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SULFUR DIOXIDE REMOVAL OF SMOKE AREA IN RUBBER SHEET INDUSTRY USING WET SCRUBBER

Husaini[1] and Abdul Haris[2]

Abstract: *The SO_2 can be produced from rubber sheet drying from wood burning rubber. The aim of this research is to design wet scrubber for sulfur dioxide removal in rubber sheet Industry. The study was conducted by entering the smoke from wood burning rubber into the wet scrubber. When SO_2 passes through the scrubber, at the same time drop water was spayed by different type of mist of nozzle in the bed. The SO_2 is dissolved in water and H_2SO_4 was formed. The un dissolved of SO_2 in scrubber was detected using Pararosanilin method. All datas were evaluated by statistical method. Base on the results, the 3 mm of mist diameter bed has highest efficiency up to 86%. For the pressure 40 psi and 3 number columns were shown the efficiency about 87% and 86%, respectively. The highest efficiency was achieved by 3 mm of mist diameter; 40 psi bed-pressure; and 1 number of column is 97% and for 4 mm of mist diameter; 40 psi bed-pressure; and 1 number of column about 96.8%.*

Keywords : *Sulfur Dioxide (SO_2), removal, wet scrubber*

1. INTRODUCTION

Air pollutants in indoor is an industry into a hidden disaster for workers and someday will also destroyed the industrial process (Husaini, 2014). Rubber sheet drying process is using hot air which used in the form of hot smoke from burning rubber wood. The process is not quite productive. From preliminary studies conducted on the levels of sulfur dioxide in the smoke of burning rubber sheet curing chamber showed that the average content of 0.856 ppm sulfur dioxide equivalent in 2247 $\mu gr/m^3$. This exceeds the threshold value of national ambient air quality standard of the Republic Indonesia Government Regulation number 41 of 1999 (Anonymous, 1999) can be affect to workers health such as lung health carcinogenic (Eva *et al.*, 2003), obstructive pulmonary disorder (Husaini, 2014; Mukono, 2008) and also peoples who are around the fumigation sheet chamber of rubber industry.

[1] Public Health Program Study, Medicine Faculty at Lambung Mangkurat University, South Kalimantan, 70714, Indonesia

[2] Environmental Health Department at Polytechnic Health of Banjarmasin, South Kalimantan, 70714, Indonesia

Correspondent E-mail: husainifawaz@yahoo.com

One of method can be done by engineering process (Silalahi and Silalahi, 1991), the nature of SO_2 gas is non-flammable, reactive, colorless, pungent odor, highly corrosive, irritating, and easily soluble in water to form acid. A cylindrical scrubber with height of 70 cm and 5 cm in diameter which have porous medium for spraying of water, it can be reduce the moisture contains in the form of aerosol particles (Ciborowski and Hulewich, 1970). Small particles in powder form have been successfully developed by using water sprayed pass through a nozzle (Rambali et al, 2003; Putri, Magdalena & Novamizanti, 2015). Previous research have been intestigated by Strock and Gohara (1994), the air pressure when water sprayed through a nozzle has effected on SO_2 removal (Strock and Gohara, 1994) Wet scrubbers was used for to reduce SO_2 concentration on dust rice with best condition on a bed of 2 mm; pressure of 30 psi; A large number of columns indicated the contacting between water and SO_2, which it can improve the efficiency of SO_2 removal. By wetting the wall, it can speed up the process of agglomeration thus increasing the efficiency of wet scrubbers (Haris, 2011).

From the above description, the SO_2 contained from wood burning rubber in rubber industry. It is interesting to investigated to determine the final concentration of SO_2 which focus on effect effect of pore diameter bed (2, 3, and 4 mm); pressure on water (20, 30, and 40 psi); and the number of columns (1, 2, and 3 columns).

2. MATERIAL AND METHOD

2.1. Materials

Materials which used is wet scrubber. Experiments conducted on laboratory scale by mimicking the process of curing rubber sheet that is mostly done in the province of South Kalimantan, Indonesia.

2.2. Design of Experiments

Hot air in the form of smoke from wood burning rubber on the smoker house flowed into wet scrubber with the pattern of flow from bottom to the top. Smoke containing SO_2 will move up through the porous bed that has been dampened by a drop of water is sprayed through a nozzle. Nozzle spread the dew that formed from water that has been given the pressure on the water tank by Air Compressor Wipro 9 models KD.

The lower part of the wet scrubber connected to the dirty water tank containing H_2SO_4. At the top of the wet scrubber, the air is relatively clean arrested with midget impinger Sampler Air Pump capacity of 2 liters / minute to put on SO_2 absorbent with Pararosanilin inspection method, with running times of each 5 minutes for each variation with repetition as much as 5 times. Experimental design can be seen in Figure 1.

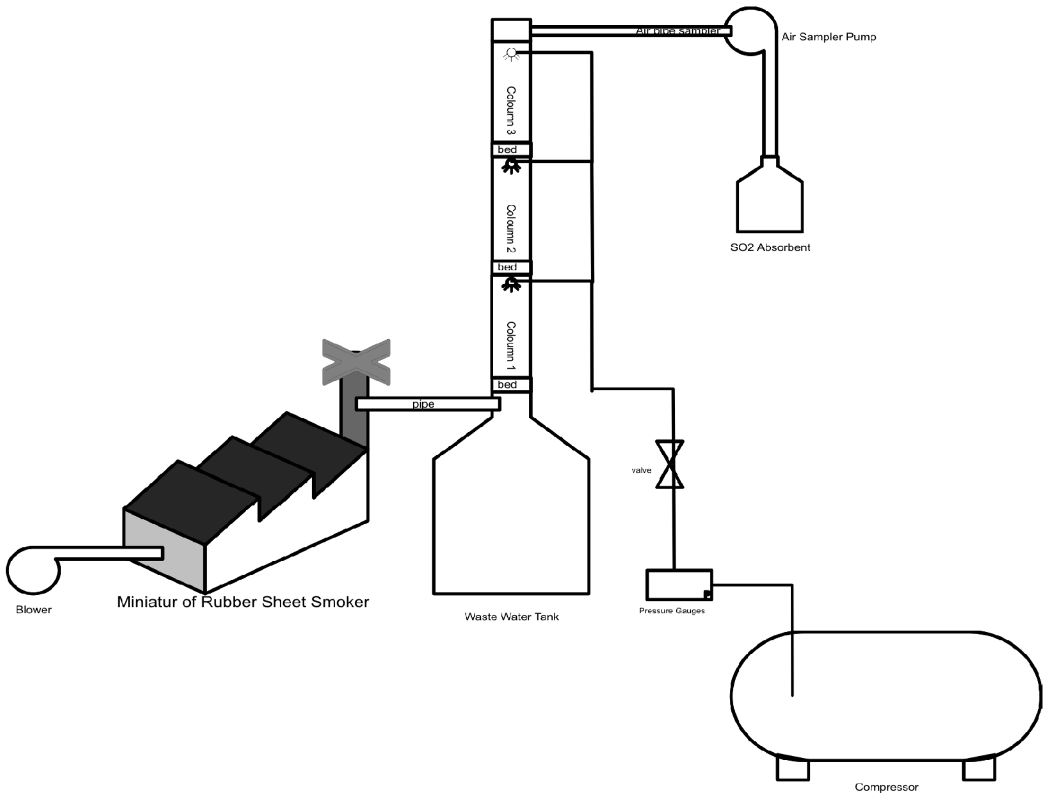

Figure 1: The Series of Experiment

The efficiency of wet scrubbers in reducing SO_2 can be calculated based on the equation [11, 12, 13]:

$$\eta = \frac{W_0 - Wt}{W_0} \times 100\% \qquad (2)$$

Explanation:

η = efficiency of wet scrubber

W0 = initial SO_2 concentration

Wt = concentration of SO_2 after passing Wet Scrubber

2.3. Bed

Bed used in this study of 5.5 cm diameter circular prepared in such a way that includes a plastic hose with holes 2 mm, 3 mm and 4 mm. For more information about bed used is shown in Figure 2 (Haris, 2011).

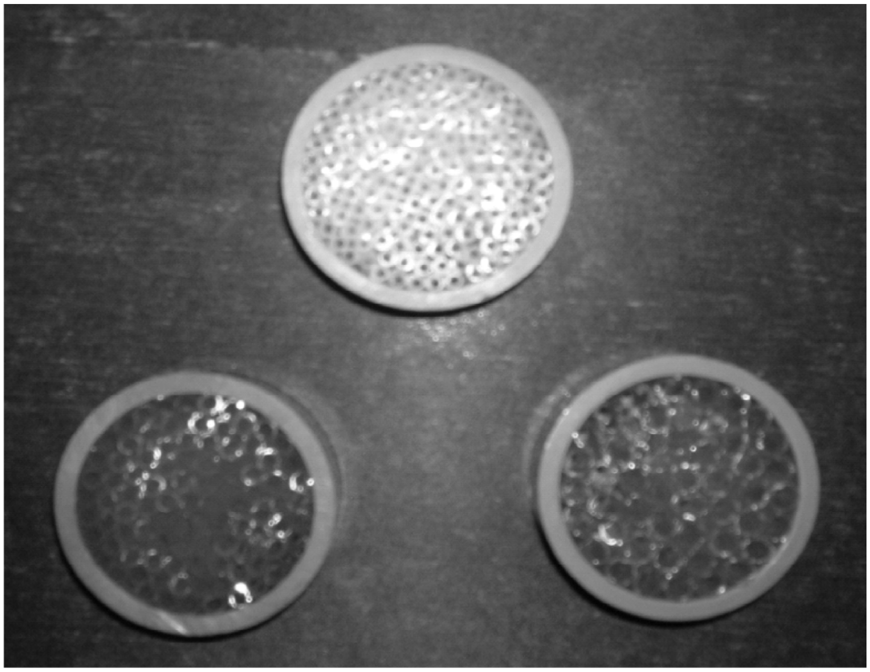

Figure 2: Bed from plastic hose with diameter 2 mm; 3 mm; and 4 mm

2.4. Nozzle and Pressure

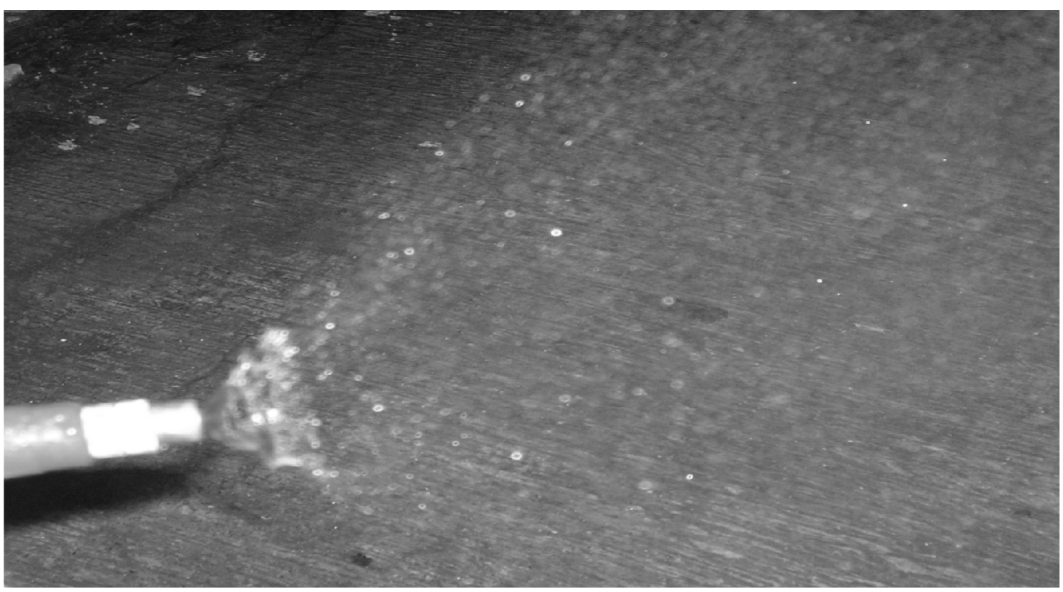

Figure 3: Coverage Dew of Nozzle (Haris, 2011)

Sprayer is used by the pressurized water nozzle. The nozzle used is nozzle of the spray equipment plants. The reasons for the use of agricultural spray nozzle of the tool are the ease to get in the market and of the spread or distribution of dew. To view the dispersive power of dew on the nozzle used in the study is shown in Figure 3 (Haris, 2011).

Figure 3 shows the dispersive power of dew on the nozzle used was 5 cm at a distance of 3 cm from the nozzle holes. This indicates that the nozzle can be used in this study because of the length of each column is 15 cm, so that when the water is falling at a distance of 3 cm from the nozzle hole, the water has reached the column wall and create conditions evenly wet the column wall. Evenly moist wall column which will help decrease SO_2 put in wet scrubber.

Furthermore, in Table 1 is presented on the performance of the nozzle associated with the volume of water released per minute. Preliminary tests on the performance of the acquired nozzle pressure ranges that produce moisture scattered power in accordance with the purpose of research, namely the pressure that produces a uniform distribution of moisture, which is 10 psi to 50 psi.

Furthermore, to determine the three variations of the pressure used to test the performance of the nozzle at a pressure of 10 psi to 50 psi. Data on the performance of the nozzle to the discharge of water per minute are presented in Table 1 (Haris, 2011).

Table 1
Performance of Nozzle toward The Debit Water (mL / min)

Pressure (psi)	*10*	*20*	*30*	*40*	*50*
			Flow (ml/menit)		
Replication					
1	138	197	243	290	325
2	145	200	244	285	328
3	140	198	245	283	328
4	135	198	240	285	325
5	137	198	243	290	326
Mean	139	198	243	287	326
Progressive Flow		59	45	44	40

Table 1 shows that the greater emphasis given to water, the volume of water that comes out even greater. Great determination the pressure used by the average gap discharge. Table 1 shows the increase in average discharge at a pressure of 10 psi to 20 psi with 59 ml / min, 20 to 30 psi with 45 ml / min, 30 to 40 psi as much as 44 ml / m, 40 to 50 psi as much as 40 ml / min, Based on the rise due to increase in discharge pressure, the obtained difference closest discharge is 20 to 30 psi and 30 to 40 psi. Therefore, the greater the pressure used is 20 psi, 30 psi and 40 psi.

3. RESULT AND DISCUSSION

3.1. Wet Scrubber's Efficiency

Efficiency wet scrubber in this study range from 64% to 100%. Table 2 presents the data efficiency of wet scrubber that is based on research by 27 variations with repetition of 5 times for each variation. Total data efficiency gained as much as 135 the data (Table 2).

This study uses references confidence level α of 5% (Hede *et al.*, 2007; Portoghese *et al.*, 2008; House *et al.*, 2008). There are two ways to make the decision to accept or reject the statistical hypothesis. Iriawan and Astuti (2006) said that the decision could use F arithmetic compared with F table at $\alpha = 0.05$ or P values using statistical calculations (Iriawan and Astuti, 2006). In this study, were used for making the decision to accept or reject the hypothesis of the study is the P value. This is done because the F Distribution Table ($\alpha = 0.05$) did not provide the value of degrees of freedom (df) for the denominator (v2 = 108). Value 108 is the error value DF on the results of a factorial design analysis program Minitab 14, so it cannot compare the calculated F and F table.

General Linear Model: Efficiency versus Bed, Pressure, Column

Analysis of Variance for Efficiency, using Adjusted SS for Tests

Source	*DF*	*Seq SS*	*Adj SS*	*Adj MS*	*F*	*P*
Bed	2	286.58	286.58	143.29	9.14	0.000
Pressure	2	760.00	760.00	380.00	24.24	0.000
Column	2	360.53	360.53	180.27	11.50	0.000
Bed*Pressure	4	811.56	811.56	202.89	12.94	0.000
Bed*Column	4	4433.02	4433.02	1108.26	70.71	0.000
Pressure*Column	4	196.27	196.27	49.07	3.13	0.018
Bed*Pressure *Column	8	762.18	762.18	95.27	6.08	0.000
Error	108	1692.80	1692.80	15.67		
Total	134	9302.93				

3.2. Influences of Bed, Pressures, and Number of Columns Toward The Efficiency

Influence on the efficiency of wet scrubbers bod indicated by P value 0,000 <α = 0.05. H0 so that said type of bed does not affect the efficiency of wet scrubber can be rejected.

Effect of pressure on the efficiency of wet scrubber indicated by the value P value 0,000 <α = 0.05. H0 so that said pressure difference does not affect the efficiency of wet scrubber can be rejected.

Mohan *et al.* (2008) reported that the use of a twin-fluid atomization in the spray scrubber to predict a decrease in the efficiency of the ash shows that the greatest efficiency of the spray tower occurred in the air flow 5.0 x 103 to 5.25 x 103 Nm^3/s (Mohan *et al.*, 2008).

Influence on the efficiency of wet scrubber column indicated by the value P value 0,000 <α = 0.05. H0 so that said number of columns does not affect the efficiency of wet scrubber can be rejected. Meikap and Biswas (2004) said that the wet scrubber made of three phases, the particle removal efficiency will increase (Meikap and Biswas, 2004). The efficiency of wet scrubbers also happens because while the wet scrubber column, SO_2 moving vertically from the ground up to be wet with dew flows that moves from top to bottom. This causes the SO_2 will dissolve in water into H_2SO_4 (Suharto, 2011).

Effect of bed for efficiency; pressure on efficiency; and the column to the efficiency of successive beds of porous 3 mm has an efficiency of 86%; pressure of 40 psi has an efficiency of 87%; and the third column has an efficiency of 86%. (Chart 1).

Table 2
Efficiency Wet Scrubber In Different Variations Of Efficiency SO2

No	*Variation*	*Efficiency (%)*				
		1	*2*	*3*	*4*	*5*
1	2mm;20;1	75	74	68	64	67
2	2mm;30;1	80	77	73	74	75
3	2mm;40;1	68	72	71	64	63
4	2mm;20;2	85	85	85	85	84
5	2mm;30;2	86	87	87	87	87
6	2mm;40;2	87	87	87	87	86
7	2mm;20;3	98	96	96	95	93
8	2mm;30;3	91	89	89	89	88
9	2mm;40;3	94	94	92	93	91
10	3mm;20;1	85	85	84	85	82
11	3mm;30;1	87	87	88	88	84
12	3mm;40;1	99	100	96	95	95
13	3mm;20;2	85	85	85	79	78
14	3mm;30;2	86	87	85	87	85
15	3mm;40;2	87	87	87	86	86
16	3mm;20;3	88	84	83	85	82
17	3mm;30;3	82	82	81	80	82
18	3mm;40;3	87	84	86	86	86
19	4mm;20;1	95	89	93	89	88
20	4mm;30;1	88	67	59	88	84
21	4mm;40;1	99	99	96	96	94
22	4mm;20;2	68	67	71	70	84
23	4mm;30;2	73	68	68	85	82
24	4mm;40;2	84	85	85	86	86
25	4mm;20;3	80	78	79	87	78
26	4mm;30;3	81	85	78	82	73
27	4mm;40;3	88	87	87	88	88

3.3. Interaction Effect of Bed-Pressure Toward The Efficiency of Wet Scrubber

Bed-pressure interaction effects on the efficiency of wet scrubbers is indicated by the value of the P value of 0, 000 < α = 0.05. H0 so that said interaction bed - the pressure has no effect on the efficiency of wet scrubber can be rejected.

Chart 2 shows the increased efficiency of the bed diameter of 3 mm and 4 mm at a pressure of 40 psi. The increased efficiency of the additional pressure that causes water droplets sprinkled from the nozzles tend to be larger so that more water soluble SO_2 into H_2SO_4.

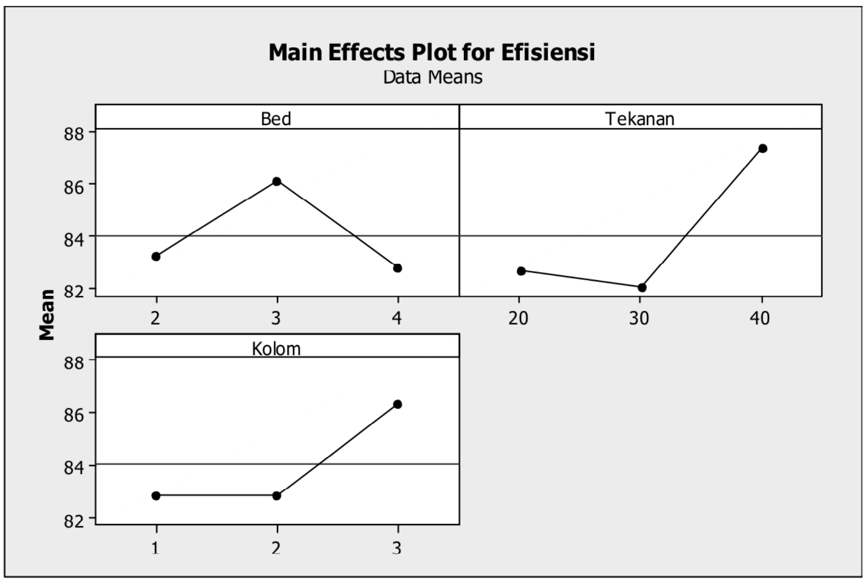

Chart 1: Influence of Bed Toward The Efficiency; Influence Pressure Toward The Efficiency; and Influence of Column Toward The Efficiency

In Table 1 shows that at a pressure of 40 psi volume of water released more in the same time (1 minute). This suggests that at a pressure of 40 psi water droplets that come out at pressures greater than 20 psi and 30 psi. Mohan *et al.* (2009) says that the particle collection efficiency is highly dependent on air discharge (Mohan *et al.,* 2009).

3.4. Influence of Interaction Bed-Efficiency Column Against Wet Scrubber

Bed-interaction effect on the efficiency of wet scrubber column shows the value P value 0,000 <α = 0.05. H0 so that said interaction bed-column does not affect the efficiency of wet scrubber can be rejected. To determine the interaction of bed-column greatest influence on the efficiency of wet scrubber can be seen in Chart 3. The highest efficiency of 93% occurred on the interaction bed diameter of 2 mm with an array of three columns.

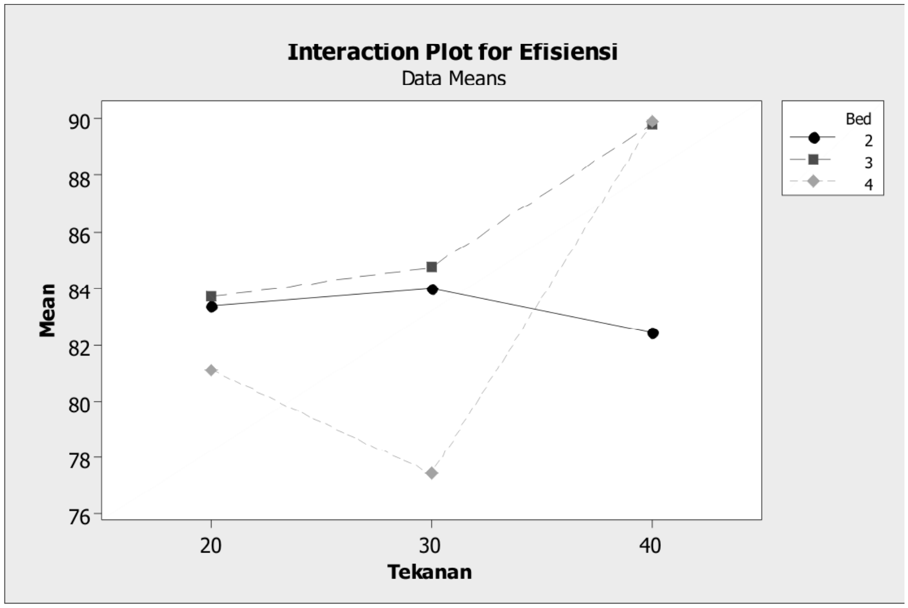

Chart 2: Interaction Effect of Bed-Pressure Toward The Efficiency

Increase in the average efficiency of wet scrubber occurs because the bed of porous 2 mm has a cavity closer together so as to have the packing porosity smaller as research conducted Ciborowski and Hulewich (1970) so that in the event of wetting through the nozzle more hold SO_2 gas, while the third column is more efficient compared to 1 column and 2 column (Meikap and Biswas, 2004), because the area of the inner surface of the wet scrubber 3 columns greater than 1 column and 2 column, so that when the wall wetting occurs more SO_2 soluble or agglomerated.

3.5. Interaction Effect of Pressure- Column Toward The Efficiency of Wet Scrubber

Pressure-interactions influence on the efficiency of wet scrubber column shows the value P value 0.018 <á = 0.05. H0 so that said interaction column - the pressure has no effect on the efficiency of wet scrubber can be rejected. Chart 4 shows that the pressure of 40 psi and the number of columns as much as 3 have the highest efficiency.

It is known that the greater pressure exerted on the water, the amount of water that comes out on the larger nozzle thus increasing the likelihood solubility of SO_2 in water to form SO_2. Added with an increase in the number of columns which enlarge the inner wall surface, the agglomeration process will be towards greater SO_2.

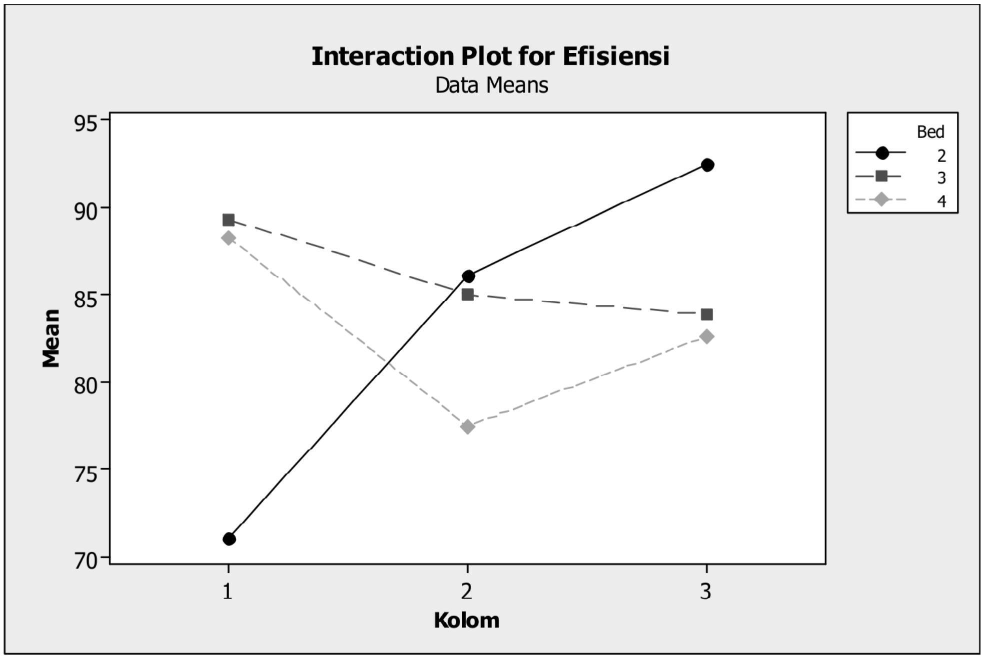

Chart 3: Interaction Effect of Bed-Column Toward The Efficiency of Wet Scrubber

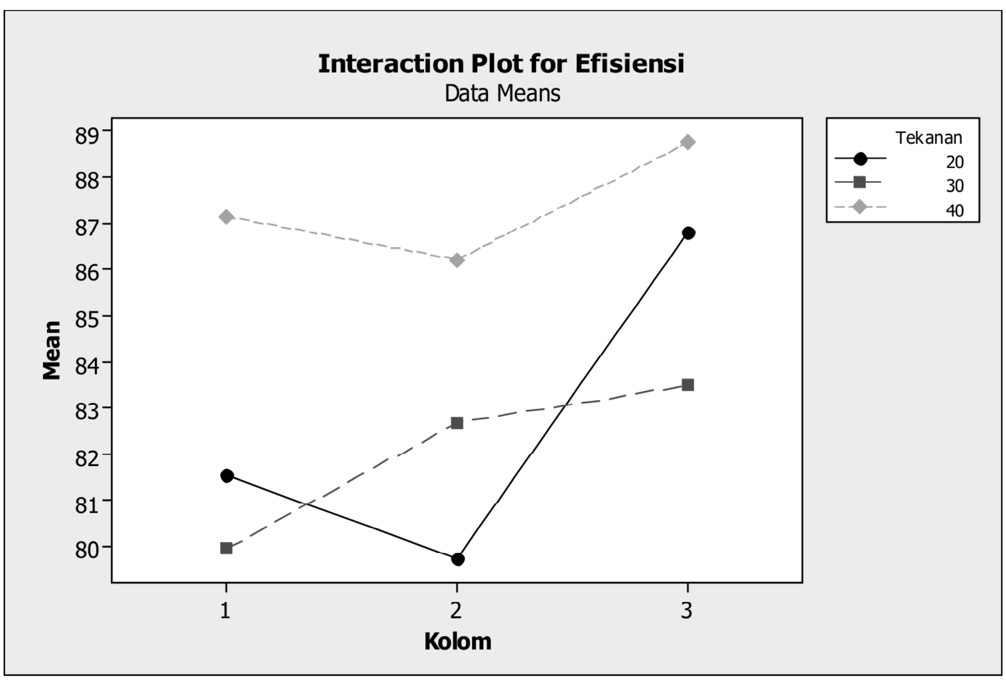

Chart 4: Interaction Effect of Pressure-Column Toward The Efficiency of Wet Scrubber

3.6. Interaction Effect of Bed-Pressure-Column Toward The Efficiency of Wet Scrubber

The highest efficiency in the wet scrubber will show in Table 3. The highest efficiency obtained from the wet scrubber variation bed of porous 3 mm; pressure of 40 psi; and the number of column 1 which is equal to 97% and 4 mm porous bed; pressure of 40 psi; and the number of column 1 of 96.8%.

Table 3
Average of Wet Scrubber Efficiency on Reducing SO_2

No	*Variation*	*η*	*No*	*Variation*	*η*	*No*	*Variation*	*η*
1	2mm;20;1	69.6	10	3mm;20;1	84.2	19	4mm;20;1	90.8
2	2mm;30;1	75.8	11	3mm;30;1	86.8	20	4mm;30;1	77.2
3	2mm;40;1	67.6	12	**3mm;40;1**	**97**	21	**4mm;40;1**	**96.8**
4	2mm;20;2	84.8	13	3mm;20;2	82.4	22	4mm;20;2	72
5	2mm;30;2	86.8	14	3mm;30;2	86	23	4mm;30;2	75.2
6	2mm;40;2	86.8	15	3mm;40;2	86.6	24	4mm;40;2	85.2
7	2mm;20;3	95.6	16	3mm;20;3	84.4	25	4mm;20;3	80.4
8	2mm;30;3	89.2	17	3mm;30;3	81.4	26	4mm;30;3	79.8
9	2mm;40;3	92.8	18	3mm;40;3	85.8	27	4mm;40;3	87.6

This wet scrubber can reduce sulfur diokside (SO_2) to 96,8%. As we know that the SO_2 gas is released in open space or indoor work will easily react with a variety of other gases present in the chamber. This is a hidden disaster for workers, especially workers who do not use personal protective equipment (Husaini, 2014).

The impact of SO_2 gas on human health is acute and cronic SO_2 exposure actually capable of causing an increase in cases of obstructive to the mechanism causing severe tracheabronchytis characterized by edema of mucous membranes, massive exudation, ulceration, hemorrhage and necrosis. In addition to causing tracheabronchytis also can cause death due to respiratory paralysis and edema pulmonary alveolar capillary membrane damage also activation of inflammatory cells that cause damage to the epithelium and endothelium. Effect of chronic exposure to lung SO_2 can cause chronic bronchitis, Chronic Obstructive Pulmonary Disease (COPD) and cystic peribronchial. Long-term exposure of SO_2 can cause changes in lung volume, histology and BALF changes and physical examination are hyperemia pharyngeal mucosa, weakening the voice of breath, coughing and wheezing. Thoracs X-ray picture often looks normal, but when the attack will be seen hyperinflation which shows a decrease in FEV_1 and FEV_1 ratio (Eva et al, 2003). There is consistent with the opinion of Rabinovitch et al in Eva et al., 2003 stated after three weeks of exposure to SO_2 gas on two different groups of age and not smoking will occur obstructive severe hypoxemia, decreased tolerance work and disorders of ventilation and perfusion visible screen Lung gallium and capable of causing chronic bronchitis, chronic obstructive pulmonary disease (COPD) and cystic peribronchial.

Another factor is reasonably suspected that the creation of secondary pollutants or other pollutants because of their increase in photochemical reaction of sunlight or temperatures due to hot environment, so it is difficult to determine the cause of pulmonary disorders by a single pollutant. It is also in accordance with the opinion of Mukono (2005) that an increase in temperature coupled absence of sunlight, including the reaction of two or more chemicals in the air create secondary pollutants, for example in the presence of sunlight can cause increased effects of chemicals in the air. Secondary pollutants have physical and chemical properties that are not stable, so it is easy to react and change their chemical makeup of the substance / other chemicals in the air and in the body (Mukono, 2005).

The above opinion is supported by Suharto (2011) that the occurrence of secondary pollutants in the air due to the reaction hydrolysis, oxidation and photochemical reactions, for example the reaction between $2SO_2 + O_2$ ====> $2SO_3$, or the occurrence of reaction: $SO_3 + H_2O$ ===== > H_2SO_4, and the reaction: CO + Fe ==> $FeCO_2$, then the end result of this chemical reaction when it goes into effect the human body is much more toxic, irritant, synergies and accumulative when compared to a single primary pollutants or pollutant materials of chemical elements / substances in the air (Suharto, 2011).

According to the Nadakavukaren opinion in Mukono (2005) that there is a correlation between increasing SO_2 with dust particles. High levels of particulate matter are usually followed by high SO_2 gas, making it difficult to distinguish the effect of both ingredients. This opinion is consistent with the explanation of the WHO (2000) that when the working system of cilia damaged by exposure to materials / chemicals either acute or chronic cause retention of harmful substances in the lungs for a long time and extended periods of exposure to repetitive necessarily increase the risk of adverse effects (WHO, 2000). According Sagai *et al.* (1996) Chronic exposure of SO2 gas can produce Superoxid (O_2) and hydroxyl radicals (OH) which is the active component to lower lung function and cause pulmonary edema, which can damage endothelial cells (Sagai *et al.*, 1996).

The discovery and scientific contributions in this study were able to create or design a tool to catch or reduce the sulfur dioxide gas (SO_2) in the industrial work place with the name of wet scrubber. Wet scrubber design is very useful for an industry that produce a lot of gas SO_2 in the study, the wet scrubber is already qualified from laboratory test that can reduce SO_2 gas on average 96.8%. Limitations of this study was not conducted an impairment test other gases that exist in the air, such as NO_2, CO, CO_2, O_3, and others.

Recommendations from this study is the need for further research to reduce other pollutants and other particles contained in the working industries like NO_2, CO, CO_2, O_3, and other pollutants, and we hope the wet scrubber can be mass produced in order to protect workers.

4. CONCLUSION

The highest efficiency on the bed diameter of 3 mm, resulting in a wet scrubber efficiency 86%, pressure on wet scrubber that produce the best efficiency is 40 psi at 87%, the highest efficiency on the number of columns by 3 columns, namely 86%. When varied between bed-pressure-column, the highest efficiency on the variation bed of porous 3 mm; pressure of 40 psi; and the number of column 1 which is equal to 97% and 4 mm porous bed; pressure of 40 psi; and the number of columns 1 of 96.8%

5. ACKNOWLEDGMENTS

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References

Anonymous, (1999). *The Indonesian Government Regulation No. 41 Year 1999 on the National Ambient Air Quality Standards*.

Chu. CY, and Hwang SJ. (2005). *Flue Gas Desulfurization In An Internally Circulating Fluidize Reactor, Journal* Powder Technology Volume 154;185-198.

Ciborowski. J and Hulewich. ZZ. (1970). The Influence of Packing Porosity and Aerosol Particle Deposition In A Scrubber. *International Journal Heat Mass Transfer.* Volume 14. Page: 185 – 198.

Eva, M., Faisal, Y., Wiwien, HW, and Mukhtar, I. (2003). *Effects of Sulfur Dioxide Inhalation Against Lung Health.* A Mirror World of Medicine. Faculty Mediciene Indonesia University, Indonesia.

Haris.A. (2011). *Dust decline Rice Using Wet Scrubber. Thesis. Institute of Environmental Engineering.* Master Program Ten November. Surabaya, Indonesia, 27 – 54.

Hede, PD., Bach, P and Jensen, AD. (2007). Top-Spray Fluid Bed Coating: Scale-Up in Terms of Relative Droplet Size and Drying Force. *Journal Powder Technology* Volume 184 318-332.

House, PK., Briens, CL., Berruti, F., and Chan, E. (2008). Effect of Spray Nozzle Design on Liquid-Solid Contact in Fluidized Beds, *Journal Powder Technology*, Volume 186 89-98.

Husaini, (2014). *Relationship Exposure CO, SO_2, NO_2, Fume and Vapor With Lung Function and Immunoglobulin Serum levels of Blacksmith.* Disertation of Doctoral Program - Medicine and Health Sciences Graduate Program of the Faculty of Medicine, University of Gadjah Mada, Indonesia, 54- 55.

Putri, E. I., Magdalena, R., & Novamizanti, L. (2015). The detection of cervical cancer disease using an adaptive thresholding method through digital image processing. *Journal of Advances in Health and Medical Sciences*, 1(1), 30-36.

Iriawan.N, and Astuti, SP. (2006). *Processing Data Statistics With Easy to Use Minitab 14, Issue 1*, Andi Offset, Yogyakarta, Indonesia, 256-278.

Meikap, BC. and Biswas, MN. (2004). Fly-ash removal efficiency in a modified multi-stage bubble column scrubber, *Journal Separation and Purification Technology* Vol. 36 177-190.

Mohan, BR., Jain.RK., and Meikap, BC. (2008). Comprehensive analysis for prediction of dust removal efficiency using twin-fluid atomization in a spray scrubber, *Journal Separation and Purification Technology* Volume 63 269–277.

Mohanty.CR., Adapala.S., and Meikap, BC. (2009). Removal of hazardous gaseous pollutants from industrial flue gases by a novel multi-stage fluidized bed desulfurizer, *Journal of Hazardous Materials* Volume 165 427–434.

Mukono, H.J. (2005). *Evironment Toxicology.* Airlangga University Press. Surabaya, Indonesia.

Mukono, HJ. (2008). *Air Pollution and Its Effect on Respiratory Tract Disorders*, Airlangga University Press, Indonesia, 71-73.

Portoghese, F., Ferrante, L., Berruti, F., Briens, C. and Chan, E. (2008). Effect of Injection-Nozzle Operating Parameters on The Interaction Between A Gas–Liquid Jet and A Gas–Solid Fluidized Bed, *Journal Powder Technology* Volume 184 1–10.

Rambali, B., Baert, L. and Massart, DL.(2003). Scaling Up of The Fluidized Bed Granulation Process, International *Journal of Pharmaceutics*, Volume 252 197 -206.

Sagai, M., Furuyama, A. and Ichinose, T. (1996). Biological Effects of Diesel Exhaust Particles Pathogenesis of Asthma Like Symptoms in Mice. *Journal Free Radic Biol Med*. 21;199-209.

Silalahi, BNB and Silalahi, RB. (1991). *Management of Health and Safety*, PT. Reader Binaman Preside, Jakarta.

Strock, TW. and Gohara,WF. (1994). Experimental Approach and Techniques for The Evaluation of Wet Flue Gas Desulfurization Scrubber Fluid Mechanics, *Journal Chemical Engineering Science*, Vol. 49, No. 24 A 4667 – 4679.

Suharto, I. (2011). *Chemical Waste In the Air and Water Pollution*, Publisher Andy, Yogyakarta, Indonesia.

WHO. (2000). *Hazardous Chemicals in Human and Environmental Health.* Publisher The International Programme on Chemical Safety. WHO. Geneva 27. Swizerland.