During the 1980s and early 1990s considerable efforts were made to develop a commercially viable AnMBR. For example, the “Membrane Anaerobic Reactor System” (MARS) developed by Dorsey Oliver, the “Anaerobic Digestion Ultrafiltration” (ADUF) promoted by Stellenbosch University and the Aqua Renaissance Project initiated by the Japanese government. Ultimately, these efforts were unsuccessful due to a combination of factors including commercial viability and technical difficulties such as reactor instability and membrane fouling.

The first commercially successful AnMBRs did not come until the early 2000s when Kubota developed a number of demonstration-scale AnMBRs in Japan (flow rates between 0.1 – 2.5 m³/h) treating night soil, fixed processing wastewater and sludge from dairies. Based on the success of these demonstration-scale projects, the first full-scale AnMBR was constructed by ADI in 2008 (Christian et al, 2012) using Kubota flat sheet (submerged) membranes, to treat wastewater from a salad dressing producer (flow rate of 12.5 m³/h). ADI have built another 2 full-scale AnMBR systems. 2008 also saw the construction of the first multi-tube (MT) side-stream system demonstration scale-AnMBR treating hay feed from a cattle cheese producer in the USA. This system utilised Pentair’s (formerly hands) ultrafiltration membranes. Based on the success, Veolia (Biethane) and Pentair co-developed a low-energy AnMBR system called Membrane. There are now 7 full-scale Membrane plants.

The water recovery plant treating effluent from Woodlands dairy in South Africa also used a process of AnMBR and RO. This demonstrates the vast potential of the Membrane AnMBR system to achieve energy and water recovery without aerobic treatment.

### TABLE 1 – Membrane AnMBR references and key performance indicators

<table>
<thead>
<tr>
<th>Application</th>
<th>Industry</th>
<th>COD Feed Wastewater (mg/l)</th>
<th>Flux (m³/h)</th>
<th>Removal</th>
<th>Flow (m³/h)</th>
<th>TSS Feed Wastewater (mg/l)</th>
<th>COD Feed Wastewater (mg/l)</th>
<th>Process performance</th>
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<td>40</td>
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<td>20,000</td>
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<td>100,000</td>
<td>Membrane AnMBR</td>
</tr>
</tbody>
</table>

### FIGURE 3 – FULL SCALE ANMBR CONFIGURATIONS

Full-scale AnMBRs are constructed from one of three configurations, flat sheet submerged from Kubota ADI, multi-tube (side-stream) parallel from Veolia Pentair and multi-tube (side-stream) serial from Veolia Pentair. Each of these configurations is shown in Figures 3 to 5 along with the typical flux rate and some comments.

### RESULTS

Figure 4 below shows that the serial configuration with medium cross flow velocity significantly lowered the energy demand for the membranes used in serial AnMBR applications. The parallel configuration has further improved this, while adding a number of other benefits, such as higher flux, which reduces the number and cost of the membranes, and, in reverse flow, which limits reliance on pre-treatment screens and enables full use of all membrane area continuously.

### DISCUSSION

### CONCLUSIONS

- AnMBR is proven with a growing list of full-scale references.
- Of the three AnMBR configurations available, the multi-tube parallel system is the most robust and cost-effective. It achieves the highest flux with the lowest energy input, thus providing a solution that is lower in both capital cost and operating cost than other configurations.
- Energy use is reduced to level that energy balance is at least neutral for most industrial wastewaters.
- There is significant potential for combining the AnMBR process with RO and eliminating aerobic stage.
- The development of membranes is continuously improving process. The application of halocarbon membranes is one of the latest developments of Veolia’s exclusive partner Pentair X-fine. The future outlook is that the filtration efficiency for anaerobic applications will become equal or close to aerobic conditions. This will enhance the cost effectiveness of Membrane applications significantly.

### REFERENCES


Acknowledgement: We would like to acknowledge Pentair, a Veolia exclusive partner in the development of Membrane (Veolia) AnMBR process.

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**AnMBR, Anaerobic Membrane Bioreactor**

**From Concept to Full-Scale and Future Outlook**

**INTRODUCTION**

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