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Identification of the microbiological community in biogas systems and evaluation of microbial risks from gas usage

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Abstract

The plans for introducing biogas produced from organic waste to the pipe system for natural gas has raised concerns about the risk of transmitting disease via the gas. To assess this risk, condensate water from gas pipes and gas from different parts of a biogas upgrading system were sampled and cultured for microbial content. On average, 10^5 cfu ml^{-1} were found in the condensate water throughout the system, while in the gas between 10 and 100 cfu m^{-3} were found. The microorganisms were subjected to further identification and found to represent a wide variety, e.g. fungi and spore-forming and non-spore-forming bacteria, including species such as *Enterobacteriaceae*. The number of microorganisms found in the biogas corresponded to the densities in sampled natural gas, which also held 10–100 cfu m^{-3}. Since no pathogens were identified and since the exposure to gas from e.g. cookers and refuelling of cars may only result in the inhalation of small volumes of gas, the risk of spreading disease via biogas was judged to be very low.

Keywords: Biofilm; Biogas; Biowaste; Natural gas; Pathogens; Upgrading of biogas

1. Introduction

Biodegradable organic waste (biowaste) is today mainly treated in three different ways in Sweden – through incineration, composting or anaerobic digestion. The number of systems that can produce biogas from solid biowaste in Sweden is increasing and the number of large-scale treatment systems is at present 14 (Tynell, 2005). In addition to these systems, most medium-sized and large wastewater treatment plants treat their sewage sludge anaerobically. Most existing systems run their digestion in a mesophilic temperature range.

Initially the raw biogas produced was mainly used internally at the treatment plants for energy production. Today, however, biogas is being diverted to other uses, in many cases in combination with natural gas (Hagen et al., 2001). For the biogas to have an energy content comparable to that of natural gas, allowing mixing of the two without lowering the energy content, the carbon dioxide has to be removed. In Sweden, a scrubber technique where the CO_2 is removed by washing with

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water is the most common method used today (Persson, 2003).

A combination of natural gas and biogas can be used in the existing gas distribution system. The materials processed in the biogas reactors for solid waste are normally heat-treated at 70 °C for 1 h, in accordance with current EU-legislation (EC No. 1774/2002). Therefore, no non-spore-forming pathogens should enter the biogas reactor. However, most of the biogas produced in Sweden comes from treatment of sewage sludge and these systems do not contain a pasteurisation step, so pathogens are often found in the sludge (Gantzer et al., 2001; Sahlström et al., 2004). Introducing the biogas produced into systems constructed for natural gas is currently causing a debate about the risks of introducing pathogens to the gas systems. No previous studies of microbiological communities in biogas have been reported. In systems for gas distribution, Zhu et al. (2003) observed that bacteria could survive, and in several cases grow, within the biofilm in existing pipes.

To determine whether there is an actual risk for transmission of disease from the use of biogas, any microorganisms present in the gas have to be enumerated and identified. The separate steps involved in upgrading the raw gas to consumer gas that can be distributed in a larger network primarily carrying natural gas must also be evaluated, as must sites where people can come in contact with the gas.

The objective of this study was to enumerate and identify the microbiological community in the system for upgrading biogas, with specific focus on potential pathogens. This information should be used in combination with a systematic overview of the technical system to assess the risks related to the handling and final usage of the processed gas.

2. Materials and methods

2.1. The biogas systems

Two different biogas systems were investigated. Both consisted of two separate digesters (Fig. 1), one for sewage sludge and one for biowaste. The treated biowaste included sorted household waste and other category 3 animal by-products (ABP) as well as manure (category 2 ABP). All reactors were mesophilic with a working temperature of approximately 35 °C. The sewage sludge was not pretreated in order to reduce incoming pathogenic microorganisms before digestion. Incoming material to the reactors treating biowaste and ABP was pasteurised at 70 °C for 1 h prior to the anaerobic treatment.

In System 1 and System 2, the gas from both the biowaste and the sewage sludge treatment was upgraded in a co-treatment in a pressurised scrubber system. In System 1, the water used in the scrubber was a circulating flow of water that was regenerated via pressure release in combination with aeration. During the study of the upgraded gas, the gas from the biowaste treatment was led through the back-up system for upgrading. The back-up system was a pressure swing adsorption (PSA) system, which had been in use for 5 h when the gas was tested (Fig. 1). In System 2, the water used in the scrubber was continuously fed treated wastewater that not had been disinfected (Fig. 1).

2.2. Sampling of condensate water

As no access to the piping system was possible in the running system, condensate water was collected from the systems at Sample K1 (Fig. 1) where condensate was formed in the cooling raw gas. As condensate is formed in the entire pipe and flows on the bottom of the pipe, it was assumed to reflect the gas and the biofilm in the pipes. The second sampling point for condensate water was at Sample K3 (Fig. 1) where after removal of CO_2 in the scrubber, the upgraded gas was dried before pressurising. Samples were collected in 50-ml sterile flasks. By using the condensate instead of sampling the pipe surface, it is possible to reflect a wider area of the pipe and also some of the gas. The drawback with this method is that no information is collected regarding the actual growth of the biofilm in the pipes. To evaluate specific features of the biofilm, further studies of pipe segments would be needed. Samples from System 1 were kept in a cool box overnight before analysis, whereas samples from System 2 were analysed within 4 h after sampling.

2.3. Sampling of gas

The processed gas was sampled by diverting a flow of gas onto an agarplate using a SMA microbial air sampler system. According to the method for using the SMA, a gas flow of 1 $ft^3\ min^{-1}$ (54 $l\ min^{-1}$) should be used (VAI, 1998). This high flow was not always possible to achieve in the system for the biogas. In the system for the raw gas, which holds a low pressure, it was not possible to achieve a sufficiently high flow. Available flow was approximately 20 $l\ min^{-1}$ and each sample was collected during approximately 20 min. Generally 200 to 500 l of biogas were sampled on each plate and the time for sampling depended on the gas flow. The upgraded gas, where the CO_2 had been