on compressive strength, because composition of slag that contains of SiO_2 and CaO, can form C-S-H bounding compound (calcium silicate hydrate). This bounding compound is more massive so that can produce higher compressive strength especially with more fine grain, due to the fact that the slag is organic material with cement characteristic. The free limestone contents in cement will be optimally used by slag as an organic material, so it will produce bounding compound (Salain, 2009). However, the quantity of slag substitution for cement should not be too much and excessive because the bounding compound in cement will be replaced by slag as organic material. The slag substitution not to be more than 20%, because it will reduce mortar compressive strength.

The porosity test was done to see the absorption level in mortar because the higher of absorption means the bigger porosity. The porosity test result can be seen in Figure 6.

Based on Figure 6, it shows that the more subtle slag size results in the smaller porosity. This is occurred when slag substitution for cement is 10% and size is 80 mesh then the porosity result is 6.53%. In addition, when size is 100 mesh, the porosity is 3.45%, and with size is 120 mesh the porosity continues to decline into 3.33%. In 20% slag substitution, when particle size is 80 mesh, the porosity is 6.06%, when it is 100 mesh then the porosity is 5.08%, and when mesh sizing is 120 the porosity decrease into 3.55%. In 0% substitution slag, when mesh sizing is 80, the porosity is 11.41%, when mesh sizing in 100, the porosity value decrease to 5.76%, and in 120 mesh the porosity is 5.62% more decreased. The decrease of porosity is directly parallel with the fineness of the slag material.. This is because of fine particles, which is derived from slag, can fill up the pores inside the mortar, that make the mortar more solid and can decrease the area that supposed to be fulfilled with water. Reducing the slag particle size will cause decrease on mortar porosity, because slag particle will rapidly react to hydration process.

Density test was performed to know the effect of slag substitution on mortar density. Density test result can be seen in Figure 7.

4. CONCLUSION

The result shows that slag particle size is affected by slag physical properties, such as compressive strength, porosity, and density. The best physical properties of slag occurred when particle size is 100 mesh, which generates the best results in terms of compressive strength, porosity, and density, compared to particle size 80 and 120 mesh. Furthermore, 10% slag substitution are able to generate greater compressive strength, porosity, and density than slag substitution of 20% and 30%. Slag can be used for cement substitution or for cement replacement in mortar production. It is more preferable to use slag with particle size of 100 mesh and not more than 10 – 20 % slag substitution, because slag substitution of 10% already has higher physical quality than mortar standard without slag addition. There are relations between compressive strength with porosity and density. Smaller porosity generates higher compressive strength and higher density.

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FWHM dimensional analysis from scattered light intensity profile for dry rubber content determination in natural rubber

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A B S T R A C T

Dry Rubber Content (DRC) describes a rubber particle percentage in natural rubber latex. In this paper, the relation between forward light scattering profiles of natural latex and rubber contents is reported for dry rubber content latex. The profile, characterized by Full Width at Half Maximum (FWHM), is increasing linearly with respect to rubber content. The measurement was performed immediately after latex being tapped with necessary addition of ammonia. This addition was meant to prevent latex coagulation. There is a high linear correlation between DRC and FWHM of both domains: one and two dimension. This is indicated by correlation factor r^2 which are higher than 0.9 for both of domains and sufficient in DRC determination.

1. INTRODUCTION

Natural Rubber Latex (NRL) is a white suspension tapped from *Hevea* tree. This suspension is mainly composed of rubber particle and water. Other substances, such as proteins, acid and inorganic material, are also contained in it at a small portion(Ho, 2014; Berthelot et al., 2014). The economic value of NRL is determined by the quantity of rubber expressed in term of dry rubber content (DRC). The DRC is defined as a percentage of solid dry rubber content obtained from dehydrated 100-gram of NRL (Zhao et al., 2010).

The standard method of measuring DRC is recommended by The International Organization for Standardization (ISO)(Standardization, 2005). In this method, a direct measurement of DRC is performed by weighing solid substance produced from coagulating and drying 100 grams of fresh latex. This method is an exhausting process which takes approximately 12 hours to ensure residual water content removal. In term of practicality, this method is difficult to be applied in daily NRL price estimation.

On the other hand, a quick estimation of DRC can be done indirectly using the measurement of latex physical properties. A level of DRC then can be inferred by making a correlation between DRC and those properties. Such physical properties include dielectric permittivity (Julrat et al., 2012), density (Tillekeratne et al., 1988), light scattering and reflectivity (Zhao et al., 2010; George et al., 2013), microwave reflection, transmission and resonant frequency

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(Aiyarak and Sunheem, 2015; Sunheem and Aiyarak, 2016)(Fizik et al., 1982).

Light scattering concept has been widely applied in a turbid medium (Moitzi et al., 2009) to infer suspension particles properties. Furthermore, the relation between DRC and scattering light profile of turbid medium has been studied experimentally by Nibu (George et al., 2013). In that study, a linear relation is indicated between DRC and full width at half maximum (FWHM) intensity of horizontal forward scattering profile. This paper develop Nibu's study which extends the calculation of FWHM on two-dimensional domain: an area of forward scattering angle, also compare linear correlation both one and two-dimensional domain.

2. METHODS

Apparatus & Reagent

The experimental setup, used to capture traversing light, is shown in

Figure .

A red commercial laser diode was used as a light source with 5mW maximum power. The laser intensity can be adjusted to the desired level by applying appropriate voltage. A latex container made of acrylic was installed close to laser diode. The acrylic thickness was 1.5 mm. The dimension of the container is 10 mm x 100 mm x 60 mm. The container wall acts as a screen where scattered light was projected at. To capture this projection, Xiaomi Yi acts as digital camera was installed and placed at 10 cm from the container. All of these parts were put inside the well-covered box (see figure 2) which ensured that no ambient light was recorded. For standardization, the rubber content of those six samples was measured using standard method (Standardization, 2005).

Procedure

Light scattering by particles is affected by several factors, such as particle concentration, structure, dimension, light wave number, and sample thickness (Mischenko, 2004). By making a variation of particle concentration and keeping the other factors constant, the relation between concentration and scattering intensity can be experimentally established.

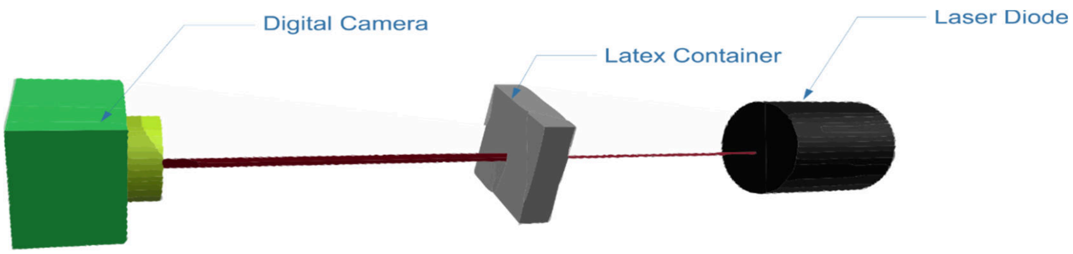


Figure 1. Experimental Setup

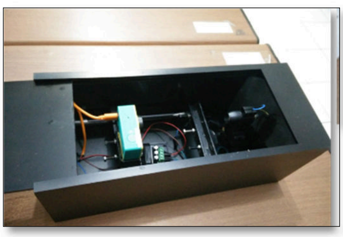


Figure 2. Box for Instrument Setup

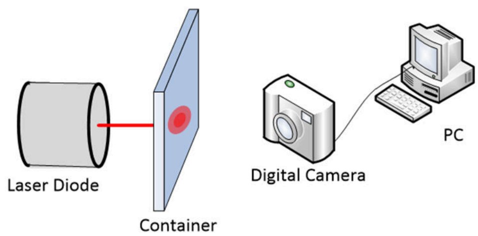


Figure 3. Experiment setup for measuring Dry Rubber Content (DRC) of latex.

The latex used in this experiment was a fresh latex, analyzed within one hour after tapped. To maintain its liquid form, 20% of ammonia was added. Variation of sample concentration was made by diluting latex with known volumes of water. In this experiment, six sample was prepared by diluting six 100 mL cups of latex with 10, 20, 30, 40, 50 and 60 ml cups of water volume respectively. The scattered light profile of those six samples was captured and stored on a personal computer.

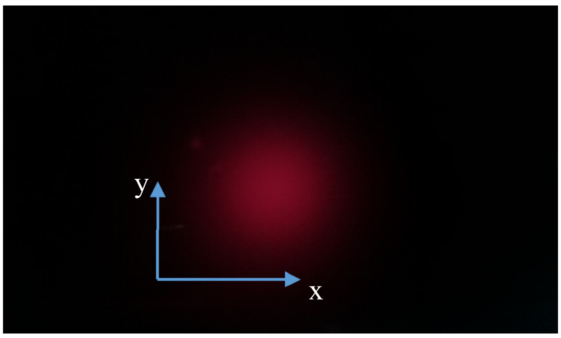
The first step of this standard analysis was coagulating DRC in fresh NRL by adding acetic acid and followed by heat it on the steam bath for 30 minutes. The next step was drying the coagulum in the oven at 75 C° until drying mass was stable. It took approximately 12 hours to remove any left-over water content.

3. RESULT AND DISCUSSION

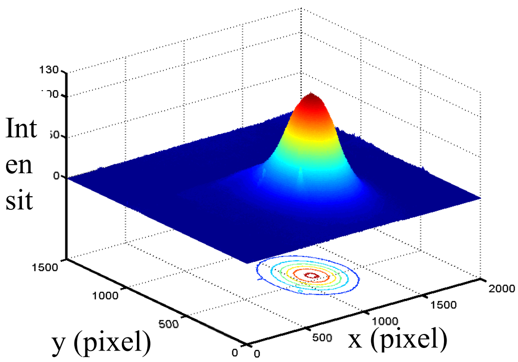
The recorded images, as can be seen in figure 3(a), were in RGB format which read by MATLAB as three layers of matrix colors (Red, Green and Blue) ranging from 0 to 255. As light source was a red laser, then green and blue layers were filtered out and leaving only a red layer. Next, this red layer is smoothed using a Gaussian filtering method. The 3-D representation of this smoothed light scattering is shown in Figure 4(b), where the top figure is a surface plot of scattered light while the bottom is contour plot.

The light scattering profile can be characterized by calculating the FWHM of its intensity distribution. FWHM is calculated as the total number of pixels at which intensity is higher than half of the maximum intensity. The dimensionsat which pixels is evaluated can be either a surface (two-dimensional FWHM) or a line (one-dimensional FWHM). Two-dimensional FWHM calculation can be demonstrated by projecting scattered light onto contour plot and counting pixels at which intensity is higher than half maximum intensity. Figure 4(a) is contour plot of the same scattered light profile as seen in Figure . Based on the figure, the maximum intensity is 126. Hence, half maximum is 63 and identified as green color. FWHM of this particular scattered light is approximately a circular area within the green line.

On the other hand, one dimensional FWHM can be calculated as a number of pixels at which intensity is half of the maximum intensity at particular line position. Scattered distribution at line 560 is shown in figure 4(b). The corresponding FWHM is the width between green points as indicated in the figure.

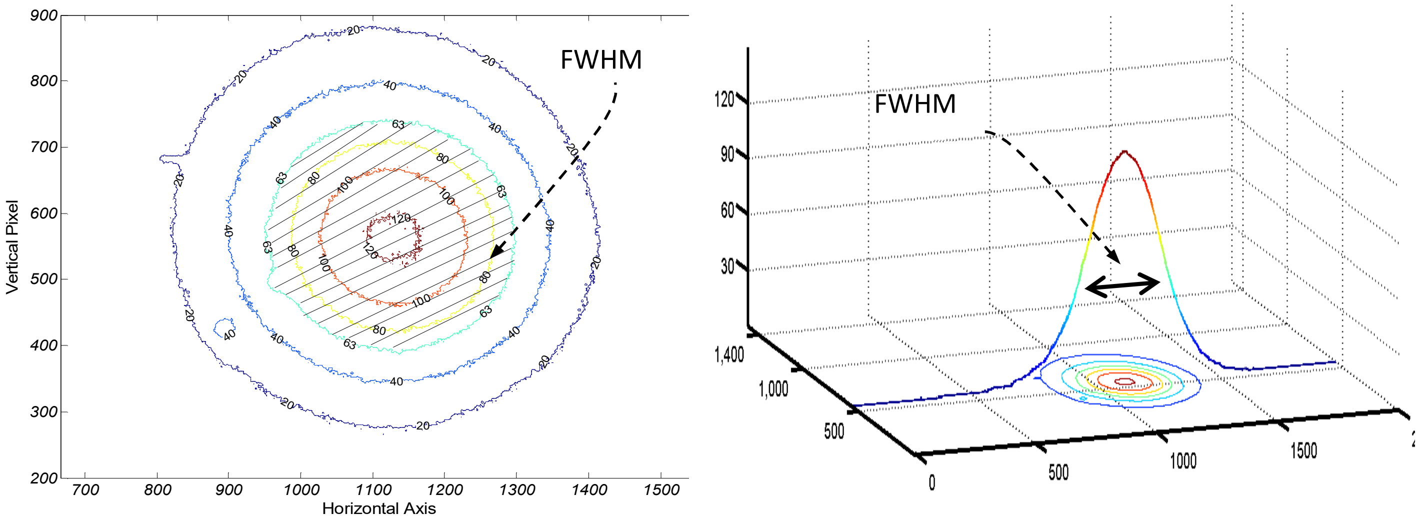


(a)



(b)

Figure 4.(a) Typical recorded image of scattered light from latex. (b) Three-dimension representation of scattered light image.



(a) (b)

Figure 5. (a) Contour plot of scattered light. (b) One dimension of scattered light is plotted overlying scattered contour plot.

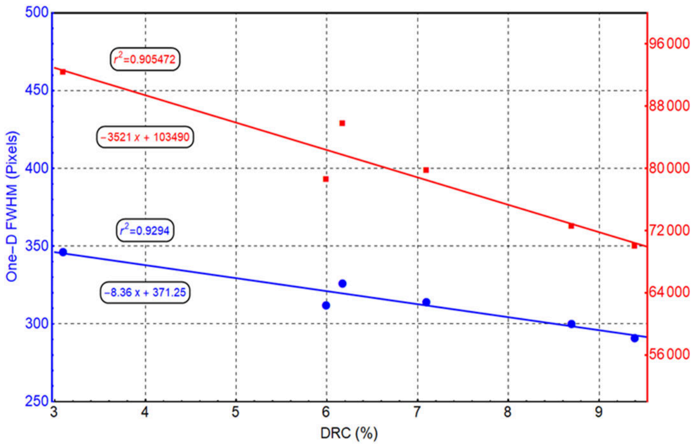


Figure 6. FWHM values as the function of DRC from two domain calculations: Blue (one dimension) and Red (two dimensions)

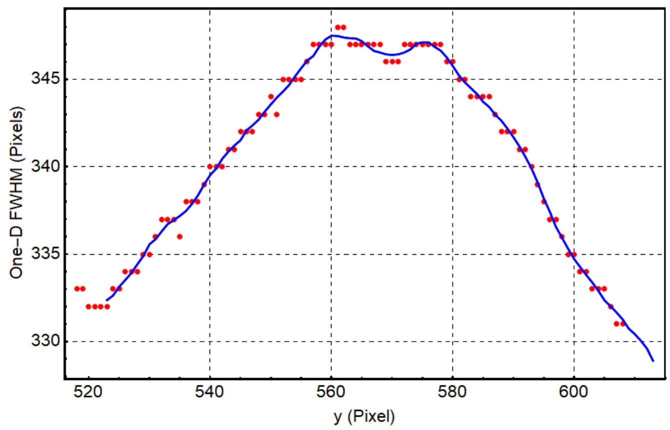


Figure 7. Various one-dimensional FWHM values as a function of y position (pixel).

Two-dimensional FWHM is calculated as an area of nearly-circular-shape of green line at which the intensity is 63 (figure5(a)). This intensity is half of the maximum intensity which is 126. One dimensional FWHM calculation is width where pixels are higher than half of the maximum. In this figure, a half maximum is indicated by green color those two plots (figure5(b)).

Six images of six different samples have been recorded. FWHM of those images were also calculated. The relation between FWHM and rubber content is shown in figure 6. The Figure is color coded based on FWHM calculation method. Blue color indicates pixels number of one-dimensional FWHM horizontal line $y = 560$ while red color represents those of two-dimensional FWHM. A horizontal line $y = 560$ was chosen due to the fact that at this position, FWHM is at maximum with respect to other horizontal lines (figure 7).

As can be seen from figure 6, there is a high linear correlation between DRC and FWHM of both domains: one and two dimensions. This is indicated by correlation factor r^2 which are higher than 0.9 for both of domains. Two points at about 6% of DRC concentration show irregularity while the others four points only slightly differ from the linear plot. For this result as (Van Loco et al., 2002) suggested r values > 0,997, some explorations should be made, like enriching the data base and latex container modification.

Red points show the measured data and the continuous blue line are smoothed data by a savoy-golay algorithm (Persson and Strang, 2003).

4. CONCLUSION

In conclusion, a linear relation between scattering light profile and rubber content has been demonstrated for low rubber content latex in both one and two- dimensional analysis. Our calculation indicates this analysis has correlation factor r^2 which are higher than 0.9 for both one and two-dimensional analysis and other explorations still possible to be accomplished.

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Adsorption of sodium dodecylbenzene sulfonate (DBS) by c-3,4-di-methoxyphenylcalix [4]resorcinarene triphenylphosphonium chloride

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ABSTRACT

Surfactants have been widely used in many industries, one of them is sodium dodecylbenzene sulfonate (DBS) which is a major component used in the manufacture of detergents and considered as toxic material. Various methods have been undertaken to reduce DBS content in water. One of them is adsorption, which is known as the most effective and environmentally friendly method so far. Our previous study has successfully synthesized an adsorbent C–3,4–dimethoxyphenylcalix[4]resorcinarene triphenylphosphonium chloride (CRP). The aim of this study is to investigate the adsorption of DBS by CRP. Adsorption studies were carried out using the batch methods at different acidity, contact time, and initial DBS concentration and analyzed using UV–Visible, FTIR, and SEM–EDX spectrophotometer. The results showed the optimum condition of DBS adsorption was at pH 8, contact time 120 min, and DBS concentration 40 mg/L. The maximum capacity for the adsorption process was 12.93 mg/g. The rate of adsorption was found to follow the pseudo second–order kinetic model and the Langmuir adsorption isotherm. The mechanism was a chemisorption that occur in monolayer (ΔG° ads = –24.87 kJ/mol).

1. INTRODUCTION

Surfactants have been widely used in various industries such as paper, electroplating, cosmetics, food, pharmaceutical, and laundry industries. The classification of surfactants is divided into 3 types: cationic, non–ionic, and anionic. Anionic surfactants are produced about 60% compared to other species (Karray et. al., 2016). Sodium dodecyl benzene sulfonate (DBS) is the major component used in detergent manufacturing (Taffarel & Rubio, 2010). The disposal of surfactant directly into water can lead into serious environmental pollution and is relatively difficult to be degraded (Lechuga et. al., 2016; Jardak, 2016). The high concentrations of DBS in the environment could be potentially xenobiotic compounds that are toxic. DBS can affect the mobility of organic compounds and minerals present in the soil/sediment to enter into plants thus interfering with the process of photosynthesis in plant leaves (Edwards et. al., 1994). Acute toxicity of DBS has a value of LD_{50} 400–5000 mg/kg body weight (OECD, 2005). DBS enter the fish body through its gills and skin (Ying, 2006) which can cause death (Budiawan et. al., 2009).

Various methods have been done to reduce surfactant concentration such as coagulation methods (Beltran–Heredia et al, 2009), photocatalytic oxidation (Ono et. al., 2012), precipitation (Takayanagi et. al., 2017),

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and adsorption (Wulandari et. al., 2016). Adsorption is one of the most effective and environmentally friendly method. Some of the adsorbents that have been used to reduce the DBS content are natural zeolite–CTAB (Taffarel & Rubio, 2010), activated carbon (Zhao et. al., 2013), and C–4–ethoxy–3–methoxyphenylcalix[4]resorcinarene triphenyl–phosphonium chloride (CERP). Adsorption of DBS using CERP is optimal at pH 8, contact time 120 min, and DBS concentration of 40 mg/L. The adsorption follows the second order pseudo and the Langmuir adsorption isotherm through chemisorption with ΔG = –23.83 kJ/mol and a maximum adsorption capacity of 11.53 mg/g (Wulandari & Jumina, 2016).

The usage of calix [4] resorcinene compound as a DBS adsorbent is still limited thus still needs to be developed. This effort has been made by synthesizing C–3,4–dimethoxyphenylcalix [4] resorcinarene triphenyl–phosphonium chloride (CRP). CRP is synthesized from vanillin through methylation reaction, electrophilic substitution of aromatic–cyclization, chloromethylation and nucleophilic substitution which has 97.14% yield with a melting point of 296 °C (Wulandari & Jumina, 2016). The ability of CRP in adsorbing Cr (VI) has been studied and it is known that its maximum adsorption capacity of Cr (VI) is 15.71 mg/g which occurs by chemisorption (ΔG = –36.24 kJ/mol) (Wulandari & Jumina 2016) however the ability of CRP in adsorbing DBS has not been studied yet. In this study, the ability of CRP to adsorb DBS was studied based on the influence of pH, contact time, and DBS concentration.

2. METHODS

2.1 Material and Equipment

Materials used in this study were methylene blue (MB) reagent 100 mg/L, Whatman 42 filter paper, H_2SO_4 6N, sodium phosphate monohydrate ($NaH_2PO_4{:}H_2O$), 100% DBS (w/v), CRP, destillated water, and chemical reagents used in sample analysis. All chemicals used were analytical grade and CRP used in this research was synthesized from previous research. CRP was synthesized through methylation reactions, electrophilic substitution, cyclization–condensation, chloromethylation, and aromatic nucleophilic substitution (Wulandari & Jumina, 2016). The equipment used in this study were laboratory glassware, analytical scales, magnetic stirrer, pH meter, UV–Visible spectrofotometer (Shimadzu, UV–1800), Fourier Transform Infrared Spectroscopy (Shimadzu, Prestige 21) in the range of 4000–400 cm–1 wave numbers, and Scanning Electron Microscope–Energy Dispersive X–Ray Spectroscopy (SEM–EDX) (JEOL JD–2300) measured at a voltage of 15 keV with 10000 times magnification.

2.2 Procedure

The adsorption study was conducted through batch method and adsorption parameter such as acidity, contact time, and DBS concentration were determined as research parameter. The effect of acidity was observed in pH range 5–10, contact time 15; 30; 60; 90; 120; 180; and 240 min, and the effect of DBS concentration was observed at concentrations of 10, 20, 30, 40, 50, and 60 mg/L. Adsorption was performed by adding 0.002 g of CRP into 100 mL of DBS solution. The solution was stirred for 3 hours at 25 °C, then centrifuged for 20 minutes at 3500 rpm. The centrifugation result was filtered with Whatmann 42 filter paper then the filtrate was added with 25 mL MB complexing solution and 10 mL chloroform then extracted. The obtained organic phase was analyzed using UV–Visible spectrophotometer at 625 nm wavelength. The standard curve was made from a series of DBS standard solutions with concentrations 0.1; 0.2; 0.4; 0.6; 0.5; 1; 2; 3; and 4 mg/L. The adsorbed DBS surfactant concentration was obtained from the initial concentration of DBS surfactant reduced by the residual DBS surfactant concentration. The concentration of DBS that absorbed into the CRP compound was calculated based on the difference between the initial concentration (C_o) and the residual concentration in the solution at time t (C_t). The experiment was performed with 3 repetitions (triplo). The interaction of CRP with DBS then studied through spectroscopic analysis with FTIR and SEM–EDX.

3. RESULT AND DISCUSSION

The effect of acidity on DBS adsorption by CRP showed that adsorption occurred optimally at pH 8. Under basic condition, DBS tended to be in its anion form (Fig. 1).

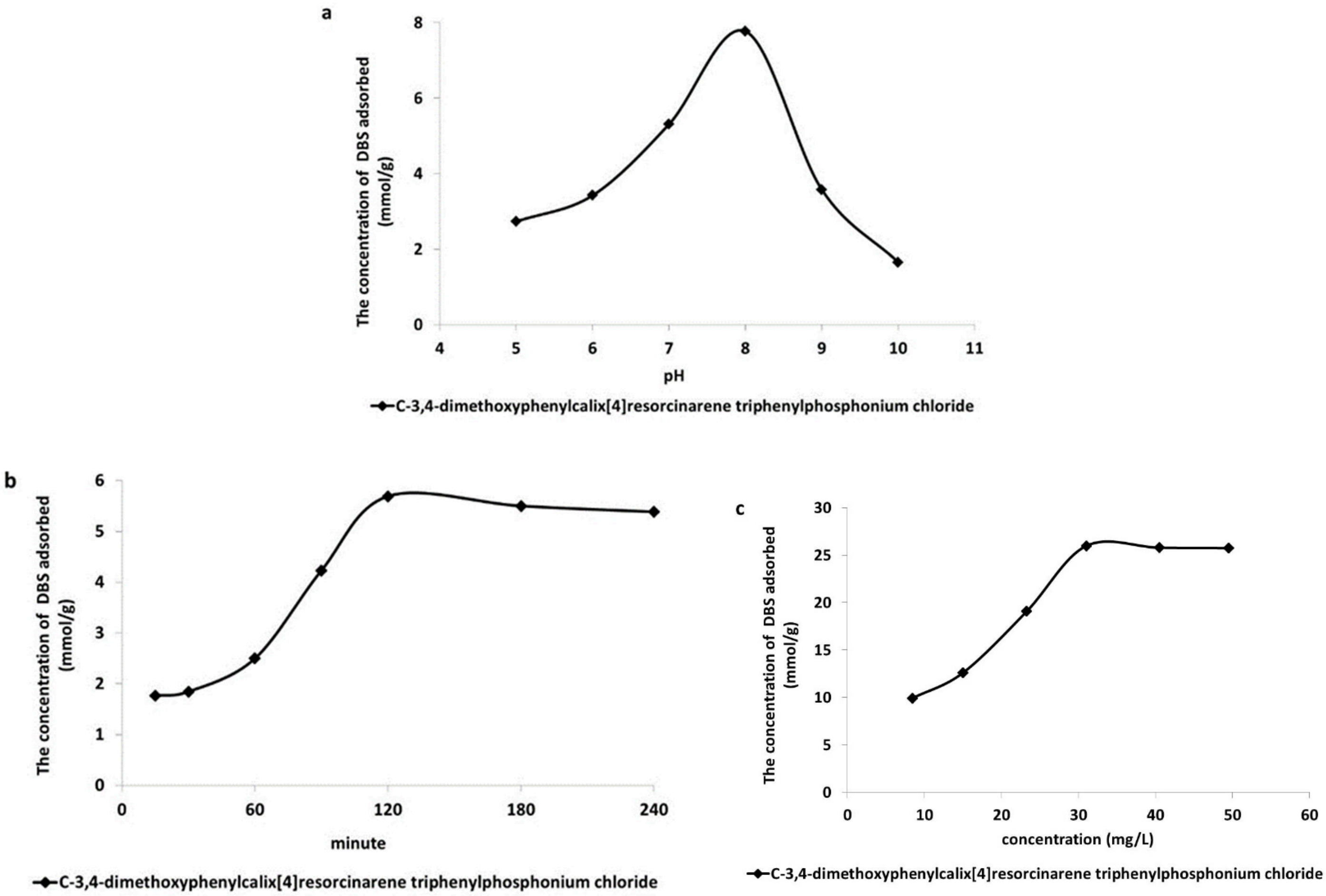

Figure 1. Effect of pH (a), contact time (b), and concentration (c) in DBS adsorption by CRP

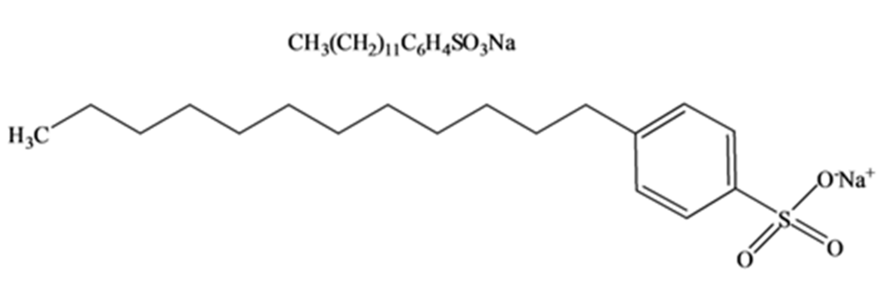

Figure 2. DBS in its anion shape (Manousaki et. al., 2004)

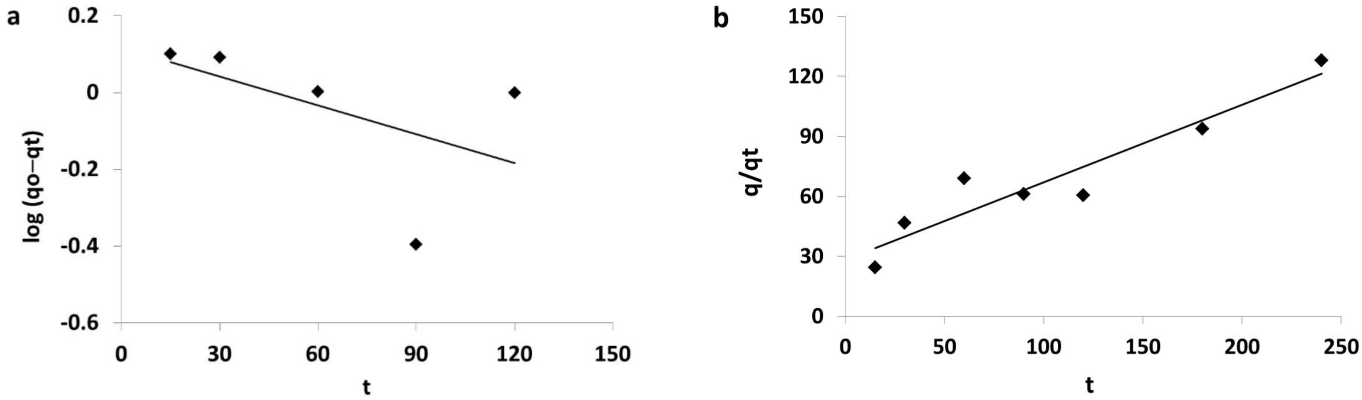

Figure 3. The pseudo first–order (a) and pseudo second–order (b) of adsorption kinetics in DBS adsorption by CRP

Table 1. Parameter value of DBS adsorption kinetics

MKinetics Model	Equation	k x10^{-3} (g mmol^{-1}minute^{-1})	R
Lagergren	log (1,3116 – q_t) = –0,0025 t + 0,1178	2,5	0,2768
Ho dan McKay	$\frac{t}{q_t}$ = 0,3872 t + 28,3450	5,29	0,8943

Based on the adsorption pattern at various contact times, it was shown that the ability of CRP in adsorbing the DBS anion increased significantly in the time span of 15–120 minutes and the adsorption equilibrium was reached at 120 minutes contact time. Observations through variation of DBS concentration on CRP adsorption power were performed to determine the maximum adsorption capacity of adsorbent to DBS anion. The optimum concentration of DBS adsorption by CRP was 40 mg/L. The decreased of DBS adsorption at contact time above 120 minutes and at concentrations above 40 mg/L due to saturation of the active site of CRP which has quarterner phosphonium group that positively charged.

The pattern of DBS adsorption by CRP was based on time changing the studied according to pseudo first–order of Lagergren adsorption kinetics model (Ho, 2004) and pseudo second–order Ho and McKay (2000).

Based on adsorption kinetics result, it tends to follow the Ho and McKay pseudo second–order of adsorption kinetics model with linearity level closed to 1 and adsorption rate constant was 5,29 x10^{-3} g mmol^{-1} minutes^{-1}. DBS adsorption by CRP then studied using Langmuir isotherm model ($\frac{1}{q_e} = \frac{1}{(X_m.K.C_e)} + \frac{1}{X_m}$) and Freundlich ($\log q_e = \log K + \frac{1}{n}\log C_e$).

Based on Figure 4, the DBS adsorption occurred in this study followed the Langmuir isotherm adsorption model equation. The maximum adsorption capacity and the adsorption energy of DBS on CRP were summarized in Table 2.

The calculation of adsorption energy on CRP was determined by Gibbs free energy equation (ΔG° ads = –RT ln K). The adsorption energy obtained for –24.87 kJ/mol was classified as chemical adsorption (Adamson, 2004). The chemical adsorption from interaction between the DBS anion and CRP was caused by the presence of an active site of quarternary phosphonium groups that could interact with the DBS anion. DBS anion adsorption by CRP only occurred under basic condition. The interaction mechanism in CRP with DBS anion should be preceded by DBS protonation. The proposed interaction model of CRP with DBS anion was shown in Figure 5.

Confirmation of the interaction between CRP and DBS anion as a target for trapping was done through spectroscopic studies using IR and SEM–EDX spectrometry method. Based on the IR spectra from the CRP–DBS and CRP complexes that had not interacted with DBS anion, there were a significant differences of absorption in certain wave number (Figure 6). Reduced absorption intensity at wave numbers 748 cm^{-1} and 694 cm^{-1} and absorption loss at 493 cm^{-1} wave numbers in the IR spectrum (Fig. 6b) indicated that the quarterner phosphonium had interacted with DBS anion and left the hydroxy group which was still readable on 3425 cm^{-1}. Thus, the CRP–DBS complex has been formed.

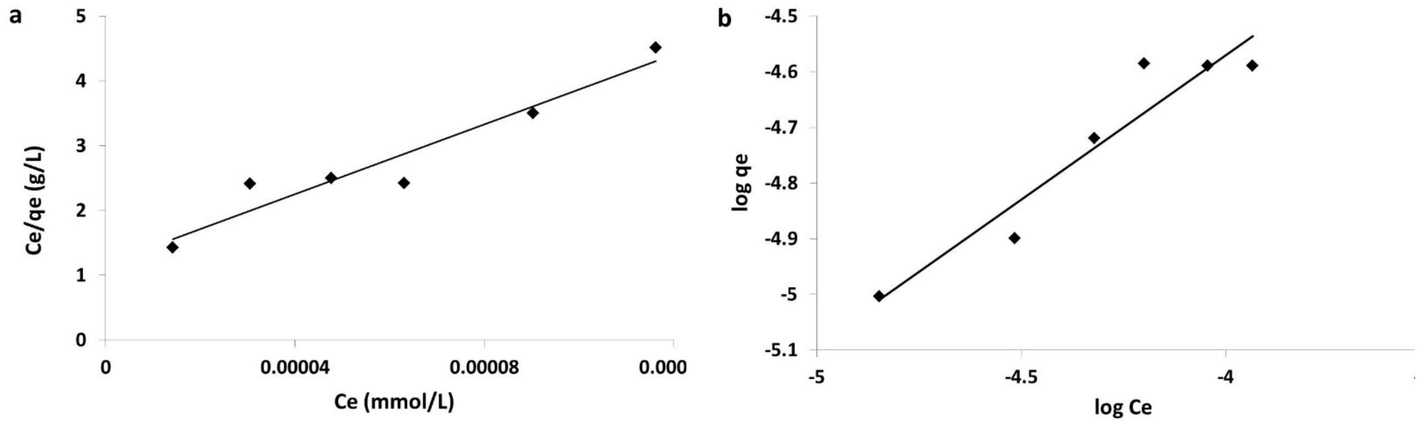

Figure 4. Langmuir (a) dan Freundlich (b) isotherm adsorption

Table 2. Capacity and energy of DBS adsorption by CRP

Isoterm Adsorption Model	Slope ($1/X_m$)	q_m (mg/g)	intercept $1/(X_m.K)$	K (L/mol)	$\Delta G°$Ads (kJ/mol)
Langmuir	26948	12.93	1.1738	22957.91	–24.87

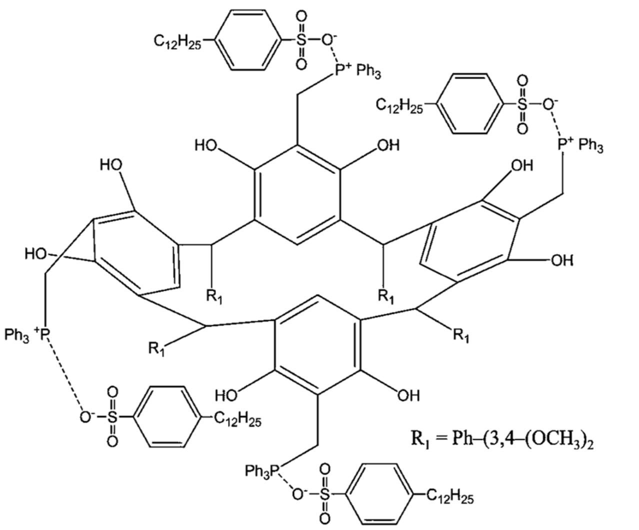

Figure 5. The adsorption interaction model of DBS by CRP (Utomo, 2012)

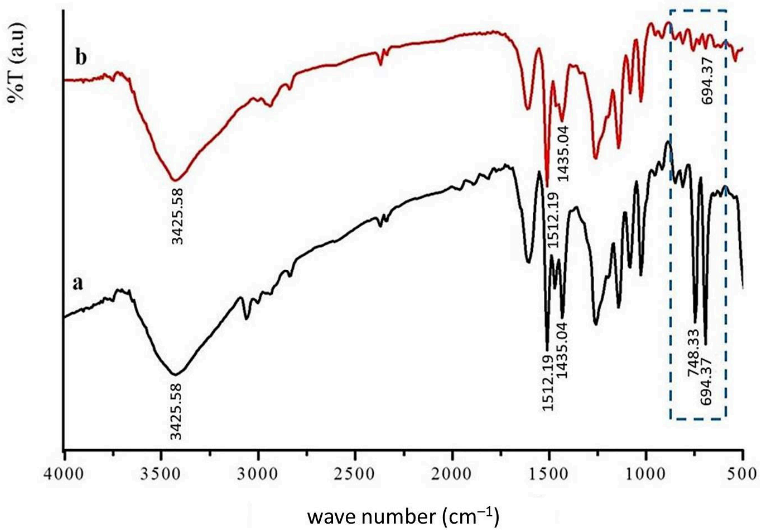

Figure 6. The FTIR spectra of CPR (a) and CRP–DBS complex (b)

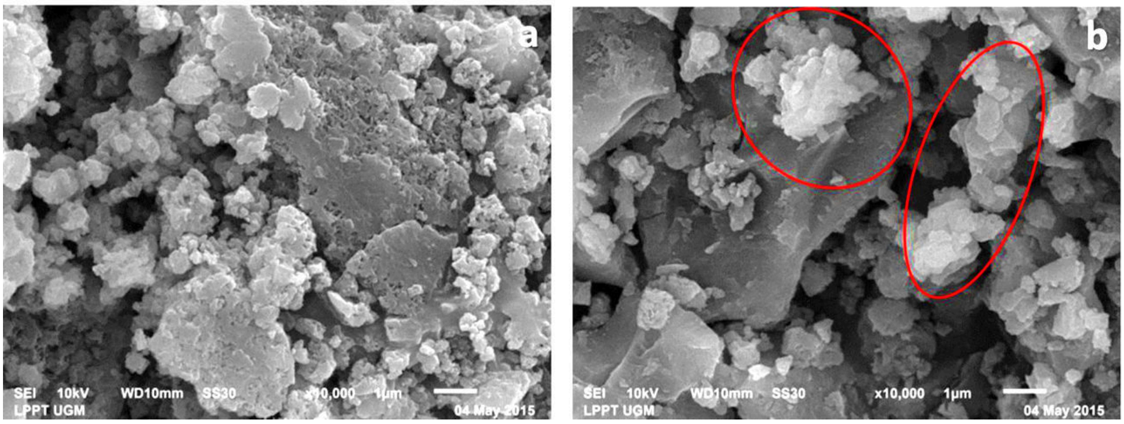

Figure 7. SEM of CRP (a) and CRP–DBS complex (b)

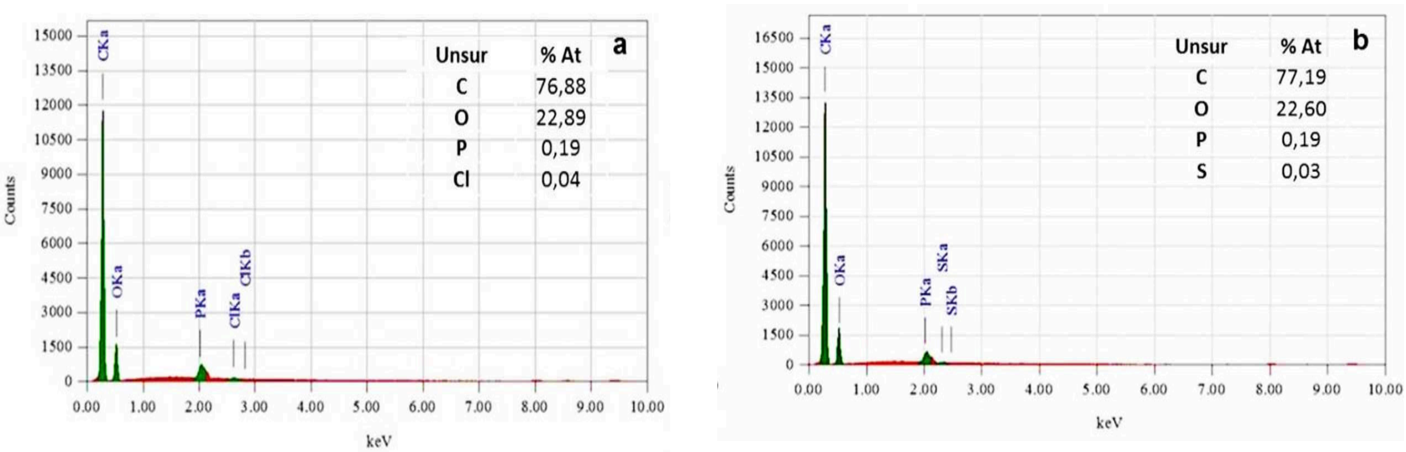

Figure 8. EDX of CRP (a) and CRP–DBS complex (b)

Characteristics of microstructure, energy, and percentage of chemical constituents in both CRP and CRP–DBS complexes were determined using SEM–EDX under operating conditions at a voltage of 15 keV and 10,000x magnification. Through enlarging 10,000x in SEM image (Fig. 7), it was clear that there were differences in the appearance of microstructure of CRP before and after adsorbing DBS anion. In the CRP–DBS complex SEM image, it appeared that the CRP surface has been covered by the DBS anion. This indicated that the CRP–DBS complex has been formed.

The formation of the CRP–DBS complex was further proved by elemental analysis to determine the content of elements and compounds in the complex through quantitative analysis of EDX. Through EDX it would be known that the element content in both CRP and CRP–DBS complex to SEM image of 10,000x magnification (Fig. 8). The elemental scanning results showed some of the dominant elements C, O, and P as well as the little Cl elements present in CRP. An important finding of SEM–EDX analysis was the replacement of Cl elements on CRP by S elements of DBS with 0.07% mass percentage. This showed that there was an interaction between CRP and DBS anion. The interaction that occured indicated that the CRP–DBS complex has formed.

CONCLUSION

Based on the adsorption study, it can be concluded that the adsorption of DBS by CRP in forming CRP–DBS complex was effective at optimum condition pH 8, contact time 120 min, and DBS concentration 40 mg/L. The adsorption followed a pseudo second–order kinetic model and the Langmuir isotherm adsorption which proceeded in a monolayer with a maximum adsorption capacity of 12.93 mg/g.

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