Experimental Performance of a Trickle-Bed Reactor for Biological Methanation

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1. Introduction and Short Description:

Methanogenic archaea are able to produce methane through metabolization of CO_2 or CO and H_2 [1]. Therefore, they present a second technological option, besides catalytic methanation, for the synthesis of substitute natural gas (SNG) [2]. A major challenge for the implementation of this process is supplying and dissolving the feed gases to the aqueous environment of the microorganisms. It is still unclear, whether the dissolving of the hydrogen in the liquid phase or the kinetic of the reaction of the biological system is the kinetic limitation of the process. The project ORBIT addresses this question and develops a new trickle-bed reactor for biological methanation, which runs experiments at OTH Regensburg (Fig. 1). Finally, its demonstration will take place at an existing power-to-gas site in Ibbenbüren and feed the gas grid. One goal of the ORBIT project is also the standardization of the biological methanation [3]. Furthermore, some experimental results from a second existing lab-scale reactor are shown.

2. Methodology, Results and Discussion

The most important parameter to characterize and compare the performances of these reactors is the normalized methane production rate (MPR_R). The MPR_R reports the methane produced in the system in standard cubic meters per hour, normalized to the reactor volume V_R and provides information on the productivity of the plant (equation 1). [3]

$$\mathrm{MPR_R} = \frac{\dot{V}_{\mathrm{CH_4,out}} - \dot{V}_{\mathrm{CH_4,in}}}{V_R} \left[\frac{\mathrm{m^3}}{\mathrm{h \cdot m^3}}\right] \quad (1)$$

Figure 2 illustrates the working principle of the trickle-bed reactor. The fluid and the microorganisms are pumped to the top where they trickle downwards to the bottom of the reactor. The feed gases are injected at the reactor bottom, flow upwards and leave the reactor at the top. The resulting large two-phase interface of the trickles enables the dissolution of the feed gas in the liquid. In batch mode the reactor is filled with H_2 and CO_2 at the beginning of the batch-experiment. While the reaction takes place, the pressure decreases. If the pressure falls below 2 bar(a), the reactor is refilled with H_2 and CO_2. After the time of the batch-experiments the product gas is analyzed and the average MPR_R is calculated. In continuous mode the reactant gases flow constantly into the reactor, are converted to methane and the product gas flows constantly out of the reactor. In the past the reactor was running on a pure biological culture. That means that there is only one specific kind of microorganism. The operation mode for the pure culture experiments were batch mode. Now the reactor runs on a

mixed culture, which was created by adding dissolved waste sludge of a biogas plant to the system. The sludge contains a bright variety of different microorganism in a changing composition. As the mixed culture shows much better results, this is preferred. The here shown mixed culture experiments are in continuous operation mode.
The trickle-bed reactor operates 24/7 to get extensive results and a wide parameter analysis. It was shown, that the pressure and the recirculation rate has an impact on the performance, and that it is strongly important to feed the archaea with nutrition media. Fig. 3 shows a variation of pressure at the trickle-bed reactor with better methane production rate (MPR_R) at higher pressure. Fig. 4 shows the dependence of new nutrition media. After feeding new media (red) the performance raises up to 9.55 $l\cdot(l\cdot d)^{-1}$. The maximum purity of methane is up to 96% in continuous mode. The maximum MPR_R is 31 $l\cdot(l\cdot d)^{-1}$.

3. Conclusion and Outlook

This work proves that a TBR for the biological methanation is a functional reactor concept. The mixed culture worked better than the pure culture and achieved a MPR_R of 31 $l\cdot(l\cdot d)^{-1}$ and a methane purity of up to 96%. The presentation at the 19 International Conference on Polygeneration Strategies will further show a broad analysis of various impacts on the biological methanation in lab-scale experiments with focusing on reactor parameter as pressure, trickles and recirculation rate. Furthermore, the influence of microorganisms, pure vs. mixed culture, and the media is going to be discussed.

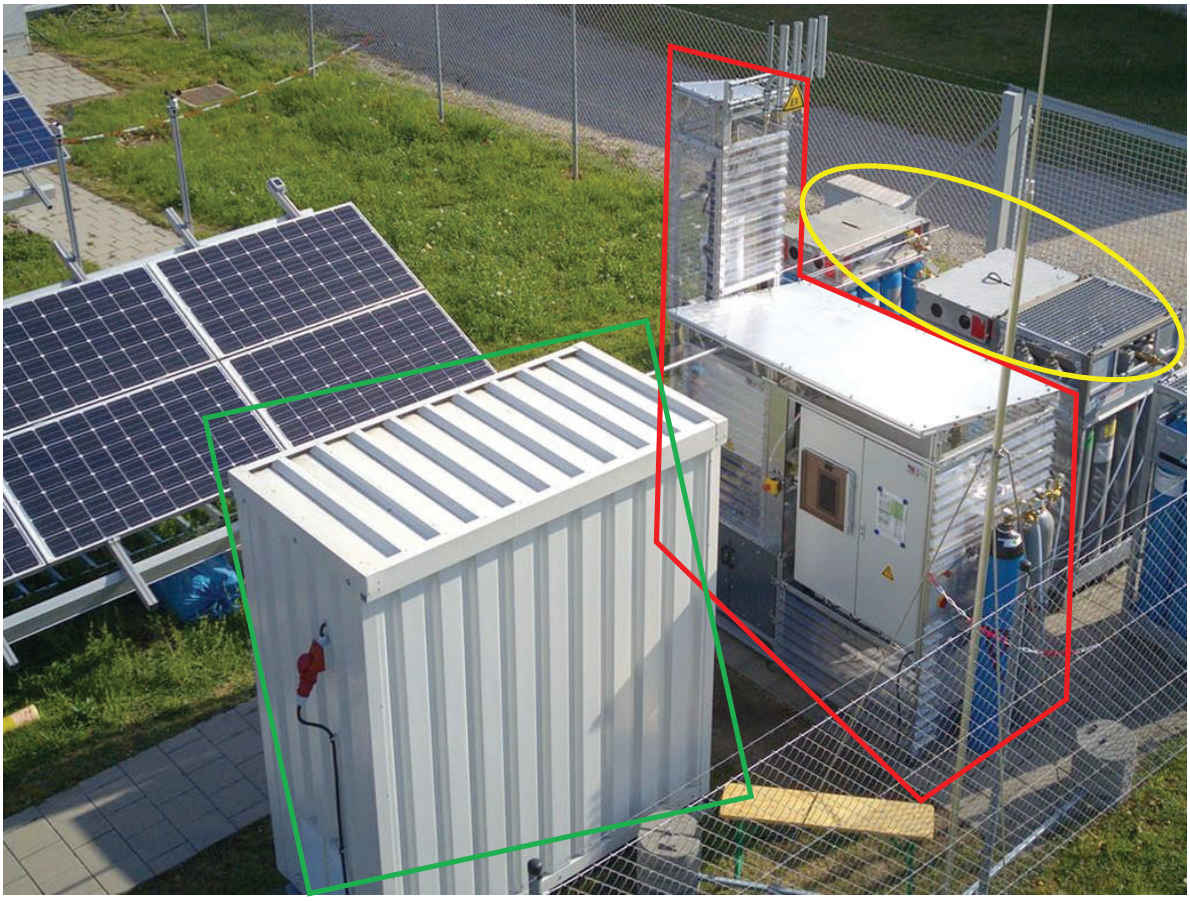

Figure 1: ORBIT reactor for biological methanation; red: trickle-bed reactor system with periphery, yellow: reactant gases, green: container with gas analyzer © Michael Heberl

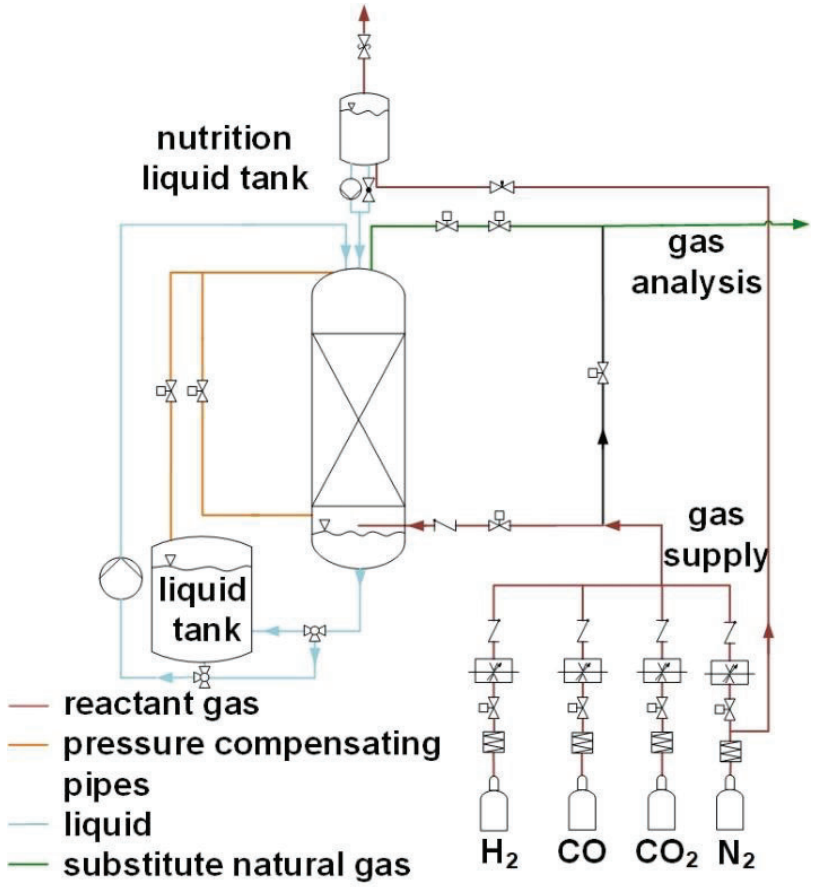

Figure 2: Existing lab-scale trickle-bed reactor at the EVT

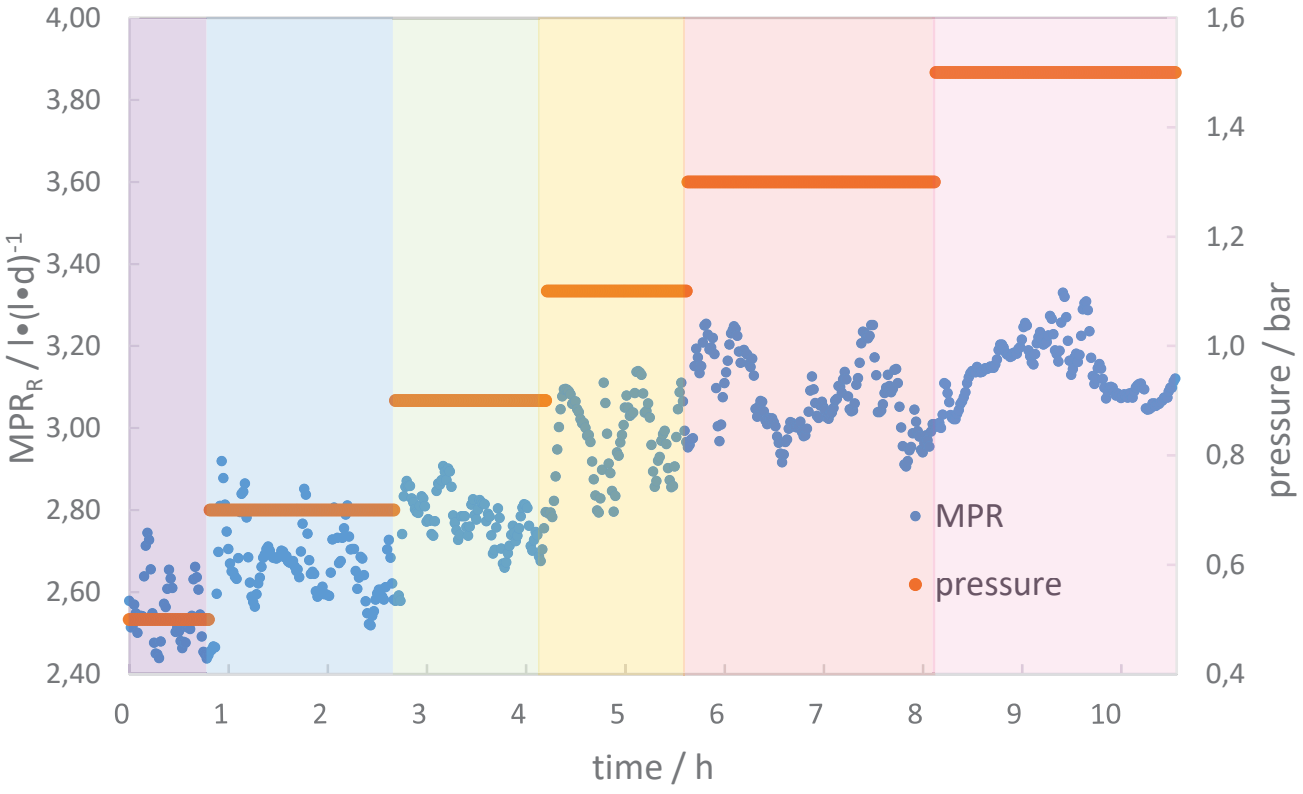

Figure 3: MPR_R over pressure at continuous operation mode with a mixed culture

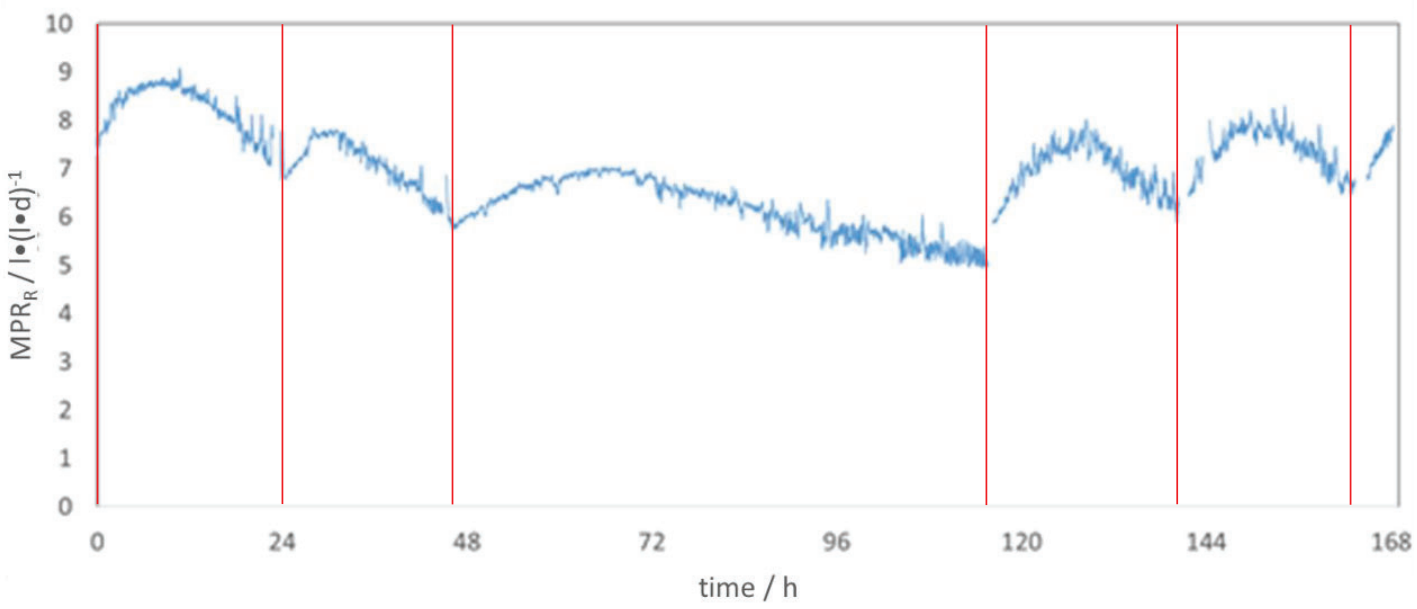

Figure 4: Influence of new media for the MPR_R at continuous operation mode using a mixed culture

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