Lowering Emission using Single Venturi Vacuum in the Wet Scrubber System

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Abstract: Burning plastic waste using an incinerator will produce emissions of gas that will damage the environment if released casually. This research was conducted to analyze the effect of air flow, water discharge and thickness of the packing media on the efficiency of the wet scrubber in removing emissions from the combustion of plastic waste. There are 3 variable variations, air flow velocity, water flow velocity, and thickness of media with thickness of 5 cm, 10 cm and 15 cm. The parameters to be investigated are the SO_2, NO and CO content and temperature at the wet scrubber. The results obtained from the experiments carried out were SO_2 efficiency values of 46.80%, CO of 26.70% and NO of 23.68%. SO_2 values tend to have high efficiency values because SO_2 solubility in water is high. In accordance with the effect test with the help of IBM SPSS, water flow and venturi flow greatly influence the removal of NO, CO and SO_2 gases. However, the thickness of the media only affects the removal of CO and SO_2 gases.

***Keywords*: Venturi vacuum, air flow velocity, water discharge and media thickness.**

I. INTRODUCTION

The problem of waste in Indonesia is something that has not been resolved to date. Increasing the number of residents will result in increased waste generated. One of the problems of rubbish is plastic waste which has the potential to pollute the environment if there is no control over usage. As many as 300 million ton of plastics waste are produced annually and around 50% is thrown away [1]. In Surabaya, the amount of waste generated reached 2,160 tons / day with plastic waste of 10.09 tons / day [2]. Data from the Ministry of Industry, imports of polypropylene (PP) products continue to increase along with the growth in consumption of chemicals. In the data mentioned. In 2012, polypropylene (PP) consumption was 1.3 million tons per year and increased in 2013 to 1.46 million tons. In general, solid waste contains 12% plastic waste which, if carried out by burning, releases toxic gases such as dioxin, furan, mercury into the atmosphere [3]. In addition to small particles, NO, SO_2 and CO are emissions from combustion gases [4].

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One effort that can be done to reduce amount of plastic waste is to do plastic waste incineration. We often encounter in the area around that one of them is burning plastic in the open. In fact, combustion with a system like this is the main source of air pollution. To prevent air pollution caused by incineration activities, we need a tool that is able to control the emission output from the combustion process carried out. The gas control device used in this study is a scrubber with a type of wet scrubber that is placed at the end of the combustion process before air is released into the environment. Wet Scrubber has been proven to be able to reduce SOx emissions up to 90% so that it is appropriate to control the emission of incinerator exhaust gases [5].

According to the Environmental Protection Agency (EPA), the term wet scrubber is a device that is useful for removing flue gas pollutants from furnaces or from other gas streams. This device is used to clean air, exhaust gases or other gases from various pollutants and dust particles by making contact between pollutants and scrubbing solutions.

II. MATERIAL AND METHODS

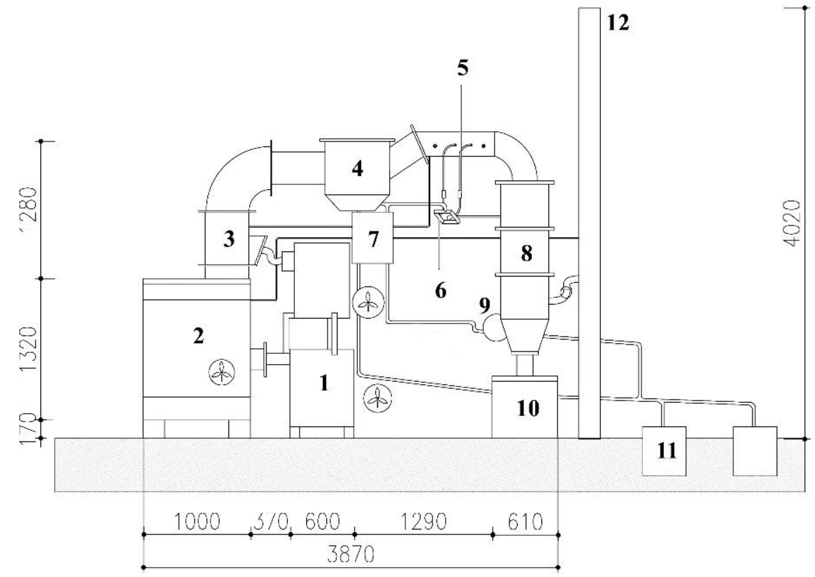
A. Research Preparation

The tool that will be used in this research is the Wet Scrubber type Co Current with a single venturi vacuum. Gas coming out of the Heat Exchanger will flow and some will go into the venturi pipe due to a pressure difference. Furthermore, the air that is combined with water will enter the wet scrubber to be cleaned with absorbent in the form of PDAM water which will later be collected in a reservoir. The wet scrubber design can be seen in Figure 1.

B. Wet Scrubber Process

In the incineration process, the waste is put into the primary burner chamber where the plastic waste will be combusted with a preheated charcoal lighter. At the pre burner stage, 30% of the mass will remain in the furnace in the form of non-burnt material and sediment ash. Combustion gases will enter through the primary chamber to be burned again and then into the secondary chamber. With this two-burn process the carbonization gases produced from the first combustion chamber will be burned up in the second combustion chamber. Gas that has been burned in the second combustion chamber will be lowered by passing the heat exchanger. The temperature reduction is done so that later the gas that enters the wet scrubber in a cold state so that no gas explosion occurs due to the contact of hot gas with the air absorber.

The gas that has been cooled will pass through the main gas pipe to get to the wet scrubber and some others will be drawn through the venturi vacuum to be mixed with the water absorber before entering the wet scrubber. The attraction of the gas to the venturi vacuum is due to the application of the Bernoulli principle applied to the venturi vacuum. When the gas fluid passes through the pipe with a small cross section, the fluid rate will increase. Based on Bernoulli's principle, the fluid pressure in the narrow pipe component is smaller if the fluid flow rate is greater. This is known as the venturi effect, which shows quantitatively that the fluid flow rate is high, so the fluid pressure becomes small. Venturi neck pressure is low from environmental pressure is the key technology where gas can enter the venturi through micro holes that have been fabricated in the venturi neck.



Caption:
1. Burner
2. Primary chamber
3. Secondary chamber
4. Heat exchangers
5. Flowmeter
6. Venturi vacuum
7. Thermocouple panel
8. Wet scrubber column
9. Water pump
10. Wastewater tub
11. Tubs of clean water
12. Chimney outlet

Fig. 1. Reactor Design

C. Research Implementation

The study based on three variables. The first variation is the amount of water discharge that is 15, 20 and 25 l/min. The second variation is the gas flow rate at venturi vacuum of 12, 14 and 16 l/min. The third variation is the thickness of the media is 5 cm, 10 cm, and 15 cm. The research procedure is as follows:

1. Prepare Polypropylene-plastic 1 kg as incinerator fuel
2. Insert Polypropylene-plastic as the material into the primary chamber
3. Arranging the reactor with the variation of research needed (the number of venturi, the filter media size, and the height of the filter media)
4. Turn on the burner as a trigger for fire in the primary chamber
5. Turn on the blower as an air supplier to keep the fire burning during combustion
6. Turn on the water pump to distribute water into the reactor
7. Combustion emissions from the incinerator flow to the heat exchanger through the reactor pipe
8. Adjust the rate of air flow into the wet scrubber by adjusting the gas discharge value on the flowmeter
9. Monitor the temperature values on the thermocouple and make sure the combustion has reached the maximum temperature
10. Turn on the stopwatch and take measurements.
11. Monitor and record the value of gas emissions at the wet scrubber inlet and outlet every minute on the gas analyzer within 10 minutes by burning 1 kg of Polypropylene-plastic

D. Efficiency of Using Venturi Vacuum

The study was conducted to determine the efficiency of the wet scrubber by adding venturi pipes in setting aside combustion gas emissions. Emission values are taken from the inlet gas and wet scrubber outlet gas for 1 kg burning PP type plastic bags lasts (10 minutes). Emission value data obtained will be analyzed and discussed so that it will get the highest efficiency value from each variation made. The study was conducted in 27 experiments with 3 variables and 3 variations on each variable. Done with the same treatment adjusted for the variations applied.

The resulting incinerator emission gas removal efficiency value can show the performance of the one stage wet scrubber reactor. The greater the resulting efficiency values indicate that the performance of the three-stage scrubber reactor is getting better. Efficiency values are calculated by Equation 1.

$$\eta = (c\ in - c\ out)/c\ in \times 100\% \quad (1)$$

η = gas emission removal efficiency (%)
C_{in} = concentration of inlet gas (ppm)
C_{out} = concentration of outlet gas (ppm)

III. RESULT AND DISCUSSION

The results are obtained from the calculation of efficiency and the relationship between variables using Anova spss statistics. For efficiency values obtained from previous calculations and statistical results obtained by entering efficiency values into statistics.

A. Result of Efficiency

The result of efficiency wet scrubber using single venturi vacuum can be seen in table I. From tables I and II it can be seen that each variation produces different efficiency values. The highest allowance for emissions is found in SO_2 gas removal where almost 50% can be reduced before being discharged into the environment. This is consistent with the study of Kaye and Laby in 1986 which stated that SO_2 has higher water solubility than NO and CO gases [7]. SO_2 solubility in water is 11.28 gr/100 gr water, NO 10.19 gr/100 gr water, and CO 0.0028 gr/100 gr water.

Table I. Efficiency of NO, CO, and SO_2

Water Discharge (l/min)	Media Thickness (cm)	Gas Flow (l/min)	NO	CO	SO_2
15	5	12	19.16	11.62	13.19
		14	16.24	45.41	32.79
		16	25.47	20.61	63.54
	10	12	18.55	28.18	14.37
		14	41.38	35.81	38.06
		16	23.84	39.93	75.02
	15	12	21.98	21.72	34.94
		14	26.73	10.42	48.05
		16	22.34	22.04	53.22
20	5	12	13.5	6.38	65.34
		14	18.91	10.24	48.32
		16	21.09	8.17	30.36
	10	12	41.84	38.36	41.92
		14	31.55	29.86	49.05
		16	21.99	16.2	35.78
	15	12	29.53	26.13	30.48
		14	27.91	22.24	56.63
		16	36.1	35.26	57.44
25	5	12	10.44	19.11	72.29
		14	11.43	42.58	92.91
		16	27.74	28.19	78.74
	10	12	20.69	18.27	26.72
		14	42.86	54.26	35.74
		16	29.03	39.21	48.45
	15	12	4.23	18.72	31.06
		14	10.05	38.64	41.15
		16	24.81	33.46	47.98

B. Result of One Way Anova

The result of one-way anova statistic test can be seen in table II.

Table II. One Way Anova Statistic Test Result

Variables	NO	CO	SO_2
Water Discharge	0.348	0.176	0.471
Gas Flow	0.024	0.119	0.251
Media Thickness	0.393	0.168	0.128

From the Anova test results, it can be seen that gas flow and media thickness test on the efficiency of SO_2 and CO gas has a significance value of more than 0.1. So it can be concluded that the initial hypothesis that there is a relationship between variables and efficiency is acceptable. As for the variable gas flow to NO gas efficiency has a significance value of 0.024 which means that there is no relationship between the variable gas flow with NO gas efficiency.

IV. CONCLUSION

There is an influence between water discharge, gas flow and media thickness on the efficiency of SO_2 and CO gas removal. Whereas the variables that affect the allowance for gas emissions are only the water discharge and media thickness variables.

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REFERENCES

1. Shingh, P., Sharma, VP. 2016. Integrated Plastic Waste Management: Environmental and Improved Health Approaches. Procedia Environmental Sciences 35 (2016) 692 – 700.
2. Trihadiningrum, Y. 2006. Reduction potential of domestic solid waste in Surabaya City, Indonesia. Proceedings, The 4th International Symposium on Sustainable Sanitation, Bandung, 4-6 September 2006. ISBN 979-26-2496-1
3. Verma, R., Vinoda, K., Papireddy, M., Gowda, N. 2015. Toxic Pollutants from Plastic Waste- A Review. International Conference on Solid Waste Management, 5IconSWM 2015.
4. Franchini, M., Rial, M., Buiatti, E., Bianchi, F. (2004). Health effects of exposure to waste incinerator emissions: a review of epidemiological studies. Istituto di Fisiologia Clinica 40(1):101-115.
5. Quina, M.J., Bordado, J.C.M., Quinta Ferreira, R.M. 2008. Air Pollution Control in Municipal Solid Waste Incinerators. Instituto Superior Técnic, Portugal

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