WIND TUNNEL AND OPEN CHANNEL FOR NH_3 REMOVAL FROM SKIM LATEX: PART I : EXPERIMENTATION AND NH_3 REMOVAL DETERMINATION

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Abstract: Skim latex is a by-product from concentrated rubber latex production via centrifugation. The skim latex which contains a high concentration of NH_3 requires high amount of acid consumption for rubber coagulation in the processing of skim rubber. The conventional deammoniation system currently used in industry to remove NH_3 from the skim latex is an open channel with dimensions 80 m long by 0.9 m wide by 0.1 m high. The channel is made from a stainless steel U sheet allowing the skim latex to flow in a thin layer across the channel. This system can handle low capacity and performs with low efficiency, especially at low temperatures during night time and rainy season. In this research, an industrial scale and a pilot scale wind tunnel were studied to improve NH_3 removal capacity. A wind tunnel for NH_3 removal is a long, closed channel connected to an air blower to generate wind blowing across the skim latex surface layer. The industrial wind tunnel was constructed by covering the open channel with another U sheet channel. The pilot wind tunnel was constructed with using a 20 m long by 0.2 m wide by 0.1 m high U sheet. A comparison between the open channel and the wind tunnel was made. The effect of wind velocity, wind direction, skim latex flow rate, wind temperature and atmospheric temperature were investigated. Results from the experiment showed that the NH_3 removal capacity for the wind tunnel was 2 times higher than the open channel. In addition, atmospheric temperatures had a direct effect on NH_3 removal for the open channel case, but not for the wind tunnel case. Moreover, countercurrent flow of the wind across the skim latex layer showed higher removal rate than for concurrent flow. Furthermore, a higher wind speed and increasing the wind temperature from 30 to 50°C significantly improved the NH_3 removal capacity. Lastly, NH_3 concentration and skim latex flow rate showed little effect on NH_3 removal.

Key Words: ***skim latex /NH_3 removal /wind tunnel /open channel***

1. INTRODUCTION

Skim latex is a by-product from concentrated rubber latex production via centrifugation. NH_3 added to the natural rubber feed is present in the skim latex at higher concentrations than the main concentrated rubber product. The skim latex contains 0.2-0.5 wt% ammonia (NH_3), while the dry rubber contains 4-5 wt%. The presence of NH_3 in skim latex results from a high usage of acid during the skim rubber sheet coagulation process leaving the serum portion with sulfate ion contamination. This sulfate ion releases hydrogen sulfide gas while undergoing microbial degradation causing malodor which is detrimental to the environment. Therefore, removal of ammonia from skim latex is an essentail step in preventing atmospheric contamination. The present conventional method uses a long, open channel which requires large area and high construction cost. The open channel removes the ammonia from the skim latex to atmosphere through atmospheric exposure without any further treatment. However, the released ammonia will effect human health and cause environmental problems. To overcome these problems, this research work proposes a new approach for removing ammonia from the skim latex using a wind tunnel. The design and performance of the wind tunnel compared to the conventional, open channel system are presented in this work.

The objective of this research is to use the wind tunnel to increase the efficiency of ammonia removal from skim latex in the rubber latex industry. Experiments were conducted to study the effectiveness of this process on ammonia removal.

2. MATERIALS AND METHODS

The experiments for ammonia removal from skim latex were carried out in an open channel and in an industrial sized wind tunnel at a concentrated rubber latex factory located in the Songkhla Province, Thailand. A pilot scale wind tunnel was constructed in a laboratory to study the parameters that are difficult to control in the industrial process. The experimental set up is explained below.

2.1 Open channel

The experiments using the open channel were conducted in a long, stainless steel U sheet as in the industry. The dimensions of the U sheet were 80 m long by 0.9 m high by 0.1 m wide. The skim latex was continuously fed and spread over the channel to form a liquid layer 3 cm thickness. From this process, the skim latex is discharged at the end of channel. Schematic diagrams for side view and front view of the open channel are shown in Figure 1.

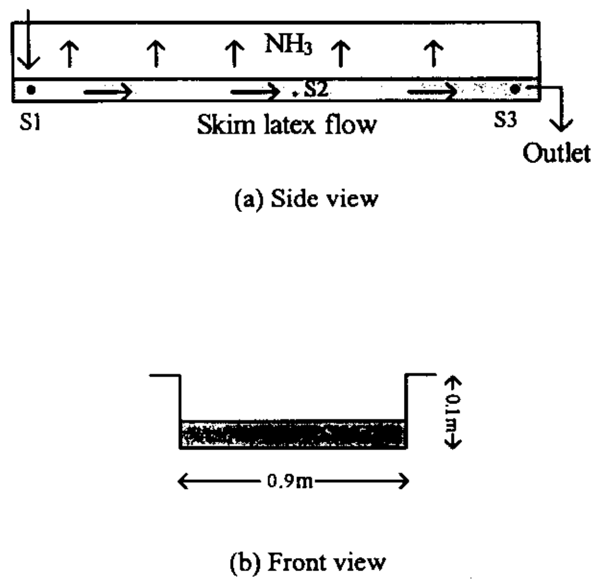

Figure 1. Schematic diagrams of the open channel for ammonia removal from skim latex for side view (a) and front view (b).

In the open channel, ammonia dissolved in the skim latex is transferred from the liquid phase to the interface and gas phase and emitted to atmosphere. Movement of the flowing liquid, natural wind and heating from the sun are the main driving force for ammonia transfer. The ammonia from this process cannot be gathered and treated before entering to environment. During rainy season, the open channel cannot be used due to the dilution of skim latex by rain water add up. Then more sulfuric acid required for the skim rubber processing.

2.2 Industrial wind tunnel

The industrial wind tunnel was constructed by covering the existing U sheet with another inverted U sheet. Joints between the 2 sheets were fixed by nuts and sealed by silicone to prevent air leakage from inside the tunnel. The dimensions of the wind tunnel were 80 m long by 0.9 m wide by 0.2 high. The thickness of skim latex layer was 3 cm. The schematic diagrams of the countercurrent flow wind tunnel are shown in Figure 2. Air flow in the wind tunnel was created by installing an air blower with a maximum wind velocity of 7 m/s. This wind velocity was obtained according to capacity of the blower, space area over the liquid surface and leakage of the system. To study the effect of wind direction, the position of the air blower was set at the liquid feed and at the discharge point for concurrent and countercurrent liquid-gas flow, respectively. An anemometer was used to measure the wind velocity at 3 sampling holes (S1, S2, and S3) along the tunnel. The ammonia contaminated air discharged from the air outlet point can be treated before entering the environment.

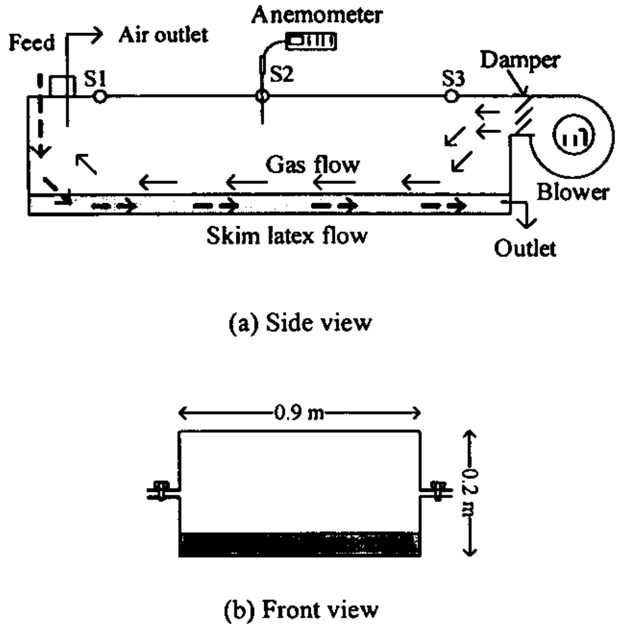

Figure 2. Schemetic diagrams of counter current flow wind tunnel for side view (a) and front view (b).

2.3 Pilot scale wind tunnel

The pilot scale wind tunnel was constructed using a U sheet with dimensions of 20 m long by 0.2 m wide by 0.1 m high. The thickness of skim latex layer was 3-5 cm. The diagram of the pilot scale wind tunnel is the same as the industrial wind tunnel as shown in Figure 2. The purpose of this experiments was to study the effect of hot wind temperature and the feed flow rate on the ammonia removal. These 2 parameters were difficult to test using the industrial wind tunnel because of industrial loading capacity limit. In this experiment, air heaters installed at the discharge point of the air blower were used to heat up the wind to 50-70°C. Thermometers were disposed at 3 sampling holes along the tunnel to monitor the temperature profile. The skim latex feed flow rate was controlled by adjusting the manual feed valve.

2.4 Experimental procedure

Operating conditions of the open channel were the same for the industrial wind tunnel except for the wind velocity. Skim latex feed flow rate for the open channel and industrial wind tunnel was fixed at 7.2 m^3/min and the atmospheric temperature was varied according to daytime time range of 28-37°C. Wind velocities of 3-7 m/s for the industrial wind tunnel were controlled by adjusting the damper at the outlet of the air blower. Directions of the air flow over the liquid surface in the industrial wind tunnel were set according to concurrent and countercurrent flow. In the pilot scale wind tunnel, the operating conditions were a liquid flow rate of 0.2-0.8 m^3/h, constant wind velocity of 2 m/s and hot air temperature of 30-70°C.

2.5 Analytical procedure

Sampling bottles were used to collect 10 ml of skim latex sample from S1, S2 and S3 in the experimental system. The bottles were tightly closed to prevent ammonia from evaporating from the skim latex samples. Sampling should be started after the liquid and gas flow have reached steady state. According to fluctuation of ammonia concentration in the skim latex, sampling time of S2 and S3 should be in sequence following S1 by the time calculated from Eq.(1). Concentrations of ammonia in the samples were measured using the titration method [1]. From the ammonia concentrations obtained, the ammonia removal capacity of the system was defined and calculated from Eq.(2).

$$R_t = \frac{V}{Q} \quad (1)$$

$$NH_3 \text{ removal } (\%) = \% C_{NH_3,I} - \% C_{NH_3,O} \quad (2)$$

where R_t is retention time (hrs.), V is liquid volume in channel (m^3), Q is feed flow rate (m^3/h) $C_{NH_3,I}$ and $C_{NH_3,O}$ is ammonia concentration (wt %) in the skim latex at inlet and outlet of the system, respectively.

3. RESULT AND DISCUSSION

3.1 Ammonia removal in open channel

Along the length of channel, the ammonia concentration in the skim latex gradually decreased. As given in Figure 3, ammonia removal for the open channel flow was 0.03% at 37°C. Decreasing the atmospheric temperature resulted in lower ammonia removal capacity. At a low temperature of 28°C, removal of ammonia for the open channel was found to be 0-0.004% indicating that the open channel cannot be used during night time and rainy season. This is because the atmospheric temperature directly affects the mass transfer of ammonia from liquid to the gas phase. The influence of ammonia concentration in skim latex on the ammonia removal was also investigated as shown in Figure 3. The results show that decreasing ammonia concentration gradually decreases the ammonia removal capacity of the system. This indicates that the removal of ammonia from skim latex is reduced along the open channel length and requires a series of open channels to obtain the final ammonia concentration target.

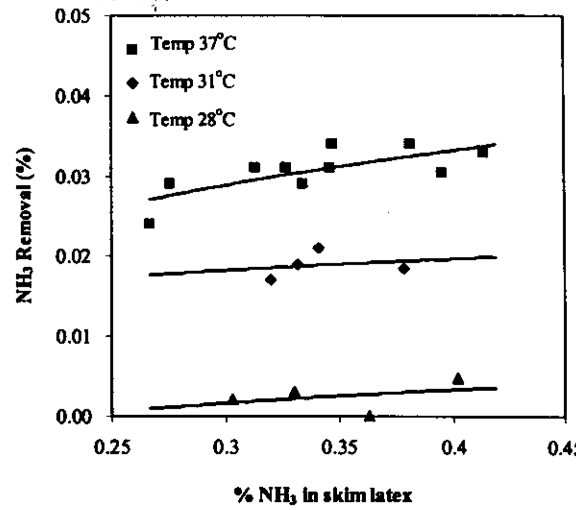

Figure 3. Ammonia removal (%) from skim latex in open channel at varying atmospheric temperature and liquid flow rate of 7.2 m^3/min.

3.2 Ammonia removal in industrial wind tunnel

The influence of wind direction and wind velocity on ammonia removal from skim latex in the wind tunnel was evaluated and presented in Figure 4. The wind direction for concurrent and countercurrent system was carried out by arranging the position of blower. From this study, higher ammonia removal was observed in the case of countercurrent flow, reaching 0.043% ammonia removal, while 0.02% was obtained for concurrent flow. Therefore, the countercurrent flow was chosen for the next set of experiments. There are two important aspects for the countercurrent flow that must be mentioned. First, there is an increase in turbulence at the interface, and second, the countercurrent flow can remove the gas film in the gas boundary layer which effectively increases the mass transfer rate of ammonia from the liquid phase.

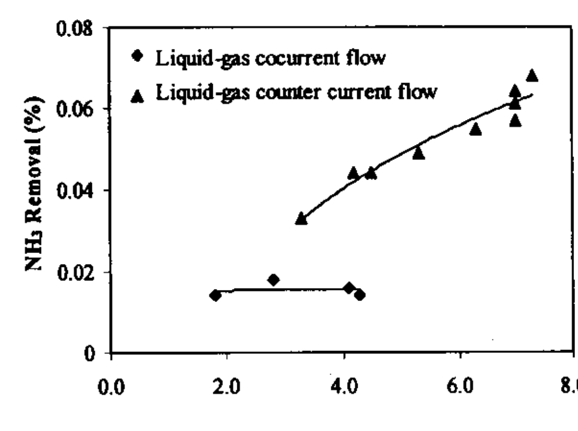

Figure 4. Ammonia removal from skim latex for the concurrent flow and countercurrent flow between gas and liquid in the wind tunnel at liquid flow rate of 7.2 m^3/min and at an air temperature of 37°C.

Moreover, increasing the wind velocity from 3.0 to 7.0 m/s led to an increase in ammonia removal efficiency for all ammonia concentration tested. Using the wind tunnel at the maximum wind velocity of 7 m/s, the ammonia removal was 2 times higher than the open channel case. Thus, wind velocity is a key parameter for wind tunnel operation which can be adjusted by increasing or reducing the tunnel height, increasing the blower capacity, and completely sealing off the tunnel. A wind velocity higher than 7 m/s can be applied to the process to get a higher ammonia removal capacity. However, if the wind velocity is too high, overflowing of the skim latex from tunnel could take place. The influence of the atmospheric temperature on the ammonia removal in the wind tunnel was also evaluated as presented in Table 1. Decreasing the temperature in the system did not have significant effect on ammonia removal from the skim latex compared to the open channel system. Therefore, the wind tunnel has the possibility for usage during night time and rainy season. Another advantage of this system is that raining water cannot accumulate and dilute the skim latex flowing across the channel.

Table 1. *Ammonia removal from skim latex in wind tunnel at wind velocity of 7 m/s and initial ammonia concentration in skim latex of 0.45%.*

Atmospheric Temperature (°C)	NH_3 removal (%)
28	0.057
31	0.061
37	0.068

3.3 Pilot scale wind tunnel

The effects of skim latex flow rate and wind temperature were determined from the pilot scale experiments. The results of these experiments are presented in Figure 5 and 6.

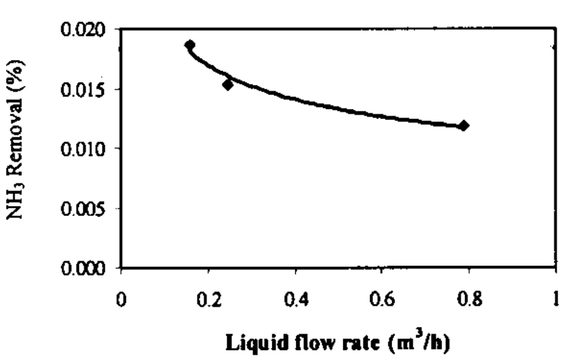

Figure 5. Ammonia removal from skim latex in a pilot scale wind tunnel at various liquid flow rate and at an air temperature of 30°C.

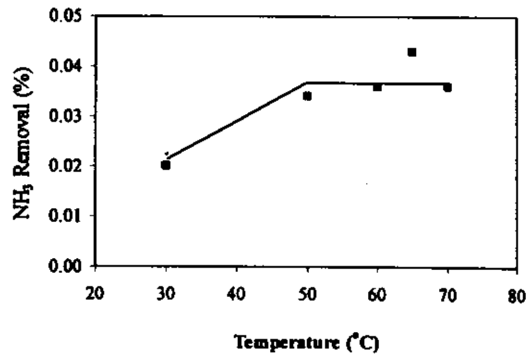

Figure 6. Ammonia removal from skim latex in a pilot scale wind tunnel using hot air at various temperatures and at a liquid flow rate 0.27 m^3/h.

Furthermore, the skim latex flow rate directly relates to retention time in the tunnel and liquid layer thickness. Results of the skim latex flow rate on the removal efficiency shown in Figure 5 indicate that the ammonia removal was not much improved with decreasing skim latex flow rate. This means that for the range of skim latex flow rate and layer thickness studied, ammonia evaporation was not much affected. In order to study the effect of wind temperature in the tunnel on ammonia removal from skim latex, the wind from the blower discharge was heated by heaters before sending it into the tunnel. Figure 6 indicates that ammonia removal significantly improved with increasing temperature from 30 to 50°C. After heating the wind up to 50-70°C the ammonia removal were not improved. The reason is the mass transfer is improved when the wind temperature is increased. However, at higher temperatures of 50-70°C, a rubber film was formed [3] and ammonia evaporation was obstructed.

4. CONCLUSION

Base on the results of this research on ammonia removal from skim latex using an open channel and a wind tunnel, the following specific conclusions can be drawn:

- An open channel cannot be used for night time and rainy season since a high atmospheric temperature directly enhanced the mass transfer of ammonia from liquid phase to the gas phase.
- The wind tunnel is two times more effective in ammonia removal from skim latex than the open channel, and it can also be used for night time and rainy season.
- Wind speed plays a key role in the ammonia removal through increasing gas turbulence and removing the surface film which effectively increases the mass transfer rate.
- High ammonia removal from skim latex in the wind tunnel can be obtained by countercurrent flow, increasing the wind velocity to higher than 7 m/s, and heating the wind temperature to 50°C.
- The wind tunnel presents a possible option for ammonia removal from skim latex in concentrated rubber latex factories with little modification to the old system.

5. REFERENCES

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