

## RECOVERY OF CO<sub>2</sub> FROM FLUE GAS OF RUBBER LATEX DRYER FOR PREPARING SPIRULINA CULTURE MEDIUM

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### ABSTRACT

The aim of this study was to recover CO<sub>2</sub> greenhouse gas from flue gas of rubber latex dryer by absorption in the bubble tower with water and a solution containing NaCl content, equivalent to Zarrouk medium. Adsorbed CO<sub>2</sub> could be converted to HCO<sub>3</sub><sup>-</sup> at appropriate pH conditions, used as a medium for cultivation of *Spirulina platensis* (*S. platensis*) algae to collect biomass and, furthermore, released oxygen which contributes to reducing climate change. The results of study showed that the height of the air bubble layer increases from 0.2 to 0.4 m, the pH of the solution decreased significantly during the first 30 minutes, then more slowly. The decrease pH of solution at the height of the air bubble layer of 0.3 to 0.4 m, is smaller than at 0.2 to 0.3 m. Increasing the air flow rate from 0.5 L/min to 1.5 L/min would reduce the absorption efficiency within the first 30 minutes (the pH of solution reduced) and the change in air flow has little effect on the pH change, then. If the concentration of NaCl in solvent was from 2.5 g/L to 5.0 g/L (suitable to the Zarrouk medium), it would increase the CO<sub>2</sub> absorption from the flue gas. These outcomes were used to calculate and design CO<sub>2</sub> absorption towers from the flue gas for the cultivation of *S. platensis* algae.

**Keywords:** CO<sub>2</sub> greenhouse gas; climate change; CO<sub>2</sub> absorption; latex dryer; *Spirulina platensis*.

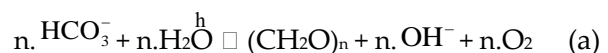
### 1. INTRODUCTION

Carbon dioxide (CO<sub>2</sub>) is the most significant long-lived greenhouse gas causing climate change, and will become a valuable raw material to produce high value products such as *Spirulina platensis* [1, 2, 3]. The sources of CO<sub>2</sub> emissions in industry are mainly from thermal power plants, boilers, dryer (the latex dryer, the agricultural products dryer,...), and some others as biogas, alcohol fermentation tanks,...

The productivity of Long Ha factory, Phu Rieng Rubber One Member Co. LTD, is about 12,000 tons/year with five products such as SVR CV50, SVR CV 60, SVR L, SVR 3L and SVR 5. The factory had to consume about 320,450 L of DO oil per year (equivalent to about 25 | 28 kg of DO oil per ton of rubber) for the drying of rubber latex. The amount of CO<sub>2</sub> emitted when burning DO oil is 3.12 | 3.15 tons of CO<sub>2</sub> per ton of DO (2.6 | 2.8 kg/L) [4] with the CO<sub>2</sub> content of 6.0% | 10.0% by volume.

For emission sources with high CO<sub>2</sub> content (40% | 50%) as biogas, alcohol fermentation tank, it was separated and collected by compressing, combined with cooling and throttling in liquid or solid forms. For the sources with low CO<sub>2</sub> content, 6% | 14%, as the dryers or the boilers, using the absorption method with a suitable solvent to collect CO<sub>2</sub> [5].

The *Spirulina platensis* algae only absorbs CO<sub>2</sub> in the form of bicarbonate ion (HCO<sub>3</sub><sup>-</sup>) [4, 6] when there are enough nutrients as carbon, nitrogen, macronutrients, micronutrients, and light, as the reaction below:



1 ton of algae produced can consume about 450 kg of CO<sub>2</sub> and generate 1,200 kg of oxygen [3]. The reaction (a) showed that, CO<sub>2</sub> in the form of HCO<sub>3</sub><sup>-</sup> was reacted but the ion OH<sup>-</sup> was also created, which causes the increasing of pH values, exceeding the appropriate pH range for the

cultivation of *S. platensis* algae (8.5 | 10.5) [4]. One of the methods to adjust the pH of the medium according to the above reaction (a) is to absorb CO<sub>2</sub> into the medium [1, 2]. However, the methods of recovering CO<sub>2</sub> from emissions in general, from flue gas of the dryers in particular, have not been studied, especially the studies in VietNam. Therefore, in order to be able to use a large amount of greenhouse gases from the flue gas of the dryers as the rubber latex dryer, it is necessary to study the appropriate technology to recover CO<sub>2</sub> by absorption and use it for the cultivation of *S. platensis* algae.

## 2. THE MECHANISM OF THE CO<sub>2</sub> ABSORPTION PROCESS USED SUBSEQUENTLY IN ALGAE CULTURE MEDIUM

Absorption of CO<sub>2</sub> into water or aqueous solutions can be considered as a physical absorption process and calculated based on Henry's law. However, this method is not completely accurate because when CO<sub>2</sub> dissolved in water, H<sub>2</sub>CO<sub>3</sub> then was formed and dissociated, so the calculation should be performed based on the model of chemical absorption.

When CO<sub>2</sub> gas is added to water [2], reactions will occur:



Thermodynamic parameters were used to calculate the equilibrium constant of reactions (b) and (c) in Table 1.

**Table 1.** Thermodynamic parameters

Chem. Formul.	$\Delta H_{298}^0$ , kJ/mol	$\Delta S_{298}^0$ , J/mol	$\Delta G_{298}^0$ , kJ/mol
CO <sub>2</sub>	-393.51	213.67	-394.38
H <sub>2</sub> O	-285.93	70.08	-237.25
H <sub>2</sub> CO <sub>3</sub>	-699	190	-623.30
H <sup>+</sup>	0	0	0

HCO <sub>3</sub> <sup>-</sup>	-619.3	93.0	-586.6
CO <sub>3</sub> <sup>2-</sup>	-676.64	-56.0	-527.6

The dissociation constant (*K*) of the two reactions was determined by the equation in below:

$$\ln K = -\frac{\Delta G^0}{RT} \quad (1)$$

Gibbs free energy was calculated base on the equation below [5, 6]:

$$\Delta G^0 = \Delta H^0 - T\Delta S^0 \quad (2)$$

The quantities of the reaction  $\Delta H^0$ ,  $\Delta S^0$  were determined as the equation (3):

$$\begin{aligned} \Delta H_{\text{Re ac.}}^0 &= \sum H_P - \sum H_M \\ \Delta S_{\text{Re ac.}}^0 &= \sum S_P - \sum S_M \end{aligned} \quad (3)$$

At 25 °C, based on equation (b) and (c), the value of the dissociation constants is calculated where

$$K_1 = \frac{C_{\text{H}^+} C_{\text{HCO}_3^-}}{C_{\text{CO}_2}} = 4,45 \cdot 10^{-7} \quad (4)$$

$$K_2 = \frac{C_{\text{H}^+} C_{\text{CO}_3^{2-}}}{C_{\text{HCO}_3^-}} = 5,6 \cdot 10^{-11} \quad (5)$$

And change and get the quantities:

$$C_{\text{H}^+} = K_1 \frac{C_{\text{CO}_2}}{C_{\text{HCO}_3^-}} \quad (6)$$

$$C_{\text{HCO}_3^-} = \frac{C_{\text{H}^+} C_{\text{CO}_3^{2-}}}{K_2} \quad (7)$$

Therefore:

$$\text{pH} = \text{p}K_1 - \lg \frac{C_{\text{CO}_2}}{C_{\text{HCO}_3^-}} = 6,4 - \lg \frac{C_{\text{CO}_2}}{C_{\text{HCO}_3^-}} \quad (8)$$

According to equations (6), (7) and (8) the pH, the concentration of HCO<sub>3</sub><sup>-</sup>, CO<sub>3</sub><sup>2-</sup>

ion depends on the ratio of  $\frac{C_{CO_2}}{C_{HCO_3^{--}}}$ . The result of the calculating the pH value according to the ratio of  $\frac{C_{CO_2}}{C_{HCO_3^{--}}}$  are presented in Table 2.

Therefore, it is easy for *S. Platensis* algae to absorb CO<sub>2</sub> gas in HCO<sub>3</sub><sup>-</sup> form. The pH of the medium should be maintained at no less than 8.5 but not beyond the appropriate pH range for the cultivation of *S. platensis* algae, 8.5 | 10.5.

**Table 2.** The pH value of the medium according to the ratio of  $\frac{C_{CO_2}}{C_{HCO_3^{--}}}$

$C_{CO_2} / C_{HCO_3^-}$	1/100	1/10	1	10	100
pH, ở 25 °C	4,5	5,5	6,4	7,5	8,35

### 3. APPARATUS, MATERIALS AND METHODS

#### 3.1 Materials

The experiment was conducted at the rubber drying workshop of Long Ha rubber latex processing factory, Phu Rieng Rubber Co.Ltd.

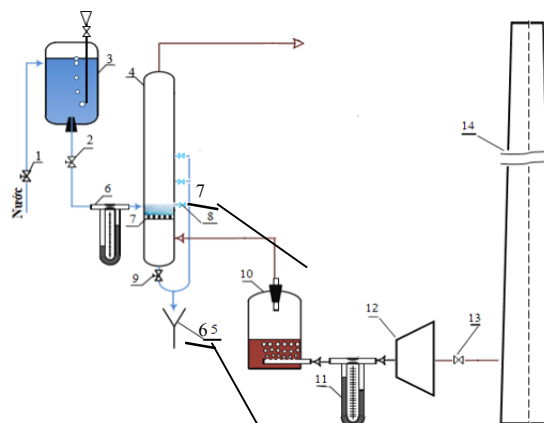
The flue gas from the rubber latex dryer had a CO<sub>2</sub> content from 6% to 8% (V), temperature of 100 | 110 °C and was cooled to 40 | 50 °C. The NaCl concentration of the solvent was used in the absorption tower, as shown in Table 3.

**Table 3.** Experimental plan

C <sub>NaCl</sub> , g/L	0	2.5	5.0
H, m	0.2	0.3	0.4
Q, L/min	0.5	1.0	1.5

#### 3.2 Apparatus

Diagram of experimental apparatus is shown as Figure 1



**Figure 1.** Diagram of laboratory equipment:  
 1 - Valve to adjust the medium into the Mariot flask; 2 - Adjusting valve liquid into the absorption tower; 3 - Mariot flask; 4 - Absorption tower; 5 - Sampling for pH measurement; 6 – Liquid flow meter; 7 - Aeration nozzles; 8 - Liquid level adjustment valve; 9 - Exhaust valve; 10 - Dust separator; 11 - Gas flow meter; 12 - Air compressors; 13 - Gas regulating valve; 14 - Chimneys.

An air compressor (9) has 5W/220V/50Hz capacity; the absorption tower with organic glass of size Φ×δ×H (30×3×400 mm); spherical porous stone nozzle (7) has a diameter of 20 mm.

Glassware: 250 ml flask, 100ml volumetric flask, 10ml pipette, 2ml pipette and quantitative balance.

Some measuring tools: wine thermometers, scale of 0 | 100 °C (France); pH measurement by pH meter of Hana, Model HI98172.

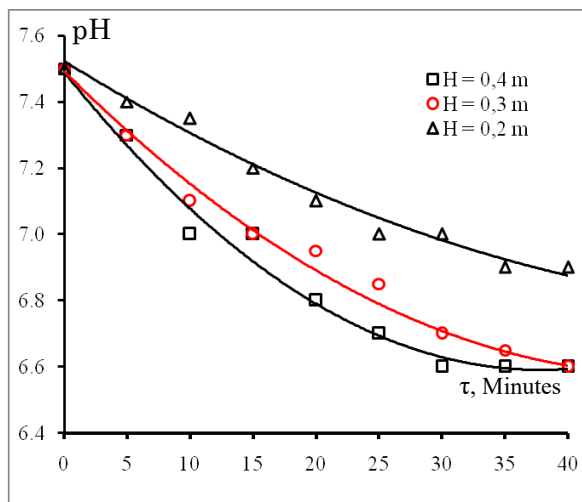
#### 3.3 Methods

The exhaust gas after being separated from the air pipe of rubber latex dryer (1) is cooled in the duct. The air is aerated into the absorption tower (7) by the air compressor (2) through the nozzle (4). The solution from container (5) passes through the flowmeter (3) after through tower (7) and samples are taken to measure pH according to the

corresponding time presented in Table 4, shown in Figure 2.

**Table 4.** The pH value of solvent

$\tau$ , Min	pH		
	H=0.4	H=0.3	H=0.2
0	7.5	7.5	7.5
5	7.3	7.3	7.4
10	7.0	7.1	7.4
15	7.0	7.0	7.2
20	6.8	7.0	7.1
25	6.7	6.9	7.0
30	6.6	6.7	7.0
35	6.6	6.7	6.9
40	6.6	6.6	6.9



**Figure 2.** The change of pH value in the heights of CO<sub>2</sub> absorption tower

## 4 RESULTS AND DISCUSSION

### 4.1 Carbon dioxide absorption process by water

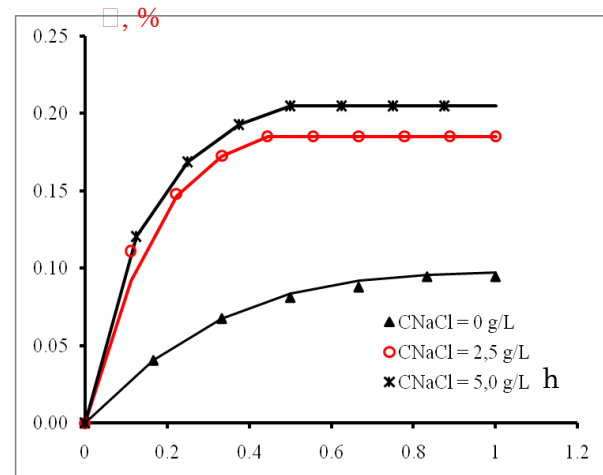
The result of CO<sub>2</sub> absorption of the exhaust gas from the rubber latex dryer by solvent is water. When changing the height of the tower at the flow rate of gas and water is constant, the pH value of the output

solution was measured and shown in Table 4 and Figure 2.

Table 4 and Figure 2 showed that the gas flow is constant, if increasing heights of tower, corresponding to the volume and retention time of equipment increases, the absorption efficiency and pH value increased gradually. In addition, Figure 2 showed that the absorption process reached equilibrium, because the CO<sub>2</sub> content in the flue gas is constant, so all three curves tended to gradually change over time.

### 4.2 Carbon dioxide absorption process by sodium chloride solution

Figure 3 shows the experimental result of the change pH of solution when absorbing CO<sub>2</sub> by solution which has the difference of NaCl concentration.



**Figure 3.** The effectiveness of absorption according to time and concentration of NaCl in solvent.

Figure 3 shows that the NaCl concentration in the solvent increases, with the increasing of alkaline, the amount of H<sub>2</sub>CO<sub>3</sub> reacted as the reaction (b) increases, so the amount of CO<sub>2</sub> absorbed increases. Besides, it is also necessary to supplement 2.5g/l NaCl to supply micro-nutrients for *S. platensis* algae, as the medium Zarrouk [4].

### 4.3 Carbon dioxide absorption process by the difference of air flow

The process of CO<sub>2</sub> absorption from the flue gas of the rubber latex dryer with the air

flow varies according to data shown in Table 2, and at height tower of 0.4 m as in Figure 4.

Figure 4 shows that, when the air flow increases, reducing the retention time of gas decreases, so the pH value decreases faster. Similarly, the CO<sub>2</sub> absorption reduced if the tower height increased. The experimental data also shows that when changing the amount of air flow does not change the absorption time that is constant.

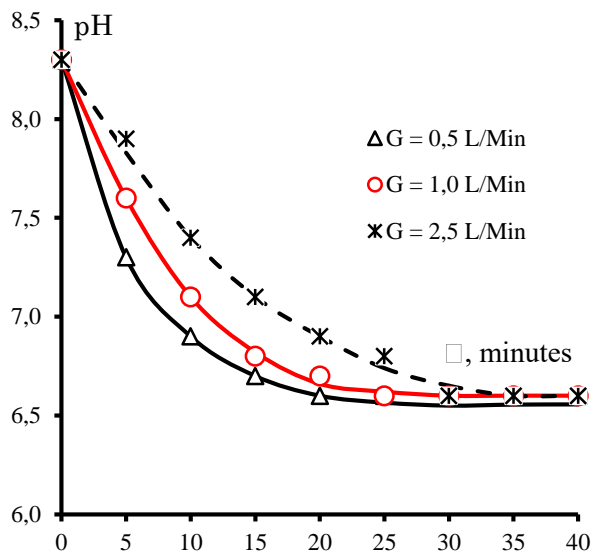


Figure 4. The change of pH value according to air flow rate at the tower height of 0.4 m

## 5 CONCLUSION

The modeling and experimental results of the process of CO<sub>2</sub> absorption from the flue gas of the rubber latex dryer in order to

reduce the pH value of culture medium that occurs according to the reaction (a), some conclusions can be given as follows:

1) To calculate CO<sub>2</sub> absorption into the water, as well as the medium containing NaCl (as the Zarrouk medium), can use the physical or chemical absorption model depending on the CO<sub>2</sub> concentration in the flue gas can be used, however, the chemical absorption model is more popular and accurate;

2) To maintain the concentration of ion HCO<sub>3</sub><sup>-</sup> which is suitable for *S. platensis*, the pH value need to be above 8.5;

3) Using medium containing 2.5 | 5.0 g/L NaCl, corresponding to the Zarrouk medium, to get the increasing of the CO<sub>2</sub> absorption capacity, increased the recovery of CO<sub>2</sub> from the flue gas of the dryer;

4) Increasing the aeration rate of 0,5 | 1.5 L/min to increase the absorption efficiency and decrease the acidity of the solution during the first time. Then, the air flow rate increased, but the absorption efficiency is constant.

## ACKNOWLEDGMENTS

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