Electroflotation of Batik Waste

Warjito[1,*], Nurrohman[2]

Department of Mechanical Engineering, Faculty of Engineering Universitas Indonesia

KampusBaru UI Depok, Indonesia 16424

Abstract: Batik production processes generate waste such as turbidyti, colour and Total Suspended Solid (TSS).which cause environment problems.Therefore a technique for separating the batikwaste from theliquid is demanding. In conjucntion with this situation, electroflotation for separation of batik's waste were studied. The aims of this study are to understand the dynamics of bubble in column flotation and effects of reagent and other parameter to flotation performance.Experimental setup were consist of water collumn, image capturing device, image processing software and standar laboratory mesurement equipment for turbidity, colour indexes, and total suspended solid. Micro bubble were generated by electrolysis method with 316L stainless steel electrodes. Alum as a collector and Ethanol as a frother were added to the waste solution.This study reveal that electrolysis generated small bubble. Bubble size and their terminal velocies were effected by voltage and reagent added into the waste. Smaller voltage generated smaller bubbles. This study observed that Alum and Ethanol can be used as collector and frother in batik's waste flotation. Measurement of turbidyti, colour indexes and total suspended solid reveal that electroflotation reduced pollutant in batik's waste.
Keywords: batik waste, electroflotation, bubble size, turbidity, colour indexes, total suspended solid.

1. Introduction

Batik industry in Indonesia have developed from home industry (handmade) into commersial industry which involment of big corporates. Thus batik industries have significant constribution to Indonesia economy [1]. However, beside its economic contribution, batik industry also potentially rises environmental problem with its waste. This problem especially occurs in small and medium batik industries because of their limited capabilities in financial and technology.Untreated waste generated in production processes of batik will degrade water quality by increasing the turbidity, color and TSS.Therefore, we need a method to resolve the issue.
Several measures have been done before to treat the liquid waste in order to neutralize the pollutant. Several measures such as coagulation, sedimentation, adsorption and filtrationmethod have been used.These methods are usually used in combination, for example work by Setyaningsih. Setyaningsihused coagulation, sedimentation and adsorption as combine method to treat the waste of batik [2]. Most methods that have been used are adsorption, as has been done by Darmawanti,Rahmawatiand Basuki[3,4,5]. However adsorptionmethod have weaknesses, it must be followed by other processes and require high investment costs [6]. Another method that has been used was electroflotation[7]. In this method, bubbles were generated by electrolysis.
Flotation is a separation process of particular solid particle from liquid. In flotation process, hydrophobic particle will attacht to the bubble surface form a frotther and rise to the liquid surface separate from the liquid.Separation efficiency in bubble flotation is affected by three parameters, namely the probability of collision between bubbles with particles, the particles stick

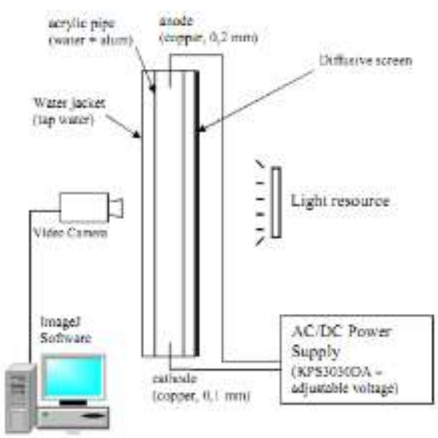
to the surface of the bubbles and the particles carried by bubbles [8]. It is known that those parameters are determined by bubbles and liquid characteristics. The bubbles and liquid characteristics that affectflotation are bubble size, terminal velocity, the concentration of frotther, collector, and modifier, temperature, pH, floated particle size, and flotation time. There are many previous works on bubble in column flotation, specifically by Jung-Eun Lee et. al. on bubble characteristic in column flotation [9] They showed a relation between bubble generator and generated bubble characteristics. Effect of frotther on bubble size was also shown by J.S Lawskoski and F. Melo. They reported that bubble size decrease with an increasing frotther concentration [10].

Previous studies have revealed many important characteristics of batik waste treatment and column flotation, however there is still lack of understanding in physical phenomena espesially in dynamics of small bubble and effects of the reagent on waste batik treatment. Most of the studies in colunm flotation are deal with flotation in mineral industries and very difficult to find similar study on application of this method in batik waste treatment.Therefore a research in this area is still needed and challenging.

This work is developed from our basic research which have been done in our laboratorium and as part of our attempts to develop a batik waste water treatment by small or micro bubbles flotation. The purpose of this research is to understand the dynamics of small bubble and effects of the frotther in batik waste flotation system. It consists of bubble size measurement, terminal velocity and capability to reduce turbidity, colour index and total suspended solid. Hence, this research results will improve our understanding on important parameters determine batik waste flotation.

2. Methodology

Schematic figure of experiment set up is shown in figure 1 and 2.



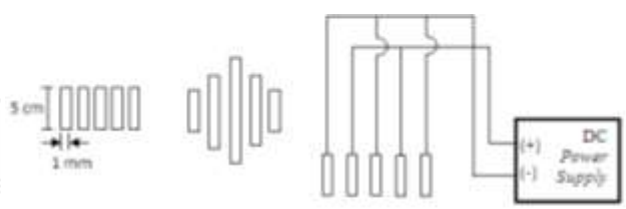


Figure 1. Experiment setupFigure 2. schematic figure of electrolysis bubblegenerator

Experimental setup are consist of water collumn, electrolysis bubble generator, image capturing device, image processing software and standar laboratory mesurement equipment for turbidity, colour indexes, and total suspended solid. Water collumn is an accrilyc pipe with 8,4 cm in diameter and100 cm length. The column was placed inside a square water jacket with a size of 80 x 80 x 2000 mm. Water jacketwas used to avoid optical distortion caused by pipe surface. It can be assume that pipe diameter is big enough compare to the bubble size. Therefore, wall effcts on the bubble is not evident.Sampling point is placed at the column at position 25 cm from the bottom pipe.

ISBN 978 979 8510 61 8

Sample liquid was prepared by added 3500 ml of distilled water, and 50 grams of alum into 500 ml batik waste taken from batik centra industry. Bubbles were generated by electrolysis. Electrolysis bubble generator was contructed from 316L Stainless steel electrodes. The schematik figure of the electrodes is shown in figure 2. Electrodes consist of 5 plate, all plates have same width and thickness, which is 5 cm and 0.1 cm.However each plate have different lengths, i.e. 2 pieces of 5.4 cm, 2 pieces of 6.9 cm, and 1 piece of 8.2 cm. The electrodes arrangement and size was adapted to the water column size and cross section. DC current was supplied by KPS3030DA of ATTEN instrument. Niklin wire with a diameter of 0.5 mm was used as conductor.
Nikon D5000 with AF-S lenses Nikorr 18-55mm f3.5-5.5G VR and extension tube was used as image capturing device. Extention tube increase camera capability in capturing micro size bubble. ImageJ software was used in image processing to measure the diameter and velocity of the bubbles.Bubble velocities were calculated by equation 1.

$$V = \frac{y_1 - y_0}{t_1 - t_0} \quad (1)$$

Where V, y_1, y_0, t_1 and t_0 is bubble velocity (cm/s), bubble position at timet_1 and t_0, t_1 and $t_0$is time.

Turbidity measurement was done by using portable turbidymeter 2100P from Hach. The working principle of this device is based on nephelometric, and have unit of NTU (Nephelometric Turbidity Unit).Spectrofotometerwas used to measure color indexes. The device adopt color indexs from APHA (American Public Health Association). The indexes indicate colour comparation of sample to Platinum-Cobalt solution (Pt-Co). APHA scales have range from 0 for clear to 500 for dark. Total suspended solid is defined as weight of solid particles in liquid divided by liquid volume and have unit mg/L.TSS was measured by Gravimetri method. Separationefficiency is indicated by flotation capability to reduce turbidity, color indexes and TSS. It isdefined by comparing the sample fluid before and after the flotation process as state in equation 2.

$$R = 100\frac{x_0 - x_1}{x_0}(\%) \qquad (2)$$

Where R, x_0 and x_1 are percent reduction, measurement value of the parameters (turbidity, color, and TSS) before and after flotation.

3. Results and discussion

3.1 Visual obeservation

Figure 3 shows the change in color and turbidity (clarity) of the liquid in each electrolysis time. This figure indicate time evolution of color and turbidity of the batik waste in 2, 4, 6, 8, 10 and 12 minutes electrolysis time for 10 Volt, 15 Volt and 20 Volt bubble generator. It is clear that the color indexes and turbidity reduce as flotation progres. progress. After 10 minutes of flotation, the clarity of the sample become like the clarity of potable water. After 12 minutes of flotation, the sample color change into green. Green color could be due to chromate thatexist in the sample as consequence of stainless steel as electrode.

ISBN 978 979 8510 61 8

a) 10 Volt

b) 15 Volt

c) 20 Volt

Figure 3. Change in color and turbidity of batik waste after 2, 4, 6, 8, 10 and 12 minutes flotation.
a) 10 Volt, b) 15 Volt and c) 20 Volt.

Figure4shows similar result for 15 Volt bubble generator, however with addition 0f Ethanol after 2, 4, 6, 8, 10and12minute of flotation. In this figure,from leftto rightshown a photograph ofthe sampleliquid, the sample after addition Ethanol, and sampleafterelectrolysisrun for2, 4, 6, 8, 10, and12minutes. Figureshows thechange inthe colorandclarity ofthe liquid ineachelectrolysis time. Similar to the previous results, sample with Ethanol addition also experience change in color into green after 12 minutes of flotation. From the results, effect of Ethanol on color index and turbidity visually not clear.

Figure 4. Change in color and turbidity of batik waste with Ethanol after 2, 4, 6, 8, 10 and 12 minutes flotation for 15 Volt bubble generator

ISBN 978 979 8510 61 8

3.2 Turbidity,Color and TSS

The results of turbidity, color and total suspended solid measurement are present in following figure 5, 6, and 7. The results indicated that electroflotation capable to reduce turbidity, color index and total suspended solid. Turbidity, color index and TSS , reduced by 69,6 %, 83,3 % and 93.96% for 10 Volt bubble generator, 63.8%, 78.56% and 95.98% for 15 Volt and 56, 9%, 72.06%93.96%. for 20 Volt bubble generator. It was eviden that electric voltage affects on turbidity, color index and TSS, however the nature of the fenomena still need further study.
Addition of Ethanol as a frother gave significant effect. Ethanol increase performance of turbidity and color index reduction for every voltage of bubble generator, however the best result was shown by 15 Volt bubble generator. 15 Volt bubble generator capable reduced turbidity and color index by 90.26% and 89.6%.

3.3 Bubble Velocity

Measurement results of bubble velocity is shown in figure 8. DC voltage was varied: 10 Volt, 15 Volt and 20 Volt. The average velocity ofthe bubbles is larger as the voltage increase.Thiscould bedue tobubblesgeneratedby thehigher voltagehas larger diameter. This graph also indicate velocity of bubble in batik waste with 0,01% addition of Ethanol. It is shown that the bubble velocity in this liquid higher than the bubble velocity in liquidwithoutEthanol. However different result is shown by Winarto work. Winartoshows that addition offrotthercanresult in smallerbubbles, and smallbubbleshavea smallervelocity [11]. The different of present and Winarto result could be caused by effect of Ethanol on electrical conductivity of the liquid. Electrical conductivity of liquid with Ethanol is 27, 1 mS/cm, while liquid without Ethanol is 23,2 mS/cm. It is already known that electrical conductivity affect the bubble generation in electrolysis.

3.4 Bubble Diameter

Bubble diameter and their population generated by different voltage are presented in figure 9. It was observed that the bubble diameter were not homogen even produced by same voltage. This figure shows that dominant bubble diameter were between 75 to 120 µm for 10 Volt bubble generator, 125 and 150 µm for 15 Volt bubble generator,and 125 and 250 µm for 20 Volt bubble generator. The average bubble size for 10 Volt, 15 Volt and 20 Voltbubble generator were 93.63 µm., 158.99 µm , and 197.28 µm respectively.From these results, the higher the voltage of bubble generator, the biger the diameter of generated bubble.
Figure 9 also shows the bubble size generated by 15 Volt bubble generator in liquid with Ethanol addition. Generated bubble were dominated by bubble size between 125 and 200 µm. with average bubble size was 162.26 µm. This bubble size is bigger than the average size of the bubbles generated by 15 Volt bubble generator in liquid without Ethanol. Work by Al Shakarji, He, and Gregory explains that the final bubble size changes slightly with increasing current density [12].

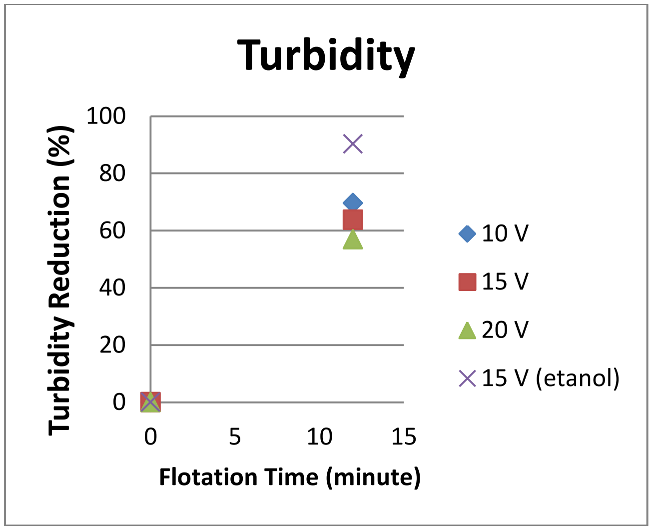


Figure 5.Turbidity reduction

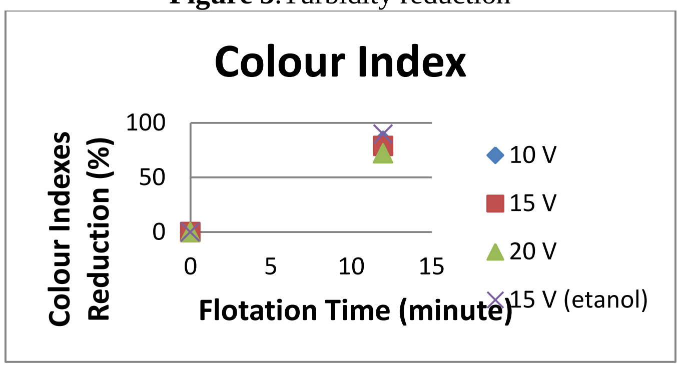


Figure 6.Color indexes reduction

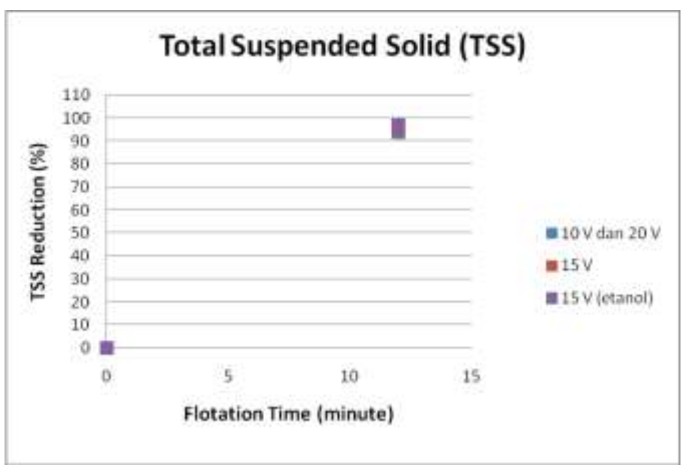


Figure 7. Total suspended solid (TSS) reduction.

ISBN 978 979 8510 61 8

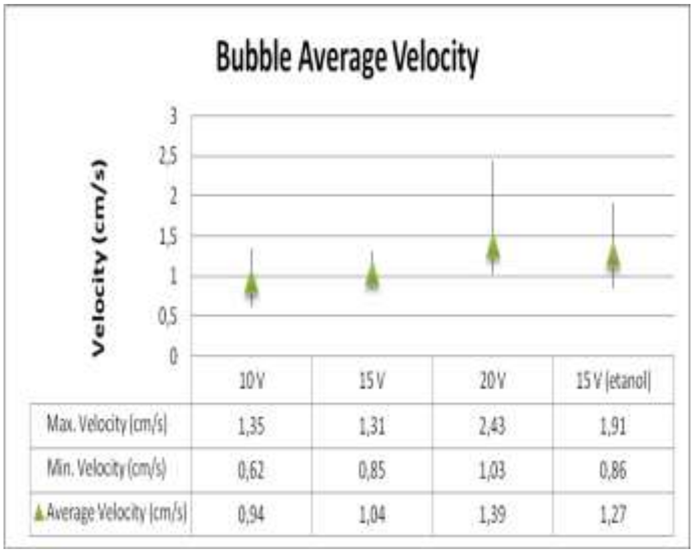


Figure 8. Bubble velocity

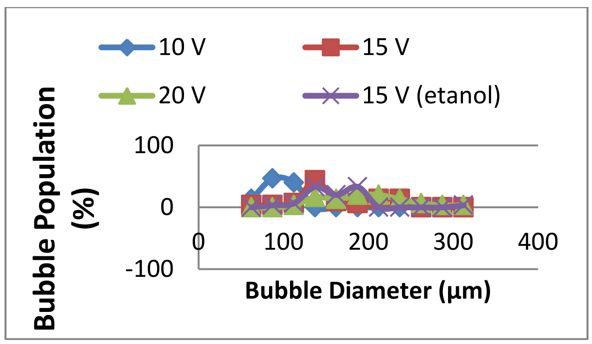


Figure 9. Bubble diameter and its population

3.5 Effect of Bubble Dynamics on Reduction of Color, Turbidity and TSS

Previous discussion have reveal that best color indexes, turbidity reduction were achieved by 10 Volt bubble generator. This is in accordance with the analysis of the bubble dynamics where the average diameter and the average velocity of the bubbles produced by 10 Volt bubble generator is small compared to that produced by larger voltage.

Addition of Ethanol as frother into the liquid increase the color indexes and turbidity reduction by 89.6% and 90.26% for 15 Volt bubble generator. This result is much higher when compared with no ethanol even for 10 Volt bubble generator. This could be due to the addition of ethanol make the bubbles more stable. Although Ethanol caused the bubble diameter increase,however Ethanol also caused increase in liquid electrical conductivity which leading to increase in number of genarated bubble. This condition increase the probability of collisions so that the flotation process become more efficient, which in turn makes TSS reduction increase. Number of bubbles generated by 20 Volt bubble generator can indeed be a lot, but because Ethanol was not added into the fluid, the bubbleswere not as stable as bubbles in liquid with Ethanol additionin flotation with 15 Volt bubble generator. The bubbles easily merged with another bubble and formed bigger one as shown in previous results. Bigger bubble decrease the flotation efficiency, and finallycause lower TSS reduction as compare with the performance of flotation in liquid with Ethanol addition.

3.6 VelocityAnalysis Based on Predictionof Stokes and Hadamard-Rybczynski

Figure 10 show terminal velocity versus bubble diameter. This figure also show predicted bubble terminal velocity by Hadamard - Rybczynskiand Stokes. Average bubble diameter and velocity from experiment data were used to construct the graph and as input into the Hadamard - Rybczynskiand Stokes prediction equation and [13].

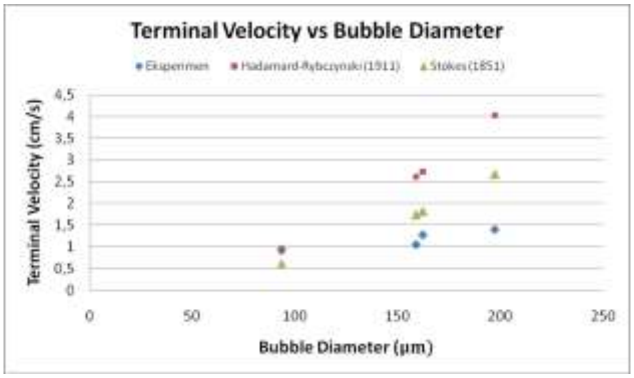


Figure 10. Terrminal velocity vs bubble diameter

It is clear that present results agree with Hadamard - Rybczynskiand Stokes prediction for small bubbles generated by 10 Volt bubble generator. However the situation differ for big bubble generated by 15 Volt and 20 Volt bubble generator. From this figure, it can be seen that the terminal velocity of bubbles generated by 15 Volt with and without Ethanol and 20 Volt bubble generator, were below the predicted Stokes and far below the predicted valueof Hadamard-Rybczynski. This suggests that the average bubble moves more slowly than predicted Stokes for solid ball moving in the liquid. It is as described by Navarra,Acuna and Finch [14]and the results of this research which shows thatthere was a second secondary Mechanisms. Navarra, Acuna and Finch describes as abubble moves with a certain velocity the bubble is deformed into an oblate spheroid, storing potential energy as well as Hooke's Law. When the diameter of the bubble is worth less than 1 mm, each deformation is linear and produces a symmetric oblate spheroid.Additionally, Navarra, Acuna and Finch also explains that a spherical bubble experience shear stress when riding in the pulp, causing the voltage gradient in the longitudinal direction. Frother on the bottom of the bubble tends to limit compression, resulting in stagnant cap. (Stagnant cap can be regarded as an ultra-viscous.) So that the voltage gradient combined (coupled) with frother concentration gradient so that there is a reduction frother on the front or top and additions to the bottom or of the bubble. This causes the frothermolecule adsorption on top and desorption frother moleculeon thebottom . Phenomenon due to the coupled between concentration and voltage gradient is called the Marangoni effect.

4. Conclusion

Research on electroflotation of batik waste has been done. It was found that electro flotation capable to reduce turbidity, color indexes and total suspended solid. Flotation performance was determined by bubble properties which is depend on applied voltage, hence the electroflotation performance was determined by applied voltage. The reduction of turbidity, color indexes and TSS are around 60 %, 75 % and 90 %. The most efficient color and turbidity reduction was achieved by 10 Volt, and for TSS reduction is achieved by 15 Volt bubble generator.
Ethanolaffect bubbleproperties. Averagebubble diameter generated in liquid with Ethanol is bigger compare that average bubble diameter generated in liquids without Ethanol. Ethanol increase electric conductivity of liquid. The addition of Ethanol in the liquid raise TSS reduction.

Bubble terminal velocity for small bubble generated by 15 Volt bubble generator was agree with Hadamard - Rybczynskiand Stokes prediction equation, however for big bubbles the value were below the predicted Stokes and far below the predicted value of Hadamard-Rybczynski.

5. References

[1] Purwaningsih, I. Pengolahanlimbahcairindustri Batik CV. Batik Indah Rara djonggrang Yogyakarta dengan metode elektrokoagulasi ditinjau dari parameter Chemical Oxygen Demand (COD) danwarna. *Final Assignment*, Environmental Engineering, Universitas Islam Indonesia. Yogyakarta: Universitas Islam Indonesia, 2008.

[2] Setyaningsih, H. Pengolahan limbah Batik dengan proses kimia dan adsorpsi karbon aktif. *Master Thesis*. Jakarta: Graduate Program Universitas Indonesia, 2007.

[3] Basuki. Penyisihan zat organic pada air limbah industri Batik dengan fotokatalisis TiO_2. Surabaya: Environmental Engineering, Institut Teknologi Sepuluh November, 2011.

[4] Darmawanti, T. Pengolahan limbah cair industri Batik dengan metoda elektrokoagulasi menggunakan besi bekas sebagai elektroda",*Undergraduate Thesis*. Semarang: Chemistry FMIPA, Universitas Diponegoro, 2009.

[5] Rahmawati, N. I. Pengolahan limbah cair industri Batik dengan metoda elektrokoagulasi menggunakan seng sebagai elektroda. *Undergraduate Thesis*. Semarang: Chemistry FMIPA, Universitas Diponegoro, 2009.

[6] Ruslinda Y. Materi pembelajaran digital: *Pemantauan kualitas udara ambien*". March 24, 2013. http://ilearn.unand.ac.id/pluginfile.php/17908/mod_resource/content/1/Pemantauan%20dan%20Pengendalian%20Pencemaran%20Udara%208.pdf (n.d.)

[7] Riyanto. Penemuan teknik baru untuk pengolahan limbah Batik. Yogyakarta: Chemistry,Universitas Islam Indonesia, 2011.

[8] Matis, K. A. *Flotation Science and Engineering*, CRC Press, Inc.,1995.

[9] Lee J.E., Choi W.S., Lee J.K.,A Study of the Bubble Properties in the Column Flotation System, *Korean J. Chem. Eng.*, 2003; **20**.

[10] Lawskoski J.S., Melo N.S.,Fundamental Properties of Flotation Frothers and Their Effect on Flotation, *Korean J. Chem. Eng.*, 2003; **20; 5**.

[11]Winarto, F. E. W. Investigation of micro bubble for removal of suspended particle and enhancement of dissolved oxygen in poluted water. *Ph.D Thesis*. Perak: Mechanical Engineering, UniversitiTeknologiPetronas, 2011.

[12]Al Shakarji, R., He, Y., dan Gregory, S. The sizing of oxygen bubbles in copper electrowinning. *Hydrometallurgy* Volume 2011; 109: pages 168–174.

[13]Clift, R., Grace, J. R., and Weber, M. E. *Bubbles, Drops, and Particles*. New York: Academic Press, Inc.,1978.

[14]Navarra, A., Acuna, C., and Finch, J. A. Impact of frother on the terminal velocity of small bubbles. *International Journal of Mineral Processing*, Elsevier,2009; 91: 68–73