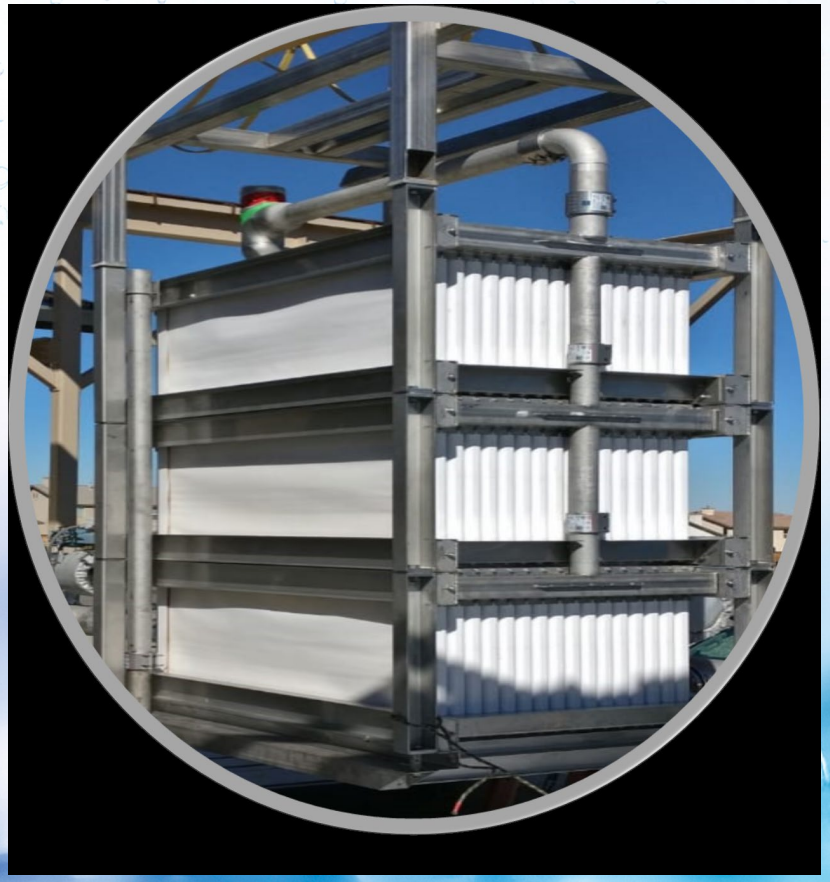
Footprint Matters.

How a Compact, MBR Hybrid Ultrafiltration Membrane can Save Space while Meeting Strict Water Reuse Permeate Quality



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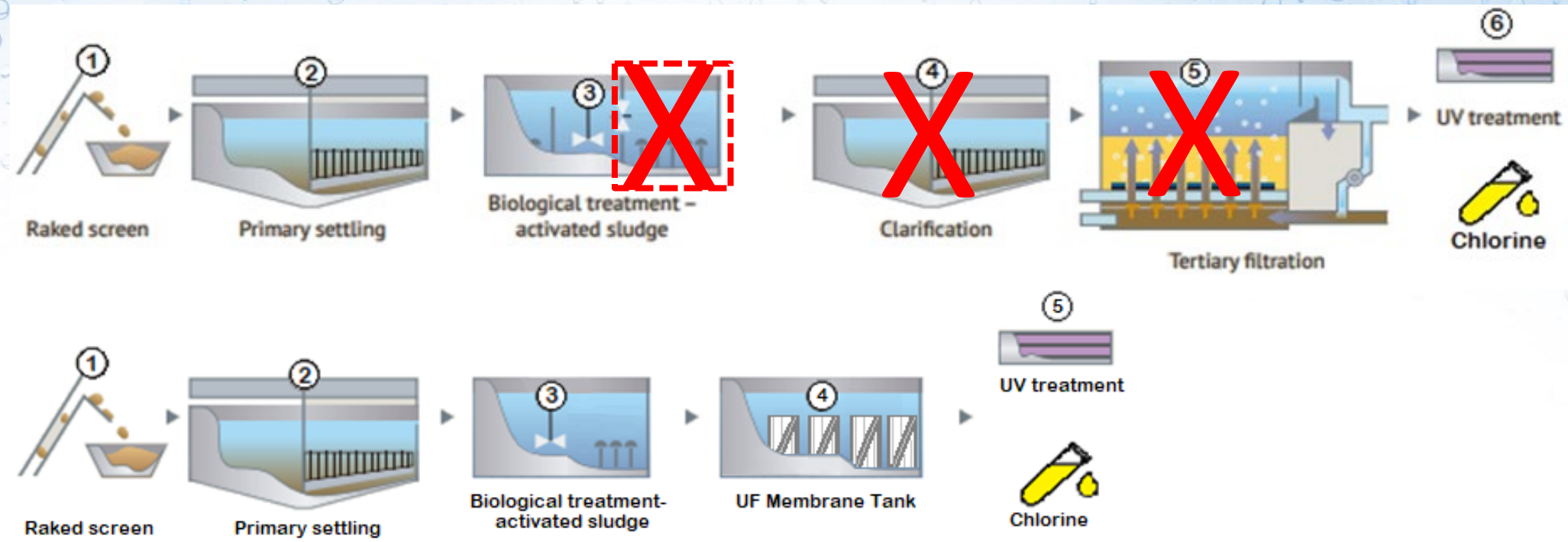
MBR Saves Footprint vs Conventional Treatment



MBR Benefits:

Smaller footprint: less civil works costs; eliminates (2) unit processes & reduction in biotank size
Quality discharge: good pathogen rejection (bacteria, virus, parasite), physical barrier (no carry-over)
Easier operation: eliminates many operating variables, allows for more automation/better control

Operations and Challenges:

Membrane fouling: filter surface must be kept clean from microbes and particulate
Screen by-passing: by-passing of screens, catastrophic to membranes leading to plant shut down or excessive desludging costs

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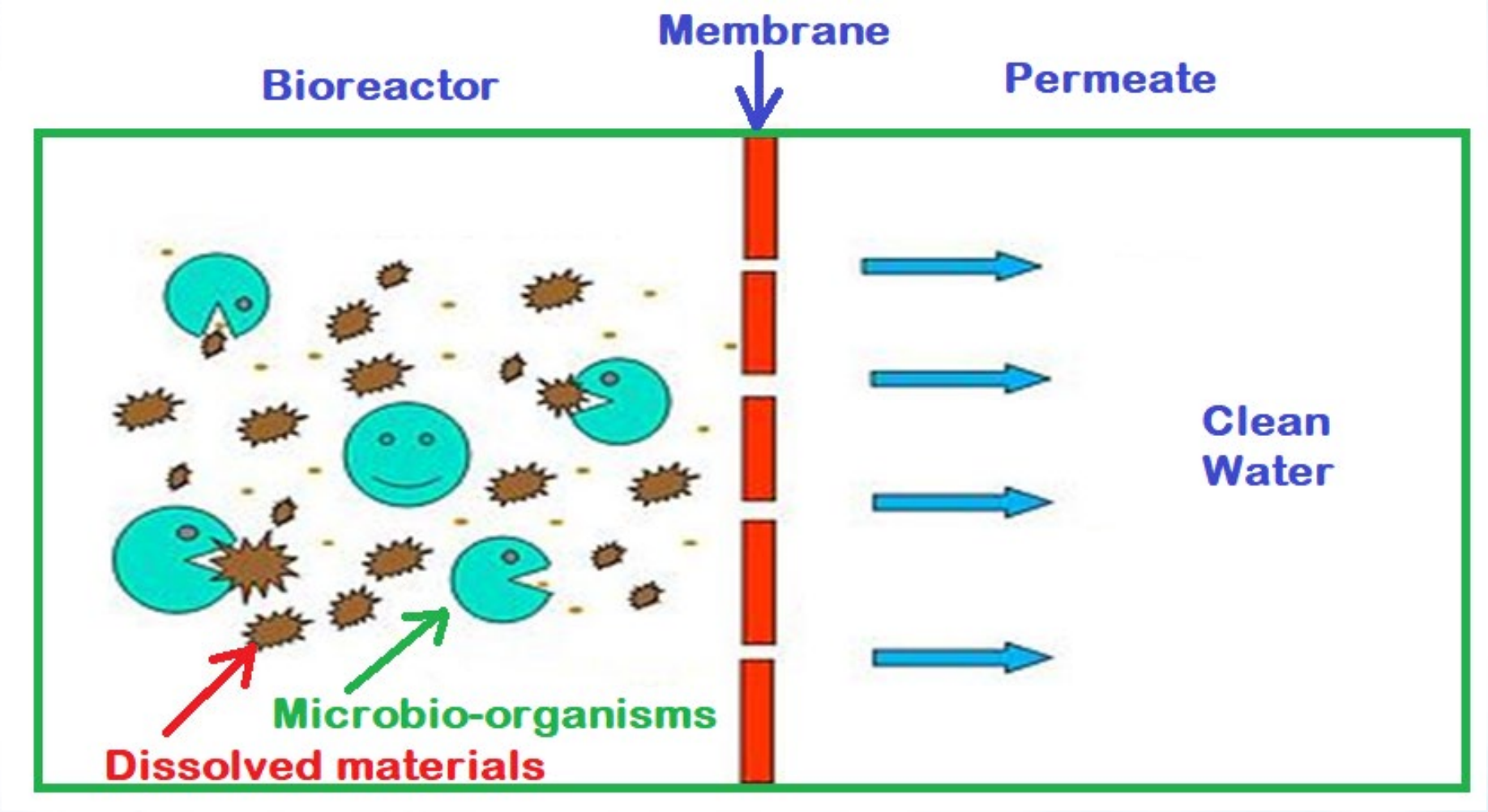
Membrane Bioreactor (MBR)



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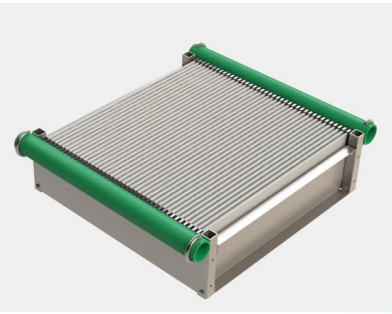
Amongst MBRs there are additional footprint savings depending on the type of membrane selected

Hollow Fibers

Plate and Frame Flat Plate

Flexible Sheets Horizontal and Vertical

Ceramic Sheets



Most membranes use the same flux, which means that they will need the same ft2 of membranes to treat the same flow

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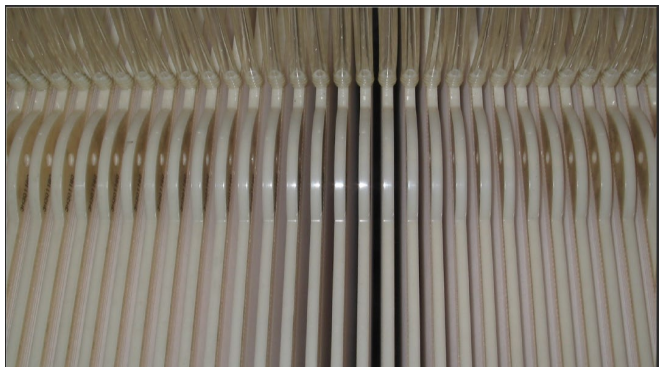
This means

Flux = Surface Area = Packing Density = Footprint

This Means that spacing between membrane sheets or fibers is directly related to Footprint

Example of Spacing in Sheet Membranes



6 – 8 mm

5 – 6 mm

1.5 mm

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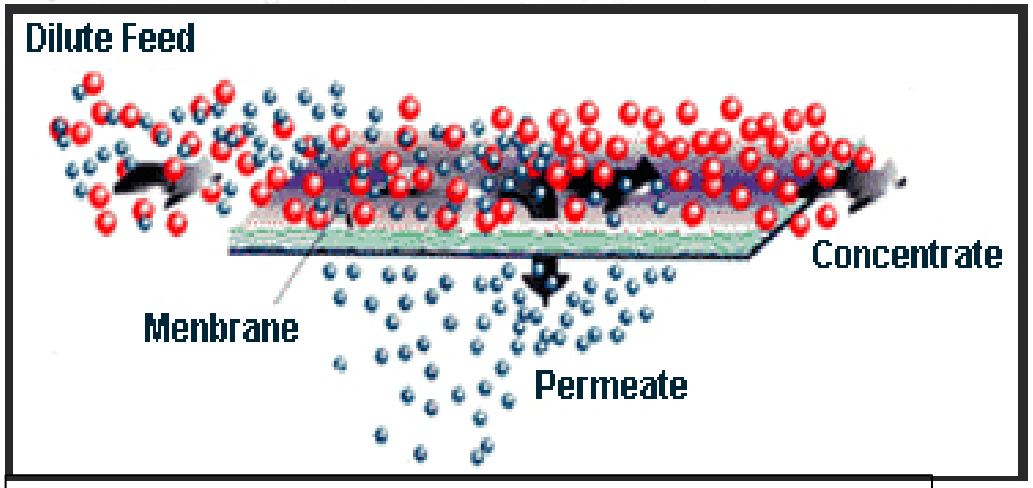
Our small spacing allows for Double Scouring

The FibrePlate Module is Designed for High Performance
It uses Aeration + the RAS energy for double membrane scouring



Principle of cross flow scouring in spiral and tubular membranes

The tight spacing between sheets allows for liquid scouring of the membrane surface just like a spiral membrane

When combined with our design to transform the membrane tank into an efficient hydraulic tank, we can harness the energy of the 4Q RAS to reduce operational costs

Thanks to this feature we can be energy efficient with a simple continuous aeration system

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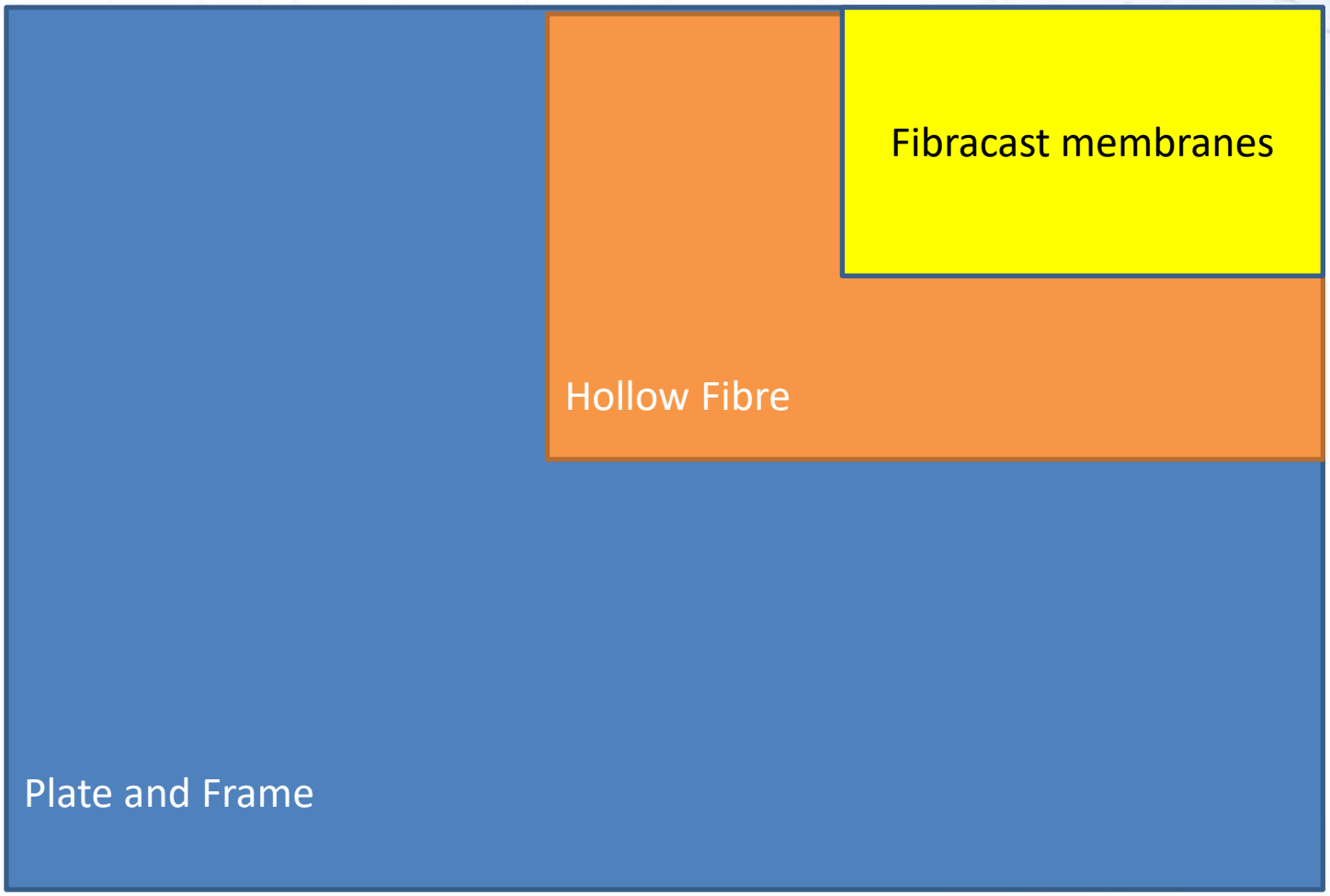
Approximate Footprint Comparison between types of Membranes



Typical Footprint Difference

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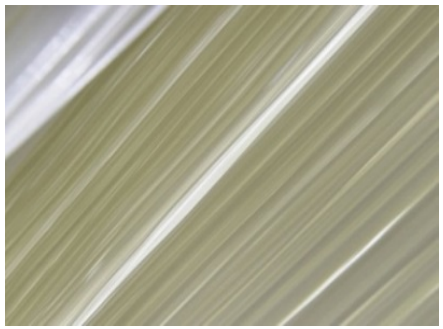
Introducing FibrePlate™ – a Hybrid Membrane

FibrePlate™ is a true ultrafilter (< 0.04 micron) membrane that combines the best attributes of hollow fiber and flat plate membranes into a high performance hybrid membrane

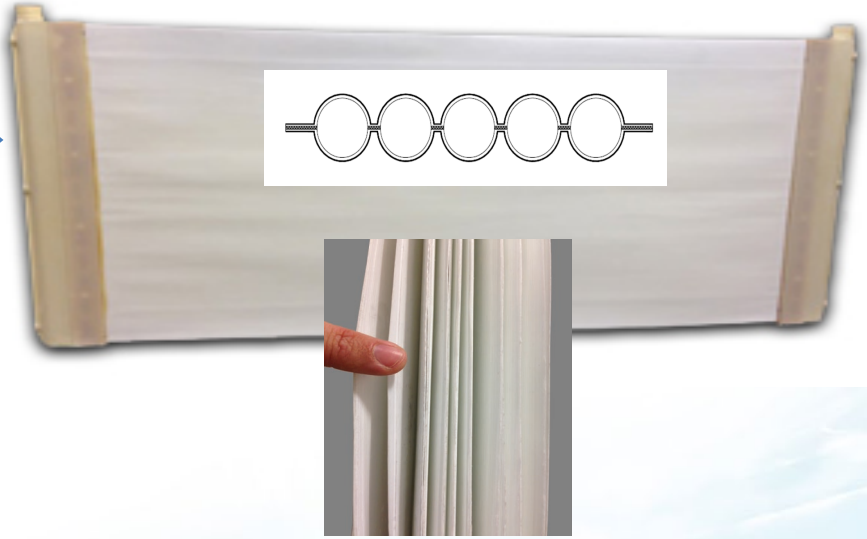
Hollow Fibre



Flat Plate

FibrePlate™

Back washable, reinforced. self healing ultrafilter



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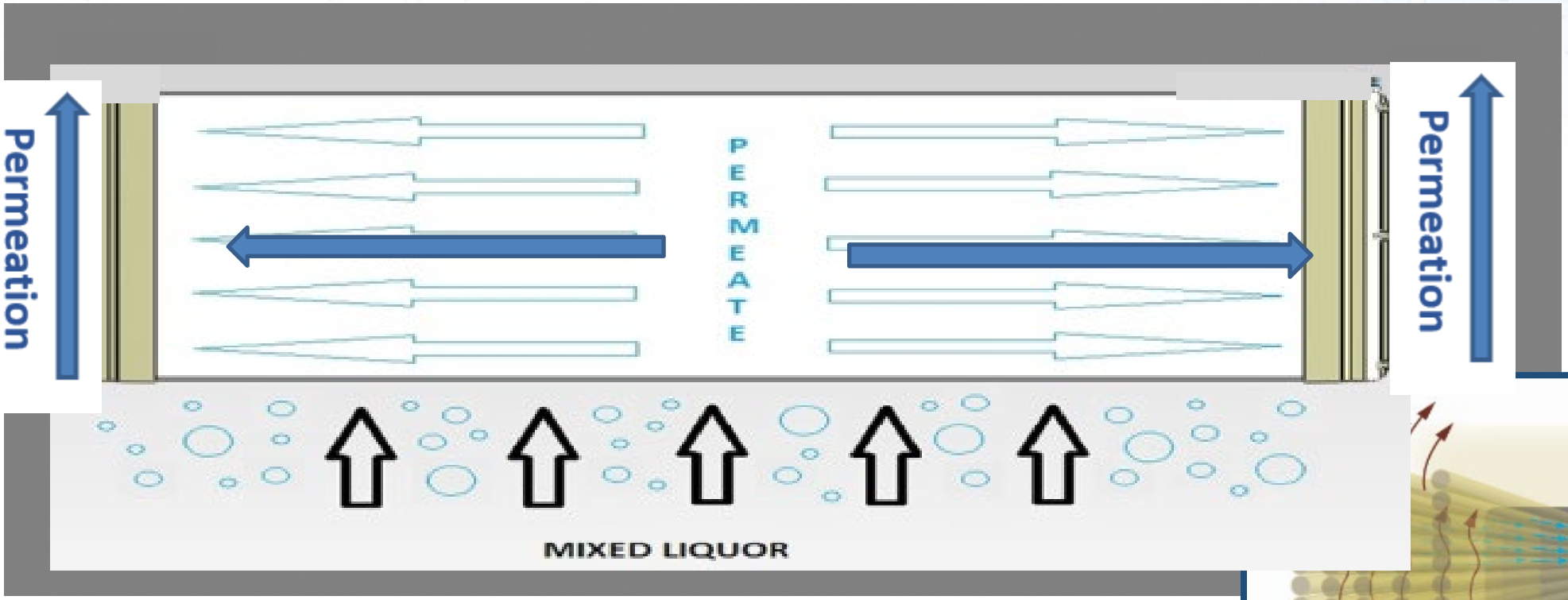
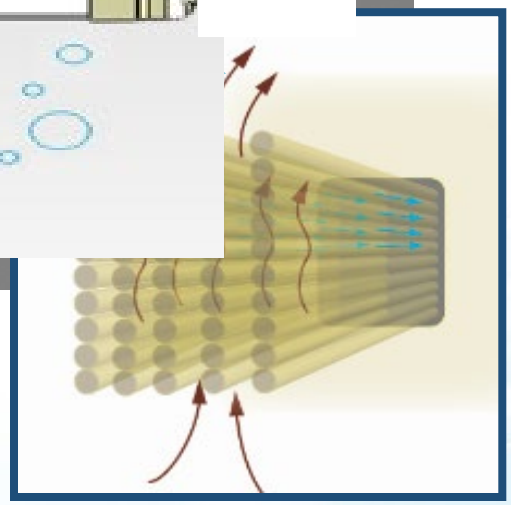
This is what Happens when Debris is trapped in Hollow Fiber

The FibrePlate Module is Horizontal with no top header

Reduced Debris Impact
Ease of Operation

A Horizontal Membranes with Permeate Headers on the sides for **free flow** of debris and no solids entrapment





- Large filtration surface area of 500 ft^2
- Backpulsable and backwashable
- Reinforced and self-healing

To avoid debris accumulation on the top headers, some hollow-fiber manufacturers tried horizontal modules but had to abandon due to fiber failure.

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FibrePlate™

SMALLER FOOTPRINT

28 Series	# of Modules	Membrane ft^2	Flow Rate (gpd)
3 Stack	84	42,000	504,000
2 Stack	56	28,000	336,000
1 Stack	28	14,000	168,000
16 Series			
3 Stack	48	24,000	288,000
2 Stack	32	16,000	192,000
1 Stack	16	8,000	96,000
10 Series			
3 Stack	30	15,000	180,000
2 Stack	20	10,000	120,000
1 Stack	10	5,000	60,000
3 Series			
3 Stack	9	4,500	54,000
2 Stack	6	3,000	36,000
FPM Module	1	500	6,000

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The FibrePlate™ Cassette

Reduced Debris Impact
Ease of Operation

No top headers allowing Debris to Flow Easy

Debris can flow up and out of the tank without being trapped on the membranes

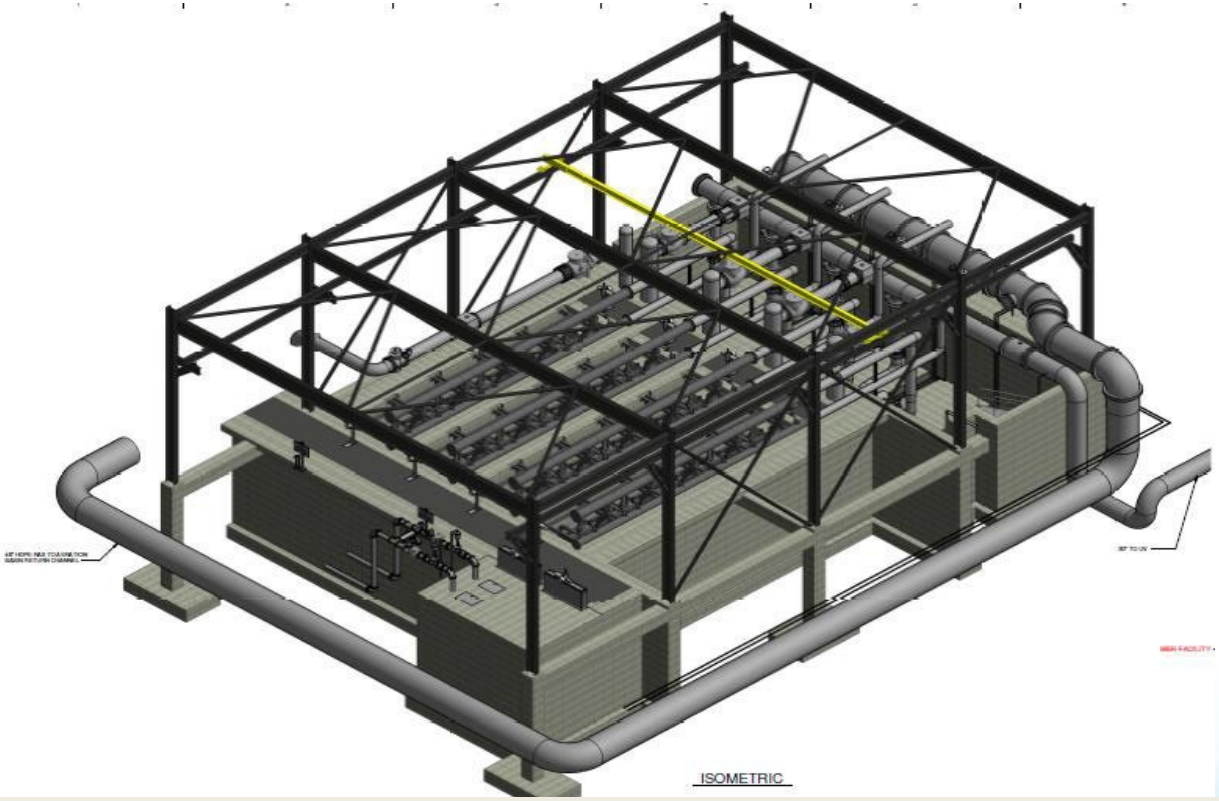
Nowhere for debris to get trapped

No matter how good your screen is, debris always shows up or re-rags

A building Block

Sheet → Module → Cassette → Train → MBR Plant

Module = 16
Sheets in a header



Very Compact Membrane Tank

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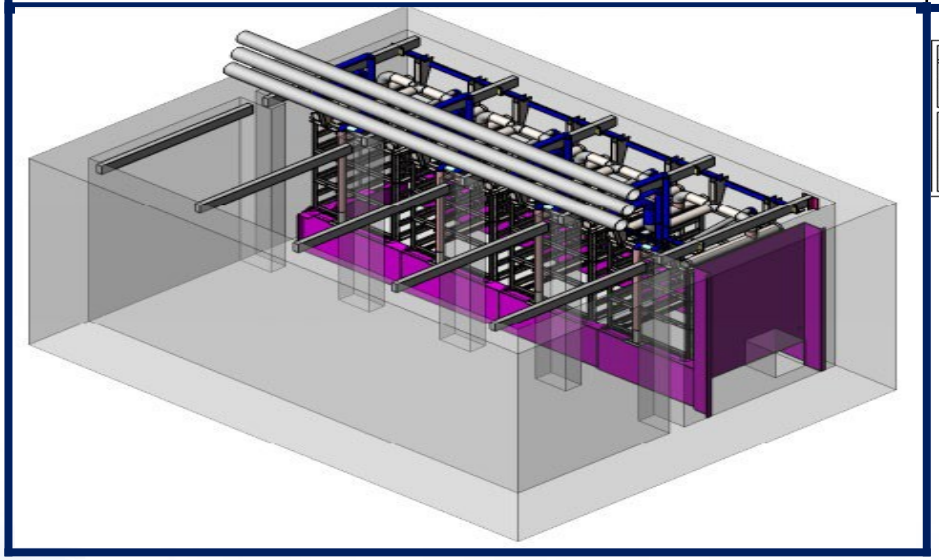
3 rows of modules per cassette

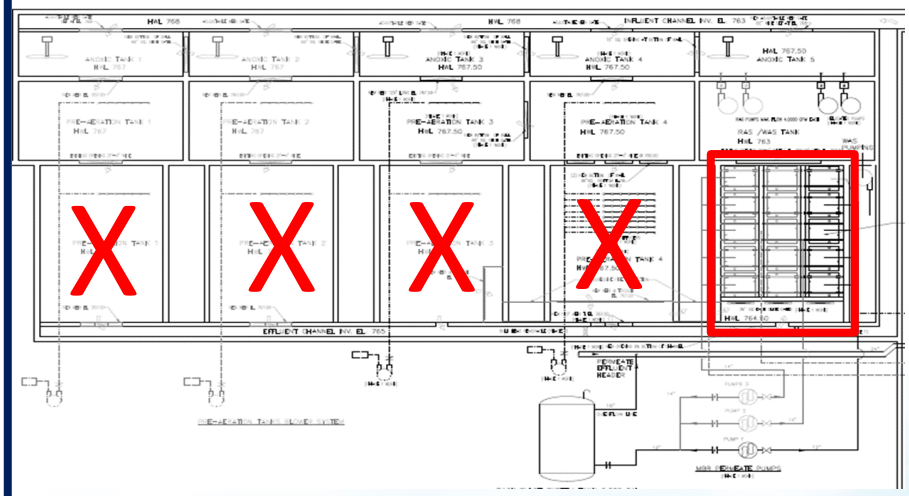
Allows for Lower Flux
Ease of Operation

Smallest Footprint on the Market

Allows for civil savings, lower OPEX, and/or easy expansion

1/2 footprint of Hollow Fiber proven at all flows			
Apple Valley – 1 MGD	Singapore – 1 MGD	Hesperia – 1.5 MGD	Victorville – 2.5 MGD
XinXeng – 5 MGD	Beaumont – 6 MGD	East Valley – 8.4 MGD	Selkirk – 1.2 MGD
1/5 footprint of Plate & Frame membranes			
Delphos		Retrofit-1/5 footprint for same flow	
Aldeno		Retrofit-1/5 footprint for same flow	





2.5 MGD HF Retrofit in California

½ the tank is now freed up for future expansion

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3.8 MGD FS Retrofit in 20% of the Space – Delphos

Footprint Matters

Typical Design and Operations Specifications

FibrePlate® Operating Specifications	
Typical Average Flux	10 - 15 gfd
Maximum Permeation(TMP)	8 psi
Typical Operating Pressure	1 - 5 psi
Maximum Operating Temperature	40 ^{0}C
Operating pH Range	4 to 10
Typical Back Pulse TMP	1.5 psi
Maximum Back Pulse TMP	4 psi

FibrePlate® Operating Parameters		
Parameter	**Mode**	**Range**
Permeate Flow	Automatic	5 - 10 minutes
Backwashing/Relaxation	Automatic	30 - 60 Seconds
Maintenance Clean	Automatic	1 - 2 Times per Week
Recovery Clean	Manually Initiated	1 - 2 Times per Year
RAS Flow Control	Automatic	4 - 5 Q
Membrane Air Scour Flow	Automatic and Continuous	0.006 - 0.012 scfm/ft^2

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Delphos keeps expanding with its new found space!

2.53 MGD – 2015

5 MGD - 2018

7.66 MGD – Q3, 2021 planned

With a Small Footprint, you have Options to Retrofit High Flux or Low Flux Operations

1) We can design at high fluxes like our competitors and only use part of an available tank or build a small rank

OR

2) We can design with lower fluxes that will make the plant easier to operate, more robust in the unplanned situations and allow for longer membrane life. Even potentially reduce operational costs

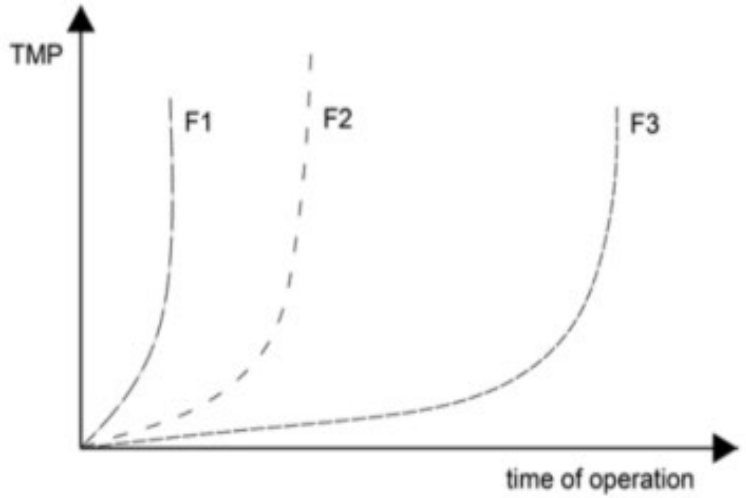

Fig. 2.12 Variation in TMP with operation time at different fluxes (F1 > F2 > F3)

Some authors employ the notion of a critical flux, or even a sustainable flux, to designate operational conditions which ensure long-term operation without the need for interventions involving invasive cleaning.

When the operation is carried out with a constant flux, a gradual increase in the transmembrane pressure (TMP) is observed, due to fouling. With low fluxes, the operation can be prolonged, without a premature and sharp increase in the TMP, as shown in Fig. 2.12.

Advanced Biological Processes for Wastewater Treatment: Emerging Technologies,
M. Decotti, G. Lippel, JP Bassin, 2017

The PROBLEM with higher fluxes, for an end of pipe plant, is related with the unplanned situations:

- **Extreme rains**
- **Trains down (pumps and blowers needing repairs or being cleaned)**

Normally Murphy is at play, these situations often happen when a train is down… So for the sake of the operators, one should design considering the N -1 flux conditions

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In addition to its small footprint, FibrePlate™ is also ideal for water Reuse Plants

Pore Size and Shape Matters

True Ultra Filtration Membrane with most pores < 0.035 um

Pore sizes are < 0.04 um

McMaster University

Brockhouse Institute for Materials Research
Canadian Centre for Electron Microscopy

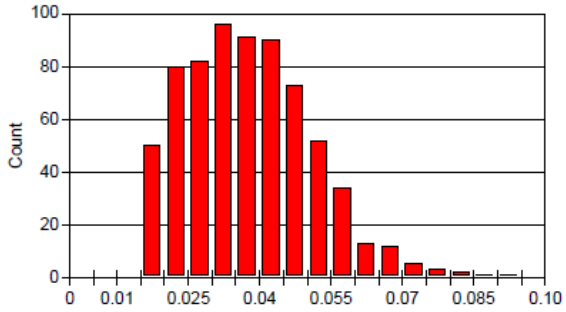
1280 Main Street West, Hamilton, ON, L8S 4M1 T: 905 525 9140, F: 905 521 2773

Results (continued)

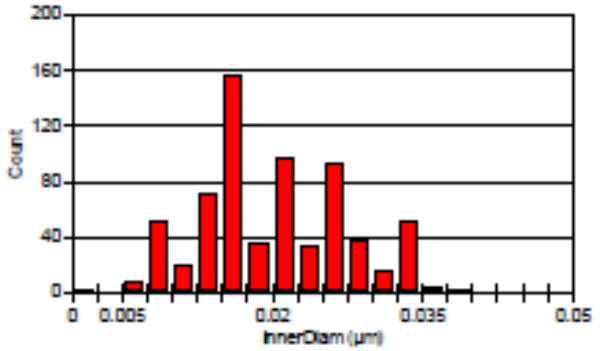
Table I:

Image	Pores per micron sq.	Pore Length (microns)	Pore Circular Diameter (microns)	Pore Inner Diameter (microns)	Pores
Figure 1(c)	120.0	0.035	0.024	0.016	707
Figure 1(e)	130.6	0.034	0.024	0.015	769
Figure 2(c)	47.4	0.037	0.027	0.018	436
Figure 2(e)	52.0	0.032	0.024	0.016	306

And tight distribution



Length of pores



Inner diameter of pores

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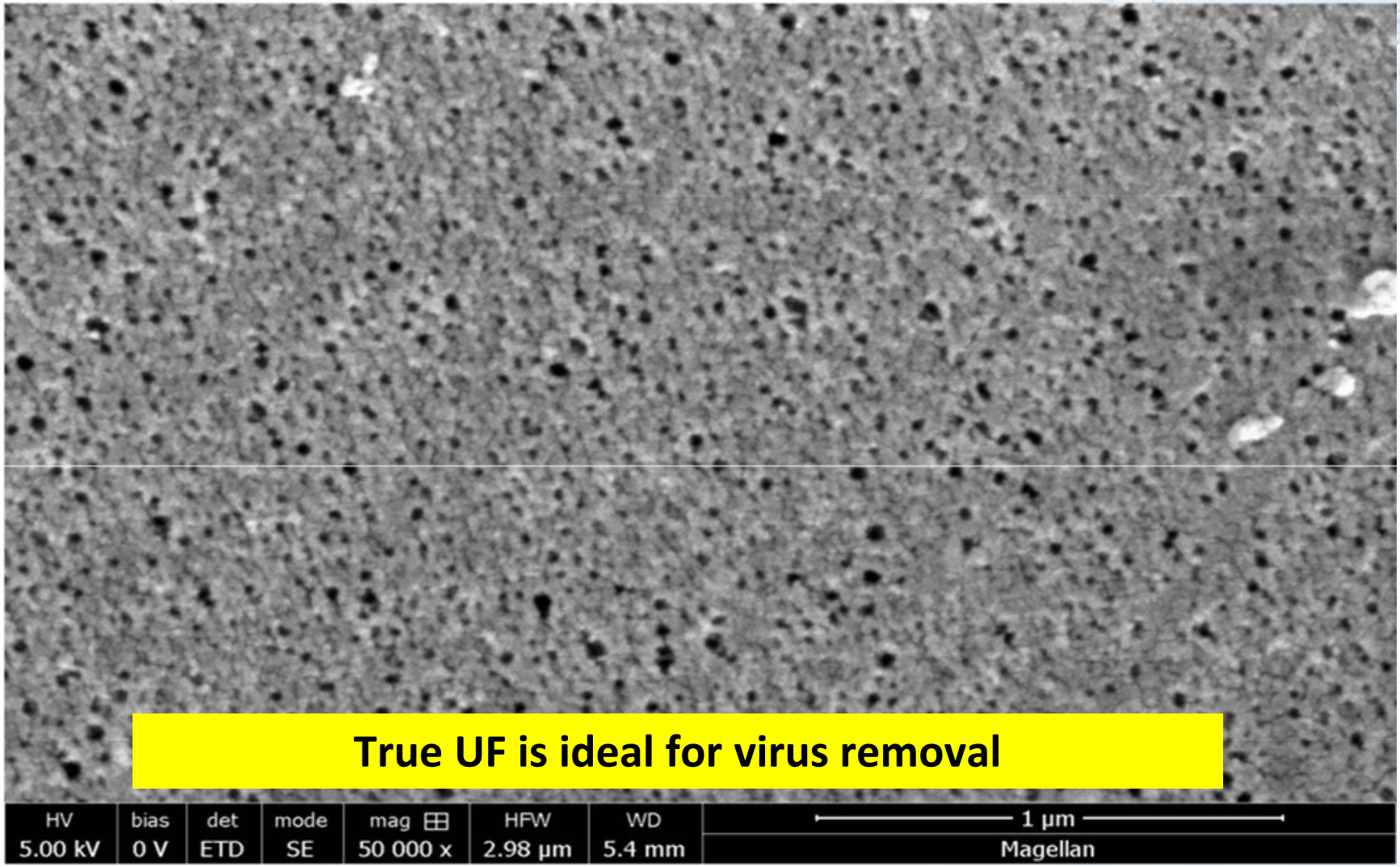
FibrePlate™ - Ready for IPR/DPR

Uniform pores < 0.04 micron PVDF UF Membrane



50,000X magnification

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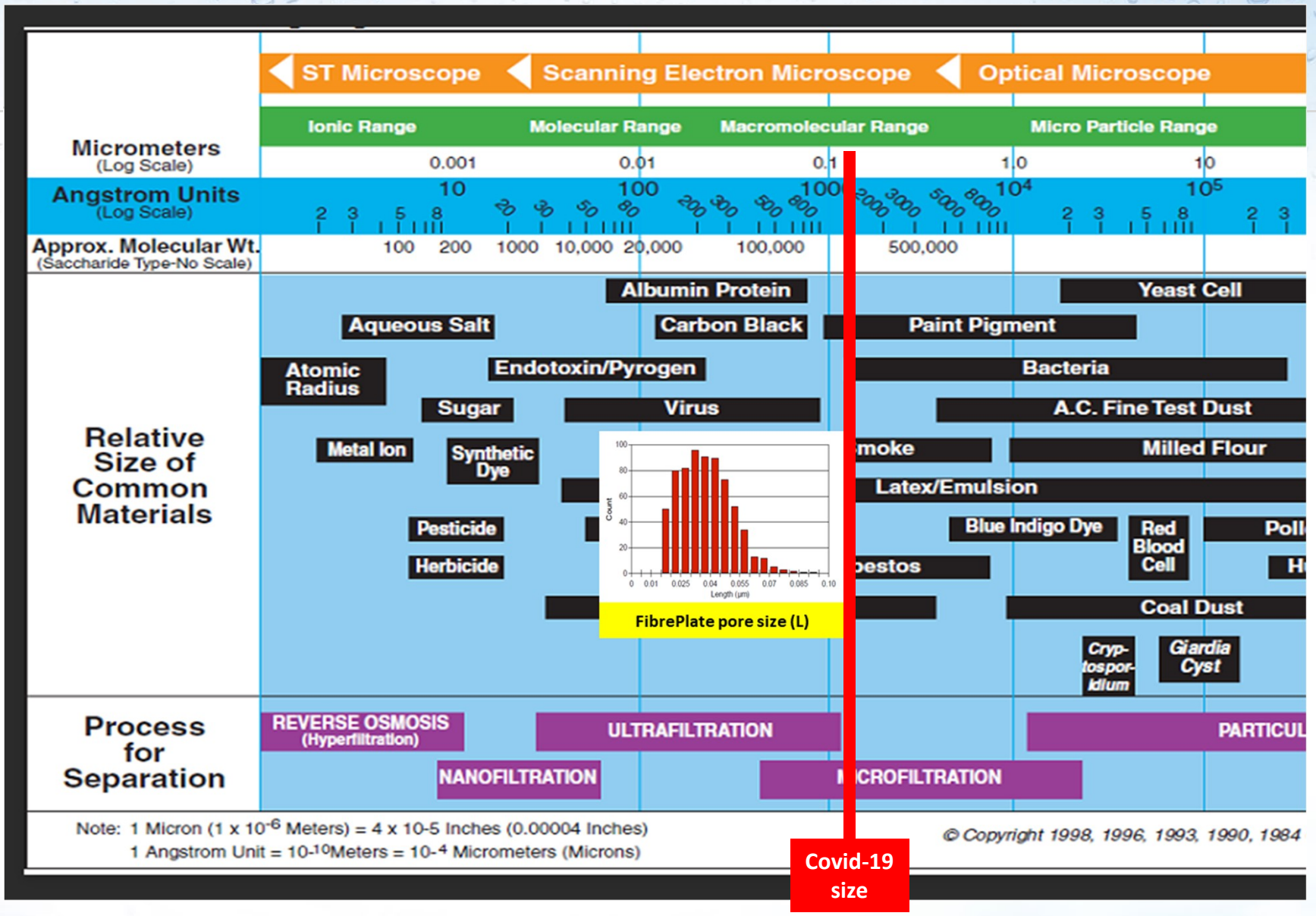
Pore Size Matters when it comes to Virus Removal
For example, Covid-19 is 3 times bigger than our pore size



- **The FibrePlate pore size is smaller than 50% of the viruses and smaller than most human pathogen viruses**

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FibrePlate™
FOR WATER REUSE

High Removal of Bacteria and Viruses – Apple Valley (CA)			
Parameter	**Units**	**Raw Influent**	**Permeate** before disinfection
Giardia	Cysts/L	4660 (average)	0
Cryptosporidium	Oocysts/L	<20	0
Bacteriophage, male specific	ptu/100 ml	$3.5x10^3$	<1
Bateriophage, somatic	ptu/100 ml	$4.7x10^3$	2
Adenovirus (1615)	GC/L	$6.7x10^6$	Not Detected
Enterovirus (PCR)	MPN/L	Not Detected	Not Detected
Norovirus GIB (PCR)	MPN/L	$3.9x10^5$	Not Detected
Total Culturable Virus	MPN/L	Too toxic to measure	<0.16
Clostridium perfringens spores	Cfu/100 ml	$3.5x10^3$	<1

Conclusion - A Small Footprint Membrane offers high effluent quality with a design option

SMALLEST FOOTPRINT	• Lower Capex • Lower Opex
CLEAR VERTICAL FLOW PATH	• Protects fibers from abrasion • Fewer maintenance cleans
RUGGED TIGHT CONFIGURATION	• Excludes large debris • Eliminates "membrane-picking" • Lower lifecycle costs
TRUE ULTRAFILTER	• Improved permeate quality and safety
HIGH VELOCITY DIRECT RAS FEED	• More effective scouring • Reduce aeration costs

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