Going Bubbleless: Design and Start-Up of the Full-Scale MABR Demonstration at the Ejby Mølle WRRF

N. Uri*, T. Constantine**, J. Sandino***, A. Willoughby**, P.H. Nielsen*

* VCS Denmark, Odense, Denmark

** Jacobs

*Email: nur@vandcenter.dk

INTRODUCTION

Utilities around the world are increasingly being challenged to “do more with less”, and this is particularly true with respect to both energy efficiency and process intensification, while still achieving or improving upon effluent targets. Membrane aerated biofilm reactor (MABR) technology has emerged as a highly attractive technology that promises to achieve both of these goals. MABRs allow for substantially higher oxygen transfer efficiencies compared to conventional technologies (i.e. fine bubble aeration) and at lower blower discharge pressures, with the result being significantly reduced electrical demand associated with aeration. In addition to the energy benefit, MABRs can be designed to operate in a similar manner to integrated fixed film activated sludge (IFAS) technology by allowing for preferential growth of nitrifying organisms in a biofilm, allowing for reduced suspended growth solids retention times (SRTs) and reduced overall bioreactor volumetric requirements. But despite the potential benefits of this promising technology and the numerous academic studies and pilot-scale tests conducted, there is scarce experience and information on full-scale application of this technology at municipal wastewater treatment plants.

VandCenter Syd (VCS) Denmark operates nine water resource recovery facilities (WRRFs) in central Denmark, the largest of which is the Ejby Mølle WRRF (EMWRRF), which has a population equivalent capacity of 415,000 and is located in the city of Odense. This facility achieved acclaim for becoming net energy positive in 2014 after an extensive process optimization program and as of 2018 is now attaining upwards of 120% electrical self-sufficiency (Constantine et al, 2018).

VCS Denmark, with the assistance of Jacobs, has developed a comprehensive demonstration testing program to validate the benefits of MABR technology (i.e. energy efficiency and process intensification) as well as to obtain further information on the operation and maintenance requirements and optimal operating conditions for the technology. The underlying rationale for carrying out this testing at the Ejby Mølle WRRF has been described in Downing et al (2016) and the primary objective of this follow-up paper will be to provide greater detail on the design of the demonstration testing plant, the testing program that has been put in place, as well as the results from the start-up of the MABR facilities, which were commissioned in September 2018.

DEMONSTRATION SET-UP

As shown in Figure 1, the Ejby Mølle secondary treatment bioreactor facility consists of four common unaerated selector zones in series followed by four parallel oxidation ditches. An optimal location for an MABR demonstration would be one that provides relatively high concentrations of ammonia nitrogen, which necessarily means at the head end of the bioreactor (in the case the unaerated zones), but also has a relatively low soluble COD concentration. This latter desirable attribute would reduce competition for space on the MABR surface by ordinary heterotrophic organisms (OHOs) and maximizes the nitrifier content of the biofilm, thereby improving the “IFAS-effect” for improved process intensification. A key outcome of the previous modelling study was the determination of the optimal location of the MABR demonstration units at the EMWRRF. As shown in Figure 2, the lowest soluble COD concentration would be in Zone 3 (as derived from BioWin™ modelling), and this can be attributed to the fact that Zones 1 and 2 are predominantly utilized for denitrification of the RAS as well as uptake of VFA associated with enhanced biological phosphorus removal (EBPR).

To support the objectives of the demonstration testing, as will be described in the following section detailing the testing program that has been developed, VCS opted to carry out testing of full-scale cassettes both "in-basin" and in a purpose-built "remote tank". In addition, it was decided to test two major vendor technologies, Oxymem and SUEZ, and therefore, four (4) full-size cassettes were procured, and ultimately installed during the summer of 2018.

A generalized P&ID of the pilot setup is provided in Figure 3. As shown, the system includes substantial instrumentation including liquid phase ammonia, nitrate, nitrite, and nitrous oxide; gas phase oxygen content and nitrous oxide; air flow meters; and influent flow meters (for the remote tanks). The pilot design was carefully developed to assist in achieving the objectives and answering key questions as detailed in the following section.

DEMONSTRATION TESTING PROGRAM

A comprehensive testing program was developed to provide answers to the following key areas or questions related to MABR performance:

- **Biofilm management, material accumulation and flow distribution.** To date, the is minimal MABR testing at full-scale and the impact of the exposure to different mixed liquor suspended solids (MLSS) concentrations and dispersible materials (hair, rags, etc.) has yet to be demonstrated. The impact of flow distribution through a MABR module, and/or between different modules installed in a reactor needs to be evaluated.
- **Stress condition response**. Cold water temperatures, varying loading conditions, and diurnal changes in bulk liquid concentrations could have an impact on the biofilm performance.
- **Oxygen transfer rate variability and long-term performance**. Different variables could affect the oxygen transfer and nitrification capacity of the MABR units, such as load variations, extended operating periods, seasonal changes, mixing, and biofilm control strategies.
- **Nitrous oxide production and control**. Research has shown that the MABR produces a unique ecology that reduces nitrous oxide emissions, which is important to VCS Denmark, who are striving to minimize their greenhouse gas footprint.
- **Specific nitrification and denitrification rates**. Measuring nitrification and denitrification rates could provide a large dataset that would allow for better understanding of the process and better control strategies.
- **Microbial ecology**. The microbial ecology can provide insight into the added benefits of the MABR biofilm that are not being guaranteed by manufacturers at this point.

The full paper will provide details of the tests that will be carried out to support answering each of the above questions. Of key importance is the indicators of biofilm health and good mass transfer. The parameters for the evaluation of success criteria in this regard are summarized in Table 1.

STATUS AND NEXT STEPS

The four MABR cassettes were fully commissioned in September 2018 (Figures 4 and 5). Data from the start-up of these systems is now being gathered and by WEFTEC 2019, there will be one year's worth of data collected including analyses as detailed above.

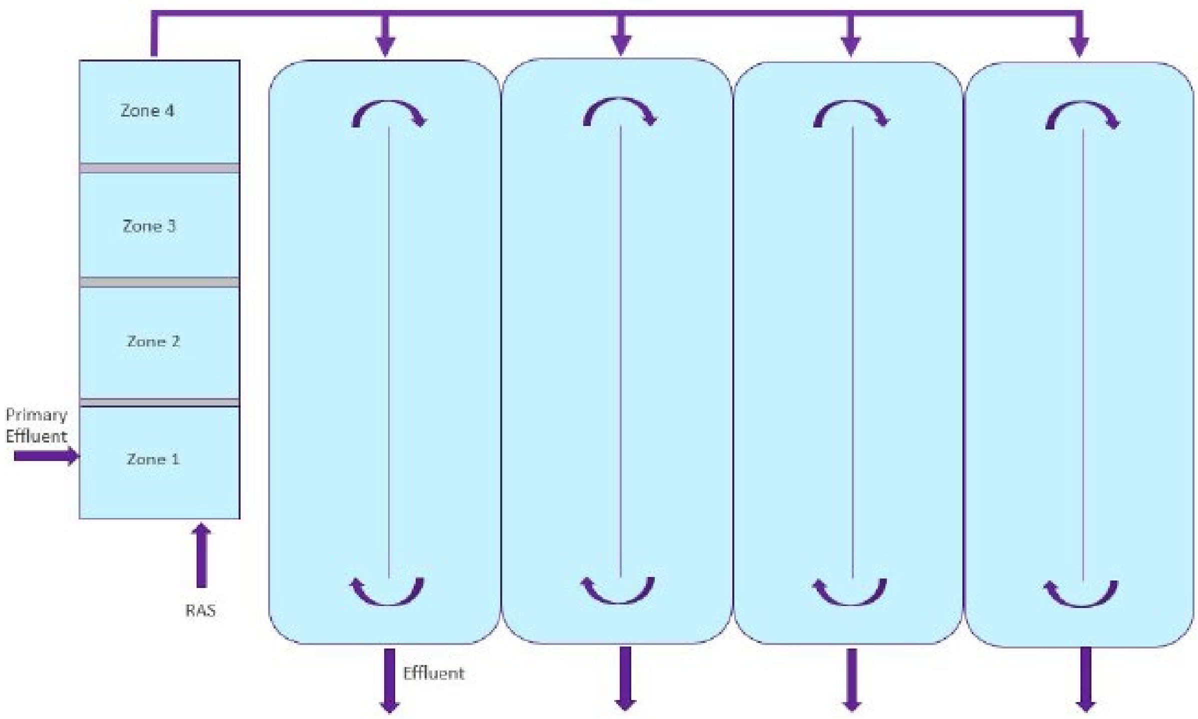

Figure 1: Ejby Mølle's secondary treatment basins' schematic and MABR units in-basin and remote placement

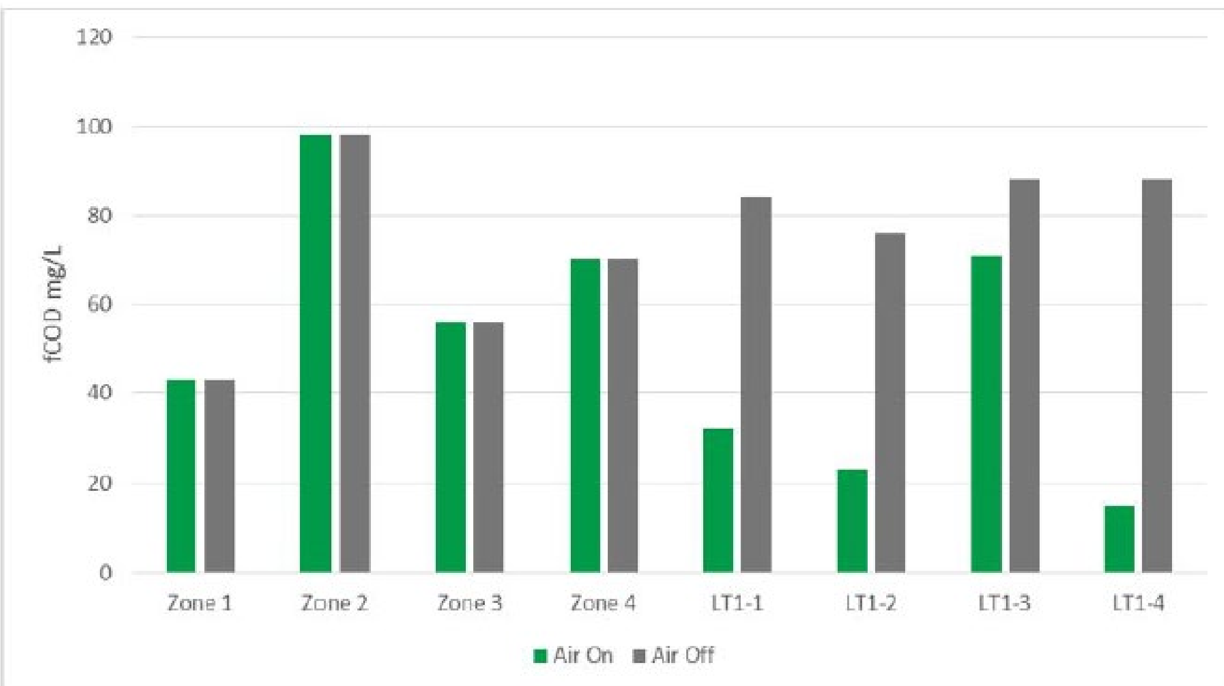

Figure 2: Simulated sCOD profile in the existing Ejby Mølle facility, supporting MABR testing location

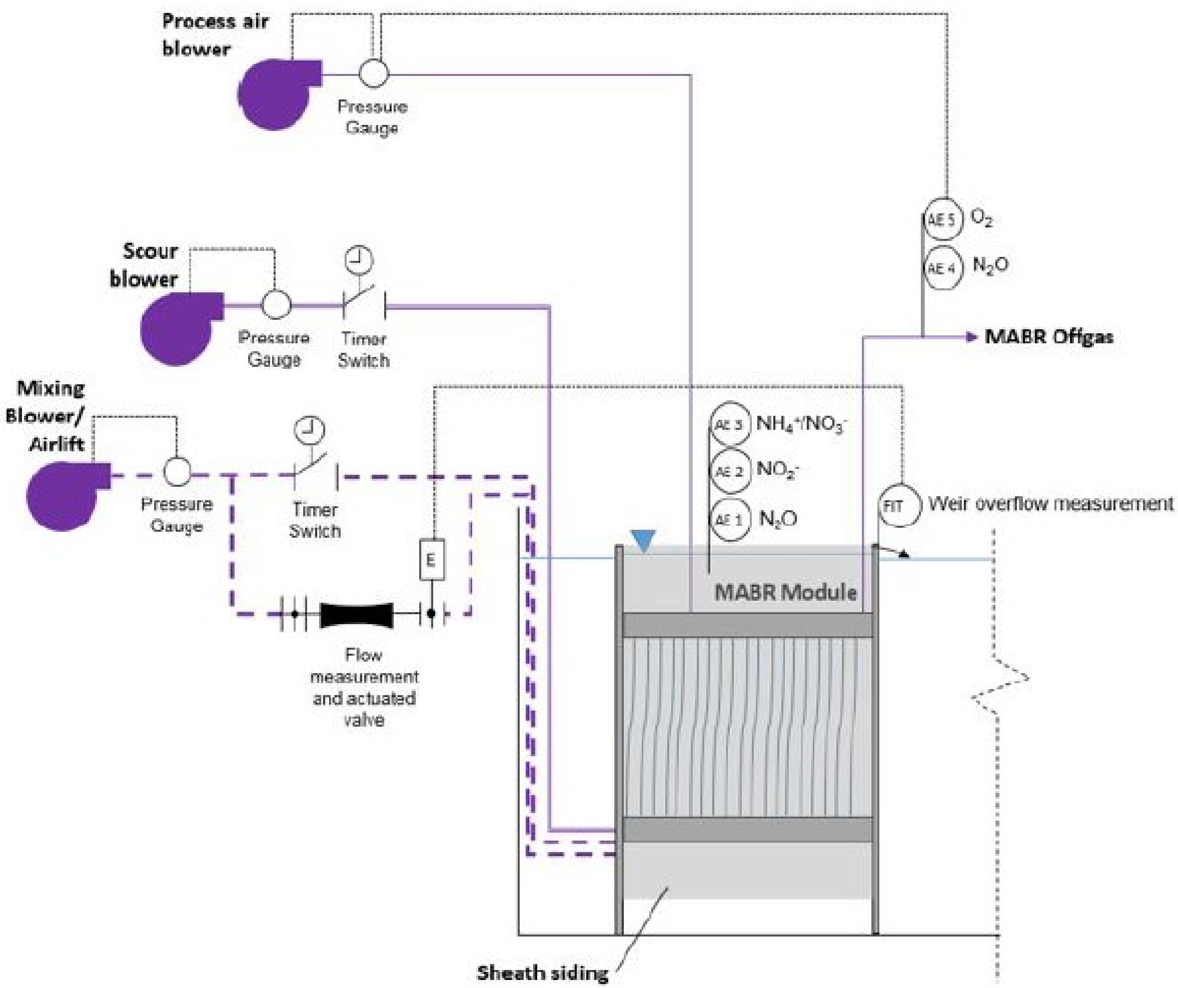

Figure 3: MABR instrumentation and auxiliary equipment schematic

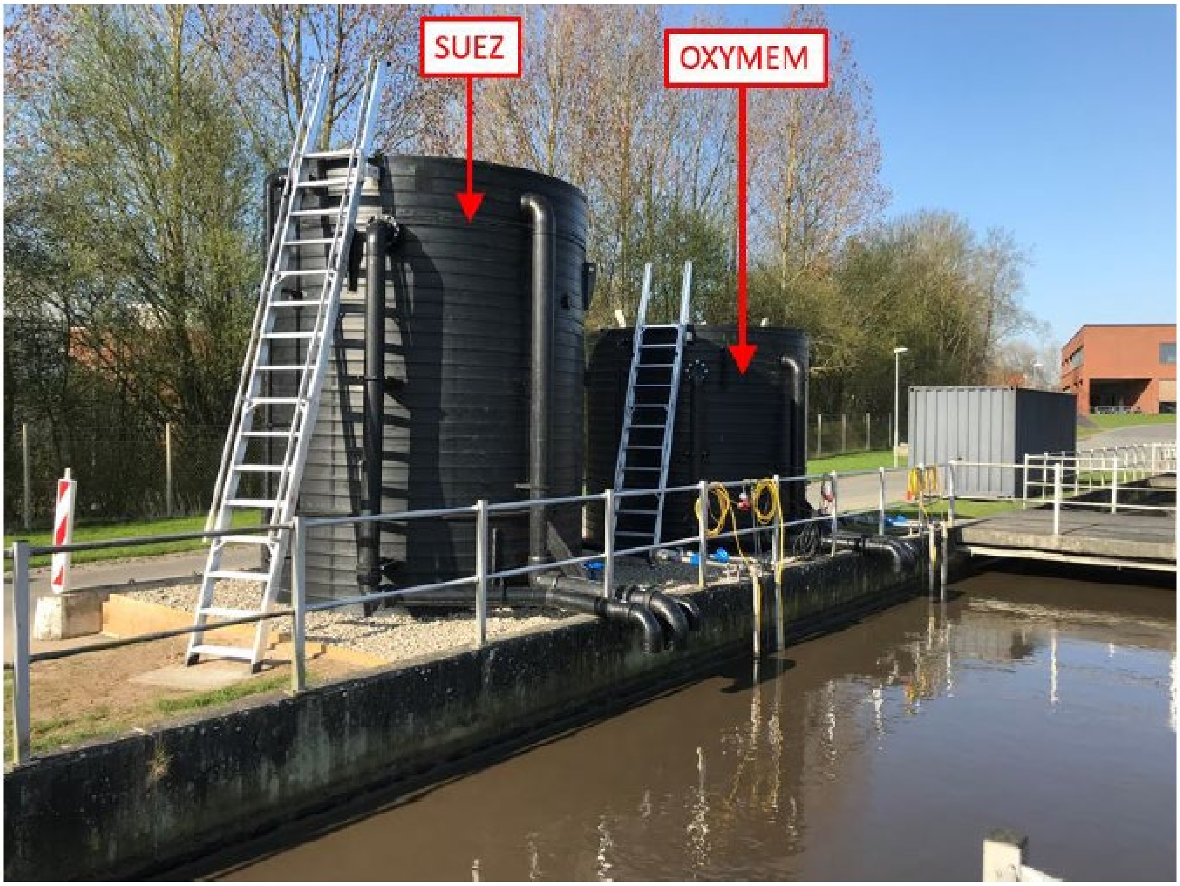

Figure 4: Remote Tank MABR Set-up

Figure 5: In-basin MABR Installation

Table 1: Summary of the main research areas for the MABR units in-basin and in the remote tanks, with the parameters to be measured and the success criteria

	Analysis Areas		**Success Criteria**	
Parameter	**In-basin MABR**	**Remote Tank MABR**	**Year 1**	**Year 2**
Oxygen Transfer Rate (OTR)	Monitored continuously with offgas analysis		• Consistent OTR achieved for given airflow condition • Confirmation of need for scour airflow • Predictable response of airflow rates to OTR	• Optimized process, mixing, and scour airflow rates • Ability to control nitrite shunt confirmed
Membrane Offgas Nitrous Oxide	Monitored continuously with offgas analysis		• Establish relationship between mixing and intramembrane pressure and nitrous oxide emissions	• Establish relationship between mixing and intramembrane pressure and nitrous oxide emissions
Nitrification Rate		Monitored ammonium change from influent to effluent of MABR tank	• Establish relationship between mixing and intramembrane pressure and nitrification rate	• Establish relationship between mixing and intramembrane pressure and nitrification rate
Nitrate and Nitrite Production Rate		Monitored nitrate and nitrite from influent to effluent of MABR tank	• Identify conditions that select for increased nitrite shunt	• TBD
Biofilm Thickness	Online monitoring in OxyMem MABR		• Develop a required air scour airflow rate for use in Year 2	
Material Accumulation	Visual inspection when MABR removed from tank; sampling of biofilm and assessment of VS/TS ratio		• Quantify operating impact on material accumulation	• Quantify operating impact on material accumulation