

Expert Opinion of PhD dissertation entitled  
**“Study on polydimethylsiloxane membrane contactors to recover dissolved gases  
(CH<sub>4</sub>, CO<sub>2</sub>) from anaerobic effluents”**  
written by **Merve Visnyei**

**Institution:** University of Pannonia, Doctoral School of Chemical Engineering and Materials Sciences

**Supervisor:** Dr. Peter Bakonyi

Dear Prof. Cecilia Hodúr,

I would like to sincerely thank you for taking the time to review my dissertation since the earlier version so thoroughly and for your valuable comments and recommendations. Your thoughtful insights and constructive remarks helped me refine and strengthen the final version in many important ways.

I am particularly pleased that you found the inclusion of the *Introduction* effective in drawing attention to the importance of the topic. I also appreciate your acknowledgment that the *Methods* and the *Results* chapters are carefully detailed and logically organized.

Below, I address your specific comments and questions:

**1. Fig.5 - Dissolved methane as a function of temperature.**

**The issue of the global problem of methane dissolved in wastewater is perhaps debatable, compared to other greenhouse gases, but for now we can safely ignore this debate. It is interesting, however, that fig. 5, "Dissolved methane in the wastewater as a function of temperature" clearly shows the strong temperature dependence, but raises the question of what kind of wastewater this is, what its origin is, what COD and BOD it is characterized by. Since this figure will be referred to several times later on, it would be important to clarify these basics. Is the solubility of a digester effluent the same?**

I appreciate your feedback, and I understand the confusion this may have caused. Figure 5 is based on data calculated using typical values for Soluble COD in municipal wastewaters, which often ranges from 100–300 mg/L, with an average of 200 mg/L (Liu, Z., Yin, H., Dang, Z., & Liu, Y. (2013). *Dissolved Methane: A Hurdle for Anaerobic Treatment of Municipal Wastewater. Environmental Science & Technology*, 48(2), 889–890. doi:10.1021/es405553j). Additionally, it is known that 0.35 L of methane can theoretically be produced from 1 g of bCOD removed (Lawrence, A. W.; McCarty, P. L. *Kinetics of methane fermentation in anaerobic treatment. J. Water Pollut. Control Fed* 1969, 41 (2), R1–R17.). My primary purpose was to provide a theoretical overview of how these calculations conducted at different temperatures reflect the behaviour of synthetic effluents. The goal was to estimate the amount of methane theoretically that would remain in its dissolved form, which is expected to be

higher at lower temperatures, particularly in anaerobic systems operating under varying temperature conditions.

**2. Otherwise, the chapter describes the methods, calculation methods, equipment and their characteristics belonging to all three subchapters very carefully and in detail. Only a few open questions or unclear information remains. e.g.:**

a. *Why exactly these gas mixture ratios were used?*

The specific gas mixture ratios used were selected based on preliminary experiments and literature precedents that was done during the research phase of my PhD studies.

b. *What microbial community did you use for the anaerobic process?*

The source of microbial community used in the anaerobic process is stated in the page 80 in my dissertation. Originally microbial community samples were collected at various stages during the fermentation process to monitor the composition and behaviour of the microbial communities, including archaea. These samples were sent to a company called Novogene, a next-generation sequencing (NGS) service provider for detailed analysis. The result is as follows:

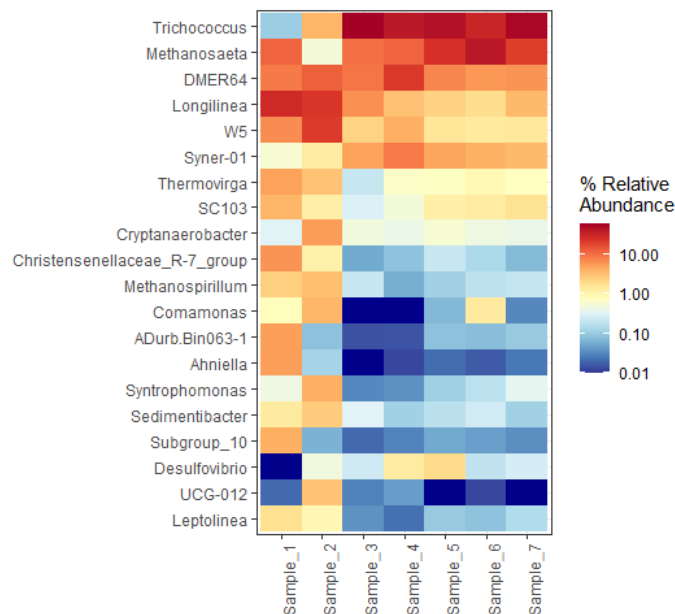


Figure: Microbial community samples analysed

We were recommended by the biologists that we should not include this figure because of the low quality of analysis. Therefore, we didn't add it but my intention was to give dynamics from the bioreactor.

### 3. Results:

#### Series #1:

- a. *The methane recovery data can really be explained well by the determining role of the resistance on the liquid side, which is almost the same in all cases, due to the same flow rate. But how can the considerable decrease be explained at a gas flow rate of 60 ml/min?*

After conducting the experiments, the results revealed that at lower sweep gas flow rates (10-20 mL/min), the CH<sub>4</sub> recovery rate remained nearly constant, between 58.0-58.6%. This consistency suggested that at these flow rates, mass transfer was primarily controlled by resistance in the liquid phase. However, a marked decrease in CH<sub>4</sub> recovery rate was observed when the gas flow rate increased to 60 mL/min. The recovery rate dropped sharply to 35.9%. This significant reduction is attributed to the dilution effect, where the higher flow rate reduces the concentration of CH<sub>4</sub> in the gas outlet, thereby lowering its recovery. This phenomenon aligns with findings reported by other researchers. Similar findings were also observed in the case of model solution-3 (MS-3).

#### Series #2:

- a. Thank you very much for your recommendations on the concept clarification. I have clarified the distinctions between "model solution," "synthetic effluent," and "synthetic anaerobic effluents".

“Model solution” term used consistently in Experimental Series #1, while the term of “synthetic effluent” was used consistently in Experimental Series #2 to avoid any confusion. I hope these changes improved the quality of the dissertation for the reader.

- b. *I would like to address your specific concerns on on the page 61: „An increase in the liquid flow rate led to a decrease in CH<sub>4</sub> recovery for all synthetic effluents.” it is correct and proved by Fig. 22. But the explanation is no longer so easy to see, because the explanation taken from the cited literature (M. Henares, M. Izquierdo, P. Marzal, and V. Martínez-Soria in Sep. Purif.Technol.) attributes the "deformation and compression of fibers" to the effect of pressure, the effect of the pressure difference, not to the flow rate.*

*„The reason for the lower pressure limit from shell to lumen is because the hollow fibres may collapse and be damaged if the pressure from the outside of the hollow fibre to the lumen side of the hollow fibre exceeds 1050 mbar. On the other hand, if the*

*pressure from the lumen side to the outside of the hollow fibre exceeds 3100 mbar, the hollow fibres may over-distend and potentially be damaged.”*

Thank you for your insightful observation. In my opinion, the decrease in CH<sub>4</sub> recovery with increased liquid flow rate could be a consecutive result of the pressure increase. As the flow rate rises, the associated pressure on the membrane also increases. If the pressure exceeds the recommended limits, it can potentially lead to the deformation or compression of the fibres, as noted in the literature, which in turn could affect the gas recovery performance. Therefore, the increase in flow rate may indirectly impact the recovery data through its effect on the membrane integrity.

### **Series #3:**

I sincerely thank you for recognizing the Series #3 as the most exciting and meaningful part of the dissertation. I am very pleased that you found the discussion of real-environment challenges, such as the optimization of glycerine dosage and membrane clogging, to be well presented. Thank you also for pointing out the need to display standard deviations more consistently.

### **4. Thesis Statements:**

I am truly grateful for your generous evaluation of my thesis statements and for acknowledging them as new scientific results. I am also deeply appreciative of your concluding remarks describing my dissertation as “an extremely substantial and valuable work.” It is an honour to receive such recognition from you.

### **5. Questions:**

#### **a. How do you think the process of membrane transport is affected by whether it flows on the lumen side or the shell side?**

For real effluent: Unfortunately, it could not be a part of the plan and we had to feed from lumen to the shell side, due to the instant clogging.

For synthetic effluent: In gas separation, flow direction does have an impact on the membrane transport. In my experiments there was an effect also. If we feed the membrane from the lumen side then for sure the flow diameter will be completely different than in comparison to the diameter of the fibres when we push all the liquid inside the fibres. It could have a significant impact on the flow regime. For instance, calculating Reynolds numbers to characterize the flow conditions then it could have a significant impact; what are the flow diameters or how we distribute the liquid.

It would also have an impact on Surface Area and Mass Transfer: The lumen side offers a more confined flow, meaning less interaction with the membrane surface compared to the shell side. This results in lower mass transfer per unit volume. However, this increased surface area can come at the cost of increased complexity in controlling the flow.

Although I don't have extensive experience yet, it could be a further aspect to explore.

**b. How are the amounts of the two gases formed in a real fermentation effluent?**

CO<sub>2</sub>: no estimation could be made based on the Henry's law, since this is not water, so we don't really have solubility data of CO<sub>2</sub> for fermentation effluent. Composition of effluent has a large impact on the solubility of particulate gas so this could be a subject of another investigation.

CH<sub>4</sub>: CH<sub>4</sub> concentrations of the prefiltered effluent supplied to the membrane were 5.7±0.8 mg/L, 4.9±1.8 mg/L, 4.5±1.1 mg/L across different experimental settings (30%, 50%, 70%).

According to the calculation and considering the 2L volume of stirred tank bioreactor:

11.4±1.6 mg, 9.8±3.6 mg, 9.0±2.2 mg across different experimental settings (30%, 50%, 70%).

**c. Figure 5 shows the temperature dependence of the amount of dissolved oxygen in water. How do these values change in real wastewater?**

Figure 5 was prepared using data calculated from typical values for soluble COD in municipal wastewaters, which usually range between 100–300 mg/L, with an average of around 200 mg/L (Liu et al., 2013). Based on the stoichiometric relationship that 1 g of biodegradable COD can theoretically produce 0.35 L of methane (Lawrence & McCarty, 1969), the calculations provide a theoretical estimation of dissolved methane under varying temperatures.

In real wastewater, these values change depending on the actual COD, BOD, and microbial activity. The amount of methane remaining dissolved is typically higher at lower temperatures due to decreased gas–liquid equilibrium constants. Therefore, under real anaerobic conditions, the trend shown in Figure 5 still applies—the solubility of methane decreases with increasing temperature—but the absolute values may be slightly higher due to the presence of organic matter and dissolved solids influencing gas solubility.

Veszprém, 08 December 2025.



Merve Visnyei