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CO_2 absorption using biogas slurry: CO_2 absorption enhancement induced by biomass ash

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Abstract

Biogas slurry can be adopted as a renewable CO_2 absorbent to combine CO_2 absorption with CO_2 biological fixation. However its CO_2 absorption performance should be enhanced. In the study, biomass ash was adopted as the additive to increase free ammonia concentration in the biogas slurry. And the effect of biomass ash dosage on CO_2 absorption performance of biogas slurry was investigated in the typical bubbling absorption apparatus. Additionally, phytotoxicity of CO_2-rich biogas slurry before or after adding biomass ash was experimented as well in terms of the germination index of Chinese cabbage seeds. Results showed that CO_2 absorption performance of biogas slurry can be enhanced by adding biomass ash due to the leaching of some alkaline substances from biomass ash, and net CO_2 absorption capacity of biogas slurry generally increases with the biomass ash dosage. Cotton stalk ash has the best performance because net CO_2 absorption capacity can increase to by about 600% compared to that of raw biogas slurry when the dosage is about 200 g/L. After adding biomass ash, CO_2-rich biogas slurry still has low phytotoxicity to the germination of cabbage seeds. When high CO_2 absorption capacity, low phytotoxicity and low biomass ash dosage are all considered, 100 g/L may be the optimal dosage for cotton stalk ash. In addition, the dosage of 50 g/L should be considered for rich straw ash and corn stalk ash. However, 200 g/L should be added into biogas slurry for groundnut shell ash.

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Keywords: biogas slurry; renewable absorbent; CO_2 biological fixation; CO_2 absorption; biomass ash

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1. Introduction

The main obstacle of CO_2 chemical absorption technology is its high regeneration heat requirement. Besides the screening of new chemical absorbents and modification/optimization of capture process [1-3], the so-called "once-through" process that only maintains the CO_2 absorption stage is considered as a potential process to reduce the cost of CO_2 avoided gigantically due to the rejection of CO_2 regeneration stage [4]. However, any once-through CO_2 capture process adopting the commodity chemicals to act as CO_2 absorbent will quickly exhaust the global supply of those chemicals before making a meaningful CO_2 emission reduction [4]. So these new absorbents with the unique characteristics of sustainable, low-cost and abundance in supplying should be focused and screened. Furthermore, it should be best if CO_2-rich solvents can be directly stored or utilized as the commodity products. More attention should be paid to biogas slurry which is the discharged effluent after the anaerobic biogas digestion of organic matter [5]. Biogas slurry is weak alkaline possessing the potential to absorb CO_2, and abundant in high concentration of nutrients and organic carbon meaning that CO_2-rich biogas slurry may be used beneficially as a liquid fertilizer to increase the production of crops and plants and amend the soil [5]. Consequently CO_2 can be fixed into the plants/crops through the carbon concentration mechanism [6]. In addition, biogas slurry is also sustainable. However, CO_2 absorption performance of biogas slurry is too low and need to enhance greatly without deteriorating its viability of agricultural or horticultural utilization [5].

CO_2 absorption of biogas slurry may be attributed to the chemical reaction between CO_2 and free ammonia in biogas slurry [5]. However the concentration of free ammonia in biogas slurry is very low because of its low pH value based on the correlation between the fraction of free ammonia in total ammonium nitrogen (TAN) and pH value [7]. Apparently, increasing pH value of biogas slurry without reducing TAN concentration may help improve CO_2 absorption performance of biogas slurry. So in the present study, four types of biomass ash generated during the combustion of biomass were added into the biogas slurry to increase the pH value. After filtration of the insoluble biomass ashes, the liquid supernatant of biogas slurry was adopted to absorb CO_2 to investigate the effect of the dosage of biomass ash on CO_2 absorption performance. Additionally, the phtotoxicity of CO_2-rich biogas slurry was also experimented in terms of the change of germination index of Chinese cabbage seeds before and after adding biomass ashes.

2. Experimental

2.1. Materials

In this study, raw biogas slurry with TAN concentration of about 943.56 mg/L was gathered from a large-scale mesophilic anaerobic biogas digestion plant (about 35 ºC) using pig manure as the digestion substrate, located at Caoda Village of Yingcheng City, Hubei province, PR China. The collected biogas slurry was stored anaerobically at ambient temperature (15±5 ºC) prior to experiments until no biogas was produced.

Four types of biomass including rice straw (RS), cotton stalk (CTS), corn stalk (CNS) and groundnut shell (GDS) were investigated in this study. Biomass ash was generated after the combustion of biomass in the muffle furnace at 600 ºC for about 2 hours. Biomass ashes were added into the biogas slurry to form the blended solutions with the dosage of 0 gram biomass ash per liter biogas slurry (g/L), 25 g/L, 50 g/L, 100 g/L and 200 g/L. Then the blended solutions were stirred in a magnetic agitator at 20±5 ºC. After about an hour, the insoluble biomass ashes were centrifugally separated from biogas slurry, and the liquid supernatant was selected for CO_2 absorption. The insoluble biomass ash was ignited for about 2 hours in the muffle furnace. After cooling, the biomass ash was ground, and then was sieved for the detection of X-ray diffraction (XRD).

2.2. Apparatus

Experimental setup for CO_2 absorption of biogas slurry with or without adding biomass ash is shown in Fig. 1. 0.2 L filtered biogas slurry was added into a 0.5 L reactor and then heated in the thermostatic water bath to the desired reaction temperature. Pure CO_2 with 0.6 L/min after water saturated in the humidifier was bubbled into