Renewable and Sustainable Energy Reviews 58 (2016) 896–910

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Review of small-scale tubular anaerobic digesters treating livestock waste in the developing world

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ARTICLE INFO

Article history:
Received 19 December 2014
Received in revised form
18 November 2015
Accepted 23 December 2015

Keywords:
Benefits
Biogas
Energy
International development
Livestock waste
Tubular digester

ABSTRACT

Small-scale tubular anaerobic digesters are an attractive technology for treatment of livestock waste in the developing world. These systems produce biogas (a mixture of CH_4 and CO_2) that is mainly used for cooking. Digester effluent is rich in nutrients (nitrogen and phosphorus) and can be used as a soil amendment. These systems also assist in mitigating deforestation by providing an alternative fuel source, reducing water pollution due to runoff of untreated livestock waste, decreasing air pollution from biomass combustion and promoting gender equality. However, for these benefits to be significant, the effects of design, substrate characteristics and operating parameters on system performance must be understood. This review provides a detailed summary of the research that has been conducted on tubular anaerobic digesters treating livestock waste in developing countries. Links between successful digester performance and energy, environmental, public health and social benefits are also provided. In addition, this review discusses governmental policies that have successfully increased adoption of livestock waste anaerobic digestion systems in Africa, Asia and Latin America.

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1. Introduction

Anaerobic digestion of livestock waste is a waste management method that can improve the quality of life of those in the developing world. Biogas produced from small-scale anaerobic

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http://dx.doi.org/10.1016/j.rser.2015.12.324
1364-0321/

Nomenclauture

ADB	Asian Development Bank
ALRI	Acute lower respiratory infections
BOD	Biochemical oxygen demand
C/N	Carbon nitrogen ratio
COD	Chemical oxygen demand
COPD	Chronic obstructive pulmonary disease
FOG	Fats, oils and grease
GHG	Greenhouse gases
HRT	Hydraulic retention time
LCFA	Long chain fatty acids
LPG	Liquefied Petroleum Gas
N/P	Nitrogen phosphorus ratio
NBP	National biogas programme
NGO	Non-Governmental Organization
NREL	National Renewable Energy Laboratory
OLR	Organic loading rate
PRC	People's Republic of China
SRT	Solids retention time
TAN	Total ammonia nitrogen
VFA	Volatile fatty acids
VOC	Volatile Organic Compounds
VS	Volatile solids
WTE	Waste to Energy

digesters is most often used as a cooking fuel, but can also be used to heat water or buildings or generate electricity for on-site use [1–4]. Anaerobic digesters can also be a useful tool to mitigate deforestation by using biogas as opposed to firewood. This also results in decreased public health concerns, especially for women and children who are disproportionally affected by indoor air pollution due to cultural and social roles. In addition, effluent from anaerobic digestion contains primary nutrients (nitrogen, phosphorus, potassium), that have agronomic benefits if used as a soil amendment to improve plant growth. Interrelationships between substrate characteristics, operating parameters and biochemical conditions within the digesters and how these condition translate to energy, environmental, agricultural, social and public health benefits as well as policies promoting anaerobic digestion of livestock waste are shown in Fig. 1.

There are three types of small-scale anaerobic digestion systems commonly used in the developing world, fixed dome, floating drum and tubular. Fixed dome digesters are constructed underground, which reduces the cost of constructing load bearing tank walls. They have no metal parts that can rust and have been reported to last as long as 20 years. The main disadvantage of fixed dome digesters is that skilled laborers are required for their construction. In addition, variations in liquid volume, methane production and use and temperature affect gas pressure in the fixed dome, which can lead to burner malfunction [3–6]. Floating drum digesters are widely used in Asia. They are similar to fixed dome digesters but incorporate a floating gas holder that is supported by a guide frame. Gas pressure is constant and biogas volume can be monitored by observing the position of the drum. They are simple to construct but require regular maintenance to prevent corrosion, especially in tropical climates [3–6]. Tubular digesters are similar to fixed dome digesters in that they are constructed in ground; however, they are normally constructed from low cost polyethylene tubing, with a separate storage bag for the biogas. Tubular digesters do not require a high level of skilled labor to install, they are the easiest to operate, cost the least and can operate at a variety of temperatures [3–6]. Due to their advantages and popularity, this review provides a detailed summary of the current and ongoing research on tubular digesters treating livestock waste in the developing world. In addition to information from the literature, the authors' observations of design, operation and maintenance of tubular digesters treating livestock waste as well as discussions with farmers and development workers in Monteverde, Costa Rica are also incorporated into this review.

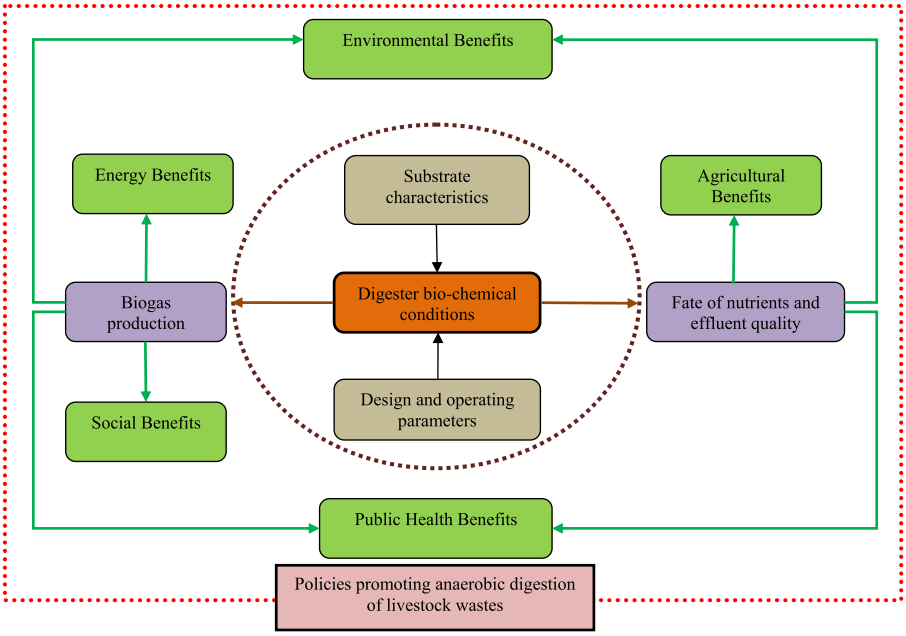

Fig. 1. Schematic illustrating link between digester operation, benefits and policies.