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Addressing problems at small-scale biogas plants: a case study from central Vietnam

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ABSTRACT

The anaerobic digestion process is an important technology in improving the environment because it solves organic waste management problems and simultaneously produces both biogas and fertiliser. The use of biogas plants has been spreading in many developing countries, bringing various operational problems with their widening use. This study attempts to identify the problems with this technology at the level of owners of biogas plants (n = 141) and local facilitators (n = 9) in central Vietnam. A survey was conducted from July to September 2012. The methods of data collection included focus group discussions, semi-structured personal interviews and a questionnaire survey. The survey revealed that 29% of biogas plant owners have experienced at least one problem with this technology. The most frequently encountered problem is linked to leakages from reactors leading to undesired CH_4 emissions, which sometimes stopped the biogas plants from functioning. Other problems concern the failure of biogas cookers to properly function with solid digestate incrustation floating in the main tank, resulting in decreased biogas production. The respondents call for better-trained builders and facilitators, who are often unable to solve difficulties encountered with BGPs. The importance of a working information flow between actors is demonstrated. The study also involves the calculation of the payback period of biogas plants. The findings show a linear relationship between the payback period and biogas plant-owners' satisfaction with biogas technology, biogas production and the biogas programme. In addition, the study recommends improvements in the skills of facilitators because they have a direct impact on the quality of training of BGP owners and builders. In conclusion, this study provided an innovative problem analysis of biogas technology along with appropriate recommendations. It demonstrated the need for further research on the eradication of problems associated with biogas technology.

1. Introduction

The resource limitations of fossil fuels and problems arising from their combustion have led to the widespread utilisation of renewable energy resources. Energy and environmental issues have become one of the most important problems of common concern and one of the first problems needing to be solved by mankind to further sustainable development (Zhou et al., 2011; Amigun et al., 2008). Biogas produced via the anaerobic digestion (AD) of organic waste materials is considered an important technology in improving the environment because it solves waste management problems and simultaneously produces biogas as a main product and digestate as a by-product, which can also be used as fertiliser (Gautam and Herat, 2000; Muller, 2007; Amigun et al., 2008; Molino et al., 2013; Adu-Gyamfí et al., 2012). A biogas plant (BGP) is a piece of equipment that uses an AD process for biodegradable waste treatment. The utilisation of AD represents an appropriate solution to health, hygiene and environmental problems (Jha et al., 2012; Jingura and Matengaifa, 2009). The production of biogas through the AD process provides significant advantages over other forms of renewable energies (Zhang et al., 2013; Lu et al., 2006). It has been demonstrated to be one of the most energy-efficient and environmentally friendly forms of energy and of technologies for renewable energy production (Pérez et al., 2014; Raposo et al., 2011). Economic prosperity and quality of life in rural areas are closely linked to per capita energy consumption, and the adopted strategy is to use energy as a fundamental tool to achieve both (Singh and Sooch, 2004). Energy consumption in the rural areas of

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central Vietnam can be met by the use of household-sized biogas plants and can provide a healthier and more sustainable way of living. One can expect that a higher number of BGPs in developing countries will also produce a significant number of problems and complications regarding their operation, thereby reducing the benefits of this technology. The objective of this paper is to analyse current problems with BGPs in the target area and outline possible easily applicable solutions in line with local conditions. This paper will also have value for other developing countries in the region.

1.1. Biogas plants in developing countries

In 1984, more than 7 million BGPs were in operation worldwide, mostly in Asian countries (Steiner and Kandler, 1984). Currently, millions of BGPs can be found in developing countries (Mwakaje, 2008). There are approximately 38 million BGPs (Chen et al., 2012) in China, more than 3.7 million in India (Rao et al., 2010), over 80,000 BGPs in Vietnam (Ghmire, 2013), 60,000 in Bangladesh and an increasing number in Peru and African countries (Thu et al., 2012). The most common BGP type is the so-called Chinese type (Maithel, 2009; Pérez et al., 2014).

The Chinese-type biogas plant was originally based on a septic tank (Fulford, 2015), but the original rectangular tank was rapidly replaced by a design based on a fixed dome shape that provided better performance. There are many varieties of fixed domes such as the KT model (described in this paper and widely used in Southeast Asia), the Janata model (the first fixed dome design in 1978 in India) (Singh and Sooch, 2004; Kalia and Kanwar, 1998), the Camartac model (developed in the 80s in Tanzania) (Pérez et al., 2014; Nzila et al., 2012), and the Deenabandu model (developed in the 90s in India) (Singh and Sooch, 2004). Different NGOs and private companies manufacture these and other designs, which is leading to increased variations in quality.

The increasing number of BGPs in developing countries also means an increase in the number of problems and complications associated with BGPs (Aburas et al., 1995). Generally, there are many advantages to biogas production but also many disadvantages. If these cons outweigh the pros, small-scale farmers abandon BGPs, as shown in China (Zhou et al., 2011). One of the most important problems hindering any biogas technology in developing countries is cost, which can create difficulties for the installation of such plants, together with sourcing spare parts (An et al., 2006; Mwakaje, 2008). It has been widely reported that the development of BGPs was greatly facilitated because of substantial support from governments, development projects and aid agencies (Mwakaje, 2008; Kristoferson and Bokhalders, 1991); however, when the subsidies were later reduced, the number of BGPs built each year fell dramatically (Desai, 1992). Technical and operational problems are common in the case of small-scale BGPs, yet suitable solutions are often found (Aburas et al., 1995). Further political measures, including training and capacity building programmes, flexible financing mechanisms and dissemination strategies, may be needed to encourage adoption (Karekezi, 2009; Greben and Oelofse, 2009; Zhou et al., 2011). System failures of small-scale BGPs can be divided into six main subsystems, as adopted from Cheng et al. (2014): structural components, biogas utilisation equipment, piping systems, biogas production, digestate disposal systems and knowledge-related problems. Problems with structural components were found in studies conducted by Chang et al. (2011) in Inner Mongolia and by Lam and Heegde (2012) in Asia and Africa. Problems with biogas utilisation equipment in Vietnam, such as biogas cookers and lamps, are described by Pipatmanomai et al. (2009) and Thu et al. (2012). Problems with piping systems, such as leakages or blockages, were found in Sovacool et al. (2015) and Cheng et al. (2014), and problems with biogas production, such as leakages in biogas digesters, were found by Chang et al. (2011) and Thu et al. (2012). Solid digestate incrustation floating in the main tank prevents biogas from escaping, as found in the studies from China conducted by Chen et al. (2010, 2012). Digestate disposal systems are important to the sustainability of BGPs because without appropriate disposal and operating procedures, there can be no long-term sustainability (Alburquerque et al., 2012). A call has been made for quality supervision, inspection, maintenance, quality controls, effectiveness evaluations and technical guidance (Chen et al., 2012; Suzuki, 2015). To ensure that BGPs continue to function properly, there is a need for improvements in knowledge (Cheng et al., 2014; Thu et al., 2012; Vu et al., 2007; Suzuki, 2015), which should be transferred from local facilitators to small-scale biogas owners (Jha et al., 2012; Maithel, 2009).

There is also a promising alternative in the form of biohydrogen production via an AD process (Lee, 2013), which is an emerging candidate among other alternative energy carriers (Bakonyi et al., 2014). This method may provide future competition to the conventional anaerobic digestion process (Ravina and Genon, 2015). Biohydrogen may also be a viable option for developing countries; however, its development in Asia is expected to be much slower than in other regions (Lee, 2013). Therefore, this study does not move towards its further recognition. Biomethane production refers to the separation of the methane fraction from other gaseous components via a treatment process commonly referred to as biogas upgrading (Ravina and Genon, 2015; Bauer et al., 2013). In the study of Bauer et al. (2013), emerging technologies for small-scale upgrading and the future application of upgraded biogas are discussed; however, these shifts into the future are expected to be introduced slowly in developing countries, especially in rural areas.

1.2. Current situation with BGPs in Vietnam

Since 2003, Vietnam has implemented a national programme for the use of biogas in the animal sector – *The Biogas Programme for the Animal Husbandry Sector in Vietnam* (BPAHS). The BPAHS has been placed into practice by the Biogas Project Division of the Ministry of Agriculture and Rural Development in collaboration with the Dutch development organisation SNV. Since 2003, more than 100,000 household biogas plants have been built under this programme, including 2900 family biogas plants in the Thua Thien Hue province, central Vietnam. In addition, builders, facilitators and technical teams have been trained to control the quality and viability of BGPs and provide training to users.

2. Methods

The survey was conducted in the province of Thua Thien Hue in central Vietnam. Its population consists of 1,045,134 inhabitants (General Statistics of Vietnam, 2013), which represent 1.13% of the population of Vietnam. One third of this population lives in and around Hue City. The population density is lower than the national average (219 and 265 persons per km^2, respectively) and varies across the province (General Statistics of Vietnam, 2013). Our survey was conducted in the districts of Huong Tra and Phong Dien. The climate in the region is tropical humid, the average temperature is approximately 25 °C, and the average rainfall is in the range of 1600–4000 mm per year. These rains can be very sudden and heavy, causing not only possible decreases in agricultural activity and school attendance but also losses of property and human lives as well as damage to the environment. These limitations (floods, storms, drought and coastal erosion) need to be considered. For example, coastal erosion is widespread and causes losses of life, prevents socio-economic development (Cat et al., 2005) and leads to economic weaknesses in the area.

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