WATEREUSE NORTHERN CALIFORNIA

Can MBR Replace MF/UF in a Potable Reuse Train - Implementation Concerns?

August 19, 2016

Ufuk G. Erdal, Ph.D., PE

ch2m SM

Outline

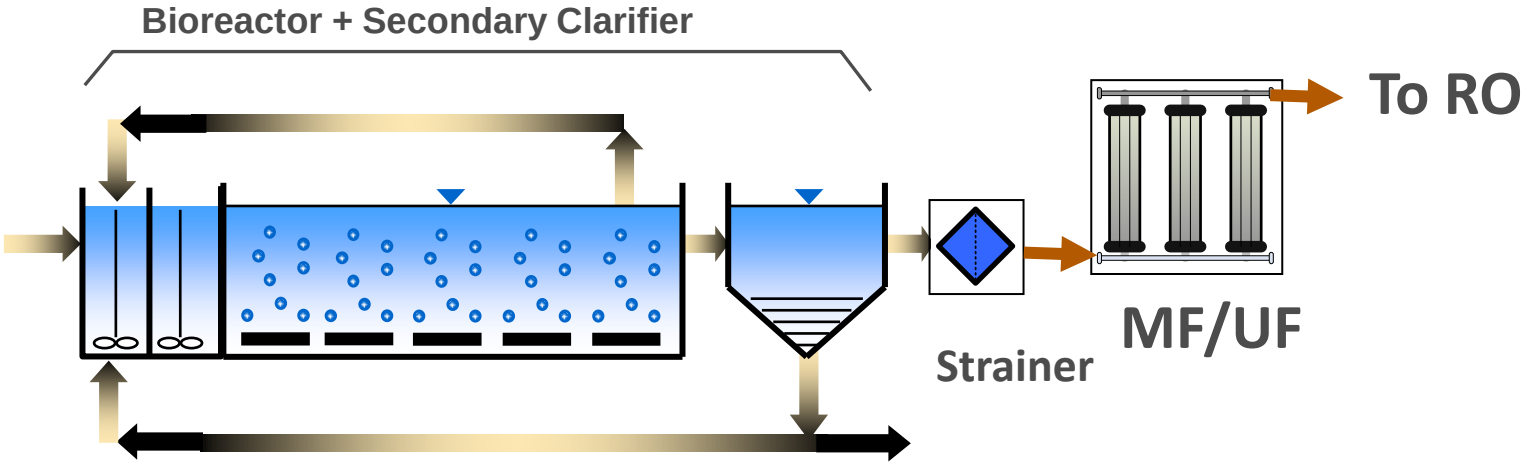
- Objectives
- Background
- Approach
- Conclusions
- Questions and Comments

We are getting the following questions

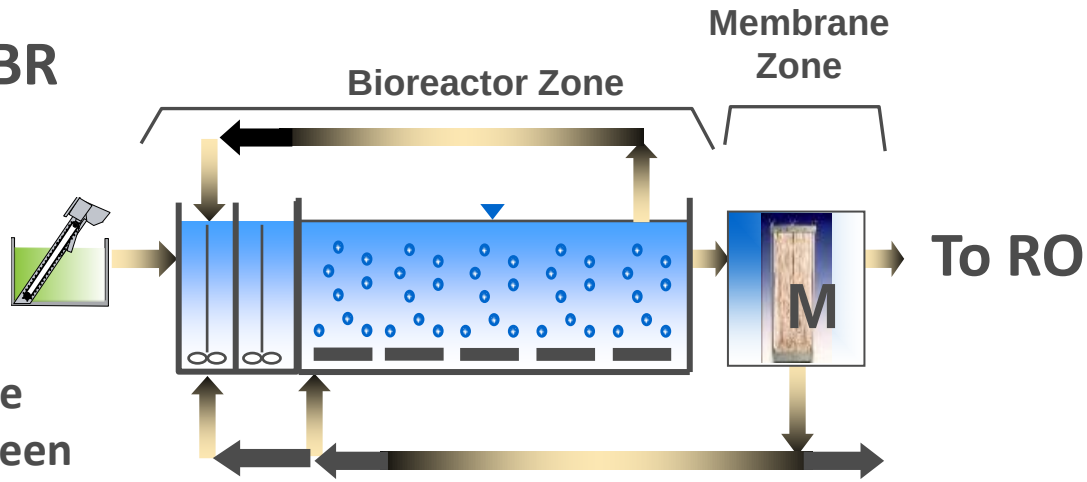
- Can we use MBR in lieu of MF/UF in a potable reuse train?
- Can we get similar pathogen credits for MBR if MBR replaces MF/UF in a potable reuse train?
- Can we apply pressure based DIT to MBRs?
- Are there any other method to assess MBR membrane integrity and warrant pathogen credits
- **Objectives**:
  - Provide answers to above questions

Background

CAS-MF/UF



MBR



MBR Has Advantages Over CAS-MF/UF

- Replaces secondary clarifiers with low pressure membranes
  - Clarifier limitations are no longer an issue; operates at much higher MLSS than CAS systems
  - Compact due to reduction of AS basin volumes and elimination of SCs
- For a given activated sludge basin volume, MBR can be operated at longer SRTs than CAS which further enhances removal of bulk (COD, BOD) and trace organics (TOC, CECs).
- For a given SRT, MBR requires less AS basin volumes than CAS

MBR Has Advantages Over CAS-MF/UF

- Median floc diameter is smaller in MBR systems (10 µM) than CAS systems (120 µM) operated under identical conditions (WEF, 2012).
- Smaller flocs observed in MBR systems increase the exposed surface area which further enhance
  - removal of certain CECs with logKow>3
  - removal of metals which reduce scaling of RO membranes
  - sorption of pathogens to MLSS and their removal during membrane filtration

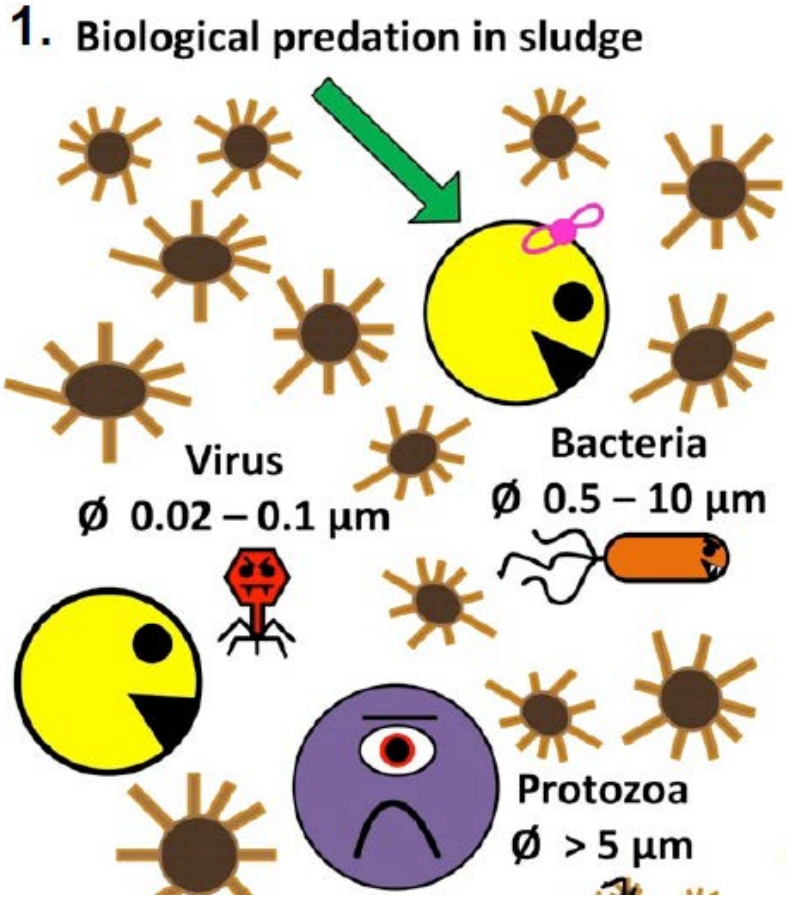
Pathogen Log Removal Credits and Requirements for CA IPR Projects

	CAS	MF/UF	RO	UVAOP	Cl2	Total	GWR	Draft IPR via SWA
Crypto	0	4	1-2	6	0	11-12	10	8/9
Giardia	0	4	1-2	6	0	11-12	10	7/8
Virus	1	0-4	1-2	6	6	14-19	12	8/9

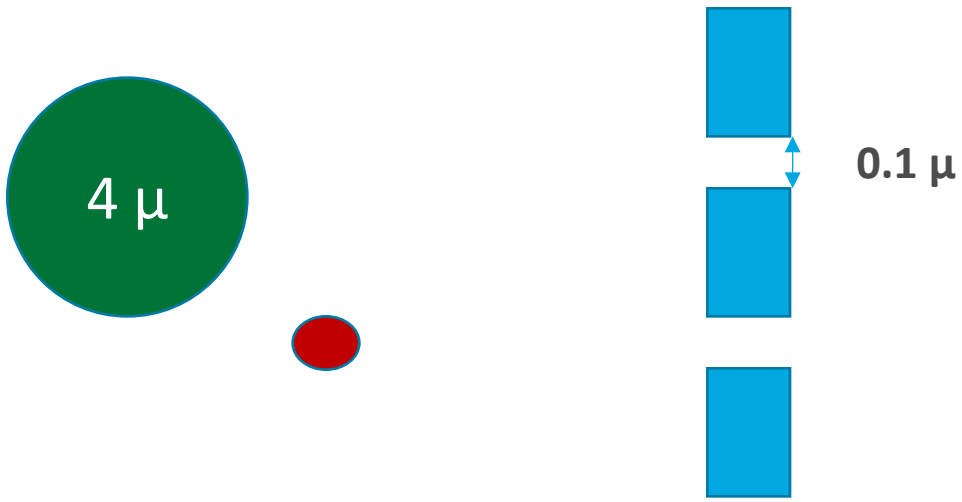
	MBR	RO	UVAOP	Cl2	Total	GWR	Draft IPR via SWA
Crypto	0	1-2	6	0	7-8	10	8/9
Giardia	0	1-2	6	0	7-8	10	7/8
Virus	0	1-2	6	6	13-14	12	8/9

Pathogen Removal Mechanisms in MBR Systems

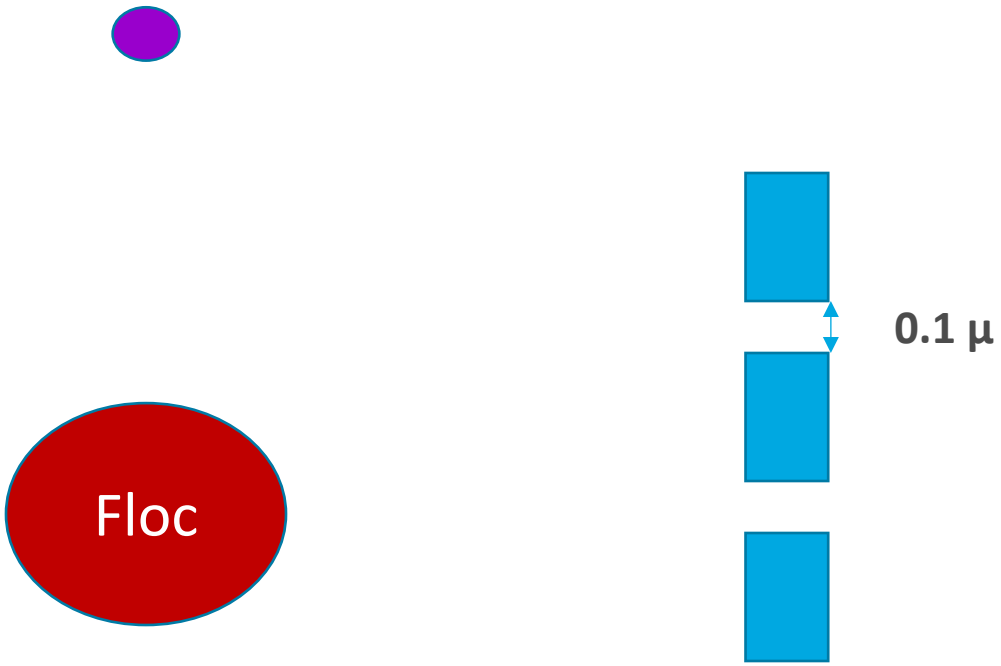
1. **Competition/Predation** - Predator organisms such as protozoa and fungi consume small microorganisms



2. Direct Removal via Size Exclusion - Molecules larger than membrane pore sizes will be rejected regardless of their surface properties (i.e., charge, polarity)

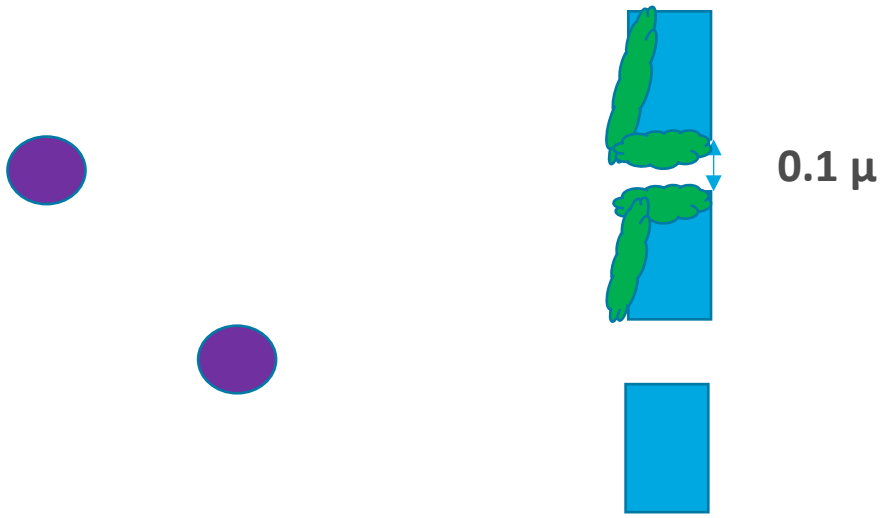


3. Absorption into Biomass (MLSS) and Sequential Removal through Membrane Filtration



4. Pore Blocking - Large molecules such as carbohydrates, polysaccharides, MLSS flocs and larger pathogens block the pores of the membranes and restrict passage of small viruses

5. Reduction of Effective Pore Size due to Biofilm Growth, Gel and Cake Layer Formation on Membrane Surface and Pores



Pathogen Removals in A Full Scale MBR Facility

Henderson WRF, NV

Normal Operating Conditions- (i.e. Design Flux, SRT, etc.)

	Size,nm	MBR Influent	MBR Permeate	Concentration Limit in Recycled Water	Log Removal Achieved
HAdV, Copies/1 L	70-110	338,555	ND (<1)	No set limit (NSL)	>5.53
Norovirus G1, Copies/1 L	35-39	ND (<1)	ND (<1)	NSL	NA
Norovirus G2, Copies/1 L	35-39	ND (<1)	ND (<1)	NSL	NA
MS2 Coliphage, pfu/100 mL	24-26	4,400	ND (<1)	NSL	>3.64
Somatic Coliphage, pfu/100 mL	30-95	6,200	ND (<1)	NSL	>3.79
Total Coliform, cfu/100 mL	~1,000	17,000,000	ND (<2)	NSL	>6.93
Fecal Coliform, cfu/100 mL	~1,000	3,000,000	ND (<2)	2.2	>6.18

Nominal pore size for GE Zeeweed 500d=40 nm

Clean Membranes with Chlorine

	Size, nm	Influent	MBR Permeate	Concentration Limit in Recycled Water	Log Removal Achieved
HAdV, Copies/1 L	70-110	37,572,276	1	NSL	7.57
Norovirus G1, Copies/1 L	35-39	1,038,037	ND (<1)	NSL	>6.02
Norovirus G2, Copies/1 L	35-39	197,974	ND (<1)	NSL	>5.30
MS2 Coliphage, pfu/100 mL	24-26	2,400	5	NSL	2.68
Somatic Coliphage, pfu/100 mL	30-95	1,900	3	NSL	2.80
Total Coliform, cfu/100 mL	~1,000	13,000,000	ND (<2)	NSL	>6.81
Fecal Coliform, cfu/100 mL	~1,000	5,000,000	ND (<2)	2.2	>6.40

Nominal pore size for GE Zeeweed 500d=40 nm

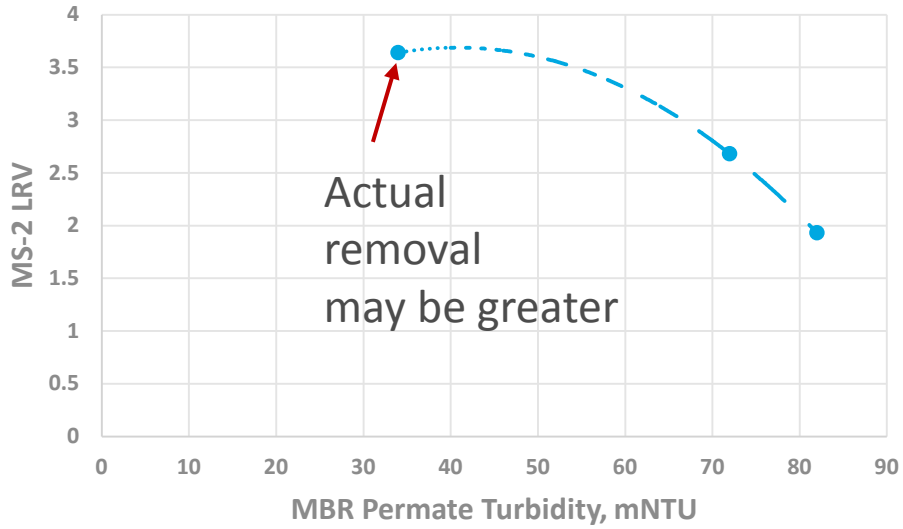
Clean Membranes with Citric Acid

	Size, nm	Influent	MBR Permeate	Concentration Limit in Recycled Water	Log Removal Achieved
HAdV, Copies/1 L	70-110	2,016	ND (<1)	NSL	>3.30
Norovirus G1, Copies/1 L	35-39	ND (<1)	ND (<1)	NSL	NA
Norovirus G2, Copies/1 L	35-39	ND (<1)	ND (<1)	NSL	NA
MS2 Coliphage, pfu/100 mL	24-26	1,800	21	NSL	1.93
Somatic Coliphage, pfu/100 mL	30-95	1,500	7	NSL	2.33
Total Coliform, cfu/100 mL	~1,000	12,000,000	ND (<2)	NSL	>6.78
Fecal Coliform, cfu/100 mL	~1,000	11,000,000	ND (<2)	2.2	>6.74

Nominal pore size for GE Zeeweed 500d=40 nm

Can Turbidity Removal Correlate with Virus Removal?

	Normal Operating Conditions	Clean Membranes Right After NaOCl Cleaning	Clean Membranes Right After Citric Acid Cleaning
Average Permeate Turbidity, mNTU	34	72	82
MS-2 Log Removal	>3.64	2.68	1.93
Somatic Coliphage Log Removal	>3.79	2.80	2.33



Limited data indicate good correlation between MBR permeate turbidity and MS-2 LRV

More research is needed

Pathogen Credit to MBR Was Given by State of Nevada

ndep NEVADA DIVISION of ENVIRONMENTAL PROTECTION
protecting the future for generations

STATE OF NEVADA — Brian Sandoval, Governor
Department of Conservation & Natural Resources — Leo M. Drozdoff, P.E., Director
DIVISION OF ENVIRONMENTAL PROTECTION — Colleen Cripps, Ph.D., Administrator

December 9, 2013

Adrian Edwards, Wastewater Operations Manager
City of Henderson
240 Water Street
P.O. Box 95050
Henderson, NV 89009-5050

RE: **Requested Modification of the Operation and Maintenance at the City of Henderson Southwest Water Reclamation Facility (SWRF)**

Dear Mr. Edwards:

Our office received a copy of your letter dated November 12, 2013 requesting approval to modify the operation of the Southwest Water Reclamation Facility (SWRF) by removing the ultraviolet disinfection equipment from normal service. After review of the backup information provided, including the City's weekly sampling data, the on-site virus removal study data and precedents from other states; it appears that the membrane bioreactors have the ability to meet the fecal coliform limits in your permit (NS80003). Based on this, it is acceptable to NDEP to receive disinfection credits for the membrane bioreactors and remove the ultraviolet disinfection equipment from normal service. This conditional approval to suspend the ultraviolet disinfection equipment from normal service comes with the following stipulations:

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HOLLYWOOD


CALIFORNIA REPUBLIC


Welcome to
California

Stringent Regulatory Requirements in CA

- State Water Board DDW requires an approved method (currently none) to assess membrane integrity in MBR systems for pathogen credits
- Potential methods/approaches to assess membrane integrity in MBRs:
  - Direct Integrity Testing (DIT)
  - On-line Turbidity Monitoring
  - Real-Time Detection via Multi-Angle Light Scattering MALS (BioSentry)
  - On-line Particle Counting
  - Membrane Integrity Sensor
  - Inject Surrogates (dyes, synthetic chemicals) to MBR Feed and Monitor them in permeate stream
  - Real-Time Detection via ATP Production Luminultra (HACH)

Membrane Integrity Assessment Methods

1. Direct Integrity Testing (DIT)

- Under LT2ESWTR, DITs should meet resolution and sensitivity requirements outlined in EPA MFGM.
- The sensitivity of a membrane filtration system is defined as the maximum LRV that can be reliably verified by a field DIT, which must be equal to or greater than the *Cryptosporidium* removal credit awarded to the system
- Up to 4-log Crypto and Giardia credits may be awarded for MF/UF based on daily DIT

DIT Testing

- DIT begins by pressurizing membrane fibers from inside to approximately 12-20 psi about 30-45 seconds.
- Once the pressure is stabilized the pressure source was isolated and the decay test started. The pressure was recorded over a 5-minute, or till the pressure decreased to the minimum permissible pressure as required by the test resolution, whichever occurred first.

Daily pressure decay test

Calculate pathogen removal

$$LRV = \log\left(\frac{Q_p \bullet ALCR \bullet P_{atm}}{\Delta P_{test} \bullet V_{sys} \bullet VCF}\right)$$

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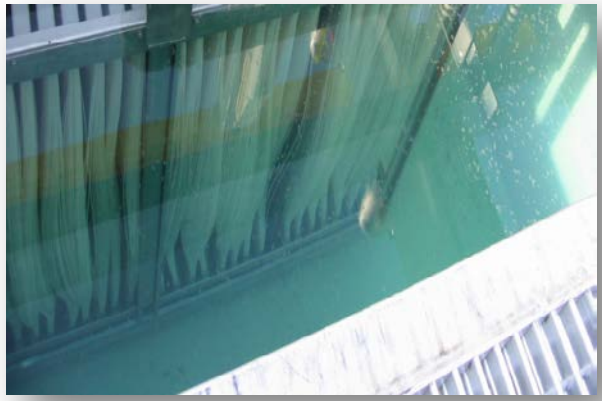
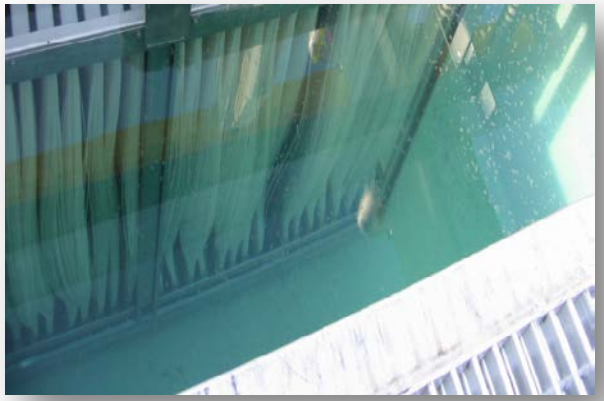
Concerns/Challenges with DIT in MBR Systems

- Historically MBR manufacturers are not used to providing pressure decay testing
- DIT test pressure is relatively high and cannot be applied to flat sheet MBR membranes.
- DIT test pressure also exceeds most of the MBR hollow fiber membrane suppliers pressure requirements (3-5 psi)
- Currently only one MBR vendor has DIT capability.
  - An MBR system used in an IPR train in Australia gets up to 3.0 log Crypto and Giardia credits via DIT



Concerns/Challenges with DIT in MBR Systems

- Inside coating of many MBR membrane fibers cannot handle the DIT testing pressure for 4-log Crypto resolution
- Lack of correlation between PDT and LRV in MBR; due to the action of mechanisms other than pure size exclusion
  - Pore blocking, cake and gel layer formation
  - Presence of predator organisms that consume pathogenic organisms
  - Absorption of pathogens to MLSS and their removal thru membrane filtration and periodic sludge wasting



MBR Membrane Integrity Assessment Methods

2. Continuous Monitoring of Turbidity

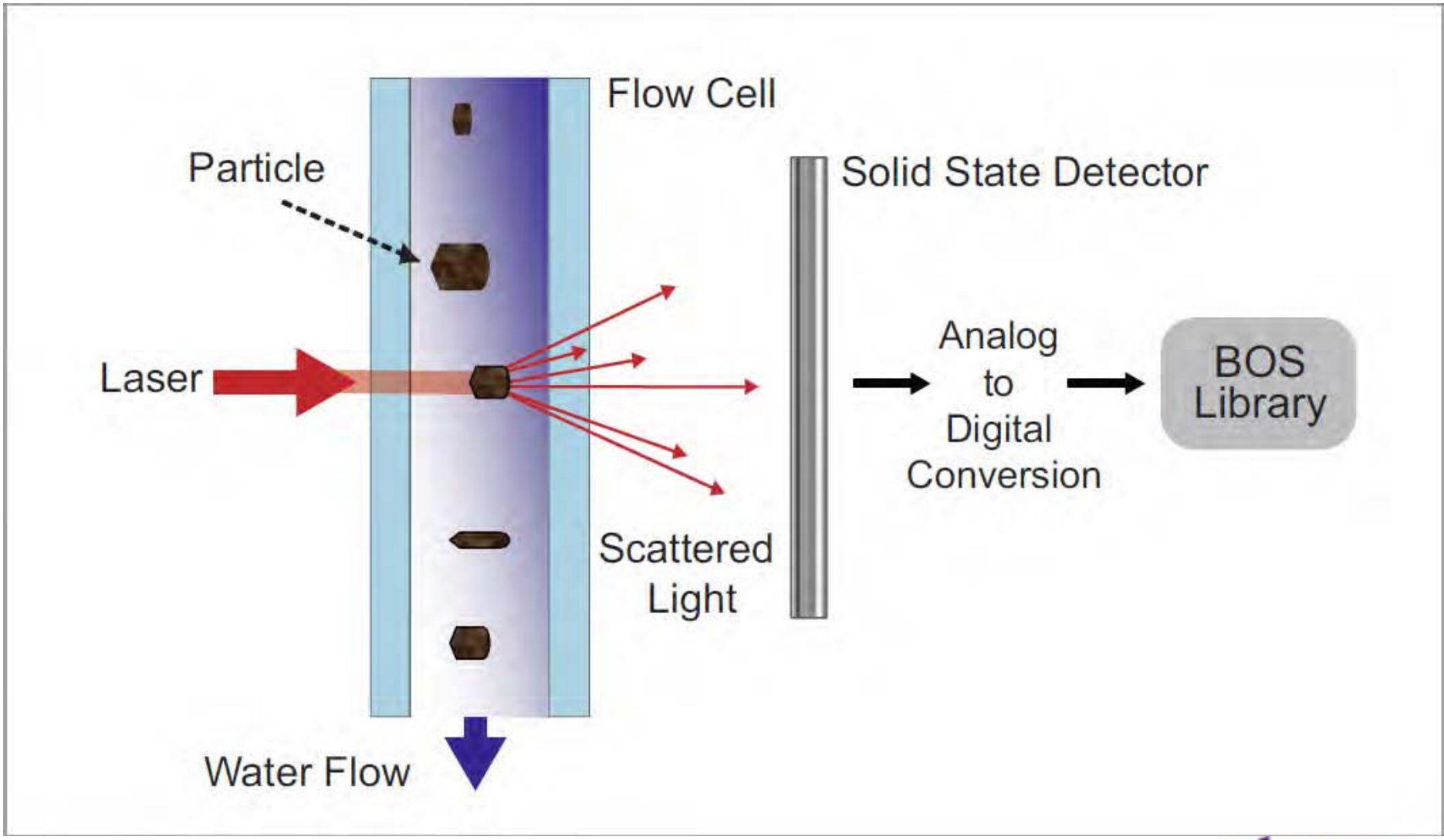
Turbidity and virus removals have been usually well correlated in full-scale demonstrations

- Jimenez *et al*. 2011 compared log removal distributions for virus and bacterial indicators at pilot scale.
- For a permeate turbidity ≤0.2 NTU, 95% of LRV measured for Somatic coliphages was above 3.1
- Erdal et al. 2013. For permeate turbidity ≤0.2 NTU
  - 95% of LRV measured for MS-2 coliphages was above 2.03
  - 95% of LRV measured for Somatic coliphages was above 2.51
  - 95% of LRV measured for Adenovirus was above 3.95
  - 95% of LRV measured for Fecal Coliform was 6.29

Monitoring Turbidity, Cont'd.

- Extensive literature search and data collection were conducted by Amos Branch and Pierre Le-Clech (2015) to establish a default LRV for MBR systems.
- Based on the data collected, they proposed the following:
  - For MBR systems, with 95th percentile ≤ 0.4 NTU, and 95th percentile flux 16.9 gfd
    - Virus: 1.5
    - Bacteria: 4.0
    - Protozoa: 2.0
  - For MBR systems, with membrane nominal pore size <0.1 µ, with 95th percentile turbidity ≤ 0.3 NTU and flux never exceeding 17.7 gfd.
    - Virus: 1.5
    - Bacteria: 4.0
    - Protozoa: 4.0

Potential Approaches to Assess MBR Membrane Integrity



Summary and Conclusions

- MBR can provide equal or even better treatment than CAS-MF/UF including pathogen removals and can be used in a potable reuse train in replacing MF/UF.
- DIT or an alternative method is needed to assess MBR membrane integrity and warrant pathogen credits by DDW
- Pressure decay based direct integrity tests may be used in MBR systems but they have limitations
  - they do not account for additional pathogens removals achieved in MBR systems
  - Cannot be applied to many existing products
- Turbidity along with MBR operational parameters seem practical and more accurately depict permeate quality and pathogen LRV relationships than DIT


Questions and Comments
For more information, please contact:
uerdal@ch2m.com
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