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Wet Scrubber for Coal Combustion with The Use of Textile Wastewater Feeding

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Abstract. Coal combustion emission contains the acidic gas SO₂. Meanwhile, textile wastewater contains high alkaline. This study inspects the performance of scrubber from boiler using coal fuel with textile wastewater as feeding. The wastewater was collected from an equalization tank. We adopted SNI standard for emission measurements at the outlet. The reduction of acidic gas pollutants concentration was 31–78%, while the operating temperature was observed at 83–190 °C. This study ascertains that using textile wastewater as scrubber feeding has mutual benefits i.e. at wastewater treatment and air pollution control devices in situ.

Keywords: feeding, reuse, scrubber, sulfur dioxide, wastewater

1. Introduction

The availability of clean water in the world lately is quite alarming because of the imbalanced rate of clean water supply with the rate of population growth. The water needs for a population includes water supply for industries which is commonly quite large. Considering the growing need for water for industries and limited water supply conditions, the re-utilization of industrial wastewater for use in processes particularly for controlling environmental pollution should be promoted. The average industrial liquid waste has high turbidity, BOD, and COD content [1]. Air pollution control devices, i.e. wet scrubbers consume plenty of clean water. For this reason, alternative water supply systems need to be sought.

In many industries, air pollution control is an important part in industrial processes. A wet scrubber is one of the air pollution control devices that have been used for minimizing particulate emission from many processes such as those emitted by boilers, heaters, and heating furnace units. In a wet scrubber, in principle, the liquid (feed water) is intensively in contact with gas stream so that particles in the gas stream will be removed from the gas and transferred to the water feed. Natural water is widely used in a wet scrubber. The amount of energy expended for contacting gas emission with water feed will determine the collection efficiency of a wet scrubber. There are numerous types of gas stream emissions which can be handled with a wet scrubber, one of them being acid gas. Wet scrubbers have a high collection efficiency, usually more than 90%, and it is comparable to other air pollution control devices such as fabric filters and electrostatic precipitators, starting from those used for dust collection in industrial process to the combination of dust collection and absorption of harmful gases produced by fossil fuel boilers.



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The high consumption of fresh water for the wet scrubber process is a disadvantage. Therefore, minimizing the amount of water used by reusing of fresh (relatively fresh) wastewater as a wet scrubber feed is a good alternative way. Textile wastewater contains alkali so that the acidic gas SO_2 could be removed by rubbing polluted gas in an alkali water stream. Alkali solvents such as urea, diluted NaOH, limestone slurry, and NaCl solution [2] can be found in textile wastewater. As for particles, ordinary scrubbers, such as Venturi or Swirl scrubbers and washing towers, have relatively high PM removal efficiency (more than 95%) for PM sizes above 2-5 μm , diameters that are too high for the waste gas from biomass boiler [3]. Therefore, several studies have been carried out on the reuse of water in various industrial sectors, one of which is the textile industry and other manufacturing industries [4]. However, there have been no studies so far about the reuse of wastewater for processing air pollution and the potential for water savings. This might be a beneficial combination of wastewater treatment and air pollution control system.

The main objective of this study was to analyze the characteristics of appropriate textile wastewater for liquid scrubbing and its efficiency in removing SO_2 from gas emissions by means of scrubber equipped with a bed system for optimizing gas-liquid contact.

2. Materials and Methods

The research scope is focused on the application of design and construction of a combination of wet scrubbers' operation by changing the feed water with wastewater. A preliminary test was done prior to the observation process and analysis tests. Liquid waste sampling was carried out by the grab sample method in accordance with SNI 6989.59: 2008 concerning the method of wastewater sampling. At the sampling stage, measurements of coal combustion flue gas were performed, namely SO_2 concentration, exhaust gas temperature and wastewater pH. Then testing was done on the characteristics of the wet scrubber outlet wastewater including pH and temperature measurements. Sampling was carried out in two parts i.e. before entering the wet scrubber and after entering the wet scrubber.

The pollutant parameter of interest was only SO_2 although particulate and NO_2 were also measured in the test. Measurement of SO_2 emission concentrations was carried out using a Bacharach PCA 3 portable gas analyzer with ppm as unit. Whereas for measuring the temperature a SENSE brand analog bimetal thermometer was used. This thermometer has $\pm 5^\circ\text{C}$ accuracy, and the temperatures were recorded manually by observing its needle showing variations of temperature during the combustion process. After completing the scrubber process, the liquid water was tested for parameters of pH and temperature.

In this study, the reactor was arranged as follows: a single combustion chamber equipped with coal stock for combustion and a burner, a wet scrubber (made of stainless steel), and a container for providing feeding of scrubbed liquid. Considering the design, we used spray tower scrubber. This scrubber was equipped with marbles as its bed media. Textile wastewater was selected in this study for scrubber water feed. The important parameter for wet scrubber, the L/G ratio, was set at 5 gal/1,000 feet. The complete device used in this study can be seen in Figure 2. We observed temperature variations during the combustion process at the top of the burning coal and at the top of the sampling point.

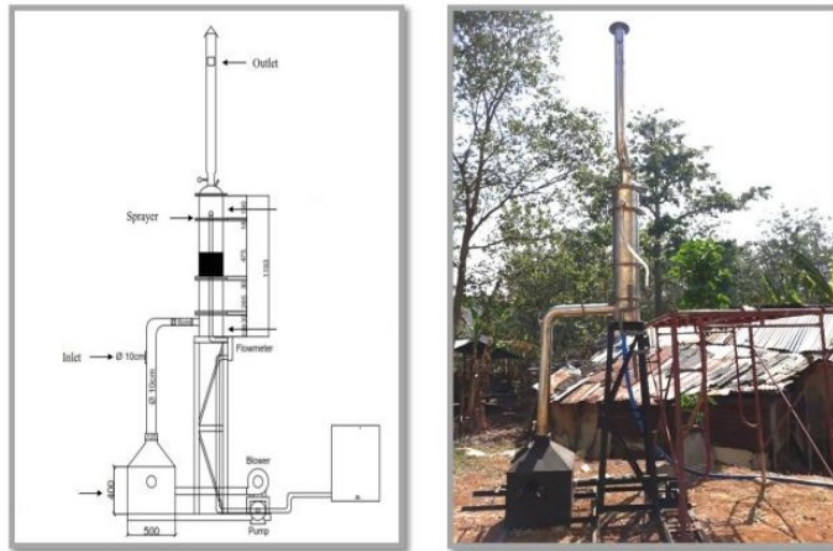


Figure 1. Scheme of Reactor Used

3. Research Results

In the preliminary study, we used clean water as a scrubber feed. The study lasted for 3 days in October 8, 9 and 16, 2019. The coal used very high contained calories (> 7,100 cal/kg) and moderate sulfur content (0.5-1%). On the sample, the total coal sulfur in Dry Base (db) reached 0.54%. According to ASTM Standards (1981), coal with a calorific value of 11,500-14,000 Btu/lb belongs to the Bituminous class. This is a type of coal with good quality (medium-rank coal) because the content of impurities (which have the potential to become pollutants) is low.

3.1 SO2 Emission Concentration Analysis

Textile wastewater was collected from an equalization tank and let settled for 3 hours. In the fresh wastewater, the COD, color and TSS were 312, 492, and 500 mg/L respectively. In this study, the parameters tested were SO₂ produced from coal combustion. Sampling in each experiment was carried out twice at an interval of 10 minutes. Duplo measurements were aimed to making the results more accurate. The following is a table of measurements of SO₂ concentrations for all three experiments.

Table 1. Emission Load Rate of SO₂

Measurement	Test #	Diameter (m)	Velocity Gas (m/s)		Measured SO ₂ (mg/m ³)		Flowrate SO ₂ (m ³ /s)		Emission Load SO ₂ (mg/s)	
			Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
			8 Oct	1	0.1	6.89	1.91	308.09	168.83	0.054
	2	0.1	2.72	1.82	14134	82.45	0.021	0.014	2.99	1.17
9 Oct	3	0.1	2.12	2.05	127.60	129.56	0.016	0.016	2.10	2.07
	4	0.1	2.93	1.26	80.48	53.00	0.023	0.009	1.83	0.52
16 Oct	5	0.1	2.25	1.83	196.31	149.19	0.017	0.014	3.44	2.12
	6	0.1	4.96	2.22	127.6	129.56	0.038	0.017	4.93	2.24

The emission load data show the number (mass) of SO₂ pollutants coming out of the coal combustion source at each time unit. Sulfur dioxide (SO₂) emission load measurement was taken once for 3 different coal combustion experiments, where each of the experiments was carried out for approximately 60 minutes or 1 hour by burning 2.5 kg of coal before the emission samples were taken. On the first day of the measurement in the first experiment, the flow rate used was 5 liters per minute. On the second day, the coal combustion experiment used a liquid feed flow rate of 10 liters per minute, but at the time of the fifth experiment, the liquid waste used was insufficient to be tested with a feed liquid flow rate of 10 liters per minute because the feed liquid flow rate as much as 10 liters per minute releases more liquid feed than 5 liters per minute and for the fifth and sixth experiments the feed liquid flow rate was 5 liters per minute. Also, on the third day of the measurement the feed liquid flow rate used was at 10 liters per minute. The flow rate affects the allowance for SO₂ gas emissions. The following are percent efficiency data for SO₂ emissions removal in all three measurements.

Based on Table 2, it can be seen that the most efficient SO₂ removal efficiency was an experiment that used a flowrate of 5 liters/minute. A previous study on the absorption of CO₂ into a NaOH solution using a spray column by Javed et al (2010) also mentioned that an increase in the flow rate of liquid flowing from 2 to 5 l/min resulted in a greater surface area of the interface per unit volume in the spray column. The greater the surface area of the liquid, the more gases were absorbed by the droplet granules so that the removal of pollutants was more optimal.

Table 2. Removal Efficiency of SO₂

Flowrate (lpm)	SO ₂ Emission Load (mg/s)		Removal of SO ₂ (%)	Average of removal SO ₂
	<i>Inlet</i>	<i>Outlet</i>		
	5	16,55 2,99 1,83		
10	2,1 3,44 4,93	2,07 2,12 2,24	1,42 38,37 54,56	31,45%

3.2 Wastewater Analysis of Wet Scrubber

In the removal of SO₂ emissions, pH greatly influenced the chemical mechanism in the scrubber and the level of removal of pollutants. The following is the average daily pH of outlet data.

Table 3. Data on Average Outlet pH

Minute	Day 1	Day 2	Day 3
0	11.31	11.15	11.89
10	11.02	10.96	11.77
20	11.06	10.21	11.70
30	11.11	10.98	11.67
40	11.10	10.98	11.55
50	11.03	10.94	11.70
60	7.38	11.01	11.72

In other research, the inlet of pH determined the efficiency of wet scrubber. For instance, Cehin [5] found that there was a strong relationship between the inlet pH and the efficiency.

3.3 Combustion temperature

Combustion temperature affects the amount of emissions produced. Figure 2 shows the profile of temperature during burning events. In this case the temperature rose to 83-190 °C where the initial combustion for giving water had a higher maximum temperature. At the output, it showed a variation in temperatures between 35 and 55°C. It was much less than those at the inlet location. The temperature was observed to be higher at the inlet position because the temperature sensor was located near the coal combustion zone. The following is a graph of temperature measurements every 10 minutes for one hour.

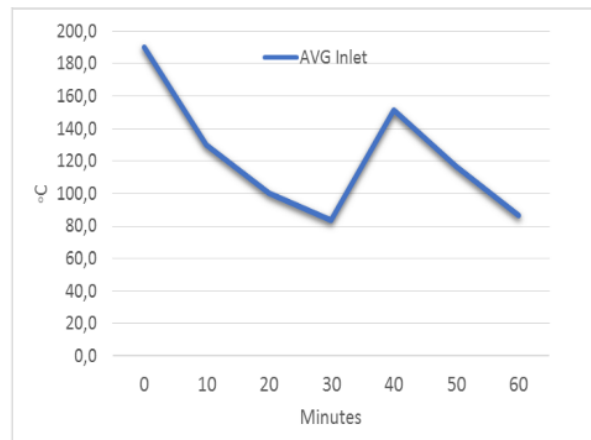


Figure 2. Temperature profile SO₂ Emission Reduction.

The effect of temperatures on wet scrubber performance was studied by Hadlocon et al [6]. They found no significant difference between 12–30 °C operating temperatures.

4. Conclusions

1. The largest SO₂ removal efficiency was observed at a flowrate of 5 l/min by 78% while the smallest SO₂ removal efficiency was at a flowrate of 10 l/min by 31.5%

2. The higher the concentration of base in wastewater, the greater the absorption of SO₂.

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