

# Water Reuse: Microorganism Removal (Title 22 Equivalency) Testing

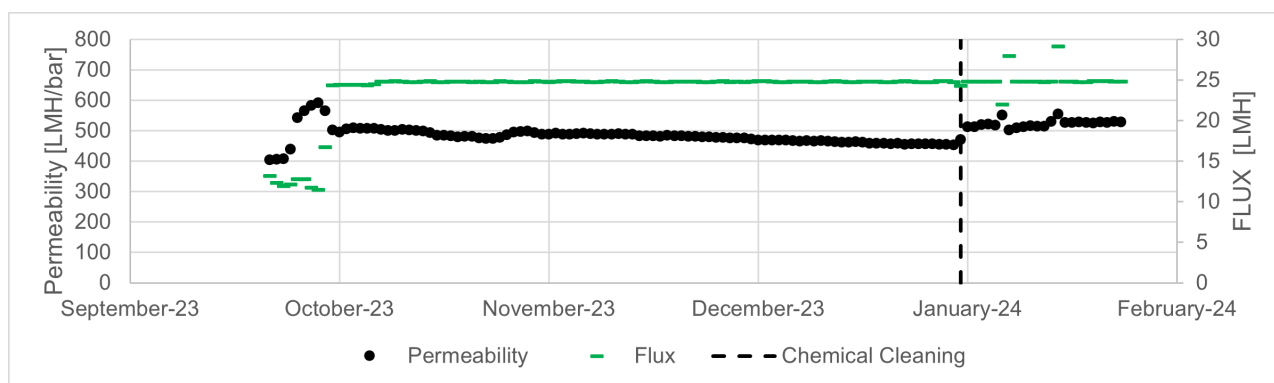
BIO-CEL L+480 equipped with new PVDF ultrafiltration membrane (UV400T).

Microorganism removal (Title 22 equivalency) trials using full scale BIO-CEL L+480 with UV400T membrane were carried out at the wastewater treatment plant at the Angel of the Winds Casino in Arlington, Washington. The L+480 module consists of 120 laminate membrane sheets with a total active area of 480 m<sup>2</sup> (5167 ft<sup>2</sup>). The BIO-CEL UV400T membrane is a polyvinylidene fluoride (PVDF) ultrafiltration membrane with a nominal pore size of 0.06 µm.

The State of California defined Title 22 equivalency standard for the testing of polymeric membrane products to ensure they could produce water that complied with membrane filtered water turbidity criteria:

- Less than 0.2 Nephelometric Turbidity Unit (NTU) at the 95th percentile, and
- Not to exceed 0.5 NTU.

A four-month observation period between October 2023 and January 2024 was used to study the BIO-CEL L+480. During the trial period the membrane module was operated at an average flux of 24 LMH (14 gfd) with turbidity monitoring and pathogen sampling throughout the sampling period to validate performance.



Based on the results observed within the study period, the MANN+HUMMEL BIO-CEL L+480 satisfactorily fulfills the above mentioned requirements and:

- Perform in an equivalent manner to previously qualified BIO-CEL L2 product with UP150 membrane in 2009.
- Meet the turbidity criteria shared by both CA Title 22 and WRF 49973.
- Meet the conditions of application as per WRF 4997 Tier 1 LRVs of 1.0 for virus and 2.5 for Giardia and Cryptosporidium as:
  - MBR product intended to be operated in a submerged mode underneath a suspended growth bioreactor.
  - Has reported nominal pore size of 0.06 micron, less than the maximum listed in WRF 4997 of 0.4 micron.
  - Has demonstrated LRV for virus and protozoa indicator microorganisms exceeding the Tier 1 LRVs.
  - Tier 1 LRVs are anticipated to be met provided an installation can remain below filtrate turbidities during service of 0.2 NTU at the 95th percentile and not to exceed 0.5 NTU.

Indicator microorganisms relevant to MBR validation testing were evaluated weekly during the trial. Pathogene removal was validated based on the Water Research Foundation (WRF) Report 4997 (WRF 4997)<sup>1</sup> providing the most recent scientific guidance on how to validate pathogene removal by membrane bio reactors for the time of conducting the trials. WRF 4997 includes a default log reduction value (LRV) that can be credited to MBRs conditional on product type and turbidity compliance which are known as Tier 1 LRVs. The Tier 1 LRV requirements as per WRF 4997 are summarized in the following table.

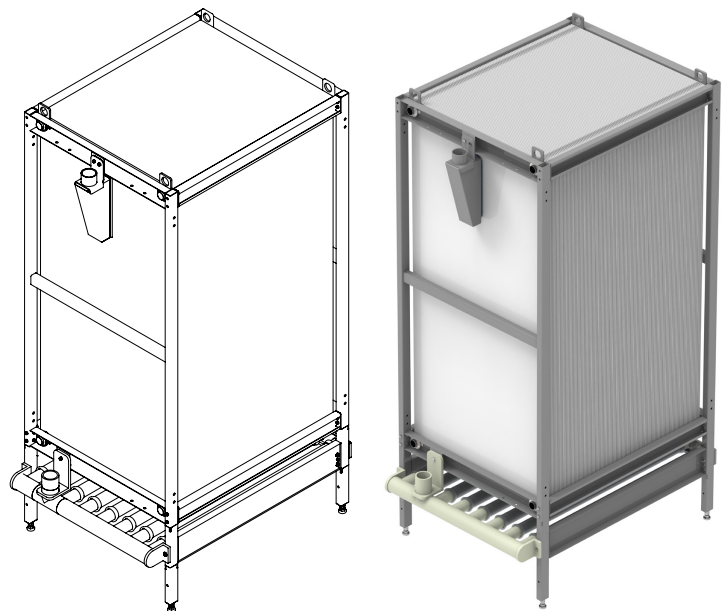
| Pathogen Group | Organism                | Median LRV Results during Trial Period | Tier 1 LRV Requirements |
|----------------|-------------------------|--|-------------------------|
| Virus          | Somatic coliphage       | 4.9                                    | >1.0 <sup>(1)</sup>     |
|                | Male-specific coliphage | >3.1                                   |                         |
| Bacteria       | Total coliforms         | 6.4                                    | >4.0 <sup>(2)</sup>     |
|                | E. coli                 | 6.3                                    |                         |
| Protozoa       | C. perfringens          | 5.8                                    | >2.5 <sup>(1)</sup>     |

Notes:

- (1) Tier 1 virus and protozoa credit from Salveson, A., Trussell, S., Linden, K., (2021)“ Membrane Bioreactor Validation Protocols for Water Reuse - WRF Project 4997”, Water Research Foundation, Denver, CO.
- (2) Tier 1 bacteria credit from WaterSecure (2017). Membrane Bio-Reactor WaterVal Validation Protocol. Australian WaterSecure Innovations Ltd, Brisbane, Australia.



Submerged L+480 modules in Customer site.



BIO-CEL L+480.

Notes:

- The state of California does not provide formal approval of polymeric membranes any more for Title 22 compliance.
- A detailed report is available upon request.

<sup>1</sup>Salveson, A., Trussell, S., Linden, K., (2021)“ Membrane Bioreactor Validation Protocols for Water Reuse - WRF Project 4997”, Water Research Foundation, Denver, CO.

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