Towards standardisation of MBR technology ?

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Abstract
Based on an extensive survey of the MBR industry, this article provides an overview of the market interests/expectations and technical potential of going through a standardisation process of submerged membrane bioreactor (MBR) technology in Europe. Eighty representative companies and institutions active in all areas of the European MBR market were individually contacted with an extensive questionnaire, 45 of these companies actually contributed to this study, which demonstrated the interest of the industry in this initiative. There is a pronounced and specific interest in guidelines/standards on interchangeable filtration systems and membrane characterisation methods in MBRs. Benefits and drawbacks, opportunities and threats of MBR standards were defined and mapped. Technical factors in a standardisation process were identified and quantified. The outcomes and recommendations were discussed in a comprehensive White Paper on MBR standardisation. A workshop with 35 participants was organised with the *Centre Européen de Normailisation* (CEN) to present and discuss the results of this study. All attendants accepted the White Paper as a reference document to start a formal procedure of standardisation. This study is expected to pave the way for an appropriate consensus-based standardisation process of MBR technology, which will therefore benefit the entire European MBR industry.

Keywords
CEN workshop; filtration systems; MBR; membrane characterisation; standardisation; survey

INTRODUCTION

The tremendous progresses of MBR technology in the last decade led to dramatic reduction of capital and operational costs. Nevertheless, in most cases MBR remains more expensive than conventional activated sludge treatment for equivalent capacities. Today, the European market is very fragmented and exhibits many MBR filtration products with diverse geometries, module capacities, and operational modes. Although this situation warrants a competitive market it is detrimental for the acceptance of the technology as “state-of-the-art” process, and raises concern with potential clients or end-users. A wish of MBR operators would be to have the possibility to interchange filtration modules of different companies/suppliers. This would facilitate the replacement of the modules at the end of their life, and would reduce the risk of a supplier withdrawing from the market or releasing a new series of product. In addition, all stakeholders in the industry employ various methods of membrane characterisation and module reception, without any real standardisation of practices so far. This contributes to the lower acceptance of the technology, as each supplier proposes different procedures for the use of their MBR product.

STUDY ON MBR STANDARDISATION

Background

In 2005 the European Commission decided to boost the development and application of European MBR processes for municipal wastewater treatment through financing a 3-year research project within the scope of the 6th Framework Program: AMEDEUS (accelerate membrane development for urban sewage purification). Within AMEDEUS (www.mbr-network.eu) and in liaison with the *Technical Committee 165*, in charge of the wastewater technologies, of the *Centre Européen de Normalisation* (CEN/TC 165), an analysis has been performed by Aquafin and Anjou Recherche to

assess the potential for MBR standardisation in Europe.

Scope
Due to the predominance of submerged filtration systems in municipal applications, the study focuses only on this configuration. Two different aspects of standardisation are considered:

- standardisation of MBR filtration modules: towards interchangeable modules in MBRs (analysis performed by Aquafin)
- standardisation of MBR acceptance and monitoring test methods: towards uniform quality assessment methods of MBR filtration systems (analysis performed by Anjou Recherche)

Objectives
The goal of this study is:

- to analyse the market interest and technical potential for dimensional standards, quality & performance standards and test method standards in MBRs
- to provide a groundbreaking publicly available discussion document on MBR standardisation in Europe
- to foster the debate on MBR standardisation in Europe with the different stakeholders and to increase the awareness and interest in the subject
- according to the outcomes and in agreement with the European MBR industry, to initiate a formal procedure of standardisation together with the CEN

Approach
The approach followed in this analysis was based on two considerations:

- Hardly any information on MBR standardisation is available. Somehow, new information needs to be collected to bridge this knowledge gap.
- Standards are mostly the result of a long process in which all interested parties (enterprises, consumers, public authorities,...) can participate. This requires dialogue between the market players.

Therefore, 80 MBR market players in Europe were identified after a thorough market review (MBR filtration system suppliers, operators, constructors, consultants, universities and research institutes), and contacted with an extensive questionnaire on MBR standardisation. The response rate was spectacular and demonstrated the interest of the industry in this initiative: more than half of the contacts cooperated. The 45 replies to the questionnaire were studied and the results were synthesised into a White Paper on MBR standardisation (available for download at www.mbr-network.eu/mbr-projects/downloads-reports.php). An international workshop on MBR standardisation was organised in order to present and discuss the outcomes and recommendations of this White Paper and to define future actions.

RESPONDENT CHARACTERISATION

A large and representative amount of companies provided information on which this paper is based:

- 45 companies contributed, of whom two are leading MBR module producers, as well as the principal outsiders on the European market
- the core activities (suppliers, constructors, operators, other knowledge institutions or experts) are equally represented (around 10 to 15 replies were gathered for each category)
- ten European countries and four non-European countries are represented
- contacts have a significant and long term MBR experience:
    - more than half of them: 6-20 years experience
    - 11 end-users operate 19 MBR plants, of which 13 plants > 1,000 m^3/day

MARKET EXPECTATIONS

Standardisation of MBR filtration systems

Relevance, need, timing, expected impact. The analysis of module standardisation interests and expectations of 45 relevant companies active on the MBR market in Europe indicates that:

- The majority of market players recognise that efforts towards a standardisation study like this one are useful or very useful.
- There is a specific interest in guidelines/standards on interchangeability of MBR filtration modules from every side of the market, for small (100-1000 m3/day), medium (1-100 MLD) and large (>100 MLD) capacities. This interest in standardisation is more pronounced for small-size MBR plants, whereas it is less for the individual household plants and the package plants.
- The majority of the MBR operators, constructors, consultants and non-commercial knowledge institutions are convinced this is the right time to initiate a process of MBR module standardisation. On the other hand, some of the module suppliers are under the impression that initiating a module standardisation process now, would be one or few years too early.
- Most market players expect that interchangeable MBR filtration modules will increase the willingness of decision makers to invest in MBR technology and will contribute to a growth of the municipal MBR market - although they do not believe this standardisation process to be one of the top three driving forces (which are increased design flux, stricter effluent quality guidelines and decreased aeration demand).
- The majority of MBR operators expect a decrease (small or large) in MBR module investment costs as a result of standardisation. While some MBR module suppliers share this opinion, a significant group is more reserved. A minority of module suppliers expect that standardised filtration modules will (probably) lead to a decrease in the quality of MBR products and services.

Potential benefits/opportunities and drawbacks/threats of standardisation. About 20 potential technological, financial, economical, or environmental benefits/opportunities and drawbacks/threats of MBR module standardisation for suppliers and operators were identified and mapped (Table 1). It appears that the number of advantages and disadvantages is quite balanced for both sides of the market, the main advantage perceived by the industry being that standardisation should contribute to the growth of the MBR market. Other main advantages/opportunities are avoidance of vendor lock-in, price decrease and increased trust and acceptance. Main disadvantages/threats for the end-users are over-dimensioning of civil constructions and supplementary works and costs to the peripherals during replacement. Main disadvantages for the module suppliers seem to be the higher competition, lower profit margins and a limitation for innovative module producers to enter the market.

Standardisation of MBR characterisation methods

Acceptance tests. The majority of the respondents, except the plant constructors, believe the harmonization of membrane acceptance tests at module delivery, will probably have a positive impact on municipal MBR market growth. Plant constructors feel that acceptance tests standardisation at plant commissioning can lead to an increase of MBR market growth, while module suppliers are divided about a possible positive impact of standardised tests at plant commissioning. There is a need for operators to receive documentation on the modules they have bought (a kind of traceability protocol), and there is a need for plant constructors to have a method to check the modules at the commissioning stage, as they are in most cases the ones who have to deal with start-up issues. In both situations, either during plant commissioning or module delivery,

membrane suppliers are divided towards harmonisation of protocols.

Table 1 Potential benefits/opportunities and drawbacks/threats of MBR filtration system standards.

	End-user	Module supplier/constructor

+ **Potential benefits/ opportunities**	• Avoids vendor lock-in (sole source contracts)
	  • No technological dead-ends - BAT at all time
	  • Security of supply
	  • Competitive market price guaranteed during re-investments
	• Price decrease
	• Increased trust and acceptance
	• Applying standardisation in tendering
	• Improved comparability of modules
	• Easier/standardised training of operators
		• Bigger market
		• Applying standardisation in design and construction - cost savings
		• Reduction of introduction times for new products and services
		• SMEs may be able to compete (fairly) with large enterprises

- **Potential drawbacks/ threats**	• Civil constructions may be over-dimensioned • Supplementary costs and works to the peripherals • Process + plant performance might be affected (smaller reliability) • Perhaps more complex legal/guarantee matters	• Increased competition • Lower profit margins • Limitation for innovative module producers to enter the market • Can restrict innovation or affect internal R&D efforts - makes differentiation more difficult

Monitoring tests. Membrane bioreactor stakeholders mainly agree that it is time to initiate a process of standardisation of membrane monitoring tests. The majority of the companies expect that a harmonization of the membrane fouling, integrity and ageing methods will lead to an increase of MBR market growth and competitiveness. Respondents show a specific interest for membrane characterisation methods standardisation. More accurately, between 70 and 80% of the respondents has currently an interest in European technical guidelines for a characterisation method on membrane fouling, integrity or ageing.

TECHNICAL CONSIDERATIONS

Standardisation of MBR filtration systems

The technical potential for standardisation of MBR filtration modules for municipal wastewater treatment in Europe was evaluated based on a unique analysis of the majority of submerged MBR filtration modules commercially available. Nine products completely different in terms of design and mode of operation were analysed and compared (Table 2), after collection of technical data provided by suppliers.

The analysis has shown that a standardisation process common for both flat sheet and hollow fiber membranes/modules is riddled with difficulties and challenges. In order to achieve interchangeability of filtration modules not only the prospect of pure dimensional standards for the module itself needs to be considered, but also design and mode of operation of the peripheral components, like the filtration tank, pumps, blowers and pre-treatment. More than thirty technical factors hampering or interfering with a standardisation process were identified and quantified, and their relative potential for affecting the possible outcome was evaluated.

High - extremely high hindering/hampering capacity (4 factors): Module dimensions, filtration tank dimensions, specific permeate production capacity (
Figure 1), specific coarse bubble aeration demand (Figure 2).
These factors are mainly the result of a totally different geometry and design of the filtration module and discussions for the standardisation of MBR filtration systems should in essence focus on these factors.

Moderate to high hindering/hampering capacity (16 factors): Pre-treatment (screen type, mesh width and redundancy), number and diameter of connections to the permeate collection and air supply manifold, MLSS concentration of sludge surrounding the membranes (and related to that: capacity of the sludge feeding/recycle pumps), flushing system of the coarse bubble aeration piping, whether or not to design permeate pumps - a permeate collection tank - chemical storage tank(s) and a lifting tackle or crane, energy consumption.
These factors are mainly the result of the fact that either a number of products are still in the early development phase of their life cycle, or because they will (drastically) increase total costs of module replacement because of required adaptation works to the peripherals.

Low to moderate hindering/hampering capacity (16 factors): Bypass of the pre-treatment, type of connections to the permeate collection and air supply manifold, air venting system on the permeate manifold, equally distributed feeding or recycling of sludge to or from the modules, type of permeate pump(s), type-pressure-redundancy of blower(s), coarse bubble aeration, kind of chemicals, pH and temperature guarantees, whether or not to cover the filtration tank and/or bioreactor - design re-screening of activated sludge over the pre-treatment - permeate heating tank.
These factors will only be a minor issue since they are either part of the common knowledge or practice, or because the module supplier will resign to the design at the moment of membrane replacement.

Table 2 Surveyed filtration systems.

MBR filtration module supplier (or partner, local distributor,...)	**MBR filtration module**	**Configuration**	
		Flat sheet (FS)	Hollow fiber (HF)
A3 water solutions GmbH	A3 module	X	
Koch Membrane Systems GmbH	PURON PSH 500		X
Kubota Membrane Europe Ltd (or HERA AMASA S.A., SOLIS Engineering bv, AV Aggerwasser GmbH)	KUBOTA Submerged Membrane Unit	X	
Martin Systems AG	siClaro FM & siClaro DM	X	
Mitsubishi Rayon Engineering Co., Ltd. (or ROTREAT Abwasserreinigung GmbH & CoKg)	Sterapore SADF & Sterapore SUR		X
Microdyn-Nadir GmbH	Bio-Cel BC-100-50 & Bio-Cel BC-100-100	X	
POLYMEM	IMMEM		X
Toray Industries,Inc. (or Keppel Seghers Belgium)	MEMBRAY	X	
GE - Zenon (or DEGREMONT)	ZeeWeed ZW 500		X

The study on the technical aspects of MBR filtration module standardisation in Europe also revealed that it would be easier and technically wiser to consider two separate standardisation groups: one for flat sheet modules and one for hollow fiber modules. From this study, it cannot be deducted whether a standardisation process would be more straightforward or would go faster for one category as opposed to the other.

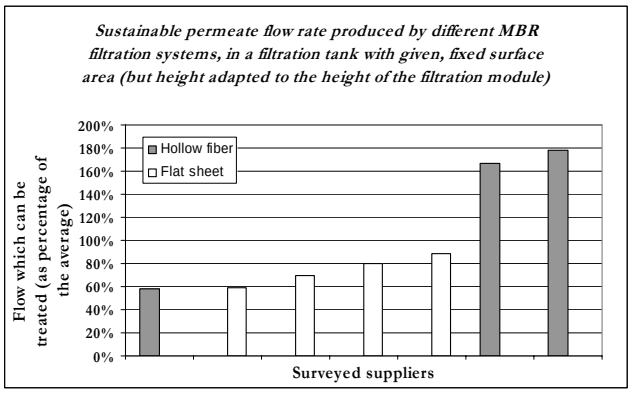

Figure 1 Sustainable permeate flow rate for the surveyed MBR filtration systems.

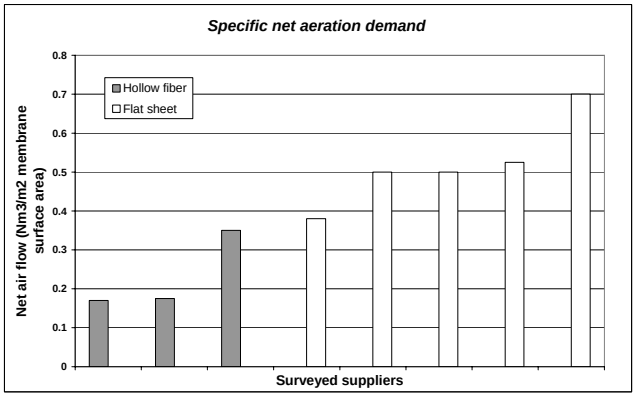

Figure 2 Specific net aeration demand for the surveyed MBR filtration systems.

For each category, more or less the same number of obstacles lies ahead. Nevertheless, the nature of some of these obstacles or points of attention can be different. Some factors are specifically important for FS modules (e.g. flushing of air supply pipes, design of a permeate collection tank), others for HF modules (e.g. type of pre-screening, gravity filtration or not).

Standardisation of MBR characterisation methods

The main operating techniques applied were assessed, and some parameters were identified for integration in a standardisation process.

Simple, well-assessed and well-defined methods to operate membrane filtration systems and to better predict membrane behaviour are necessary. An official and common standard test to check product quality and performances at module delivery and at plant commissioning will probably confirm and extend the position of membrane technology in the wastewater treatment world.

This study emphasizes some important parameters for which a common definition and measurement protocol could be helpful, such as:

- Clearly defined and harmonised parameters to monitor membrane fouling, integrity and ageing.
- A common definition of "membrane life time" for the guarantee clause
- Determination / definition of flux (operation and nominal design)
- Common definition for sustainable peak hydraulic load
- Harmonised tests to check membrane performances over a defined period and under specific conditions

In a second step, the industry would welcome if the following guidelines and characterisation protocols could be established and harmonised:

- Characterization method for membrane acceptance at module delivery
- Minimum requirements and technical methods to check membrane performance at plant commissioning
- Monitoring methods of normalized permeability in clear water, permeability in sludge, trans membrane pressure and fouling rate
- Monitoring methods of sustainable flux and maximum flux
- Operating conditions (biology and filtration systems) for warranty clauses

Harmonisation of parameters definition and measurement methods should precede, or accompany the harmonisation of the technologies in sight of product interchangeability: this will increase trust in the technology, and will also reduce the risk of lower quality products.

Table 3 presents the main membrane monitoring methods commented or suggested by the respondents of the survey. This list could be the basis for the selection and development of harmonised monitoring methods.

Table 3 Summary of main membrane monitoring methods

	Monitoring methods		
	Membrane fouling	Membrane deterioration	Membrane ageing
Main procedures used	TMP	Visual control	TMP
	Permeability	Chemical & biological parameters in permeate.	Permeability in sludge
			Permeability in clean water
(Additional) requirements/considerations in a standardisation process	Prediction of duration to maintain flux level at specified conditions	Turbidity measurement	Membrane surface investigation in laboratory
	Monitoring and controlling biological parameters	Pressure decay test	Threshold values for evolution of normalized flux after chemical cleaning and performance after an active cleaning
		Integrity indicators	
		Visual control	Turbidity

RECOMMENDATIONS - TOWARDS CEN WORKSHOP AGREEMENTS ?

Developing European MBR standards will definitely be a time-consuming and delicate process, but meanwhile CEN Workshop Agreements (CWAs) might be a good approach to get there. A CWA bridges the gap between consortia documents and European Standards (EN). It is a technical agreement, developed by the participants in an open CEN workshop structure within the framework of CEN and owned by CEN as a publication. It is this openness that distinguishes the CWA from documents developed by industry consortia featuring limited participation (commonly known as de facto standards). Participants to a CEN Workshop are interested in developing one or more reference documents where neither the lack of openness of a de facto standard nor the rigour and consensus of a EN is judged to be appropriate, but which still possesses the authority derived from openness of participation and consent. Participation in such a workshop will be open to anyone and the opportunity to participate will be widely advertised in advance by its proposers and by CEN. A CWA may be further developed into a EN if such additional authority is required by the market by transferring it into the traditional CEN committee process.

On 24/11/06 a workshop was organised in Berlin by the AMEDEUS consortium together with the Deutsches Institut für Normung (DIN), the national normalisation institution secretary of CEN/TC165, to present the White Paper on MBR standardisation to the industry, to debate the results of this study and to discuss future actions. 35 MBR representatives from 9 different countries participated in this workshop. The major outcomes are:

- The White Paper was accepted by plebiscite: the participants replied unanimously positive to the question “Can the White paper be used as a reference document to initiate a procedure of standardisation within the MBR industry?”
- A large majority of the companies argues that their company would be interested one way or another to commit/participate in a process of standardisation of submersed MBR filtration systems (75%) and membrane characterisation methods (90%) in the coming years.
- A minority of the participants believe normative standards are not needed for submerged MBR filtration systems (25%) or membrane characterisation methods (15%). Instead they favour the development of technical guidelines.

- A significant amount of the participants (40%) argue that normative standards for both MBR filtration systems and membrane characterisation methods are needed only within a few years.

Furthermore, the representatives of the MBR industry present at this workshop:

- decided to initiate a standardisation process on submerged MBR technology through a CEN Workshop Agreement (CWA)
- decided that the scope of this CWA may include the following:
    - common terms and definitions of MBR technology
    - characterisation and test methods of the product (acceptance tests) and operation (monitoring tests)
    - set of guidelines to facilitate interchangeability of MBR filtration systems
- decided to ask the AMEDEUS project and DIN to develop the draft Business Plan in cooperation with interested parties

CONCLUSIONS

There is a pronounced and specific interest in guidelines/standards on the interchangeability of MBR filtration modules and membrane characterisation methods. Most market players expect standardisation will increase the willingness of decision makers to invest in MBR technology and will contribute to a growth of the municipal MBR market. A majority of the surveyed companies is convinced this is the right time to initiate a process of MBR module standardisation. Benefits and drawbacks, opportunities and threats of MBR standards were identified and mapped. Technical factors forming the possible subject in a standardisation process were identified and quantified. All results, outcomes and recommendations were published in an extensive White Paper. A preliminary reconnaissance workshop was organised to present and debate the results of this study to the MBR industry, and to discuss future actions. The large majority of participants to this workshop argues that this study can be used as a reference document to initiate a procedure of standardisation within the MBR industry. Upcoming actions like the redaction of a CEN Workshop Agreement were defined. The White Paper and preliminary workshop are expected to pave the way for an appropriate standardisation process of MBR technology, which will benefit the entire European MBR industry.

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The recommendations herein are those of the authors, and do not necessarily reflect the positions of the EC, CEN, DIN or any of the companies who replied to our questionnaire.