Effect of Liquid Scrubber's Flowrate and Residence Time on Efficiency of Ammonia Gas Removal.

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***Abstract*—, Ammonia gas is an alkali gas which can causes various effects towards living organisms if these strong alkali gases are release to the environment without treated properly. The objectives of this research are to study the effect of flowrate and residence time on efficiency of ammonia gas removal. An optimum flowrate of inlet gases and the residence time for the reaction which is absorption process are essential or very important in conducting the contaminant gases absorption process because it will affect the efficiency of the alkali gas removal or the percentage of the alkali gas that have been absorbed. In this research, the analysis was conducted to study the efficiency of the ammonia gas removal by using different flowrate and residence time. The relationship or effect of the flow rate and residence time is shows in the graph. In this research the flowrate that were used is 1ml/min, 2ml/min, 3ml/min, 4ml/min and 5ml/min and the residence time are varies 2min, 4min, 6min, 8min and 10min. The ammonia is transfer into the scrubber with contain 200ml each solution at every experiment respectively. Therefore, based on this research the most efficiency ammonia gas removal that have been tested was determined and record for treatment of ammonia.**

Keyword – NH_3, Wet Scrubber, H_2SO_4, Removal

1) INTRODUCTION

Ammonia or known as NH_3 is a compound of Nitrogen (N) and Hydrogen (H) with a characteristic pungent smell and a colourless gas. NH_3 is very toxic an also flammable is a commonly produced in industrial with value of LEL 15% [1]. China is the prime worldwide producer in 2014 with 176 million tonnes which is nearly one-third of total production followed by India, Russia and also the United States [2].

NH_3 exists naturally in humans and the atmosphere and it is utilized in industry and commerce. NH_3 is a precursor for organic compound and ester synthesis and also important for several biological processes. NH_3 is made in soil from microorganism processes such as decomposition of organic matter, as well as plants, animals and animal wastes.

Within the presence of wet such as high relative humidity, the NH_3 gas is lighter than the air and can rise. The vapours that are produced by liquefied anhydrous NH_3 gas are heavier than air which increase the chance of exposure from leaks to massive NH_3 refrigeration plant.

High-concentration NH_3 is employed as a producing process gas for the production of compound semiconductors, like gallium nitride, however harmful gas emitted from production devices needs to be removed to a level below the threshold limit value (TLV), the safe level for the human body, in thought of the work surroundings. [3].The exposure of NH_3 gas will lead to irritating to the eyes, throat, and breathing passages. Everything from gentle irritation to destruction of the eye will occur depending on whether a spray or gas is involved. NH_3 penetrates the eye faster than other alkalis [4]. In terms of inhalation, NH_3 may cause nasopharyngeal and tracheal burns, bronchiolar and alveolar edema, and airway destruction resulting in respiratory distress or failure and NH_3's odor threshold is sufficiently low to acutely provide adequate warning of its presence (odor threshold = 5 ppm; OSHA PEL = 50 ppm) [5]. There are a few methods to remove NH_3 gas. Figure 1.1 show the general scrubber system which is one of the methods used to remove NH_3 from the exhaust gas.

In this research study, the method that will be used is wet scrubber to remove the NH_3. What is scrubber? A cleaning installation that neutralize harmful components in industrial air or waste gas streams, for instance to prevent fumes that have an irritating effect or cause odor nuisance. Before the gases may be disposed in the open air, the gas particles causing the irritating effect or cause odor nuisance have to be removed from the gas stream during the process. The gas flow in the scrubber is brought in intensive contact with a fluid which is aim to remove the gaseous components from the gas to the fluid. When a scrubber is used in an optimal manner, a very high removal efficiency of the harmful gas particles can be achieved [6]. In this research project, the author wants to know how the flow rate and residence time manipulating the efficiency of the scrubber.

Excess nitrogen can cause species composition changes and other deleterious effects because of eutrophication and acidification effects on semi-natural ecosystems. At the turn of the 21st century, total NH_3 emissions in the UK were estimated to be 283 kt N yr^- [7]. As the climate warms, volatilization of NH_3 emissions can result in an additional rise in NH_3 concentrations. Emissions trends have largely been downward since peak in late 80's and early 90's however have currently flattened [1]. Moreover, NH_3 will form tiny sized (< **2**.5 μm) particulate matter (known as PM2.5) along with different compounds, that penetrate the lungs and cause serious respiration and cardiovascular issues [8]**.** The regulation for NH_3 exposure for human must not exceed 15 min for 35 ppm and 25 ppm for 8 hours [9]. So, in order to prevent from air pollution and human health problem happen, the NH_3 gas need to remove from the exhaust gas before it releases to environment.

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NH_3 emissions are very common in operations such as composting, fertilizer manufacturing, and intensive swine, poultry or cattle production [10]. NH_3 has a moderate odor threshold (5–20 ppmv) and emissions are regulated both due to odor nuisances and pollution considerations [11]. There is two option to remove the NH_3 gas which is by using wet scrubber and dry scrubber. The wet scrubber were choose because dry industrial scrubbers usually aren't capable of achieving the identical level of pollutant removal as wet scrubbers, they're higher fitted to certain applications, particularly in facilities that do not have infrastructure in place to properly handle produced wastewater [12]. The wet scrubbers are one of the most effective pollution control technologies as it can get rid of pollutants by passing the contaminated gas through a liquid designed. Besides that, the wet scrubber can neutralize the NH_3 as the NH_3 is a corrosive gas.

Water and sulphuric acid are the most common solution that were used for NH_3 scrubber. To compare both solutions, the concept of exergy is the parameter to observe. The minimum exergy consumption to get rid of one mole of NH_3 with chemicals from an airstream might be two to eight times larger than the heat of evaporation of 1 mole of water counting on whether a concentrated sulphuric acid solution is used. So, the sulphuric acid is more effective to remove the NH_3 gas compare to water. However, the flowrate and residence times also will affect the efficiency of the NH_3 scrubber to remove the NH_3 gas.

Lastly, the objective of this research is to observe the effects of the flow rate and the residence times on removal NH_3 by using the wet scrubber. This research will determine the most optimum flow rate and residence to be use to remove the NH_3 from the exhaust gas.

There are a few numbers of variables can be the parameter that affect the efficiency of the wet NH_3 scrubber such as the presence of other chemicals in the exhaust stream, the temperature and flow rate of the waste stream, the initial concentration of the NH_3 in the system and the residence time. But, in this research study is focusing on the effect of flow rate of the solution and the residence time in efficiency of the removal of NH_3 gas by using wet NH_3 scrubber. These two variables will be manipulated in order to observe the most efficient condition for the wet NH_3 scrubber to operate. For the flow rate of solution, the observation will be based on the effectiveness of the wet NH_3 scrubber if the flowrate is higher or lower than the reference flowrate. For the residence time, the observation will be based on the effectiveness of the wet NH_3 scrubber if the residence time is higher or lower than the reference residence time

2) METHODOLOGY

2.1 Material and Methods.

In this experiment, sulfuric acid solution has been used as the scrubbing liquid to absorb the NH_3 gas. The concentration of the sulfuric acid is maintained at 0.05 M and the concentration of NH_3 gas is maintained at 50 ppm. Gas Chromatography (GC) is been used in this experiment to measure the amount of NH_3 gas had been scrubbed in scrubber bottle. The initial and final amount of NH_3 gas had been collected in gas bag and analysis in GC. The condition of GC had been set before the gas is entering into GC. The Chromatograph condition is the inlet temperature is at 80°C while detector outlet temperature at 220°C. The NH_3 gas is passing to the scrubber bottle with the liquid scrubbing in amount of 200 ml. This amount of liquid scrubbing is constant every experiment and the concentration also maintained at 0.05 M. the flow rate that will be use is 1ml/min, 2ml/min, 3ml/min 4ml/min and 5ml/min. Lastly, for each flow rate the residence time that will be use is 2mins, 4mins, 6mins, 8mins and 10mins.

Table 1: [the Gas chromatograph program]

Setting	Value
Inlet Temperature	80^{O}C
Outlet Temperature	200 ^{O}C
Detector temperature	220 ^{O}C
Detector	TCD
Carrier gas	Helium
Model	Thermo Finniga TraceGC, GC gas
Length	25M
Film thickness	1.5µm
Diameter	0.53mm
Column	PoraPlot Q Chromatography Column Detector

Table 2: Operating condition for NH_3 that pass through in Sulphuric acid

Operating Condition	Value
Initial Concentration	0.05 M
Solution	200ml
Temperature	25-30^{0}C
NH_3 amount in Gas	50ppm
Gas temperature	25-30^{0}C

NH_3 gas will diffuse into the liquid scrubber which is sulfuric acid solution (H_2SO_4) in the scrubber bottle where the process of absorption occurs during that time. Equations below shows the reaction occur during the absorption of NH_3 gas in the scrubber bottle by the H_2SO_4 solution .

$$2\ NH_3 + H_2SO_4 \rightarrow (NH_4)2SO_2$$

At first the NH_3 gas pass through from gas phase to gas-liquid phase, dissolved and dissociated. Ea. Gas Chromatography (GC) is been used in this experiment to measure the amount of NH_3 had been scrubbed in scrubber bottle. The initial and final amount of NH_3 had been collected in gas bag and analysis in GC. The condition of GC had been set before the gas is entering into GC. The Chromatograph condition is the inlet temperature is at 80 ^{O}C and the detector outlet temperature at 220 ^{O}C.

There is a several number of other measurable guideline that to determine the NH_3 removal capability on the wet scrubber liquid absorber. The NH_3 efficiency removal of a scrubber is determined by the amount of final product pass through the wet scrubber by compared with the initial amount of the gas before goes to wet scrubber. In this experiment the NH_3 is first is tested by collected into the gas bag and by using Gas chromatography to detect the amount of NH_3. Thus the initial amount of gas NH_3 before entering wet scrubber had been collected. Calculation via chemical equilibria calculation were also had been performed based on different type of the liquid scrubber used. Figure.1 shows that tested in GC before Gas NH_3 gas had been scrubbed

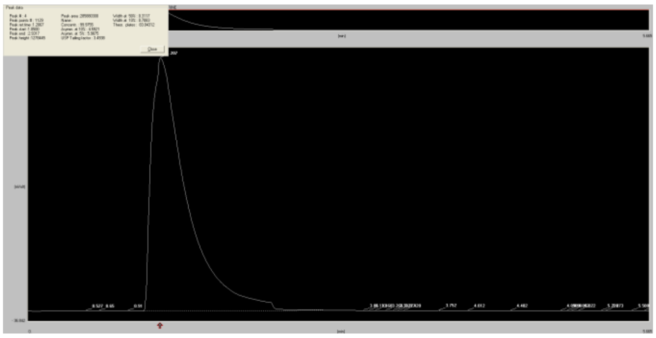

Figure 1: the NH_3 detection in graph at GC

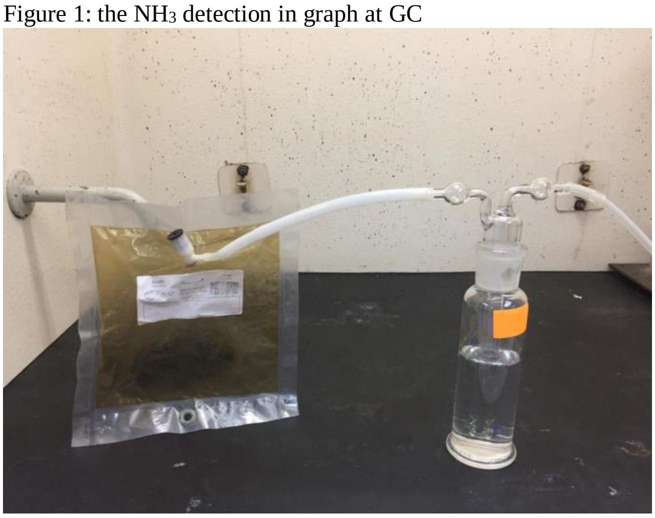

Figure 2: Scrubber bottle in fume chamber.

Figure 3: The Gas NH_3 at outside of fume chamber into scrubber bottle via tube.

3. RESULTS AND DISCUSSION

3.1 Absorption of Ammonia gas (NH_3)

Table 3: Effect of 1ml/min flowrate of NH_3 gas

Percentage of removal NH_3 (%)	Residence time (min)
91.15	2
89.56	4
81.78	6
78.67	8
75.57	10

Table 3.1.1 gives the effect of flowrate at 1ml/min of NH_3 gas on the NH_3 recovery by percentage. Based on this table, by increase the residence time, there was seem decrease in recovery of NH_3. The Higher recovery of NH_3 is 91.15% follow by 89.56% at 4 min, and 81.78% at 6 min. This may due to the amount of ion of H^+ available in the solution is decrease, thus the absorption of NH_3 is decrease.

Table 4: Effect of 2ml/min flowrate of NH_3 gas.

Percentage of removal NH_3 (%)	Residence time (min)
90.54	2
84.51	4
76.21	6
59.1	8
55.65	10

Table 4 showed the result of NH_3 recovery for 2ml/min flowrate. It is can be found that at 2ml/min flowrate the recovery of NH_3 lower then 1ml/min flowrate. At the 2ml/min flowrate, the highest percentage of removal NH_3 gas is at 2 min residence time which is 90.54% and the lowest percentage of removal NH_3 at 8 min residence time which is 55.65%.

Table 5: Effect of 3ml/min flowrate of NH_3 gas.

Percentage of removal NH_3 (%)	Residence time (min)
89.98	2
80.14	4
70.26	6
54.17	8
41.81	10

Table 5 shows the percentage of NH_3 gas recover by using 3ml/min flowrate and the several of residence time or reaction time between the solution and the NH_3 gas. The higher recovery of the NH_3 gas is 89.98% at the 2 minute of residence time and the lowest recovery of the NH_3 gas is 41.81% at the 10 minute of residence time.

Table 6: Effect of 4ml/min flowrate of NH_3 gas.

Percentage of removal NH_3 (%)	Residence time (min)
85.79	2
70.28	4
53.57	6
42.24	8
31.65	10

For table 6, the highest percentage of removal NH_3 is 85.79% at 2 minutes residence time and the lowest percentage of removal at 10 minutes which is 31.65%.

Table 7: Effect of 5ml/min flowrate of NH_3 gas.

Percentage of removal NH_3 (%)	Residence time (min)
77.67	2
60.82	4
48.49	6

39.69	8
28.39	10

The range of NH_3 gas recover by using this flowrate below 80% of NH_3 gas recovery. This might be happen because the flowrate is too high as the contact time with the liquid scrubber is too low. The higher recovery of the NH_3 gas is 77.67% at the 2 minutes of reaction time and the lowest recovery of the NH_3 gas is 28.39% at the 10 minutes of reaction time for 5ml/min flow.

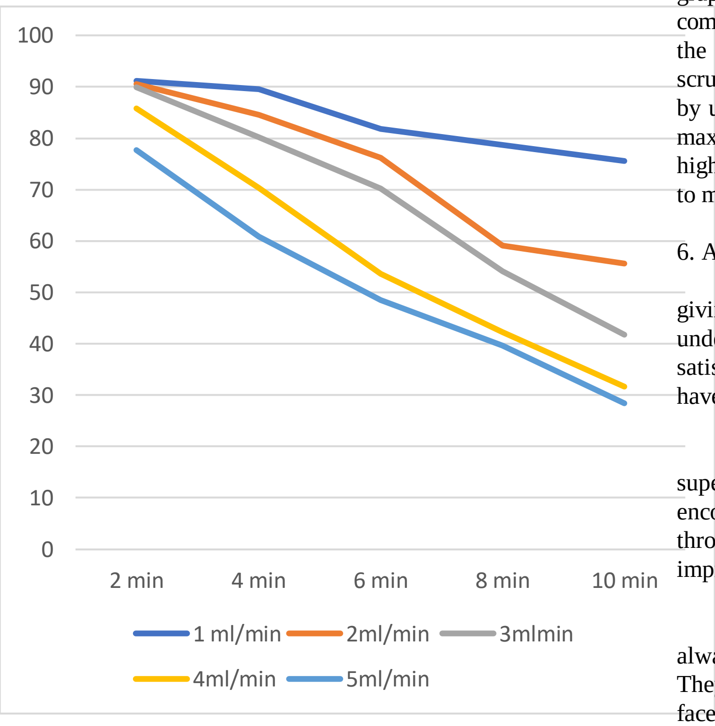

Figure 4: The percentage removal of NH_3 vs Residence time (min)

Maximum percentage of absorption NH_3 was obtained at 1ml/min flowrate and 2 minutes of residence time which is 91.15%.

4. Conclusion

From the specific observation that had undertaken at laboratory, all NH_3 gas flowrate and residence time that are different for every experiment can absorb NH_3 gas through the scrubber bottle but in different efficiency that can be decided from areas under the graph for initial NH_3 gas and the areas under the graph for final NH_3 gas. As conclusion, the most optimal efficiency removal of NH_3 gas is by using 1ml/min at 2 minutes. Moreover, at 2 minutes until 10 minutes of residence time, this flowrate still produce above 75% of percentage recovery of NH_3 gas which is at the higher recovery of NH_3 gas compare to others flowrate. Nevertheless, others NH_3 gas flowrate and residence time had also given NH_3 gas recovery but in low efficiency. Increasing the NH_3 gas flowrate will influence NH_3 gas absorption efficiency which would reduce NH_3 gas absorption and the longer the residence time also reduce the efficiency as the ion availability in scrubber liquid will drop because reaction time that is longer. Finally, there is one way to improve NH_3 gas removal efficiency because in this study, highest efficiency NH_3 gas removal is around 90%

5. RECOMMENDATION

First of all, the tedlar bag that been used to collect the NH_3 gas need to be ensure there is no other gas inside the tedlar bag. In order to ensure there is no other gas in the tedlar bag, the tedlar bag need to be purge first before the tedlar bag collect the NH_3 gas. Condition in gas chromatography must be set at optimum condition such as the detector outlet temperature, the carrier gas temperature, detector inlet temperature and the ramp for the graph. For the research further investigation must be compromised parameter which involves different concentration of the liquid scrubber and also different temperature of the liquid scrubber for better percentage of the removal NH_3. If test is done by using method continue not method batch like scrubber bottle, maximum percentage NH_3 removal can be reached could be much higher from experiment carried out. Lastly, the atmosphere need to make sure was protected from effects of NH_3.

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