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In-situ Biomethane Enrichment by Recirculation of Biogas Channel Digester Effluent Using Gas Stripping Column

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Abstract

This study was conducted to examine the in-situ methane enrichment in a biogas system by continuously stripping carbon dioxide from the effluent and recirculating back to the system. A laboratory-scale biogas digester with 1,000-liter working volume was coupled with a 110-liter stripping column and was operated using chicken manure as the substrate. It was found that the carbon dioxide stripping performance depended on the ratio between liquid and gas flow rates (L/G Ratio) in the column. The optimum L/G ratio was indicated to be 0.83 times. In a continuous experiment, the effluent recirculation rate was varied from 200%-400% of the digester volume. The higher recirculation rate resulted in the higher methane enrichment. The methane enrichment was in a range of 10-23% while the methane loss was between 3.7% to 16.0% for the system with 200% and 400% recirculation rate, respectively. The overall mass transfer coefficients were in the range of 1.4-6.9 x 10^{-4} s^{-1}.

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Keywords: biogas; in-situ methane enrichment; gas stripping column

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1. INTRODUCTION

Biogas from anaerobic digestion is a well-known source of renewable energy which can be used for many purposes such as electricity generation, heating or fueling vehicles. In the past decades, many countries have developed a variety of biogas systems using different substrates such as maize, perennial grasses, livestock manure, food wastes and agro-industrial wastewater. Nevertheless, one obstacle in biogas utilization is the poor quality of biogas due to its undesirable components like carbon dioxide, hydrogen sulfide, water and ammonia which can cause corrosion and damage to machineries, reduces the system lifetime and increases maintenance costs [1].

Technologies to upgrade biogas quality are classified into physical, chemical and biological methods [2]. The commonly used technology are water absorption, polyethylene glycol absorption, carbon molecular sieving and membrane separation which are popular in Europe, USA and Canada [3]. However these methods require high investment and operational costs, making it not affordable for farmers in developing countries.

Another alternative technology to upgrade biogas is the in-situ methane enrichment which is carried out by continuously stripping carbon dioxide from the effluent and recirculating the effluent back to the digester. This method shifts the carbonic equilibrium in the digester towards the liquid phase, so carbon dioxide in the biogas dissolves more in water and hence increases the methane proportion in the gas phase [1]. In the similar manner, hydrogen sulfide, which is also very soluble in water, can be removed simultaneously. The main advantage of the in-situ methane enrichment is the significantly lower capital and operational costs compared to conventional biogas upgrading techniques [4].

A pilot-scale experiment on in-situ methane enrichment was performed by Linberg et al. (2003) who used a continuous-stirred tank reactor (CSTR) as the digester with the volume of 15 m^3 and a bubble column as the striping column with the volume of 0.15 m^3 [1]. Buffer capacity was affected by the effluent recirculation but there was no negative impact on the digestion process. The methane enrichment resulted in the increasing of CH_4 concentration up to 95% by volume and the methane loss was as low as 2% of the total volume. O'Keefe et al.(2000) who used a digester with the volume of 45 m^3 and a bubble column with the volume of 1 m^3 found that the methane concentration reached 90% by volume and the recirculation of sludge did not affect microbial activity in a municipal-wastewater digester [5]. Lindberg and Rasmuson (2006) found that the liquid to gas ratio was the key operating parameter in the stripping process and the methane content could be increased to 95% by volume with the L/G ratio of 0.7-2.8 times [6]. All in all, it has been proven that effluent recirculation can enrich the methane content in biogas without causing deteriorating effects on the CSTR type of digester. Richards et al.(1994) who performed process a digester with the volume of 12 liters and a bubble column with the same volume used L/G ratio range 0.17 to 1.0 found that the maximum methane concentration was 95% by volume [7]. Moreover at pH higher than 8.1, the sludge recirculation could cause the inhibition of methanogenesis.

The main objective of this study was to investigate the potential of using in-situ methane enrichment in a channel-type digester which is popular in developing countries. The effects of gas–stripping parameters on the removal of carbon dioxide from the effluent were investigated. Also, the impacts of effluent recirculation on the digester performance such as methane yield, organic removal and system stability, were also studied.

2. MATERIALS AND EXPERIMENTALS

2.1. Reactors

The reactors used in this study were two sets of channel digesters with the working volume of 1,000 liters each. One digester was used for a control experiment while the other was employed to study the effects of effluent recirculation. Pre-mixed wastewater was prepared from chicken manure and tap water at the ratio of 1:10 w/v and was fed into the digester once a day using a submersible pump (SSP-255SA). The hydraulic retention time was controlled to be10 days while the excess sludge was withdrawn from the digester at the rate of 75 liters per week. The produced biogas was collected, stored in a HDPE bag and measured for its volume on the daily basis. The composition of biogas was analyzed using a portable gas analyzer (GA2000, Geotechnical Instruments).