Chapter 17
Explicit Conceptual Design Approach to Adapt a Biomass-Fed Anaerobic Digester and Status Indicators in Semi-Arid Areas

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ABSTRACT

The mitigation of adverse climate change requires holistic strategies. The strategies include the proper handling of biomass wastes such as cow dung. The handling of the wastes has to be efficient using appropriately designed anaerobic digesters. In addition, the operating status of these digesters has to be monitored for detection of any fault of the digesters. Unfortunately, existing approaches for designing and monitoring the working condition of digesters have limitations. This chapter presents the innovative and explicit conceptual design approach of adapting the biomass-fed anaerobic digester and the digester operating-status-indicators in semi-arid areas. The approach is recommended to the renewable energy system designers. Finally, the appropriate indicators are recommended to be applied by the biogas plant operators or users.

INTRODUCTION

The performance improvement of biomass-fed anaerobic digesters for sustainable bioenergy generation is essential. Several ways of employing engineering design approaches are available for digester design improvement. In addition, the approaches are useful in adapting the anaerobic digester (AD). Adaptation refers to modifying the existing AD design to get its improved design with high performance (Divya *et al.*, 2015). The existing designs of the biogas plants have some pitfalls, which render poor plant performance. The pitfalls oblige the adaptation of the biomass-fed AD design. The adaption process involves

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comprehensive engineering designing procedures, including conceptual design explained by Andreasen *et al.* (2015). The shortcomings noted in the methodologies presented by researchers, including Wu (2013) and Al *et al.* (2019), who applied the approaches for AD designing, impose the investigation of the innovative but explicit conceptual design approach. The faults of biogas plants harm the financial base of users, e.g. failing to attain the predetermined net present value, and polluting the environment. Additionally, the pollution of the environment due to the biogas plant faults, like biogas leakage, exacerbate the adverse climate change. Wu *et al.* (2019) and others have proposed several methodologies of monitoring the biogas plant working conditions intending instantly to track the faults. However, the methodologies have some limitations, including late detection of the faults resulting in the search for novel biogas plant working-status-monitoring methodology with appropriate indicators. Therefore, this chapter aims to demonstrate i) the development and application of the innovative but explicit conceptual design approach for adapting biomass-fed digesters and ii) the establishment of the novel biogas plant working-status-monitoring appropriate indicators.

BACKGROUND

Biomass is a renewable energy resource that harvests solar energy and stores that energy in the form of chemical energy. It includes animal, agricultural, and municipal wastes. Various ways are available to convert biomass into bioenergy, e.g., biogas. The conversion of biomass may be done through the anaerobic digestion process. The process is run without air while employing microbial degradation to produce biogas, among other by-products. The process is a proven technology. Several factors, including temperature, influence the technology of sustainable biogas generation and the state of feedstock applied (Theuerl *et al.*, 2015). Other factors affecting the efficient production of biogas from anaerobic digesters (ADs) include substrate pH, Carbon-Nitrogen ratio of feedstock, feedstock loading rate and particle size, hydraulic retention time and additives. The essential and critical factor, especially in batch-fed ADs, is temperature. It significantly affects biogas generation and other factors (Adekunle and Okolie, 2015). Here below is the information on the temperature relative to the biogas generation. The mesophilic state requires AD temperature to be within 20°C to 45°C. However, keeping the AD at a constant temperature, around 35°C, increases biogas generation. The biogas microbes survive optimally at a temperature variation of 0.5°C/day; henceforth, keeping ADs at temperature variations approaching this value is important (Rowse, 2011). Usually, biogas microbes can sustain temperature variation of ±3°C/day. Therefore, devising a simple temperature control system to reduce temperature variation of biogas digester toward 0.5°C/day is of paramount importance for sustainable biogas generation.

The feedstock employed in biogas generation may consist of dry matter of up to 15% wet basis for the liquid state digestion, i.e. liquid anaerobic digestion (LAD) or above 15% wet basis for the solid-state digestion, i.e. high solid anaerobic digestion (HSAD) (Li *et al.*, 2011). The HSAD feedstock has a much longer retention time and lacks control over the biological process (Li *et al.*, 2011). Therefore, it produces more biogas and needs less or no addition of water compared to the LAD feedstock. However, the HSAD feedstock needs a large amount of inoculum for exciting biogas generation (Yang *et al.*, 2015).

Biogas generation technology is essential for the sustainable energy supply to communities and conserving the environment (Surendra *et al.*, 2014). The technology is relevant in rural areas of economically growing countries of most sub-Saharan African regions. In these countries, Tanzania inclusive, the energy insufficiency rate, especially for cooking, is increasing (Kusekwa, 2011). The energy insufficiency is