SYSTEMIC Living Lab conversations: Membrane filtration technologies and reverse osmosis

27/11/2020 11:00h CET – 11:45h CET – TEAMS online meeting

Moderator: Marieke Verbeke (VCM, SYSTEMIC project)

Extra information inserted in this summary after the discussion.

Expert Panel:

SYSTEMIC Demonstration Plants, Outreach Locations and Associated Plants

For more information, check out:

https://systemicproject.eu/plants/demonstration-plants/

https://systemicproject.eu/plants/outreach-plants/

https://systemicproject.eu/plants/associated-plants/

What is your motivation for installing membrane filtration and RO?

Biogas plant in Flanders, Belgium

We wanted to reduce the volume of digestate that we needed to transport and also reuse the water (permeate from the membrane filtration and RO) on site. A third reason was that we wanted recover the nutrients instead of creating N_2 gas (biological nitrification-denitrification technology).

Biogas plant in Finland

At our plant we wanted to reduce the water from the feedstock (manure) with 50% by cleaning the condensate from the evaporator to a degree where we could discharge it.

Another reason was that we could use a part of the recovered water for cleaning purposes instead of tap water. However, this was more a 'nice-to-have', because tap water is quite cheap in Finland.

How did you choose a technology supplier or how would you start to test this on your digestate?

Biogas plant in Finland

We did pilot tests to determine the type of membranes and the performance before we made a decision to invest.

Biogas plant in Flanders, Belgium

The best way is to ask the technology supplier to test with a small module on site and to test long enough. Because the surprises (cfr. problems) come after some months.

For the rest, you will have to rely on the experience of the technology suppliers and you cannot do very much yourself during this testing. You will also never find the perfect membrane. For example, we were in the situation where they suddenly stopped producing our type of membranes and then we had to start looking for a new similar type that worked on our digestate.

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How do you chose the membrane type (UF, microfiltration, different charges)? Because all this needs to be adjusted to type of digestate.

Marieke Verbeke, SYSTEMIC project, VCM (BE)
(Waeger, Delhaye, and Fuchs 2010) *recommended ceramic ultrafiltration membranes with pore sizes of 20–50 nm for biogas digestate filtration applications.*

For RO, is it recommended that you only send in input of 1.5%DM to prevent clogging?

Biogas plant in Flanders, Belgium
I think it is also important to know that every type of product you would like to treat on RO, is different. So comparing the settings and constraints for the RO when treating different products is difficult.

Technology provider, The Netherlands

When talking about fouling and clogging, you have to make a different between suspended solids and salts.
Spiral wound RO membranes cannot handle any solids, so you have reduce them maximally in your pre-treatment, otherwise you will need continuously cleaning to keep it operational.
On the other hand salts will cause gradual fouling of the membranes: the more you want to concentrate, the higher the pressure is required (osmotic pressure to overcome). In general you see already scaling occurring before you see limitations based pressure.
The key is to find a balance in administration of cleaning agents (caustic) and anti-scalant for your membrane configuration.
When you monitor the DM content of the input stream well and you can guarantee that the suspended solid content is very low, the design software of the suppliers is relatively accurate in estimating the performance and the cleaning intervals needed.

What are the constraints for ultrafiltration: f.e. UF membranes tend to foul or clog quite fast?

Ultrafiltration can remove particles with a size of up to 0.1 µm. The influent is pressed into the membranes at a low pressure. The membranes should be rinsed regularly, which can be done by using permeate as feed. This will rinse particles from the membranes. Because the membrane is on the inside of the tube, tubular membranes are almost always flowed from the inside out. The adhesion of the membrane to the support layer is the weakest link. The diameter of tubular membranes ranges from 5 to 15 mm. The large surface area that flows through reduces the risk of total blockage of tubular membranes. However, the low packing density leads to high module prices.

Technology provider, The Netherlands
For UF you will need cross flow velocity to clean the UF membranes.
Cross-flow relies on the concept of sending a high velocity cross flow over the membrane surface, which will prevent fouling of the membranes.

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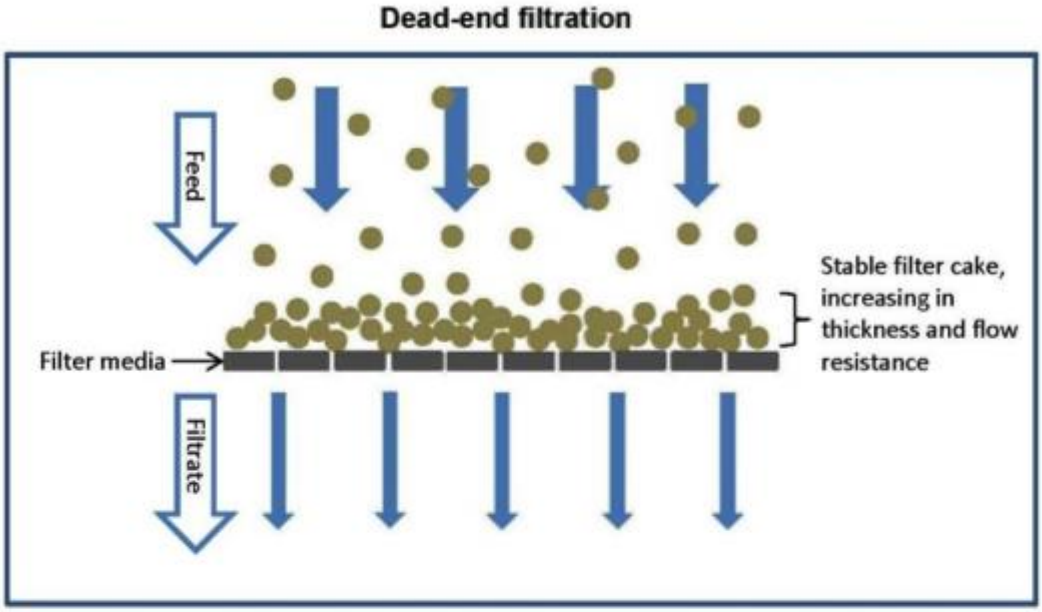

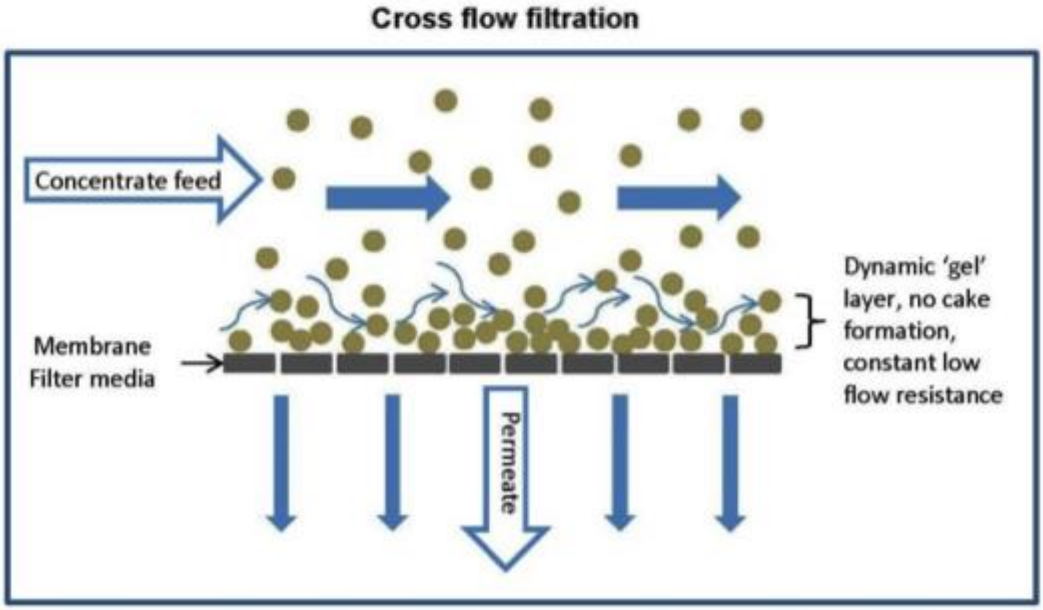

You can also combine it with physical cleaning steps (caustic, anti-scalant).
For chemical cleaning intervals, you should need one every several months. If you want to be safe, once every month.

Because UF can be prone to pronounced organic fouling, repeated permeate backflushing operations and intensive chemical cleaning strategies are required to ensure stable, high membrane performances.
Cleaning is usually done by creating extreme pHs (by adding caustic, NaOH) or chelating agents. In cases where the membranes do not tolerate a high pH, enzymes such as protease and amylase are used as catalysts for the hydrolysis.
Read more about cleaning of the membranes in Chapter "Membrane filtration"

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Of "Schemes and scenarios for nutrient recovery and reuse", 2021
https://systemicproject.eu/downloads/ →Project Deliverables > D 3.2 Final report on schemes and scenario's for nutrient recovery and Reuse (update 2021)

Technology provider, The Netherlands
I don't think that you can have precipitation of salts on UF membranes. Maybe only some struvite, but you are not changing the concentration of the salts, so precipitation cannot occur. Fouling is purely the interaction between particles and the membrane.

There is a big difference in membrane materials in the market, which can really make a difference. But you cannot see it when you look at the membrane, it is 95% the same material and the other 5% makes the difference. So you have to test it to really see the difference and test long enough. Cleaning strategy and intervals also needs to be finetuned depended of the feed stream.

Biogas plant in Flanders, Belgium
We have had problems with our antifoam from the evaporator that was fouling the membranes of the RO. The main problem ware silicones in the antifoam. We could start up the RO, and after 3-4 weeks the flow through the membranes started to decrease. This meant that we eventually had to empty and clean all the tanks with the condensate from the evaporator (containing traces of antifoam) because they all still had a layer of the silicones on them, continuing to foul the RO membranes.

Before sending a stream through the RO, the stream is usually acidified (H_2SO_4) to improve the retention of ammonia (pH 6.6–6.8). The acidification creates a shift in the ammonia equilibrium towards NH_4^+ present, which can then be retained by the membranes as NH_4^+ or ammonium sulphate.

Technology provider, The Netherlands
Indeed, RO membranes can only separate charged material: NH_4^+ is removed for 98-99% but NH_3 (gas) and CO_2 behave like water and go through the membranes and end up in the permeate.

What is your opinion on the following: "Increasing temperatures (20°C and 40°C) lead to reduced viscosities of anaerobic sludges (Gienau, Kraume, and Rosenberger 2018) which can have an effect on the performance of UF."

Biogas plant in Flanders, Belgium
You can heat up to maximum 30°C, but if you go higher this will decrease the separation.

Technology provider, The Netherlands
From the viscosity point of view, there is indeed an advantage. You will have better permeate production and lower energy requirements (because of the lower pressure that is needed).
From an engineering point of view it will become more complex to design the whole system with heating. This could end up being a higher cost than the benefits you would have with the lower viscosity.
Also, sudden changes in temperature can seriously damage the membranes, so I would not go far above 40°C.

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Does membrane filtration/RO require a lot of maintenance? How much time does the staff need to keep the technology operational?

Technology provider, The Netherlands

It depends on how you design the automation of the installation. In theory you can design something that is completely automated and that you only have to refill the chemicals.
In practice, when doing membrane filtration or RO on digestate/manure, the operator should check on it once or twice a day. This way they acquire the experience and can start to do some forecasts on the chemical consumption etc. After that you can integrate it gradually in the whole plant operation.
You also see a lot of installations where they prefer to do the CIP (cleaning in place) manually. This could be a cheap solution if the operator has to spend only 2 days per month on cleaning.
In general, the level of automatization is an (economical) choice of the plant owner.

However, it is important to nuance that membrane filtration can be automated to operate several days or a month on its own, but to a certain degree there is always monitoring by the operator needed.
Every day it needs to be checked if the system is operating well (check the performance by monitoring the membrane pressure etc; look at "trendings"), because everything is happening in closed vessels. Also look on long term trendings, which can reveal underlying emerging problems.

Biogas plant in Flanders, Belgium

Our RO system was completely automated but it still requires some monitoring.
In our previous configuration we were treating purified liquid fraction of digestate with our RO, and now we are treating condensate ("distillate") from the evaporator.
However, we knew how the RO performed on liquid fraction but we do not have much experience yet on how the RO reacts on this new type of feed.
We have had some unforeseen issues like a high pressure pump breaking down and problems with clogged membranes, probably due to the silicone antifoam. As you see, we are still in start-up phase, in which regular monitoring by an operator is required. We will have to see how this evolves, but hopefully treating the condensate in the RO will be easier and less time consuming than treating the liquid fraction.

What about operational costs for UF?

According to (Drosg et al. 2015, Gienau et al. 2018) the ultrafiltration step has the highest operational energy demand and consequently the highest operational costs.
Another technology provider from the Netherlands also indicated that UF for removal of suspended solids (as pre-treatment for RO or evaporation) has too high operational costs, and that there are cheaper alternatives. Currently, they are using with a pre-treatment cascade of flotation unit + belt press to remove suspended solids, which should be cheaper according to them.

Read more about the investment and operational costs of the membrane technology in Chapter "Membrane filtration" of "Schemes and scenarios for nutrient recovery and reuse", 2021
https://systemicproject.eu/downloads/ →Project Deliverables > D 3.2 Final report on schemes and scenario's for nutrient recovery and Reuse (update 2021)

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What are the end products form the membrane filtration and how are they marketed/disposed of?

Biogas plant in Finland

The mineral concentrate (MC) is produced from condensate from the evaporator, so it has only a very low concentration of ammonia and volatile compounds. It will be used for dilution purposes or making polymer solution.
Because of the low amount of ammonia still present, it cannot be used for example for cleaning of trucks (smell issues).

Technology provider, The Netherlands

The MC of Groot Zevert Vergisting is used in the region (pilot region "De Achterhoek") as alternative for mineral fertiliser. They get paid for the amount of N on market level. However, they had to invest in machinery and transportation to apply it on the fields of the farmers. In the end the MC has a negative value for them, but the total balance ends up positive.
Persuading the farmers costs time. We started with 10 farmers and they did a half field with conventional fertilisers and half of it with the MC. The yield was similar but with the MC there were smell issues.
In conclusion, if you would like to get payed for the MC as a fertiliser, you have to be able to deliver the same quality as mineral fertiliser for the farmer (i.e. agronomic performance) but also for his neighbours (i.e. smell issues).
This is important for all anaerobic digester plants: think also in terms of (marketing) products, not just producing biogas.

Also try to provide or have the appropriate (adapted) application machinery for the products (MC) that can reduce ammonia emissions to the air, smell etc.

Technology provider, The Netherlands

Groot Zevert developed a new injection application machine that does this and also is adapted to the amounts of MC that need to be injected. Because the concentration of nutrients is lower than conventional liquid mineral fertilisers, more has to be injected on the same surface but the injector has to be able to keep riding on the same speed than he does when injecting mineral fertiliser or manure.
Also, in the Netherlands there are experts/advisors that provide farmers advice on their fertilisation plan or scheme. Including them in the whole 'project' could also help to convince farmers and give you support. They also have the knowledge on how to adjust your plant operation. For example, we started blending other recovered products (ammonia water, ammonia sulphate) in the MC to make 'tailor-made' MC that responded more to the nutrient demand of crops in the growing season in our region.

Is the permeate clean enough for discharge? Are extra polishing technologies needed?

Biogas plant in Finland

We have earlier experience with activated carbon (AC) after RO. The permeate was already very clean, so the AC was only for reducing remaining odours. AC is relatively expensive.

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Technology provider, The Netherlands

In the Netherlands you cannot achieve discharge limits with only a RO. We use a second RO for polishing and an ion exchanger to reach discharge limits.

Gienau, Tobias, Matthias Kraume, and Sandra Rosenberger. 2018. "Rheological Characterization of Anaerobic Sludge from Agricultural and Bio-Waste Biogas Plants." *Chemie INgenieur Technik* 90(7).

Waeger, F., T. Delhaye, and W. Fuchs. 2010. "The Use of Ceramic Microfiltration and Ultrafiltration Membranes for Particle Removal from Anaerobic Digester Effluents." *Separation and Purification Technology*.

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