



*Guidance WQD-002
August 2017*

GUIDANCE

Membrane Bioreactor (MBR)

This guidance document is intended to provide general design criteria since the Oklahoma Department of Environmental Quality (DEQ) has no official regulations in place for the design and construction of a membrane bioreactor. The DEQ Water Quality Division has a Variance Committee (OAC:656-3-7) to review processes or equipment not specifically covered by the standards in Chapter 656 provided the permittee requests a variance.

Definitions

Membrane bioreactor (MBR) – an activated sludge process, most commonly used for secondary treatment of municipal wastewater, which combines a suspended growth biological reactor with solids removal via filtration in a single unit

Microfiltration – a type of physical filtration process where a contaminated liquid is passed through a semipermeable membrane, typically with a nominal pore size of 0.1 – 0.4 μm , to remove microorganisms and suspended particles

Abbreviations

CIP – Clean-in-place

DO – Dissolved oxygen

DEQ – Department of Environmental Quality

ER – Engineering report

MBR – Membrane bioreactor

MLSS – Mixed liquor suspended solids

O&M – Operations and maintenance

SRT – Solids retention time

WWTP – Wastewater treatment plant

Applicable OAC Sections

OAC 252:656-16

Background

The MBR process is capable of producing an effluent quality equal to that of the combination of conventional activated sludge, secondary clarification, and microfiltration. The high-quality effluent produced makes MBRs suitable for surface water discharge applications or reuse applications. Typical performance data for treatment of domestic wastewater is shown in Table 1 below.

The design of an MBR has a smaller footprint and the same requirements as an activated sludge system, but with additional requirements as follows:

- (A) Pilot Study. Perform a pilot study to determine design parameters through testing and evaluations made under the supervision of a competent process engineer. Submit the pilot study protocol to the DEQ for review prior to commencing the study.
- (B) Pretreatment.
1. Provide fine screen(s) with spacing no larger than 1-2 mm for hollow fiber membranes or no larger than 2-3 mm for flat plate membranes consistent with membrane manufacturer requirements.
 2. The membranes will require frequent cleaning. Discuss clean-in-place (CIP) system in the engineering report (ER), as determined by the pilot study.
 3. Provide fully redundant fine screens for WWTPs with membranes.
 4. Provide grit removal if primary clarification is not provided.
 5. Provide pretreatment to remove fats, oils, and grease as determined by the pilot study to prevent fouling of the membranes.
- (C) Biological Treatment for MBR Systems.
1. Design the mixed liquor suspended solids (MLSS) concentration range to be less than 12,000 mg/L, with the preferred concentrations between 8,000 to 10,000 mg/L. MLSS will be verified during the pilot study.
 2. Design the solids retention time (SRT) to be greater than or equal to 10 days (range of 10-20 days). The justification for the design basis must be from pilot study results and/or long-term process data from similar facilities to demonstrate that no detrimental impacts on membranes and its permeability will occur.
 3. Provide aeration tank volumes and select aeration system that is capable of meeting the predicted oxygen uptake rate at the design MLSS concentrations.
 4. Provide a clear rationale for the α value selected in the ER. Higher mixed liquor concentration in MBRs is expected to result in lower design α values than for conventional activated sludge.
 5. Provide aeration blowers to supply adequate air for membrane scour and process requirements. Blower redundancy criteria shall be as defined in OAC 252:656-16.
- (D) Sludge Recycling and Wasting.
1. Design sludge recycle rates for MBR systems to be at least 400 percent of influent flow. The ER must include justification for the selected recycle rate, taking into account peak hour flows and dissolved oxygen (DO) requirements in the aeration basin.
 2. Sludge recycle pumps must include provisions for operator adjustment.
 3. Include in the ER the means to prevent excess DO from entering anoxic and anaerobic zones (if applicable) or account for oxygen recycle.
 4. Identify in the ER the location(s) and metering of waste sludge flow (e.g., membrane basin, aeration basin, recirculation lines, or basin surfaces).
- (E) Membrane Design Factors.
1. Size the MBR system (including membranes and flow equalization) to hydraulically pass peak instantaneous flows anticipated in the MBR reactors.

2. Identify in the ER the average day, peak hour, and peak day flux based on design temperature, solids concentration, and solids retention time.
 - a. Design average flux at maximum month flows to be no greater than 15 gallons per day per square foot (gpd/ft²) at 68°F (20°C), with adjustment for lower temperatures.
 - b. Design maximum flux at peak hour flow to be no greater than 30 gpd/ft² at 68°F (20°C), with adjustment for lower temperatures.
 - c. Design maximum flux at peak day flow to be no greater than 23 gpd/ft² at 68°F (20°C), with adjustment for lower temperatures.
 - d. Facilities that expect a peak instantaneous flow rate greater than 2.5 times the maximum month average daily flow must accommodate higher flows with equalization volume, off-line storage, or reserve membrane basin capacity.
3. Membrane Cleaning.
 - a. Identify in the ER an appropriate combination of cleaning strategies to maintain membrane permeability.
 - b. Hollow fiber membrane cleaning methods must include air scour, backpulse/backwash, chemical backwash, clean in place (CIP), chemically enhanced backwash, and recovery cleaning.
 - c. Flat plate membrane cleaning methods must include air scour, relaxation, and CIP.

(F) Redundancy.

1. Design the MBR process to treat the daily average flow with one membrane train/tank out of service (e.g., 4 design tanks + 1 out of service = 5 total).
2. Design the facility to run in full manual mode in case of an automatic control failure. An operational backup programmable logic controller is required if manual control is not practical.
3. Provide the facility with sufficient standby power generating capabilities for continuous flow through the membranes during a power outage (e.g., preliminary screening, process aeration, recycle/RAS/permeate pumps, air scour, vacuum pumps) or an adequate method to handle flow for an indefinite period (e.g., private control of influent combined with contingency methods).

(G) Other MBR System Considerations.

1. Design the MBR for scum and foam control. Discuss scum and foam control in the ER.
2. Design the MBR for easy removal of the membrane cartridges for cleaning considering the membrane cassette wet weight plus additional weight of the solids accumulated on the membranes.
3. Design the MBR to include provisions for the operator to monitor membrane integrity as defined in the ER and O&M manual. On-line continuous turbidity monitoring of filtrate or equivalent must be provided for operational control and indirect membrane integrity monitoring.

Table 1. Typical operational and performance data for a membrane bioreactor

Parameter	Unit	Typical
Operational data		
COD loading	kg/m ³ ·d	1.2-3.2
MLSS*	mg/L	5,000-20,000
MLVSS	mg/L	4,000-16,000
F/M	g COD/g MLVSS·d	0.1-0.4
SRT	d	5-20
τ	h	4-6
Flux	L/m ² ·d	600-1,100
Applied vacuum	kPa	4-35
DO	mg/L	0.5-1.0
Performance data		
Effluent BOD	mg/L	<5
Effluent COD	mg/L	<30
Effluent NH ₃	mg/L	<1
Effluent TN	mg/L	<10
Effluent Turbidity	NTU	<1
Source: Metcalf & Eddy, <i>Wastewater Engineering Treatment and Reuse</i> , 2003, p. 858.		

* See Section (C) 1. for Design Criteria.

References

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3. Water Environment Federation; American Society of Civil Engineers; Environmental and Water Resources Institute (2009) *Design of Municipal Wastewater Treatment Plants*, 5th ed.; WEF Manual of Practice No. 8; ASCE Manual and Report on Engineering Practice No. 76; McGraw-Hill: New York

4. Wilf, M.; Bartels, C.; Bloxom, D.; Christopher, J.; Festger, A.; Khoo, K.; Frenkel, V.; Hudkins, J.; Muller, J.; Pearce, G.; Reardon, R.; Royce, A. (2010) *The Guidebook to Membrane Technology for Wastewater Reclamation*; Chapters 7-10 on Membrane Bio-Reactors (MBR); pp 249 – 324, Balaban Publishers Desalination Publications Science and echnology Park of Abruzzo Via Antica Arischia 1, 67100 L’Aquila, Italy
5. Libing Chu and Chuping Li, “Filtration capability and operational characteristics of dynamic membrane bioreactor for municipal wastewater treatment,” *Separation and Purification Technology*, Volume 51, Issue 2, September 2006, Pages 173-179, www.sciencedirect.com.
6. Wastewater Management Fact Sheet, “Membrane Bioreactors,” EPA, September 2007.
7. Hector Monclus, Jan Sipma, Giuliana Ferrero, Ignasi Rodriguez-Roda, and Joaquim Comas, “Biological nutrient removal in an MBR treating municipal wastewater with special focus on biological phosphorus removal,” *Bioresource Technology*, Volume 101, Issue 11, June 2010, Pages 3984-3991, www.sciencedirect.com.
8. Metcalf & Eddy. 2003. *Wastewater Engineering, Treatment and Reuse*. 4th ed. McGraw-Hill, New York.