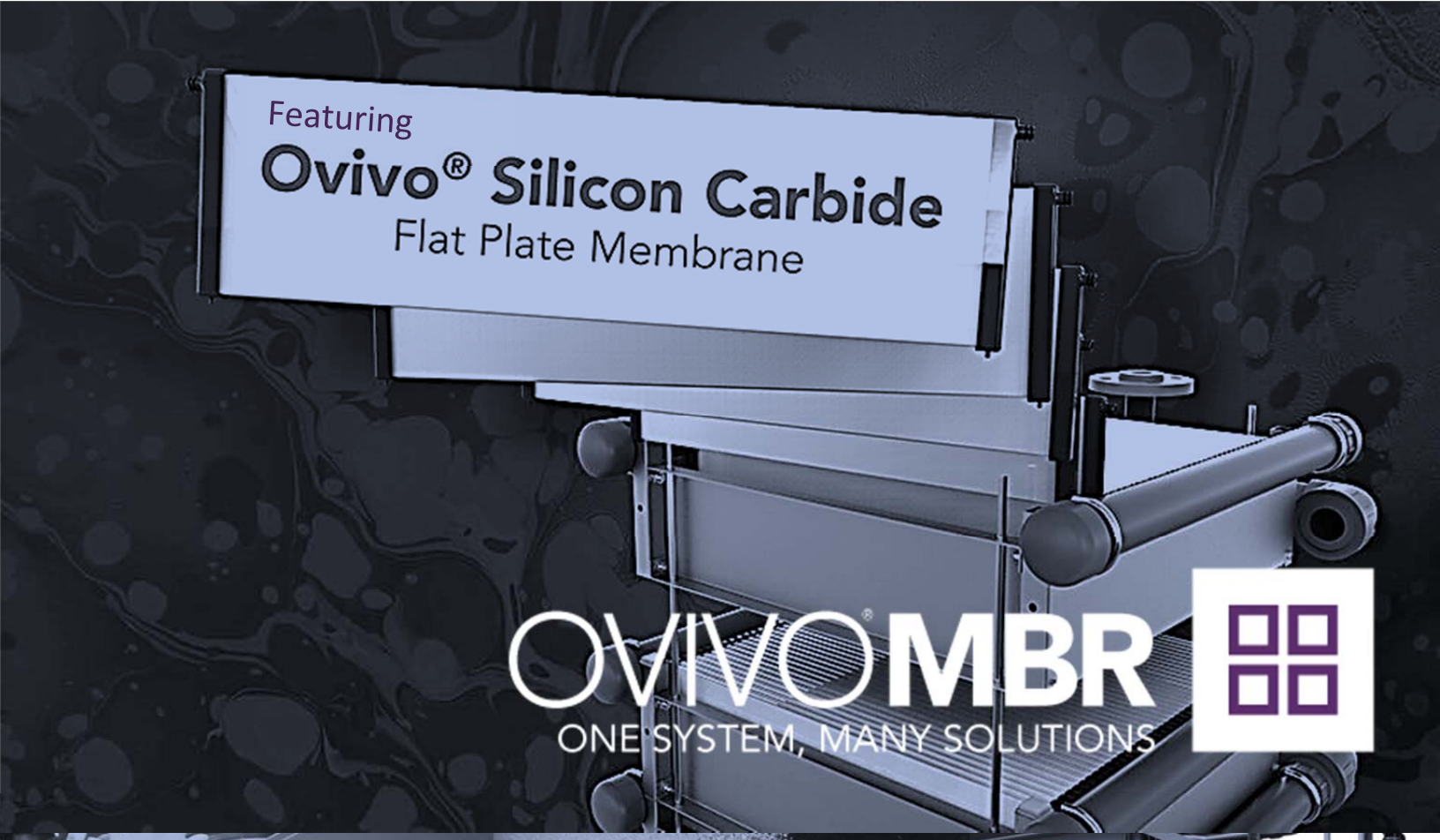

Silicon Carbide (SiC) Technology, MBR Systems

OVIVO
Ovivo USA LLC
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1-855-OVIVO-MBR
ovivowater.com

mbrcentral.com
A unique portal for MBR and Packaged Wastewater Treatment information

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ovivo mbr - one system, many solutions

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executive summary
customized, innovative mbr solutions

Ovivo has been in the U.S. wastewater market since 1914 and our Austin, TX office has been serving the market since 1966. Our heritage extends back to the very first activated sludge patent in the U.S. (Jones & Atwood) and the first ever MBR patent (Dorr Oliver). As a company we have over 50,000 pieces of equipment installed at every major treatment plant in the U.S., we have sold more than 2,000 biological processes and 361 total Ovivo MBR & MBT installations in North America.

310 Total Ovivo MBR System Supply Plants

51 MBT System Supply Plants

~60 Silica Carbide (SiC) Installations

Since, 2001, Ovivo has played a **pivotal role in establishing and innovating submerged MBR technology** in the North America. Continuing on our technology and market advancement, in late 2015 Ovivo added Silicon Carbide (SiC) membranes to our product offering. Ovivo has partnered with Cembrane with an ownership purchase and exclusive rights to SiC membrane technology into the electronic market globally and to the North American municipal water and wastewater markets.

Ovivo MBR carried both Polymeric and SiC membranes for 4 years and during this time period has successfully integrated SiC flat plate membranes into its wastewater solutions. While offering both membranes types, it allowed us to assess the market acceptance and the SiC product readiness, to the point that in January of this year, Ovivo MBR dropped the polymeric product line from any new opportunities, **concentrating on building our future with 100% SiC**. With this said, any existing polymeric plants which we hold the warranty or as the client wishes, we will fully support. SiC membranes are backward compatible with most all polymeric membrane from Hollow-Fiber to Flat Plate.

Ovivo is proud to be **one of the first in the water industry to be expanding this type of technology**. Ovivo's investment in Cembrane's sustainable and innovative technology will increase manufacturing capacity to meet the growing demand for reliable, efficient, high-quality water treatment with SiC membranes.

section 1
technology reference

1.a Commercialization of SiC Membranes

The team behind Cembrane consists of the pioneers of Silicon Carbide membranes as well as experts with a long experience in Silicon Carbide processing. **In 1999, the current CEO of Cembrane A/S,** established a membrane manufacturing company which concentrated on the manufacturing of honeycomb SiC ceramics. This lead to the formation of Cembrane A/S to create new standards for challenging drinking and wastewater applications making Cembrane the preferred solution.

Ovivo is perhaps the first major company to commercialize SiC here in the US. The unique properties of our SiC flat sheet membrane will allow multiple Ovivo product groups access to various markets. This multi-product market commitment and investment assures our clients that at any of our installations, **Ovivo will stand behind the technology,** just as we have done for all of our vast installations.

1.b SiC Technology Installations, Ovivo North America and Cembrane Worldwide

The following is a select installation list of the flat plate SiC membrane unit.

Installation	Flow	Commission	Application	Source Water
43 Various Installations	**--**	**2015-Present**	**--**	**Cembrane Worldwide**
17 Various Installations	**--**	**2016-Present**	**--**	**Ovivo USA Installations**
Canada	--	2015	Municipal	Sludge Dewatering
UAE	250 m3/day	2015	Industrial	Edible Oil MBR
USA	--	2016	Industrial	Winery
Germany	--	2016	Industrial	Tertiary Treatment Oil Refinery
USA	--	2016	Municipal	Sludge Thickening
Norway	--	2016	Municipal	Sewage
Italy	--	2017	Municipal	Sewage
Iran	26,000 m3/day	2017	Drinking Water	Brackish Water, Beach Well
Denmark	--	2017	Industrial	Metal Wastewater
Thailand	--	2017	Industrial	PTA Plastic Tertiary Wastewater
Slovenia	--	2017	Industrial	Ground Water
USA	--	2017	Industrial	Textile Dying
Germany	--	2017	Industrial	Marine Scrubber
Scandinavia	--	2017	Drinking Water	Drinking Water
Argentina	--	2017	Industrial	Ground Water Silt
UAE	--	2017	Industrial	Ice Cream Processing
UAE	--	2017	Municipal	Sewage Clarified Water
UAE	--	2017	Desalination	Harbor Water
Tehaleh, WA	0.06 MGD	2017	Municipal	Municipal Wastewater
Walbarger, TX	0.010 MGD	2017	Municipal	Municipal Wastewater

SiC Installations Continued;

Installation	Flow	Commission	Application	Source Water
Liberty, MO	--	2017	Municipal	Sludge Thickening
Italy	--	2018	Industrial	Olive Oil Processing
Switzerland	--	2018	Drinking Water	Surface Water
Indonesia	--	2018	Drinking Water	Surface Water
Saudi Arabia	--	2018	Drinking Water	Ground Water
Venice Italy	--	2018	Resort Hotel	Sewage
Dubai	--	2018	Industrial	Ice Cream Process
Turkey	--	2018	Industrial	Cheese Whey
Latvia	--	2018	Industrial	Slaughterhouse
Belgium	--	2018	Industrial	Meat Factory
Jack Brown Produce, MI	0.032 MGD	2018	Industrial	Sanitary Wastewater
Grinnel, IA	--	2018	Municipal	Sludge Thickening
Oak Hill, WV	--	2018	Municipal	Sludge Thickening
Minden, WV	--	2018	Municipal	Sludge Thickening
Eagle Grove, IA	--	2018	Municipal	Sludge Thickening
Tesuque Casino, NM	0.078 MGD	2018	Resort	Sewage
King County, WA	--	2019	Municipality	Wet Weather Pilot
Boerne, TX	0.03 MGD	2019[1]	School	Sewage
Paradise Cove, CA	0.065 MGD	2019[1]	Municipal	Municipal Wastewater
Spring Hill, MA	0.065 MGD	2019[1]	Municipal	Municipal Wastewater
Kiawah River	0.11 MGD	2019[1]	Municipal	Municipal Wastewater
Taos, NM	0.450 MGD	2019[1]	Municipal	Municipal Wastewater
New Braunfels, TX	--	2019[1]	Municipal	Sludge Thickening
Miles City, MT	--	2019[1]	Municipal	Sludge Thickening

Notes:
1. Under Construction

1.c SiC Video Introduction

The following are links to two YouTube videos introducing SiC membranes.

https://www.youtube.com/watch?v=rDmynNL0ojA

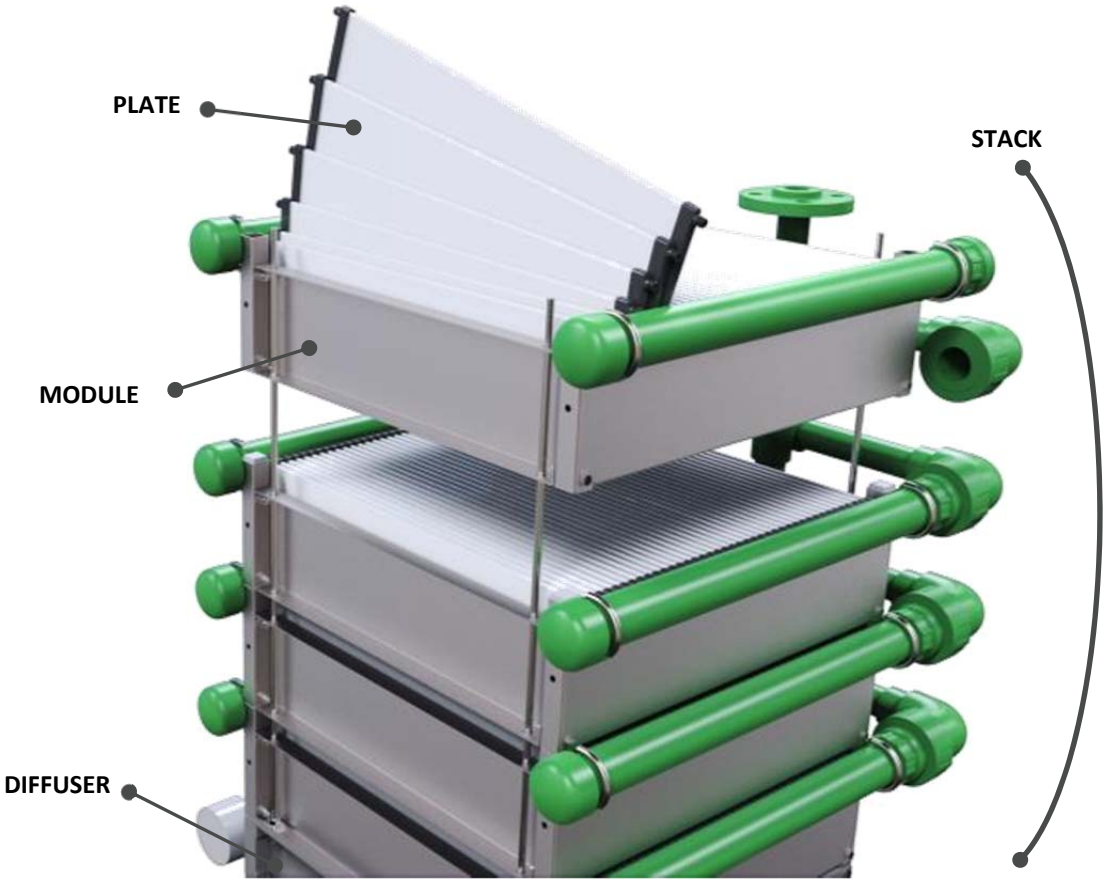
https://www.youtube.com/watch?v=ZwBDeVXdOOs&feature=youtu.be

section 2
mbr system design considerations

2.a Membrane Unit Design

SiC Technology data shown below is customized specific to each project. Flux rates vary with MLSS concentration.

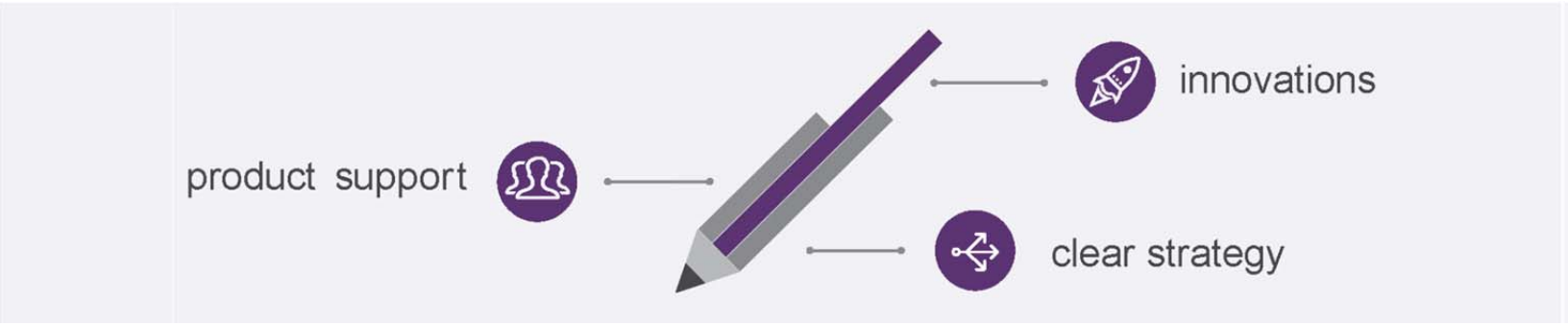
Parameter	Data 1	Data 2	Data 3
Membrane Unit (Stack)	UF/MF	316SS Housing	1 to 12 modules
Membrane Plate Properties	Flat Plate	Silicon Carbide	0.1 µm (avg)
	1.625 ft^2/plate	Ave TMP 1.0 to 3.0 psig	Max TMP 5.8 psig
Membrane Module Properties	65 ft^2/module	40 plates/module	6 mm plate spacing
	2.1' w x 2.25' l x .55'h	79 lbs dry weight	99 lbs wet weight
Membrane Diffuser Properties	Coarse Bubble	--	SS316 Housing
Typical Flux @ 15°C	35 gfd @ 10,000 mg/L MLSS	29 gfd @ 15,000 mg/L MLSS	23 gfd @ 20,000 mg/L MLSS



2.b Commentary on MBR System Design

01
the commentary

Ovivo's design considerations **pay respect to a simplistic flow sheet to capture maximum value** in capital, construction, and operational costs. There are diverse techniques in which the design may be approached. A cost effective MBR system design is a balancing act between process flexibility, turndown, energy efficiency, bio-hydraulics and sustainable membrane flux while meeting the design requirements in accordance with the parameters set forth. Ovivo's MBR system design is focuses on key points, which we believe will bring the most value to a project.



02
the membranes

The heart of the system is Ovivo's Ceramic Membrane Technology, comprised of hydrophillic Silicon Carbide UF/MF (0.1µ) flat plate which provides unmatched flux rate, repellling negatively charged particlaes including oil. The chemically inert membrane material can operate in extreme enivronments, a pH range from 1-14 and high sludge concentrations of 4% organic waste or 10% inorganic waste. The plates have a high resestance to oxidents even ozone. The very hydrophillic nature of membranes, allows the membrane zones to be shut down and drained without the addition of preservative. Membranes are kept clean with an automated backwash system and a regular maintenance clean (MC) which can utilize non-chlorine based chemicals, such as parasitic acidic or ozone.

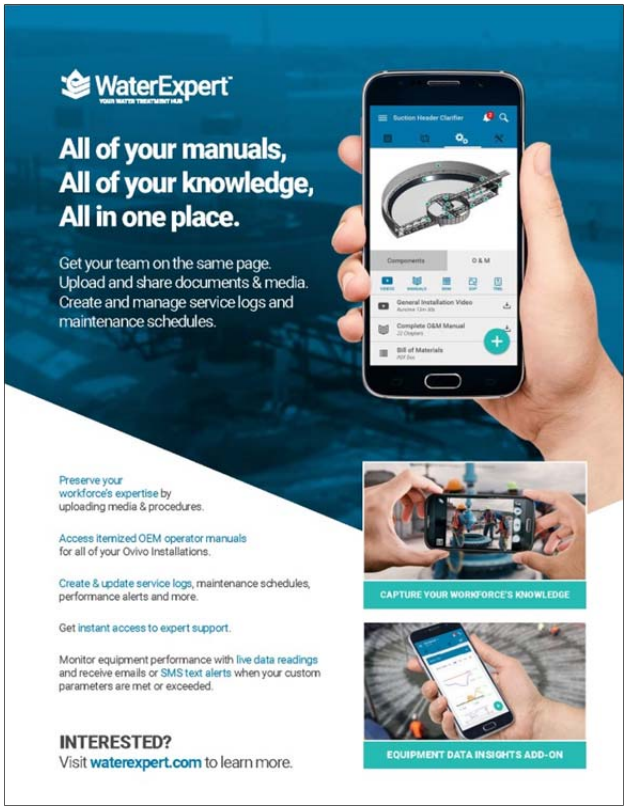
the process zone
03

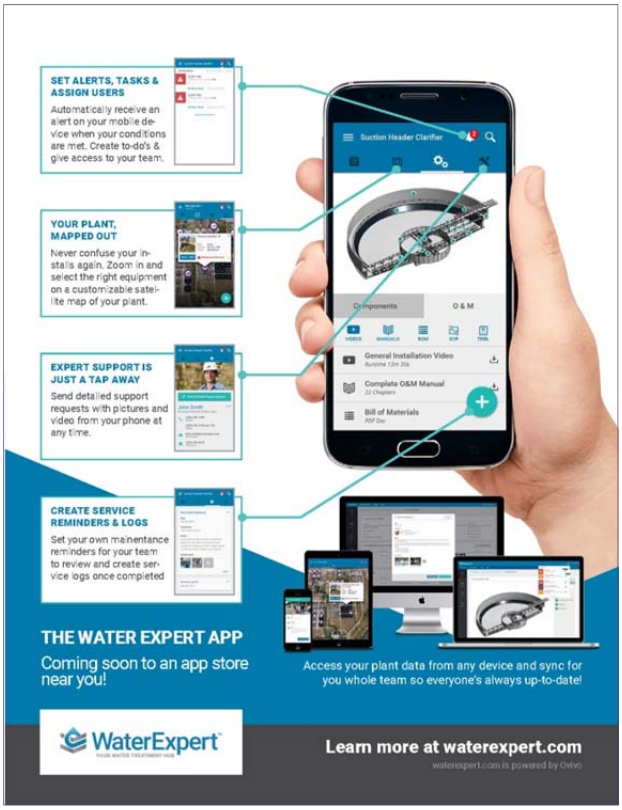
On the process side, Ovivo AEROSTRIP® diffusers have been the leading technology to reduce operational costs and improve plant performance. Advanced perforation technology and a high strength polyurethane membrane are the secrets to the AEROSTRIP® fine pore diffusers high performance and long service life. Ovivo guarantees clean water transfer efficiencies of 8.5-10%/m (2.6-3.0% ft) 20' side-water depth (SWD) in virtually all applications.

WaterExpert™ is included with each Ovivo SiC MBR System. WaterExpert™ is a platform provided to help better maintain and operate the equipment and harness the power of cloud to provide real time **data insights into the equipment.** Included in the WaterExpert™ base plan are data trending charts, alerts, maintenance calendars, digital documentation of Ovivo's scope of supply, drawings, IOM manuals and generic videos of basic process, operation and maintenance your MBR equipment.

04
operational tools

These tools can be accessed from any smart phone, tablet or computer. A brief video demonstrating WaterExpert™ capabilities is available at the following youtube link: https://www.youtube.com/watch?v=qWvU6fjlypY





05
MBR system summary

At Ovivo, our goal is to provide customers with comprehensive system solutions to meet their unique and specific wastewater needs. MBR systems have many subsystems, from headworks all the way through permeate discharge that must be integrated properly to ensure successful long term system operation. Ovivo MBR systems are designed to be customizable, with the objective of achieving lowest total system cost and are an ideal solution for any type of project. **SiC represents the Best Available Technology (BAT) for municipal wastewater treatment due to its durability with the widest operational window**. Continual improvements in the technology have significantly reduced capital and operating costs compared to 10-15 years ago.

section 3
membrane & equipment durability

3.a Warranties

warranty 01

As a multi-product wastewater treatment system supplier for over 50 years, Ovivo understands that each system is only as reliable, only as efficient, as the weakest component. Our commitment is to the complete Ovivo® MBR System. Our multiple product ownership, strong licensing and OEM agreements allow us to provide for meaningful warranties and guarantees.

One interesting, differentiating feature of an **Ovivo Membrane Warranty is that the Owner is not required to monitor, report or record instrument (online) field data for the purpose of maintaining warranty** coverage as long as WaterExpert™ is maintained. This allows Ovivo and the Owner to collaborate in managing the data trends and alerts. The Owner shall be required to maintain a reliable, high-speed connection to the processor and to maintain manual records regarding MBR MLSS, CSS and chemical use data.

Warranties presented in this proposal are:

Warranty	Description[1]	Duration Yrs	Type
Membrane			
Workmanship	Workmanship and Defects	12	4 Full, 8 Prorated
Performance[2]	On-site installation inspection	12	4 Full, 8 Prorated
Equipment			
Ancillary	Workmanship	1	Full
Fine Bubble Diffusers[3]	Workmanship and Performance	5	Full
Blowers[4]	Workmanship	2	Full
Pumps[5]	Workmanship	2	Full
Mixer[6]	Workmanship	2	Full
MBR System			
Process[2]	System Process Performance	1	--

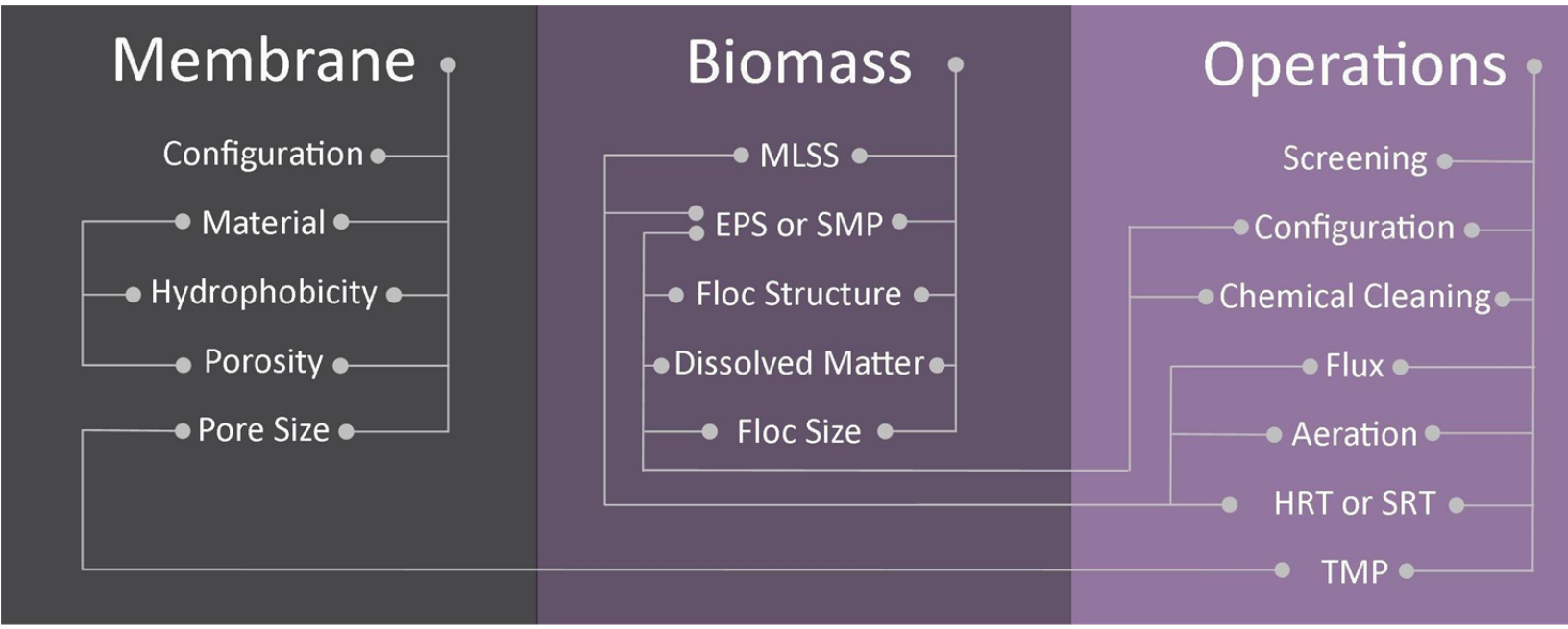
Notes:

1. See warranty statements and specifications for full description.
2. Must have WaterExpert maintained.
3. Applies to aeration basin flat panel Aerostrip diffusers.
4. Applies to Aerzen Blowers.
5. Applies to Gorman Rupp, Flygt and Wilo pumps.
6. Applies to Flygt and Wilo Mixers.

3.b Membrane Aging

replacement & risk assessment 01

Membrane life-time has a strong impact on competitiveness and viability of MBRs. Polymeric membrane manufactures provide conditional guarantees on membrane longevity, typically 4-7 years. However, many evidences suggest that the polymeric membrane longevity can be 10 years, if the membranes are properly installed and used under reasonable operating conditions. With Silicon Carbide (SiC) membranes, lifecycle will almost certainly improve as many of the life expectancy factors, including membrane fouling, are mitigated with the physical characterizes of SiC membrane plate configuration. Longevity of SiC, under the right conditions, are expected to be 15+. The factors that affect membrane life are common and major influences at every MBR application. This factors are show below.



While this discussion can be expanded to detailed explanations for each of the fouling factors listed above, the purpose is to decide a lifecyle assessment risk of SiC membrane vs polymeric membrane. The most common factors which impact membrane life are:

1) Membrane Material / Manufacturing Process

2) Chemical Cleaning & Exposure

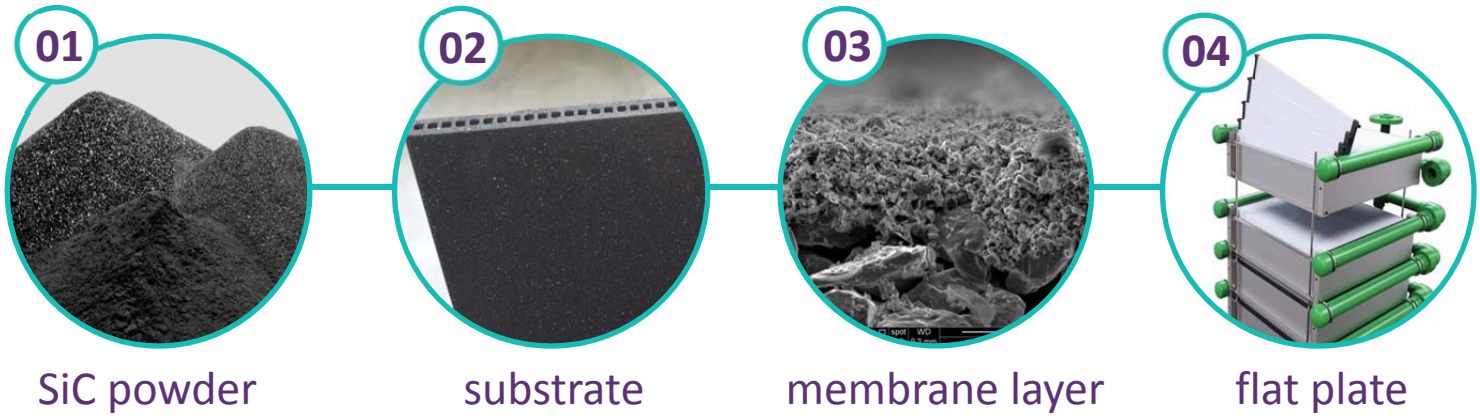
3) Material Fatigue | In-Basin Physical Damage | Physical Cleaning.

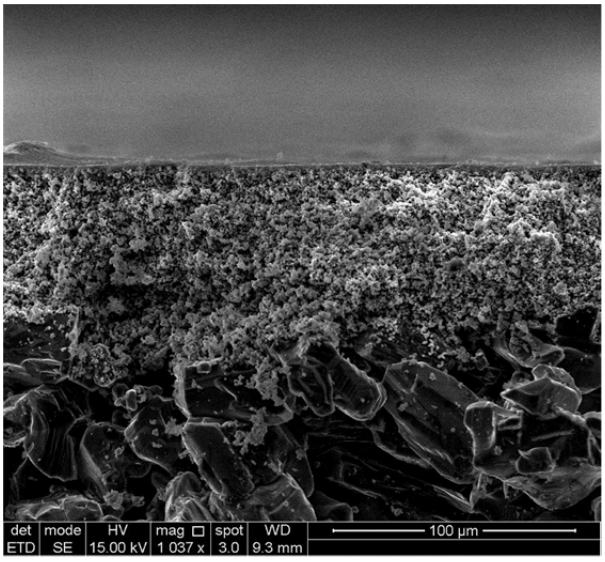
4) Hydrophobicity | Porosity | Flux Design

SiC unique properties 02

Silicon carbide is also **one of the hardest materials in world** and forms membrane plates that are solid as a brick and able to withstand the broadest range of temperature, pH, chemicals, and pressures. SiC membranes have achieved a new level of performance in some of the most demanding applications.

The manufacturing process begins with the extrusion of the SiC plate. The extruded plate is fired (sintering) at a precise temperature (~2,000 °C) to bind the SiC grains. The membrane layer consists of finer SiC particles and is applied to the surface of the substrate. Sintering of the plate then binds the membrane layer to the substrate.





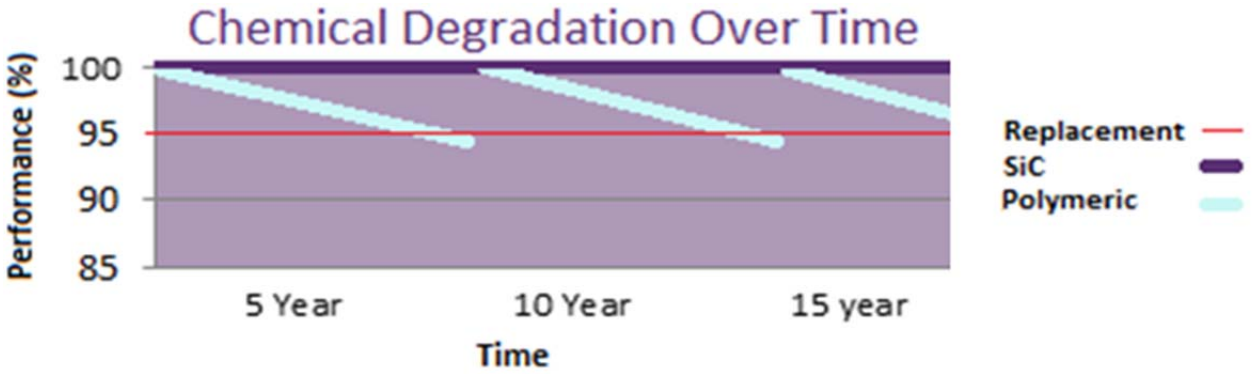
The final result of the manufacturing process is a plate that is made of only SiC. The SiC particles are permanently bonded to one another, creating **unique membrane properties and unsurpassed material strength**.

03 degradation resistance

Every membrane, be it polymeric or SiC, will require chemical cleaning to mitigate organic and inorganic fouling. Cleaning regimes will vary in frequency, chemical type and solution concentration. **SiC membranes are resistance to degradation** by a wide range of chemicals and chemical concentrations, which allows more aggressive chemical cleaning procedures (if necessary) to be used over a pH range of 0-14. Ceramic membranes have a high resistance to ozone and chlorine frequently in use at municipal wastewater treatment plants.

Polymeric components of membranes can degrade after exposure to cleaning chemicals (Arkhangelskys et al. 2007). Chlorine exposure can reduce the weld strength of the membrane/module connection, which is widely accepted as one of the weakest integrity points of MBR membrane modules (Judd 2011). One of the most common membrane raw materials is polyester, which is vulnerable to elevated pH levels.

All **polymeric membranes will have a chlorine PPM hour value and a pH limit** as both will **degrade the membrane material over time**. Chlorine in municipality's water and the frequent cleaning intervals (chlorine at 500 to 5,000 mg/L for organic fouling) degrade with each contact. Frequencies of this chemical cleaning process for membranes vary from 7 to 90 days. With each clean the recovery of polymeric membrane performance is impacted slightly and the cumulative effect over time reduces the performance to a point of replacement. Overtime chemical adsorption into and onto pores decreases cleaning efficacy. The cleanability of SiC, especially with chlorine cleaning, deliver a 100% recovery of the membrane performance with every membrane clean.



Additional factors impacting membrane performance are 1) chemical adsorption into pores and 2) the leaching of additives which make polymeric membranes somewhat hydrophilic.

1) **Chemical Adsorption -** With SiC membranes any chemical adsorption build up is generally alleviated with an automated high pressure backwash. If backwash does not fully alleviate, an elevated concentration of cleaning chemical may be applied, and as noted above with no degradation to the plate material.
2) **Leaching of Additives -** The various polymers used to make membranes are naturally hydrophobic. The most common way to add hydrophilic properties is to add a polymer called PVP. PVP does not chemically bond to the membrane polymer, but it is "trapped" within the membrane structure. Over time the PVP breaks apart and washes out of the membrane, mainly during chlorine CIP. In all likelihood, after years 3-5 there probably is not a whole lot of PVP left in the membrane matrix. With SiC, the hydrophilic properties are inherent to the material itself so the membrane is permanently hydrophilic.

A Membrane Bioreactor environment is not very forgiving and is further challenged by design, operation protocols, knowledge and equipment failure. The following items impact the life of submerged membranes:

04
physical strength

1) **Material Fatigue** – Polymeric membranes by nature of move around due to the air scour requirement of the membranes. This includes ridged flat plat membranes which are constructed with a solid backing plate but have a flexible membrane sheet glued or sonically welded to a rigid backer plate. The air scour creates movement of the membrane, which can 'rub' fibers together causing delamination, fiber slack or 'tearing' at the welds on flat plate configurations. A couple examples are shown below.

Flat Plate - Weld Tear

Hollow Sheet Repair

Hollow Fiber Repair

SiC membranes are solid plate as noted in the manufacturing process sections above. The membranes are held firmly in the module and are not impacted by air scour or over-aeration as the polymeric membranes shown in the pictures above.

2) **In-Basin Physical Damage** – Membranes can exhibit manufacturing defects and damage from air scour, but solid particles and foreign bodies within the bioreactor can also breach or damage membranes. Grains of silicon carbide are bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. The mohs hardness rating of SiC membrane is 9-9.5 (Diamond is 10 mohs) **eliminating the likelihood of damaging debris which would tear, abrase, scratch or puncture** the SiC membrane as the debris would with polymeric membranes.

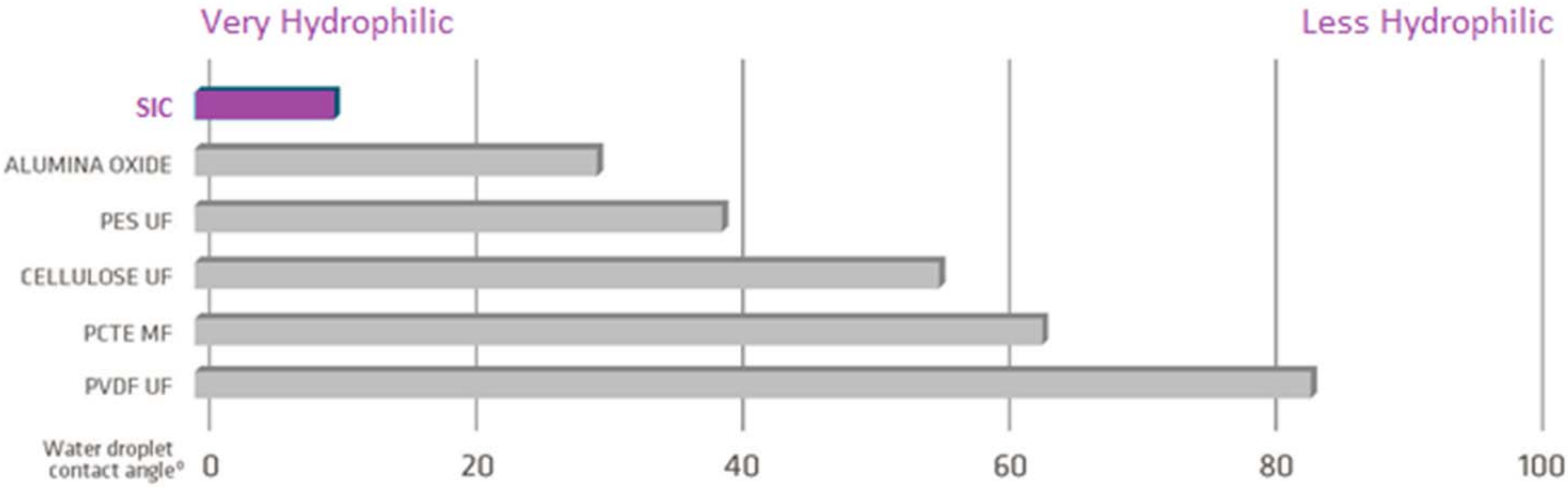
Damaging Debris

Mohs' Scale of Hardness

3) **Physical Cleaning** – In the event that membranes do need to be physically cleaned. SiC membranes are durable enough to withstand a pressure wash, which polymeric membranes cannot. Any type of other physical cleaning on polymeric membranes such as scraping or combing will increase the risk of tears or breakage.

05
hydrophilic properties

1) **Hydrophilic vs. Hydrophobic** - An important characteristics in membrane selection is whether you want a membrane that is Hydrophobic or Hydrophilic. Hydrophilic literally means "water loving." SiC membranes are naturally Hydrophilic and as such, will attract water, and in the process repel foulants in order to allow water access to the membrane. This allows the membrane to remain clean and for a longer periods of time without chemical cleaning. Hydrophobic on the other hand, literally means "afraid of water." Hydrophobic membranes naturally repel water while attracting hydrophobic foulants. The various polymers used to make polymeric membranes are naturally hydrophobic. The most common way to add hydrophilic properties is to add a polymer called PVP. PVP does not chemically bond to the membrane polymer, but it is "trapped" within the membrane structure. Over time the PVP breaks apart and washes out of the membrane, mainly during chlorine CIP. In all likelihood, after years 3-5 there probably is not a whole lot of PVP left in the membrane matrix and the membrane performance can drop precipitously.



2) **Porosity and Flux -** The nature in which SiC membranes are formed leads to a significantly higher surface porosity compared to polymeric membranes. Such a high surface porosity allows SiC membranes to operate at 4-6X the flux rate as polymerics in municipal wastewater applications.

summary
longer life
06

Silicon Carbide's natural properties effortlessly attracts water while repelling foulants. This results in extremely high sustainable fluxes and the ability to operate reliably in high solids and oils, as well as under other difficult conditions that polymeric membranes have shied away from. The resistance to chemicals provides for another layer of long life. SiC membranes have achieved a new level of performance in some of the most demanding applications, while providing a wide operational window.

Although ceramic membranes present a higher capital cost compared to polymeric membranes, they are **able to obtain a higher productivity, longer life spans,** and the ability to couple in-operation rapid backpulsing allows for further enhancements in operational productivity not achievable with conventional polymeric membranes.

appendix
supplementary information

Silicon Carbide Specification

Silicon Carbide Brochure

TECHNICAL SPECIFICATION
SILICON CARBIDE MEMBRANE, MBR APPLICATION

The specification below represents Ovivo's Silicon Carbide membrane as applied to a MBR application. While other applications such as wet weather, membrane thickening and tertiary treatment utilize the same membrane the system design, operational parameters will vary and therefore will have specific specifications written for those applications. Please consult the proper Ovivo product group for other application types.

Note, that this specification is related to the Membrane only. MBR systems design parameters and other components for a complete and operable MBR System will be required. Specifications and worksheets for a total MBR System are available from Ovivo and will be supplied upon request.

Items shown as highlighted [XXXXX] are updated based on project specific requirements.

PART 1 GENERAL

1.01 DEFINITIONS

For the purposes of this specification terms have meanings indicated below which are applicable to both the singular and plural thereof:

A. Backwash: Synonymous with backpulse and backflushing. Backwashing is any instance where water and or a chemical solution are charged to membranes in the reverse direction of permeate flow with a membrane soak time less than 0.5hr. A Backwash is performed in-situ and in mixed liquor or activated sludge.

B. CIP: See Maintenance Clean.

C. Flux: Gallons of permeate flow per day per square foot of membrane area (gfd). Additional definitions of flux that are used to characterize design criteria and membrane performance include:

   1. Gross Flux or Instantaneous Flux: Calculated by dividing measured permeate flow rate by working membrane area at any instant.

   2. Net Flux: Calculated by dividing the total amount of permeate produced (available for discharge) in a given time frame by the working membrane area.

D. Maintenance Clean (CIP): Synonymous with chemically enhanced backwash and CIP. A Maintenance Cleaning is performed in-situ and in mixed liquor or activated sludge. The procedure is conducted by charging cleaning chemicals to membranes in the reverse direction of permeate flow with a soak time lasting more than 0.5hr.

E. Membrane Conversion Frame: The membrane conversion rack contains multiple membrane stacks, within in a frame designed specifically to fit and replace other Hollow-fiber or Flat plate/sheet Large Membrane Sub-unit models.

F. Membrane Module: May be considered a membrane cassette comprised of multiple Membrane Plates assembled in a module frame. The modules are stackable and assembled into a complete Membrane Stack.

G. Membrane Plate: May also be considered a small membrane subunit comprised of a single backwashable membrane plate constructed in a monolithic gradient membrane filtration and drainage layer. The Membrane Plates are combined to make a Membrane Module/Cassette.

H. Membrane Stack (Membrane Unit): May also be considered a large membrane subunit consisting of membrane modules and an integral diffuser system.

I. Permeability: Equals the instantaneous flux rate divided by the transmembrane pressure (TMP). The units of permeability are gfd/psi.

J. Silicon Carbide: A material containing silicon and carbon. Grains of silicon carbon are bonded together by the sintering process to form a very hard monolithic ceramic product requiring high endurance.

K. Sintering: The process of compacting and forming a solid mass of material by heat or pressure without melting to the point of liquefaction.

L. Stefanski Method: A standard test method for assessing ragging propensity in a reactor.

M. Transmembrane Pressure (TMP): The effective pressure differential across the membrane during normal operation.

N. Vicker's Hardness: A standard test method indicating the hardness of a given material.

1.02 QUALITY ASSURANCE

A. The MBR System Supplier and Membrane System Manufacturer shall demonstrate their quality of performance, timeliness of performance, customer satisfaction, on-budget performance, ability to minimize change orders, ability to prepare plans, technical capacity, qualifications, and ability to assess and minimize risks.

B. All the furnished equipment and services specified under this Section shall be standard units of proven ability as manufactured and integrated by competent companies that are fully experienced, reputable and qualified in the integration and manufacture of the equipment to be furnished. The equipment shall be designed, constructed and installed in accordance with the best practice and methods, and shall operate satisfactorily when installed.

C. To show evidence of being able to provide the quality of equipment and services described in this specification, the Membrane System Supplier shall submit their quality system ISO 9001 certification. The company identification and quality procedures shall indicate for the MBR System Supplier that the Quality Management System is applicable to design, manufacturing, supply, installation, and servicing of wastewater and water treatment plants, associated equipment and systems and for the Membrane Manufacturer the Quality Management System is applicable to the manufacturing membrane material and equipment. The quality system shall be audited by a third party independent inspector. Certification shall remain in effect throughout 1 year past the commissioning of the project.

D. All membrane small membrane subunits furnished under this Section shall be new and unused and shall be the standard products of a Membrane Manufacturer having a successful record of manufacturing membrane equipment.

1.03 WARRANTY

A. GENERAL

1. Supplier shall provide phone support for the SiC Membrane an MBR System for one year following successful completion of the System Commissioning. Phone support shall be 24 hours a day, 7 days a week.

2. The warranty period shall begin following completion of the System Commissioning as specified herein or not to exceed 6 months past equipment delivery.

3. For warranty claims the Supplier shall provide an acceptable remedy to the Owner in accordance with the contract documents.

4. All on-site support required for the warranty, as defined in the warranty statement, shall be coordinated by the MBR System Supplier directly with employees of the supplier. Subcontractors of the supplier shall not provide warranty coordination or support.

    a. Approved Controls Integrators of the project may provide warranty coordination or support as related to the control system.

B. MEMBRANE MODULE PERFORMANCE WARRANTY

1. The MBR System Supplier warrants that the membrane modules will be used for treatment of wastewater and will achieve the effluent water quality indicated herein.

    a. The membrane module warranty shall be from the MBR System Supplier, not the membrane manufacturer.

2. MBR System Supplier Membrane Module Warranty Period shall be a minimum warranty period of 144 months after date of installation.

    a. The first 48 months shall be a full replacement, with the remaining 96 months pro-rated.

    b. Any membrane modules replaced under warranty shall assume the remaining warranty of the membrane modules.

    c. Membrane modules provided by means other than warranty replacement (e.g. purchase by Owner) shall be provided with the same warranty as the membrane modules provided as part of the original equipment installation period for a period of 3 years after the warranty start date.

    d. Membrane replacement may be with new or modified designs.

3. The MBR System Supplier warrants that the membrane modules will be free from non-conformance in materials, workmanship, membrane integrity failure, and irreversible flux loss.

    a. Repair or replace any Small Membrane Subunits that fail during the warranty duration.

        i Failure is defined as any of the following:

            a) Inability to meet production capacity requirements as specified herein.

            b) Inability to meet TSS and turbidity requirements as specified herein.

4. After final acceptance, if the membrane modules are determined to be non-conforming with respect to membrane integrity and/or irreversible flux loss, the MBR System Supplier will remedy.

5. If within sixty (60) days after notification to the MBR System Supplier it has become apparent to the Owner that membrane modules are not able to meet the provisions of the warranty, the Owner may pursue a breach of warranty claim or other available remedies.

6. Limitations of Membrane Module Warranty. Owner recognizes that the occurrence of any of the following shall void the remaining membrane module warranty.

    a. Physical damage or faulty installation of the membrane modules by others.

b. Unauthorized alteration of components manufactured by MBR System Supplier.

c. Exposure to chemical or physical conditions outside of the recommended operating range for the membrane modules. Examples of such conditions include:

   i Inappropriate operation of the biological system that results in exposure of the membrane modules to mixed liquor suspended solids concentrations in excess of design values, for more than 24 hours greater than three times per year or a cumulative total of 72 hours.

   ii Catastrophic exposure to chemicals not normally associated with water or wastewater treatment as a result of accidents, vandalism or other acts outside the bounds of routine and normal treatment plant operation.

   iii Exposure to fats, oils and grease at concentrations greater than 500 mg/l.

   iv Use of chemicals or cleaning procedures other than those recommended and approved by the MBR System Supplier.

   v Maximum chlorine exposure is 5,000,000 ppm-hrs with a maximum allowable concentration of 10,000 mg/l.

d. Improper maintenance of equipment.

e. Failure of the Owner to maintain electronic and hand-written operational logs.

f. Changes in the MBR System Supplier's established operational and maintenance guidelines cannot be applied retroactively to invalidate the membrane module warranty.

g. Maximum allowable coarse suspended solids (CSS) concentration in membrane basin is 200 mg/l. CSS is to be measured using CSS/Stefanski method .

h. Introduction of foreign debris >2.1 mm in diameter into the membrane basin is not permitted. This includes debris that can enter the membrane basin directly from the external environment as well as debris present in the wastewater itself.

   i All screen bypass events void the membrane warranty and must be reported to Ovivo. In the event of a screen bypass event, the following procedure must be followed:

      a) Drain and inspect basins for ragging. Any and all raging should be removed

      b) Perform integrity tests on membranes to determine if any damage has occurred.

      c) If there are damaged membranes, damaged membranes are to be replaced at Buyer's cost.

      d) A chemical clean per Ovivo's O&M is to be performed.

      e) After damaged membranes are replaced and chemical cleaning performed, a 2-week evaluation will be performed to determine if all adverse effects of screen bypass event have been remedied.

      f) If deemed acceptable by Ovivo, the original membrane warranty will be reinstated.

i. The MBR System Supplier is solely responsible for identifying water quality parameters, instrumentation and control programming required to satisfy and maintain membrane module

warranty provisions for operation and cleaning. The MBR SUPPLIER shall establish instrumentation alarm and shutdown limits to prevent operation of the equipment outside the established limits.

i The Owner shall maintain a high speed connection to the processor but all data monitoring shall be the responsibility of the MBR Supplier. The Owner shall not be required to monitor, report or record instrument field data for warranty purposes.

ii Any event or instance where connectivity is lost or where one or more operating parameters is non-conforming per Contract Documents for a period of one consecutive hour or for a total of six hours or less in each calendar year, shall not reduce or void the membrane warranty.

j. In order to maintain the provisions of the membrane module warranty, the Owner agrees to the following:

i The Owner will maintain a hand-written log if an occurrence develops that is totally outside the bounds of routine and normal operation or automated operation.

ii The Owner shall maintain records regarding:

a) Date and time membranes are taken out of service or cleaned.

b) Chemical concentration, amount of chemical per treatment and soak time.

c) MLSS concentration once per day per MBR.

iii In the event of the warranty claim, the Owner shall provide the MBR System Supplier with electronic and written logs.

k. Aeration without filtration can be required at times for the purposes of mixing and oxygen delivery.

i Aeration without filtration shall not reduce or void the warranty.

ii For the first year of service, the MBR System Supplier shall guarantee that the air scouring diffusers will not clog or need manual cleaning under any and all conditions.

iii If diffusers clog, the MBR System Supplier shall bear all costs to repair or remediate the diffusers and membranes as necessary to fully recover performance at no cost to the Owner.

PART 2 PRODUCT

2.01 GENERAL EQUIPMENT PERFORMANCE REQUIREMENTS

A. The Membrane and MBR System shall be configured such that seasonal, diurnal, and peak flows shall be equalized in order to accommodate no more than [500,000] gallons per day at a single flux rate that shall not exceed [69] gfd.

B. The Membrane shall be designed to include the reliability features for all flow conditions with any one basin out of service indefinitely:

1. Hydraulically treat [all flow] parameters.

2. Maintain flux with the remaining membranes, not to exceed [30] gfd at all flows.

D. The Membrane and Membrane Stack components shall:

1. Operate over a MLSS range from 5,000 to 35,000 mg/L.
2. Operate over the ph range of 2-12.
3. Have a lifetime chlorine tolerance of 5,000,000 ppm hours.
4. Be tolerant of fat, oil and grease (FOG) concentrations up to 500 mg/L.
5. Resist damage by foreign debris <2.1 mm in size.
6. Withstand backpressures up to 30 psi.
7. Be able to be dried without the use of preservative of humectants without any temporary or permanent loss in clean water permeability.

E. Membrane cleaning shall:

1. Be automated.
2. Have automated backwash capabilities.
3. Be mechanically cleaned with water under the following pressure, flow, and distance specifications:
    a. <10 bar and <30 m3/hr within 30 cm
    b. <5 bar and 25 m3/hr within 20 cm
    c. <2 bar and <20 m3/hr within 10 cm
4. Withstand temperatures up to 45°C and a pH of 14.
5. Withstand a pH range of 1-14.
6. Be compatible with 1.0% sodium hypochlorite.
7. Be compatible with Ozone Gas for cleaning purposes.

2.02 GENERAL EQUIPMENT DESIGN ASSEMBLY REQUIREMENTS

1. Silicon Carbide (SiC) Membrane Stack.
    a. Membrane process zones shall be used for biological treatment and to house the membrane units used to separate effluent from mixed liquor.
    b. Membrane plate
        i. Utilize Silicon Carbide flat plate membranes which have a Vickers Hardness of 40 kg/mm2. Tube type membranes, Polymeric membranes or other ceramic materials are not acceptable.
        ii. Membranes shall be monolithic in construction with a uniform SiC filtration layer and an integral drainage layer.
        iii. Membrane plates shall:
            a) Be asymmetric and backwashable.
            b) Have a pore size of 0.1 micron or smaller.
            c) Have a Porosity great than 40%.

d) Be naturally hydrophilic.

e) Be 6 mm in thickness.

f) Have a negative zeta potential at pH levels <4.0

c. Membrane Modules.

i. Modules shall be constructed of type 316 stainless steel, PVC, and PE components as necessary for operation submerged in mixed liquor as part of an MBR System. 304 stainless steel is not acceptable.

ii. Plates shall be rigid and held firmly within the membrane module at a distance of 7mm apart.

iii. Individual modules shall be not more than 8" in height.

iv. Modules shall be stackable.

d. Membrane Diffusers.

i. The diffusers housing shall be constructed of type 316 stainless steel, PVC, and PE components as necessary for operation submerged in mixed liquor as part of an MBR System. 304 stainless steel is not acceptable.

ii. Diffusers cases shall consist of a diffuser housing with individual coarse bubble diffusers, each fed by a common manifold and easily replaceable.

iii. Diffuser system shall be designed to promote efficient air scouring of the membrane modules.

e. Membrane Stack (MS)

i. MS shall be comprised of a diffuser case and one or more membrane modules.

ii. MS shall be capable of being aerated during periods of no filtration.

iii. MS shall have integral diffuser and permeate manifolds.

iv. MS shall be easy to recover from localized dewatering or clogging in the event of miss-operation or operation outside of normal operating conditions.

a) Only a routine Maintenance Cleaning shall be required following a dewatering event to recover specified performance

b) In situ physical or mechanical cleaning only, no manual cleaning shall be required to recover

v. MS shall be prefabricated, preassembled and factory certified before shipment to the site. Membrane units shall be installed at the factory. No installation of membranes units shall be done onsite.

vi. In a membrane conversion application, multiple membrane stacks shall be mountable into a conversion frame designed to match up with the existing membrane unit.

f. Design Basis.

a)	Service:	Aerated Biological Zone
b)	Material of Construction (membrane):	Silicon Carbide (SiC)
c)	Vickers Hardness:	40 kg_f/mm^2
d)	Material of Construction (diffuser):	--
e)	Chlorine & Oxidant Compatible:	1.0 wt% free chlorine

f)	Hydrophilic Properties:	Yes
g)	pH Operating Range:	2-11 Continuous
h)	Cleaning pH Range:	1-14
i)	Solids Concentration Range:	5,000 to 35,000 mg/L
j)	Maximum Design Flux:	69 gfd @ 35°C & 5,000 mg/L MLSS
k)	Maximum Peak Flux:	138 gfd @ 35°C & 5,000 mg/L MLSS
l)	Maximum TMP:	10 psi
m)	Maximum Backpressure:	30 psi
n)	Maximum FOG:	500 mg/L
o)	Nominal Pore Size:	<0.1
p)	Air Scour Range:	33 SCFM to 55 SCFM
q)	Air Flow Source:	Blower
r)	Diffuser Type:	Coarse Bubble

g. Manufacturer and Model: Ovivo Cembrane SiC Membrane Stack, no or-equal.

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MUNICIPAL WASTEWATER
SILICON CARBIDE MEMBRANE

ACHIEVING A NEW LEVEL OF PERFORMANCE IN MEMBRANE TECHNOLOGY

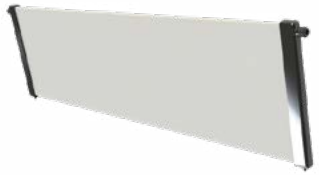
- Highest Flux
- Withstands the Harshest Environments
- Quick & Easy Cleaning for Full Recovery
- Longest Life of Any Membrane

Ideally suited for Sludge Thickening, High Rate MBR, Tertiary Treatment and Wet Weather Overflow Applications

SILICON CARBIDE FLAT PLATE MEMBRANES

KEY HIGHLIGHTS

- 0.1 µm pore size
- Completely hydrophilic
- High chemical and temperature tolerance
- Submerged design
- Resistant to damage from debris, grit, and coarse material
- Easily re-wetted after drying



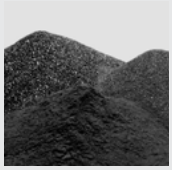
PLATE

WHAT'S SO SPECIAL ABOUT SILICON CARBIDE?

Silicon Carbide's natural properties effortlessly attracts water while repelling foulants. This results in extremely high sustainable fluxes and the ability to operate reliably in high solids and oils, as well as under other difficult conditions that polymeric membranes have shied away from. Silicon carbide is also one of the hardest materials in the world and forms membrane plates that are solid as a brick and able to withstand the broadest range of temperature, pH, chemicals, and pressures. SiC membranes have achieved a new level of performance in some of the most demanding applications.

MODULE

HOW IT'S MADE

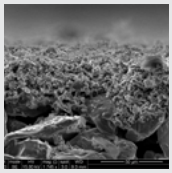


SiC POWDER

Silicon Carbide mixed into paste and extruded

SUBSTRATE

Extrusion fired at 2,000 °C to bind SiC grains



MEMBRANE LAYER

Membrane layer applied to substrate

SiC PLATE

0.1 micron SiC flat plate membrane

STACK

POTENTIAL APPLICATIONS

HIGH RATE MBR

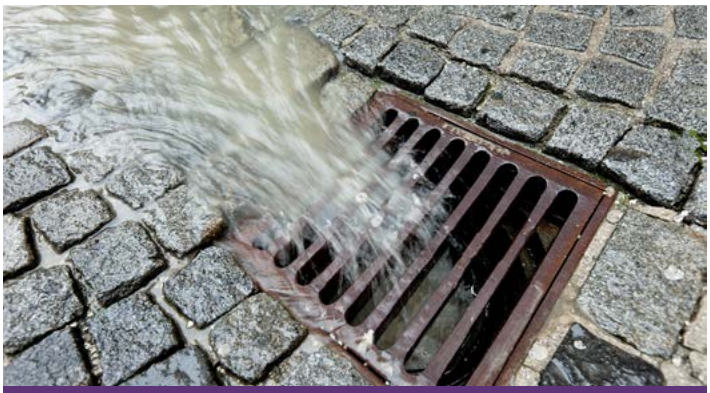
SiC allows for operation at high MLSS, increasing MBR capacity within the same footprint

SLUDGE THICKENING

SiC expands the operating window for MBT, easier to recover from dewatering

TERTIARY TREATMENT

High flux, low footprint design with lower energy consumption than hollow fibers



WET WEATHER OVERFLOWS

CSO, SSO MBR peak flow, CAS peak flow. SiC can be completely dried, allowing for intermittent storm use

WITHSTANDS THE HARSHEST ENVIRONMENTS

THE **OVIVO** DIFFERENCE

200+ YEARS OF HERITAGE • 100% FOCUSED ON WATER

OPERATING LIMITS/CAPABILITIES

Operating Parameter	Units	Silicon Carbide
TSS	mg/l	< 45, 000
Oil & Grease	mg/l	< 500
Free Oil	mg/l	< 500
pH	-	1 - 14
Temperature	°C	1 - 80
Backwash Pressure	psi	< 30
Chlorine Tolerance	wt%	1.0

CSO Results
(Raw Sewage)

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ALL OF YOUR KNOWLEDGE,
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