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Reducing biogas emissions from village-scale plant with optimal floating-drum biogas storage tank and operation parameters

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HIGHLIGHTS

- Performance of a village-scale plant with semi-continuous feeding was analyzed.
- Models, including biogas production rate and biogas consumption rates, were established.
- A biogas flow chart with key parameters was proposed.
- Optimal tank and appropriate operation could guarantee reduced biogas emissions.

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ABSTRACT

In this study, an approach to optimize the components and operation of biogas plant systems, which temporarily stores biogas in floating-drum biogas storage tank (BS) and feeds in a semi-continuous manner, was developed. First, the parameters of biogas production and consumption were characterized into mathematical models, and estimated with a 1-year operating data set of a village-scale biogas plant (fermentation volume, 80 m^3). Then, the established models, which included biogas production and consumption rates, were used to determine the optimal BS volume and operation parameters for improving biogas plant performance. In contrast to the biogas usage level achieved with the established BS (76.4%), that obtained with an optimal system could reach up to 85.7% and the feeding frequency for a 1-year operation could be decreased 6.5 times. Our proposed approach exhibited a number of attractive features, including accurate determination of parameters, reduced biogas emission, and cost efficiency, which may not only enhance biogas benefits, but also increase economic and environmental feedback on village-scale biogas plant operation.

1. Introduction

In recent years, village-scale biogas plant (fermentation volume: 300 m^3 > V ≥ 20 m^3), which can decentralize the supply of renewable energy, has been broadly applied, because of its suitability to relatively small-scale agriculture structures (village division, cultivated area, and livestock breeding) scattered throughout most of the regions of China [1,2]. This kind of biogas plants could be an ideal solution to treat distributed agricultural waste and produce both biogas and organic fertilizer conveniently and simultaneously, thus favoring long-term sustainable agriculture [3]. Besides, biogas plants could be a reliable renewable energy supply source in residential areas from the points of both technology and practice [4]. As a result, biogas can be delivered to nearby settlements, thus reducing the need for a large biogas pipe network, and fertilizer could be easily applied to the surrounding farmlands, without the need for transportation [5]. Based on these advantages, more than 103,000 village-scale biogas plants had been established in China by the end of 2015, and the number and volume of such plants are rapidly and continuously increasing. In addition, it is also very popular in developing regions, such as Vietnam and Africa [6].

Nevertheless, biogas emission in these plants may be overlooked under normal circumstances, because the relationship between biogas production and biogas consumption cannot be accurately managed. In commercial systems, most of the technical support personnel have recently tried to further improve high biogas production rate by some

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