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Submerged Membrane Bioreactor (MBR) Technology

Getauchte Membranbelebungsreaktor (MBR) Technologie

Technologie MBR - Bioréacteurs à membrane immergée

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Technologie MBR - Bioréacteurs à membrane immergée

Getauchte Membranbelebungsreaktor (MBR) Technologie

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European foreword

This document (CEN/TR 15897:2018) has been prepared by Technical Committee CEN/TC 165 “Wastewater engineering”, the secretariat of which is held by DIN.

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This document is based on the CWA 15897:2008, Submerged Membrane Bioreactor (MBR) Technology which was prepared by the CEN Workshop 34 – 'Submerged' Membrane Bioreactor (MBR) technology.

This document supersedes CWA 15897:2008.

Introduction

This document deals with custom designed MBR systems for more than 500 PT. It became clear that it is not possible to have interchangeable membrane modules without considering a complete system. So this led to the conclusion that this document deals with the entire membrane system rather than the membrane modules alone.

It was realized that today's market is a growing one with fast developments in membrane technology. Standards might be too early and may hamper the technological development. So it was decided at this stage to create a basic document for submerged MBR technology by means of a Technical Report.

Regarding interchangeability of MBR systems, this document especially focuses on separate membrane tanks as there is a tendency that large MBR systems (more than 10 000 m3/d) are designed with separated membrane tanks.

Although there are differences between hollow fibre and flat sheet membrane manufacturers' designs, it is believed that there is no need for separate guidelines because these are focused on membrane tanks. Furthermore, it is clear that interchangeability between hollow fibre membrane systems is not so easy and the same is true for flat sheet membrane systems. Thus, producing two sets of guidelines would be of no real benefit to interchangeability.

1 Scope

This Technical Report defines terms commonly used in the field of membrane bioreactor technology.

This document aims at submerged MBR systems for the treatment of municipal wastewater with MBR Separate Systems and MBR Integrated Systems.

This document establishes general principles for MBR filtration systems interchangeability between different MBR filtration systems from different manufacturers.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12255-11, *Wastewater treatment plants - Part 11: General data required*

EN 16323, *Glossary of wastewater engineering terms*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 16323 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

• IEC Electropedia: available at http://www.electropedia.org/

• ISO Online browsing platform: available at http://www.iso.org/obp

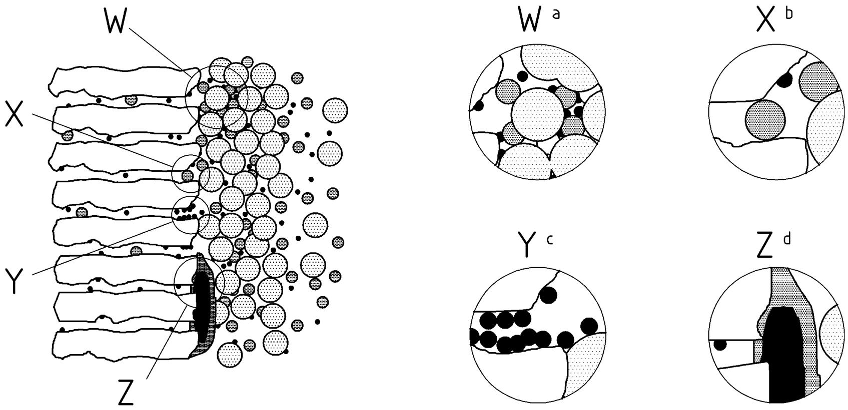
NOTE Some manufacturers may use different terms for their products, but nevertheless the following terms and definitions are used in this document.

3.1
backwashing
backflush
backpulse
short-term reversal of the flow direction through the membrane in intervals to remove the particles accumulated during the filtration process (covering layer), usually with permeate

3.2
biofouling
development of a biofilm on the membrane surface or in the membrane due to the growth of micro-organisms

Note 1 to entry: See Figure 1.

Note 2 to entry: Biofouling causes a reduction of the performance or the permeability (see also fouling and scaling).



Key

W	irreversible cake layer	a	adsorption, compaction precipitation, inclusion of colloids, etc.
X	pore blocking	b	particle diameter approximately Pore diameter
Y	inner pore adsorption	c	permeable substances with affinity to membrane material
Z	biofouling	d	microorganisms in film consisting of EPS

Figure 1 — Principle of biofouling

3.3
cleaning interval
interval of time between successive cleanings

Note 1 to entry: Depending on the manufacturer there might be different types of cleanings (see 3.26 and 3.34).

3.4
clogging
accumulation of solids within the membrane system

3.5
concentrate
partial flow of the material mixture in which the activated sludge retained by the membrane is concentrated

Note 1 to entry: It is usually recycled as return sludge into the activated sludge tank.

3.6
covering layer
accumulation of substances retained by the membrane surface

3.7
cross flow
transverse flow which develops at the membrane surface and serves to control fouling

Note 1 to entry: The term cross flow comes from the configuration of the dry-arranged membrane systems operated in a pressure vessel. During this process, the membranes are subjected to liquid flows parallel to the surface that limit the development of a covering layer on the membrane surface.

3.8
cross flow aeration
aeration required to induce cross flow

Note 1 to entry: As a result of the two-phase flow, the effective mechanisms clearly differ from the principle of classic crossflow operation of pressure tube systems with inside flow.

Note 2 to entry: The cross flow aeration flow rate per unit membrane surface area is expressed in $Nm^3/m^2/h$.

3.9
cycle
temporal sum of filtration phase and following backwashing phase and/or relaxation phase

3.10
Dalton
Da
molecular mass relative to that of a hydrogen atom

3.11
feed flow
flow to the membrane bioreactor system at the inlet of the aeration tank

3.12
filament
single hollow fibre or capillary tube

3.13
flux
specific filtrate volume per unit surface area per time unit

Note 1 to entry: The flux is expressed in litres per square metres of membrane surface area, per hour, $[l/(m^2h)]$. In some cases the abbreviation LMH is used.

3.14
flux, instantaneous
flux, gross
actual flux during filtration

3.15
flux, net
overall flux achieved during the filtration cycle including periods of filtration and relaxation and/or backwashing

3.16
flux, corrected
flux viscosity-corrected for temperature

Note 1 to entry: The water temperature has a major impact on the maximum allowable flux, due to the fact that the transmembrane pressure (TMP) is theoretically proportional to the water viscosity.

Note 2 to entry: The following equation gives a good approximate value of the viscosity vs. temperature:

$$\frac{\nu_t}{\nu_{20}} = 0{,}3804 + 0{,}1696 * EXP(0{,}040 * (20 - t)$$

Where

ν_t is the water viscosity at t °C

ν_{20} is the water viscosity at 20 °C

3.17
flux, critical
flux below which permeability decline is considered negligible

3.18
flux, sustainable
flux for which the transmembrane pressure increases gradually at an acceptable rate, such that chemical cleaning is not necessary

3.19
fouling
deposition of existing solid material in the feed stream on the element of the membrane at or in the pores

Note 1 to entry: Fouling can either be reversible or irreversible.

Note 2 to entry: Depending on the material involved, a distinction can be made between organic fouling, inorganic fouling and biofouling. Fouling always results in a reduction of the performance or the permeability of the membrane (see also biofouling and scaling).

3.20
lumen
interior of a hollow fibre membrane

3.21
maintenance cleaning
cleaning with low concentrations of chemicals to maintain membrane permeability

Note 1 to entry: Maintenance cleaning is usually carried out *in situ*.

Note 2 to entry: Maintenance cleaning uses less aggressive procedures and/or chemicals than recovery cleaning.

3.22
MBR integrated system
system where the membranes are placed in the aeration tank

3.23
MBR Separate System
system where the membranes are placed in the separate membrane tank

Note 1 to entry: See 3.35.

3.24
membrane element
smallest unit of operation typically combined in assemblies known as modules, units, racks or cassettes

Note 1 to entry: A membrane element could also be called a panel or cartridge.

3.25
membrane area
feed side area of the membranes

Note 1 to entry: The membrane area is expressed in m^2.

3.26
membrane packing density
membrane area per unit volume of a membrane assembly

Note 1 to entry: The membrane packing density is expressed in m^2/m^3.

3.27
panel
flat sheet membrane element

3.28
permeate
filtrate
portion of the feed stream that passes through the membrane

3.29
permeability
property of a material characterising its ability to selectively permit substances to pass through it

Note 1 to entry: The permeability is expressed in $l/(m^2 \cdot h \cdot bar)$.

Note 2 to entry: The permeability can be corrected to a reference temperature in order to allow a more accurate comparison of values.

3.30
permeability, corrected
permeability corrected for the effect of temperature on viscosity

Note 1 to entry: The corrected permeability is expressed in $l/(m^2 \cdot h \cdot bar)$ considering a reference temperature.

3.31
pore diameter
pore size
size of the pores in the membrane

Note 1 to entry: As a rule, the pores are not uniform, i.e. they show a relatively wide pore size distribution.

Note 2 to entry: The pore diameter with a maximum in pore size distribution is called the nominal pore diameter.

Note 3 to entry: The pore diameter is expressed in µm.

Note 4 to entry: The maximum pore diameter can be determined with the help of the bubble point method according to DIN 58355-2, which is used to determine the pressure required to extrude the first air bubbles through the membrane. The maximum pore diameter is then calculated by means of a formula.

3.32
recovery cleaning
intensive cleaning
cleaning with high concentrations of chemicals to recover membrane permeability

Note 1 to entry: Recovery cleaning is either carried out *in situ* or in a separate cleaning tank.

3.33
relaxation
ceasing permeation whilst continuing to scour the membrane with air bubbles

3.34
scaling
precipitation of inorganic solids in or on the membranes

3.35
separate membrane tank
membrane tank
filtration tank
separate basin containing submerged membranes where the primary function is filtration

Note 1 to entry: The volume of the separate membrane tank filled with mixed liquor can be considered as biological treatment volume.

3.36
surface porosity
percentage of the membrane surface occupied by the pores

3.37
transmembrane pressure
TMP
pressure loss across the membrane

Note 1 to entry: The transmembrane pressure is expressed in kPa or bar. For practical measurement see 7.4. In practice this measurement includes losses attributable to the hydrodynamics of the system.

3.38
viscosity
property of a fluid to resist internal movements (turbulences) or global movements (flowing)

Note 1 to entry: Viscosity contributes to pressure loss in water flowing in pipes or through membranes.

There are two types of viscosities:

— dynamic (or absolute) viscosity μ (Pa·s);

— kinematic viscosity $\nu = \frac{\mu}{\rho}$ (m^2/s).

Where

P is the specific gravity of the fluid (kg/m^3).

3.39
clean water permeability
corrected permeability of membrane in clean water

4 General system — requirements

4.1 Basic considerations

Possible negative effects on MBR system performance can arise from:

— fibres and/or hair;

— organic solvents;

— fats, oils and greases;

— synthetic polymers;

— limited biodegradability;

— temperature;

— abrasive substances (e.g. sand);

— silicon;

— calcium;

— alkalinity;

— flow (sewer infiltration);

— type of sewer system;

— unwanted short-circuiting of raw, untreated wastewater directly to the membrane.

In the case of severe negative effects predictable from the wastewater characteristics - especially in the case of unfavourable COD/BOD ratios and of industrial wastewater fractions - a feasibility membrane test should be carried out to assess the suitability of the membrane bioreactor process. The aims of such a test are to evaluate the principal filterability and to estimate the filtration performance over time. Whereas for reverse osmosis a simple parameter such as SDI (silt density index) is used to evaluate the feasibility of the process application, such a parameter does not exist for membrane bioreactors. The main difference is that for membrane bioreactors the feed is activated sludge and not the raw wastewater. Thus the feasibility test has to be conducted with activated sludge as the raw wastewater characteristics are of limited use. As membrane fouling interactions are always dependent on the properties of a fouled membrane, a prediction of membrane filterability based on the characteristics of a clean/new membrane is unreliable.

Comparative pilot-scale tests are the most reliable means of predicting the suitability of membrane bioreactors for a specific wastewater. Under the given wastewater conditions the comparative studies should be directed towards resolving the following issues (adopted from [13]):

— functionality and performance of the membrane (peak flux, critical or sustainable flux);

— biological treatment (COD removal, nitrogen removal, phosphorus removal, sludge characteristics);

— membrane fouling (TMP evolution, fouling rate);

— achievable effluent quality;

— system operability;

— cleaning procedures.

Even if bench-scale or pilot-scale tests were performed the relative contribution of biomass supernatant to the overall membrane fouling varies in a wide range from 17 % to 81 % [7] and emphasizes the need of a comparable protocol to minimize the impact of differing test conditions. Because of different module designs general specifications of applicable pilot plants are impractical. Therefore because of a well-established membrane bioreactor market with several suppliers [6] the know-how of the suppliers should be used for the design and operation of the pilot plants.

The following criteria have been recommended [13] for the pre-selection of membrane suppliers for a comparative pilot-scale test series:

— world-wide experience with full-scale applications of membrane bioreactor technology;

— expected technical suitability for application of the membranes for the given wastewater and the given circumstances;

— future membrane production capacity and pricing;

— liability of the companies involved.

The full self-supporting and independent pilot plants should be equipped with all features necessary for automatic operation including data collection and processing. The size of the pilot plants should be according to the prerequisite of a representative scale [13]. The use of a standard full-scale membrane module is necessary for reliable results.

Prior to the start-up of an installed membrane bioreactor the clean water permeability (PWP) and the membrane integrity should be determined. These two parameters are reliable tools for the quality control and the monitoring of the membrane status during the life-time by the end-users.