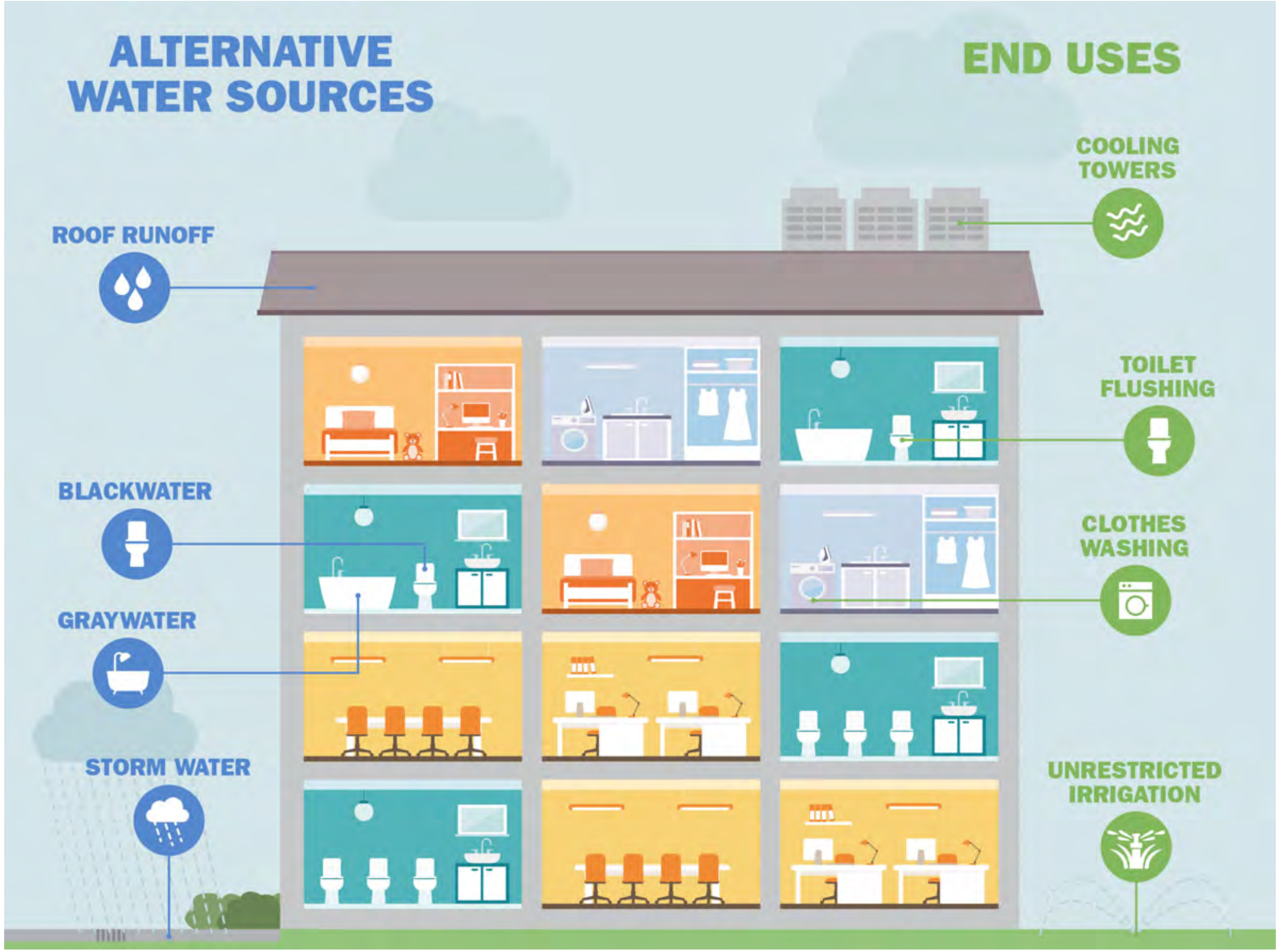
Module 1: Introduction

Introduction to ONWS

ONWS = *Onsite* non-potable water systems

Develop local, sustainable water supplies using alternative source waters at building or neighborhood scale

What is Onsite Non-Potable Water?



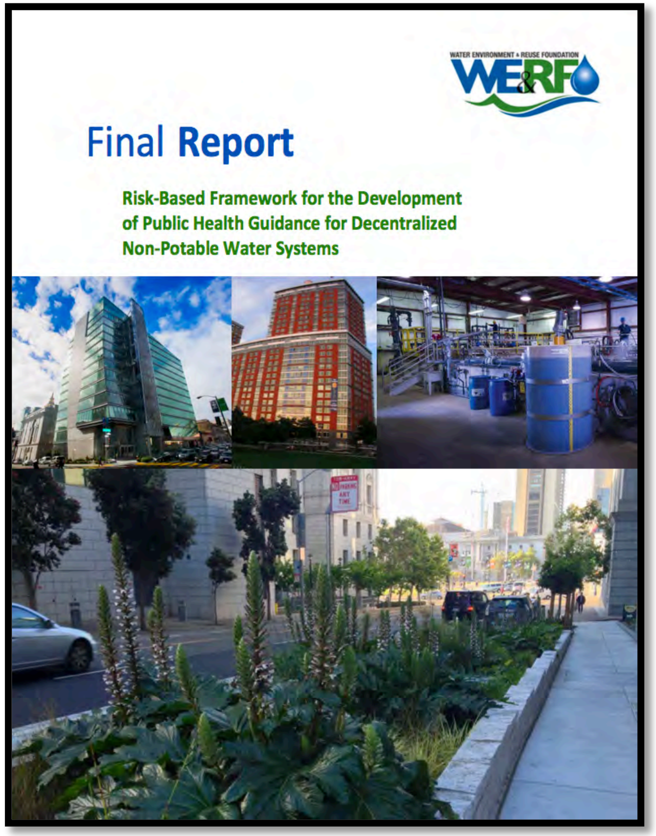
National Blue Ribbon Commission for Onsite Non-potable Water Systems

- Aims to advance use of onsite non-potable water systems by sharing best practices and fostering a supportive policy and regulatory environment
- Water Research Foundation Project 4909 funded by NBRC

National Blue Ribbon Commission
for Onsite Non-potable Water Systems

Public Health is the Top Priority

- Commission convened Expert Panel to determine pathogen reduction required to make alternative source waters protective of public health



The goal of this Guidance Manual is to provide guidance to ONWS stakeholders who are seeking to implement the risk-based public health framework and promote the safe design, operation, and permitting of ONWS systems.

ONWS Stakeholders

DESIGN ENGINEER

REGULATOR

OPERATOR

PROGRAM ADMINISTRATOR

SYSTEM OWNER

Assumed Stakeholder Experience

Stakeholder	Assumed Minimum Experience
Design engineer	Professional Engineer with previous experience in the design of wastewater, recycled water, or drinking water treatment. Experience may be either at building-scale or municipal-scale. Design engineer should be familiar with the control of pathogenic microorganisms.
Regulator	Previous experience regulating wastewater or drinking water systems (*optimal*), or other programs with similar public health goals (e.g., food safety, air quality, etc.). Familiarity with the control of pathogenic microorganisms. Experience in the review of permitting documents including engineering reports and operations & maintenance plans.
Operator	Previous experience operating treatment systems in wastewater, recycled water, and/or drinking water. Basic understanding of pathogen control and public health protection. Meet operator certification requirements, as required by the Regulator.
Program Administrator	Understanding of all the basic elements of ONWS (e.g. design, public health, permitting, and operations).
System Owner	Understanding of all the basic elements of ONWS (e.g. design, public health, permitting, and operations).

Training Modules

1. Introduction
2. Public Health Goals
3. Treatment Selection and Crediting Overview
4. Treatment Selection and Crediting: Biological Treatment
5. Treatment Selection and Crediting: Filtration
6. Treatment Selection and Crediting: Disinfection
7. Treatment Selection and Crediting: Flow Equalization and Distribution
8. Developing Multiple Barrier ONWS Systems
9. Operations Plan
10. Regulatory and Permitting Plan

Module 2:
Public Health Goals

Training Modules

1. Introduction
2. **Public Health Goals**
3. Treatment Selection and Crediting Overview
4. Treatment Selection and Crediting: Biological Treatment
5. Treatment Selection and Crediting: Filtration
6. Treatment Selection and Crediting: Disinfection
7. Treatment Selection and Crediting: Flow Equalization and Distribution
8. Developing Multiple Barrier ONWS Systems
9. Operations Plan
10. Regulatory and Permitting Plan

Learning Objectives

- Understand requirements for public health protection in ONWS
- Identify the treatment targets for the control of pathogens
- Discuss importance of water quality in the distribution system

Primary Target Audience

Primary Audience:

DESIGN ENGINEER

REGULATOR

PROGRAM ADMINISTRATOR

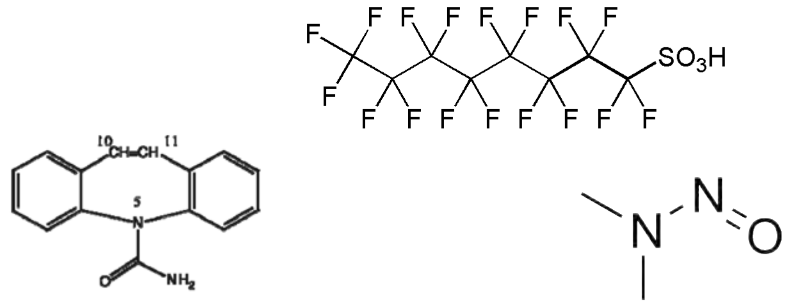
General Awareness:

OPERATOR

SYSTEM OWNER

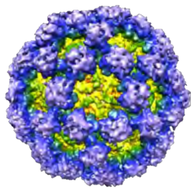
What treatment is required for ONWS?

- What are the typical contaminants of concern found in alternate water sources?

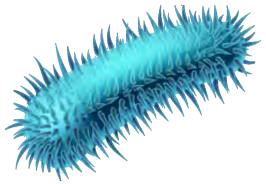


Chemicals

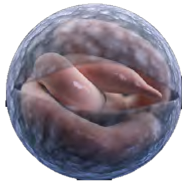
Virus



Bacteria



Protozoa



Pathogens

What treatment is required for ONWS?

- How relevant are toxic chemicals in ONWS settings?

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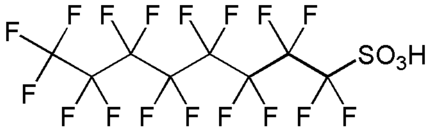
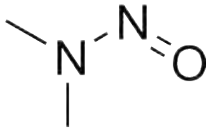
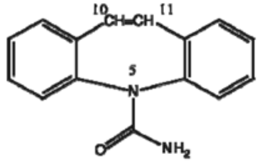






Low Concentrations

=

Negligible Public Health Impacts

Pathogens are the main public health concern

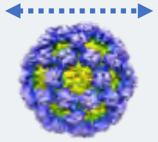
- **Pathogens are of concern due to three reasons:**
  - High likelihood of pathogens in ONWS source waters
  - Pathogens can cause infection from a single exposure
  - Even with low exposure, pathogens may be important source of risk

ONWS Expert Panel recommended log reduction targets (LRTs) to protect public health against pathogens

Which pathogens are relevant for ONWS?

Enteric Viruses

0.01 µm | 0.1 µm | 1 µm | 10 µm | 100 µm



Examples	Enterovirus, norovirus, hepatitis A
Size	Typically 10- to 1000-fold smaller than bacteria and protozoa
Physical removal	Small size makes physical removal challenging (e.g., filtration)
Disinfection	Susceptible to chlorine and ozone disinfection, but more resistant to UV than bacteria and protozoa

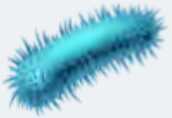
Protozoa

0.01 µm | 0.1 µm | 1 µm | 10 µm | 100 µm

Examples	*Cryptosporidium, Giardia, Toxoplasma*
Size	Significantly larger than virus and generally larger than bacteria
Physical removal	Larger size allows for greater removal by physical processes (e.g., filtration)
Disinfection	Less susceptible to chemical disinfectants than other pathogens (particularly *Cryptosporidium*), though generally sensitive to UV disinfection

Enteric Bacteria

0.01 µm | 0.1 µm | 1 µm | 10 µm | 100 µm



Examples	*E. coli, Salmonella, Campylobacter*
Size	Generally larger than viruses and smaller than protozoa
Physical removal	Intermediate size allows for moderate to high removal by filtration technologies
Disinfection	Susceptible to many forms of disinfection including chlorine, chloramine, and UV

Differences important because it makes them more/less susceptible to various treatment options

Risk-Based Treatment Requirements

Risk Threshold

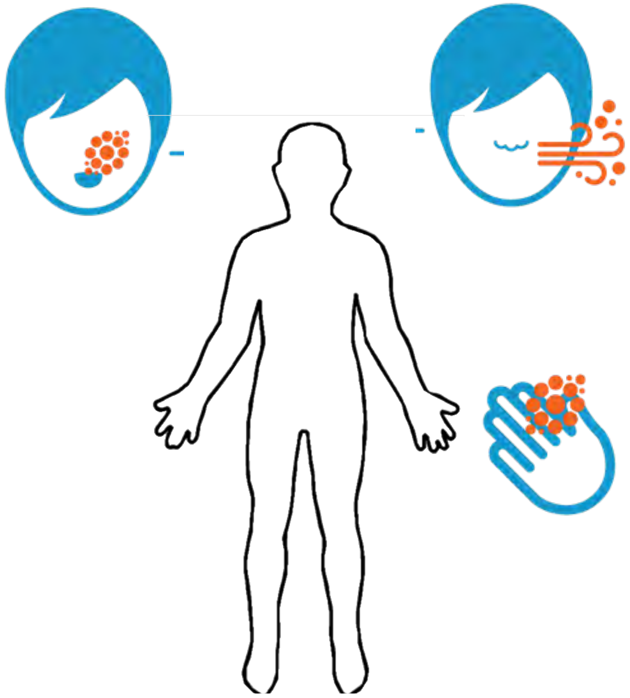
1 infection per 10,000 people per year

Risk-Based Treatment Requirements

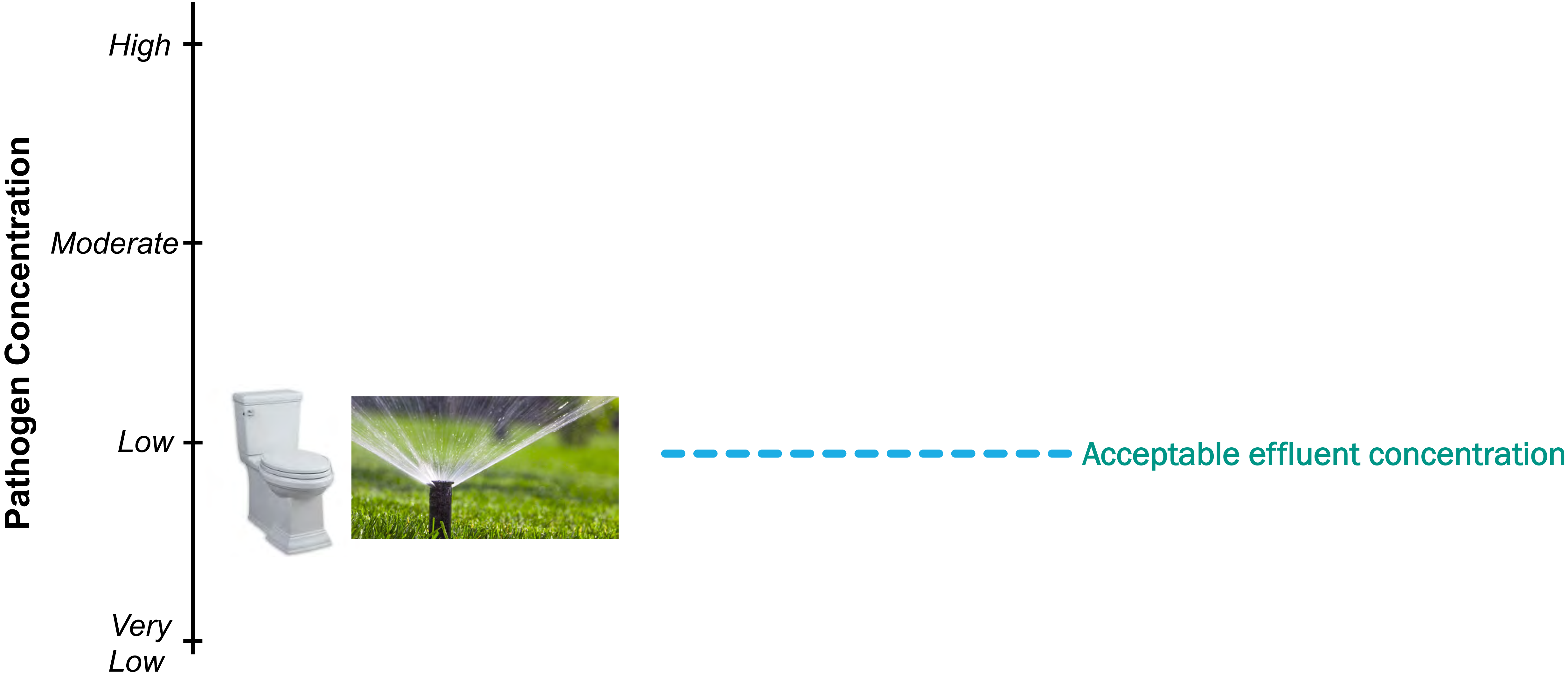
Risk Threshold

10^{-4} infections per person per year

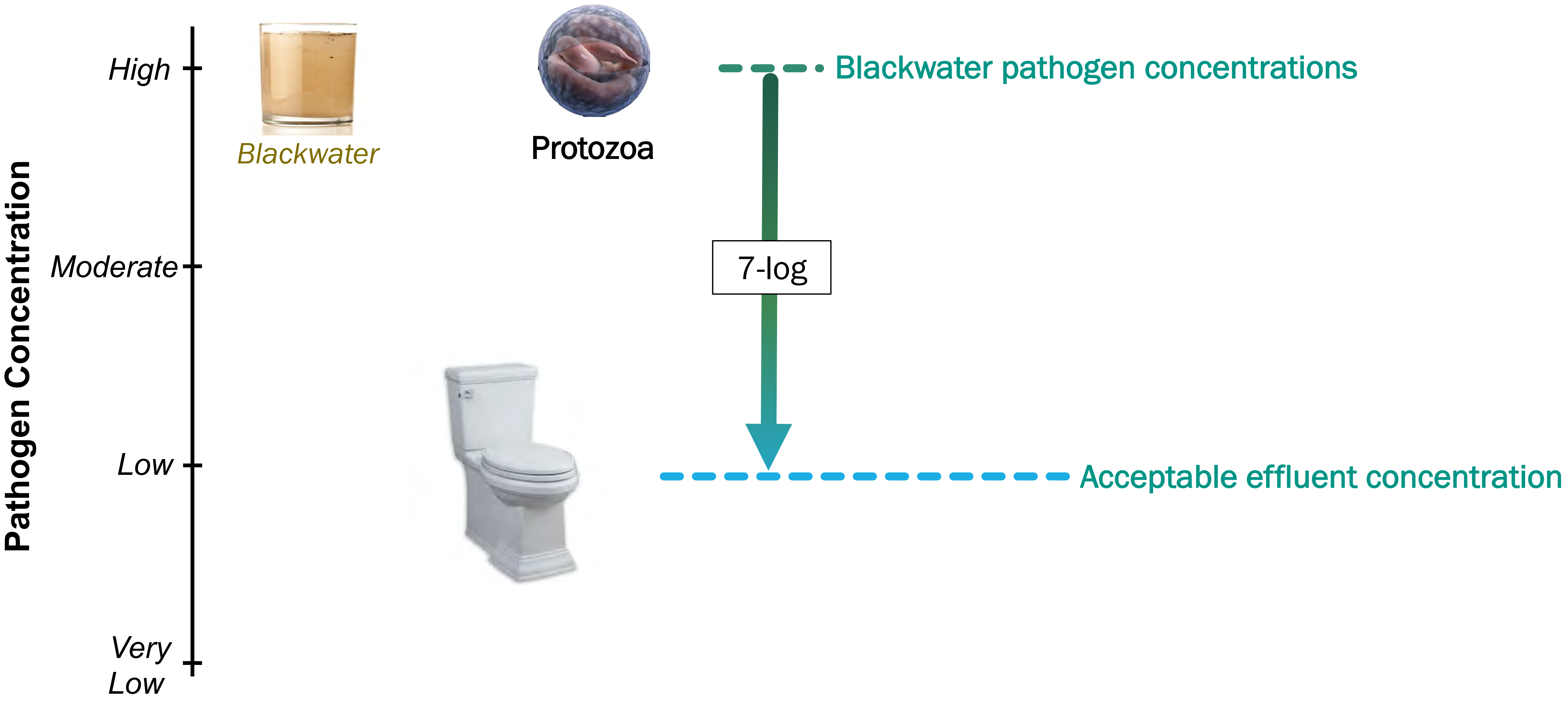
Exposure Pathways



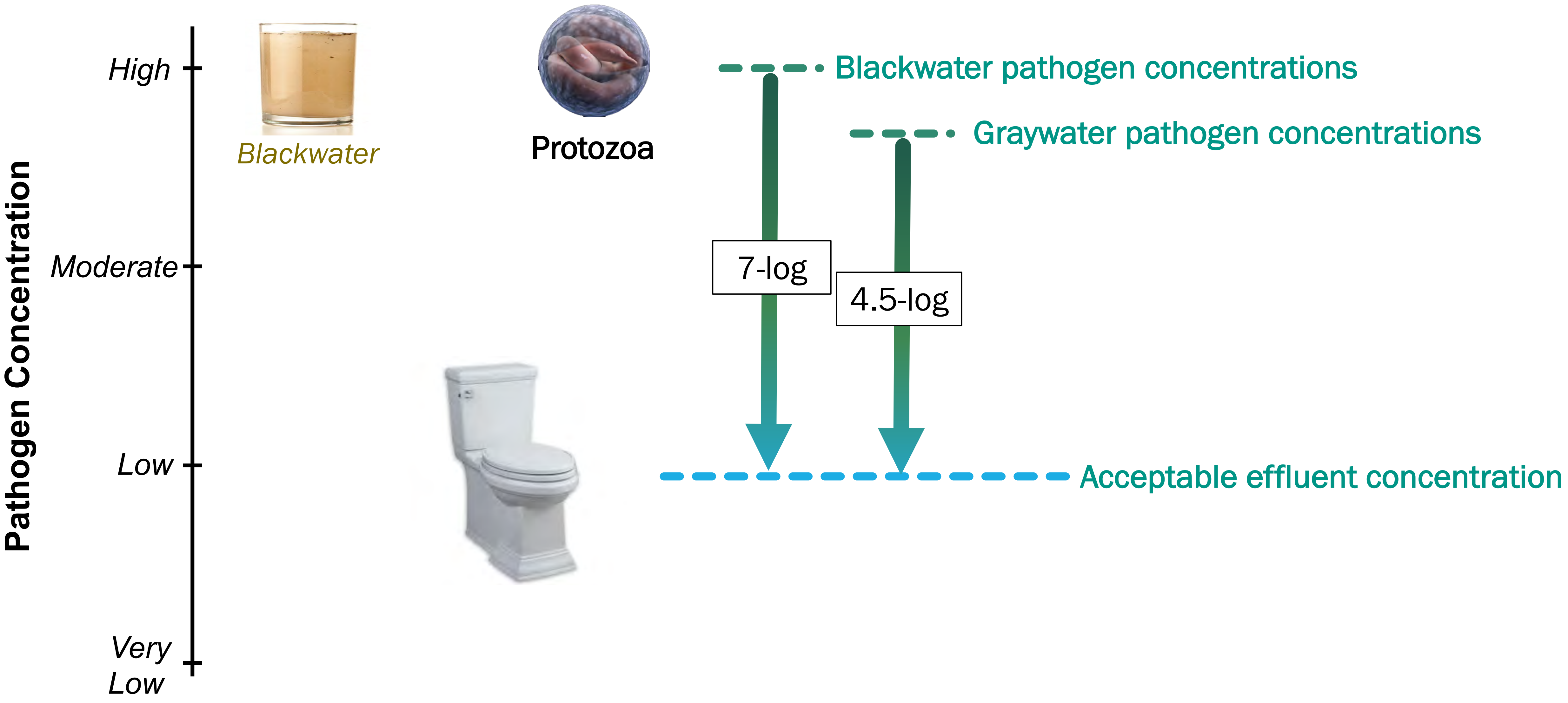
Risk-Based Treatment Requirements



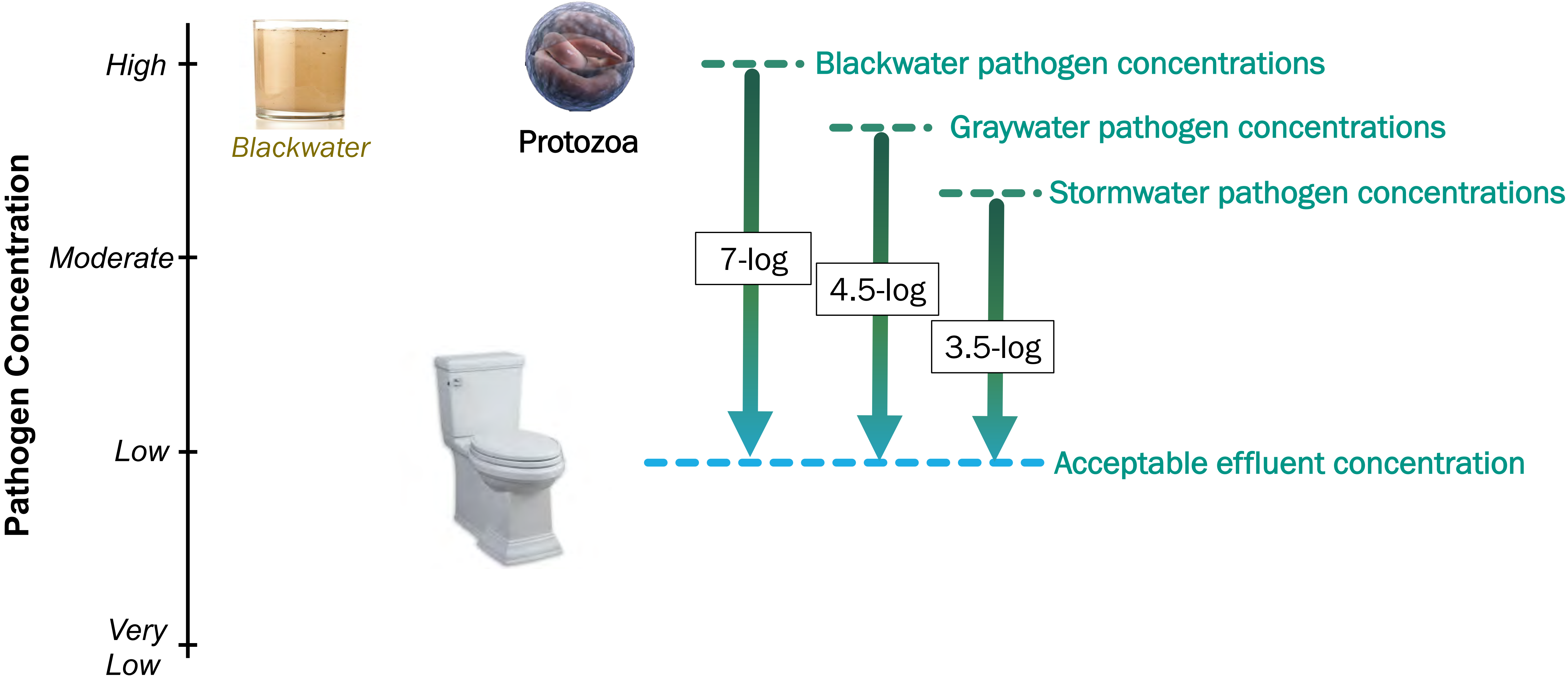
Risk-Based Treatment Requirements



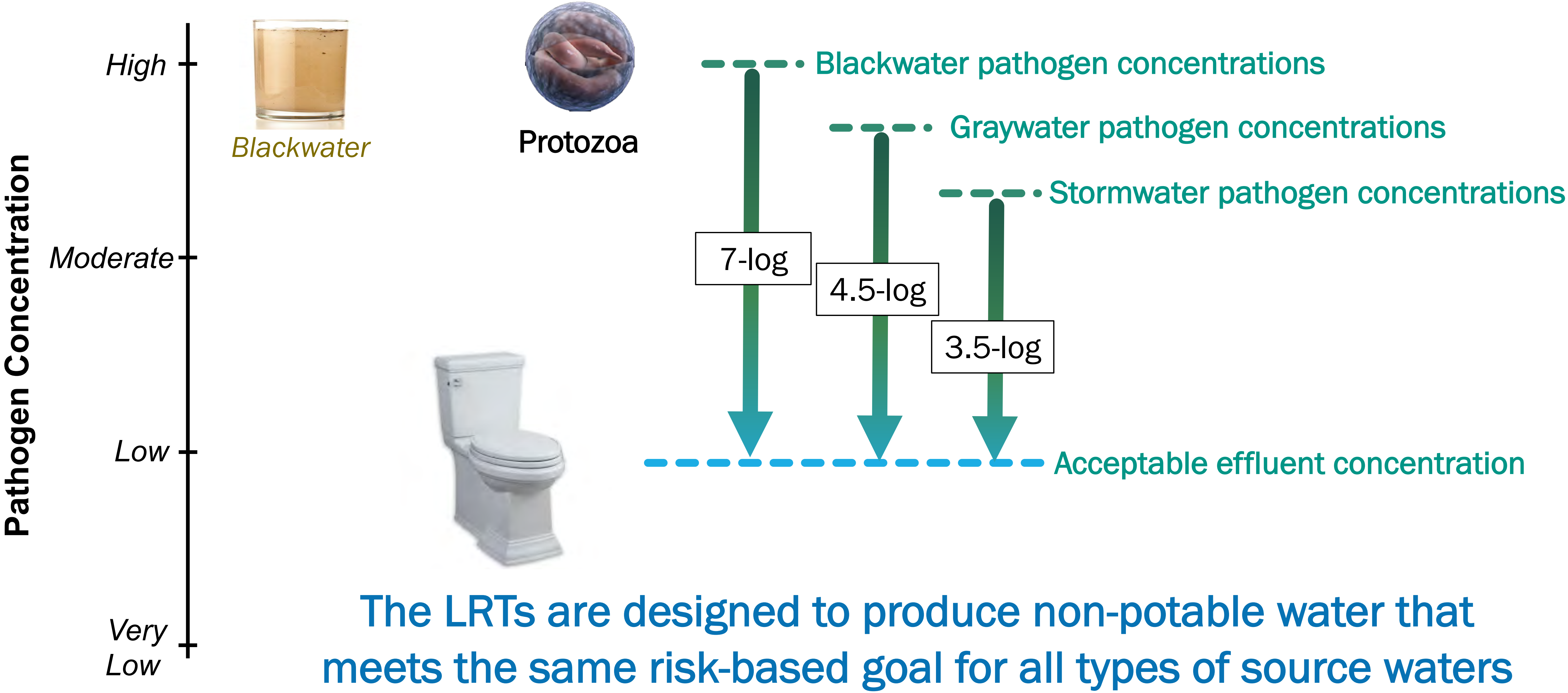
Risk-Based Treatment Requirements



Risk-Based Treatment Requirements



Risk-Based Treatment Requirements



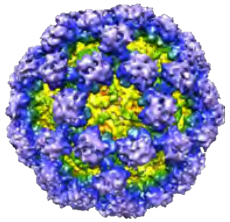
The LRTs are designed to produce non-potable water that meets the same risk-based goal for all types of source waters

Log Reduction Targets for Source Waters and End Uses

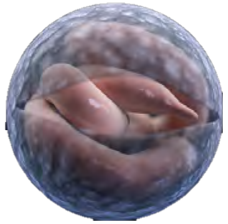
Water Use Scenario	Enteric Viruses	Parasitic Protozoa	Enteric Bacteria
Domestic Wastewater/Blackwater			
Unrestricted irrigation	8.0	7.0	6.0
Indoor use[1]	8.5	7.0	6.0
Graywater			
Unrestricted irrigation	5.5	4.5	3.5
Indoor use	6.0	4.5	3.5
Stormwater (10% wastewater contribution[2])			
Unrestricted irrigation	5.0	4.5	4.0
Indoor use	5.5	5.5	5.0
Stormwater (0.1% wastewater contribution[2])			
Unrestricted irrigation	3.0	2.5	2.0
Indoor use	3.5	3.5	3.0
Roof runoff water			
Unrestricted irrigation	N/A	No data	3.5
Indoor use	N/A	No data	3.5

Any other concerns?

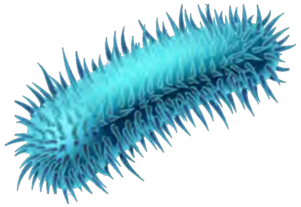
- We just covered control of these pathogens...



Enteric Virus



Parasitic Protozoa



Enteric Bacteria

Pathogen LRTs

- What else should we care about?

Regrowth of Bacteria

Bacterial Regrowth

- ONWS waters may promote regrowth of bacteria
- Organic matter present in treated waters can:
  - Consume the disinfectants added to minimize growth
  - Serve as an energy source for bacterial growth
- Regrowth impacts both public health and aesthetics
- Public health impacted if promotes growth of opportunistic pathogens
  - *Legionella pneumophila*
  - *Mycobacterium avium*
  - *Pseudomonas aeruginosa*
- Control concepts discussed in Module 7

Problem Solving Exercises

True or False?

Blackwater treatment requires higher LRTs than graywater. Therefore, treated blackwater is of better quality than treated graywater.

- A. True
- B. False

What is the relative size of each pathogen group?

- A. virus > protozoa > bacteria
- B. bacteria > protozoa > virus
- C. protozoa > bacteria > virus
- D. virus > bacteria > protozoa
- E. protozoa > virus > bacteria

What two parasitic protozoa are regulated in drinking water:

- A. *Legionella*
- B. *E. coli*
- C. *Giardia*
- D. *Cryptosporidium*
- E. *Entamoeba histolytica*

Why is bacterial regrowth a risk for building distribution systems?

- A. Regrowth can cause color and odor issues
- B. May promote the growth of *Legionella*
- C. May promote the growth of *Cryptosporidium*
- D. A and B are true
- E. All of the above are true

Module 3: Treatment Selection and Crediting

OVERVIEW

Training Modules

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2. Public Health Goals
3. **Treatment Selection and Crediting Overview**
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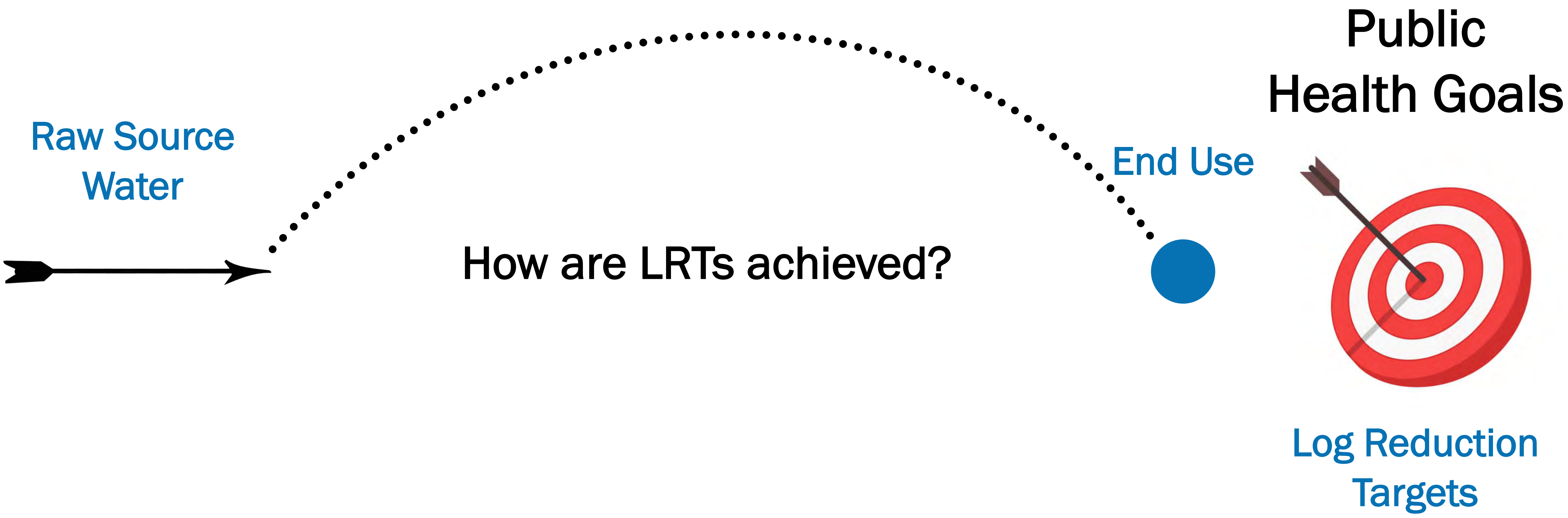
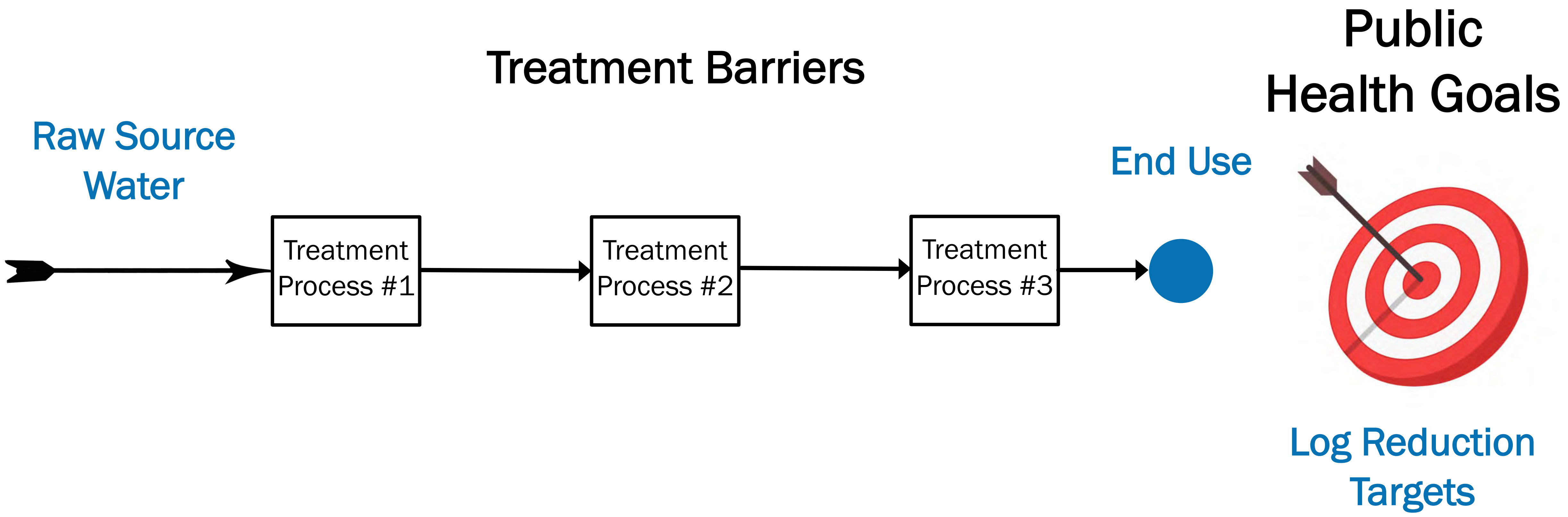
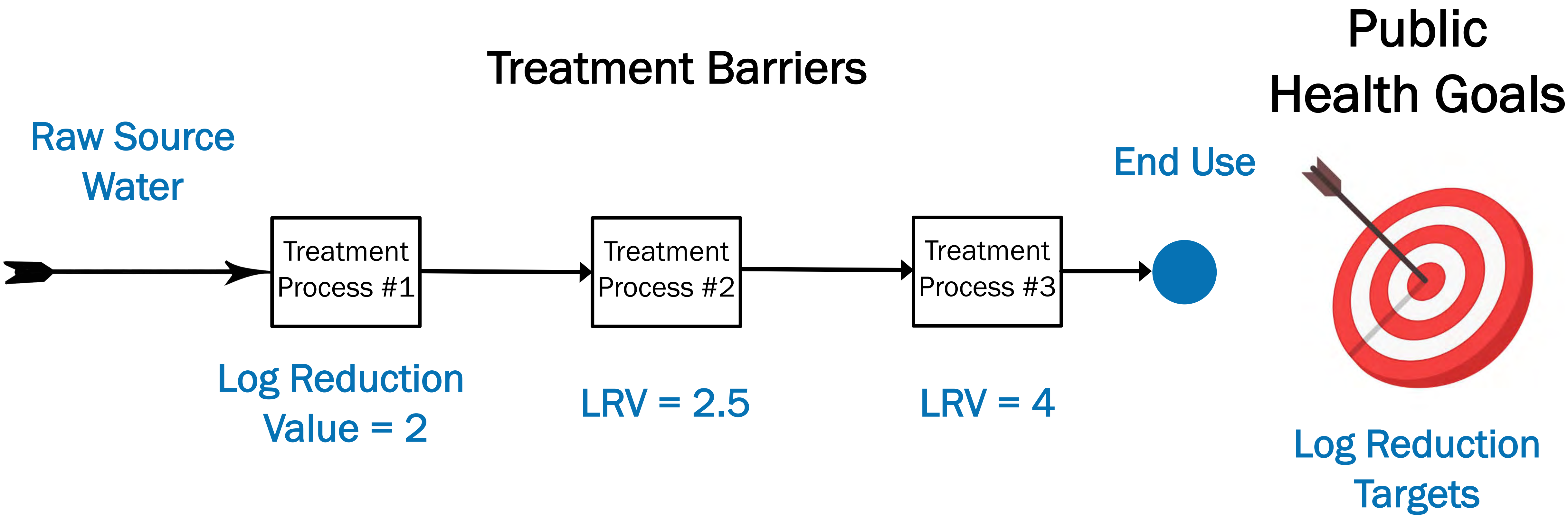
Introduction to Pathogen Crediting



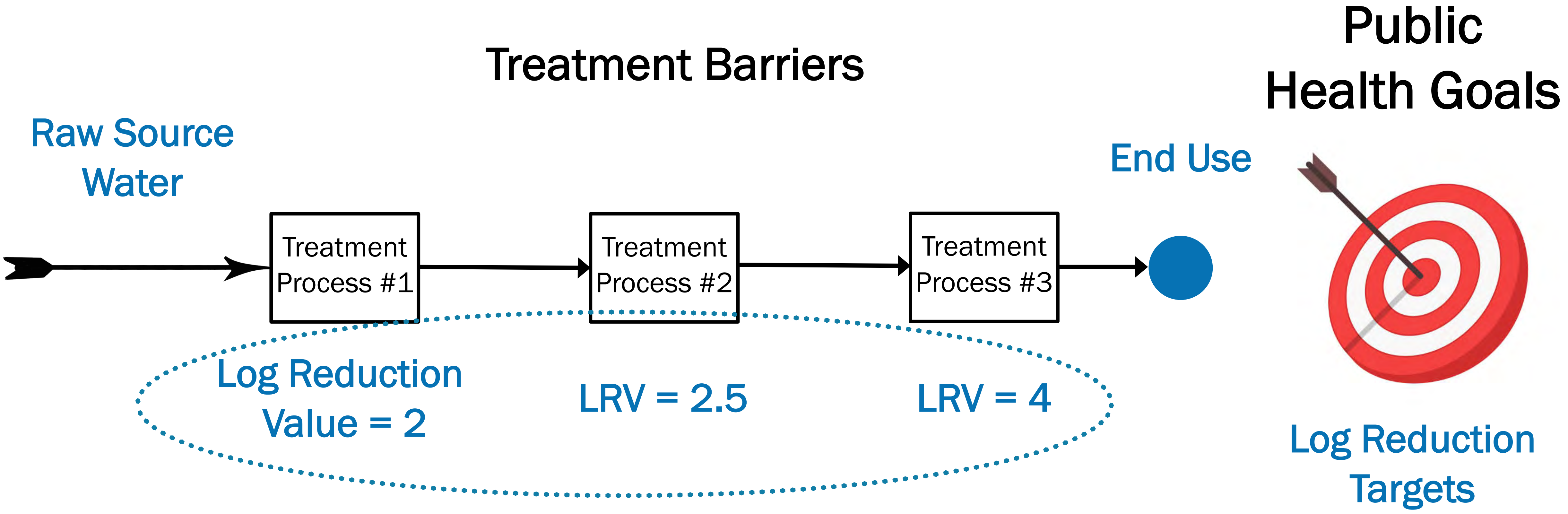
Introduction to Pathogen Crediting



Introduction to Pathogen Crediting



Introduction to Pathogen Crediting



How are these specific values assigned?

Pathogen Crediting

Learning Objectives

- Introduction to pathogen reduction crediting for ONWS
- Overview of existing crediting frameworks and alternative crediting approaches
- Summary of key treatment processes for ONWS

Primary Target Audience

Primary Audience:

- DESIGN ENGINEER
- REGULATOR

General Awareness:

- OPERATOR
- PROGRAM ADMINISTRATOR
- SYSTEM OWNER

Course Overview

- Pathogen Crediting 101
- Overview of Pathogen Crediting Frameworks
- Pathogen Crediting Without Existing Framework
- Bacterial Crediting
- Key Treatment Process Groups

Course Overview

- Pathogen Crediting 101
- Overview of Pathogen Crediting Frameworks
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- Key Treatment Process Groups

Pathogen Crediting 101

- Meeting the LRTs requires putting pathogen crediting into practice

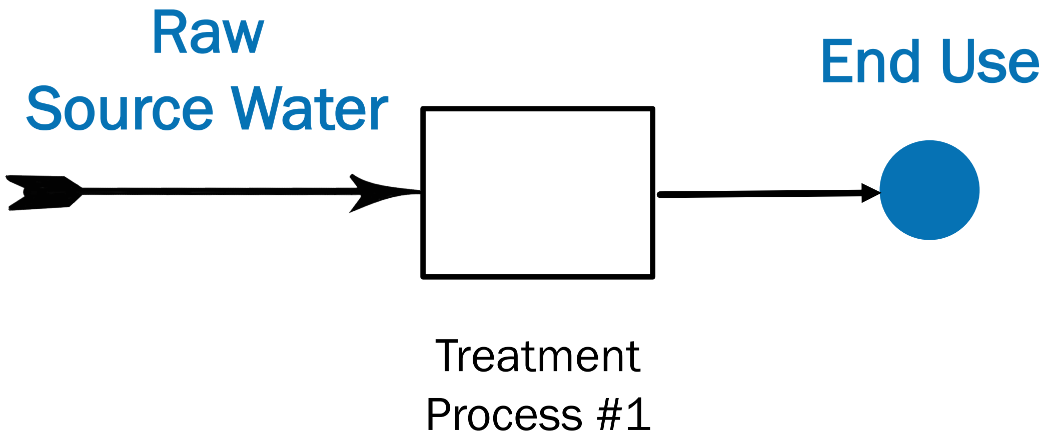
NBRC's Expert Panel defined LRTs for various source waters and end uses

Water Use Scenario	Enteric Viruses	Parasitic Protozoa	Enteric Bacteria
Domestic Wastewater/Blackwater			
Unrestricted irrigation	8.0	7.0	6.0
Indoor use[1]	8.5	7.0	6.0
Graywater			
Unrestricted irrigation	5.5	4.5	3.5
Indoor use	6.0	4.5	3.5
Stormwater (10% wastewater contribution[2])			
Unrestricted irrigation	5.0	4.5	4.0
Indoor use	5.5	5.5	5.0
Stormwater (0.1% wastewater contribution[2])			
Unrestricted irrigation	3.0	2.5	2.0
Indoor use	3.5	3.5	3.0
Roof runoff water			
Unrestricted irrigation	N/A	No data	3.5
Indoor use	N/A	No data	3.5

Pathogen Crediting 101

- Each unit process can achieve a specific Log Reduction Value (LRV)
- The **treatment train** must achieve:

Log Reduction **Value (LRV)** ≥ Log Reduction **Target (LRT)**



LRV = 4-log
protozoa

LRT = 4.5-log
protozoa

LRV < LRT X

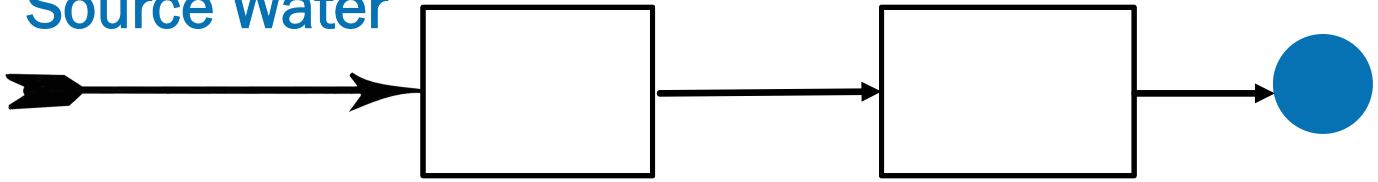
Pathogen Crediting 101

- Each unit process can achieve a specific Log Reduction Value (LRV)
- The **treatment train** must achieve:

Log Reduction **Value (LRV)** ≥ Log Reduction **Target (LRT)**

Raw Source Water

End Use



Treatment Process #1

Treatment Process #2

LRV = 4-log protozoa

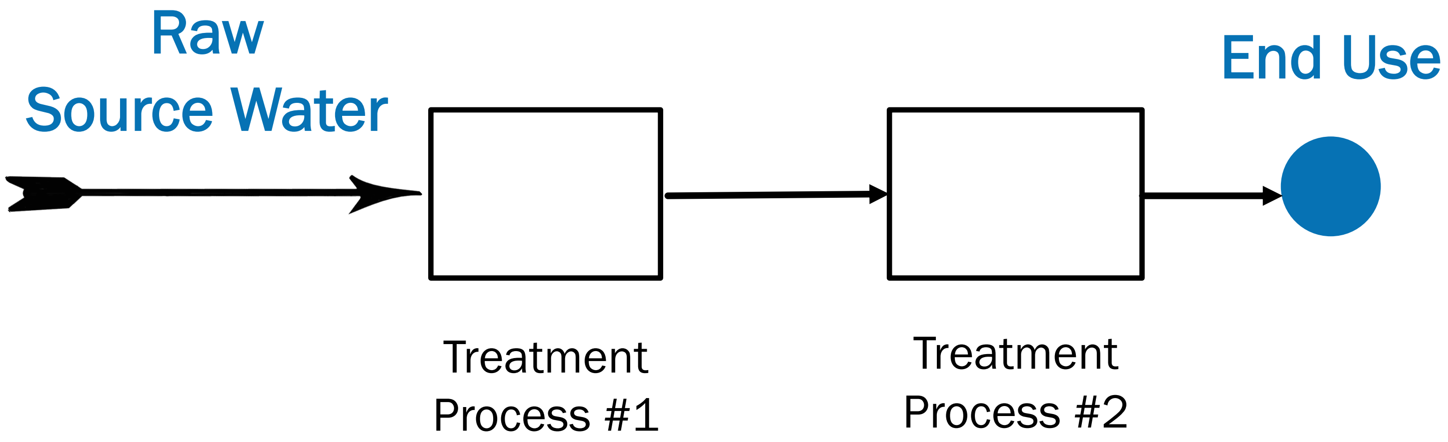
LRV = 2-log protozoa

LRT = 4.5-log protozoa

LRV ≥ LRT ✓

Pathogen Crediting 101

LRT = 4.5-log protozoa LRV ≥ LRT ✓



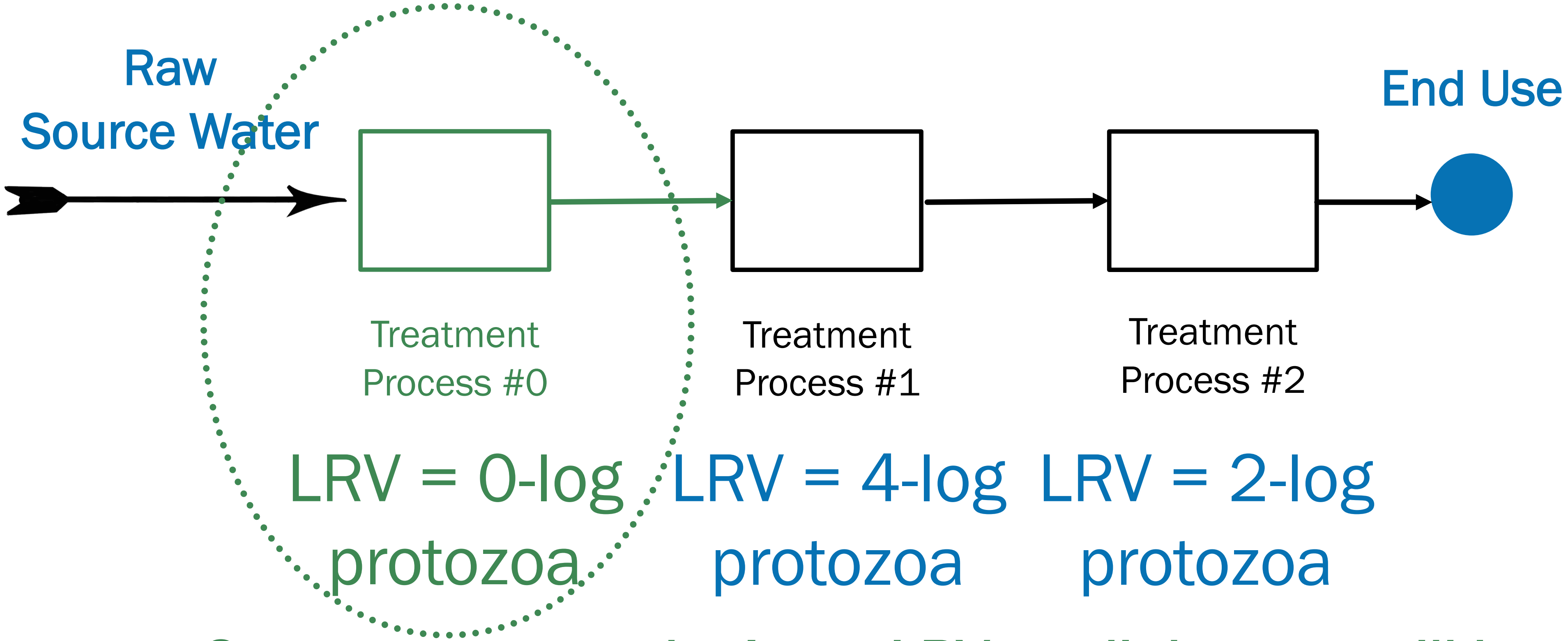
LRV = 4-log protozoa

LRV = 2-log protozoa

Is meeting LRTs the only treatment goal?

Pathogen Crediting 101

LRT = 4.5-log protozoa LRV ≥ LRT ✓



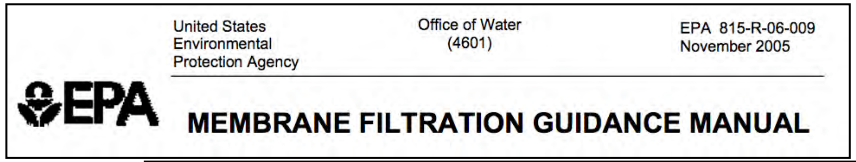
Some processes don’t get LRV credit but are still beneficial for improving water quality and preparing water for downstream treatment

Course Overview

- Pathogen Crediting 101
- **Overview of Pathogen Crediting Frameworks**
- Pathogen Crediting Without Existing Framework
- Bacterial Crediting
- Key Treatment Process Groups

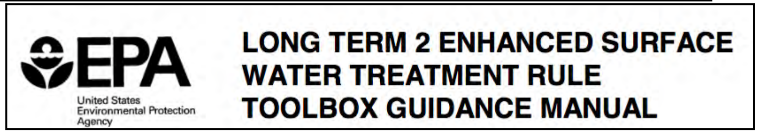
Pathogen Crediting 101

- Crediting frameworks exist for multiple drinking water processes
- Frameworks are also available for alternative source waters → potable and non-potable reuse
- Using existing frameworks streamlines ONWS implementation

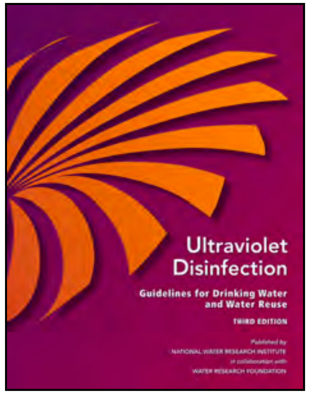

United States Environmental Protection Agency | Office of Water (4601) | EPA 815-R-06-009 November 2005

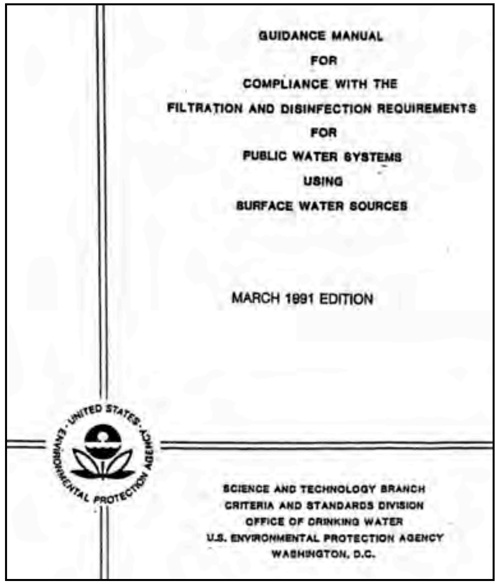
EPA

MEMBRANE FILTRATION GUIDANCE MANUAL


EPA United States Environmental Protection Agency

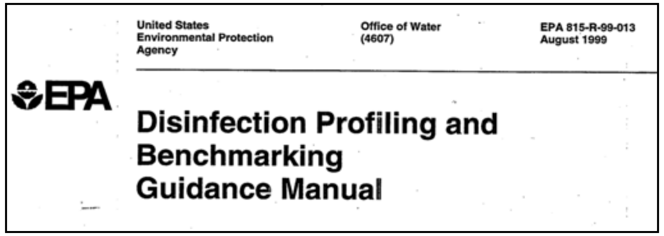
LONG TERM 2 ENHANCED SURFACE WATER TREATMENT RULE TOOLBOX GUIDANCE MANUAL




GUIDANCE MANUAL FOR COMPLIANCE WITH THE FILTRATION AND DISINFECTION REQUIREMENTS FOR PUBLIC WATER SYSTEMS USING SURFACE WATER SOURCES

MARCH 1991 EDITION

SCIENCE AND TECHNOLOGY BRANCH
CRITERIA AND STANDARDS DIVISION
OFFICE OF DRINKING WATER
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C.


United States Environmental Protection Agency | Office of Water (4607) | EPA 815-R-99-013 August 1999

EPA

Disinfection Profiling and Benchmarking Guidance Manual

Pathogen Crediting 101

- **Step 1:** How much removal and/or inactivation does a unit process achieve?
- **Step 2:** How can you prove that removal and/or inactivation is occurring at all times?

Pathogen Crediting 101

- **Step 1:** Identify applicable framework

Treatment Category	Application	Unit Process	Applicable Pathogens
EPA Disinfection	Surface Water	Free Chlorine	V / G
		Chloramine	V / G
		Chlorine Dioxide	V / G / C
		Ozone	V / G / C
		UV	V / G / C
EPA Filtration	Surface Water	Membrane Filtration	G / C
		Reverse Osmosis	V / G / C / B
		Bag and Cartridge Filters	G / C
NWRI UV Disinfection	Potable Water & Recycled Water	UV	V / G / C
Australian MBR	Recycled Water	MBR	V / G / C / B
Australia Chlorine	Recycled Water	Free Chlorine	V / B

Pathogen Crediting 101

- **Step 1:** Identify applicable framework

Treatment Category	Application	Unit Process	Applicable Pathogens
EPA Disinfection	Surface Water	Free Chlorine	V / G
		Chloramine	V / G
		Chlorine Dioxide	V / G / C
		Ozone	V / G / C
		UV	V / G / C
EPA Filtration	Surface Water	Membrane Filtration	G / C
		Reverse Osmosis	V / G / C / B
		Bag and Cartridge Filters	G / C
NWRI UV Disinfection	Potable Water & Recycled Water	UV	V / G / C
Australian MBR	Recycled Water	MBR	V / G / C / B
Australia Chlorine	Recycled Water	Free Chlorine	V / B

Pathogen Crediting 101

- **Step 1:** Identify applicable framework and requirements for achieving a specific LRV

Australian WaterVal Free Chlorine CT Table

pH	Log_{10} inactivation	≤0.2 NTU					≤2 NTU					≤5 NTU				
		5 °C	10 °C	15 °C	20 °C	25 °C	5 °C	10 °C	15 °C	20 °C	25 °C	5 °C	10 °C	15 °C	20 °C	25 °C
≤7	1	4	3	2	2	1	4	3	2	2	1	4	3	2	2	1
	2	5	4	3	2	2	5	4	3	2	2	6	4	3	2	2
	3	7	5	4	3	2	7	5	4	3	2	7	5	4	3	2
	4	8	6	4	3	2	9	6	4	3	2	9	7	5	3	3
≤7.5	1	7	5	4	3	2	7	5	4	3	2	8	6	4	3	2
	2	10	7	5	4	3	10	7	5	4	3	13	9	6	5	4
	3	13	9	7	5	4	13	9	7	5	4	16	12	9	6	5
	4	16	11	8	6	4	16	11	8	6	4	21	15	11	7	6
≤8	1	9	7	5	3	3	10	7	5	4	3	12	9	6	4	3
	2	14	10	7	5	4	15	10	7	5	4	19	13	9	7	5
	3	18	13	9	7	5	19	13	10	7	5	25	18	13	9	7
	4	23	16	12	8	6	23	16	12	8	6	32	23	16	11	8
≤8.5	1	11	8	6	4	3	12	9	6	5	4	14	10	7	5	4
	2	17	12	9	6	5	19	13	9	7	5	21	15	11	8	6
	3	23	16	12	9	6	25	17	13	9	7	29	21	15	10	8
	4	29	21	15	10	8	31	22	16	11	8	37	26	18	13	9
≤9	1	13	9	6	5	3	14	10	7	5	4	15	10	7	5	4
	2	20	14	10	7	5	22	16	11	8	6	23	16	12	8	6
	3	28	19	14	10	7	30	21	15	11	8	32	23	16	11	8
	4	35	25	17	12	9	38	27	19	13	10	41	29	20	14	10

Pathogen Crediting 101

- **Step 1:** Identify applicable framework and requirements for achieving a specific LRV

LRV range from 1 – 4 logs depending on:

- ❖ [Chlorine] * Time
- ❖ Turbidity
- ❖ pH
- ❖ temperature

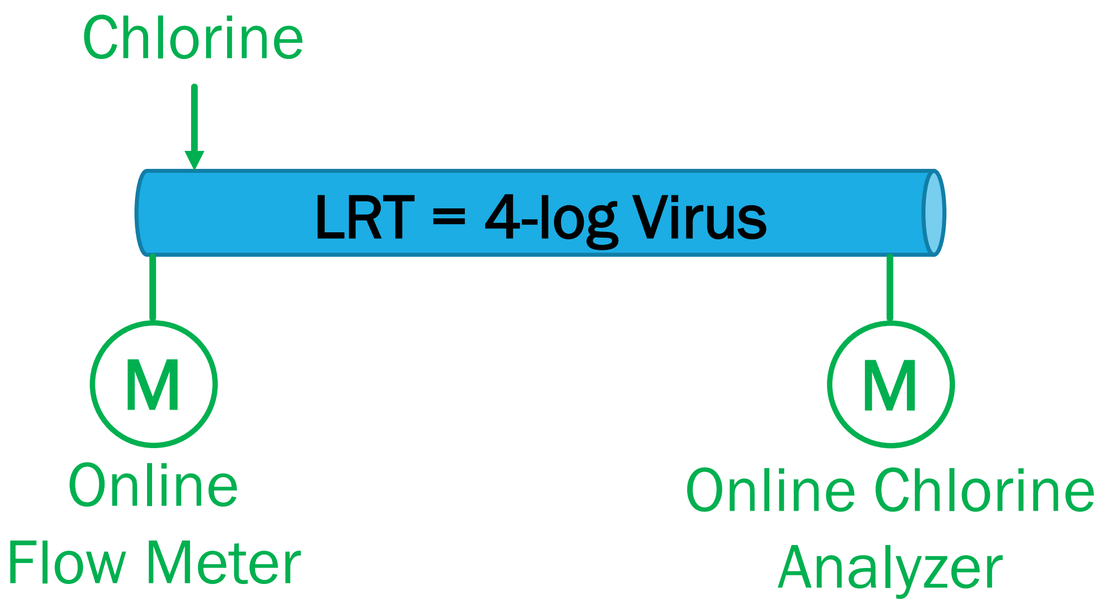
Australian WaterVal Free Chlorine CT Table

pH	Log_{10} inactivation	≤0.2 NTU					≤2 NTU					≤5 NTU				
		5 °C	10 °C	15 °C	20 °C	25 °C	5 °C	10 °C	15 °C	20 °C	25 °C	5 °C	10 °C	15 °C	20 °C	25 °C
≤7	1	4	3	2	2	1	4	3	2	2	1	4	3	2	2	1
	2	5	4	3	2	2	5	4	3	2	2	6	4	3	2	2
	3	7	5	4	3	2	7	5	4	3	2	7	5	4	3	2
	4	8	6	4	3	2	9	6	4	3	2	9	7	5	3	3
≤7.5	1	7	5	4	3	2	7	5	4	3	2	8	6	4	3	2
	2	10	7	5	4	3	10	7	5	4	3	13	9	6	5	4
	3	13	9	7	5	4	13	9	7	5	4	16	12	9	6	5
	4	16	11	8	6	4	16	11	8	6	4	21	15	11	7	6
≤8	1	9	7	5	3	3	10	7	5	4	3	12	9	6	4	3
	2	14	10	7	5	4	15	10	7	5	4	19	13	9	7	5
	3	18	13	9	7	5	19	13	10	7	5	25	18	13	9	7
	4	23	16	12	8	6	23	16	12	8	6	32	23	16	11	8
≤8.5	1	11	8	6	4	3	12	9	6	5	4	14	10	7	5	4
	2	17	12	9	6	5	19	13	9	7	5	21	15	11	8	6
	3	23	16	12	9	6	25	17	13	9	7	29	21	15	10	8
	4	29	21	15	10	8	31	22	16	11	8	37	26	18	13	9
≤9	1	13	9	6	5	3	14	10	7	5	4	15	10	7	5	4
	2	20	14	10	7	5	22	16	11	8	6	23	16	12	8	6
	3	28	19	14	10	7	30	21	15	11	8	32	23	16	11	8
	4	35	25	17	12	9	38	27	19	13	10	41	29	20	14	10

Pathogen Crediting 101

- **Step 2:** How can you prove that removal and/or inactivation is occurring at all times?

Monitoring Performance



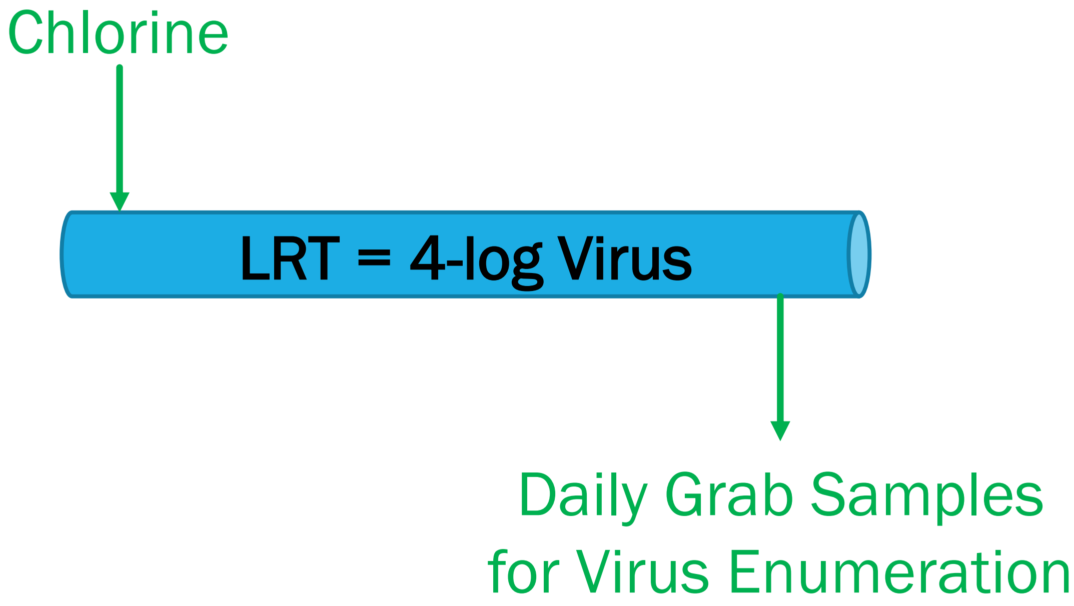
Online verification of chlorine residual and flow rate confirms LRV continuously

Pathogen Crediting 101

- ONWS Expert Panel recommended continuous monitoring in lieu of end-point monitoring
- Offers more temporal control over treatment process performance

Pathogen Crediting 101

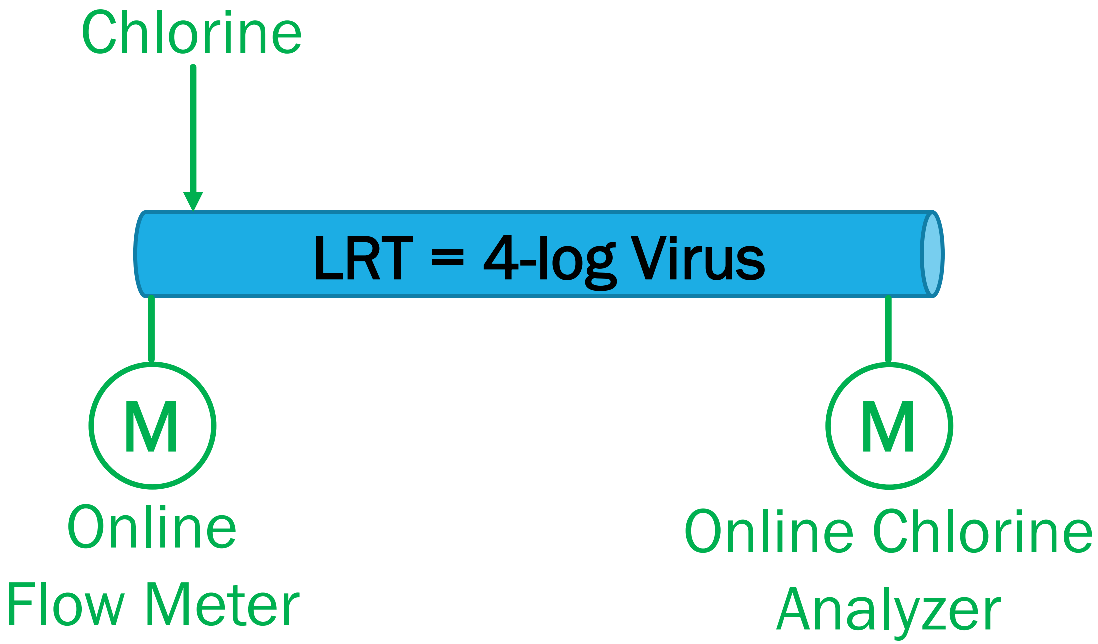
Periodic Pathogen Sampling



LRV confirmed only 1/day

VS

Surrogate Monitoring



Online verification of chlorine residual and flow rate confirms LRV continuously

Course Overview

- Pathogen Crediting 101
- Overview of Pathogen Crediting Frameworks
- **Pathogen Crediting Without Existing Framework**
- Bacterial Crediting
- Key Treatment Process Groups

Pathogen Crediting Without Existing Framework

- Level of effort may be significant
  - Rigorous testing and evaluation of treatment efficacy required

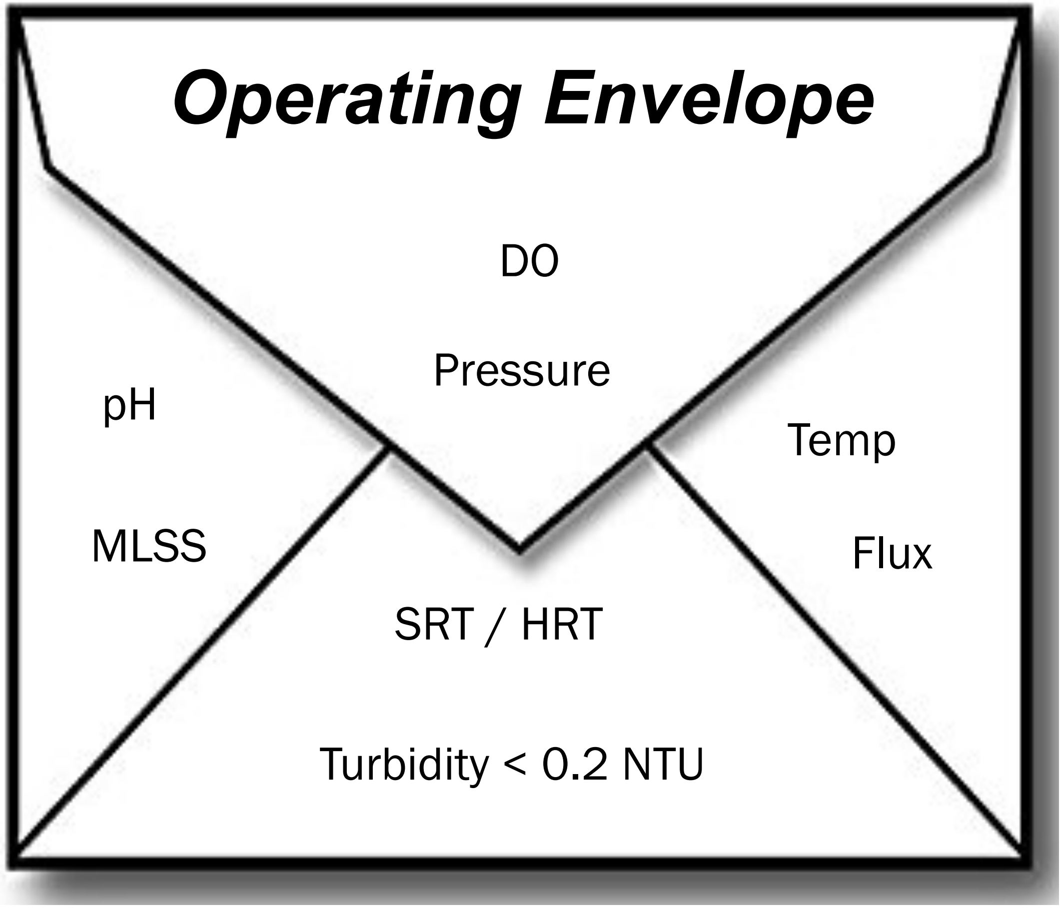
$$ Cost of microbial challenge studies >? Cost of treatment technology

- Joint decision by **Design Engineer** and **System Owner**
- **Regulator** ultimately decides level of effort needed to develop framework

Pathogen Crediting Without Existing Framework

Considerations for Validation Testing:

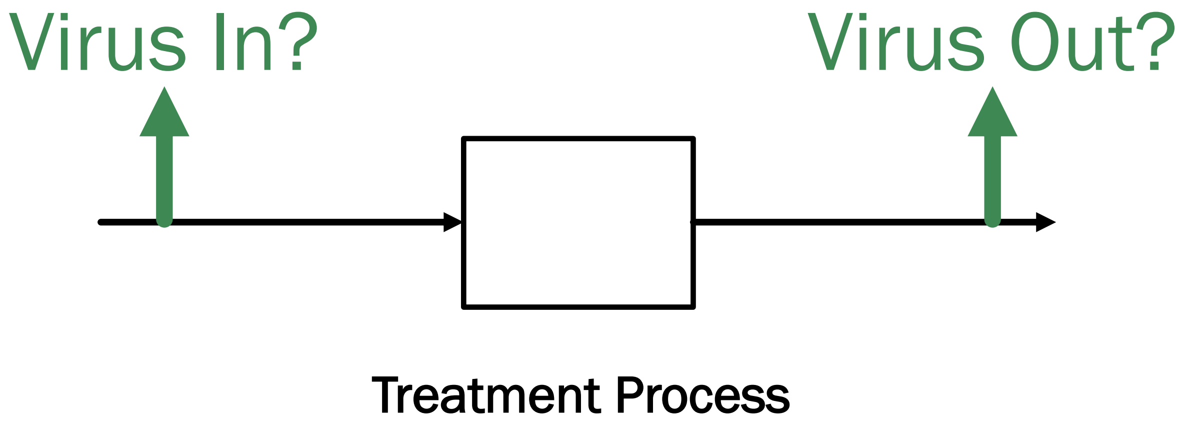
- Quantify pathogen reduction through process to assign LRV
- Use actual pathogens or microbial indicators
- Surrogate parameters also measured to link pathogen reduction with surrogate reduction
- Consider impact of changing water quality
- Develop water quality and operating requirements to achieve LRV



Pathogen Crediting Without Existing Framework

Site-specific validation may require significant investment

- Quantify virus using EPA 1615
  - ~$1,500/sample
- Test range of operating conditions
  - ~20 paired samples
- **$60,000 to validate one treatment process**



Summary of Pathogen Crediting

- Pathogen credits assigned via either:
  - Existing crediting framework
  - Developing and conducting site-specific validation
- **Utilizing existing frameworks is the most efficient way** to implement systems that comply with pathogen LRTs
- Online monitoring via surrogates allows for continuous verification of pathogen reduction

Course Overview

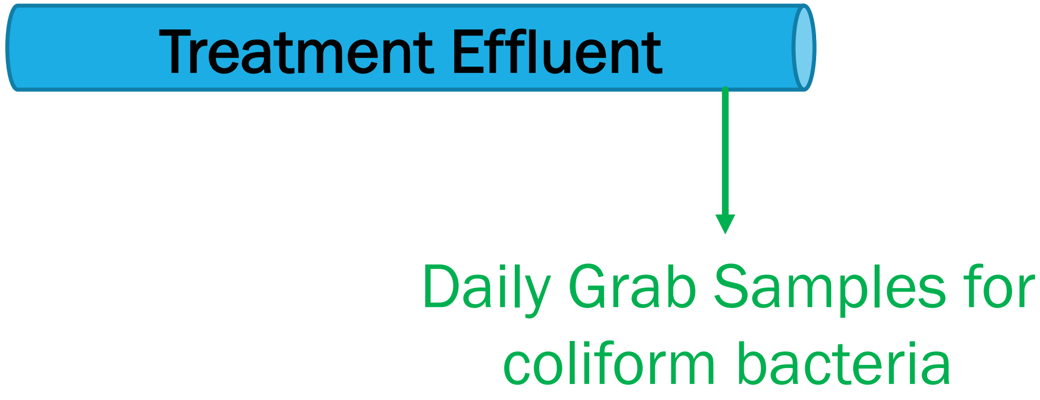
- Pathogen Crediting 101
- Overview of Pathogen Crediting Frameworks
- Pathogen Crediting Without Existing Framework
- **Bacterial Crediting**
- Key Treatment Process Groups

Bacterial Crediting

No existing crediting frameworks for bacteria

Historical Model

- Routine end-point monitoring
- On-line verification not required
- Limitations:
  - Departs from intention to replace end-point monitoring
  - Provides only a snapshot of performance



LRV confirmed only 1/day

Bacterial Crediting

Alternative Approach: Assign Bacterial Credits

Alternative Approach

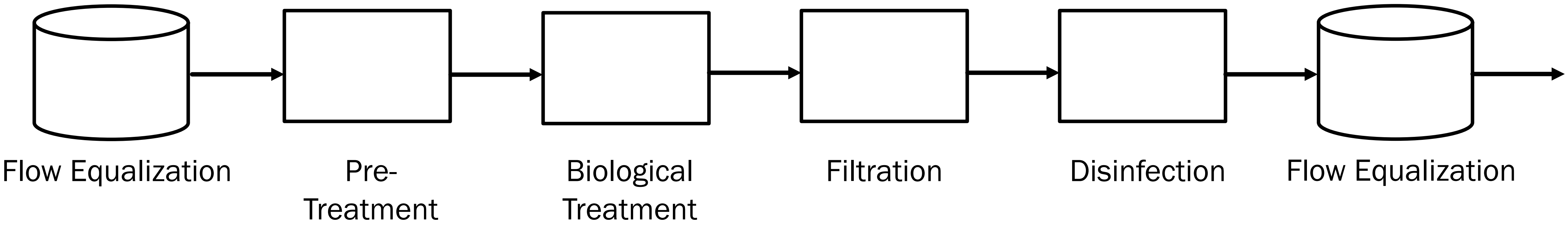
- Credits based on understanding pathogen removal and/or inactivation
- Leverage existing frameworks considering differences and similarities of bacteria vs. other pathogens

Continuous verification of surrogates confirms LRV continuously

Course Overview

- Pathogen Crediting 101
- Overview of Pathogen Crediting Frameworks
- Pathogen Crediting Without Existing Framework
- Bacterial Crediting
- **Key Treatment Process Groups**

Key Treatment Process Groups



The **Treatment Selection and Crediting** modules will cover each of these processes and how they:

- Achieve required LRTs
- Improve water quality and operations

Problem Solving Exercises

What is the main objective of pathogen crediting?

- A. Conservatively quantify the treatment system's ability to meet pathogen log reduction targets
- B. Protect public health
- C. Minimize the risk of *Legionella*
- D. Reduce the level of pathogens in the product water to zero
- E. None of the above

Why is it easier to use existing crediting frameworks?

- A. Typically does not require costly site-specific validation
- B. Frameworks are built on significant investment to understand the link between process performance and pathogen reduction
- C. Expedites the permitting process
- D. None of the above
- E. A, B, and C are true

Bacteria crediting frameworks are uncommon because:

- A. Bacteria are not an important public health threat
- B. Bacteria are easy to inactivate
- C. Routine end-point monitoring can be used to show compliance
- D. None of the above
- E. A, B, and C are true

Which of these statements is false?

- A. The treatment train's LRVs must be equal to or greater than the LRT
- B. Drinking water crediting frameworks always apply to ONWS applications
- C. Multiple treatment processes can be used to meet the LRT
- D. Continuous surrogate monitoring can be used to assess unit process performance
- E. Using existing crediting frameworks streamlines ONWS implementation

True or False?

The goal of site-specific validation is to quantify pathogen reduction through a unit process and link that reduction to a measurable surrogate parameter.

- A. True
- B. False

Module 4: Treatment Selection and Crediting

BIOLOGICAL TREATMENT

Training Modules

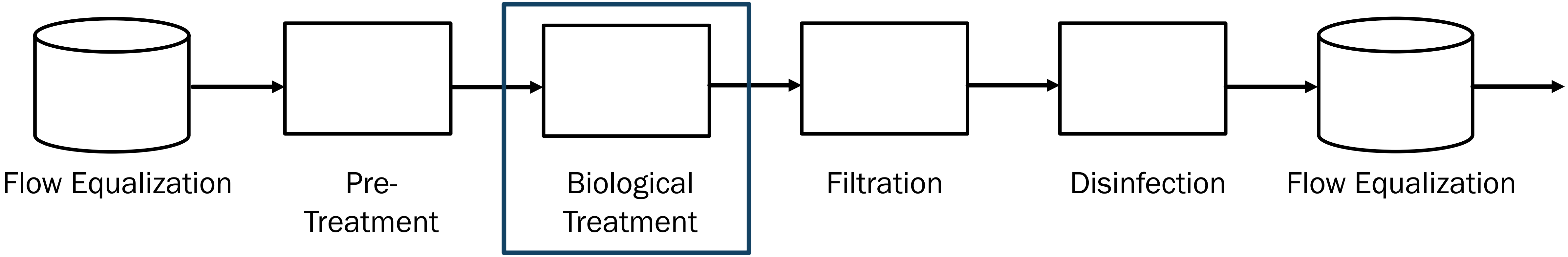
1. Introduction
2. Public Health Goals
3. Treatment Selection and Crediting Overview
4. **Treatment Selection and Crediting: Biological Treatment**
5. Treatment Selection and Crediting: Filtration
6. Treatment Selection and Crediting: Disinfection
7. Treatment Selection and Crediting: Flow Equalization and Distribution
8. Developing Multiple Barrier ONWS Systems
9. Operations Plan
10. Regulatory and Permitting Plan

Framing Questions

- Why is biological treatment an important treatment process?
- How do we know the system is performing as designed?
- Does biological treatment reduce pathogens—and if so how do we get credit?

Learning Objectives

- Understand design goals for biological treatment processes
- Learn key design and monitoring concepts
- Introduce pathogen crediting for biological treatment processes



Primary Target Audience

Primary Audience:

DESIGN ENGINEER

REGULATOR

General Awareness:

OPERATOR

PROGRAM ADMINISTRATOR

SYSTEM OWNER

Course Overview

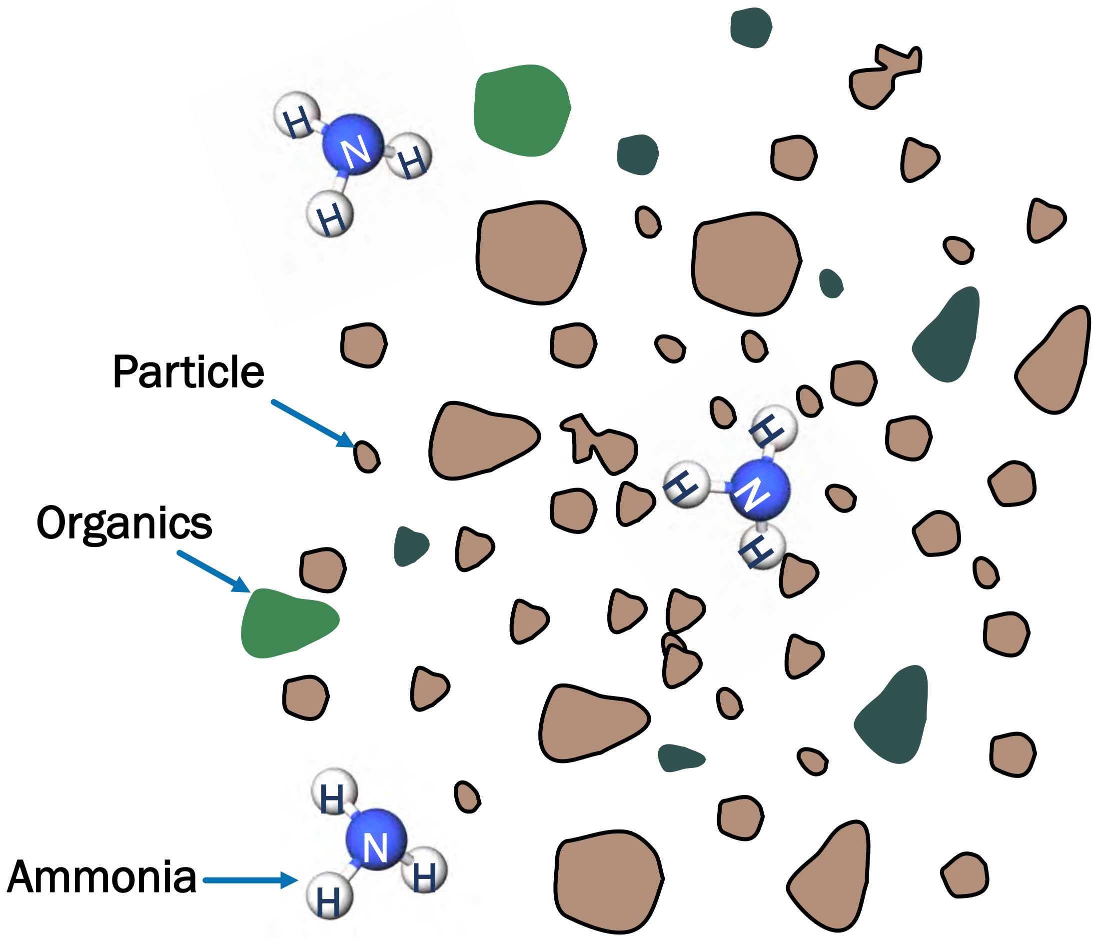
- Biological Treatment 101
- Membrane Bioreactors
- Engineered Treatment Wetlands

Course Overview

- Biological Treatment 101
- Membrane Bioreactors
- Engineered Treatment Wetlands

Biological Treatment 101 – Treatment Objectives

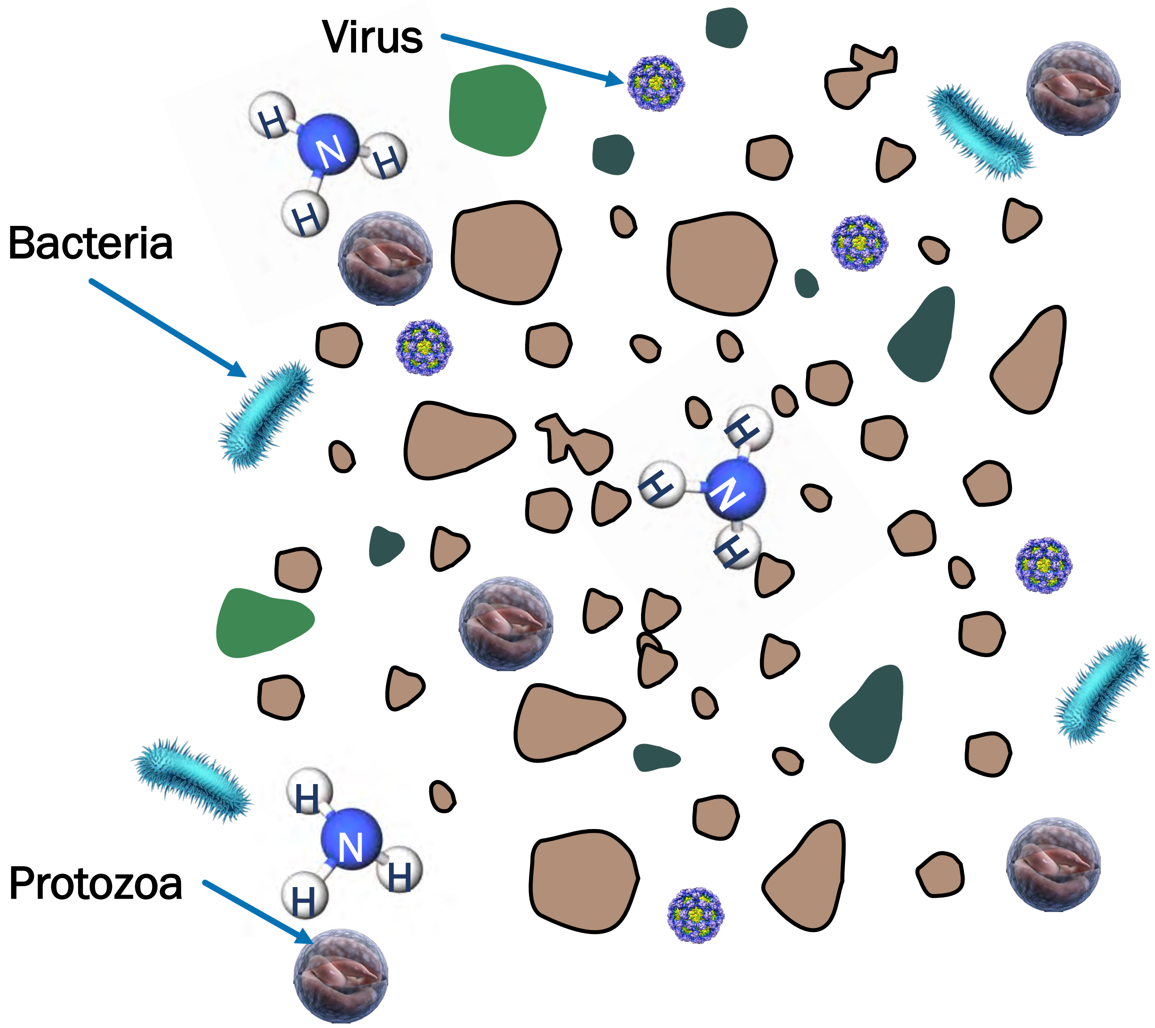
Unwanted Constituents in Blackwater and Graywater:



- **Particles**
  - Total suspended solids
  - Turbidity
- **Biodegradable Organics**
  - Biological oxygen demand (BOD)
- **Ammonia**

Biological Treatment 101 – Treatment Objectives

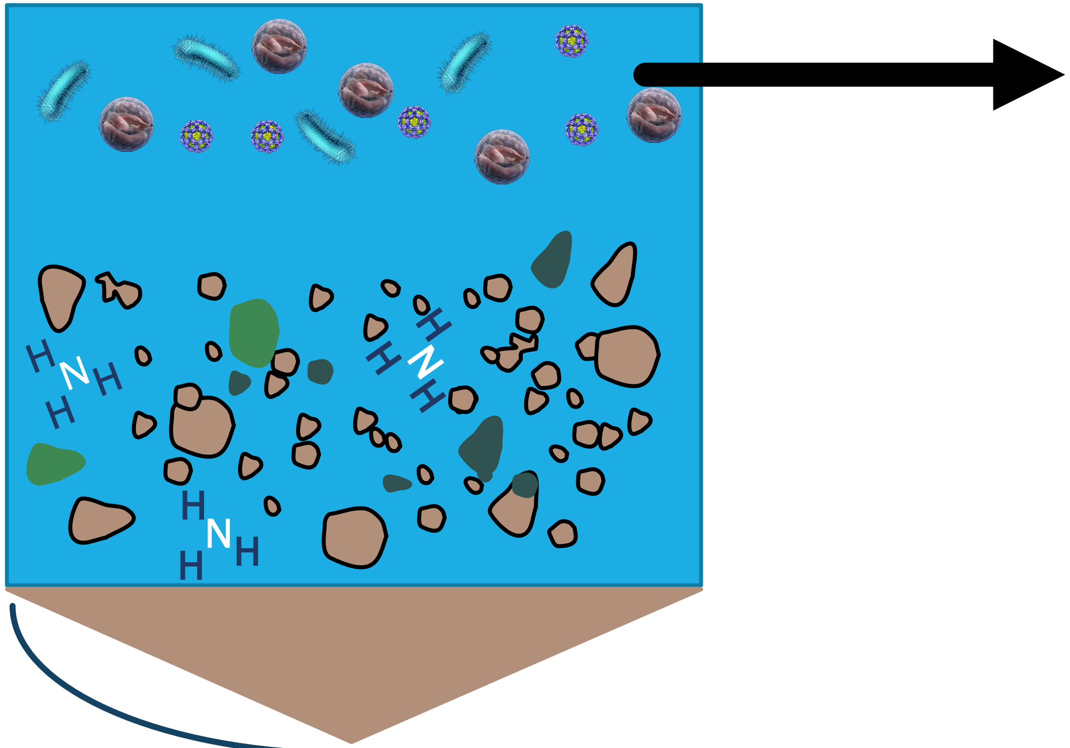
Unwanted Constituents in Blackwater and Graywater:



- **Pathogens**
  - Virus
  - Bacteria
  - Protozoa

Biological Treatment 101 – Treatment Objectives

Biological Treatment

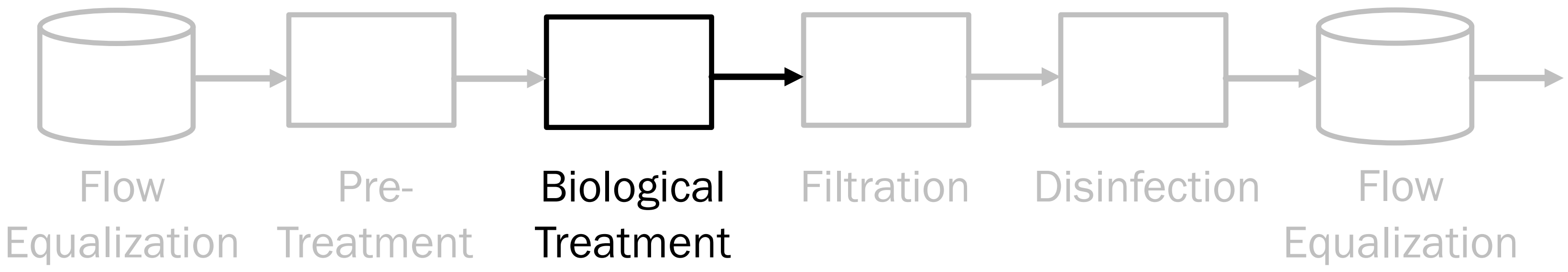


- ✓ Reduce **TSS** by 85% - 95+%
- ✓ Reduce **turbidity** 85% - 95+%
- ✓ Reduce **BOD** 85% - 95%
- ✓ Improves **UV Transmittance**
- ✓ Can be designed to reduce **ammonia** to below detection
- X **Pathogen** reduction not well understood

Improves subsequent filtration and disinfection

Biological Treatment 101 – Treatment Objectives

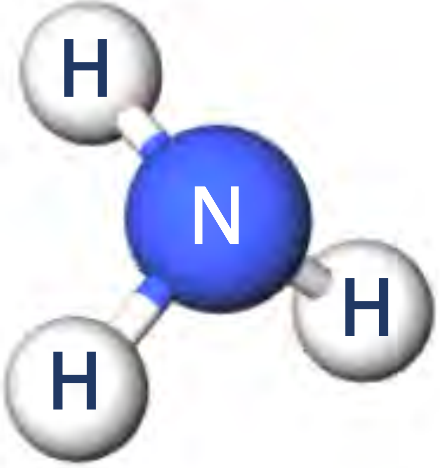
Essential treatment step for blackwater and graywater to prepare water for downstream treatment and distribution



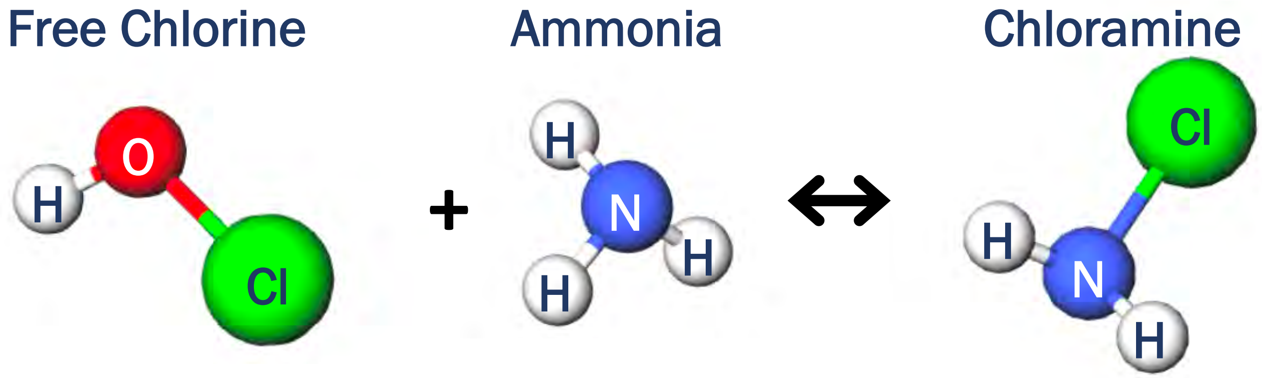
Biological Treatment 101 – Treatment Objectives

- EPA's 2012 Guidelines for Water Reuse suggest:
  - BOD ≤ 10 mg/L
  - Turbidity ≤ 2 NTU
- Additional references note TSS ≤ 10 mg/L
  - Minimizes microbial regrowth in ONWS distribution systems
- BOD, TSS, UVT, and turbidity can have significant impact on design, cost, and treatment performance of downstream processes

Biological Treatment 101 – Treatment Objectives



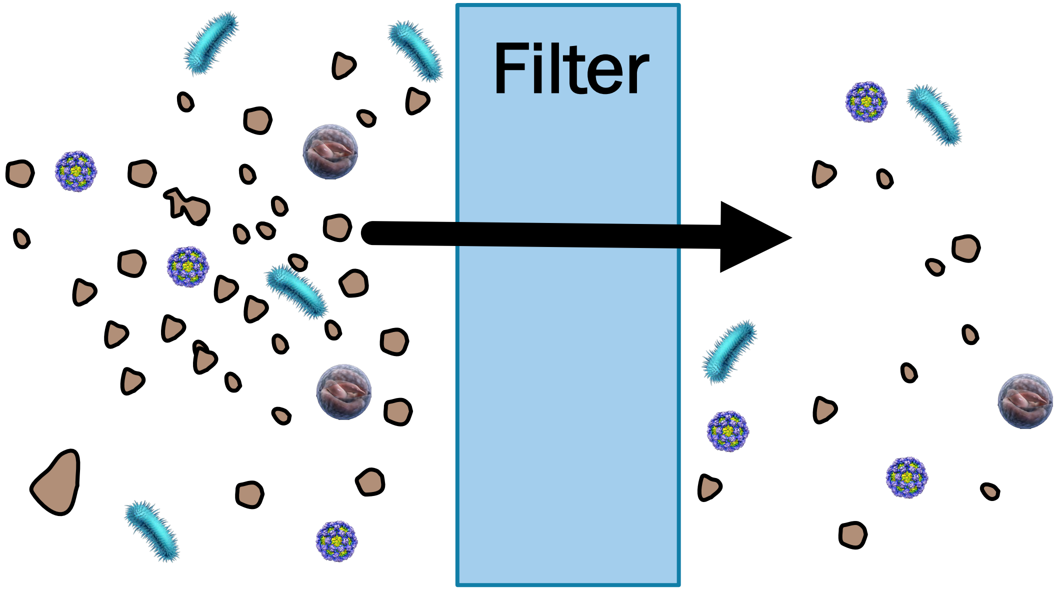
- **Ammonia Reduction**
  - Blackwater and graywater may have significant levels of ammonia
  - Ammonia impacts ability to do free chlorine disinfection



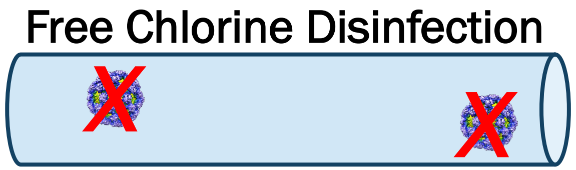
- **Nitrification biologically converts ammonia to nitrate**
  - Requires aerobic conditions and appropriate solids retention time
  - Provides greater reduction in BOD and improves UVT

Biological Treatment 101 – Treatment Objectives

- Improved downstream treatment, such as:



✓ Less solids = more efficient filtration



✓ No ammonia = more effective disinfection with free chlorine

X With ammonia = less effective disinfection with chloramine

Biological Treatment 101–Technologies

Two types of biological treatment that can meet treatment goals:

Membrane Bioreactors

Engineered Treatment Wetlands

There are other **suspended growth aerobic processes** (e.g. activated sludge) and **attached growth aerobic processes** (e.g. trickling filters) but they won't be covered in this training module

MBR photo taken at Metropolitan Water District's Advanced Purification Center

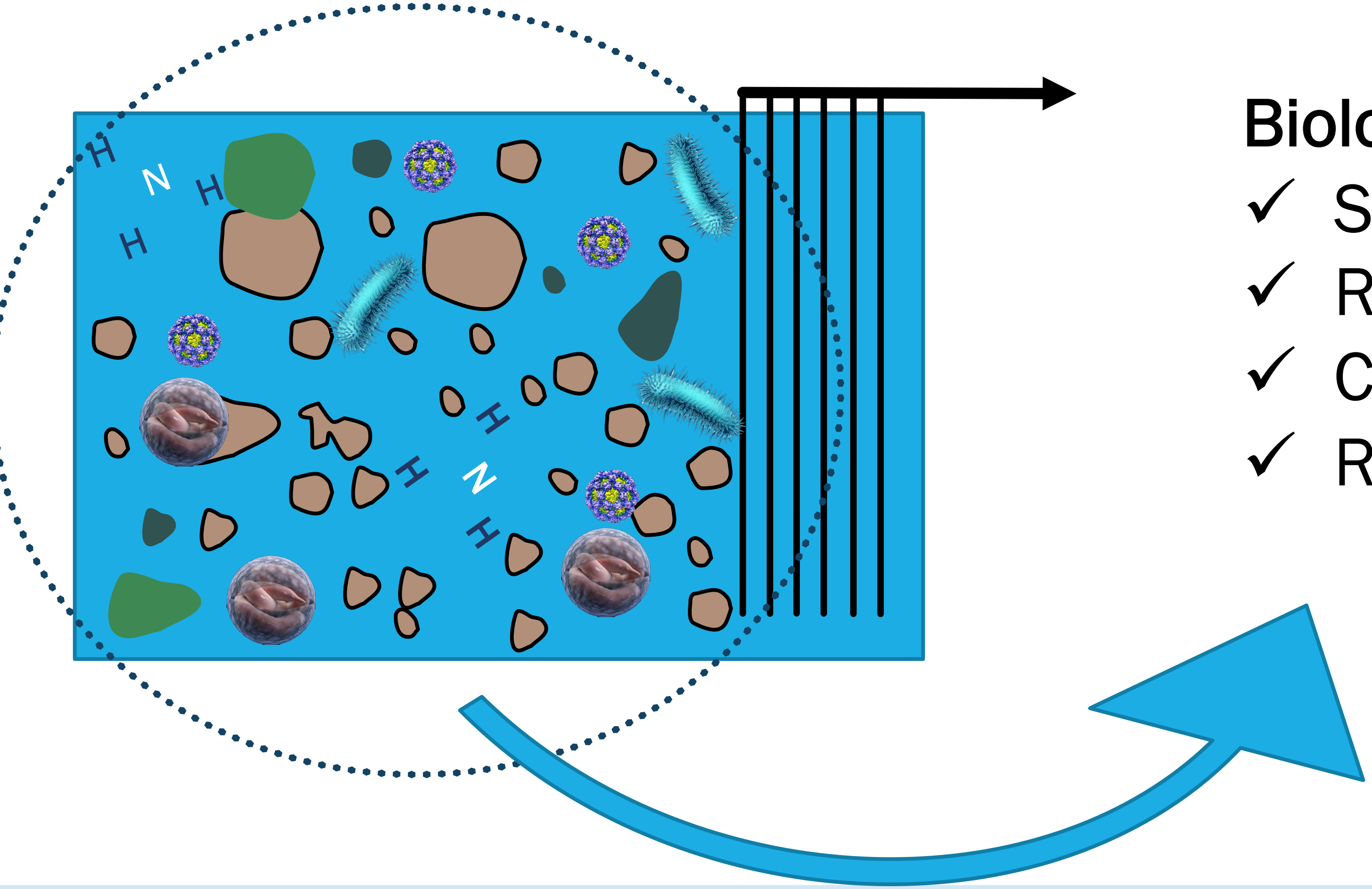
Course Overview

- Biological Treatment 101
- Membrane Bioreactors
- Engineered Treatment Wetlands

- Treatment Objectives
- Design Considerations

Membrane Bioreactor– Treatment Objectives

Biological Treatment + Membrane Filter

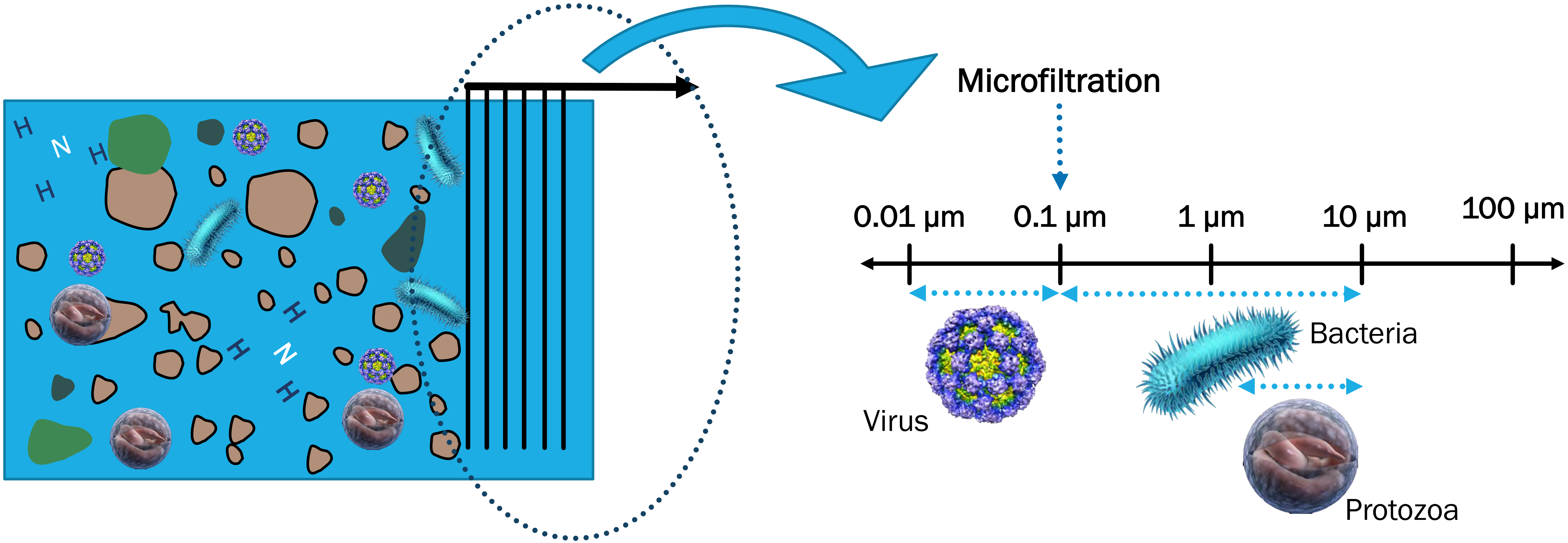


Biological Treatment:

- ✓ Suspended growth system
- ✓ Reduces **BOD**
- ✓ Converts **ammonia** to nitrate
- ✓ Reduces **pathogens**

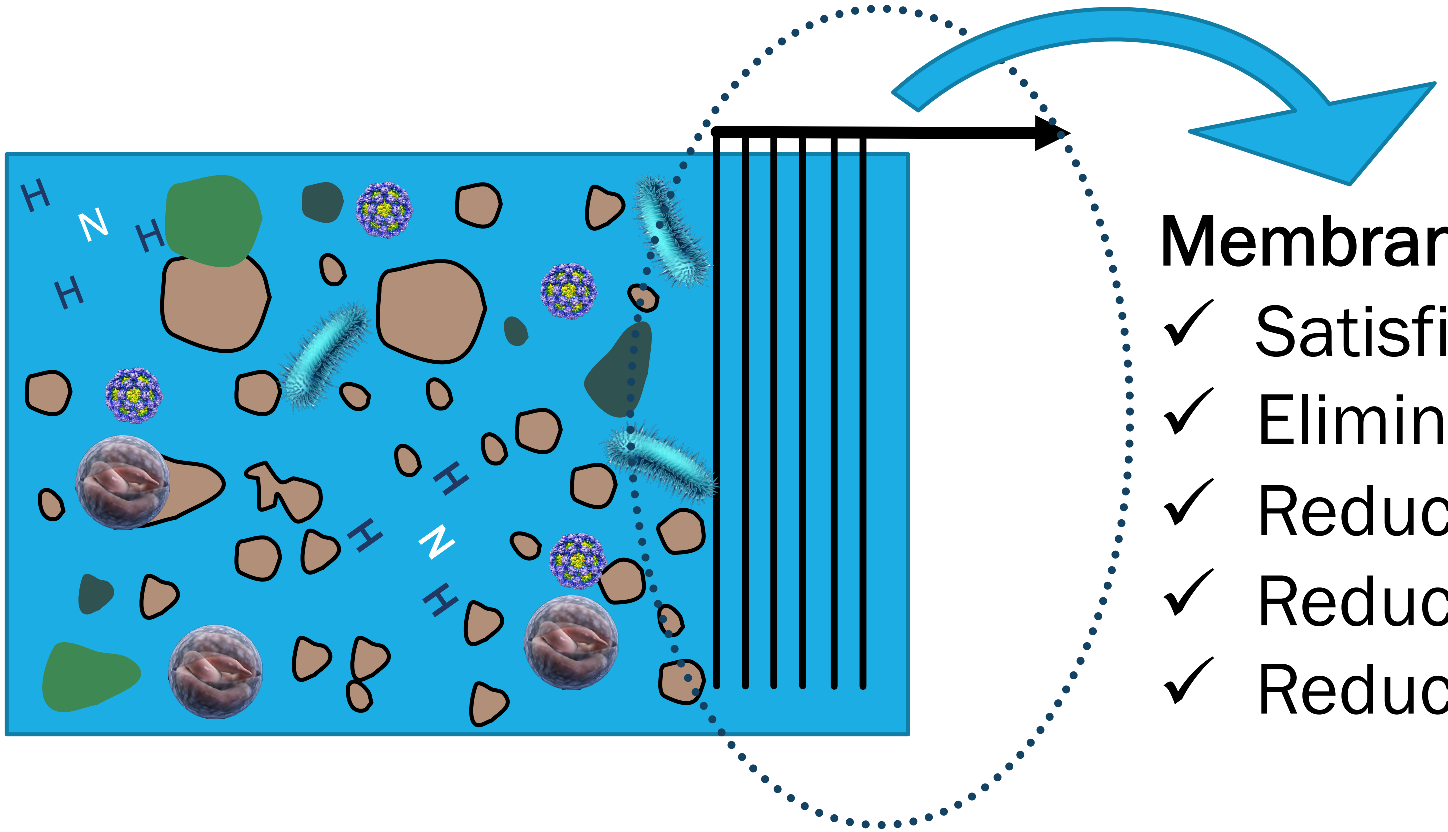
Membrane Bioreactor– Treatment Objectives

Biological Treatment + Membrane Filter



Membrane Bioreactor– Treatment Objectives

Biological Treatment + Membrane Filter



Membrane Filter:

- ✓ Satisfies need for filtration
- ✓ Eliminates need for solids settling
- ✓ Reduces footprint
- ✓ Reduces **TSS and turbidity**
- ✓ Reduces **pathogens** via size exclusion

Course Overview

- Biological Treatment 101
- Membrane Bioreactors
- Engineered Treatment Wetlands

- Treatment Objectives
- Design Considerations

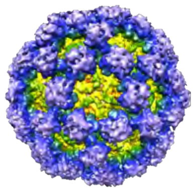
Membrane Bioreactor – Design Considerations

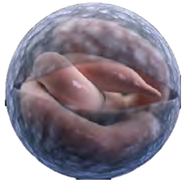
1. Biological Reactor
2. Membranes
3. Permeate Pump and Air Blower
4. Permeate and Air Piping

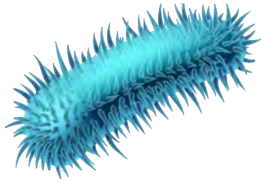
MBR schematic courtesy of Suez Water Technologies & Solutions

Membrane Bioreactor – Design Considerations

- Crediting framework = **Australian WaterVal Validation Protocol**
- Specifies conditions to receive credit without requiring site-specific validation
- Tiers define amount of credit and **operating envelope**
- Ongoing monitoring required to verify operation within envelope


1.5-log virus


2-log protozoa


4-log bacteria

Membrane Bioreactor – Design Considerations

- Monitoring requirements for **Tier 1 operating envelope:**

Parameter	Units	Minimum	Maximum
Bioreactor pH	pH units	6	8
Bioreactor dissolved oxygen	mg/L	1	7
Bioreactor temperature	Celsius	16	30
Solids retention time	days	11	--
Hydraulic retention time	hours	6	--
MLSS	g/L	3	--
Transmembrane pressure	kPa	3	--
Membrane flux	$L/m^2/h$	--	30
Turbidity	NTU	--	0.2

Membrane Bioreactor – Design Considerations

Additional MBR design considerations…

- Pros:
  - Relatively small footprint for biological treatment
  - Produces high-quality filtered effluent low in BOD, TSS, and turbidity
- Cons:
  - High energy consumption
  - Complex operations

Membrane Bioreactor – Design Considerations

Summary of MBR Design Considerations:

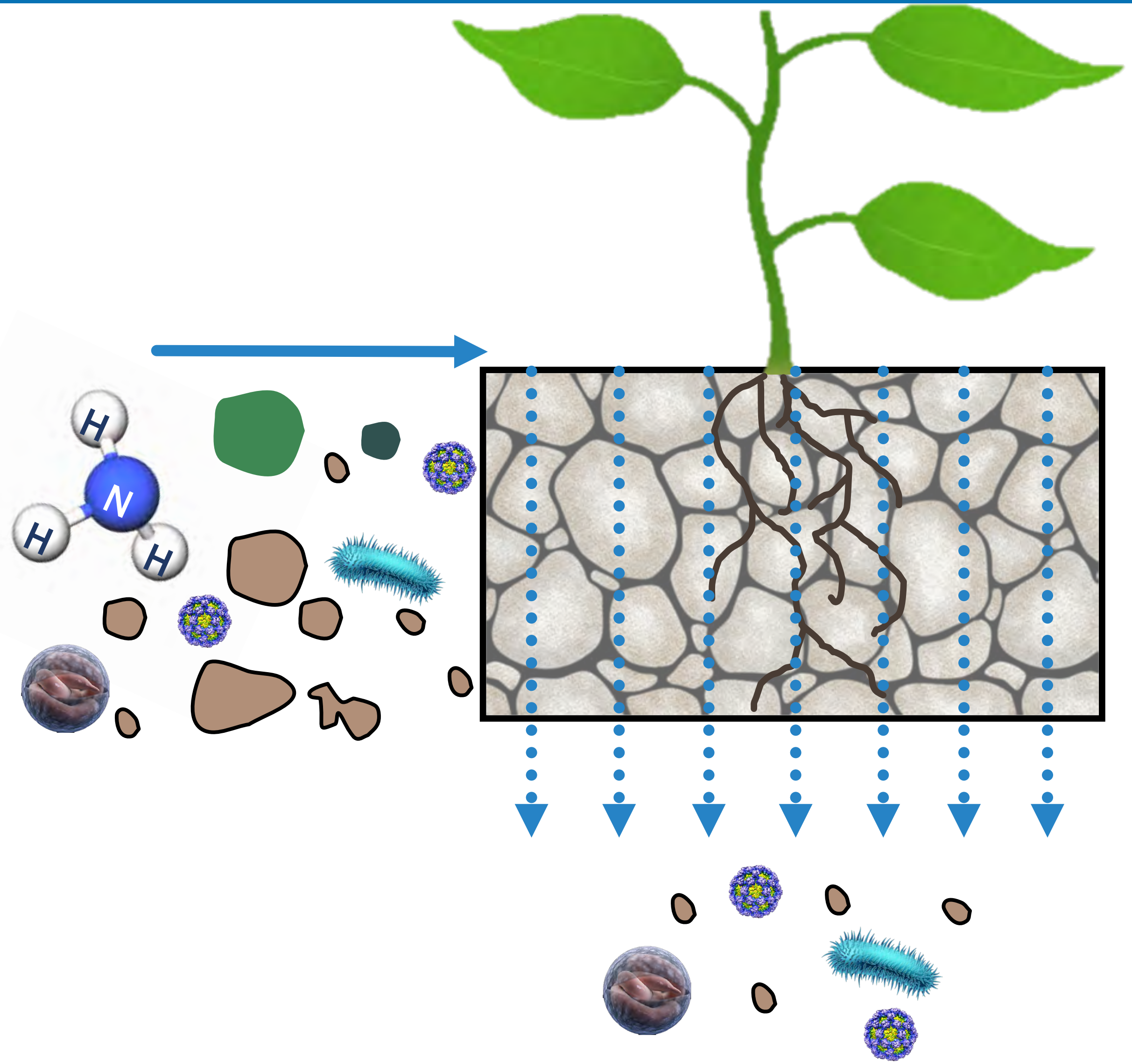
Treatment Process	Pathogen Credit	Pros	Cons
Membrane Bioreactors	1.5 virus 2 protozoa 4 bacteria LRV	♦ Small footprint ♦ High-quality filtered effluent low in BOD, TSS, and turbidity ♦ Pathogen crediting framework available	♦ Higher energy requirements ♦ Complex operations

Course Overview

- Biological Treatment 101
- Membrane Bioreactors
- **Engineered Treatment Wetlands**

- **Treatment Objectives**
- Design Considerations

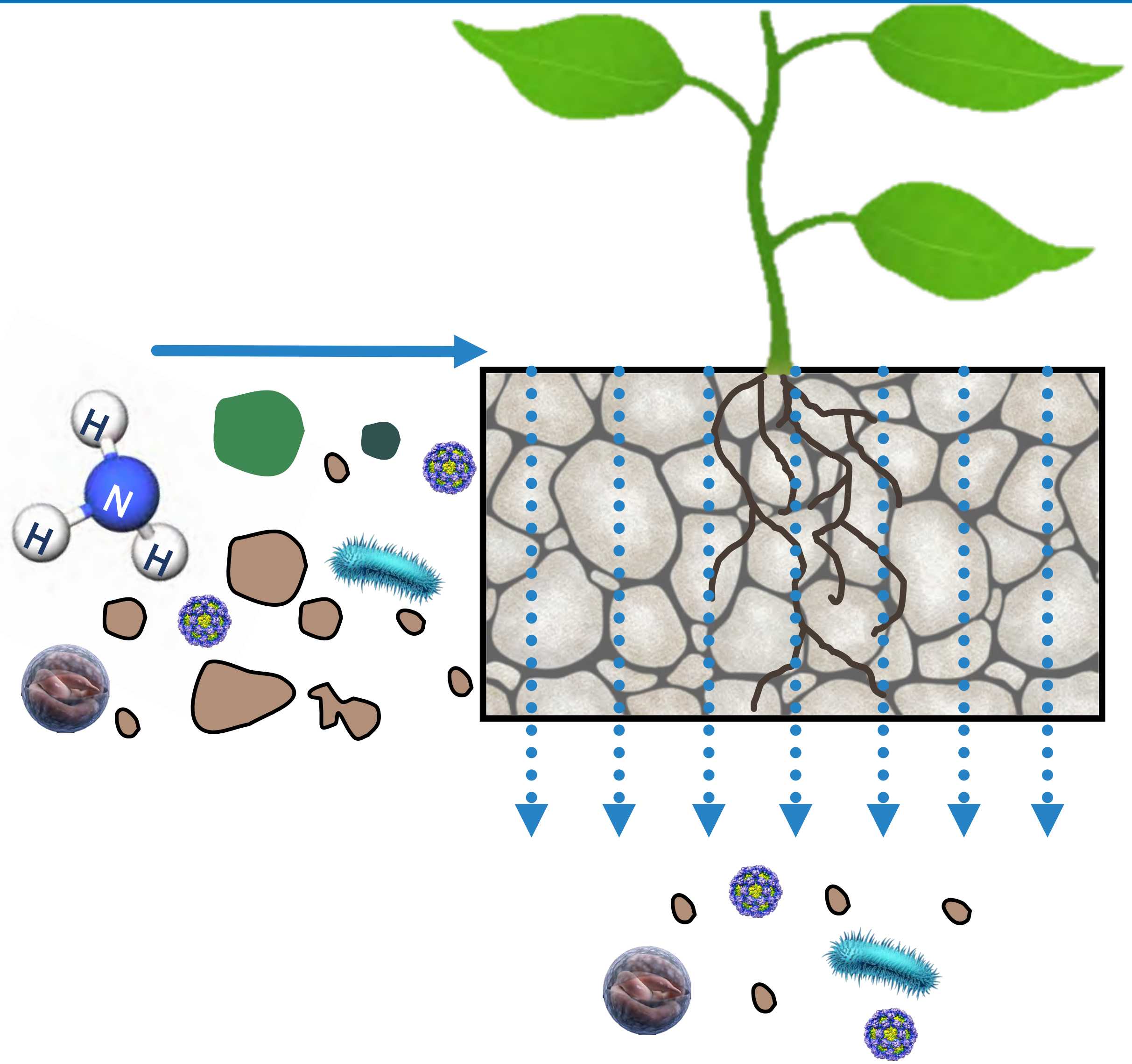
Treatment Wetlands – Treatment Objectives



Treatment Mechanisms:

- Water flows through porous media
- Microorganisms and plants populate wetland and improve water quality

Treatment Wetlands – Treatment Objectives



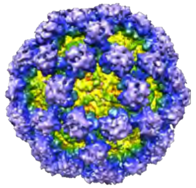
- ✓ Reduces **TSS and turbidity**
- ✓ Reduces **BOD** and **TOC**
- ✓ Reduces **ammonia**
- X **Pathogen** reduction not well understood

Course Overview

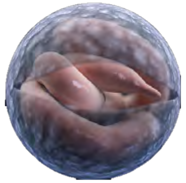
- Biological Treatment 101
- Membrane Bioreactors
- **Engineered Treatment Wetlands**
  - Treatment Objectives
  - Design Considerations

Treatment Wetlands – Design Considerations

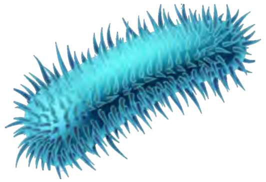
- **No existing frameworks for pathogen reduction crediting**
  - Pathogen reduction has been evaluated on a case-by-case basis
- Site-specific studies could be done to correlate pathogen reduction to surrogate parameters



0-log virus



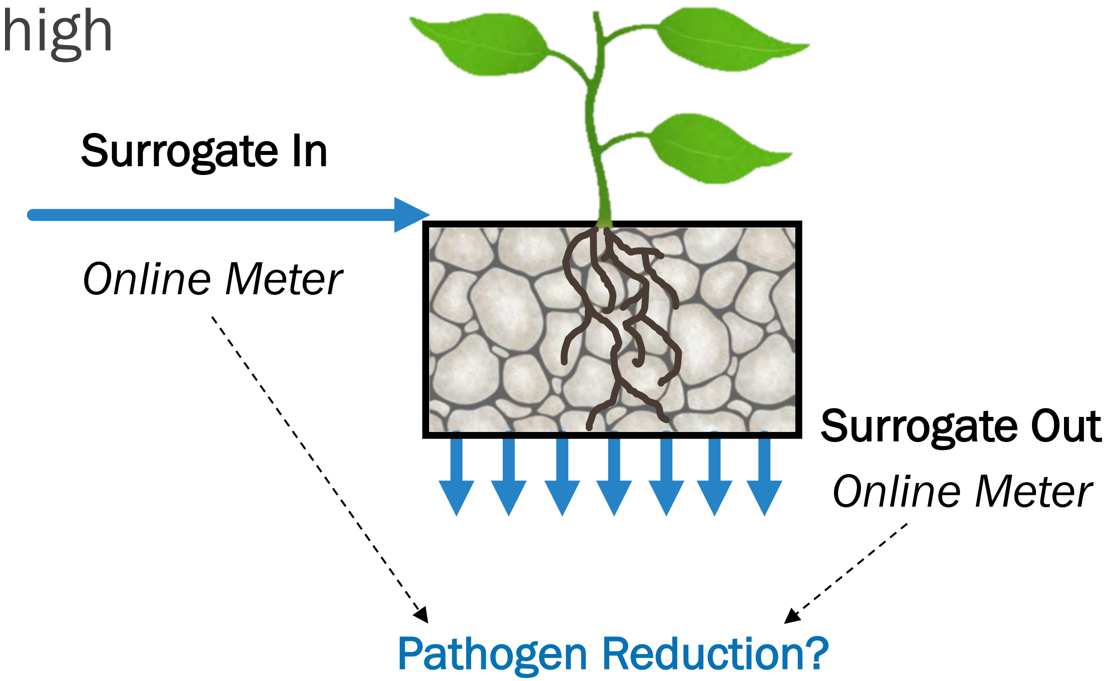
0-log protozoa



0-log bacteria

Treatment Wetlands – Design Considerations

- Site-specific study for pathogen crediting may present challenges:
  - Little precedent due to limited studies of pathogen reduction in biological treatment
  - Cost could be high



Treatment Wetlands – Design Considerations

- Although pathogen credit may not be sought, wetlands provide important water quality benefits
- **Monitoring is still important to ensure performance**
- Consider on-line or grab sampling for:
  - BOD
  - Ammonia
  - TSS
  - TOC
  - Turbidity

Hach 1720E Online Turbidimeter

Treatment Wetlands – Design Considerations

- Larger footprint compared to MBR
- Minimal energy usage
- Natural aesthetics enhance visual quality of building
- Visual reminder of ONWS system

Treatment Wetlands - Summary

Treatment Process	Pathogen Credit	Pros	Cons
Engineered Treatment Wetlands	0 LRV	♦ Lower energy requirements ♦ High degree of BOD and TSS reduction ♦ Aesthetics	♦ Large footprint ♦ No existing pathogen crediting framework ♦ Lower effluent quality than MBR

Biological Treatment – Summary

	Engineered Treatment Wetland	Membrane Bioreactor
Pathogen Reduction	X / ?	✓✓
WQ Improvements	✓✓	✓✓✓
Footprint	✓	✓✓
Energy Use	✓✓✓	✓
Operability	✓	✓

Problem Solving Exercises

Choose the treatment objective(s) that is achieved with biological treatment:

- A. Reduce dissolved inorganic constituents like sodium and chloride
- B. Reduce particulate matter
- C. Minimize the risk of *Legionella*
- D. Reduce biodegradable organics
- E. Both (B) and (D)

What types of biological treatment are commonly used for ONWS applications?

Select all that apply:

- A. Membrane bioreactors
- B. Conventional activated sludge
- C. Treatment wetlands
- D. Granular activated carbon
- E. None of the above

Why is it important to include biological treatment prior to filtration?

- A. Organics can foul filters
- B. Biological treatment reduces solids loading on subsequent filters
- C. Minimizes microbial regrowth in ONWS distribution systems
- D. None of the above
- E. (A), (B), and (C) are correct

What are key benefits of using an MBR for biological treatment?

- A. MBRs can provide consistent, high quality product water
- B. MBRs receive pathogen credit without site-specific validation testing
- C. MBRs remove all pathogens in the water
- D. MBRs have a relatively small footprint
- E. (A), (B), and (D) are correct

Are all pathogen groups reduced by membrane bioreactors?

- A. Yes
- B. No

Module 5: Treatment Selection and Crediting

FILTRATION

Training Modules

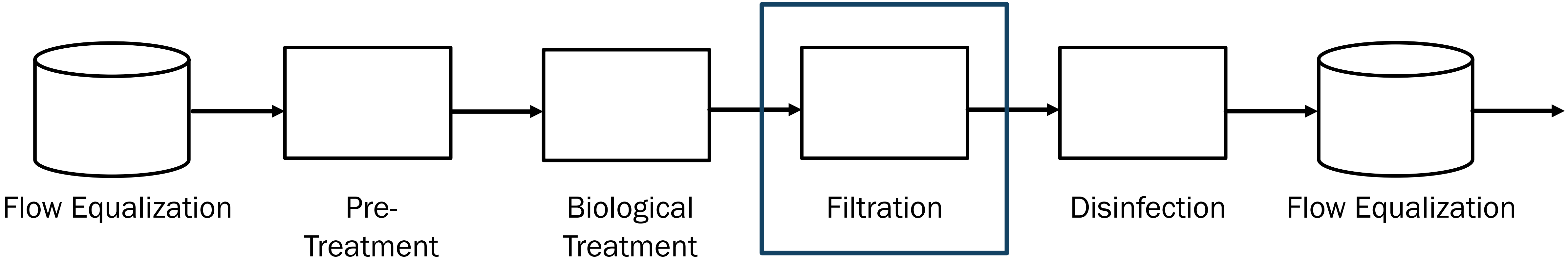
1. Introduction
2. Public Health Goals
3. Treatment Selection and Crediting Overview
4. Treatment Selection and Crediting: Biological Treatment
5. **Treatment Selection and Crediting: Filtration**
6. Treatment Selection and Crediting: Disinfection
7. Treatment Selection and Crediting: Flow Equalization and Distribution
8. Developing Multiple Barrier ONWS Systems
9. Operations Plan
10. Regulatory and Permitting Plan

Framing Questions

- Why is filtration an important treatment process?
- How do we know the system is performing as designed?
- Does filtration reduce pathogens—and if so how do we get credit?

Learning Objectives

- Design goals for filtration processes
- Key design and monitoring concepts
- Pathogen reduction crediting for filtration processes



Primary Target Audience

Primary Audience:

DESIGN ENGINEER

REGULATOR

General Awareness:

OPERATOR

PROGRAM ADMINISTRATOR

SYSTEM OWNER

Course Overview

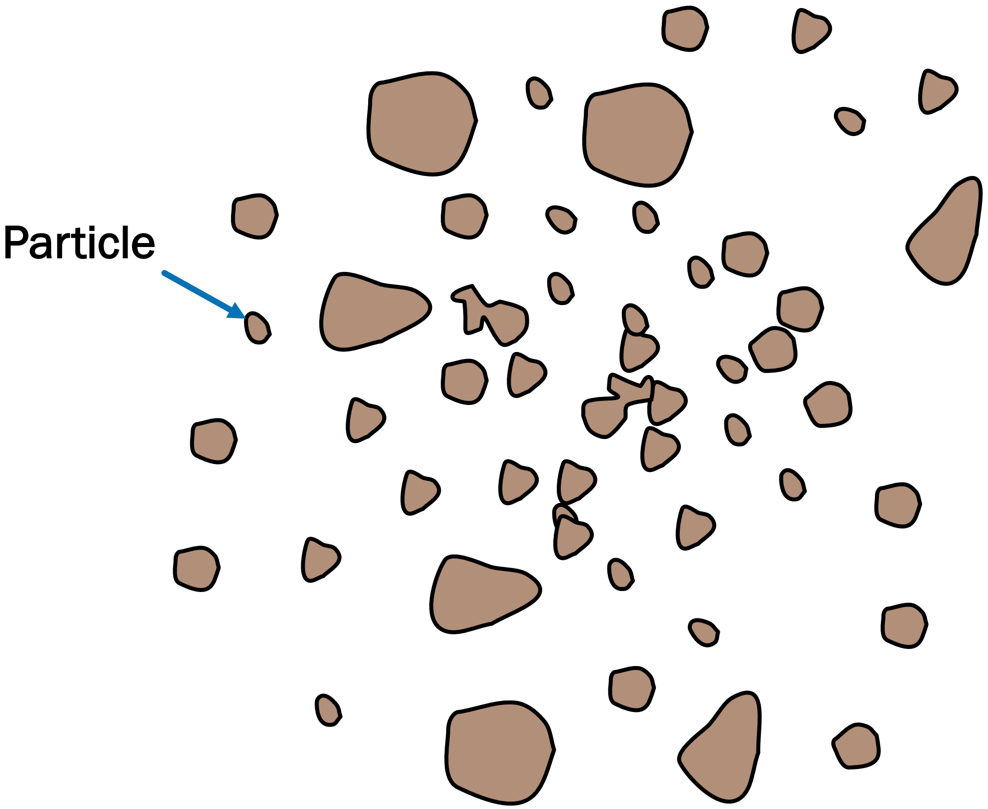
- Filtration 101
- Cartridge Filtration
- Membrane Filtration
- Reverse Osmosis

Course Overview

- Filtration 101
- Cartridge Filtration
- Membrane Filtration
- Reverse Osmosis

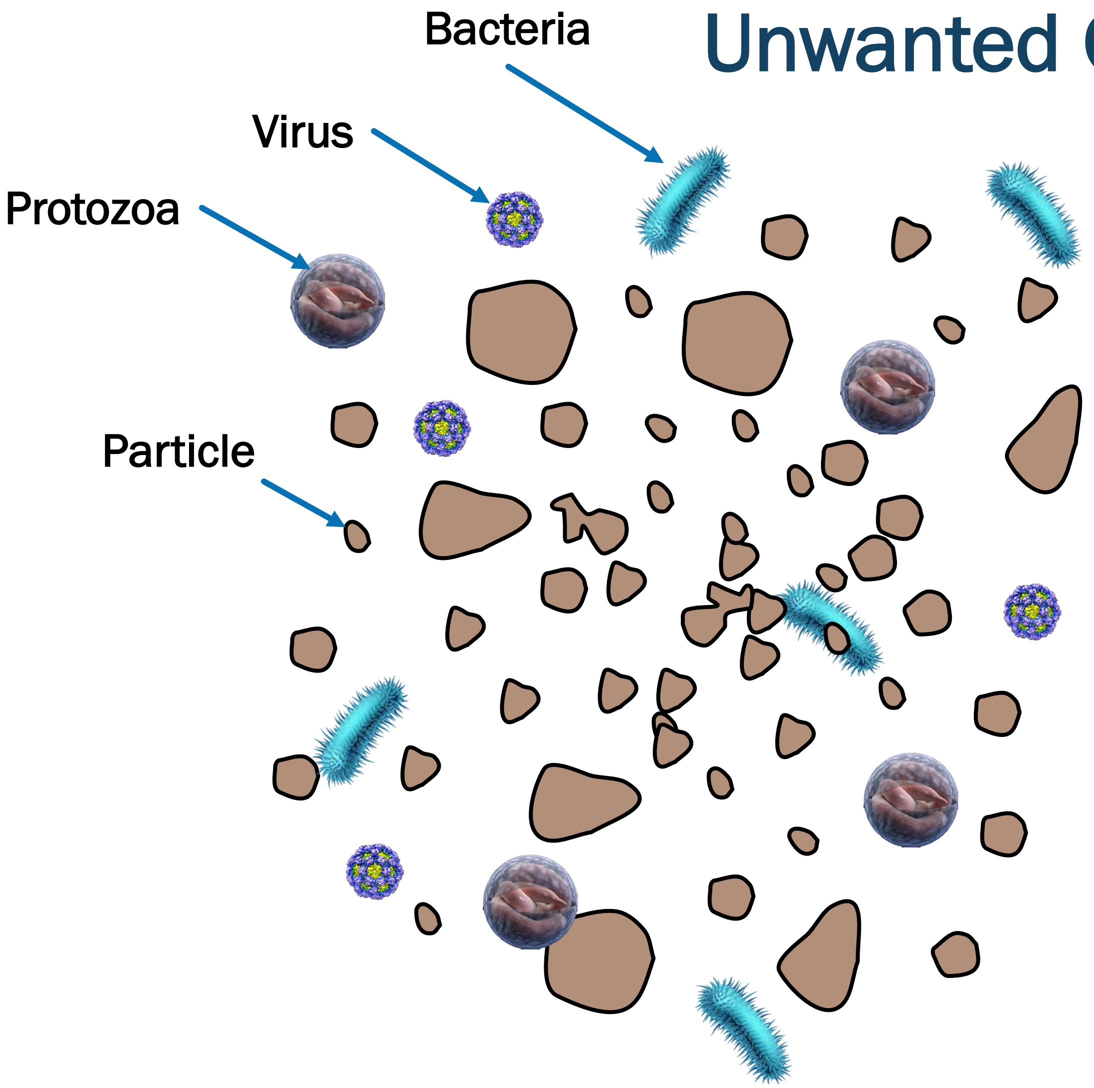
Filtration 101 – Treatment Objectives

Unwanted Constituents in ONWS Source Water:



- Particles
  - Total suspended solids
  - Turbidity

Filtration 101 – Treatment Objectives



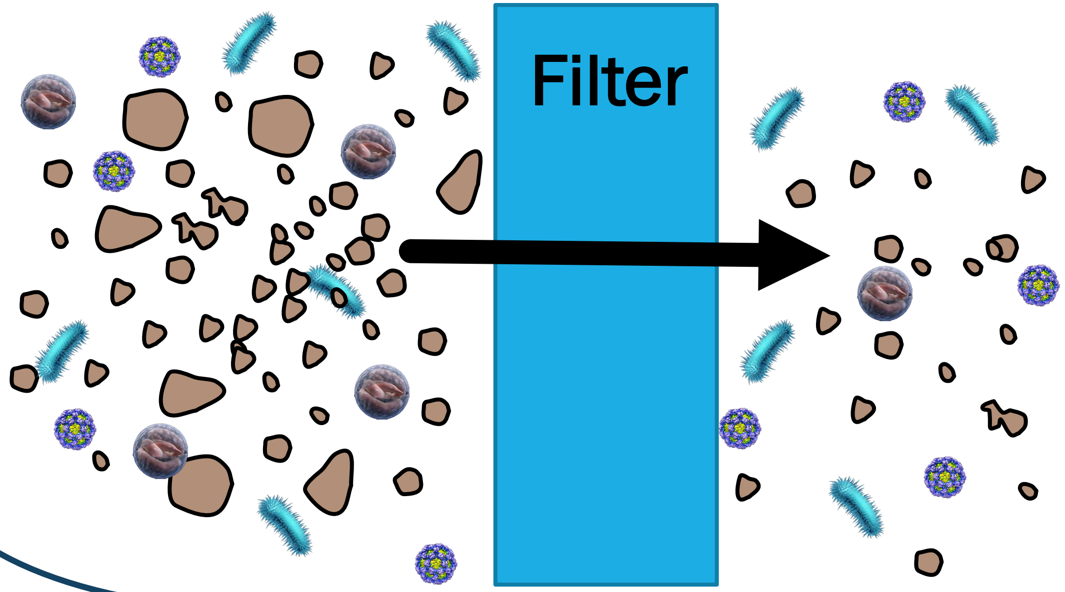
Unwanted Constituents in ONWS Source Water:

- Particles
- Pathogens
  - Protozoa
  - Virus
  - Bacteria

Filtration 101 – Treatment Objectives

- Particulate reduction quantified via total suspended solids (TSS) and turbidity
  - Measured as mg/L and NTU
- Pathogen reduction quantified via log reduction values (LRVs)

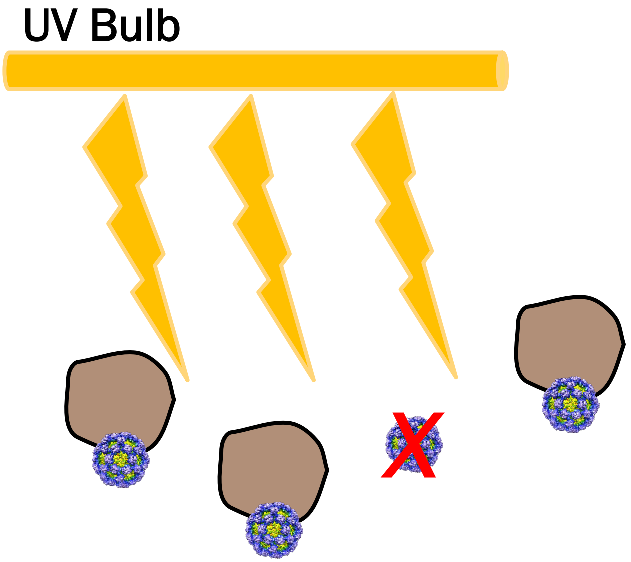
Filtration 101 – Treatment Objectives



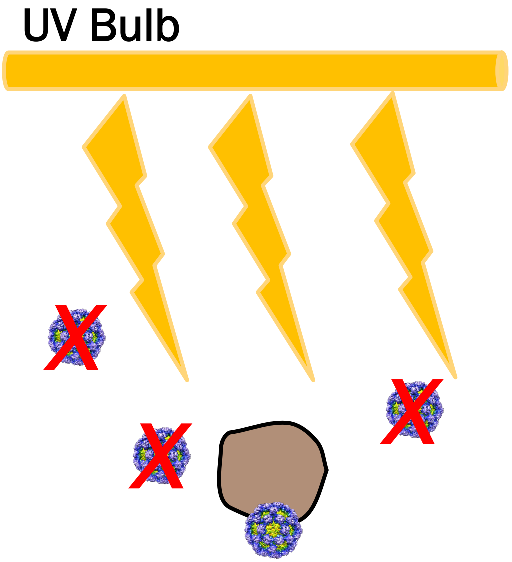
- ✓ Reduce **TSS**
- ✓ Reduce **turbidity**
- ✓ Remove some **pathogens**

Improves downstream disinfection performance

Filtration 101 – Treatment Objectives



Particles can shield pathogens from disinfection



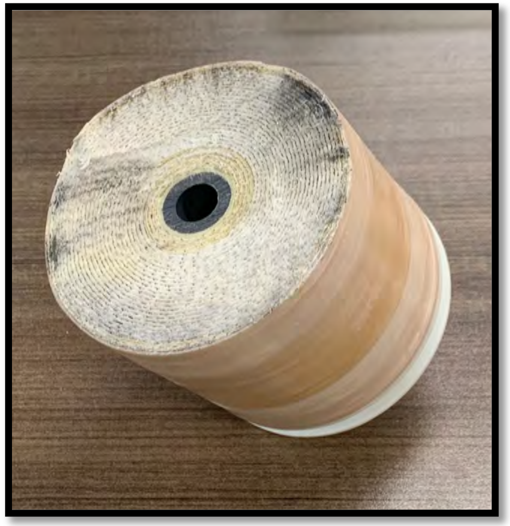
Fewer particles = more effective disinfection

Filtration 101 – Filtration Technologies

Three types of filters that can meet treatment goals:

Cartridge Filter

Membrane Filter



Reverse Osmosis

Additional Technologies: granular media filtration, cloth filters, etc.
but won't be covered in this training module

Filtration 101 –Filtration Technologies

	Particulate Reduction	Pathogen Reduction
Cartridge Filter	✓	✓
Membrane Filter	✓ ✓ ✓	✓ ✓
Reverse Osmosis	✓ ✓ ✓	✓ ✓ ✓

Course Overview

- Filtration 101
- **Cartridge Filtration**
- Membrane Filtration
- Reverse Osmosis

- Treatment Objectives
- Design Considerations

Cartridge Filtration – Treatment Objectives

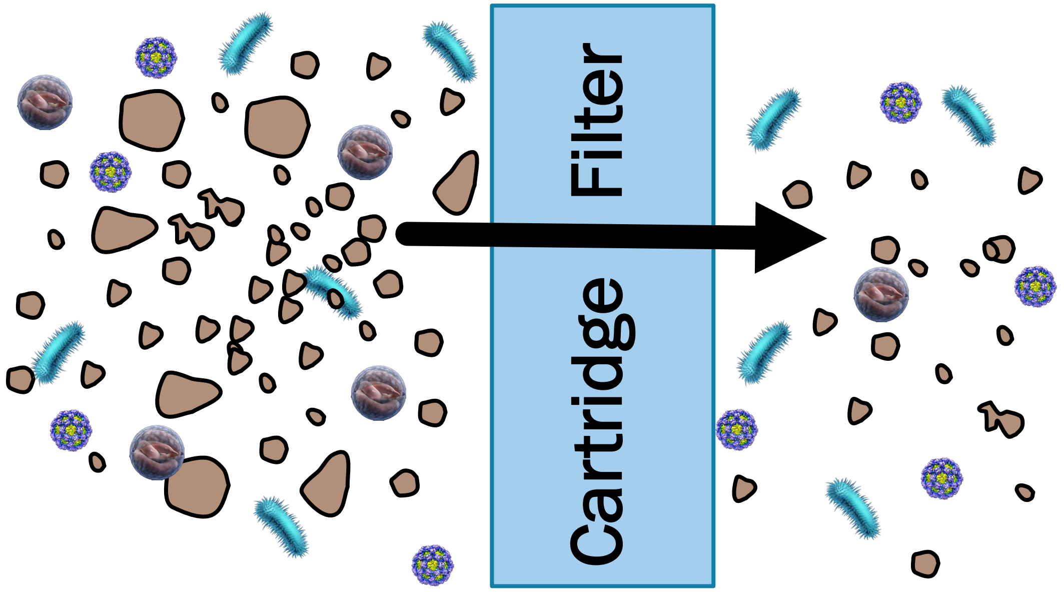
- Pressure-driven separation device
- Removes large particles
- Particles collect on filter surface and filter elements are periodically replaced

Cartridge Filtration – Treatment Objectives

↑ Pressure = faster flow through filter

High pressure typically requires a pump

Cartridge Filtration – Treatment Objectives



- ✓ Reduce **TSS**
- ✓ Reduce **turbidity**
- ✓ Remove some **pathogens**

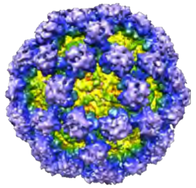
Course Overview

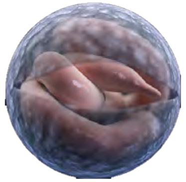
- Filtration 101
- **Cartridge Filtration**
- Membrane Filtration
- Reverse Osmosis

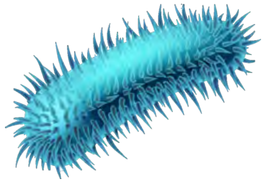
- Treatment Objectives
- **Design Considerations**

Cartridge Filtration – Design Considerations

- Crediting framework = EPA's Long Term 2 Enhanced Surface Water Treatment Rule (LT2)
- 2.0- to 2.5-log protozoa credit
  - 2.0-log credit for one cartridge filter
  - 2.5-log credit for two filters in series


0-log virus


2- to 2.5-log protozoa


0-log bacteria

Cartridge Filtration – Design Considerations

- Validation testing required to verify:
  - Particles > 1 μm are removed
  - Demonstrate a minimum of 3.0-log removal through challenge testing
- Effluent turbidity requirements should be specified
  - Example: 95% of values < 1 NTU with no values > 5 NTU*

* EPA Surface Water Treatment Rule guidance on cartridge filter performance

Cartridge Filtration – Design Considerations

- Filter selection
  - LT2 approved filters provide easiest pathogen crediting
  - Larger filter pore sizes can provide removal of particulates, lower operating pressures, less frequent replacement – but more difficult crediting
- Monitoring
  - Turbidity: online turbidimeters used for continuous monitoring of pathogen removal performance
  - Pressure: pressure gauges provide indication of fouling and need for filter replacement

Cartridge Filtration – Design Considerations

Additional cartridge filter design considerations…

- Pros:
  - Easy operation
  - Lowest energy usage
- Cons:
  - Particulate removal sufficient but less compared to other options
  - Requires more frequent replacement than membrane filters
  - Lower pathogen credits

Cartridge Filtration– Summary

Treatment Process	Pathogen Credit	Pros	Cons
Cartridge Filtration	2- to 2.5-log Protozoa	♦ Easy operation ♦ Lowest energy usage	♦ Particulate removal sufficient but less compared to other options ♦ Requires more frequent replacement than membrane filters ♦ Lower pathogen credits

Course Overview

- Filtration 101
- Cartridge Filtration
- Membrane Filtration
- Reverse Osmosis

- Treatment Objectives
- Design Considerations

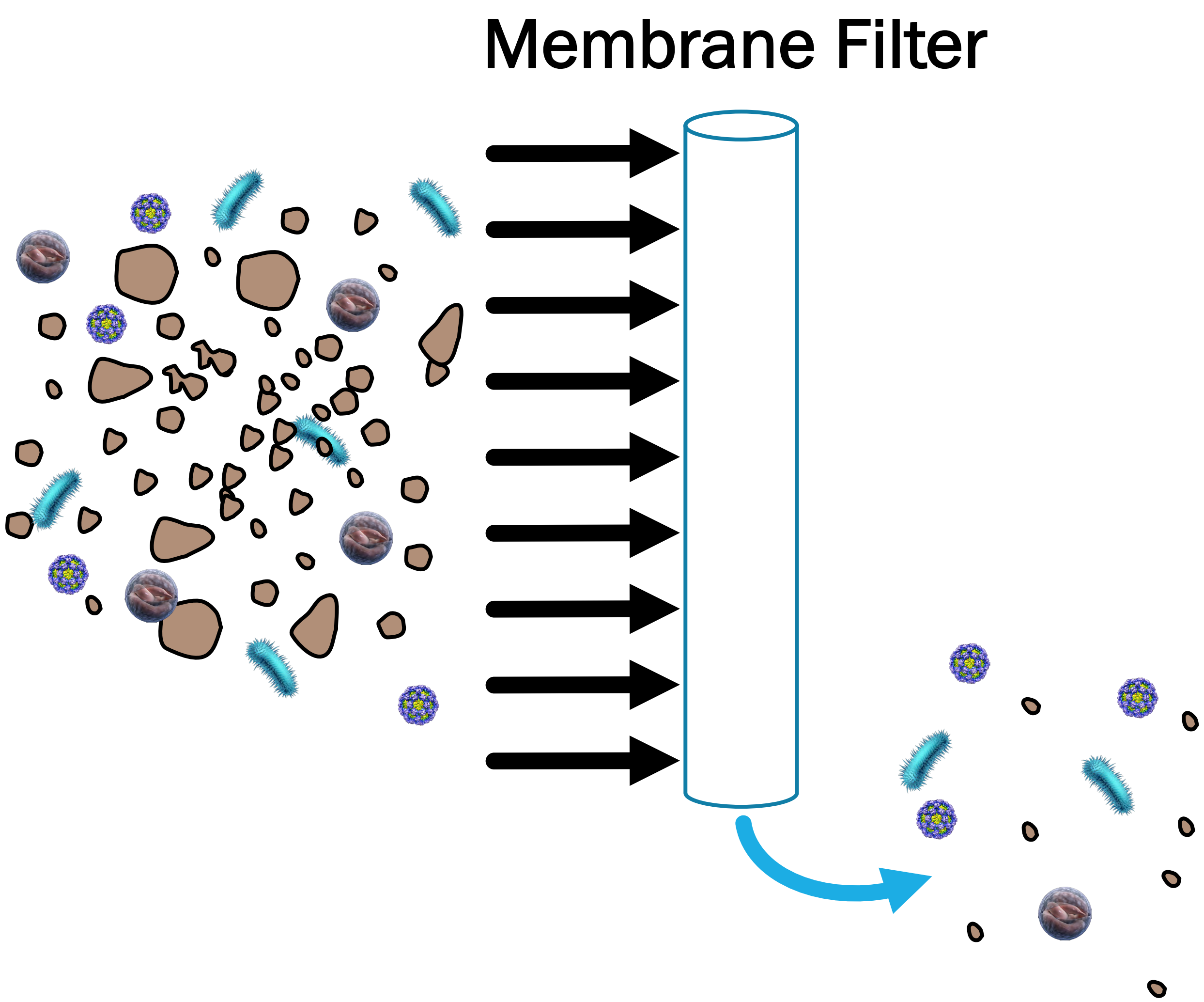
Membrane Filtration – Treatment Objectives

Hollow fiber membranes…

…are housed in a vessel…

….installed on a skid

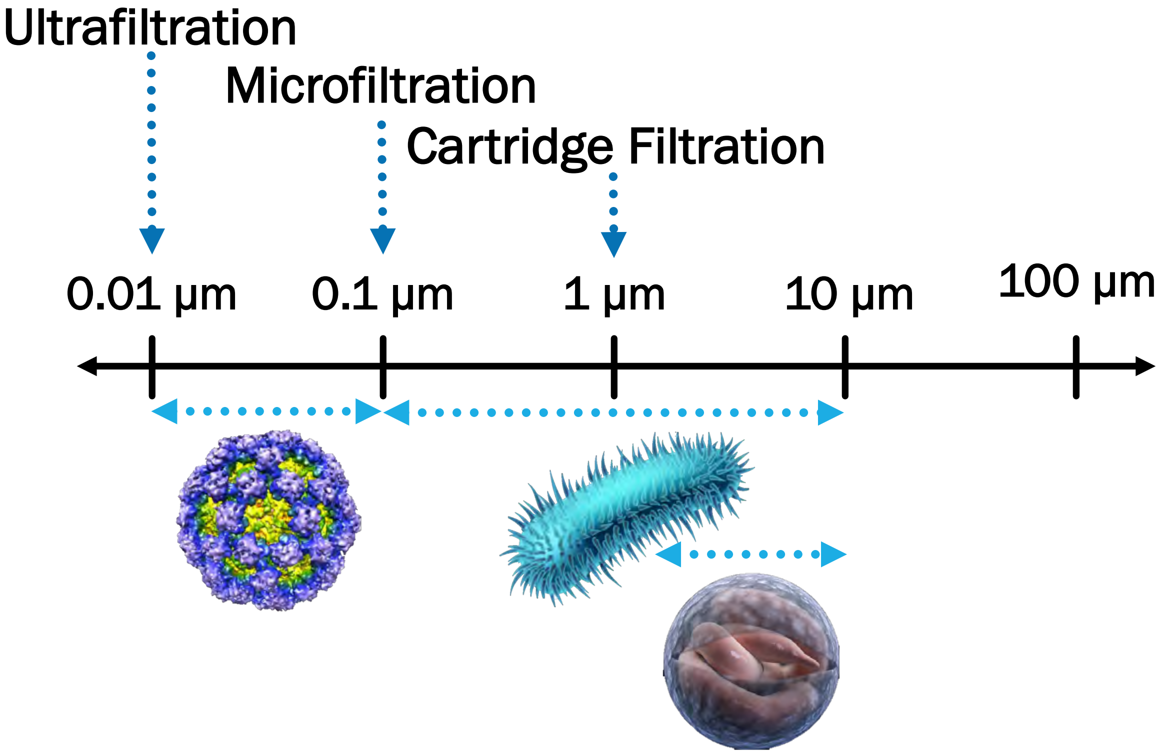
Membrane Filtration – Treatment Objectives



- ✓ Reduce **TSS**
- ✓ Reduce **turbidity**
- ✓ Effective against some **pathogen types**

Membrane Filtration – Treatment Objectives

- Reduction of particles > ~0.1 µm or 0.01 µm diameter, depending on type
- Reduction of protozoa, which range in size from 3 – 10 µm



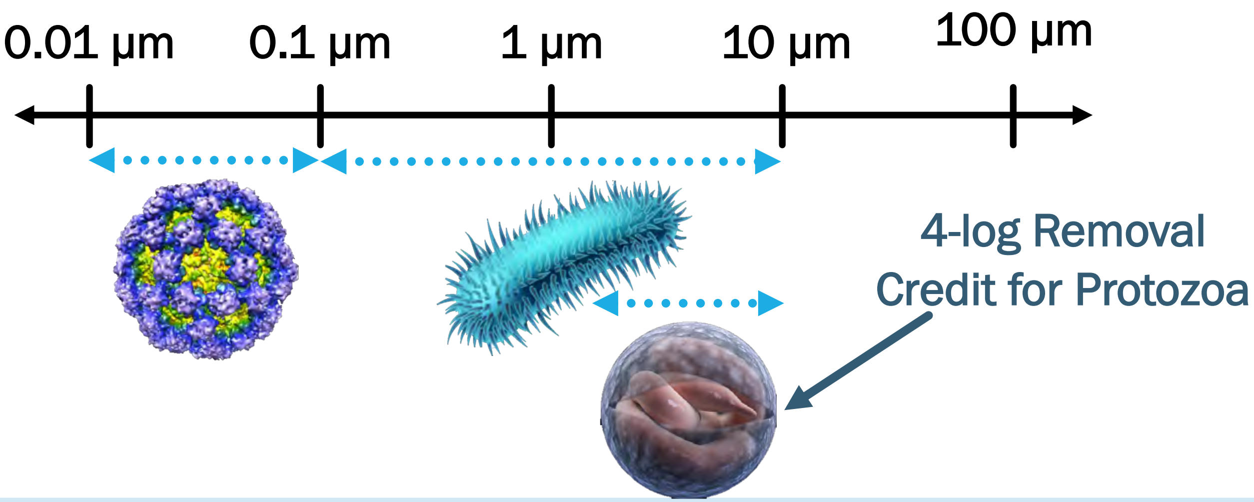
Course Overview

- Filtration 101
- Cartridge Filtration
- **Membrane Filtration**
- Reverse Osmosis

- Treatment Objectives
- **Design Considerations**

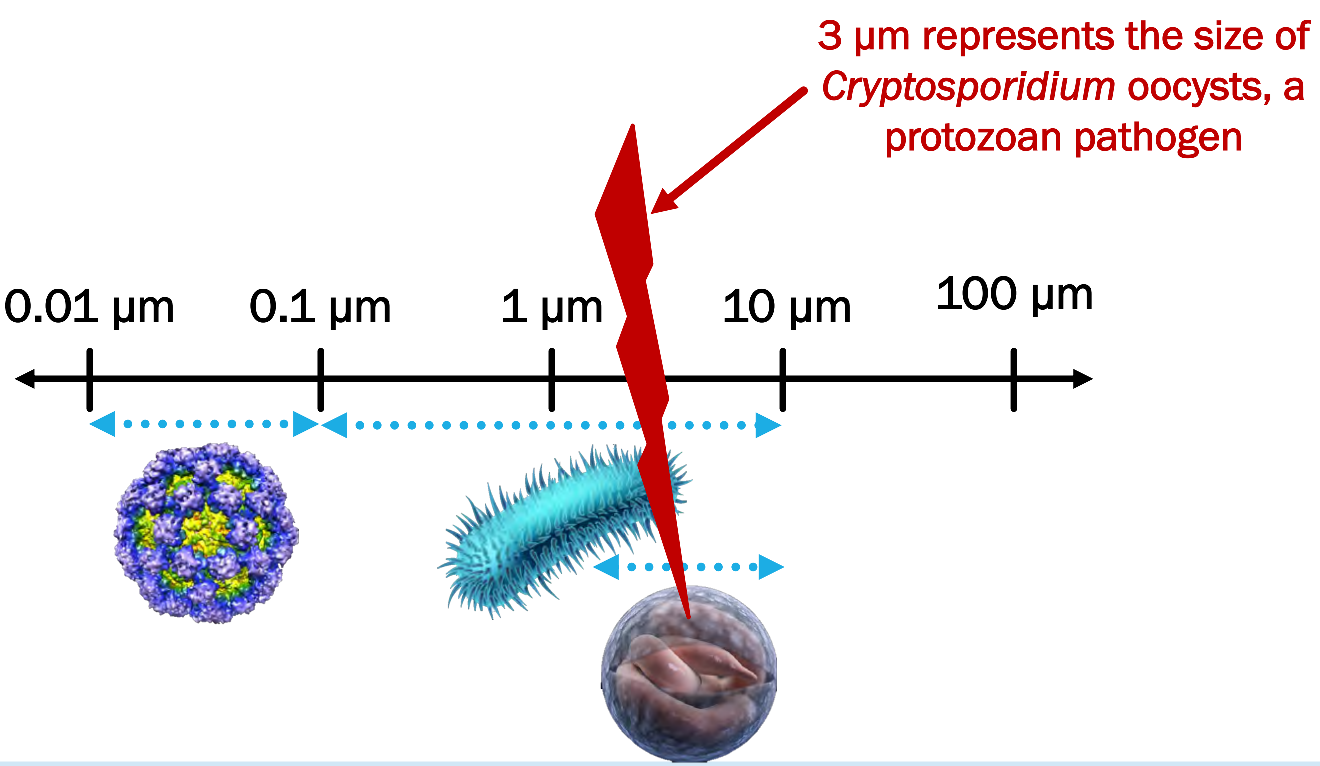
Membrane Filtration – Design Considerations

- EPA's Membrane Filtration Guidance Manual provides framework
- Gives protozoa removal credit only
  - Protozoa are the largest of the pathogen groups



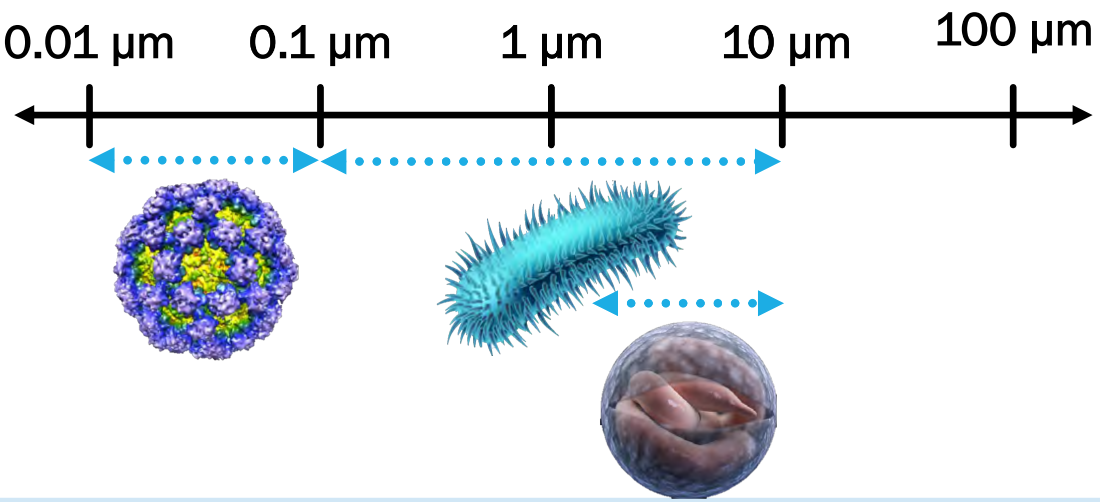
Membrane Filtration – Design Considerations

- **Demonstration of removal** is required through:
    1. Detecting a breach of 3 µm or larger via membrane integrity test



Membrane Filtration – Design Considerations

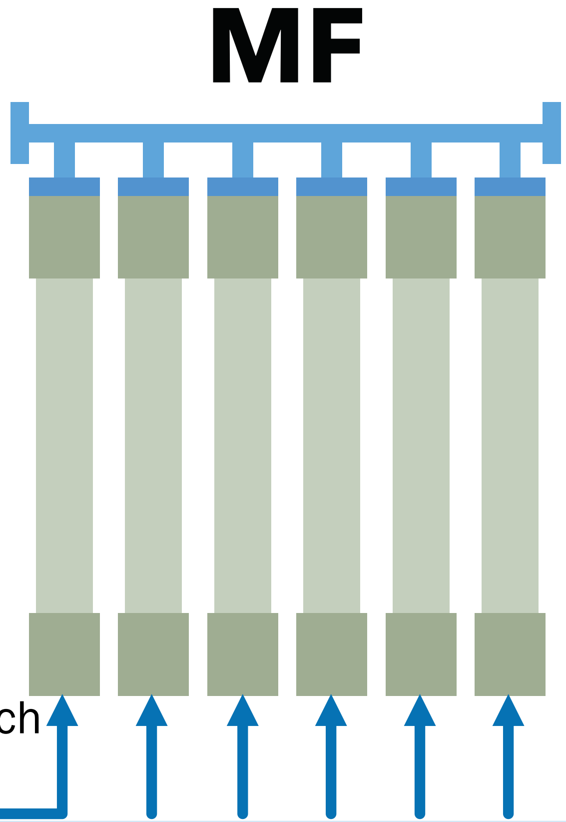
- **Demonstration of removal** is required through:
  1. Detecting a breach of 3 μm or larger via membrane integrity test
  2. Meeting the continuous turbidity requirements



Membrane Filtration – Design Considerations

- **Direct integrity testing:** a physical test applied to a membrane unit to identify and isolate integrity breaches

Pressure Decay Testing



Pressure is applied to each membrane unit ***daily***

Rate of pressure loss is related to membrane hole size

↑ Pressure Loss Rate ↑ Breaches

Membranes must be validated to ensure identification of breaches on the order of 3 µm

Membrane Filtration – Design Considerations

Pressure Decay Testing

Higher pressure needed for detecting

Smaller breaches

Pressure required to detect virus-sized integrity breach is beyond what MF/UF membranes can withstand

Only protozoa log reduction is credited

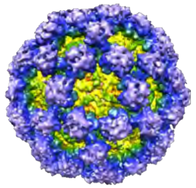
Membrane Filtration – Design Considerations

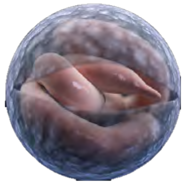
- **Indirect integrity testing:** continuous monitoring of the filtrate water quality (typically turbidity) to verify removal of particulate matter

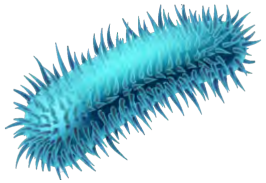
Continuous monitoring = measuring at least once every 15 minutes

Membrane Filtration – Design Considerations

- Direct and indirect testing required
- 4-log protozoa credit


0-log virus


4-log protozoa


0-log bacteria

Membrane Filtration – Design Considerations

Additional membrane filter design considerations…

- Pros:
  - Reliable, high degree of turbidity removal
  - Existing pathogen crediting framework
- Cons:
  - Complex operations
  - Higher energy use
  - Membrane replacement is required
  - Special cleaning is occasionally required due to membrane fouling

Membrane Filtration – Summary

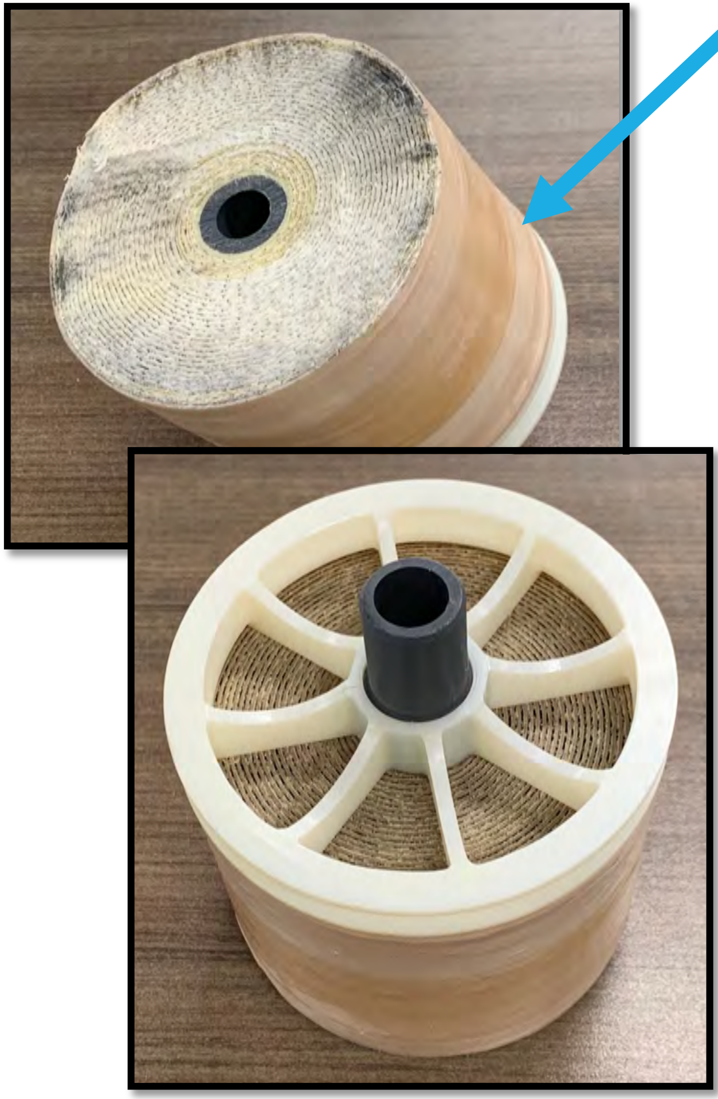
Treatment Process	Pathogen Credit	Pros	Cons
Membrane Filtration	4-log Protozoa	♦ Reliable, high degree of turbidity removal ♦ Existing pathogen crediting framework	♦ Complex operations ♦ Higher energy use ♦ Membrane replacement is required ♦ Special cleaning is occasionally required due to membrane fouling

Course Overview

- Filtration 101
- Cartridge Filtration
- Membrane Filtration
- **Reverse Osmosis**

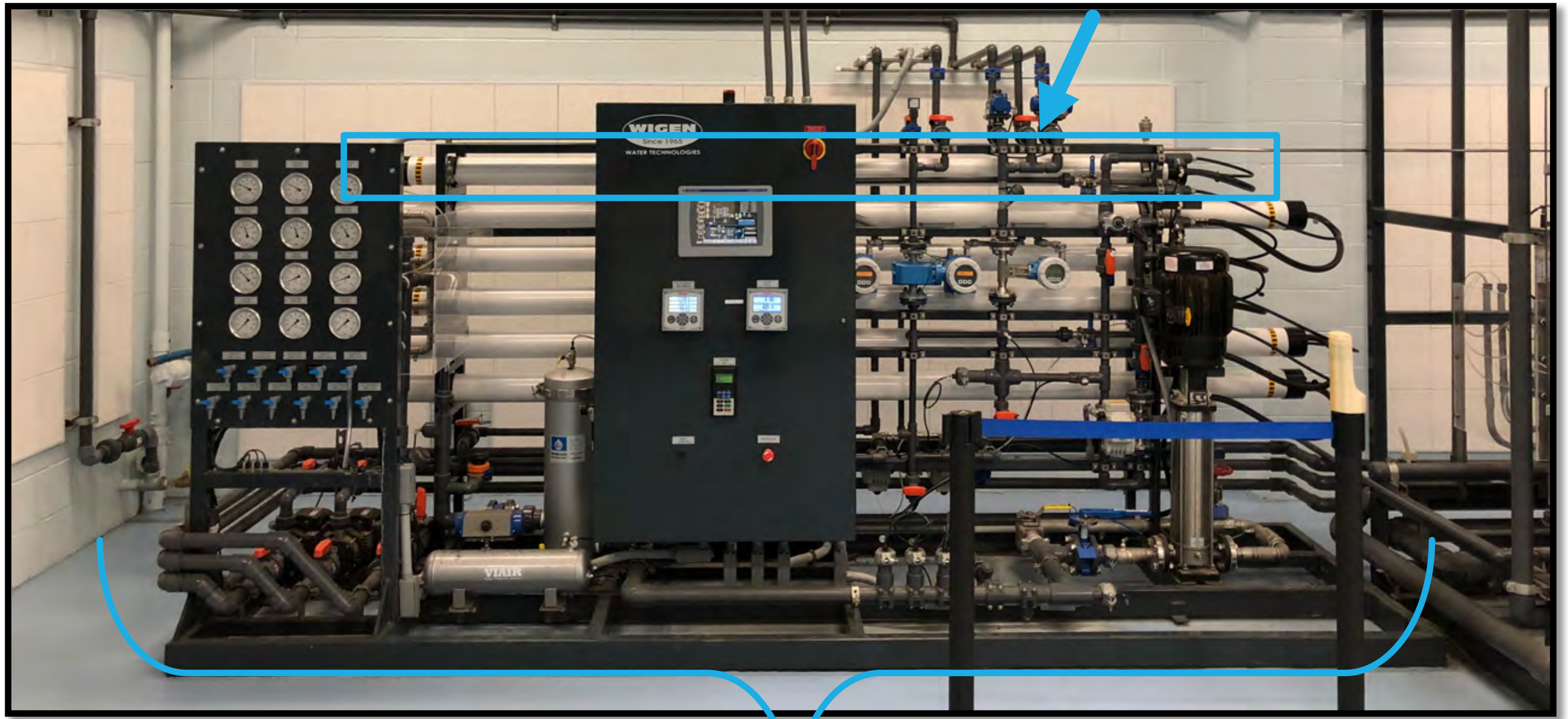
- **Treatment Objectives**
- Design Considerations

Reverse Osmosis – Treatment Objectives



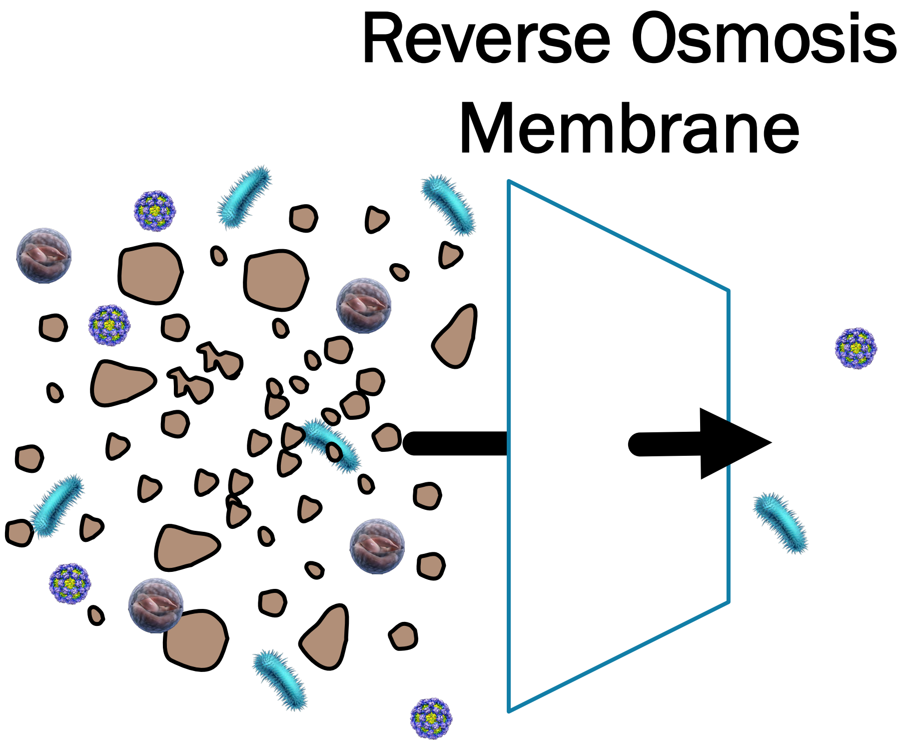
Membrane sheets...

...are housed in elements...



....installed on a skid

Reverse Osmosis – Treatment Objectives



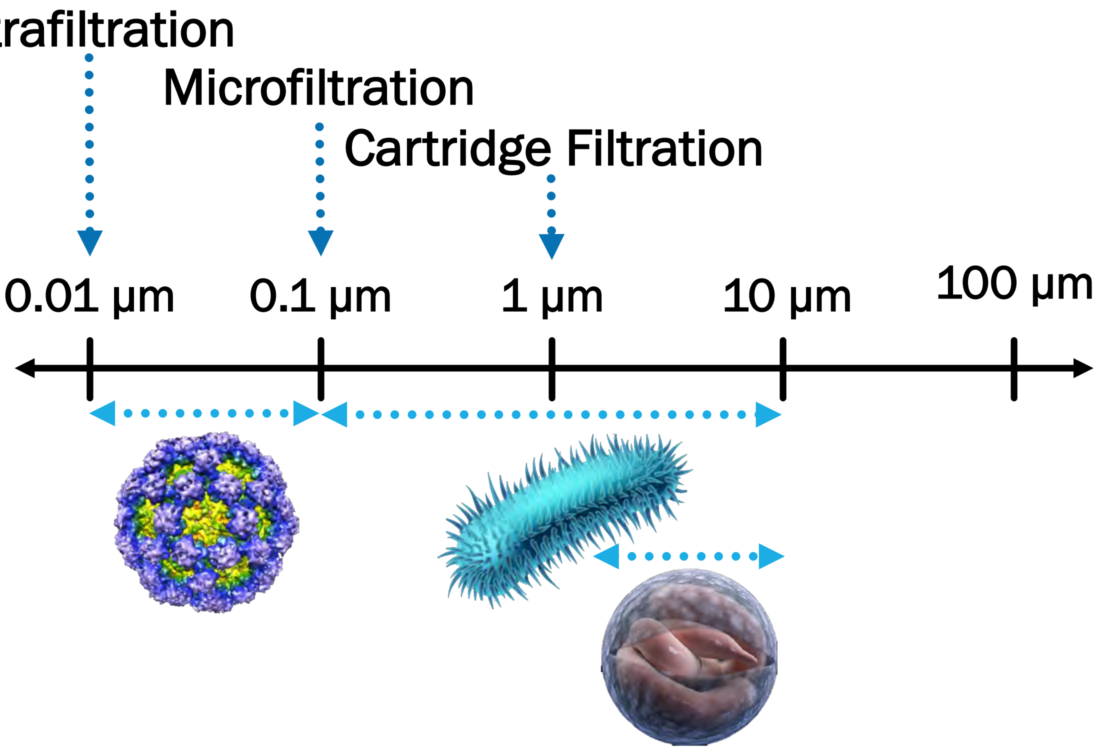
- ✓ Reduce **inorganic and organic compounds**
- ✓ Reduce **color and odor-causing compounds**
- ✓ Remove **TSS**
- ✓ Remove **turbidity**
- ✓ Improve **UVT**
- ✓ Effective against all **pathogen types**

Pretreatment via membrane filtration is required to operate a reverse osmosis system

Reverse Osmosis– Treatment Objectives

- Complete turbidity removal
- Reduction of virus, bacteria, and protozoa
- Reduction of many dissolved compounds

RO membranes have no pores

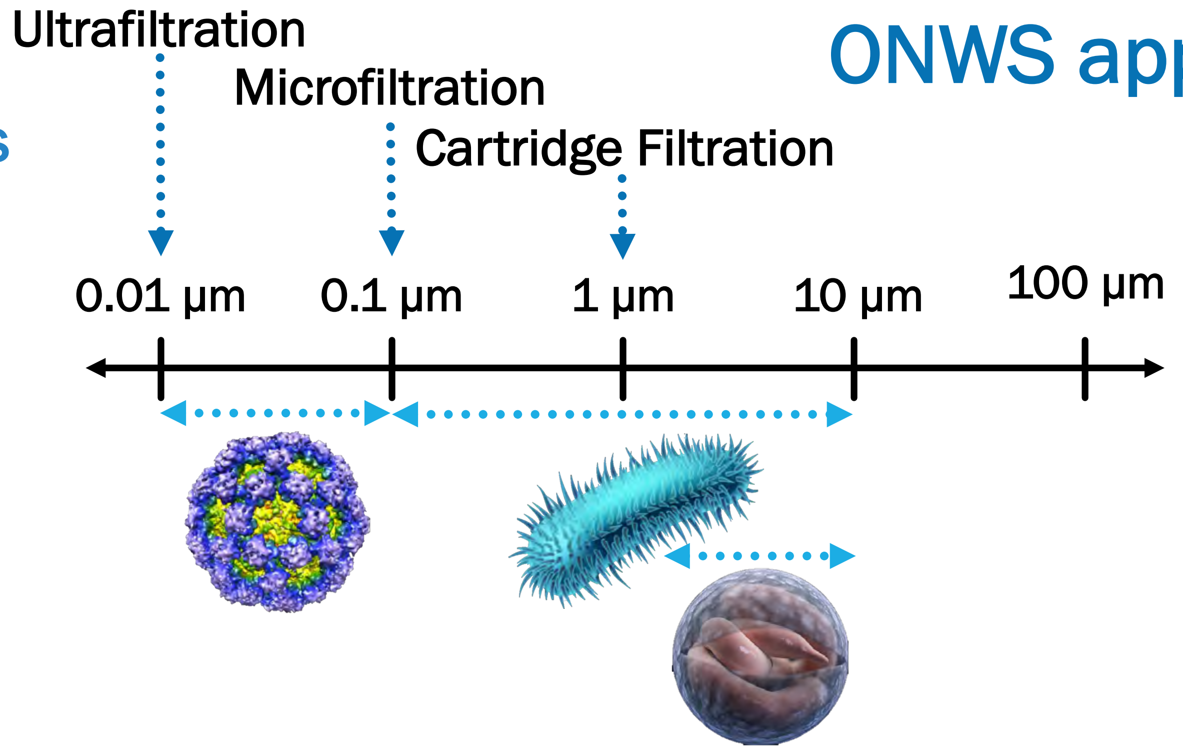


Reverse Osmosis– Treatment Objectives

- Complete turbidity removal
- Reduction of virus, bacteria, and protozoa
- Reduction of many dissolved compounds

Goes above and beyond what is required for many ONWS applications

RO membranes have no pores



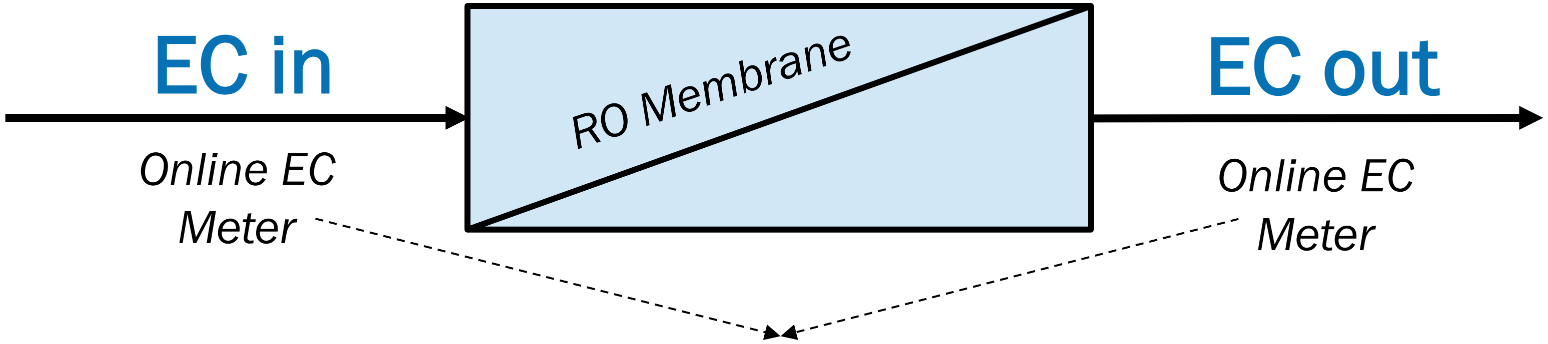
Course Overview

- Filtration 101
- Cartridge Filtration
- Membrane Filtration
- Reverse Osmosis

- Treatment Objectives
- Design Considerations

Reverse Osmosis – Design Considerations

- Crediting frameworks developed by the EPA and state regulators
- LRV equal to removal of a continuously measured conservative surrogate parameter
  - Electrical conductivity
  - Total organic carbon



Continuously measure **surrogates** to **verify achievement of LRTs**

Reverse Osmosis – Design Considerations

- Credit awarded based on reduction of surrogate parameter
- Direct integrity testing not possible for RO membranes

RO systems receive less protozoa credit than MF/UF systems

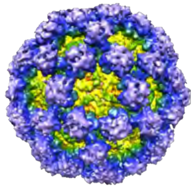
- but -

RO systems receive credit for *all* pathogen groups—including virus

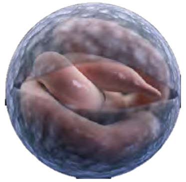
Reverse Osmosis – Design Considerations

- Pathogen removal credit depends on surrogate selection

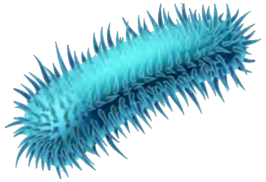
Electrical Conductivity



1-log virus

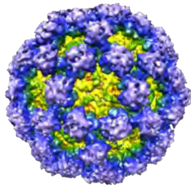


1-log protozoa

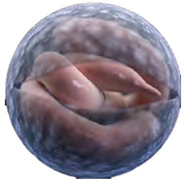


1-log bacteria

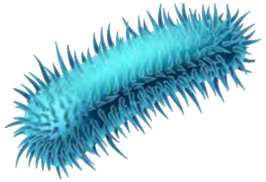
Total Organic Carbon



2-log virus



2-log protozoa



2-log bacteria

Reverse Osmosis – Design Considerations

Additional RO design considerations…

- Pros:
  - Complete turbidity removal
  - Existing pathogen crediting framework
  - Highest water quality (BOD, TOC, UVT, color, etc.)
- Cons:
  - Highest energy use
  - Membrane replacement is required
  - Special cleaning is occasionally required due to membrane fouling
  - A concentrate waste stream is created that requires proper disposal and decreases the amount of water produced

Reverse Osmosis – Summary

Treatment Process	Pathogen Credit	Pros	Cons
Reverse Osmosis	Up to[1]: 2-log Virus 2-log Protozoa 2-log Bacteria	♦ Complete turbidity removal ♦ Existing pathogen crediting framework ♦ Highest water quality (BOD, TOC, UVT, color, etc.)	♦ Highest energy use ♦ Membrane replacement is required ♦ Special cleaning is occasionally required due to membrane fouling ♦ A concentrate waste stream is created that requires proper disposal and decreases the amount of water produced

1: Pathogen log removal credit depends on surrogate parameter.

Filtration Summary

	Particulate Reduction	Pathogen Reduction
Cartridge Filter	< 1 NTU	2- to 2.5-log protozoa
Membrane Filter	< 0.2 NTU	4-log protozoa
Reverse Osmosis	All particulates removed	*Up to:* 2-log protozoa 2-log bacteria 2-log virus

Problem Solving Exercises

Choose the treatment objective(s) that is achieved with filtration:

Select all that apply:

- A. Total suspended solids reduction
- B. Improves downstream treatment performance
- C. Pathogen reduction
- D. Dissolved constituent reduction
- E. Turbidity reduction

What types of filters are commonly used for ONWS applications?

Select all that apply:

- A. Cartridge filters
- B. Granular media filters
- C. Membrane filters
- D. Cloth filters
- E. None of the above

What is the typical pore size of a microfiltration membrane?

- A. 0.01 µm
- B. 0.1 µm
- C. 1.0 µm
- D. 10.0 µm
- E. None of the above

What filtration technologies receive virus reduction credit?

- A. Microfiltration
- B. Cartridge filtration
- C. Reverse osmosis
- D. Granular media filtration
- E. None of the above

What pathogen reduction credit is given to cartridge filters?

- A. 0-log virus, 2- to 2.5-log protozoa, 0-log bacteria
- B. 0-log virus, 4-log protozoa, 4-log bacteria
- C. 1-log virus, 2- to 2.5-log protozoa, 2-log bacteria
- D. 0-log virus, 2- to 2.5-log protozoa, 2-log bacteria
- E. None of the above

How do you demonstrate pathogen reduction with microfiltration?

Select all that apply:

- A. Membrane integrity testing
- B. Meeting effluent turbidity requirements via online measurement
- C. Electrical conductivity reduction
- D. Total organic carbon reduction
- E. None of the above

What are some of the key design considerations when implementing reverse osmosis?

- A. Energy consumption is highest for reverse osmosis compared to other filtration technologies
- B. Reverse osmosis receives credit for the reduction of all pathogen types
- C. Reverse osmosis creates a waste stream that requires separate disposal
- D. A, B, and C are true
- E. None of the above

Module 6: Treatment Selection and Crediting

DISINFECTION

Training Modules

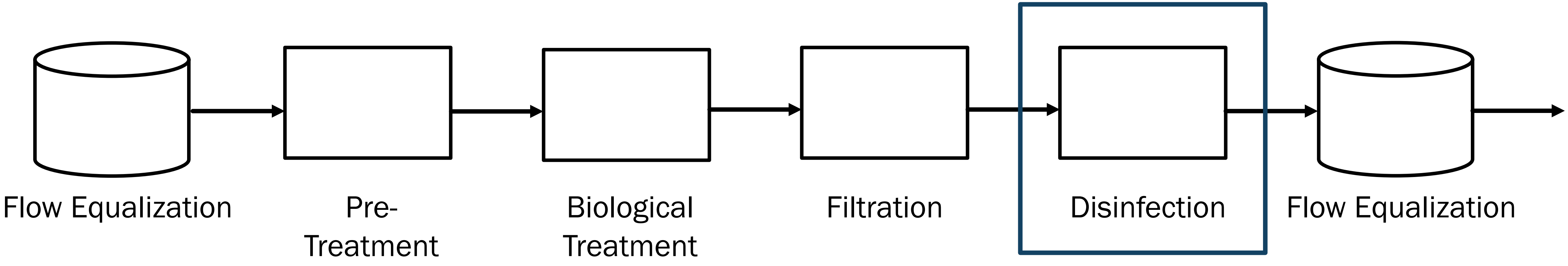
1. Introduction
2. Public Health Goals
3. Treatment Selection and Crediting Overview
4. Treatment Selection and Crediting: Biological Treatment
5. Treatment Selection and Crediting: Filtration
6. **Treatment Selection and Crediting: Disinfection**
7. Treatment Selection and Crediting: Flow Equalization and Distribution
8. Developing Multiple Barrier ONWS Systems
9. Operations Plan
10. Regulatory and Permitting Plan

Framing Questions

- Why is disinfection an important treatment process?
- How do we know the system is performing as designed?
- How do we get credit for the pathogen reduction achieved?

Learning Objectives

- Design goals for disinfection processes
- Key design and monitoring concepts
- Pathogen reduction crediting for disinfection processes



Primary Target Audience

Primary Audience:

DESIGN ENGINEER

REGULATOR

General Awareness:

OPERATOR

PROGRAM ADMINISTRATOR

SYSTEM OWNER

Course Overview

- Disinfection 101
- Chlorine Disinfection
- UV Disinfection
- Ozone Disinfection

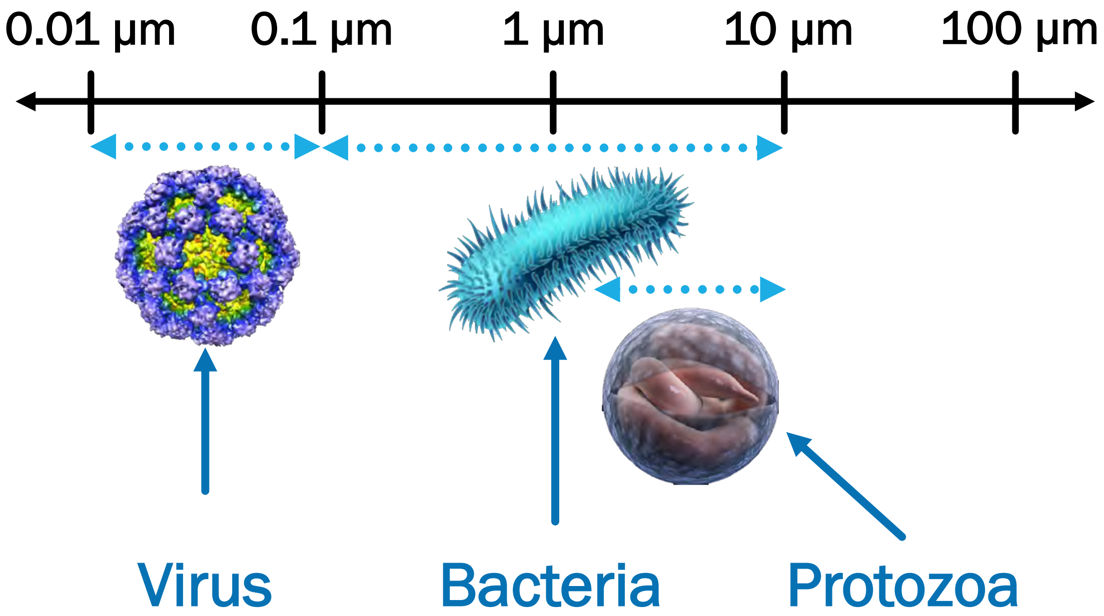
Course Overview

- Disinfection 101
- Chlorine Disinfection
- UV Disinfection
- Ozone Disinfection

Disinfection 101 – Pathogens of Concern

Not all pathogens are:

- Removed/reduced to the same degree by upstream physical treatment processes
- Equally sensitive/resistant to the same disinfectant



Disinfection 101 – Review of LRTs

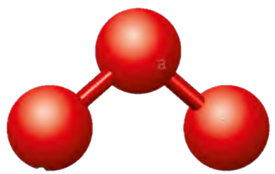
Water Use Scenario	Enteric Viruses	Parasitic Protozoa	Enteric Bacteria
Domestic Wastewater/Blackwater			
Unrestricted irrigation	8.0	7.0	6.0
Indoor use[1]	8.5	7.0	6.0
Graywater			
Unrestricted irrigation	5.5	4.5	3.5
Indoor use	6.0	4.5	3.5
Stormwater (10% wastewater contribution[2])			
Unrestricted irrigation	5.0	4.5	4.0
Indoor use	5.5	5.5	5.0
Stormwater (0.1% wastewater contribution[2])			
Unrestricted irrigation	3.0	2.5	2.0
Indoor use	3.5	3.5	3.0
Roof runoff water			
Unrestricted irrigation	N/A	No data	3.5
Indoor use	N/A	No data	3.5

Disinfection 101 – Types of Disinfectants

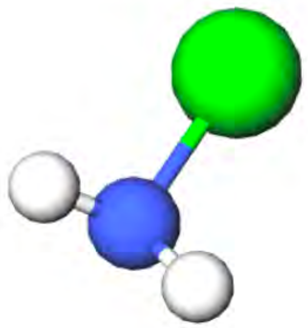
Chemical Disinfection

Free Chlorine

Ozone



Chloramine



UV Disinfection

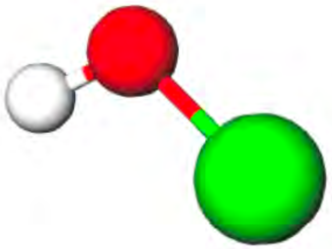
Ultraviolet Light

Additional Technologies: chlorine dioxide, hydrogen peroxide, etc.
but won't be covered in this training module

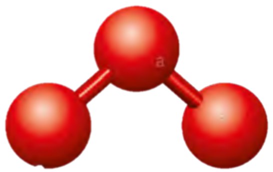
Disinfection 101 – Types of Disinfectants

Chemical Disinfection

Free Chlorine



Ozone



UV Disinfection

Ultraviolet Light

Focus on three most common forms of disinfection: free chlorine, UV, and ozone

Disinfection 101 – UV vs. Chlorine Disinfection

- Chlorine sensitivity
  - Viruses and bacteria sensitive
  - Protozoa highly resistant
- UV sensitivity
  - Protozoa, bacteria, and some viruses highly sensitive
  - Other viruses highly resistant
- Multiple disinfection barriers may be required

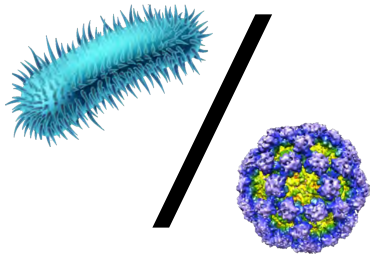
Course Overview

- Disinfection 101
- **Chlorine Disinfection**
- UV Disinfection
- Ozone Disinfection

- **Treatment Objectives**
- Design Considerations

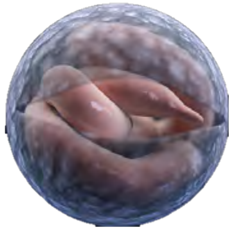
Chlorine Disinfection – Treatment Objectives

- Inactivation of pathogens by free chlorine disinfection
- Focus is on free chlorine disinfection for ONWS systems
- Which pathogens should be targeted?



BACTERIA / VIRUS

GIARDIA
(Protozoa)



CRYPTOSPORIDIUM
(Protozoa)

MOST EFFECTIVE — EFFECTIVENESS OF FREE CHLORINE → LEAST EFFECTIVE

Course Overview

- Disinfection 101
- Chlorine Disinfection
- UV Disinfection
- Ozone Disinfection

- Treatment Objectives
- Design Considerations

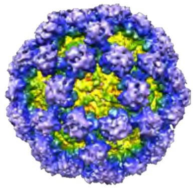
Chlorine Disinfection – Design Considerations

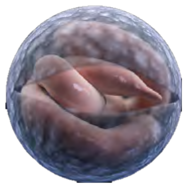
- Select framework based on application

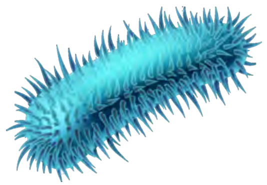
Treatment Category	Application	Unit Process	Applicable Pathogens
EPA Disinfection	Surface Water	Free Chlorine	V / G
		Chloramine	V / G
		Chlorine Dioxide	V / G / C
		Ozone	V / G / C
		UV	V / G / C
EPA Filtration	Surface Water	Membrane Filtration	G / C
		Reverse Osmosis	V / G / C / B
		Bag and Cartridge Filters	G / C
NWRI UV Disinfection	Potable Water & Recycled Water	UV	V / G / C
Australian MBR	Recycled Water	MBR	V / G / C / B
Australia Chlorine	Recycled Water	Free Chlorine	V / B

Chlorine Disinfection – Design Considerations

- Blackwater and graywater crediting framework = Australian WaterVal Validation Protocol for Chlorine Disinfection
- Up to 4-log virus and bacteria credit
  - Dependent on operating conditions and upstream treatment*


4-log virus


0-log protozoa


4-log bacteria*

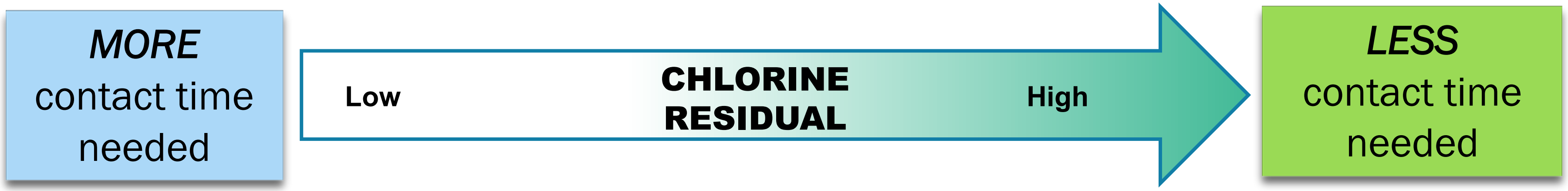
*The CT framework should only be used for bacterial crediting with free chlorine if the disinfection process has been preceded by membrane filtration, MBR, or RO (i.e., filtration processes that produce low-turbidity effluents)

Chlorine Disinfection – Design Considerations

The CT Concept: “C” x “T”

CT (mg-min/L) = Chlorine Residual (mg/L) x Contact Time (min)

- **“Chlorine Residual”** is the concentration of chlorine remaining at the end of the Contact Time
- **“Contact Time”** is the amount of time there is contact between the chlorine and the water



Do Not Confuse ”CT” and “Contact Time”

Chlorine Disinfection – Design Considerations

- WaterVal links pathogen LRV with specific water quality conditions and CT

Australian WaterVal Free Chlorine CT Table

pH	Log_{10} inactivation	≤0.2 NTU					≤2 NTU					≤5 NTU				
		5 °C	10 °C	15 °C	20 °C	25 °C	5 °C	10 °C	15 °C	20 °C	25 °C	5 °C	10 °C	15 °C	20 °C	25 °C
≤7	1	4	3	2	2	1	4	3	2	2	1	4	3	2	2	1
	2	5	4	3	2	2	5	4	3	2	2	6	4	3	2	2
	3	7	5	4	3	2	7	5	4	3	2	7	5	4	3	2
	4	8	6	4	3	2	9	6	4	3	2	9	7	5	3	3
≤7.5	1	7	5	4	3	2	7	5	4	3	2	8	6	4	3	2
	2	10	7	5	4	3	10	7	5	4	3	13	9	6	5	4
	3	13	9	7	5	4	13	9	7	5	4	16	12	9	6	5
	4	16	11	8	6	4	16	11	8	6	4	21	15	11	7	6
≤8	1	9	7	5	3	3	10	7	5	4	3	12	9	6	4	3
	2	14	10	7	5	4	15	10	7	5	4	19	13	9	7	5
	3	18	13	9	7	5	19	13	10	7	5	25	18	13	9	7
	4	23	16	12	8	6	23	16	12	8	6	32	23	16	11	8
≤8.5	1	11	8	6	4	3	12	9	6	5	4	14	10	7	5	4
	2	17	12	9	6	5	19	13	9	7	5	21	15	11	8	6
	3	23	16	12	9	6	25	17	13	9	7	29	21	15	10	8
	4	29	21	15	10	8	31	22	16	11	8	37	26	18	13	9
≤9	1	13	9	6	5	3	14	10	7	5	4	15	10	7	5	4
	2	20	14	10	7	5	22	16	11	8	6	23	16	12	8	6
	3	28	19	14	10	7	30	21	15	11	8	32	23	16	11	8
	4	35	25	17	12	9	38	27	19	13	10	41	29	20	14	10

Chlorine Disinfection – Design Considerations

- WaterVal links pathogen LRV with specific water quality conditions and CT

LRV range from
1 – 4 logs depending on:

- CT
- Turbidity
- pH
- Temperature

Australian WaterVal Free Chlorine CT Table

pH	Log_{10} inactivation	≤0.2 NTU					≤2 NTU					≤5 NTU				
		5 °C	10 °C	15 °C	20 °C	25 °C	5 °C	10 °C	15 °C	20 °C	25 °C	5 °C	10 °C	15 °C	20 °C	25 °C
≤7	1	4	3	2	2	1	4	3	2	2	1	4	3	2	2	1
	2	5	4	3	2	2	5	4	3	2	2	6	4	3	2	2
	3	7	5	4	3	2	7	5	4	3	2	7	5	4	3	2
	4	8	6	4	3	2	9	6	4	3	2	9	7	5	3	3
≤7.5	1	7	5	4	3	2	7	5	4	3	2	8	6	4	3	2
	2	10	7	5	4	3	10	7	5	4	3	13	9	6	5	4
	3	13	9	7	5	4	13	9	7	5	4	16	12	9	6	5
	4	16	11	8	6	4	16	11	8	6	4	21	15	11	7	6
≤8	1	9	7	5	3	3	10	7	5	4	3	12	9	6	4	3
	2	14	10	7	5	4	15	10	7	5	4	19	13	9	7	5
	3	18	13	9	7	5	19	13	10	7	5	25	18	13	9	7
	4	23	16	12	8	6	23	16	12	8	6	32	23	16	11	8
≤8.5	1	11	8	6	4	3	12	9	6	5	4	14	10	7	5	4
	2	17	12	9	6	5	19	13	9	7	5	21	15	11	8	6
	3	23	16	12	9	6	25	17	13	9	7	29	21	15	10	8
	4	29	21	15	10	8	31	22	16	11	8	37	26	18	13	9
≤9	1	13	9	6	5	3	14	10	7	5	4	15	10	7	5	4
	2	20	14	10	7	5	22	16	11	8	6	23	16	12	8	6
	3	28	19	14	10	7	30	21	15	11	8	32	23	16	11	8
	4	35	25	17	12	9	38	27	19	13	10	41	29	20	14	10

Chlorine Disinfection – Design Considerations

Chlorine Residual versus Dose:

Chlorine Dose

Amount of chlorine added to the water

⇩

Chlorine Demand

Chlorine consumed during reaction with organic and inorganic material present

⇩

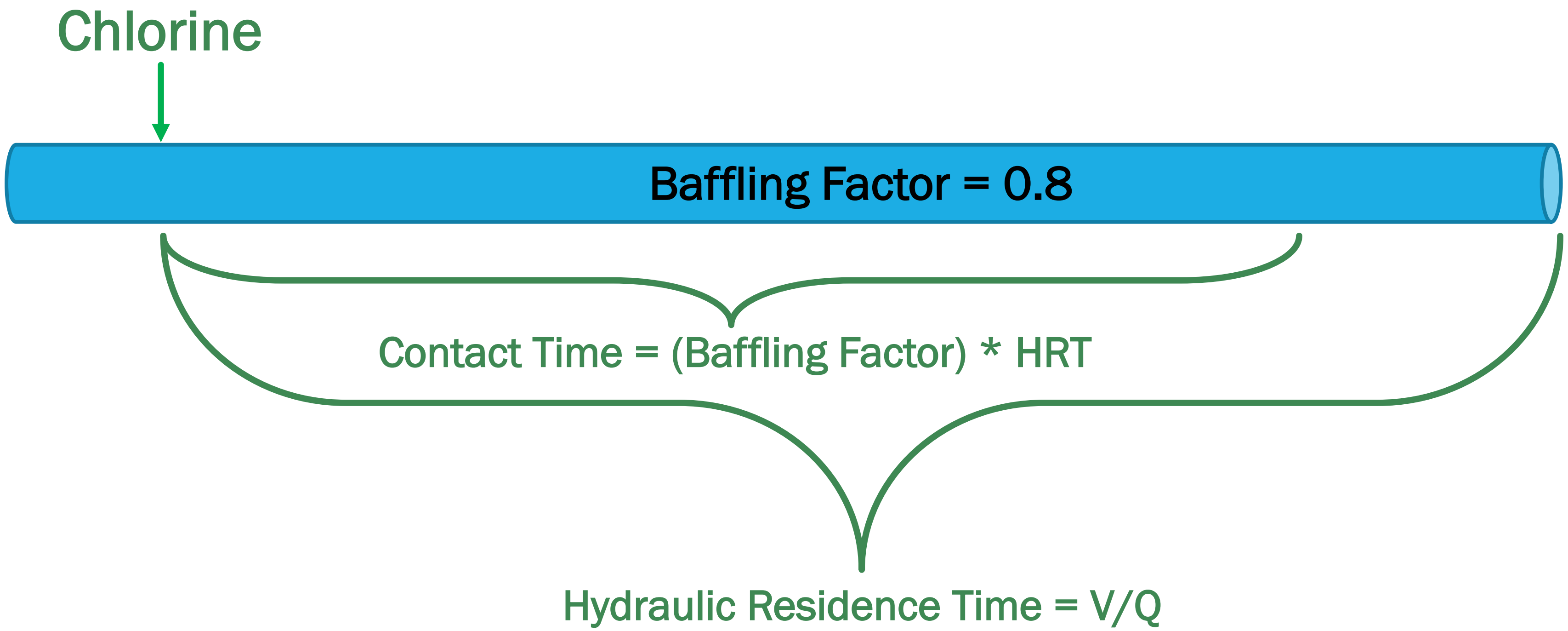
Chlorine Residual

Chlorine remaining after chlorine demand has been satisfied and disinfection has occurred. Chlorine residual is monitored with online meters

Chlorine Disinfection – Design Considerations

Contact Time = Baffling Factor x Average Hydraulic Residence Time (min)

- **“Baffling Factor”** accounts for the hydraulic efficiency of the flow through a system
- **“Average Hydraulic Residence Time”** is flow divided by the volume of the pipeline, contact basin, etc.



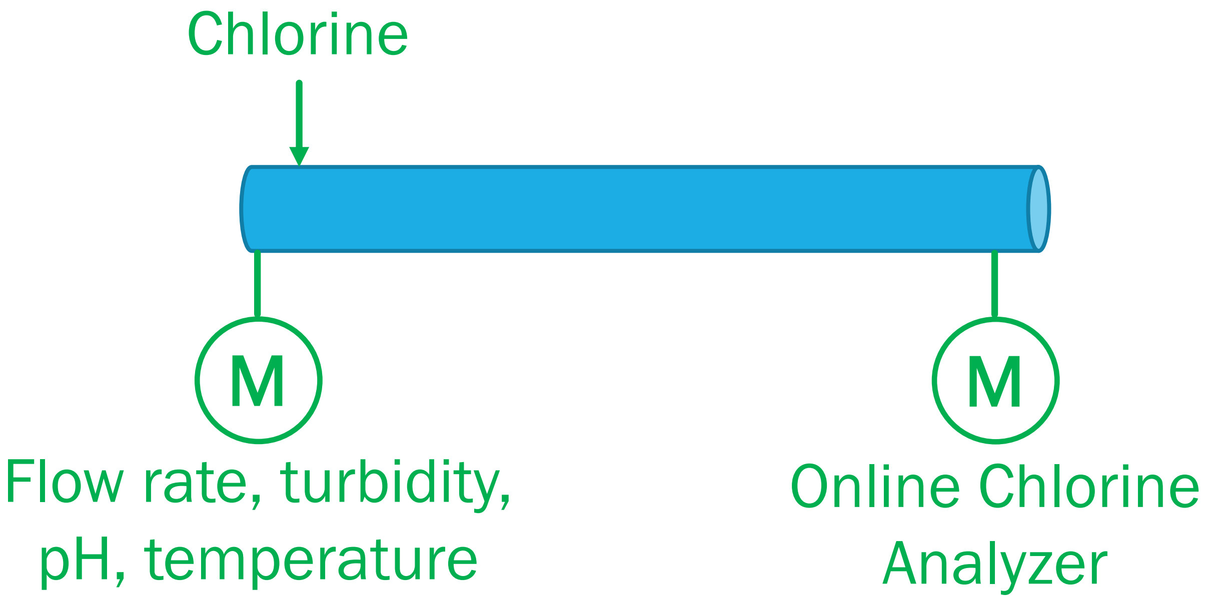
Chlorine Disinfection – Design Considerations

- How can you prove that inactivation is occurring at all times?

Monitoring Performance

LRV range from
1 – 4 logs depending on:

- CT
- Turbidity
- pH
- Temperature

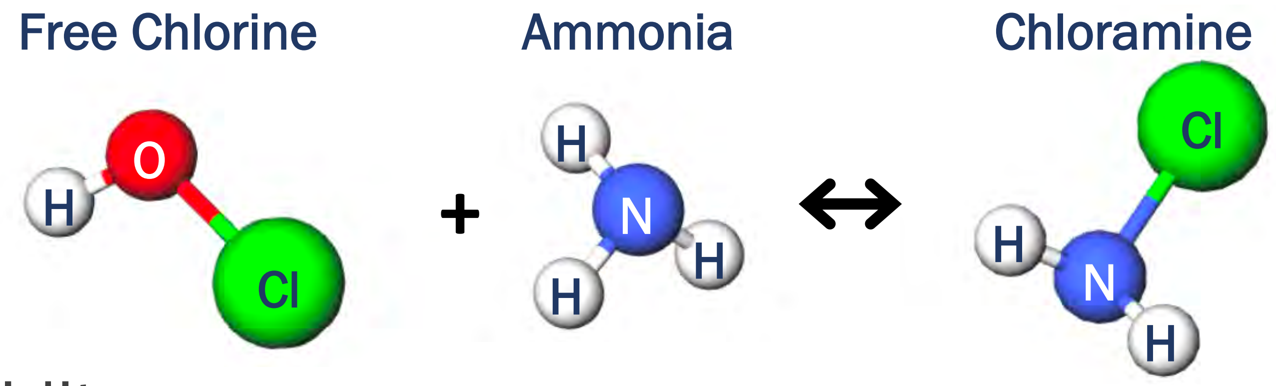


Continuous verification of chlorine residual and flow rate confirms LRV continuously

Chlorine Disinfection – Design Considerations

Importance of Pre-Treatment and Water Quality:

- Impact of ammonia
  - Ammonia impacts ability to do free chlorine disinfection
  - Ammonia < 1 mg/L required for free chlorine disinfection



- Impact of turbidity
  - May ‘shield’ microorganisms from the inactivating effects of chlorine
  - WaterVal crediting framework requires higher CT with higher turbidity

Chlorine Disinfection – Design Considerations

Additional free chlorine design considerations…

- Pros:
  - Effective virus control
  - Common disinfectant
  - Serves as disinfectant for both LRT compliance and distribution system control
  - May improve aesthetics through the reduction of color
- Cons:
  - Limited control of protozoa
  - Requires footprint for infrastructure providing contact time
  - Safety considerations:
    - Requires considerations for ventilation and exhaust systems
    - Further guidance should be sought in local building and fire codes

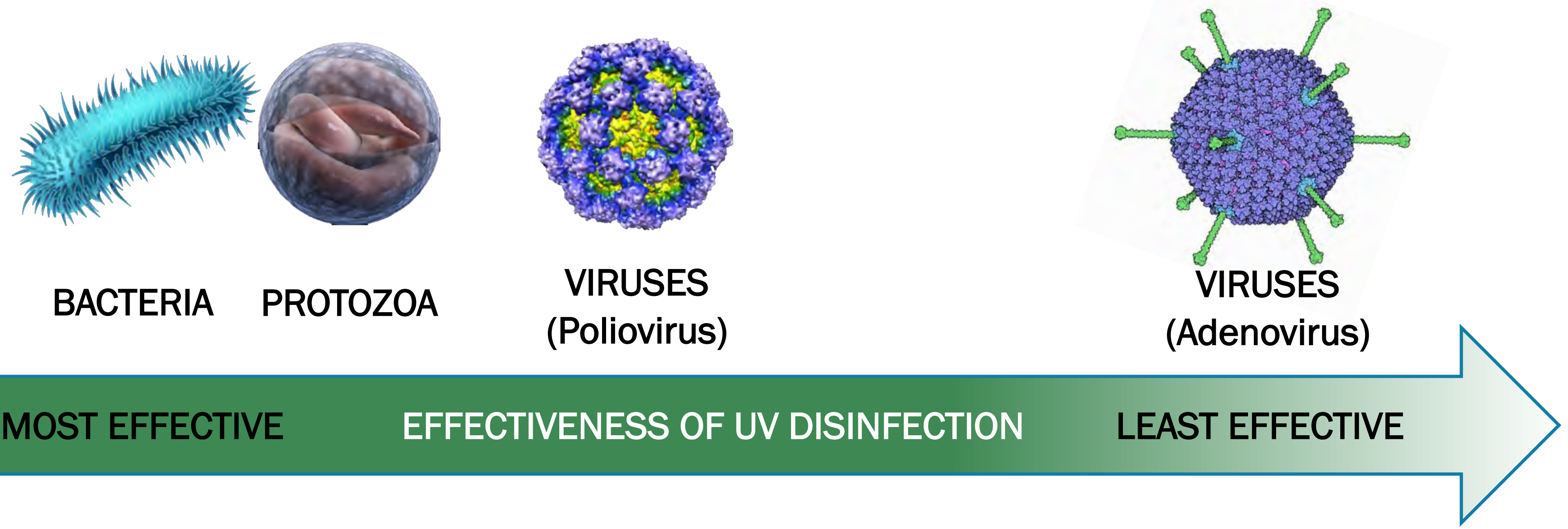
Course Overview

- Disinfection 101
- Chlorine Disinfection
- **UV Disinfection**
- Ozone Disinfection

- **Treatment Objectives**
- Design Considerations

UV Disinfection – Treatment Objectives

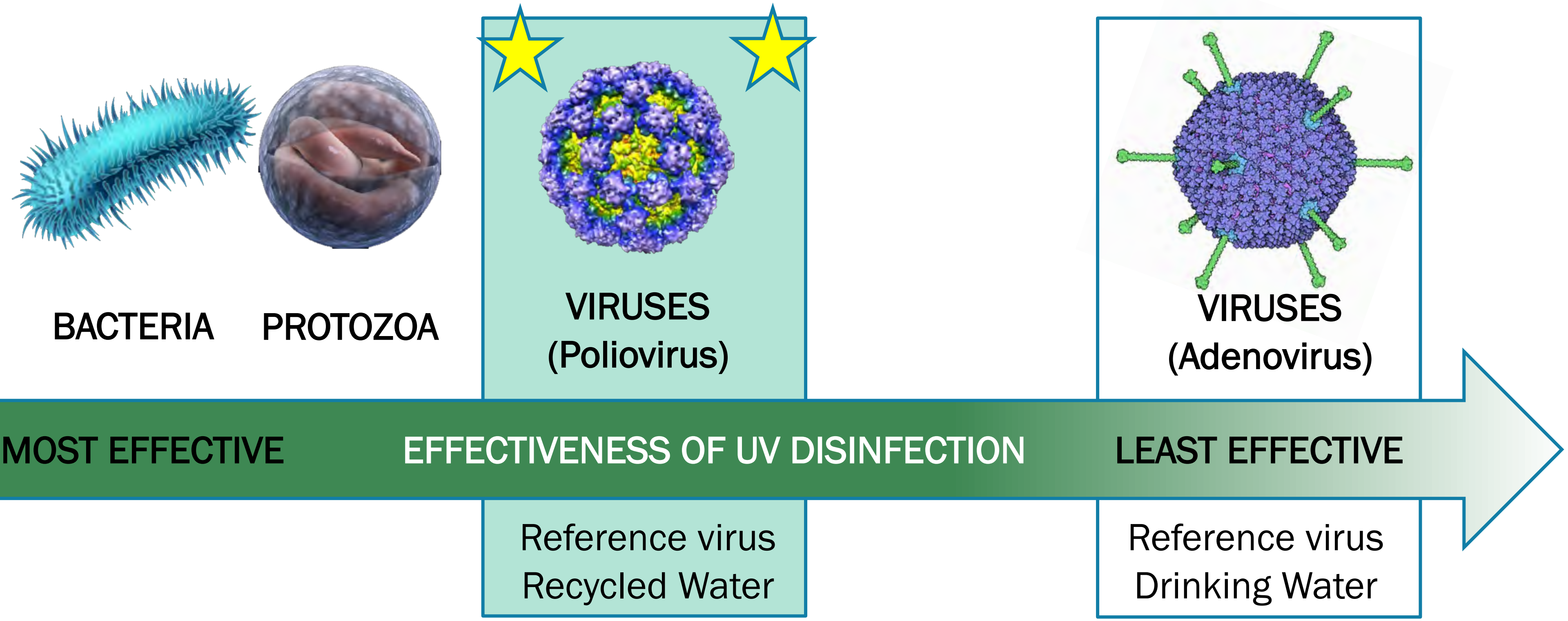
- Inactivation of pathogens by UV disinfection
- Which pathogens should be targeted?



UV effective against all pathogen types – though some viruses show high resistance

UV Disinfection – Treatment Objectives

- Inactivation of pathogens by UV disinfection
- Which pathogens should be targeted?



Guidance Manual assumes LRT compliance with recycled water viruses

Course Overview

- Disinfection 101
- Chlorine Disinfection
- **UV Disinfection**
- Ozone Disinfection

- Treatment Objectives
- **Design Considerations**

UV Disinfection – Design Considerations

The UV Dose Concept: similar to chlorine CT framework

CT (mg-min/L) = Chlorine Residual (mg/L) x Contact Time (min)

UV dose (mJ/cm^2) = UV intensity (mW/cm^2) x Residence Time (s)

- **"UV intensity" (UVI)** measurement of the UV output of a lamp or set of lamps in a reactor
- **"Residence Time"** is the amount of time water passes through UV reactor

UV Disinfection – Design Considerations

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- **"UV intensity"** measurement of the UV output of a lamp or set of lamps in a reactor
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Target Pathogens	Log Inactivation							
	0.5	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

[1] 40 CFR 141.720(d)(1)

UV LRVs

UV dose requirements

UV Disinfection – Design Considerations

The UV Dose Concept: similar to chlorine CT framework

CT (mg-min/L) = Chlorine Residual (mg/L) x Contact Time (min)

UV dose (mJ/cm^2) = UV intensity (mW/cm^2) x Residence Time (s)

- Unlike chemical disinfectants, UV does not produce a residual that can be used to calculate CT
- Water is not uniformly exposed to the UV light, and so a distribution of doses may occur
- How do we know how much pathogen inactivation we're getting?

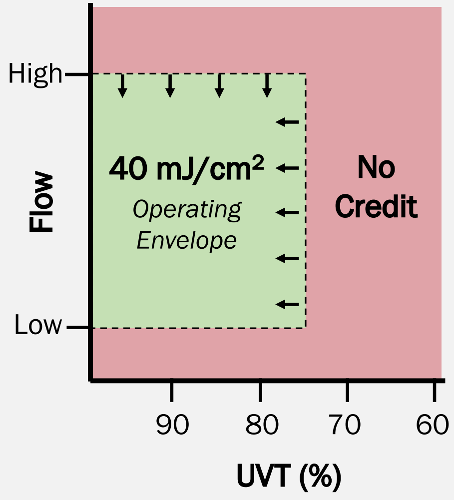
UV Disinfection – Determining UV Dose

- How you monitor dose impacts:
  - How the reactor is validated
  - What parameters are used to confirm dose
  - How reactor is operated
- Two principal approaches
  - UV Intensity Setpoint
  - Calculated Dose
- Guidance Manual recommends UV Intensity Setpoint approach
  - Greater simplicity
  - More conservative

UV Disinfection – UV Intensity Setpoint Approach

- Validating with UV Intensity Setpoint Approach
  - Test range of flow, UVI, UVT
  - Identify conditions that achieve minimum UV dose (e.g., 40 mJ/cm^2)
  - Define operating envelope

Validation Testing Conditions	UV Intensity (mW/cm^2)	UV Dose (mJ/cm^2)
Low flow, high UVT	15	80
High flow, high UVT	12	60
Low flow, low UVT (75%)	12	60
High flow, low UVT (75%)	10	40
High flow, lowest UVT (65%)	8	35



UV Disinfection – UV Intensity Setpoint Approach

Validating with UV Intensity Setpoint Approach

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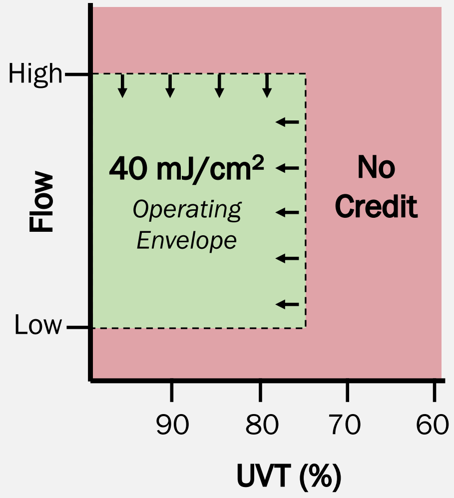

Benefits

- Conservative: credits a single UV dose in entire operating envelope
- Simple: only requires UVI and flow rate measurement (not UVT)
- Recommended by US EPA for small water systems

Potential Pitfall

- Many reactors validated for use in potable applications (high UVTs)
- Ensure UVT range suitable for ONWS applications

UV Disinfection – UV Intensity Setpoint Approach

Validating with UV Intensity Setpoint Approach

- Test range of flow, UVI, UVT
- Identify conditions that achieve minimum UV dose (e.g., 40 mJ/cm^2)
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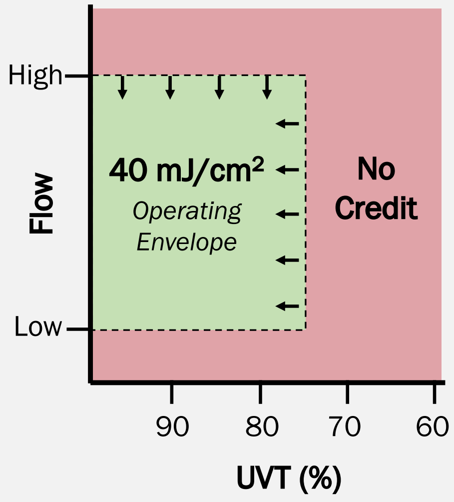
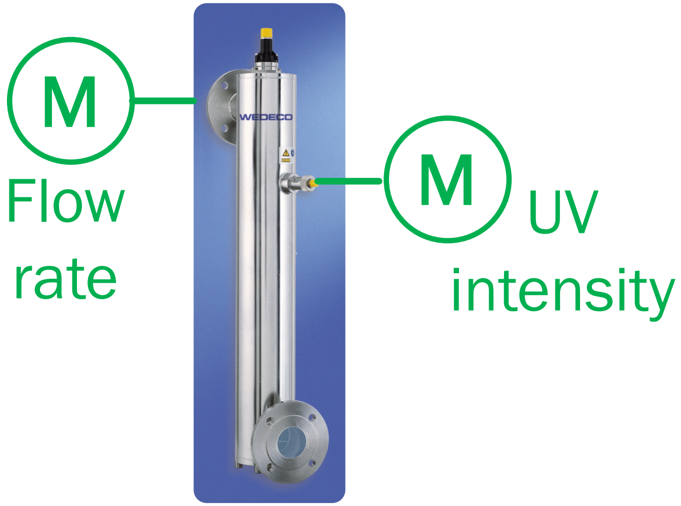


Verifying UV Dose

- Measure flow rate and UV intensity
- Confirm reactor meets minimum UVI for given flow rate



UV Disinfection – UV Intensity Setpoint Approach

- Validating with UV Intensity Setpoint Approach
  - Test range of flow, UVI, UVT
  - Identify conditions that achieve minimum UV dose (e.g., 40 mJ/cm^2)
  - Define operating envelope

Validation Testing Conditions	UV Intensity (mW/cm^2)	UV Dose (mJ/cm^2)
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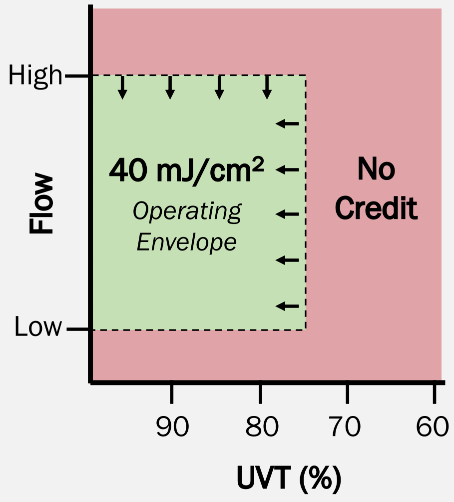
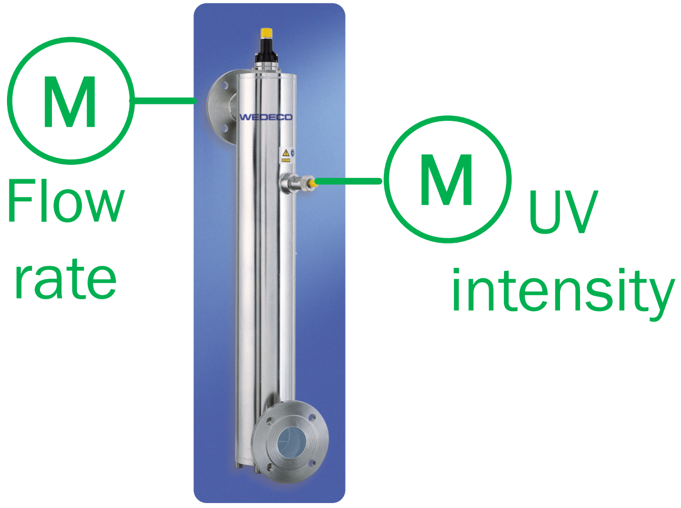


- Verifying UV Dose
  - Measure flow rate and UV intensity
  - Confirm reactor meets minimum UVI for given flow rate



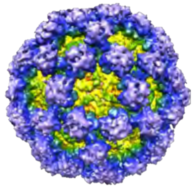
Both UVDGM and NSF 55A validate reactors using the UV Intensity Setpoint Approach

UV Disinfection – Assigning Pathogen Credit

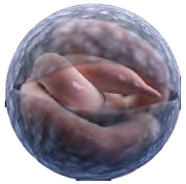
- Validation does not require testing with every pathogen of interest
  - Typically conducted with a “challenge organism” like bacteriophage MS2
- Credit assigned for different pathogen groups based on results of validation testing, consistent with EPA UVDGM methods

Validated Dose[1]	Virus Credit	Protozoa Credit	Bacteria Credit
40	2	3	2
80	3.5	6	3.5
100	4.25	6	4.25
150	6	6	6

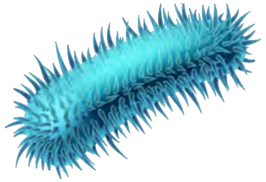
1. This dose table is intended to apply for validation protocols using MS2.



Up to 6-log
virus



Up to 6-log
protozoa



Up to 6-log
bacteria

UV Disinfection – Design Considerations

Additional UV disinfection design considerations…

- Pros:
  - Robust protection against all pathogen types
  - Highly effective against protozoa
  - Small footprint
  - Lower chemical costs
  - Not impacted by ammonia in feed water
- Cons:
  - Requires additional chlorine for distribution system control
  - Higher energy costs

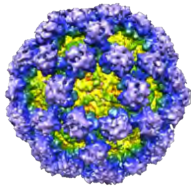
Course Overview

- Disinfection 101
- Chlorine Disinfection
- UV Disinfection
- **Ozone Disinfection**

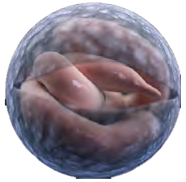
- Treatment Objectives and Design Considerations

Ozone Disinfection

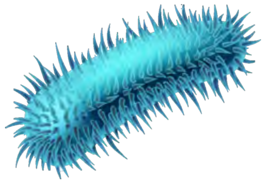
- Ozone disinfection credit based on CT framework
  - Highly effective against virus and *Giardia; Cryptosporidium* is more resistant
  - EPA CT tables provide credit for all pathogens but bacteria



Up to 4-log
virus



Up to 3-log
protozoa



0-log bacteria

- Safety considerations
  - Ozone processes generate heat and potential ozone gas leaks
  - Requires stringent considerations for ventilation and exhaust systems
  - Further guidance should be sought in local building and fire codes

Ozone Disinfection – Design Considerations

Additional ozone design considerations…

- Pros:
  - Effective for disinfection of viruses and protozoa
  - Effective control of odor and color
- Cons:
  - High capital and energy cost
  - Requires additional safety measures
  - Requires additional chlorine for distribution system control
  - No existing crediting framework for bacteria

Disinfection– Summary

	Free Chlorine	UV	Ozone
Pathogen Reduction	✓✓	✓✓✓	✓✓
Footprint	✓	✓✓✓	✓
Energy Use	✓✓✓	✓	✓
Chemical Handling	✓	✓✓✓	✓

Problem Solving Exercises

Choose the treatment objective(s) that is achieved with disinfection:

- A. Reduce dissolved inorganic constituents
- B. Reduce pathogens
- C. Minimize the risk of *Legionella*
- D. Reduce biodegradable organics
- E. Both (B) and (C)

What constituent reacts with chlorine to make a weaker disinfectant?

- A. Nitrogen
- B. Phosphorous
- C. BOD
- D. Ammonia
- E. None of the above

What pathogen type is more resistant to free chlorine disinfection?

- A. Virus
- B. Protozoa
- C. Bacteria
- D. *Legionella*
- E. None of the above

What pathogen type is more resistant to UV disinfection?

- A. Virus
- B. Protozoa
- C. Bacteria
- D. *Legionella*
- E. None of the above

How much pathogen reduction credit does the WaterVal framework offer for free chlorine?

- A. Up to: 0-log virus, 2-log protozoa, 0-log bacteria
- B. Up to: 4-log virus, 0-log protozoa, 4-log bacteria
- C. Up to: 1-log virus, 2-log protozoa, 2-log bacteria
- D. Up to: 0-log virus, 0-log protozoa, 2-log bacteria
- E. None of the above

What pathogens receive reduction credit when using UV?

- A. Virus
- B. Protozoa
- C. Bacteria
- D. All the above
- E. None of the above

How is system performance verified for UV disinfection via the UV intensity setpoint method?

- A. Measuring flow rate
- B. Measuring UV intensity
- C. Measuring both flow rate and UV intensity
- D. Measuring UV transmittance and UV intensity
- E. None of the above

What are key design considerations when implementing ozone disinfection?

Select all that apply:

- A. Ozone is an effective barrier for virus and protozoa
- B. Ozone can reduce color and odor
- C. Ozone requires additional safety measures
- D. A secondary disinfectant (*e.g.* chlorine) should be used to maintain a disinfectant residual in the distribution system
- E. Relatively high capital and energy costs

Module 7: Treatment Selection and Crediting

FLOW EQUALIZATION, PRETREATMENT, AND DISTRIBUTION

Training Modules

1. Introduction
2. Public Health Goals
3. Treatment Selection and Crediting Overview
4. Treatment Selection and Crediting: Biological Treatment
5. Treatment Selection and Crediting: Filtration
6. Treatment Selection and Crediting: Disinfection
7. **Treatment Selection and Crediting: Flow Equalization and Distribution**
8. Developing Multiple Barrier ONWS Systems
9. Operations Plan
10. Regulatory and Permitting Plan

Framing Questions

- Why are flow EQ and distribution system management important?
- Why is pretreatment important?
- How are these concepts implemented?

Learning Objectives

- Design goals for flow equalization and distribution system management
- Design goals for pretreatment
- Key design concepts

Primary Target Audience

Primary Audience:

DESIGN ENGINEER

REGULATOR

General Awareness:

OPERATOR

PROGRAM ADMINISTRATOR

SYSTEM OWNER

Course Overview

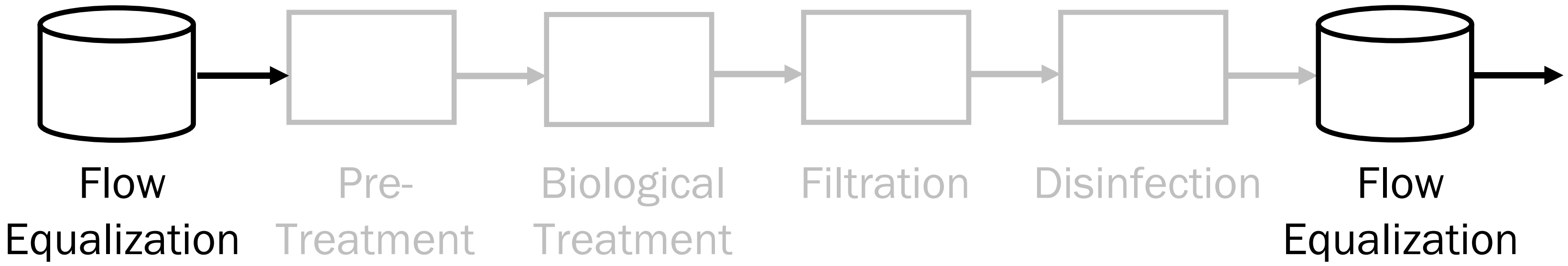
- Flow Equalization
- Pretreatment
- Distribution System Management

Course Overview

- Flow Equalization
- Pretreatment
- Distribution System Management

Flow Equalization – Overview

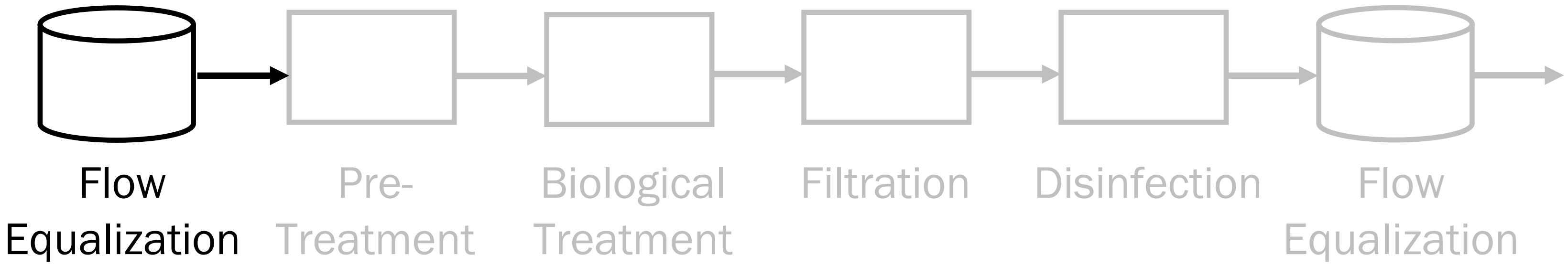
Important treatment step for all ONWS systems and is beneficial at the beginning, end, or both



Flow Equalization – Overview

Key Considerations:

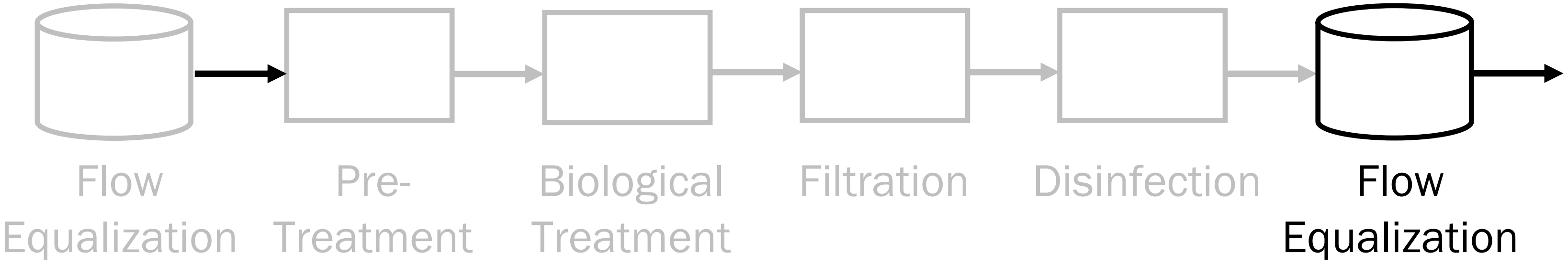
- Source water variability – quality and quantity



Flow Equalization – Overview

Key Considerations:

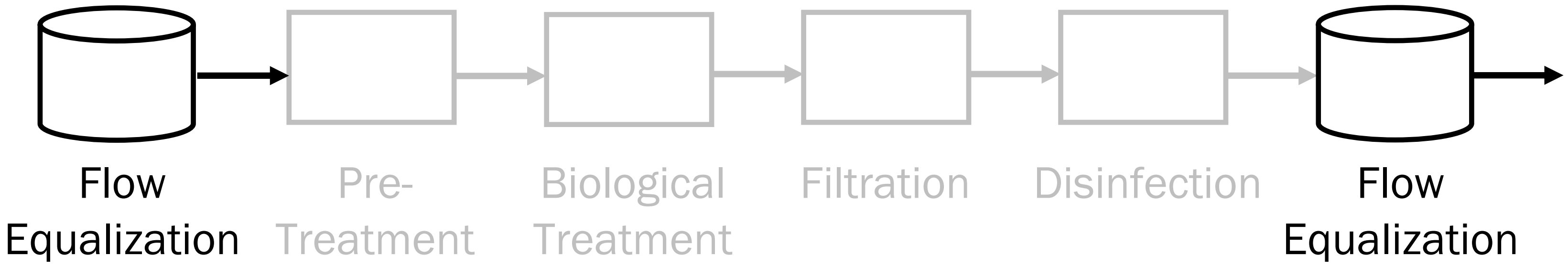
- Source water variability – quality and quantity
- End-use demand variations



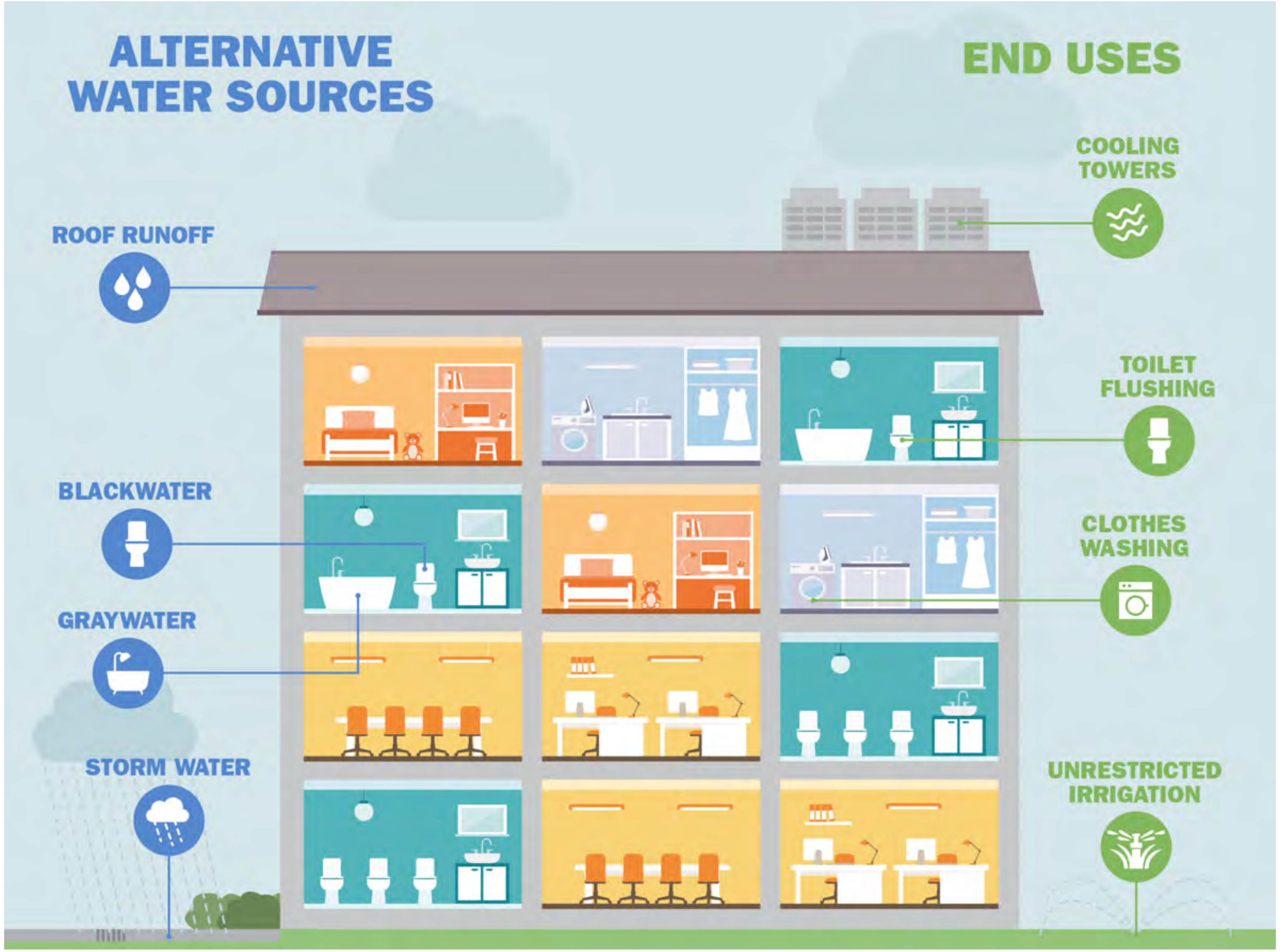
Flow Equalization – Overview

Key Considerations:

- Source water variability – quality and quantity
- End-use demand variations
- How to design sufficient equalization capacity



Source Water Variability



Flow Equalization – Source Water Variability

Building type and source water type

impact

Quality, quantity, and timing

- Quality
  - BOD, TSS, turbidity, ammonia, and pathogens differ **between** sources and **within** a source
- Quantity
  - Volume of treatable water is higher for blackwater than graywater
  - Volume of rain water available depends on many factors (precipitation, storage, etc.)
- Timing
  - Black- and graywater have more uniform production than rainwater or stormwater
  - Commercial buildings may have fluctuations over days, weeks, and longer periods

Flow Equalization – Source Water Variability

Typical Ranges of Water Quality

Type of Source Water	Total Coliform (CFU/100ml) [1]	BOD (mg/l)	TSS (mg/l)	Turbidity (NTU)	pH	Ammonia (mg/l as N)
Rainwater	10^2 - 10^3	<15	20 - 50	10 - 30	No Data	N/A
Stormwater	10^2 - 10^5	<40	100 - 500	No Data	No Data	No Data
Graywater	10^4 – 10^7	100 – 300	100 – 300	20 - 200	6 – 9	3 – 10
Blackwater	10^8 – 10^{10}	700 – 1,000	300 – 600	No Data	6 – 9	50 – 150

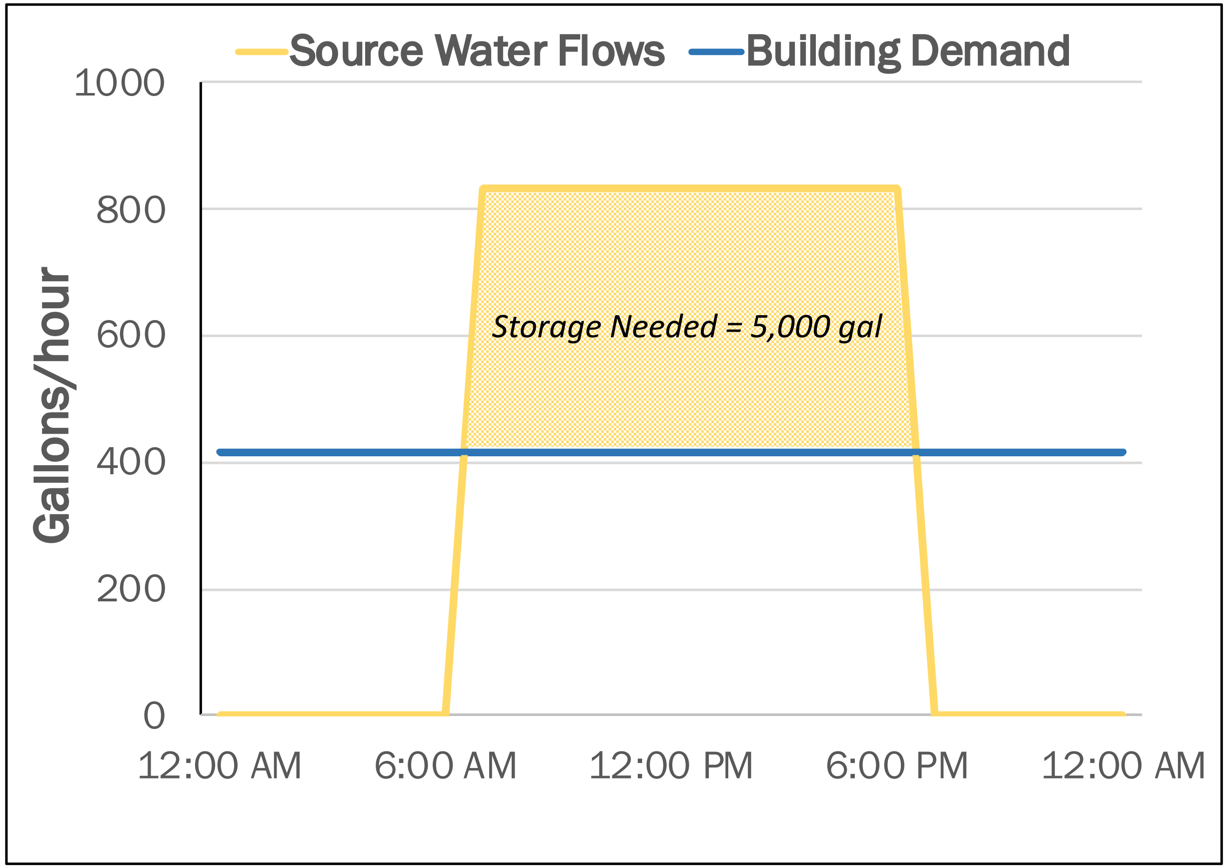
- Water quality data are often not available

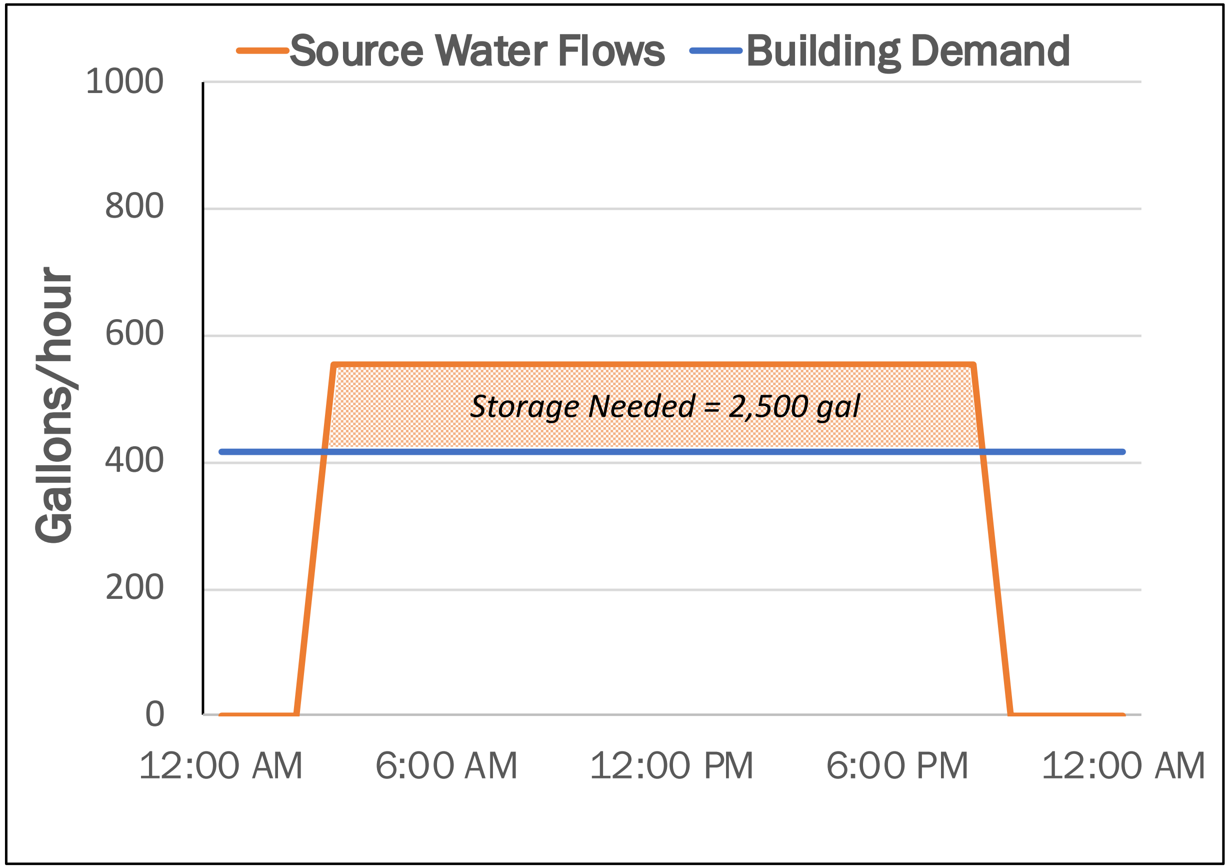
Flow Equalization – Design Considerations

- Beneficial at beginning and end of treatment train

Flow EQ at Start of Train	Flow EQ at End of Train
Buffers out variability in influent flows to provide more consistent flow rate to downstream processes	Provides greater flexibility to meet variations in water demand
Allows for more optimized sizing of downstream processes	Can be designed to hold process water and potable make-up water
Improves operation of downstream processes by providing more consistent quality	Provides treated water supply during short-term system shutdowns

Flow Equalization – Design Considerations





Source water generation over a shorter time period = larger storage volume required

Flow Equalization – Design Considerations

Without flow equalization:

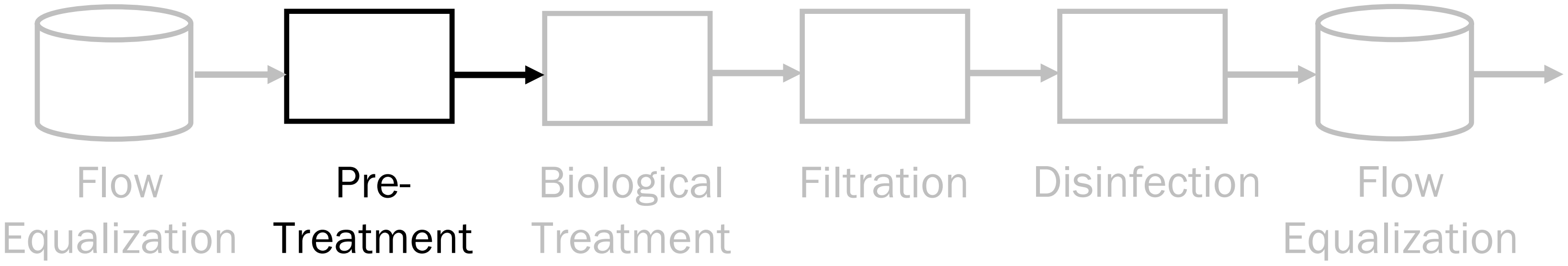
- Unit processes designed to handle peak source water flow
  - Increases cost of treatment
- Unit processes must treat extremes – minimum and peak flows
  - Performance may be negatively impacted at extremes
- ONWS system production may not handle peak demands
  - Potable makeup water may be required to meet demands

Course Overview

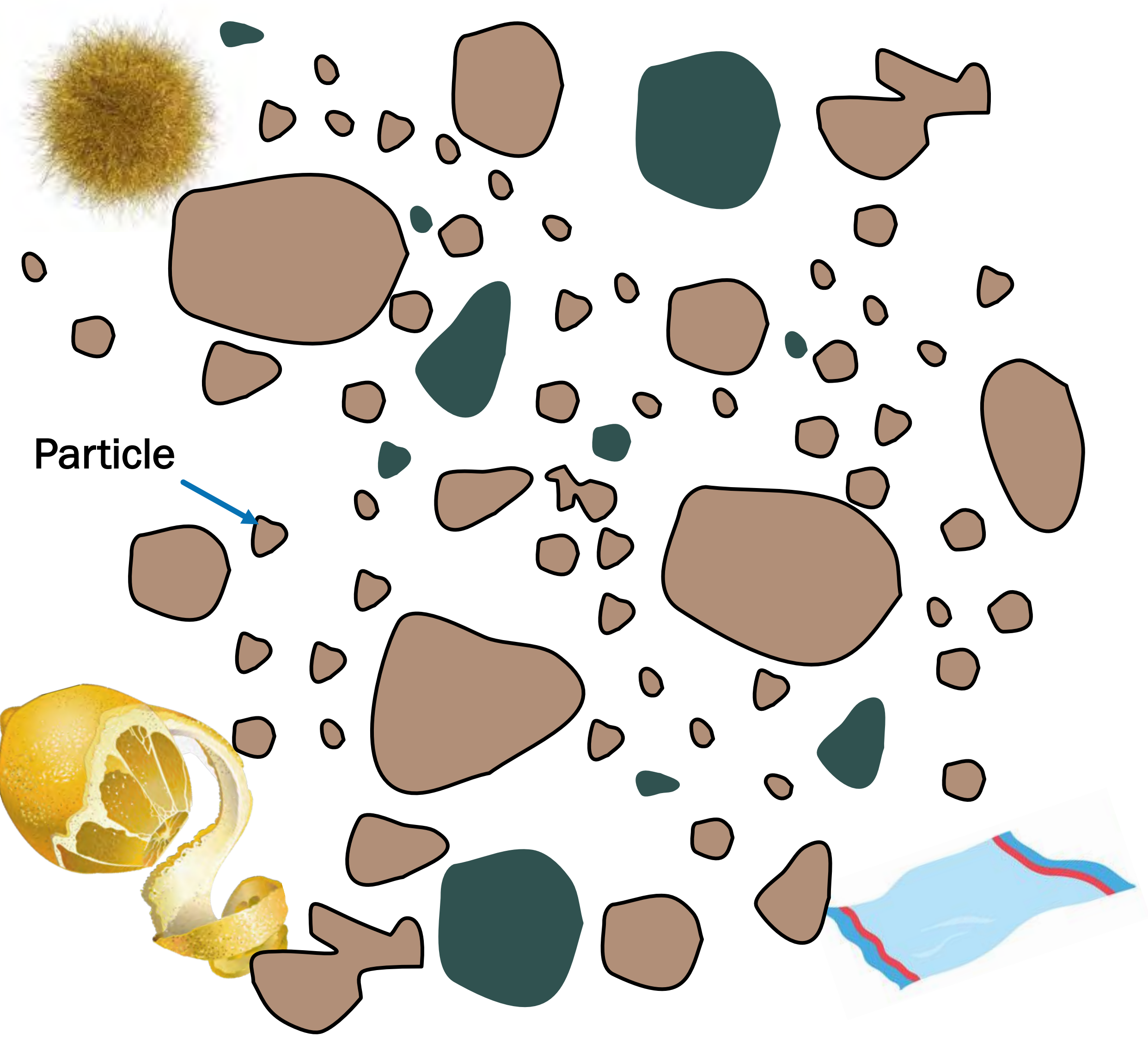
- Flow Equalization
- **Pretreatment**
- Distribution System Management

Pretreatment – Overview

Important treatment step for all ONWS systems



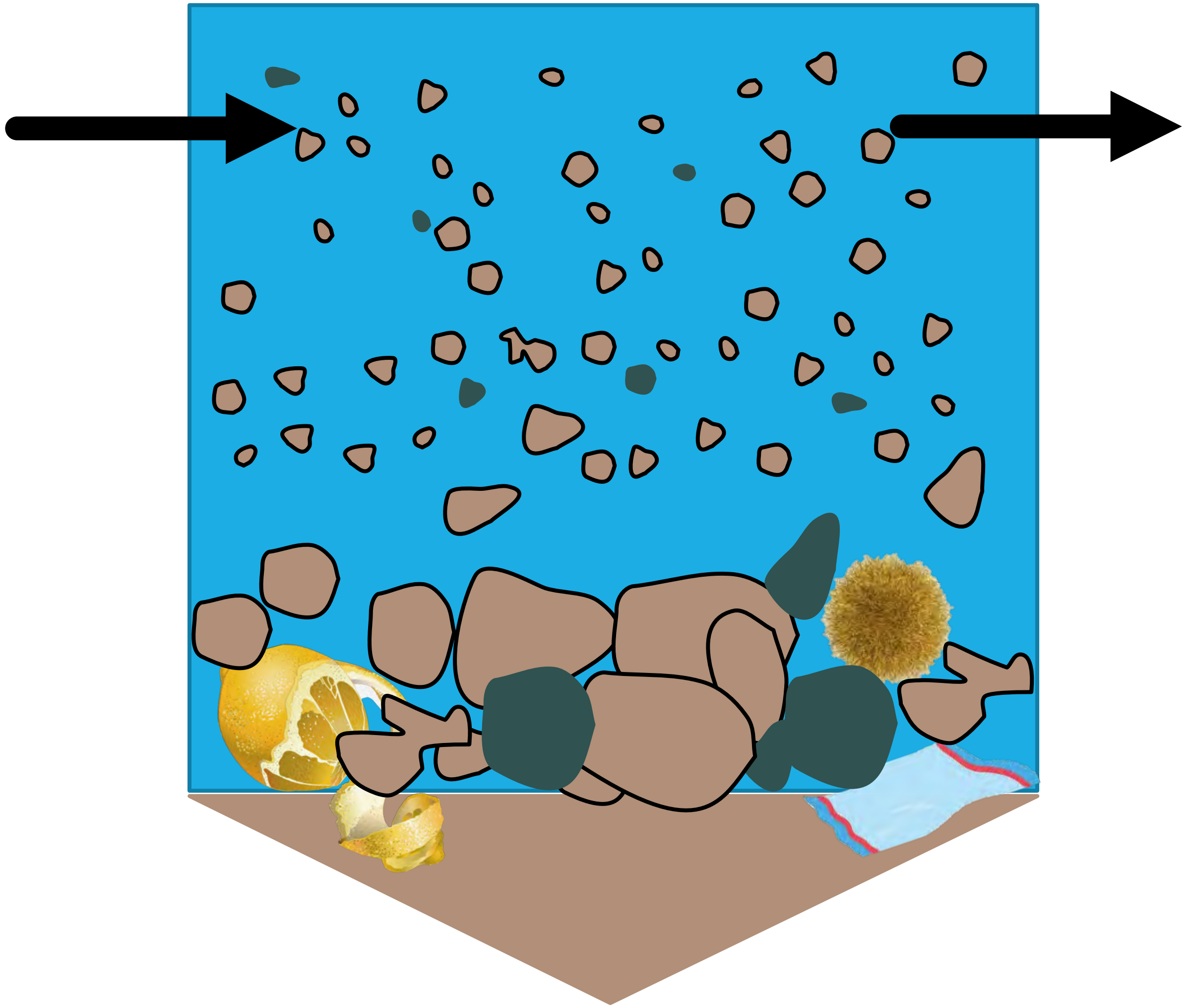
Pretreatment – Treatment Objectives



Unwanted Constituents in ONWS Source Water:

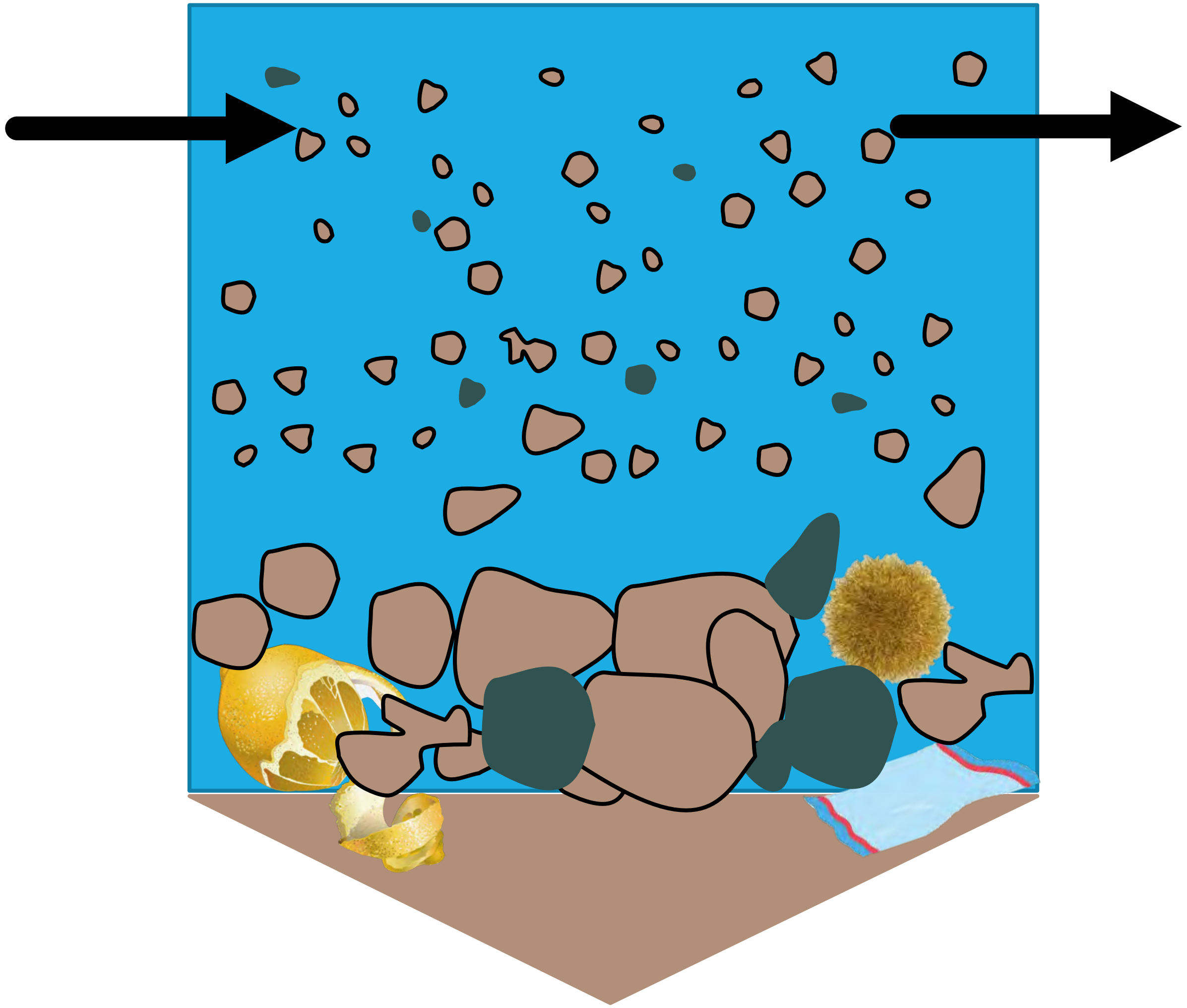
- Course materials
  - Large solids
- Debris
  - Rags
  - Hair
  - Food scraps
  - Etc.

Pretreatment – Treatment Objectives



- **Primary Goal:**
  - Remove coarse materials prior to downstream treatment
  - Avoids excessive solids loading on downstream treatment

Pretreatment – Design Considerations



- **Design Options:**
  - Coarse Screens
  - Fine Screens
  - Vortex Filters

Pretreatment – Design Considerations

Coarse Screens

- Remove larger solids and debris
- Finer solids will remain in water

Fine Screens

- Remove smaller solids and debris
- Could clog if larger solids remain in water

Both types can self-clean and discharge to sewer

Pretreatment – Design Considerations

Vortex Filters

- Common for treatment of stormwater and rainwater
- Separates solids via hydraulics
- Collected solids are removed manually
  - Requires regular (but minimal) maintenance

Course Overview

- Flow Equalization
- Pretreatment
- Distribution System Management

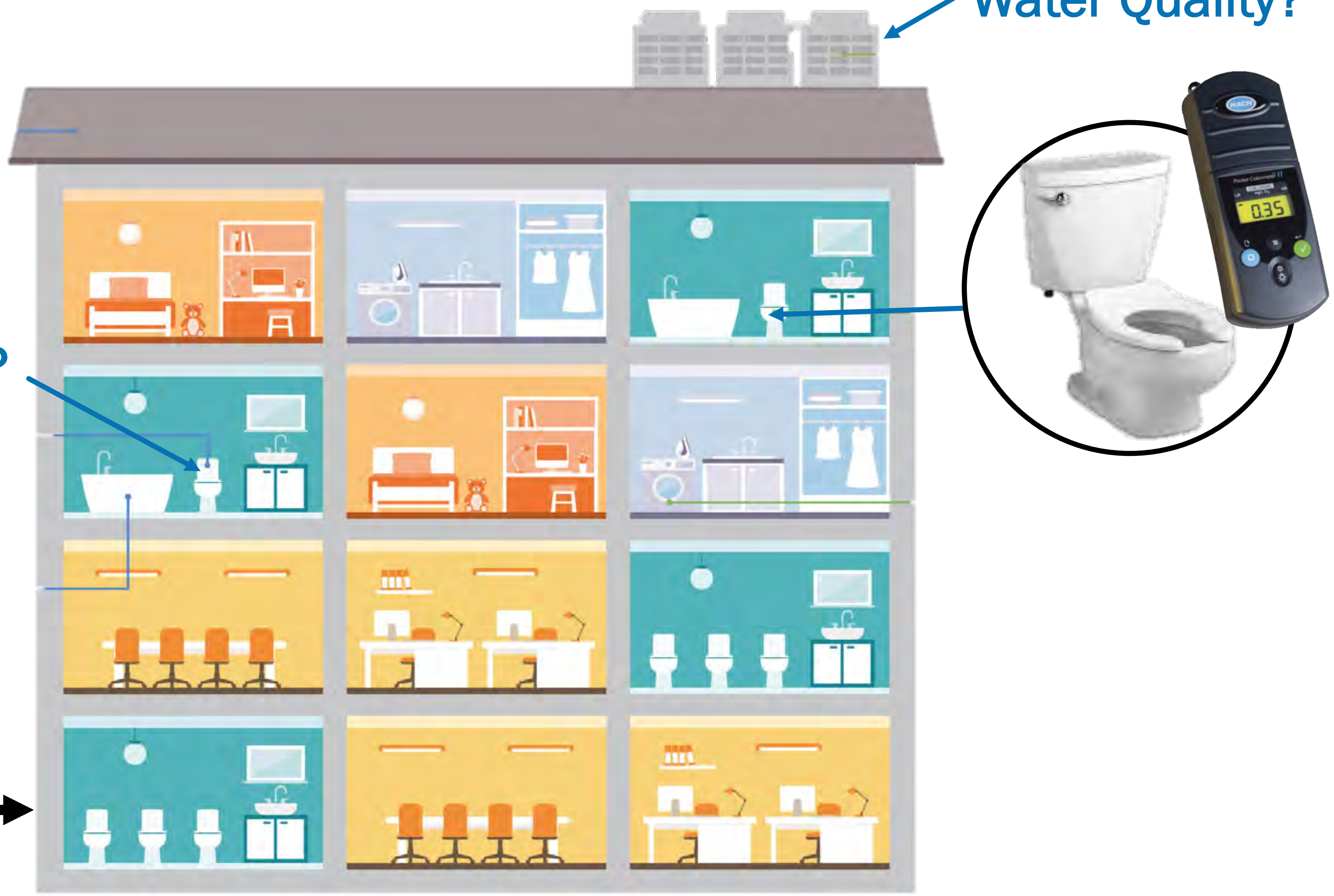
Distribution System Management – Overview

Distribution System = all plumbing between treatment and point of use

Water Quality?

Known Water Quality

ONWS Treatment System



Distribution System Management – Treatment Objectives

Poor management can lead to water quality degradation, adversely impacting:

- Aesthetics
  - Color and odor
- Maintenance requirements
  - Microbial regrowth, scaling, corrosion
- Public health
  - Opportunistic pathogens such as *Legionella*

Distribution System Management – Treatment Objectives

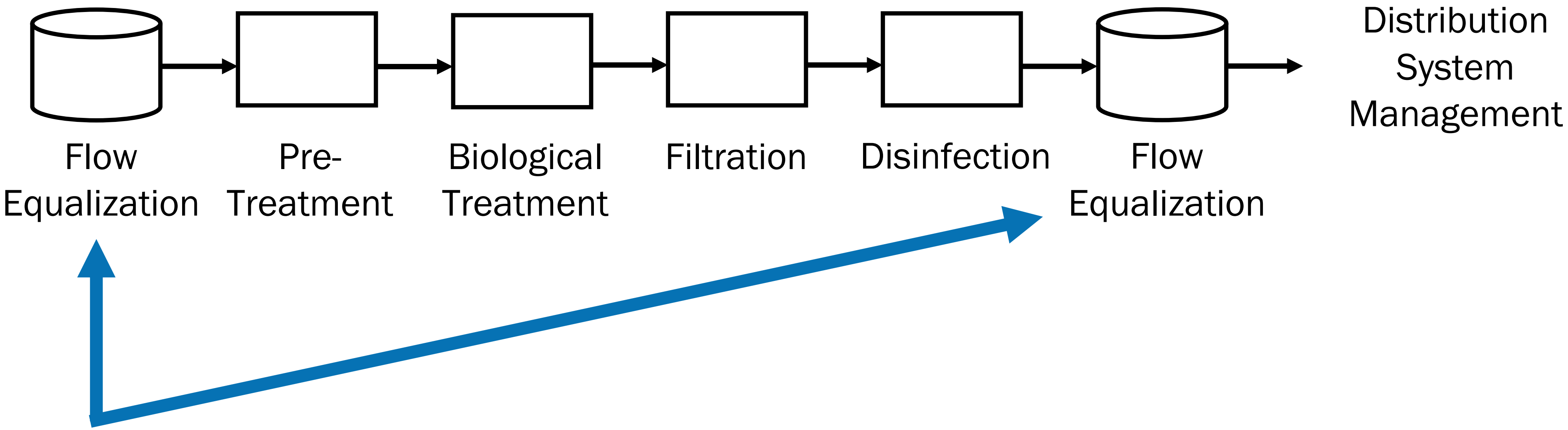
- Example distribution system water quality goals:

Parameter	Average	Maximum
Effluent BOD	< 10 mg/L (4-week)	25 mg/L
Effluent TSS	< 10 mg/L (4-week)	30 mg/L
Odor	The system shall not emit offensive odors	
Chlorine residual at or near point of use	0.2 mg/L free chlorine residual, *or* 0.5 mg/L combined chlorine residual	

Distribution System Management – Design Considerations

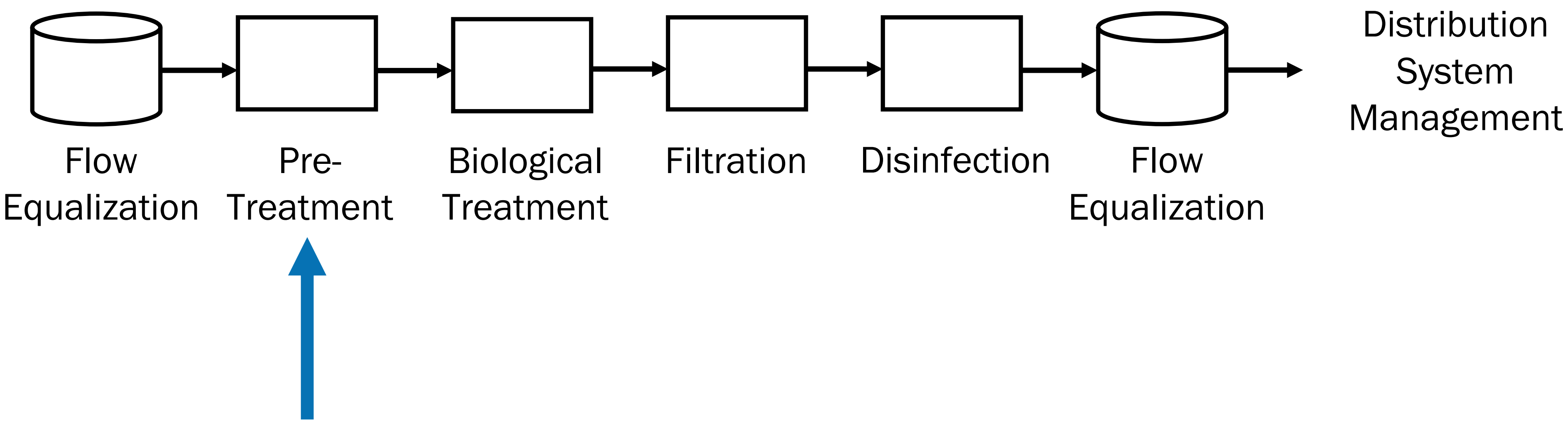
- Maintain disinfectant residual in distribution system
- Additional treatment for blackwater and graywater:
  - Biological treatment to reduce organics and stabilize the water
- Pipe materials and design:
  - Select non-reactive materials (*e.g.* iron can react with chlorine)
  - Pipe size and flow velocity (faster is better)
  - Avoid stagnation
- Maintenance considerations:
  - Design system to allow for periodic flushing
  - Monitor chlorine residual at different points of use throughout the building

Flow EQ, Pretreatment, Distribution – Summary



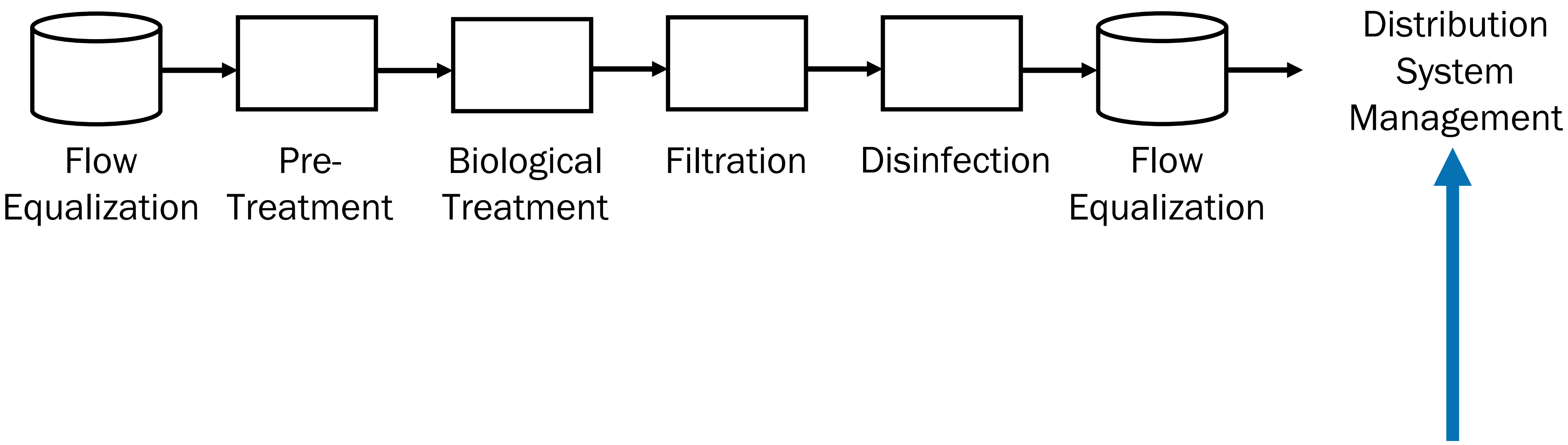
- Equalizes source water and end-use demand variability
- Allows for optimal design and operation of downstream processes

Flow EQ, Pretreatment, Distribution– Summary



- Removes large solids and debris
- Protects downstream treatment processes

Flow EQ, Pretreatment, Distribution– Summary



- Protects aesthetics and safety of the product water
- Minimizes maintenance of distribution system pipes and fixtures

Problem Solving Exercises

Choose the treatment objective(s) that is achieved with flow equalization:

- A. Reduce variability of source water quality and quantity
- B. Optimize treatment process capacity
- C. Allow system to meet end-use demand variations
- D. Reduce biodegradable organics
- E. (A), (B) and (C)

Flow equalization is beneficial for treating what types of source water:

- A. Rainwater
- B. Graywater
- C. Blackwater
- D. Stormwater
- E. All the above

Choose the treatment objective(s) that is achieved with pretreatment:

- A. Remove large solids and debris
- B. Remove dissolved constituents
- C. Decrease solids loading on downstream treatment
- D. Decrease color
- E. (A) and (C)

What are the common types of pretreatment used for ONWS applications:

Select all that apply:

- A. Coarse screens
- B. Fine screens
- C. Vortex filters
- D. Granular media filters
- E. (A), (B), and (C)

What is an opportunistic pathogen that can be controlled by proper distribution system management:

- A. *Cryptosporidium*
- B. *E. coli*
- C. Norovirus
- D. *Legionella*
- E. *Giardia*

Choose the treatment objective(s) that is achieved with distribution system management:

Select all that apply:

- A. Maintain treated water quality between the treatment system and point of use
- B. Minimize maintenance caused from microbial regrowth
- C. Reduce the total organic carbon in the water
- D. Minimize the risk of *Legionella*
- E. None of the above

What is *not* a recommended management strategy to maintain a distribution system:

- A. Maintain disinfectant residual throughout distribution system
- B. Provide additional treatment for blackwater and graywater to reduce organics
- C. Design the distribution system to allow for periodic flushing
- D. Use a primary disinfectant that rapidly reacts with the water and does not leave a residual
- E. Design pipe size and flow velocity to minimize stagnation of water in the distribution system

Module 8:
Developing Multiple Barrier ONWS Systems

Training Modules

1. Introduction
2. Public Health Goals
3. Treatment Selection and Crediting Overview
4. Treatment Selection and Crediting: Biological Treatment
5. Treatment Selection and Crediting: Filtration
6. Treatment Selection and Crediting: Disinfection
7. Treatment Selection and Crediting: Flow Equalization and Distribution
8. **Developing Multiple Barrier ONWS Systems**
9. Operations Plan
10. Regulatory and Permitting Plan

Framing Questions

- Why should multiple barriers be considered when designing ONWS systems?

- What are management barriers and why are they useful?
- How can an ONWS system be designed with multiple barriers?

Learning Objectives

- Benefits of multiple barrier treatment trains
- Benefits of non-treatment management barriers
- Designing multiple barrier treatment trains

Primary Target Audience

Primary Audience:

DESIGN ENGINEER

REGULATOR

OPERATOR

General Awareness:

PROGRAM ADMINISTRATOR

SYSTEM OWNER

Course Overview

- Benefits of Multiple Barrier Trains
- Benefits of Non-Treatment Management Barriers
- Designing Multiple Barrier Treatment Trains

Course Overview

- Benefits of Multiple Barrier Trains
- Benefits of Non-Treatment Management Barriers
- Designing Multiple Barrier Treatment Trains

Benefits of Multiple Barrier Trains

- Ensure **reliability** of public health protection

- Maintain a high degree of **availability**

Benefits of Multiple Barrier Trains

- Wide diversity of contaminants to remove

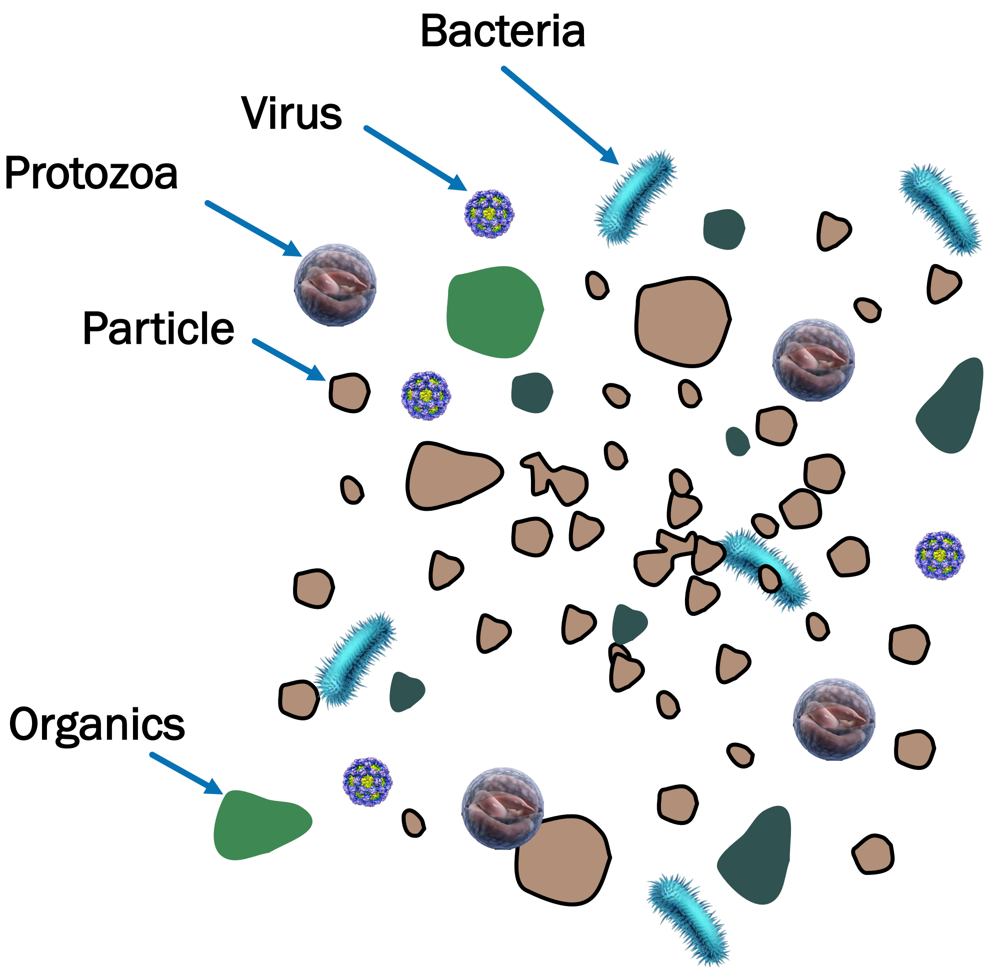
Pathogens

Biodegradable organics

TSS

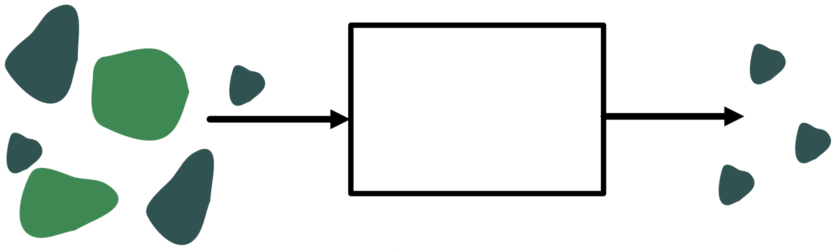
Color

Odor

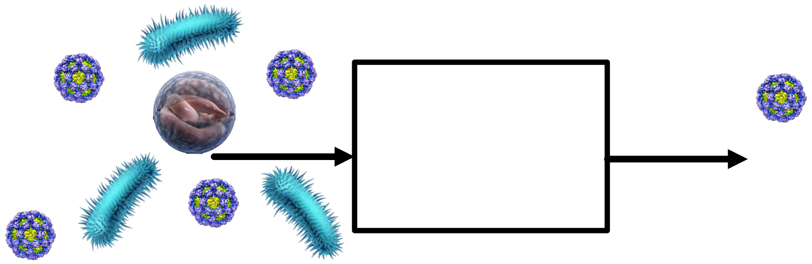


Benefits of Multiple Barrier Trains

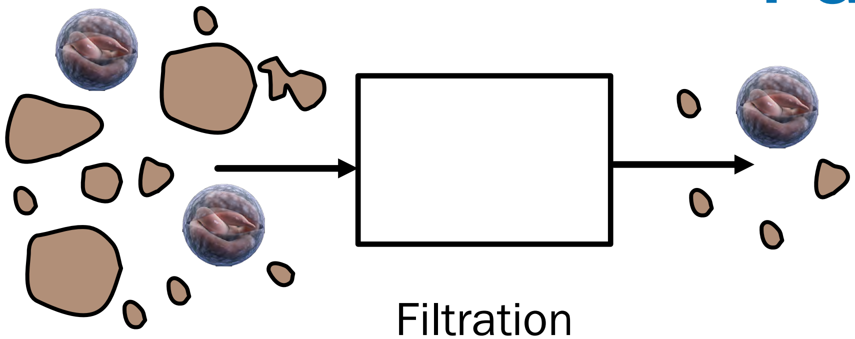
- Often, one technology doesn't remove everything



BOD Reduction
TSS Reduction



Pathogen Reduction



TSS and Pathogen Reduction

Benefits of Multiple Barrier Trains

Green = effective

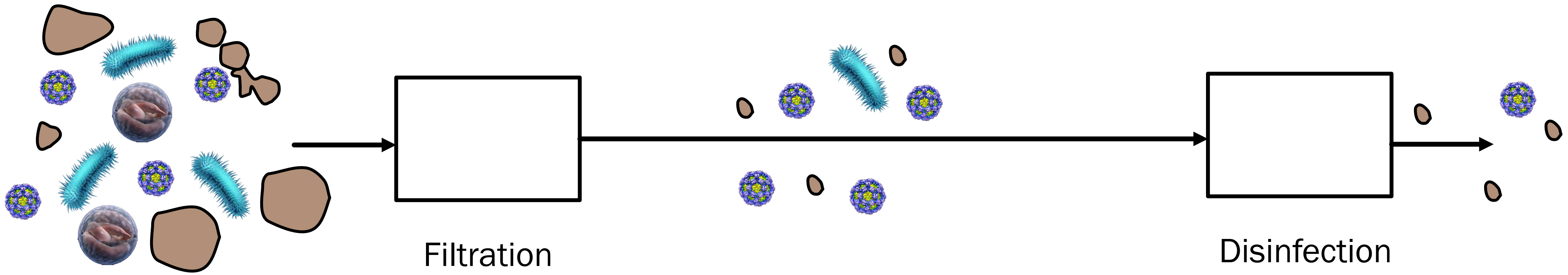
Yellow = somewhat effective

Red = not effective

Unit Process	Pathogens			Water Quality		Removal / Inactivation Mechanisms
	Virus	Protozoa	Bacteria	Particulates	Organics	
Biological Treatment						
Non-membrane options	Red	Yellow	Yellow	Yellow	Green	Biodegradation, adsorption, predation
MBR	Yellow	Green	Green	Green	Green	Same as above plus size exclusion
Filtration						
Granular media filter	Red	Yellow	Yellow	Green	Red	Physical removal (e.g., size exclusion, interception, diffusion)
Cartridge filter	Red	Yellow	Red	Green	Red	
Membrane filter	Red	Green	Green	Green	Red	Physical removal (e.g., size exclusion)
Reverse osmosis	Green	Green	Green	Green	Green	
Disinfection						
UV	Green	Green	Green	Red	Red	Physical degradation
Free chlorine	Green	Red	Green	Red	Red	Chemical inactivation and oxidation
Chloramine	Red	Red	Green	Red	Red	
Ozone	Green	Yellow	Yellow	Red	Red	

Benefits of Multiple Barrier Trains - Robustness

- **Robustness** – treatment ***diversity*** improves control of diverse contaminants by employing different mechanisms of removal/inactivation



Cartridge filter effectively reduces turbidity and protozoa

Free chlorine effectively reduces viruses and bacteria

Benefits of Multiple Barrier Trains - Robustness

- ONWS systems will likely require filtration and disinfection to meet pathogen reduction requirements
- Further diversity may be needed within each type of treatment:
  - Free chlorine, combined chlorine, UV light
  - Cartridge filtration, membrane filtration, reverse osmosis
- Biological treatment may be needed for some source waters

Benefits of Multiple Barrier Trains - Robustness

- Blackwater and graywater systems will need biological treatment

Biological Treatment

Reduces:

✓Nutrients
✓Biodegradable organics
✓Color
✓Odor

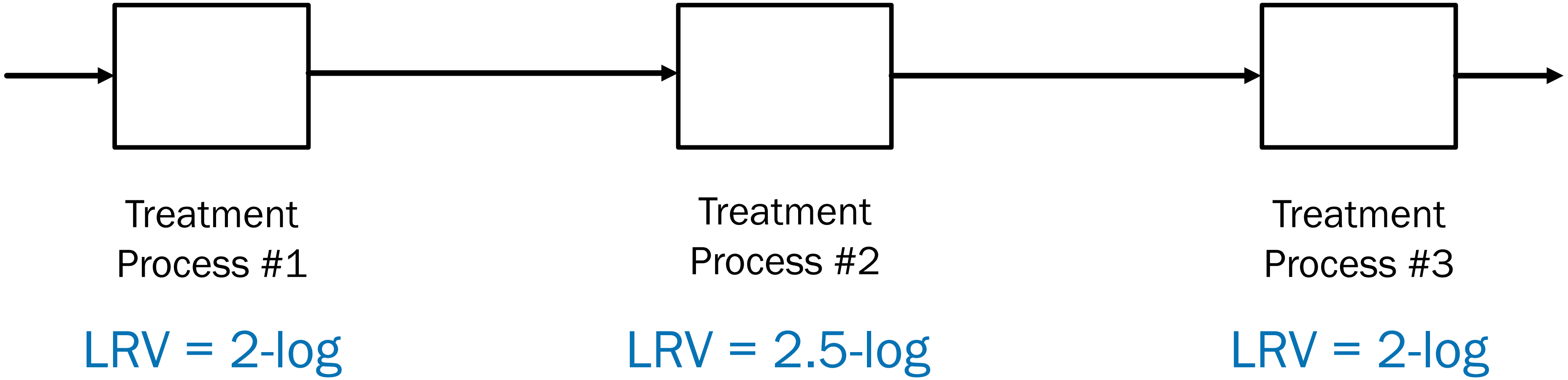
Prepares water for downstream filtration and disinfection

- Aesthetics also important to consider

Benefits of Multiple Barrier Trains - Redundancy

- **Redundancy** – the use of treatment beyond minimum requirements to reliably meet treatment goals
- Reduces probability that a treatment excursion leads to failure in public health protection

LRT = 4.5-log protozoa



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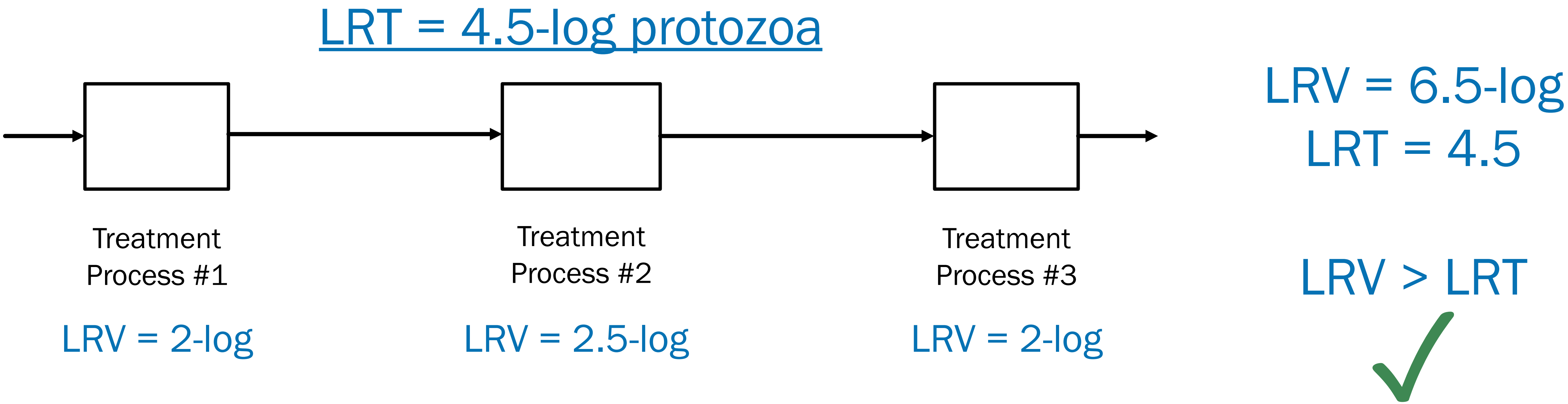

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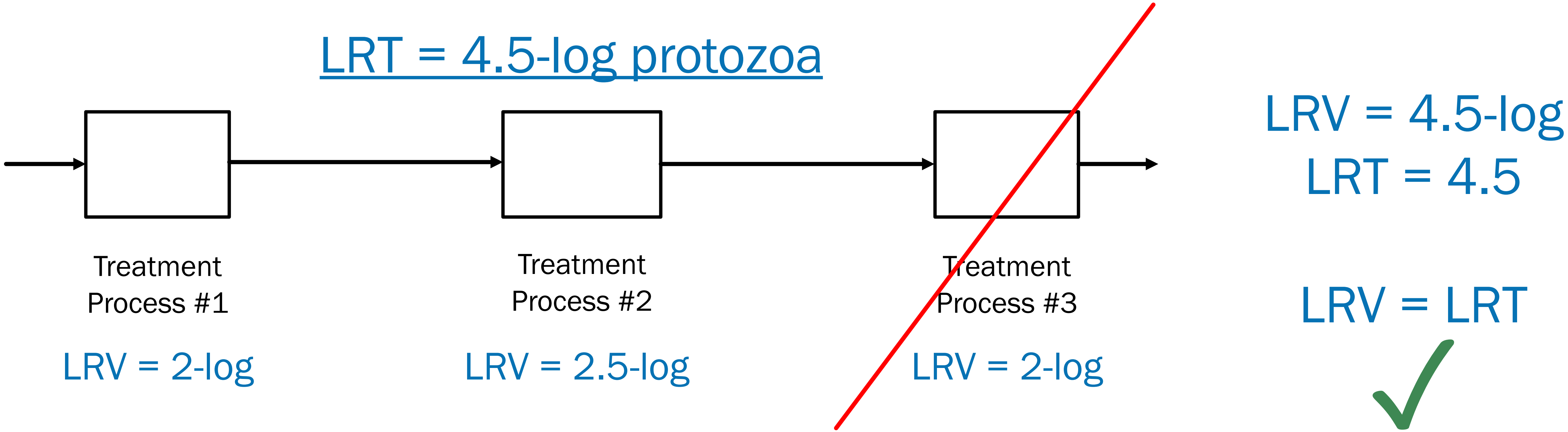
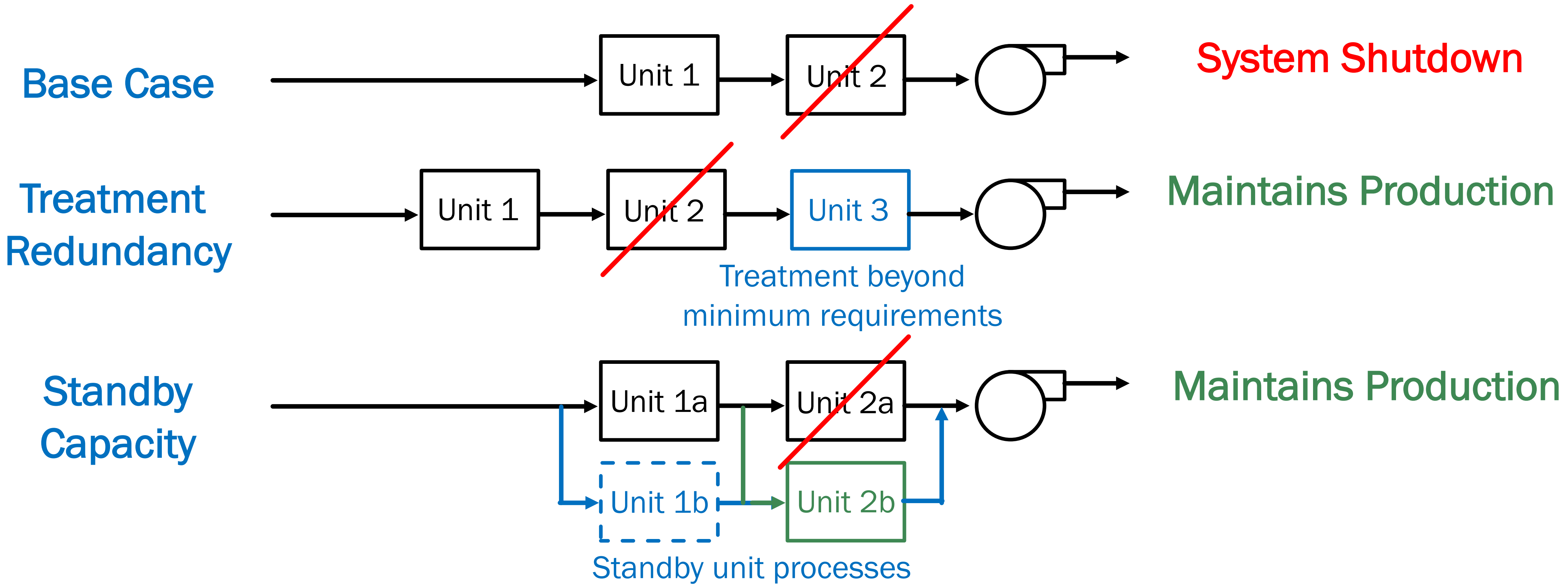


Benefits of Multiple Barrier Trains - Availability

- Redundancy also improves system **availability** and operability
- **Stand-by capacity** also improves **availability**



Benefits of Multiple Barrier Trains - Considerations

DESIGN ENGINEER

Frequent Communication

SYSTEM OWNER

- Regarding assumptions for:
  - Performance
  - Cost
  - Operability
- Balance cost/footprint constraints with operability and uptime

Multiple Barrier Treatment Trains – Add'l Considerations

- Importance of aesthetics

Turbid

Off-colored

Malodorous

}

May cause public opposition

Course Overview

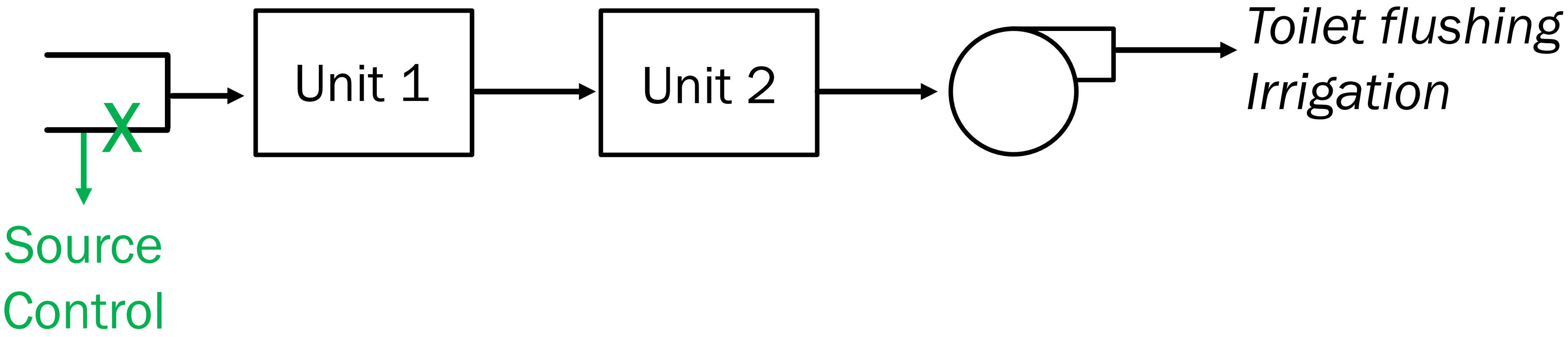
- Benefits of Multiple Barrier Trains
- Benefits of Non-Treatment Management Barriers
- Designing Multiple Barrier Treatment Trains

Benefits of Non-Treatment Management Barriers

- Management Barriers
  - Source Control
  - Alternative Disposal and Supply Options
  - Flow Equalization
  - Monitoring
  - Operational Optimization
- Promote goals of public health protection and system availability

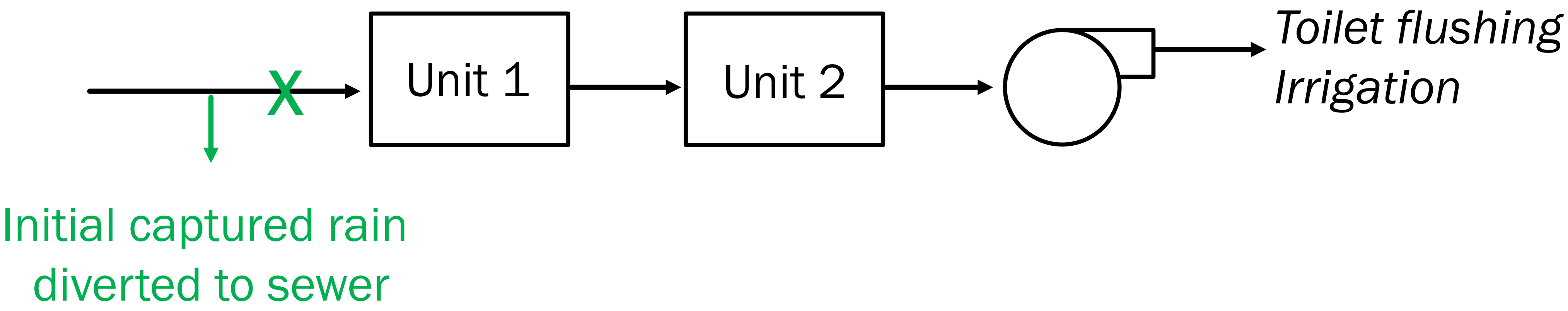
Management Barriers – Source Control

- Prevent passage of pathogens, chemicals, or other quality concerns
  - Separate challenging feed water
  - Public outreach throughout the building to alert users that water is recycled



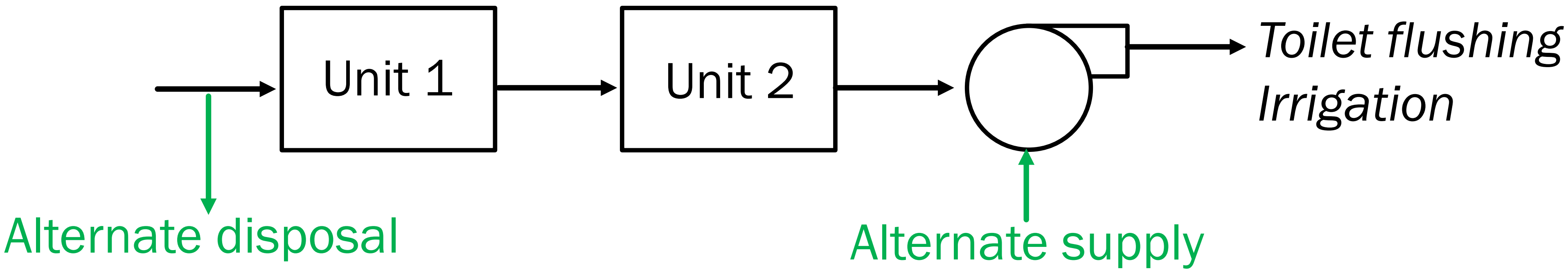
Management Barriers – Source Control

- **First flush diverters** for rainwater and stormwater systems
- Minimizes contaminant load to treatment system



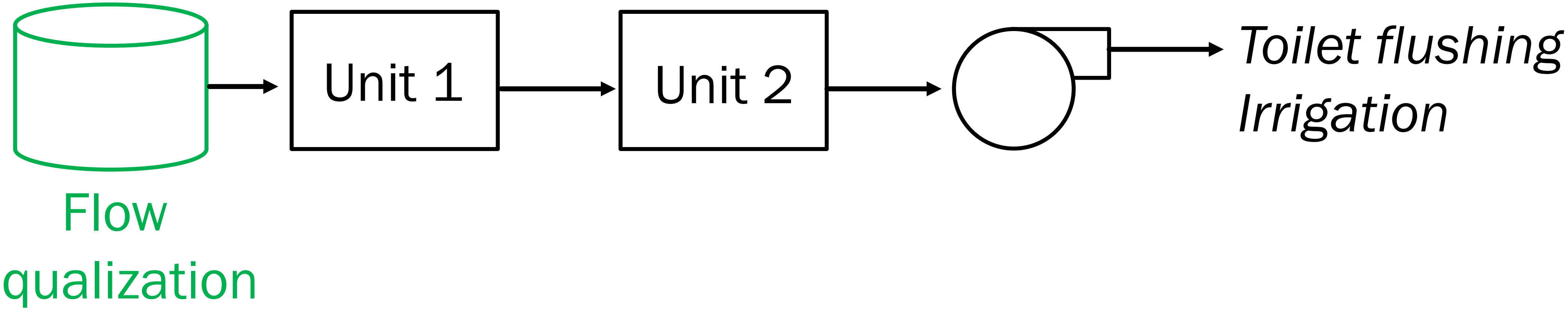
Management Barriers – Alternative Disposal and Supply

- Alternate options for wastewater disposal and treated water supply
- Reduce need to design systems for rigorous, continuous reliability



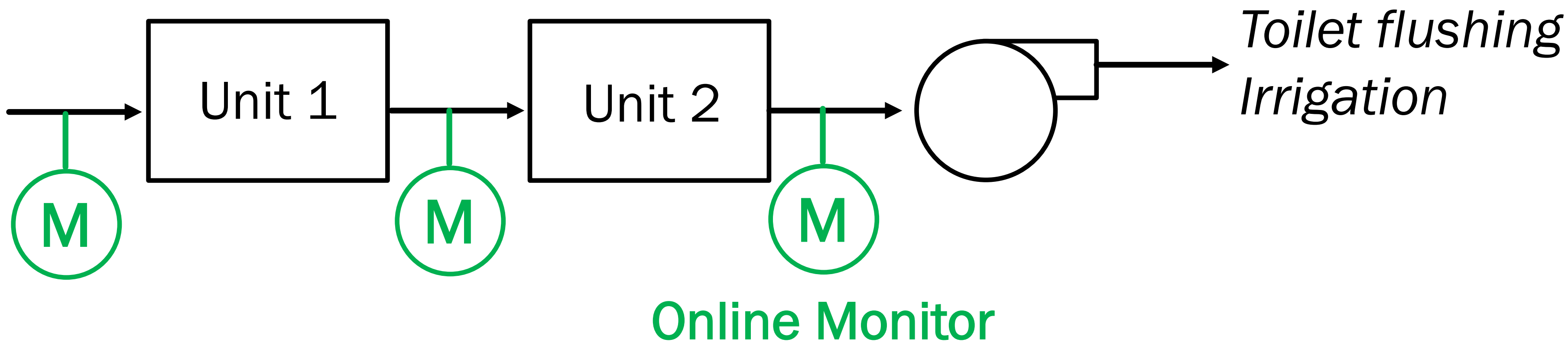
Management Barriers – Flow Equalization

- Dampens out peaks of contaminants
- Provides response time and more consistent water quality and flow to downstream treatment processes
- *See Module 7 for additional information*



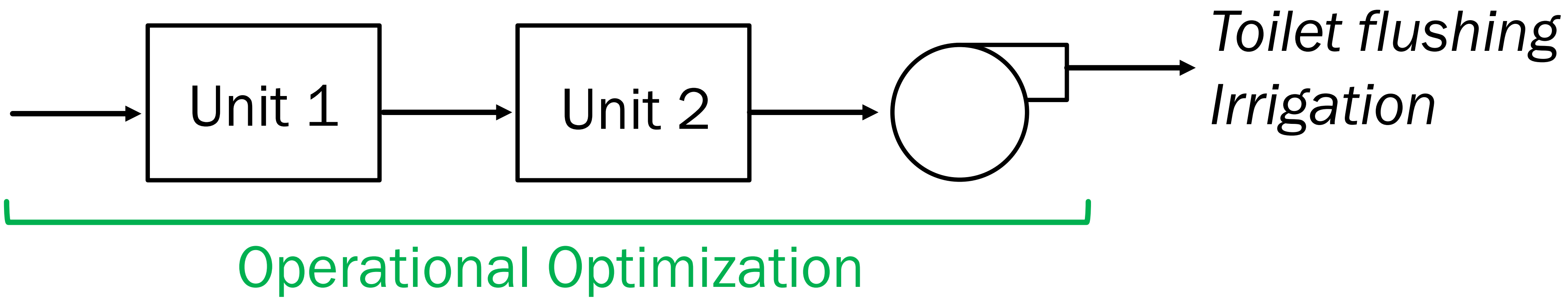
Management Barriers - Monitoring

- **Monitoring is an essential element of ONWS systems**
- Continuous monitoring via on-line analyzers provides on-going assurance of treatment efficacy
- Shortens duration of off-spec operation



Management Barriers – Operations Optimization

- Trained, onsite operators can improve system reliability through:
  - Proper operation
  - Maintenance
  - Optimization of system barriers
- Capability for remote operation also beneficial



Balancing Treatment and Management Elements

- Systems designed to utilize best configuration to fit site constraints

Space Limited? →
- Less standby capacity
- Seek alternate disposal and supply options

Remote Operation Required? →
- Use redundant online monitoring
- Design system with redundant treatment

No Alternate Supply Available? →
- Design redundant and robust system
- Include standby capacity

Course Overview

- Benefits of Multiple Barrier Trains
- Benefits of Non-Treatment Management Barriers
- Designing Multiple Barrier Treatment Trains

Designing Multiple Barrier Treatment Trains

What is the quality of my source water?

What is the intended non-potable use?

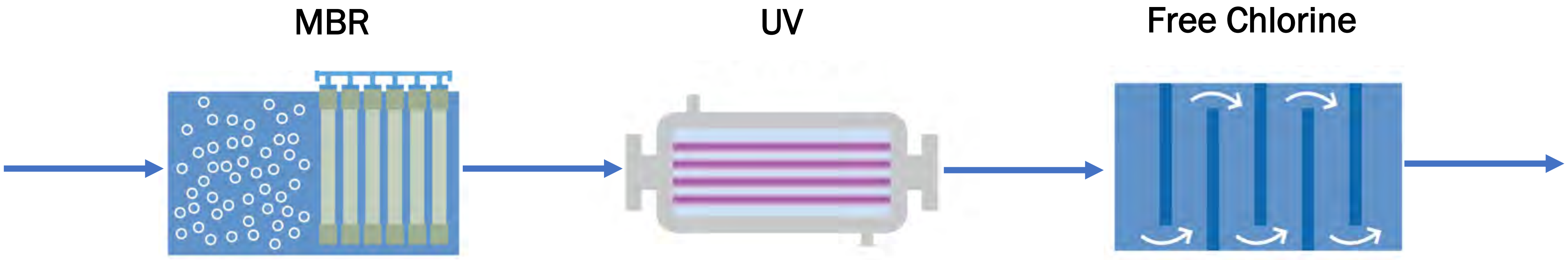
Barriers used to bridge the gap

Goals for Blackwater

- Design system to achieve pathogen reduction for use in ONWS
- Provide assurance that LRTs are being met
- Decrease organics to create a biologically stable water
- Create aesthetically acceptable water (particulates, odor, color)

Multiple Barrier Treatment Trains - Blackwater

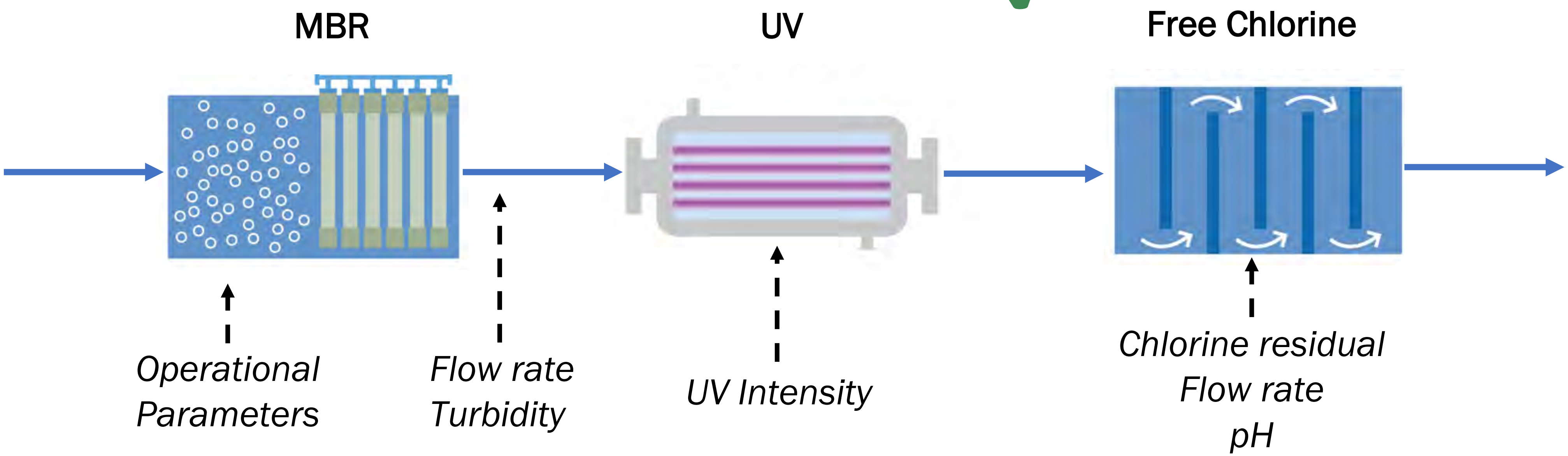
- Design system to achieve pathogen reduction for use in ONWS ✓



	Unit Process Pathogen Credits			Total Log Removal	LRTs for Blackwater
	MBR	UV	Free Chlorine		
Virus	1.5	3.5	5.0	10.0	8.5
Protozoa	2.0	6.0	0.0	8.0	7.0
Bacteria	4.0	3.5	5.0	12.5	6.0

Multiple Barrier Treatment Trains - Blackwater

- Provide assurance that LRTs are being met ✓

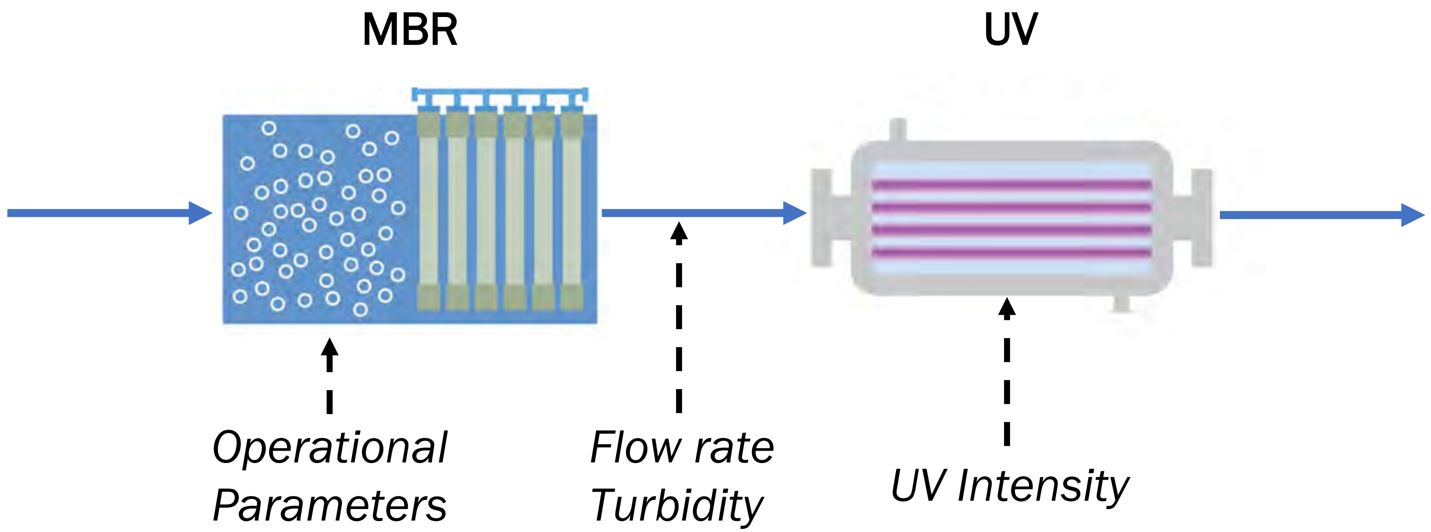


	Unit Process Pathogen Credits			Total Log Removal	LRTs for Blackwater
	MBR	UV	Free Chlorine		
Virus	1.5	3.5	5.0	10.0	8.5
Protozoa	2.0	6.0	0.0	8.0	7.0
Bacteria	4.0	3.5	5.0	12.5	6.0

Goals for Blackwater

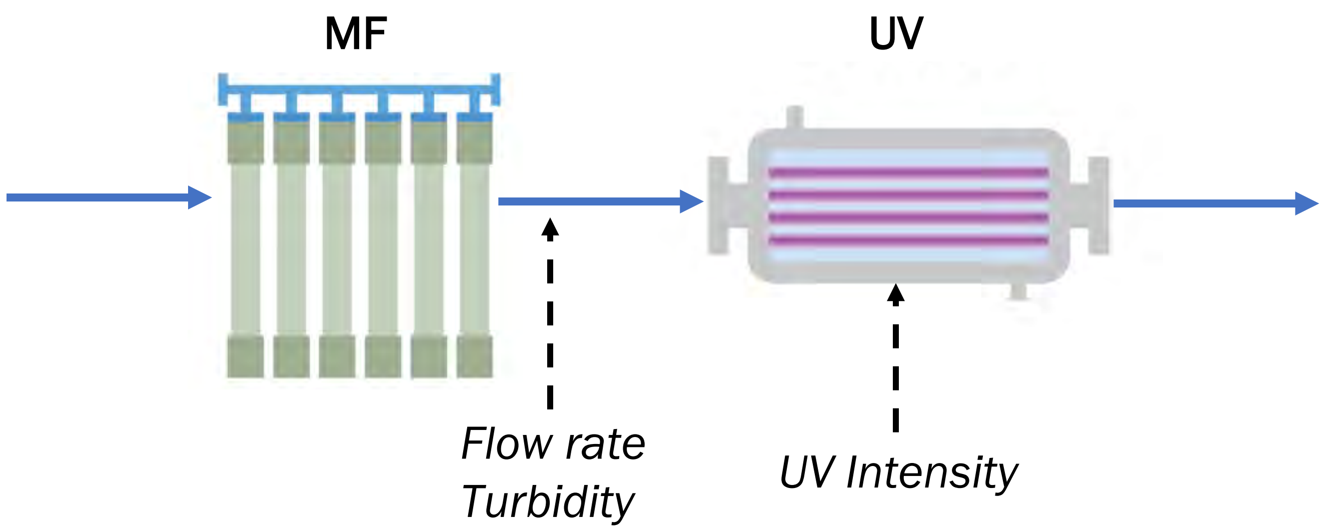
- Design system to achieve pathogen reduction for use in ONWS ✓
- Provide assurance that LRTs are being met ✓
- Decrease organics to create a biologically stable water ✓
- Create aesthetically acceptable water (particulates, odor, color) ✓

Multiple Barrier Treatment Trains - Graywater



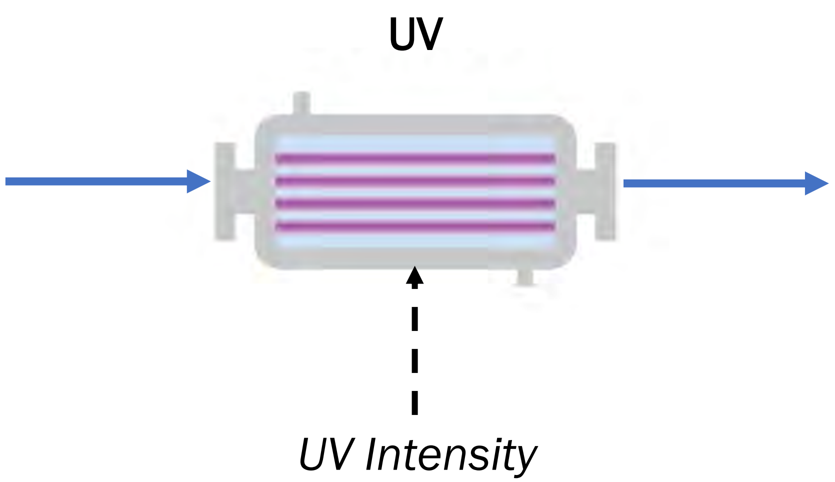
	Unit Process Pathogen Credits		Total Log Removal	LRT for Graywater
	MBR	UV		
Virus	1.5	6.0	7.5	6.0
Protozoa	2.0	6.0	8.0	4.5
Bacteria	4.0	6.0	10.0	3.5

Multiple Barrier Treatment Trains - Stormwater



	Unit Process Pathogen Credits		Total Log Removal	LRT for Stormwater
	MF	UV		
Virus	0.0	3.5	3.5	3.5
Protozoa	0.0	6.0	6.0	3.5
Bacteria	0.0	3.5	3.5	3.0

Multiple Barrier Treatment Trains – Roof Runoff

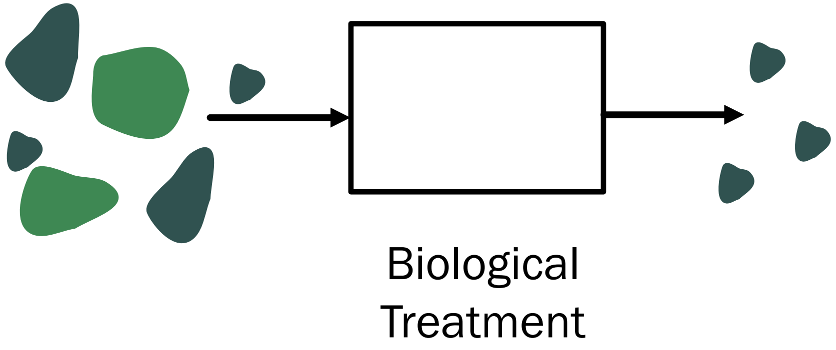


	Unit Process Pathogen Credits	Total Log Removal	LRT for Roof Runoff
	UV		
Virus	N/A	N/A	N/A
Protozoa	N/A	N/A	N/A
Bacteria	3.5	3.5	3.5

Multiple Barrier Treatment Trains - Monitoring

- Highest priority for monitoring barriers achieving LRT credit
- Recommend on-line, high frequency monitoring
  - Better than end-point monitoring for understanding performance
  - Allows for higher degrees of automated control and remote operation

- Still beneficial to monitor barriers not receiving LRT credit



Is ammonia being removed?
BOD and odor reduced?

Multiple Barrier Trains – Additional Considerations

- Selection of meters and sensors
- Hydraulic profile
- Serviceability
- Sample tap location

Multiple Barrier Treatment Trains – Summary

- Pathogen control
- Particulate removal
- Biological stabilization
- Color and odor control
- Distribution system protection

Because no single process can meet all of the goals…
…multiple barriers are frequently required

Problem Solving Exercises

What is *not* a key benefit of a multiple barrier treatment train:

- A. It can enhance reliability
- B. It can reduce a wide diversity of contaminants
- C. It can guarantee the system will perform 100% of the time
- D. It can help to maintain a high degree of system uptime
- E. It can reduce the risk of treatment excursions that lead to failure in public health protection

What does *robustness* mean in the context of an ONWS design:

- A. The use of treatment beyond the minimum requirements to reliably meet treatment goals
- B. Using a diversity of treatment processes to improve control of diverse pathogens and chemical contaminants
- C. The prevention of passage of pathogens, chemicals, or other quality concerns
- D. All the above
- E. None of the above

What is a key benefit of treatment redundancy in an ONWS setting:

- A. It reduces the probability that a treatment excursion leads to failure in public health protection
- B. It makes it impossible to have a treatment failure
- C. It minimizes maintenance requirements for the ONWS
- D. All the above
- E. None of the above

What are examples of non-treatment management barriers:

Select all that apply:

- A. Treatment performance monitoring
- B. Source control
- C. Treatment redundancy
- D. Flow equalization
- E. Operational optimization

What are some of the benefits to having alternative disposal and supply options:

- A. Reduces the need to design systems for rigorous, continuous reliability
- B. Allows for more streamlined commissioning testing
- C. Provides for rapid failure response while continuing to meet building demand
- D. (A) and (C) are true
- E. None of the above

Link the Design Consideration with Potential Solutions

A. Remote Operation Required?

B. Space Limited?

C. No Alternate Supply Available?

a.
- Less standby capacity
- Seek alternate disposal and supply options

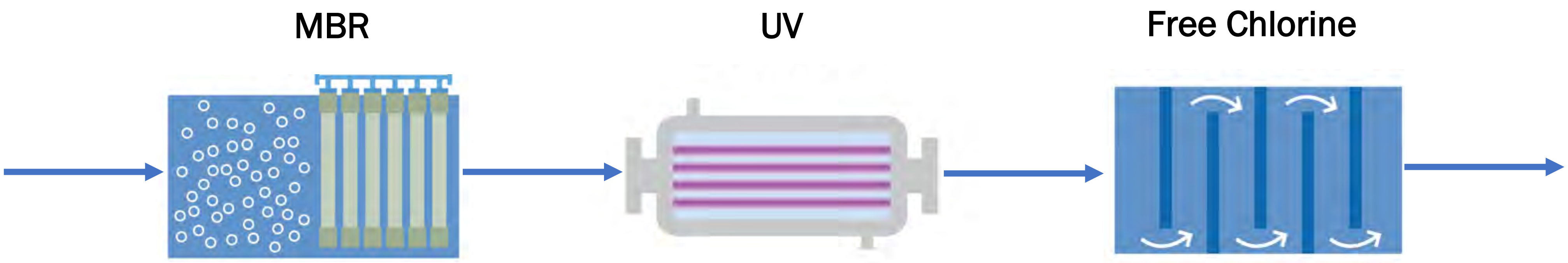
b.
- Use redundant online monitoring
- Design system with redundant treatment

c.
- Design redundant and robust system
- Include standby capacity

Complete the following treatment trains to meet the required LRTs

Blackwater

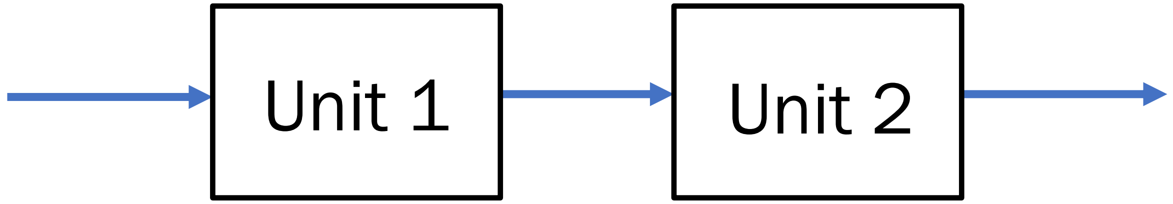
Fill in the missing LRVs for each pathogen group for the treatment train provided. Does this train meet the LRTs for blackwater being reused for toilet flushing?



	Unit Process Pathogen Credits			Total Log Removal	LRTs for Blackwater
	Tier 1 MBR	UV	Free Chlorine with WaterVal		
Virus		3.5	4.0		
Protozoa					
Bacteria					

Graywater

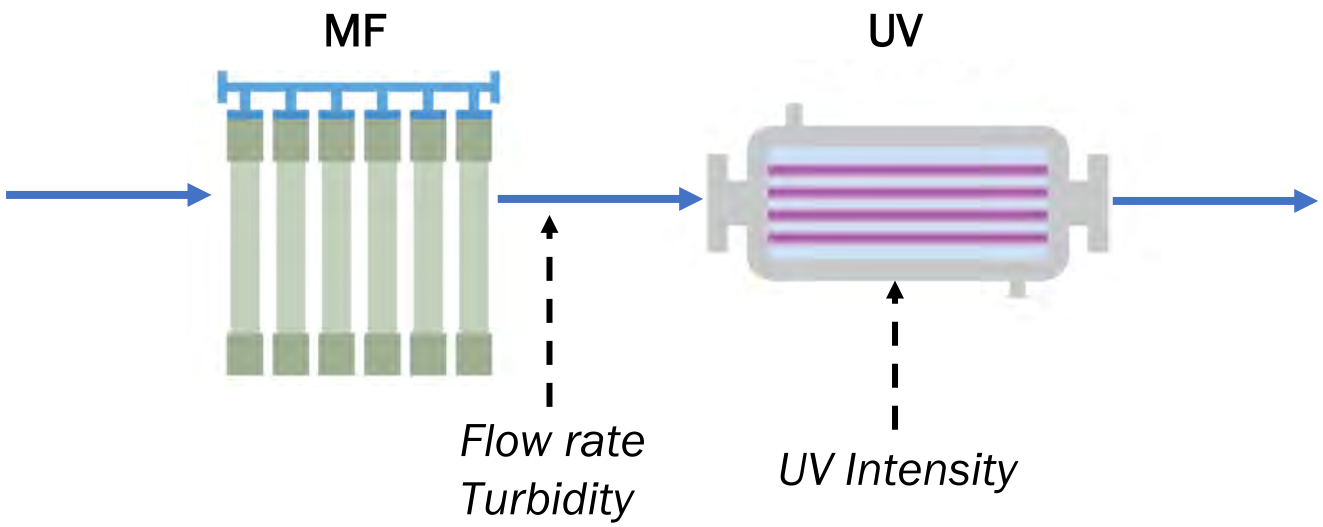
Select two treatment processes that provide the required LRTs:



	Unit Process Pathogen Credits		Total Log Removal	LRT for Graywater
Virus				6.0
Protozoa				4.5
Bacteria				3.5

Stormwater

Fill in the missing LRVs for each pathogen group for the treatment train provided. Does this train meet the LRTs for stormwater being reused for toilet flushing?



	Unit Process Pathogen Credits		Total Log Removal	LRT for Stormwater
	MF	UV		
Virus		3.5		
Protozoa				
Bacteria				

Roof Runoff

Develop a treatment train that provides the required LRTs:

	Unit Process Pathogen Credits	Total Log Removal	LRT for Roof Runoff
Virus			N/A
Protozoa			N/A
Bacteria			3.5

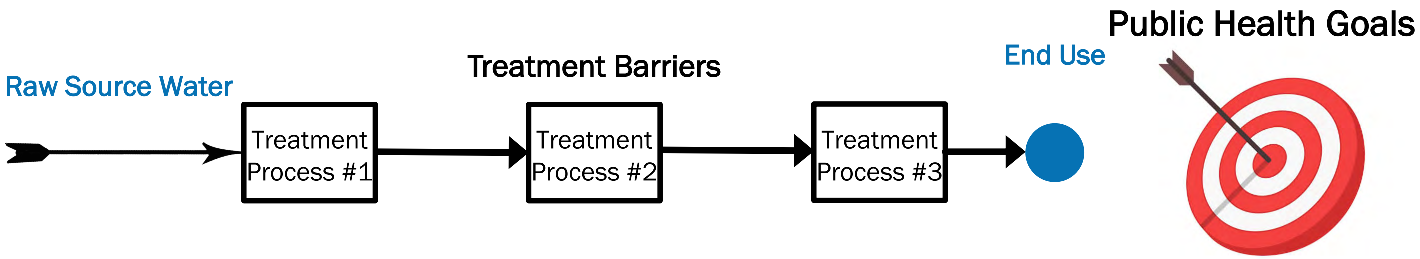
Module 9: Operations Plan

Training Modules

1. Introduction
2. Public Health Goals
3. Treatment Selection and Crediting Overview
4. Treatment Selection and Crediting: Biological Treatment
5. Treatment Selection and Crediting: Filtration
6. Treatment Selection and Crediting: Disinfection
7. Treatment Selection and Crediting: Flow Equalization and Distribution
8. Developing Multiple Barrier ONWS Systems
9. **Operations Plan**
10. Regulatory and Permitting Plan

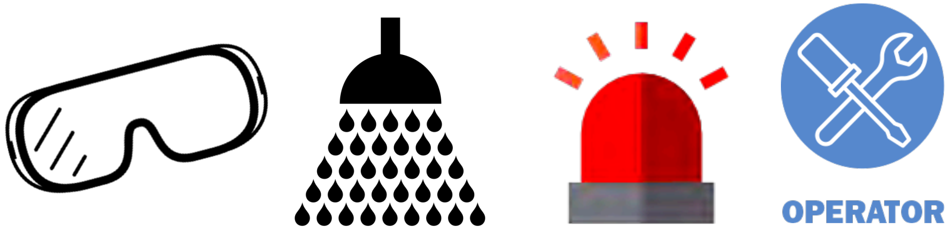
Primary Goals of ONWS System Design and Operation

- Meet or exceed all compliance objectives – protect public health



- Maintain reliability and uptime of the equipment

- Ensure the safety of all operating personnel



Primary Goals of ONWS System Design and Operation

- An Operations Plan is a critical part of a successful ONWS system
- Documents key components of operating and maintaining system

Developed by:

DESIGN ENGINEER

With input from:

OPERATOR

SYSTEM OWNER

- Engineer should describe key elements of the Operations Plan to the Operator

Learning Objectives

- Importance of interface between design, permitting, and operations
- Critical documentation for operating and commissioning ONWS systems
- Roles for Design Engineers, Regulators, and Operators related to start-up, commissioning, and ongoing operations of ONWS systems

Primary Target Audience

Primary Audience:

DESIGN ENGINEER

REGULATOR

OPERATOR

PROGRAM ADMINISTRATOR

General Awareness:

SYSTEM OWNER

Course Overview

- **Introduction to the essential elements of an Operations Plan:**
  - Process Design and Control Theory
  - Standard Operating Procedures
  - Maintenance Plan
  - Compliance Reporting
  - Environment, Health and Safety Plan
  - Emergency Response Plan
  - O&M Staffing Plan
  - Commissioning and Acceptance Test Plan
  - Process Optimization

Course Overview

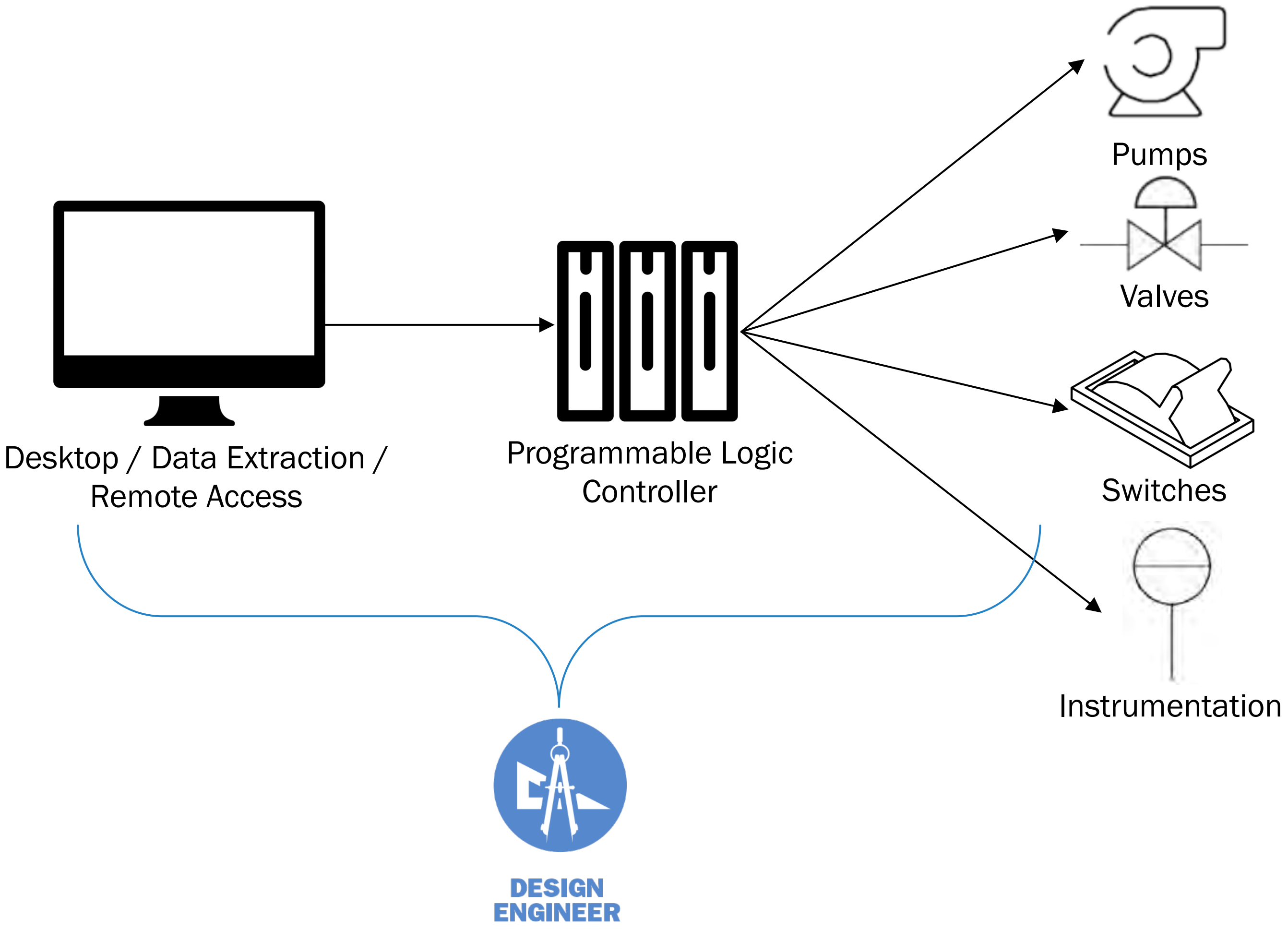
- Introduction to the elements of an Operations Plan:
  - Process Design and Control Theory
  - Standard Operating Procedures
  - Maintenance Plan
  - Compliance Reporting
  - Environment, Health and Safety Plan
  - Emergency Response Plan
  - O&M Staffing Plan
  - Commissioning and Acceptance Test Plan
  - Process Optimization

Process Design and Control Theory

- Process Control
  - Defines how the system *should* be operating
- Performance Monitoring
  - Confirms the system is operating as designed
- Alarms and Notifications
  - Alerts the operator when a parameter is out of the typical range

Process Design and Control Theory

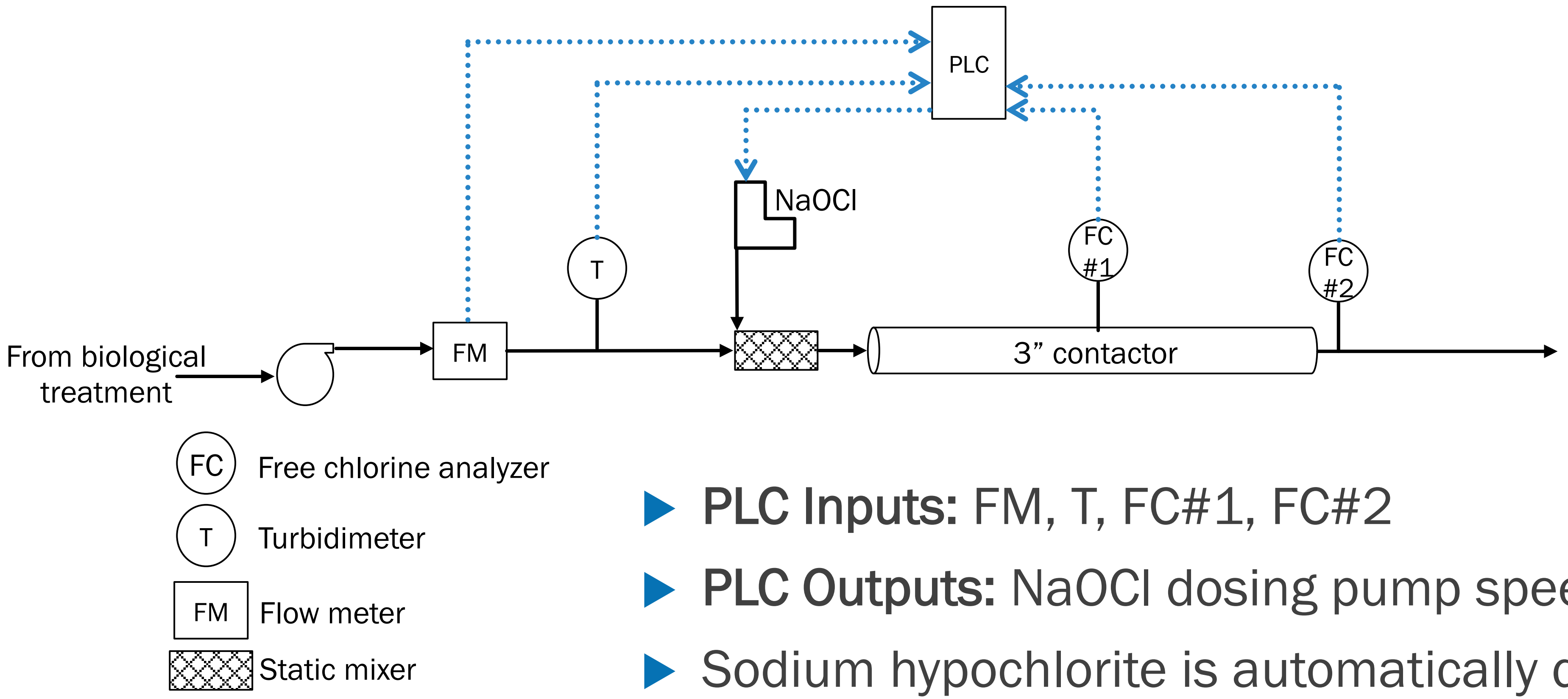
Process Control



- Developed by Design Engineer
- Control Narrative
  - Operating modes
  - Event sequences
  - Instrumentation
  - Setpoints, alarms, feedback controls

Process Design and Control Theory

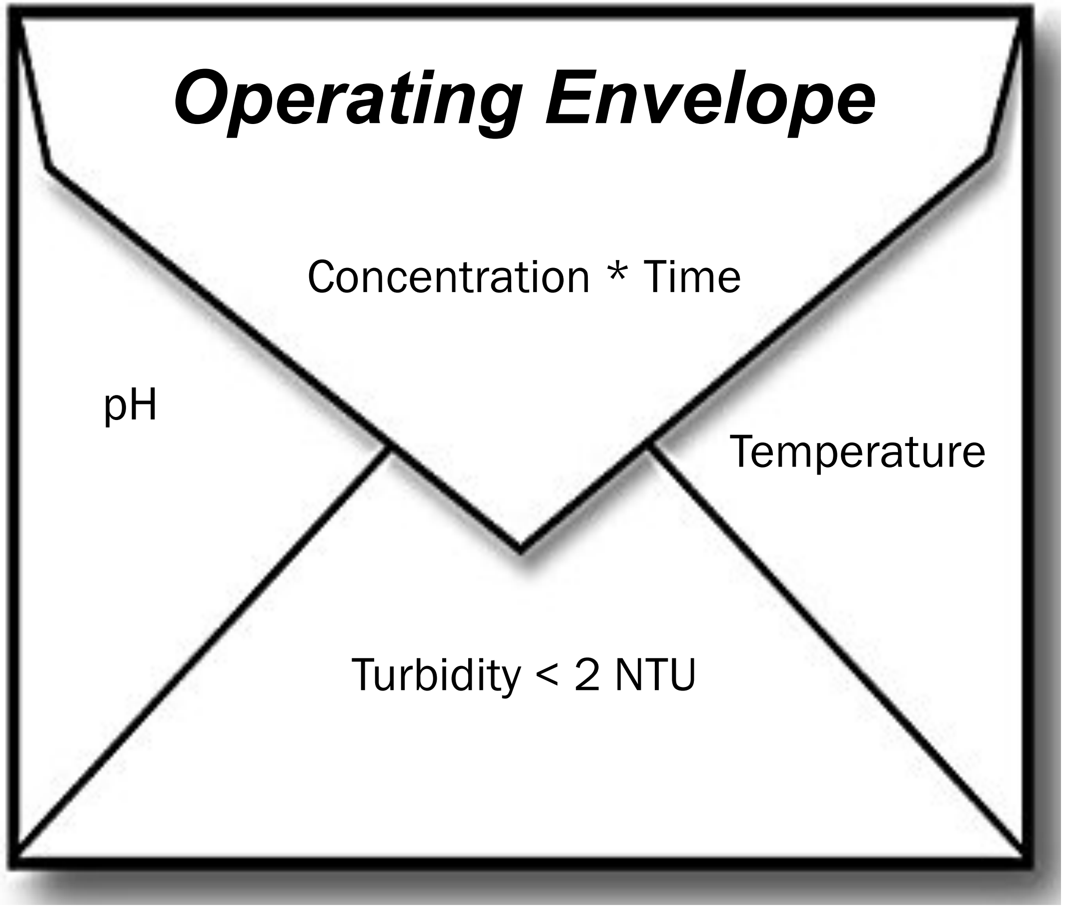
Process Control – Example Chlorine Dosing System



- **PLC Inputs:** FM, T, FC#1, FC#2
- **PLC Outputs:** NaOCl dosing pump speed
- Sodium hypochlorite is automatically dosed at controlled rate to maintain chlorine residual

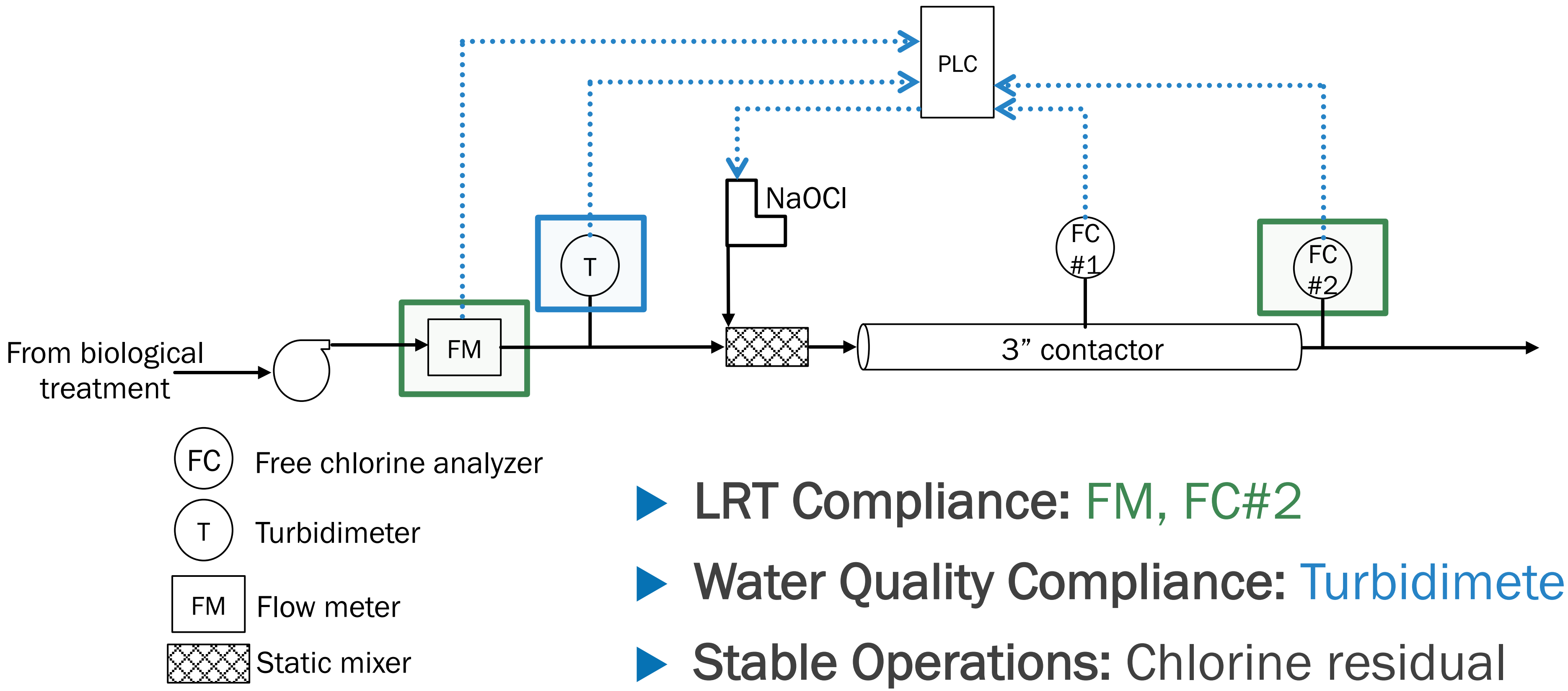
Performance Monitoring

- Identify monitors used for:
  - Assessing LRT compliance
  - Assessing water quality compliance
  - Maintaining stable operations
- Identify operating ranges



Process Design and Control Theory

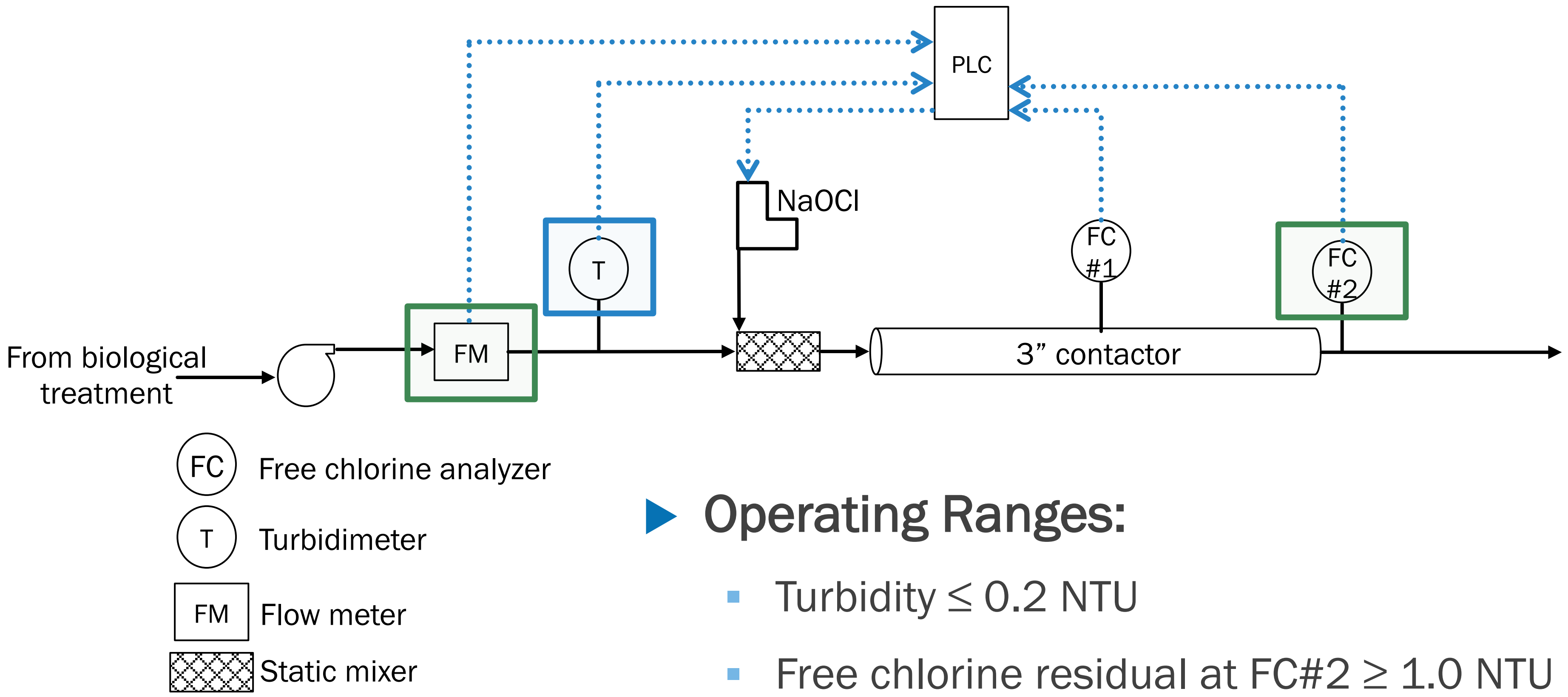
Performance Monitoring



- **LRT Compliance:** FM, FC#2
- **Water Quality Compliance:** Turbidimeter
- **Stable Operations:** Chlorine residual maintained at target concentration

Process Design and Control Theory

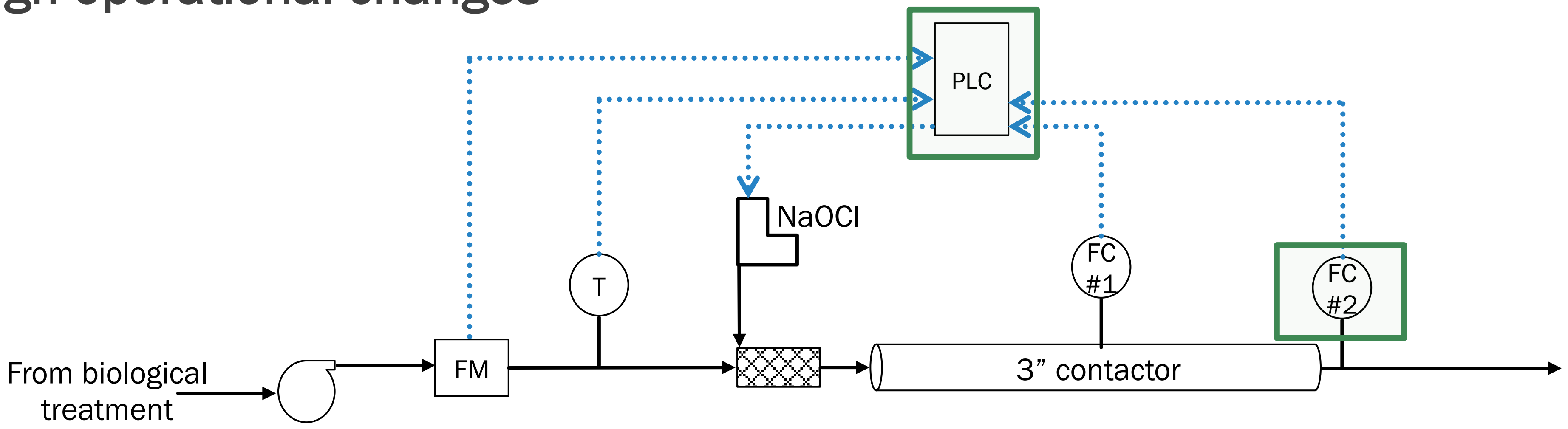
Performance Monitoring

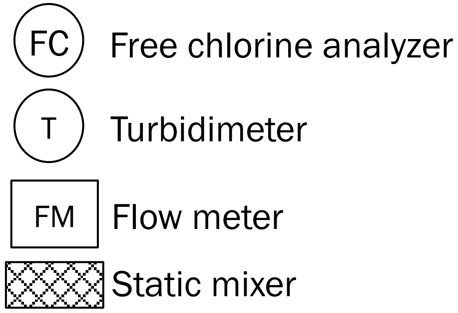


- **Operating Ranges:**
  - Turbidity ≤ 0.2 NTU
  - Free chlorine residual at FC#2 ≥ 1.0 NTU
  - Flow rate ≤ 10 gpm → contact time ≥ 15 min

Alarms and Notifications

- Key monitoring parameters have **setpoints = target value or range controlled through operational changes**





- FC#2 **setpoint** = 1.5 mg/L
- PLC programmed to maintain residual +/- 0.25 mg/L
  - Modifies chemical pump speed

Process Design and Control Theory

Alarms and Notifications

- Alarm triggered when processes operate outside setpoint to:
  - Initiate operator response
  - Initiate automatic response
- Critical alarm categories:
  - LRT compliance
  - Water Quality
  - Operational
- Routine testing of alarms and shutdown features is recommended

LRT Compliance Alarm

Indicates a problem with a unit process's ability to achieve the credited LRT

Water Quality Alarm

Indicates a problem with unit process or overall treatment train's ability to achieve a water quality target

Operational Alarm

Indicates a problem with a unit process or the overall treatment train's ability to function as designed and continue to produce water

Alarms and Notifications

Example Alarms and Responses

Location	Alarm Name	Alarm Type	Alarm Level	Response
Cartridge Filter	High effluent turbidity (NTU)	Water Quality	**Alert:** 0.2	**Alert:** Operator visually inspect for signs of integrity breach
			Critical: 0.5	**Critical:** Automated diversion to sewer
UV	Low influent UVI (mW/cm^2)	LRT Compliance	**Alert:** 12	**Alert:** Operator inspect upstream process data for indications of performance deteriorating
			Critical: 10	**Critical:** Automated diversion to sewer
Treated water tank	Low chlorine residual (mg/L)	Water Quality	**Alert:** 0.7	**Alert:** Operator verify residual reading and check chlorine dosing pump
			Critical: 0.5	**Critical:** Automated diversion to sewer

Course Overview

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Standard Operating Procedures

- SOP = set of **step-by-step instructions** developed to help operators carry out complex or routine operations

✓ Achieves efficient and consistent performance
✓ Reduces miscommunication and compliance failures
✓ Knowledge transfer among operators

Developed by: 

OPERATOR

With input from: 

DESIGN ENGINEER

Standard Operating Procedures

SOPs Should Be:

- Written down
- Up-to-date
- Consistent with industry best practices
- Aligned with regulatory requirements
- Effective (test that it works)
- Reviewed and revised periodically with revision date posted

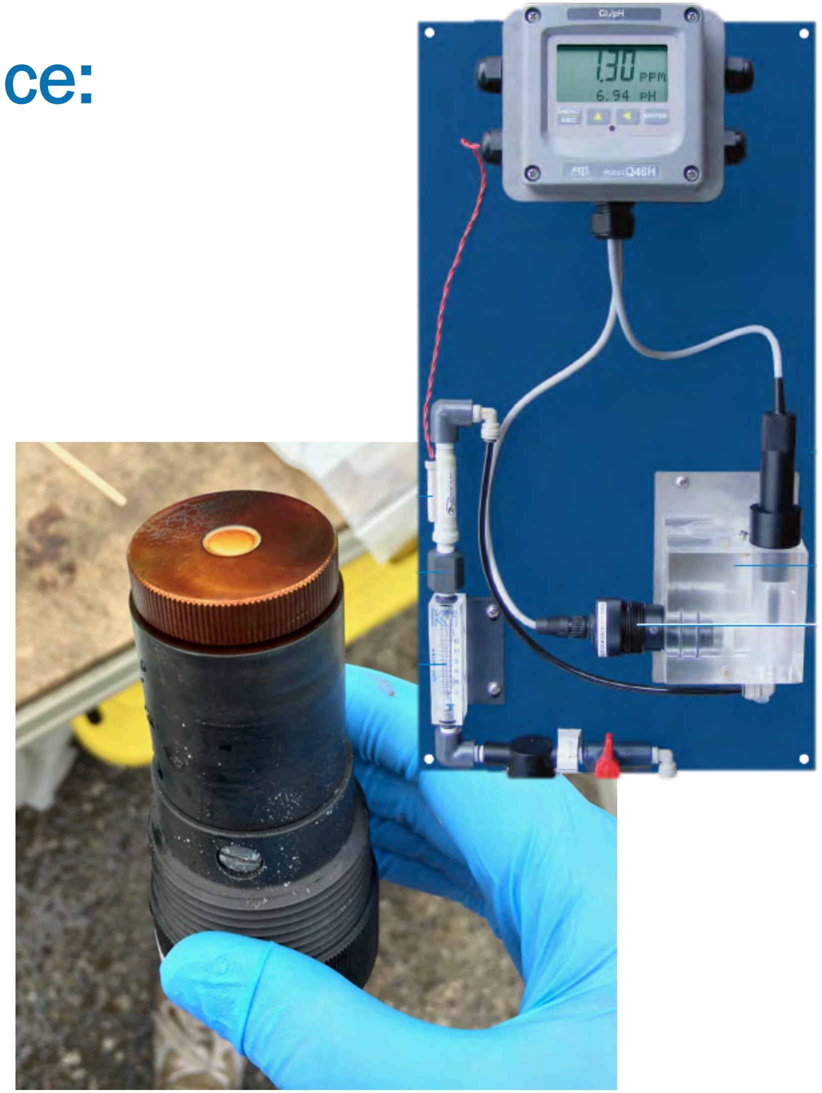
Sample SOPs:

- Safely filling a chemical storage tank
- Shutting down the ONWS system
- Replacing the lamps in a UV reactor
- Replacing the chemical reagent for a chlorine analyzer
- Collecting and analyzing water quality samples
- Equipment calibration

Standard Operating Procedures

Example SOP for chlorine analyzer (FC#2) maintenance:

- Place PLC in "Continuous Dose Mode"
  - Allows operator to disable automatic dose control based on FC#2 residual
- Remove chlorine sensor from flowcell
- Disconnect sensor from digital display
- *etc…*



Analyzer schematic courtesy of ATI, Inc. spec sheet

Course Overview

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Maintenance Plan

- Maintenance activities can be grouped by level:
  - *Level 1:* Routine
  - *Level 2:* Preventative
  - *Level 3:* Equipment repair
  - *Level 4:* Equipment replacement

Maintenance Plan

- Level 1: Routine Maintenance
  - Monitoring and responding to alarms
  - Reviewing operational logs
  - Performing housekeeping
  - Conducting walk-throughs of ONWS system
  - Replacing consumables in analyzers

Maintenance Plan

- Level 1: Routine Maintenance - example

Routine Operations and Maintenance Activities

Daily

- Check for leaks and odors
- Check and respond to any alarms or warnings
- Record key operating parameters
- Perform any required grab sampling (e.g. turbidity and chlorine residual)
- Check and record chemical levels

Weekly

- Check chemical levels and fill as needed
- Drain condensate from air receivers
- Perform any required grab sampling (e.g., total coliform)
- Check biomass color and MLSS, and any signs of foaming
- Inspect screens for any buildup of debris

Monthly

- Perform service and calibration on critical instruments
- Check mixer and aeration distribution is normal
- Check UV sleeve and lamps

Periodic

- Perform chemical cleans on membranes
- Replace UV lamps as needed (typically 12-18 months)
- Replace or refurbish analytical probes as required

Maintenance Plan

- **Level 2: Preventive Maintenance**
  - Tasks performed according to manufacturer requirements and recommendations
  - Work is scheduled and tracked with results recorded
  - Tasks categorized as daily, weekly, monthly, or periodic
  - Results are evaluated and adjustments made to enhance reliability and reduce risk of failure

Preventive > Reactive

✓ Reduces overall maintenance costs
✓ Decreases frequency, cost, and downtime of repairs

Maintenance Plan

- Level 3: Equipment Repair
  - Repair activities may be indicated by inspections, readings, or manufacturer recommendations
  - Should be carried out in a timely fashion and scheduled
- Level 4: Equipment Replacement
  - Replacement activities determined by operational and maintenance data collected over time
    - Based on design criteria, operational data, inspections, and condition assessments
  - May be planned, scheduled, and budgeted for via capital expenditures

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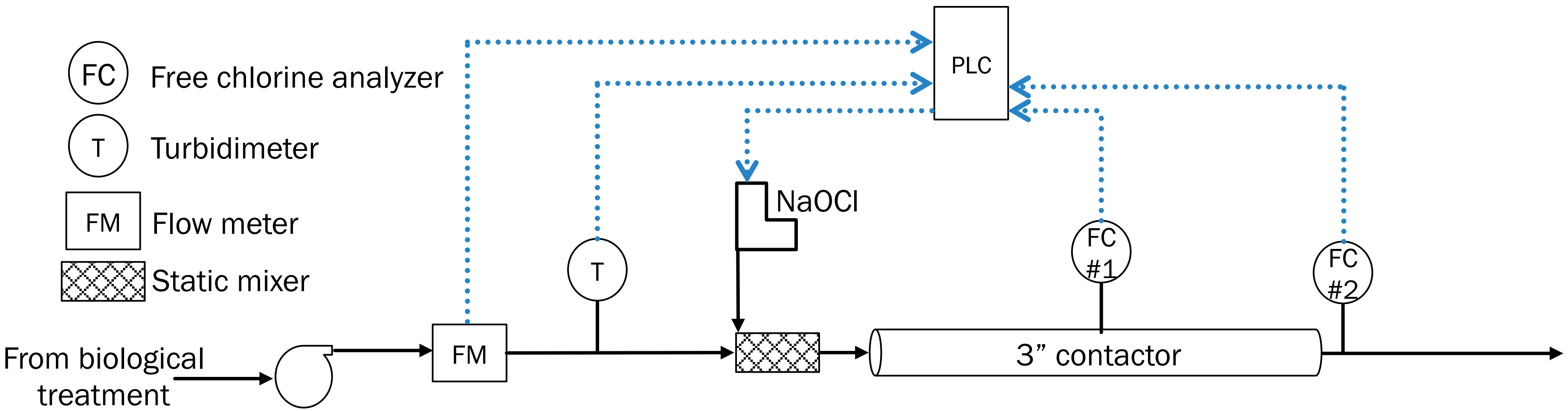
Compliance Reporting

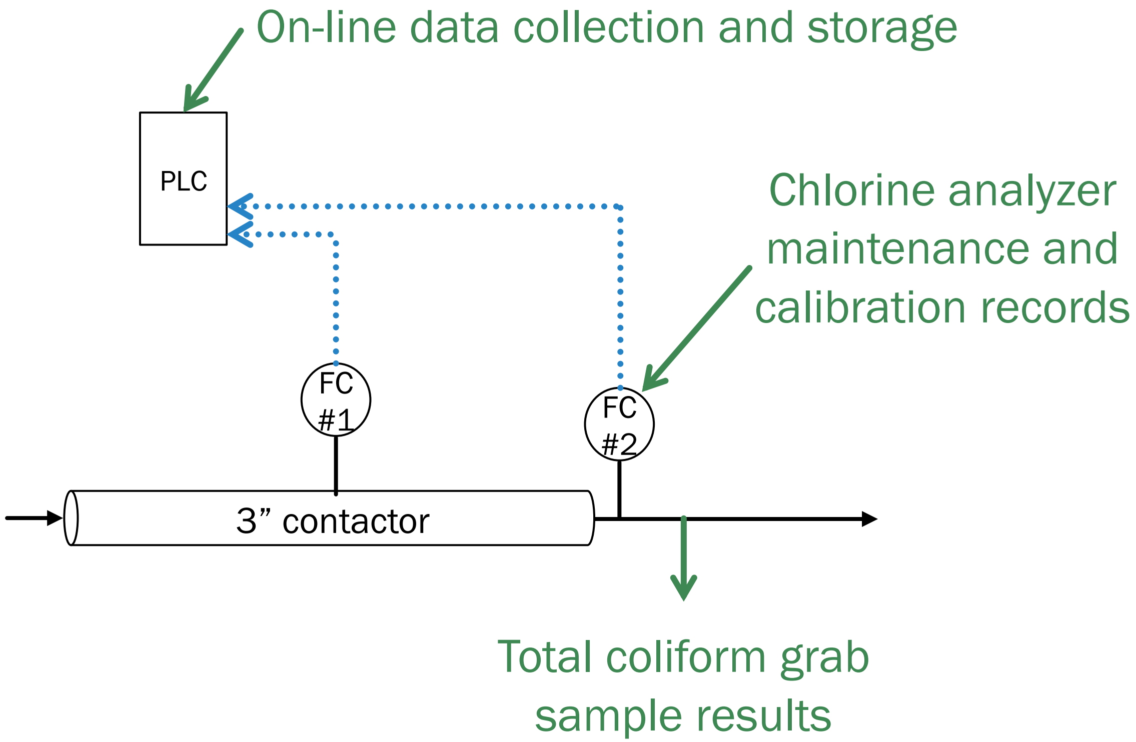
- **Compliance reporting is a regulatory requirement!**
- Ensures ONWS system is meeting conditions of the operating permit
  - Reporting requirements detailed in permit



Was the CT requirement continuously met?

Compliance Reporting

- Data required for compliance reporting may include:
  - On-line process data
  - Grab sample analytical results
  - Maintenance records
  - Meter calibration records
  - System event logs



Compliance Reporting

DESIGN ENGINEER

REGULATOR

Work together to develop the daily and monthly treatment plant report form. Ideally, compliance and operational reporting needs can be combined in a single report format

Course Overview

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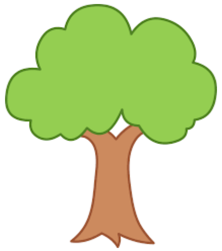
Environment, Health and Safety Plan

- Communicate and implement practices of environmental protection and workplace safety

Health and Safety

- ✓ Complies with OSHA regulations
- ✓ Develops procedures for identifying workplace hazards
- ✓ Reduces accidents and exposure to harmful situations



Environmental

- ✓ Creates system approach to comply with environmental regulations
- ✓ Considers air quality, hazardous material containment, *etc.*

Environment, Health and Safety Plan

- A **chemical safety plan** is an essential element of an Environment, Health and Safety Plan
- Safety data sheets (SDS) and a site map should accompany the plan

Hazardous Material Storage and Management

- Provide inventory of hazardous substances and their locations
- Provide proper labeling, secondary containment, and compatible storage materials where needed
- Follow applicable rules for inspection procedures and documentation

Personal Protective Equipment

- Identify appropriate PPE for each chemical onsite and each activity involving hazardous substances
- Store necessary PPE onsite for handling of hazardous materials

Eyewash and Shower Stations

- Identify appropriate use procedures, station locations, frequency of inspections, and inspection protocols
- Provide description of maintenance procedures and frequency

Chemical Spill Kits

- Store near chemical storage sites
- Provide list of spill kit contents for each chemical stored onsite
- Inspect kits regularly and document inspection results

Chemical Deliveries

- Use licensed carrier to transport hazardous materials
- Provide list of chemical suppliers and contact information
- Describe procedures for receiving chemical deliveries, including receiving location, minimum training requirements, precautions needed, etc.

Course Overview

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Emergency Response Plan

Provides:

SYSTEM OWNER

+

OPERATOR

+ outside agencies

a description of procedures that will be implemented in the event of an emergency

Emergency Response Plan

- Procedures designed to protect the public and emergency personnel
- Key elements include:
  - ONWS system operator/owner contact information
  - Evacuation plan
  - Emergency contacts (fire, police, poison control center, *etc*.)
  - Natural disaster response procedures
  - Power outage response procedures
  - *Etc.*

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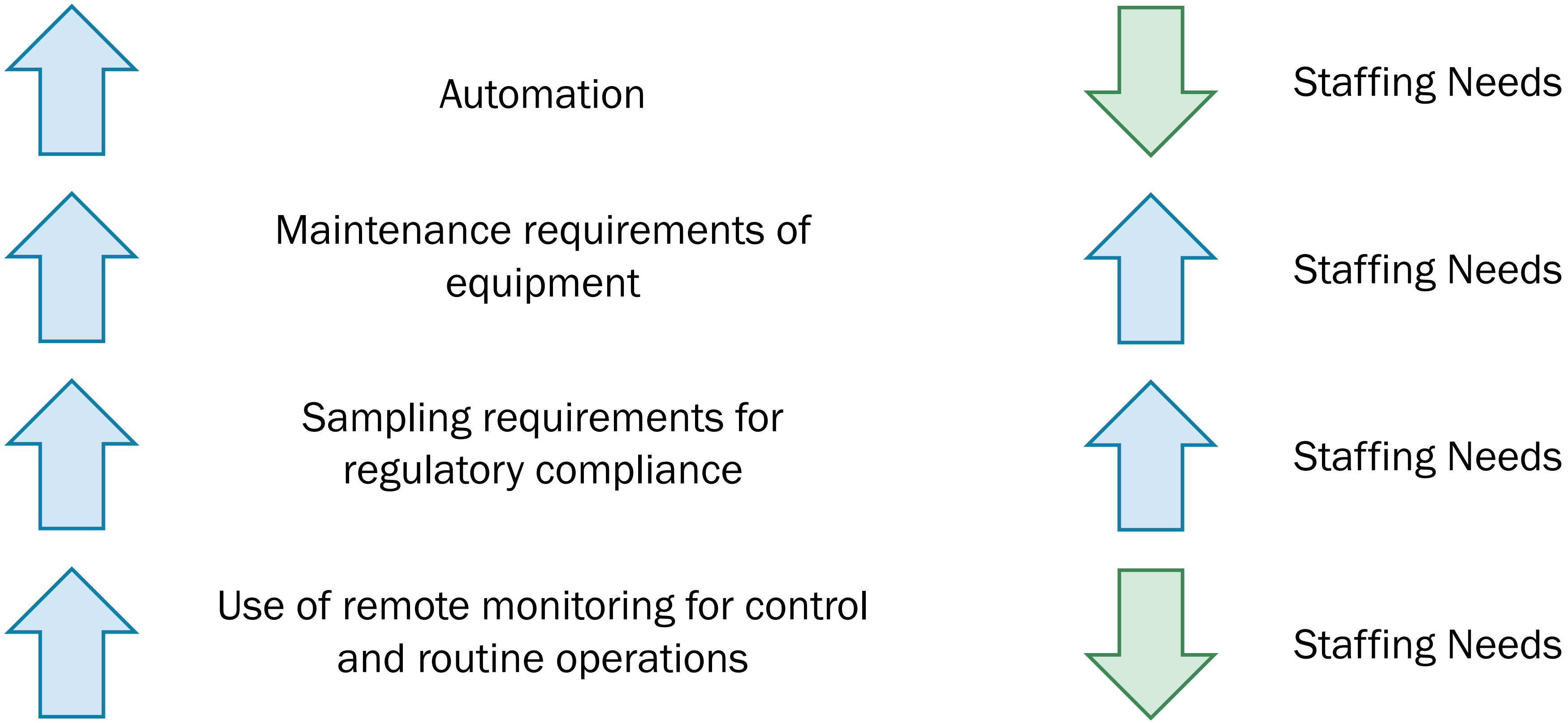
O&M Staffing Plan

- An O&M Staffing Plan should be developed well before commencement of start-up
- Key questions:
  - How many hours per day or week are on-site staff needed to support the ONWS system?
  - What type of staff are needed to both operate and maintain the ONWS system?
  - What type of training do staff need to successfully operate the ONWS system?

O&M Staffing Plan

- How many hours per day or week are on-site staff needed to support the ONWS system?



O&M Staffing Plan

- **What type of staff are needed to both operate and maintain the ONWS system?**
  - Requirements may vary by jurisdiction
  - Full-time, part-time, on-call, or service contractors may be used
- Special considerations:
  - Highly automated systems tend to be more complex when maintenance is required
  - Biological treatment may require staff with specific training

O&M Staffing Plan

- What type of training do staff need to successfully operate the ONWS system?
  - Some level of training should be provided to all staff engaged in ONWS system
  - Often provided by:

\+ equipment manufacturers

  - Should include training materials to augment the O&M Manual, SOPs, Environment, Health and Safety Plan, *etc.*

Course Overview

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Commissioning and Acceptance Test Plan

- Describes specific procedures to ensure both design and performance specifications are met
- Confirms compliance with regulations
- Defines schedule and duration of commissioning
- Provides documentation of system performance expectations

Commissioning Test Plan Checklist

- [ ] Set up system to ensure all treatment processes receiving pathogen credit can be sampled
- [ ] Ensure treated water can be discharged safely, e.g. to sewer
- [ ] Ensure adequate chemicals and consumables are available
- [ ] Notify relevant agencies about test plan and schedule
- [ ] Verify system controls are effective for ensuring LRT compliance, for example:
  - [ ] *Low UVI alarm*
  - [ ] *Low chlorine residual alarm*
  - [ ] *High turbidity alarm*
  - [ ] *Other critical LRT compliance alarms*
- [ ] Provide results to relevant agencies

Course Overview

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  - Process Optimization

Process Optimization

- Optimization has many benefits:
  - ✓Operator ownership in performance of system
  - ✓Reduced energy and chemical usage
  - ✓Reduced operating costs
  - ✓Improved reliability
  - ✓Consistent regulatory compliance to protect public health

Process Optimization

- **The path to optimization may include:**
  - Testing beyond routine requirements
  - Regular review and trending of operational data to identify trends, spot unexpected changes, and determine causation between certain system factors
- **Optimization examples:**
  - Tuning a control loop to prevent overdosing of chlorine
  - Determining the optimal frequency to change cartridge filter
  - Adjusting operation of biological treatment to reduce organic loading downstream

Problem Solving Exercises

What are some of the goals of ONWS system design and operation:

- A. Meet or exceed all compliance objectives to protect public health
- B. Minimize costs of ONWS treatment processes and O&M
- C. Maintain reliability and uptime of equipment
- D. Ensure the safety of all operating personnel
- E. All the above

What is *not* an element of an Operations Plan:

- A. Process Design and Control Theory Descriptions
- B. Engineering Plan
- C. Maintenance Plan
- D. Emergency Response Plan
- E. Commissioning and Acceptance Test Plan

What are examples of alarm categories that may be used for an ONWS:

- A. LRT compliance alarm
- B. Water quality alarm
- C. Operator safety alarm
- D. Operational alarm
- E. All the above

What is *not* a maintenance level described in this presentation:

- A. Routine
- B. Preventative
- C. Equipment repair
- D. Troubleshoot
- E. Equipment replace

What information may be required for compliance reporting:

- A. On-line process data
- B. Maintenance records
- C. System event logs
- D. All the above
- E. None of the above

Select impact on staffing needs

Select whether the situation on the left increases or decreases staffing needs:

Staffing Needs:

1. Automation — OR ?
2. Maintenance requirements of equipment — OR ?
3. Sampling requirements for regulatory compliance — OR ?
4. Use of remote monitoring for control and routine operations — OR ?

What are the main objectives of a commission and acceptance test plan:

- A. Confirms compliance with regulations
- B. Provides documentation of system performance expectations
- C. Describes specific procedures to ensure both design and performance specifications are met
- D. All the above
- E. None of the above

Module 10: Regulatory and Permitting Plan

Training Modules

1. Introduction
2. Public Health Goals
3. Treatment Selection and Crediting Overview
4. Treatment Selection and Crediting: Biological Treatment
5. Treatment Selection and Crediting: Filtration
6. Treatment Selection and Crediting: Disinfection
7. Treatment Selection and Crediting: Flow Equalization and Distribution
8. Developing Multiple Barrier ONWS Systems
9. Operations Plan
10. Regulatory and Permitting Plan

Learning Objectives

- Importance of communication between the project team and regulators
- Steps of the regulatory process and how to navigate them
- Key documentation required for regulatory compliance

Primary Target Audience

Primary Audience:

DESIGN ENGINEER

REGULATOR

OPERATOR

PROGRAM ADMINISTRATOR

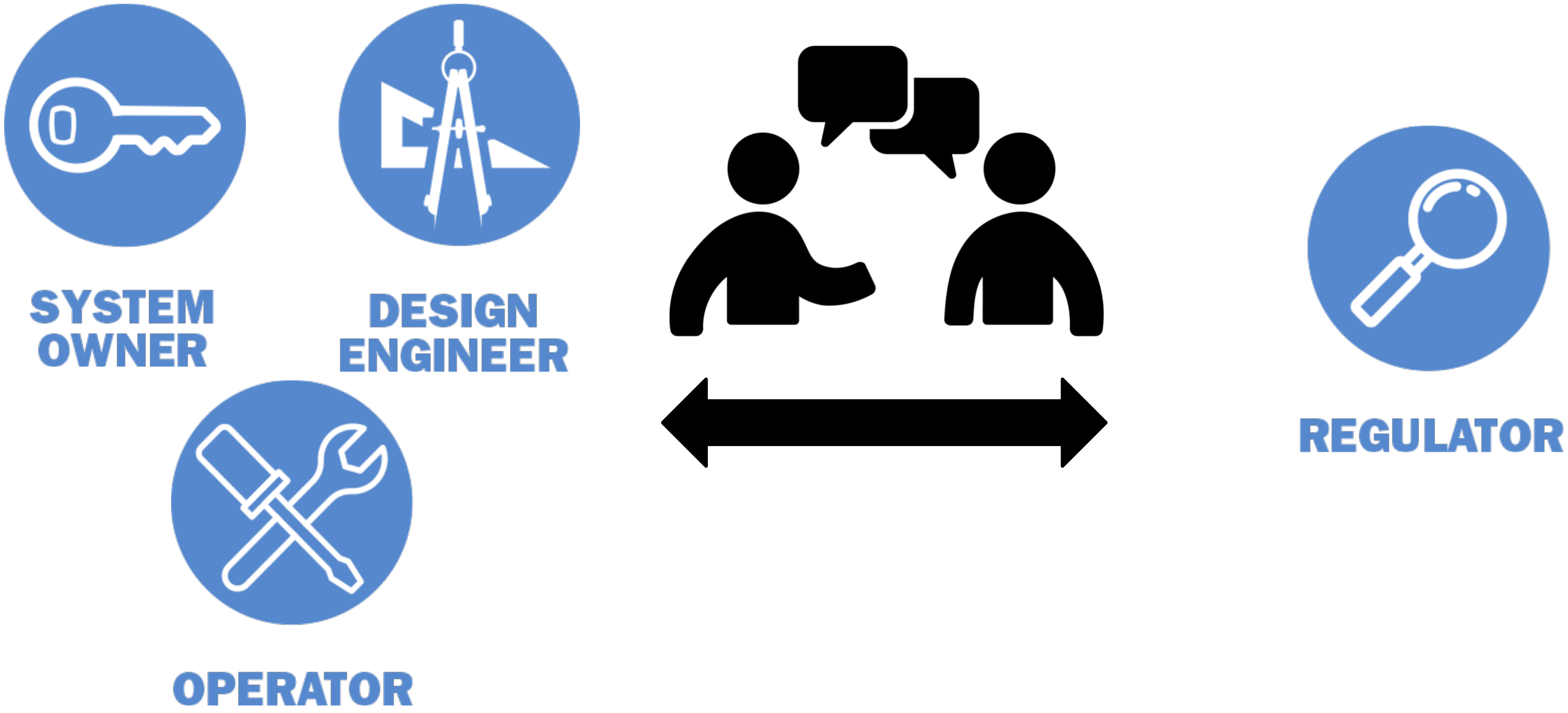
General Awareness:

SYSTEM OWNER

Communication is Key…

Project Team

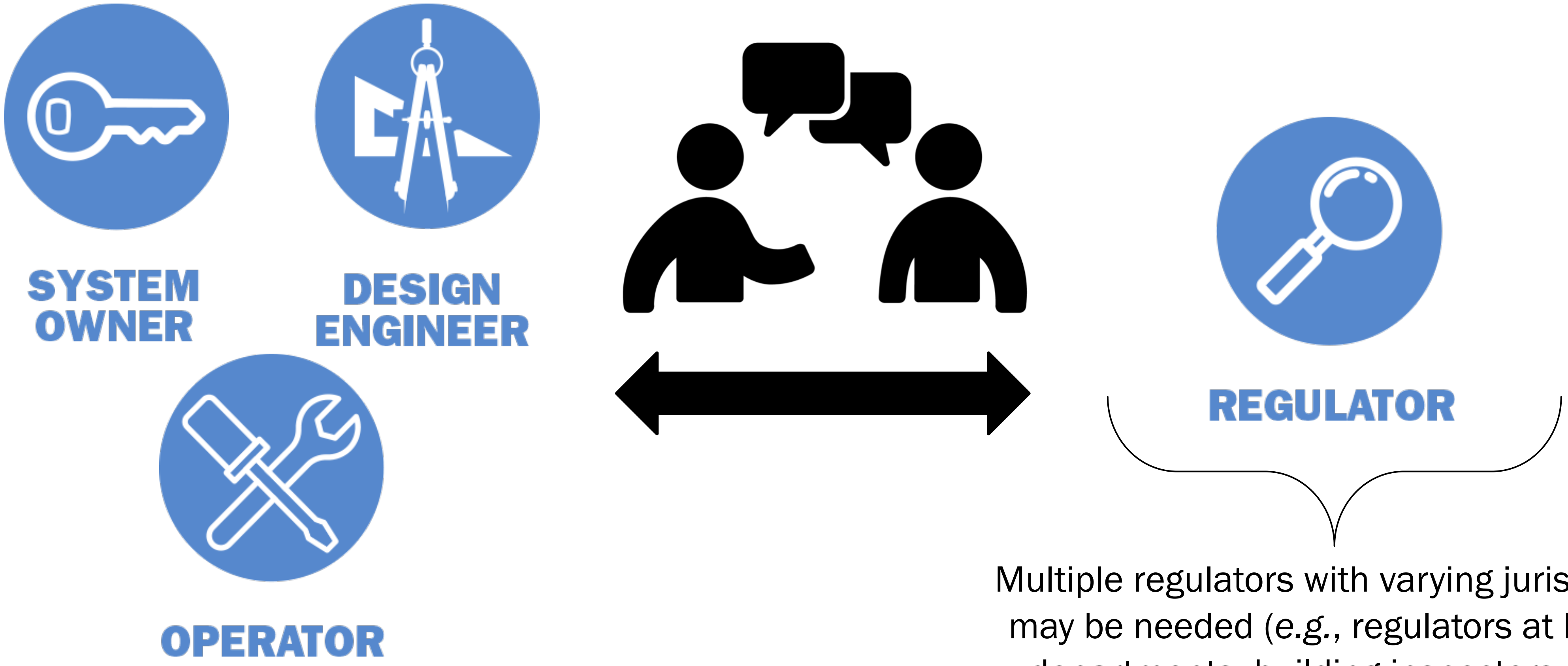
Regulators



Communication is Key...

Project Team

Regulators



Multiple regulators with varying jurisdiction may be needed (*e.g.*, regulators at health departments, building inspectors, *etc.*)

Communication is Key…

… to efficient and successful ONWS implementation

- **Early and frequent communication minimizes:**
  - Costly last-minute revisions to ONWS design
  - Start-up delays due to permitting issues
  - Risk of non-compliance from insufficient monitoring capabilities

Communication is Key Throughout Implementation

PROJECT TEAM	REGULATOR
INITIAL PROJECT DEVELOPMENT	
• Project Application	• Review and approve Project Application
PRELIMINARY DESIGN	
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FINAL DESIGN, CONSTRUCTION, AND INITIAL INSPECTIONS	
• 100% Design • Engineering Report (Final) • Operations and Maintenance Plan including Commissioning Plan • Construction • Cross-connection inspection	• Permit to Operate
PROJECT STARTUP	
• Commissioning	• Installation inspection • Permit to Use
ON-GOING MONITORING AND REPORTING	
• On-going monitoring and reporting	• Performance and water quality data review • Inspections and enforcement • Periodic permit renewal

Multiple opportunities to evaluate projects and ensure compliance

Course Overview

- Initial Project Development and Preliminary Design
- Final Design, Construction, and Initial Inspections
- Project Startup and Commissioning
- On-Going Monitoring, Reporting, Inspection and Enforcement

Course Overview

- Initial Project Development and Preliminary Design
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Initial Project Development and Preliminary Design

- Project Application
- Preliminary Design
- Engineering Report

REGULATOR

PROJECT TEAM	REGULATOR
INITIAL PROJECT DEVELOPMENT	
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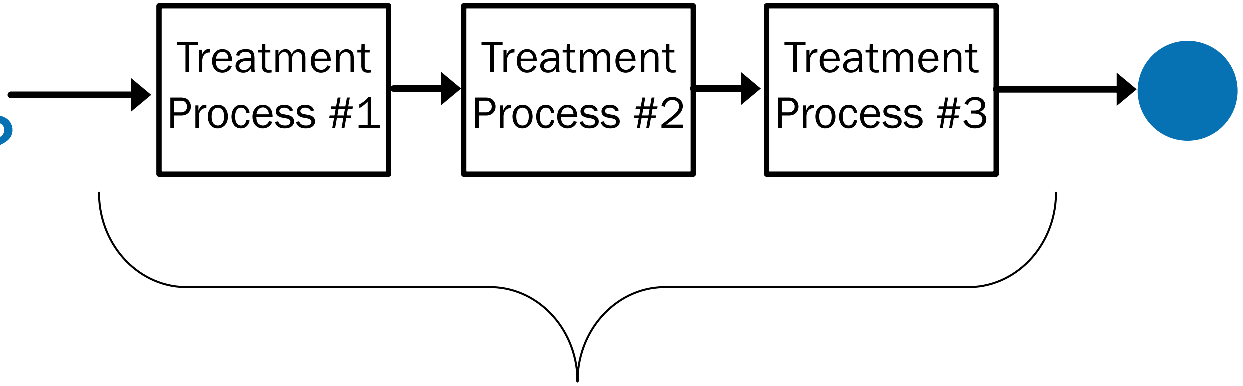
Initial Project Development and Preliminary Design

- **Project Application** includes basic information about the ONWS system:

Project team?

Source Water type?



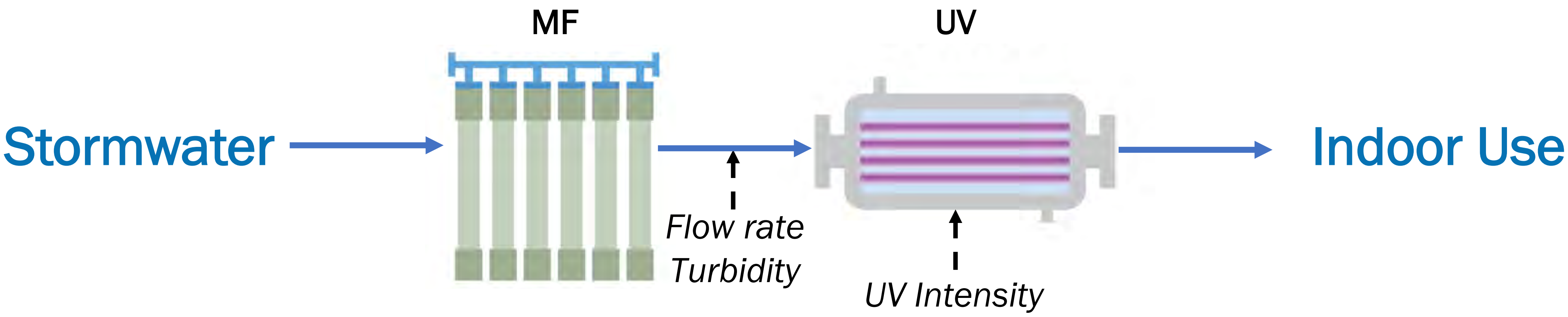
Intended end uses?

Size and location?

Scale – building-scale or district-scale?

Initial Project Development and Preliminary Design

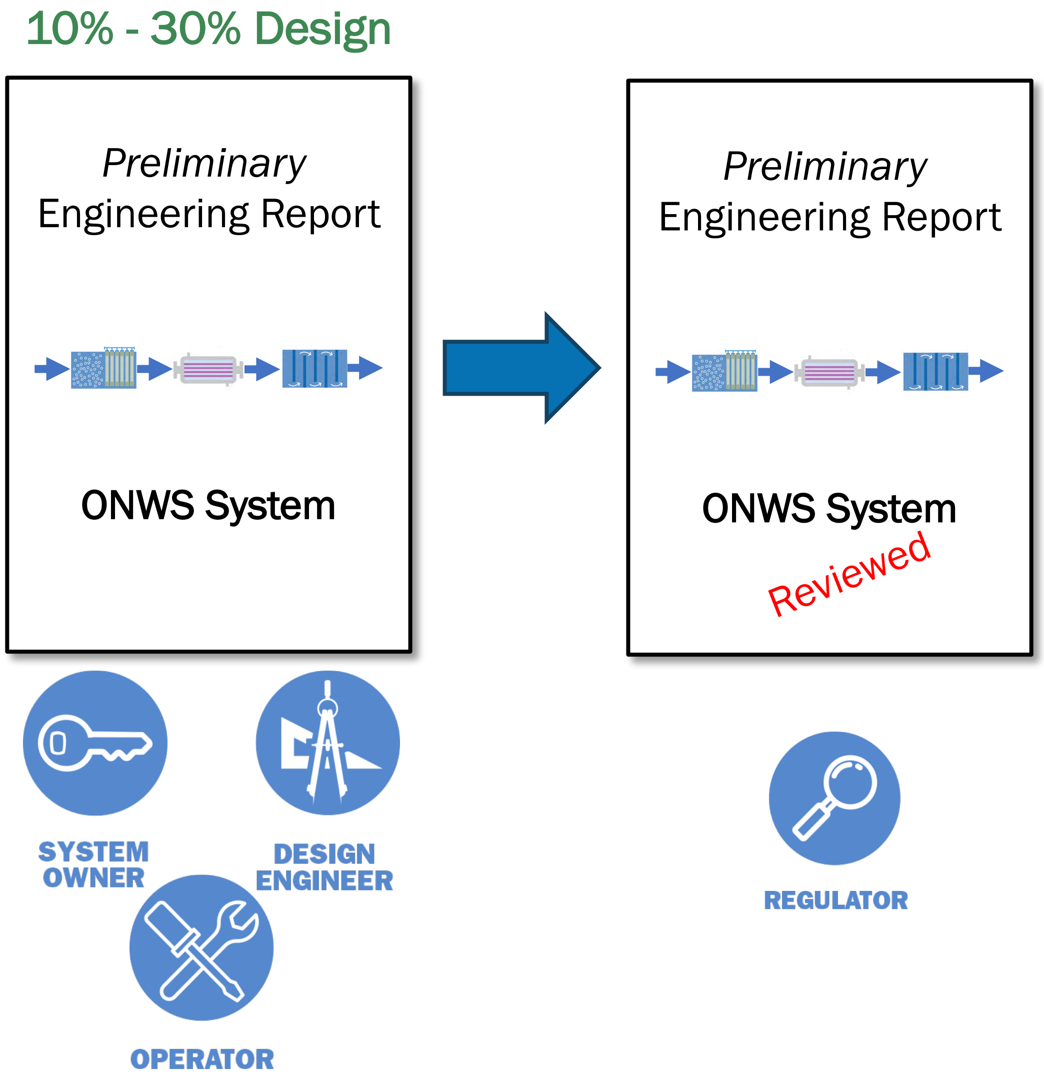
- **Preliminary Design** at 10% - 30% includes:
  - Selected treatment processes and basic process control description
  - Monitoring capabilities
- **Engineering Report**
  - Describes how design complies with requirements for ONWS including LRTs



✓LRV ≥ LRT for virus, protozoa, and bacteria

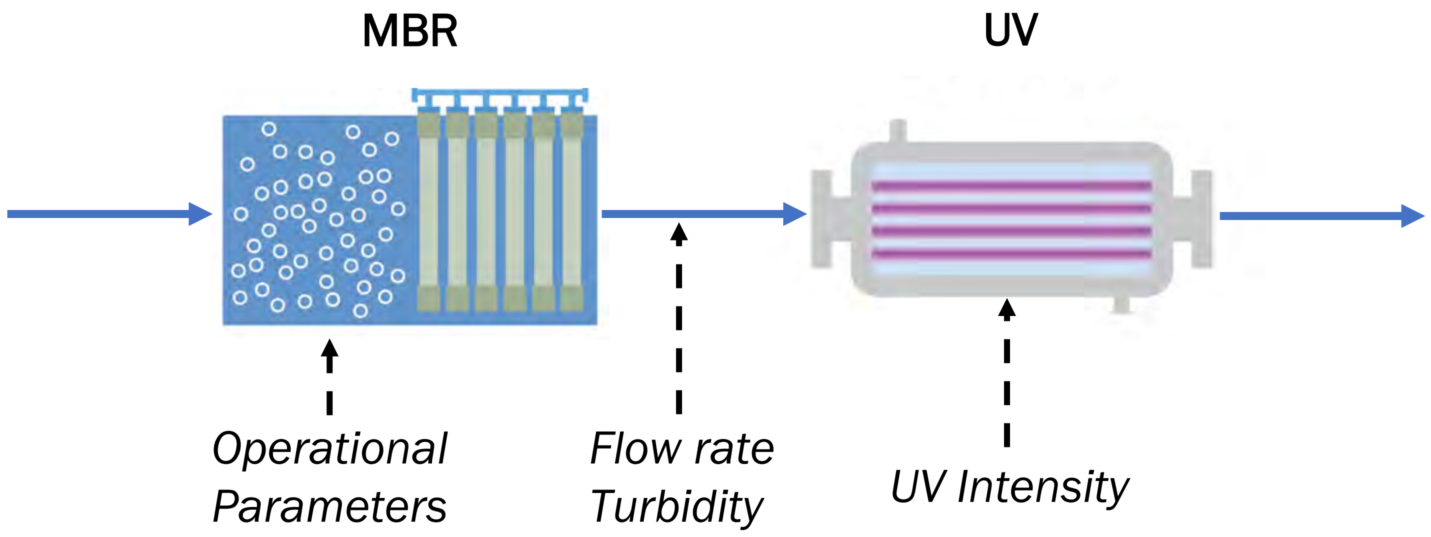
Initial Project Development and Preliminary Design

- **Engineering Report** describes how the project meets applicable regulatory requirements
- Report must be stamped by a PE registered in the relevant state with experience in water and/or wastewater
- Submitted at least twice throughout development process:
  - 10 - 30% design
  - 60 – 100% design



Initial Project Development and Preliminary Design

Preliminary Engineering Report for blackwater ONWS system for indoor end uses:

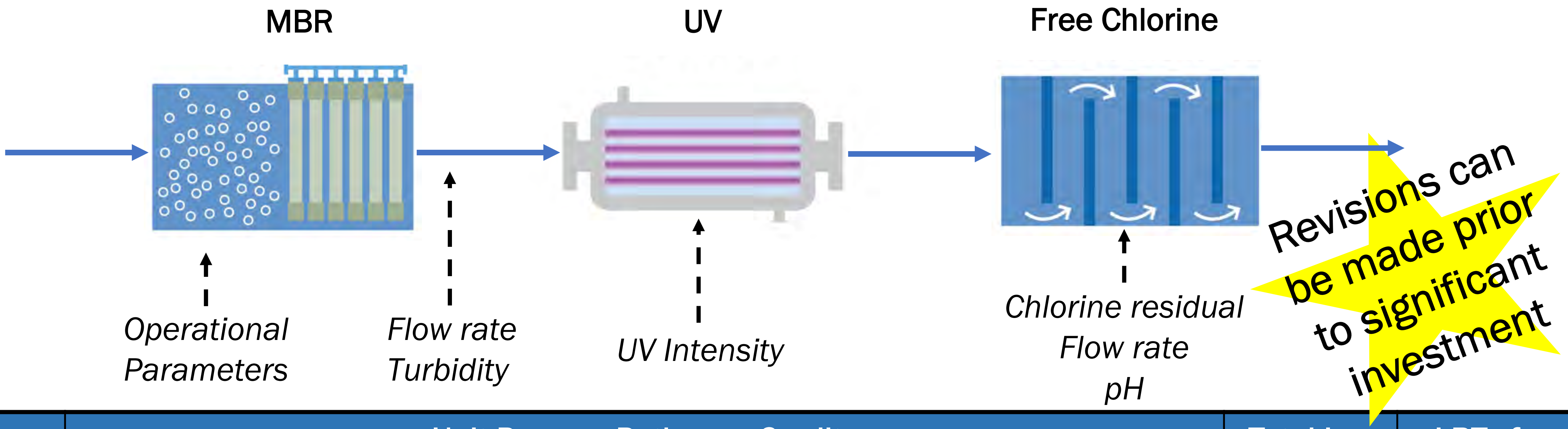


Regulators can point out inadequacies early

	Unit Process Pathogen Credits		Total Log Removal	LRT for Blackwater
	MBR	UV		
Virus	1.5	6.0	7.5	8.5 ✗
Protozoa	2.0	6.0	8.0	7.0 ✗
Bacteria	4.0	6.0	10.0	6.0 ✓

Initial Project Development and Preliminary Design

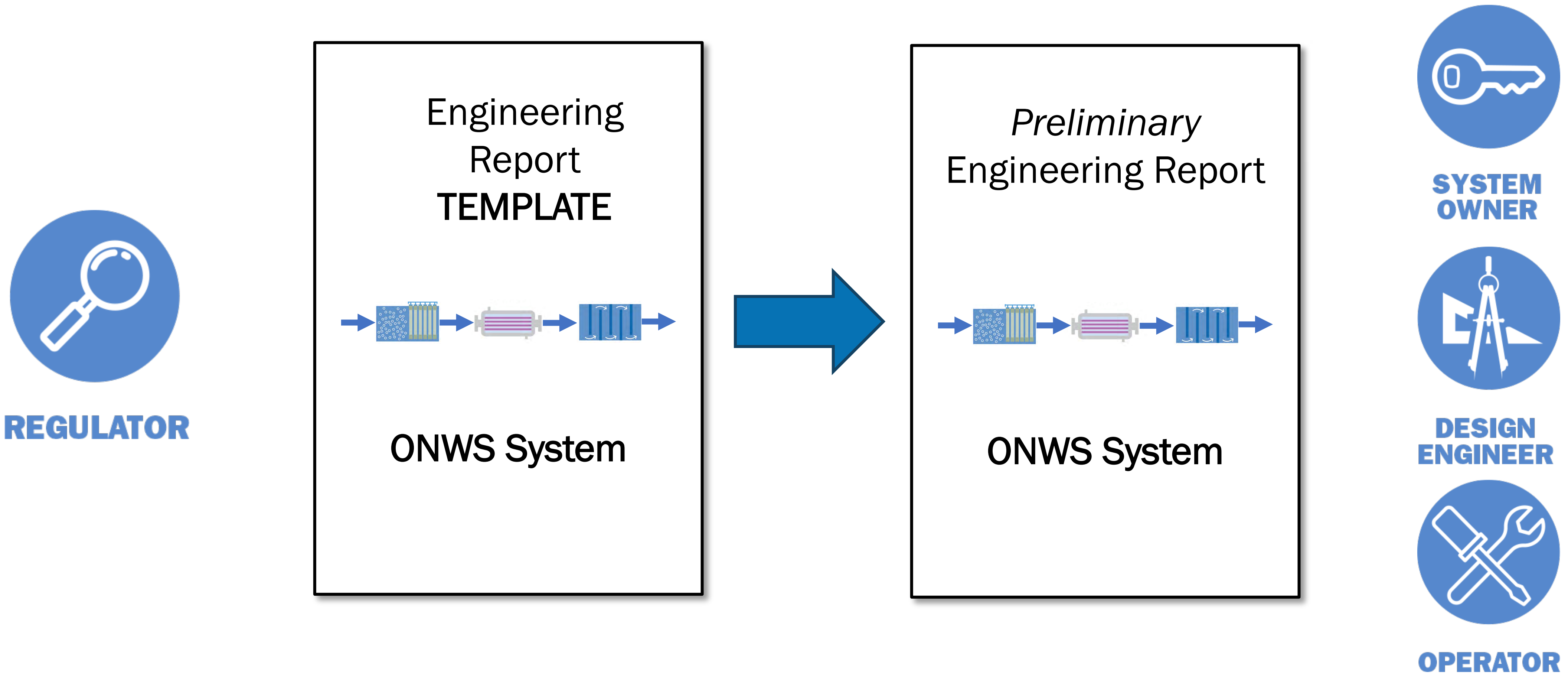
Preliminary Engineering Report for blackwater ONWS system for indoor end uses:



	Unit Process Pathogen Credits			Total Log Removal	LRTs for Blackwater
	MBR	UV	Free Chlorine		
Virus	1.5	3.5	5.0	10.0	8.5 ✓
Protozoa	2.0	6.0	0.0	8.0	7.0 ✓
Bacteria	4.0	3.5	5.0	12.5	6.0 ✓

Initial Project Development and Preliminary Design

- Report template can streamline regulatory review

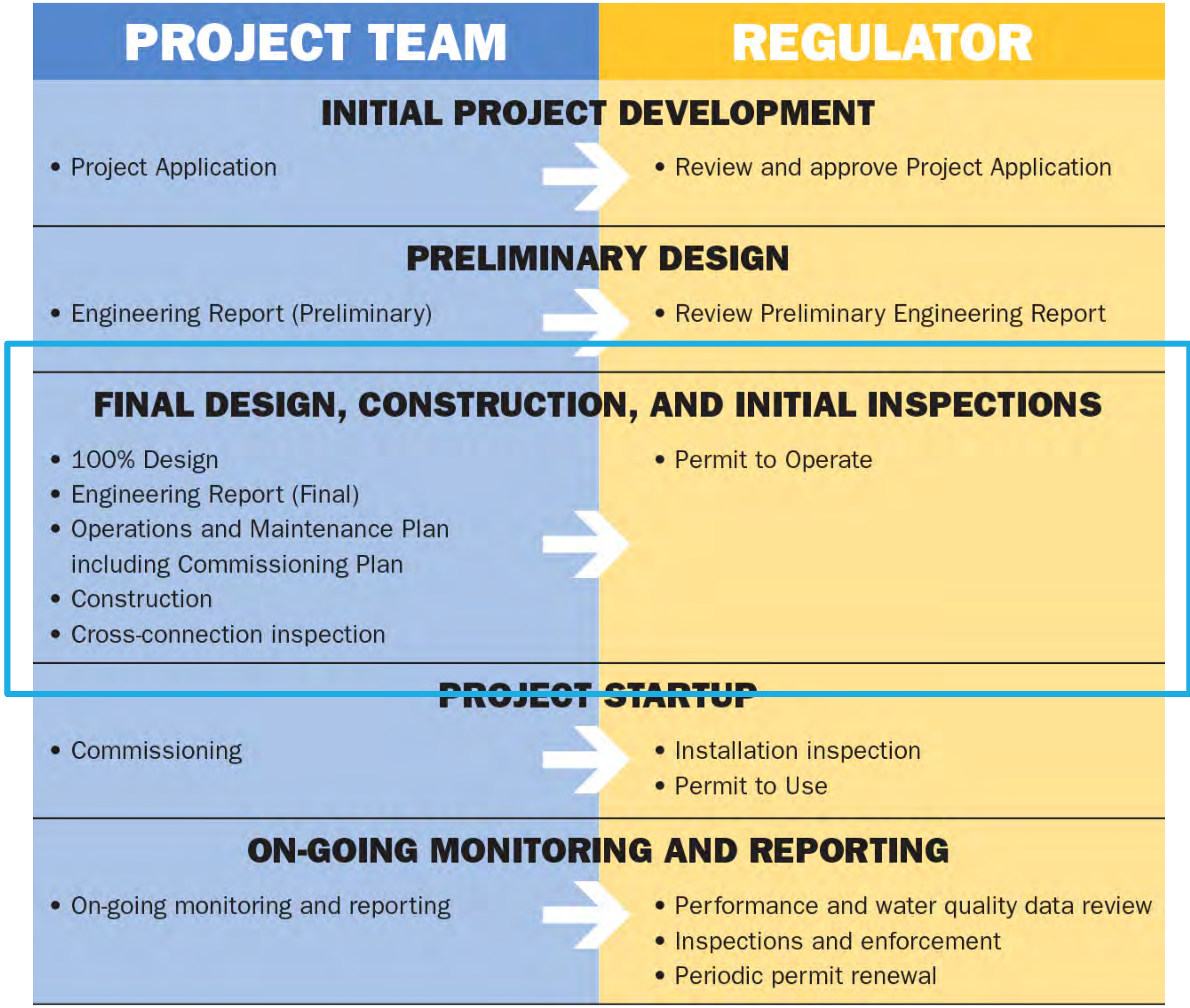


Course Overview

- Initial Project Development and Preliminary Design
- **Final Design, Construction, and Initial Inspections**
- Project Startup and Commissioning
- On-Going Monitoring, Reporting, Inspection and Enforcement

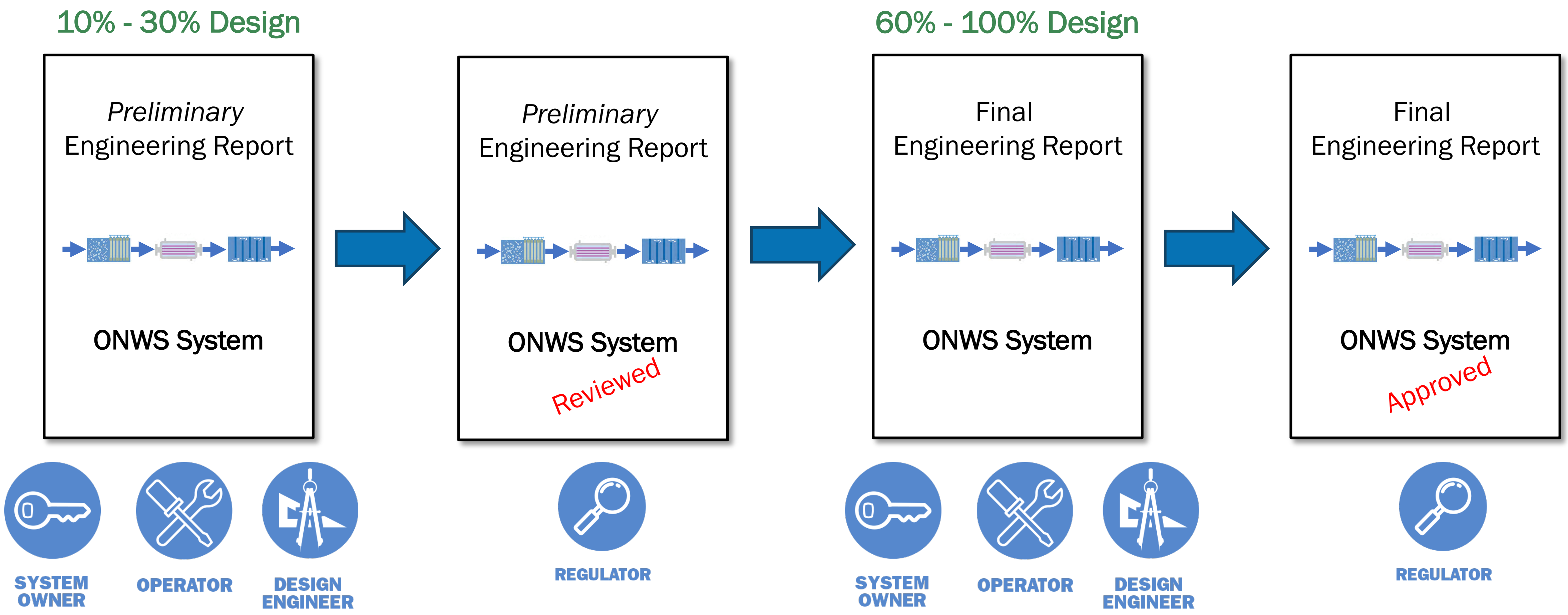
Final Design, Construction, and Initial Inspections

- Final Design and Engineering Report
- Operations Plan
- Cross-Connection Inspection
- Permit to Operate



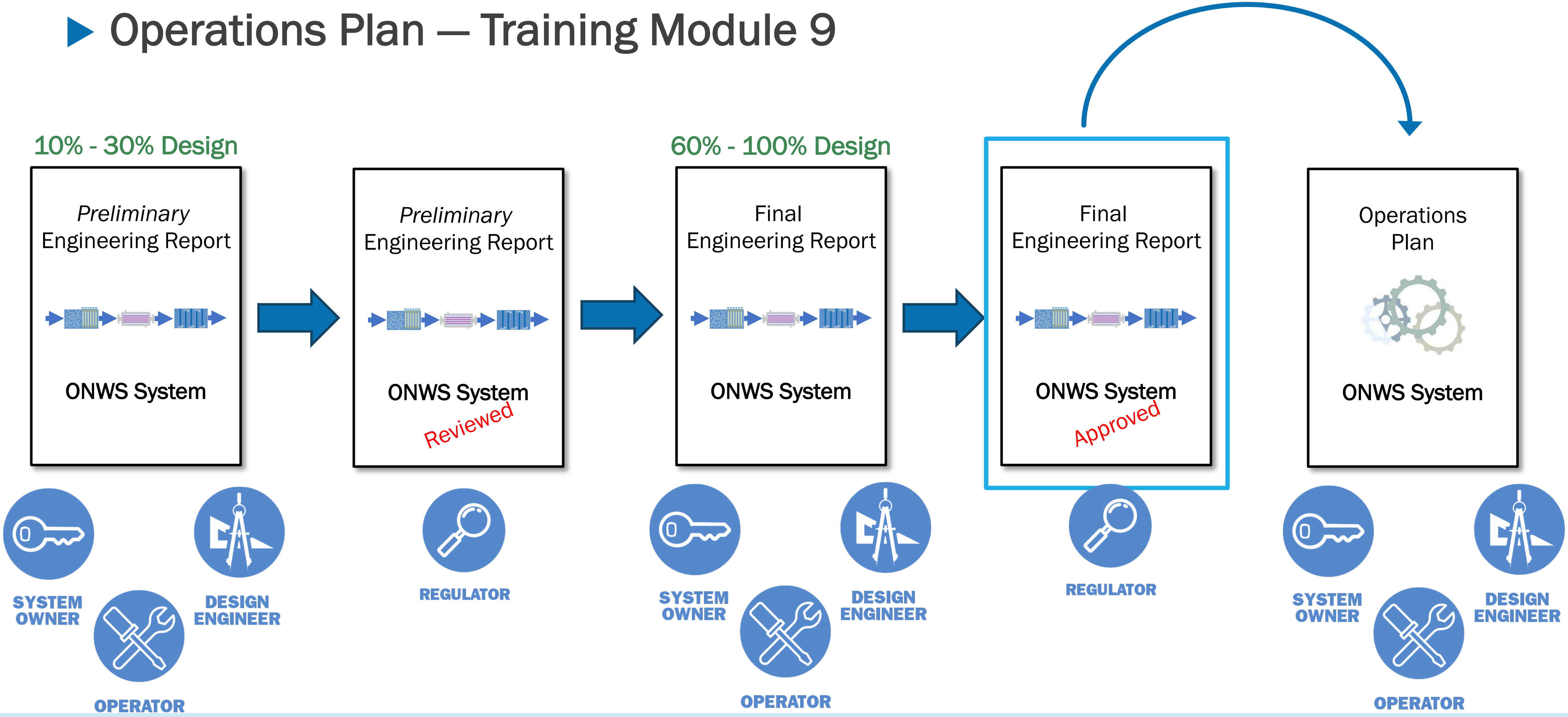
Final Design, Construction, and Initial Inspections

- Final Design and Engineering Report



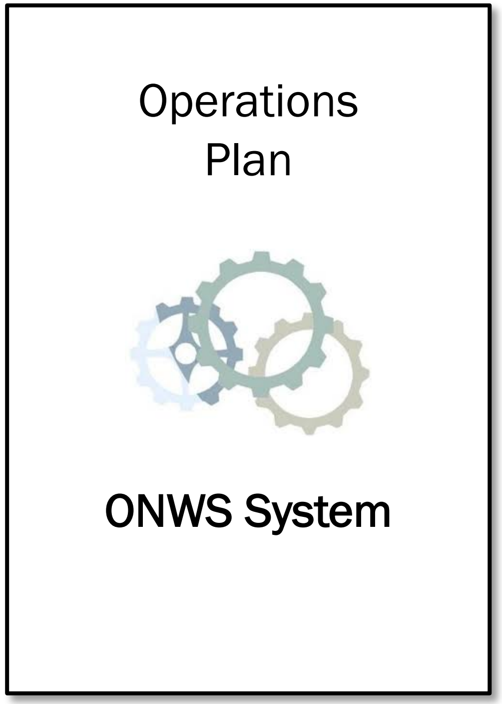
Final Design, Construction, and Initial Inspections

- Operations Plan — Training Module 9



Final Design, Construction, and Initial Inspections

- Operations Plan — Training Module 9
- Focused on:
  - Operation
  - Monitoring
  - Reporting
- Requirements may vary depending on project jurisdiction

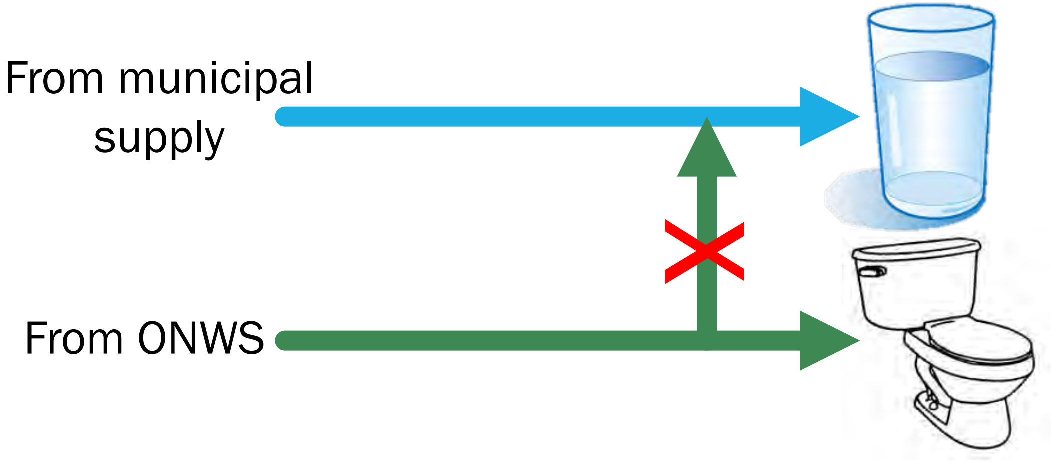


Final Design, Construction, and Initial Inspections

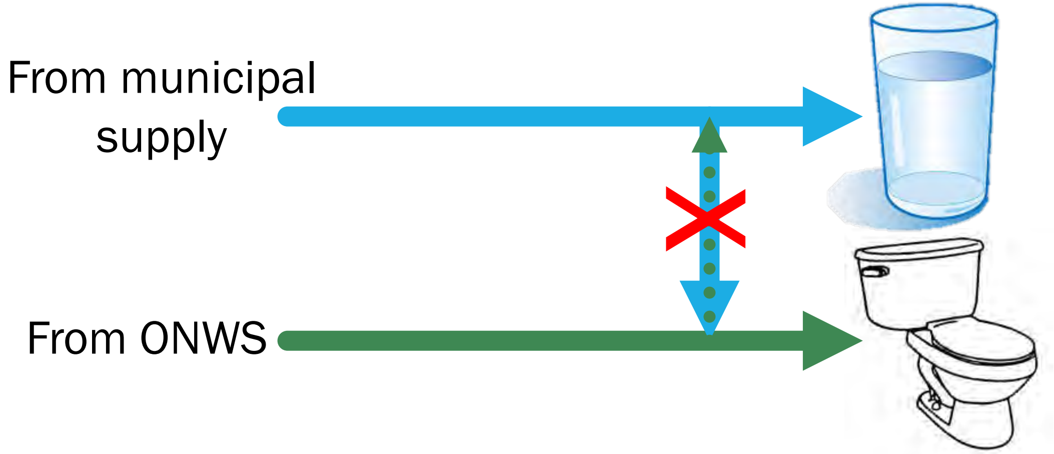
- **Cross-Connection Inspection** is required to ensure proper separation of ONWS product water and potable water
- May occur during and/or after construction is complete
- Numerous other inspections may be required and will vary depending on jurisdiction

Final Design, Construction, and Initial Inspections

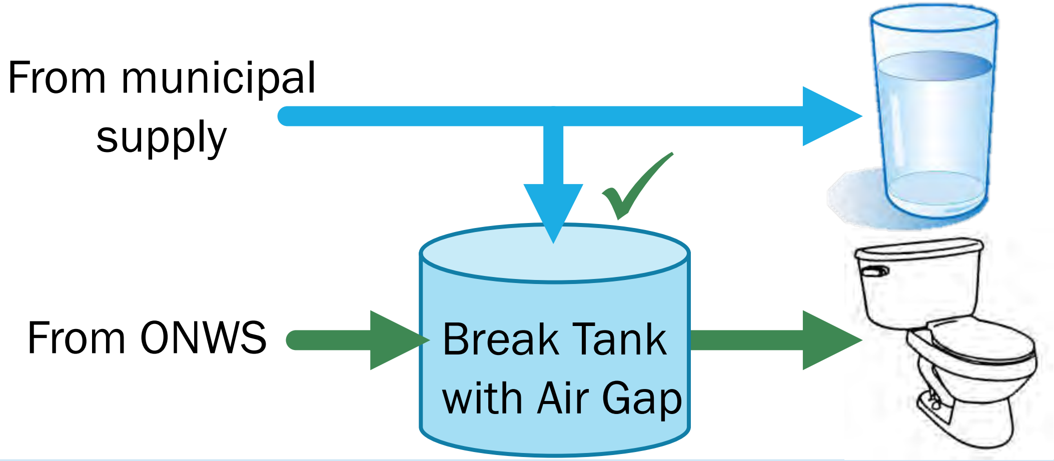
Cross Connection



Backflow Prevention



Example Backflow Prevention:



Final Design, Construction, and Initial Inspections

- **Permit to Operate** provided by the regulators after review and approval of key documents

REGULATOR

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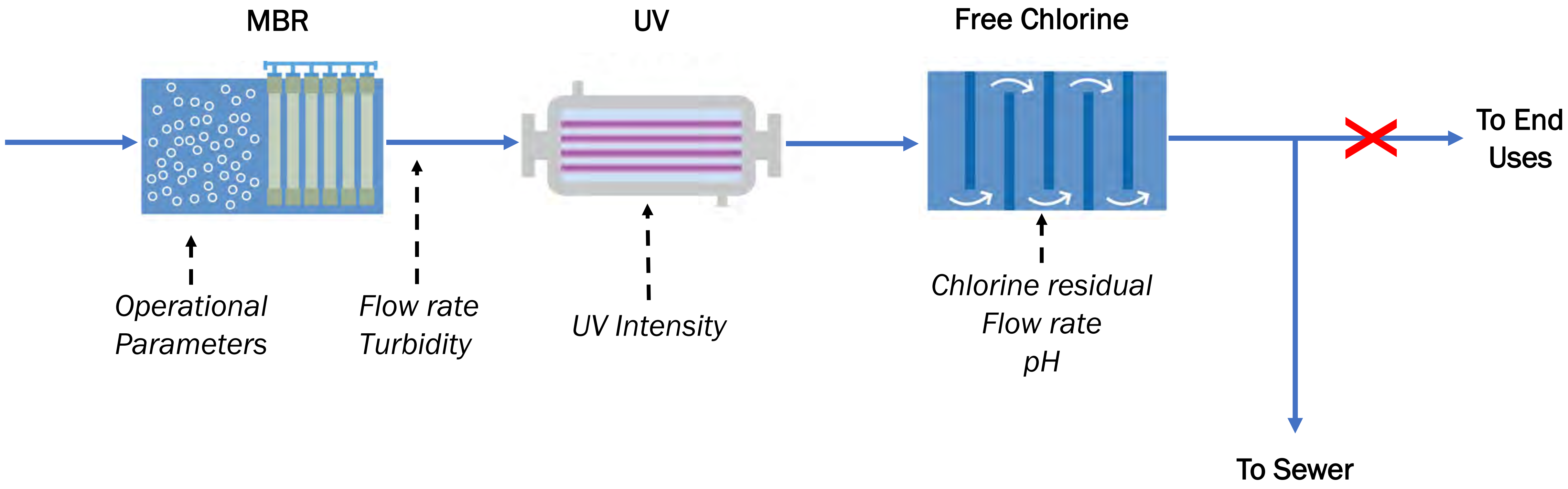
Final Design, Construction, and Initial Inspections

- **Permit to Operate** for start-up and commissioning, but not necessarily for distribution



Course Overview

- Initial Project Development and Preliminary Design
- Final Design, Construction, and Initial Inspections
- **Project Startup and Commissioning**
- On-Going Monitoring, Reporting, Inspection and Enforcement

Project Startup and Commissioning

- Installation Inspection
- Commissioning
- Permit to Use

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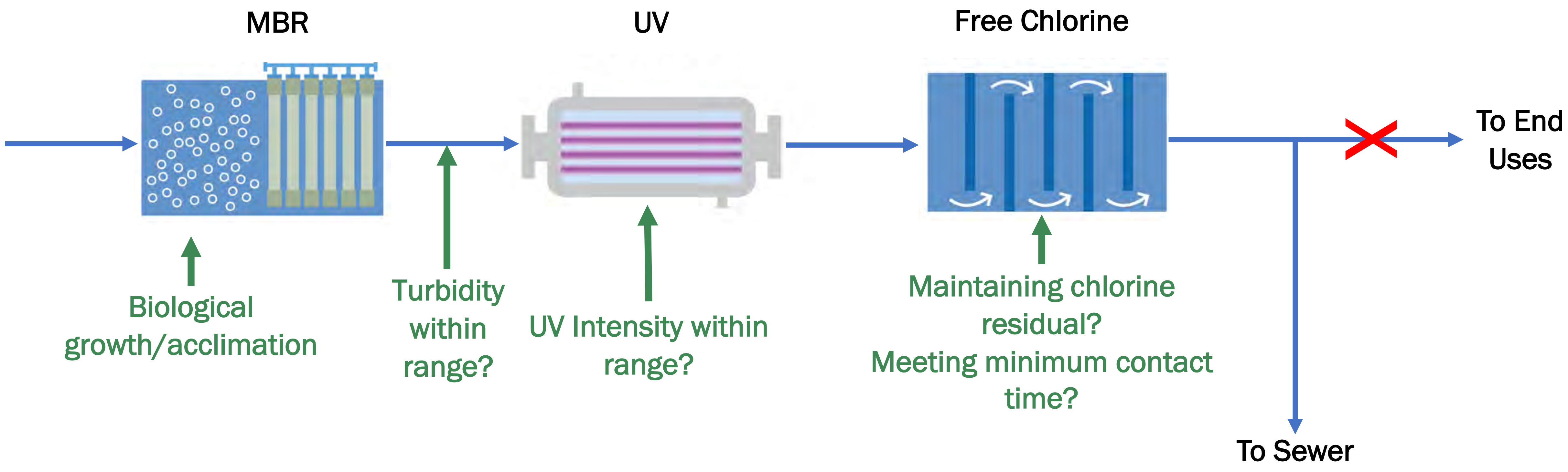
Project Startup and Commissioning

- **Installation Inspection** involves verifying proper installation, calibration, and function of treatment processes
- Project startup and acclimation period

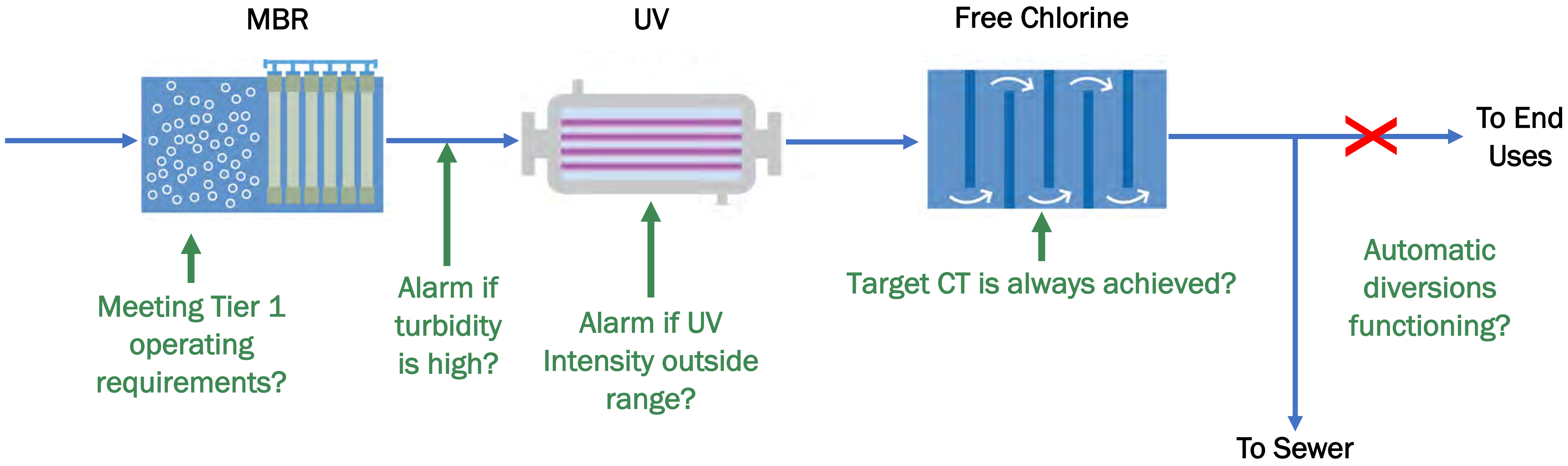


Project Startup and Commissioning

- **Installation Inspection** includes confirmation of:
  - Installation of proper monitoring at specified locations
  - Use of specified chemicals
  - Installation of correct unit process equipment
  - Presence of flow diversions
  - Provision of back-up wastewater disposal and supply options

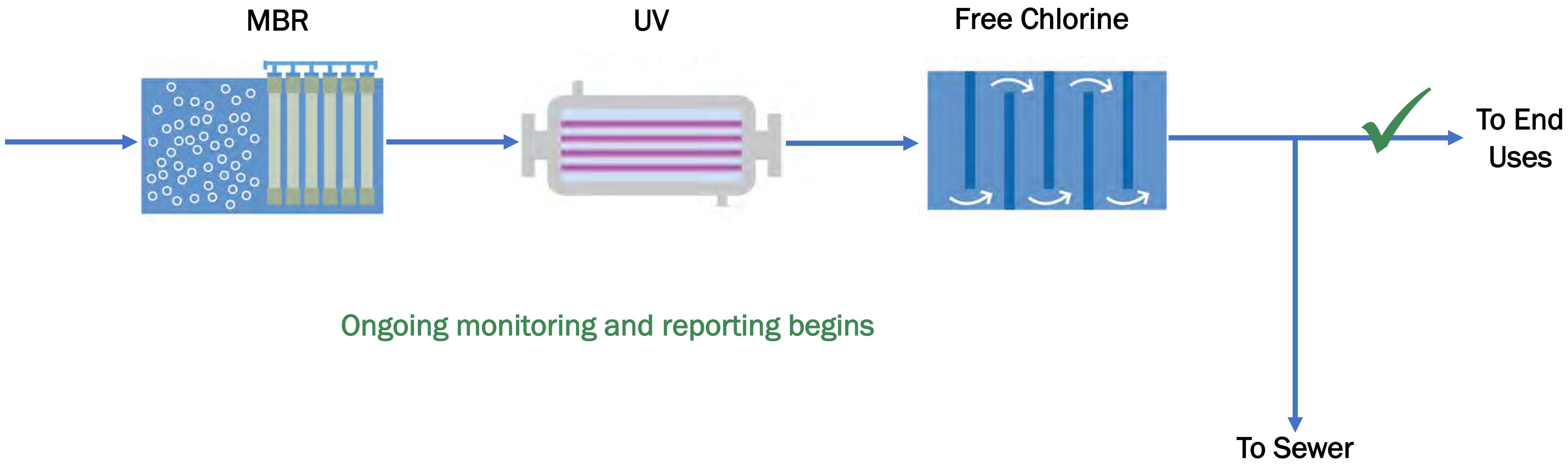
Project Startup and Commissioning

- **Commissioning** to verify proper functioning of critical system elements and expected design performance



Project Startup and Commissioning

- **Permit to Use** is issued by the regulator when sufficient documentation of the commissioning phase has been provided.
- Requirements vary depending on jurisdiction



Ongoing monitoring and reporting begins

Course Overview

- Initial Project Development and Preliminary Design
- Final Design, Construction, and Initial Inspections
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On-Going Monitoring, Reporting, Inspection, and Enforcement

- On-going Monitoring and Reporting
- Inspection and Enforcement

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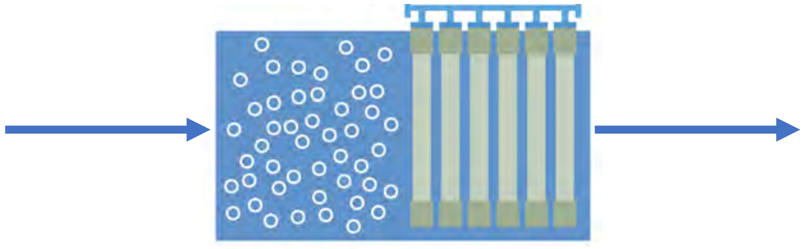
On-Going Monitoring, Reporting, Inspection, and Enforcement

On-going Monitoring and Reporting

- Evaluation of system performance over time
- Requirements are specified in the Operations Plan

MBR



Monitoring Requirements for LRV Credit:

- ❖ Measure turbidity continuously (sample ≤ 15-min intervals)
    - Effluent turbidity always ≤ 0.2 NTU
- ❖ Measure pH continuously
    - 6 < pH < 8
- ❖ Etc.

On-Going Monitoring, Reporting, Inspection, and Enforcement

- **Inspection and Enforcement** is responsibility of the regulator
- Executed via:
  - Review of performance and water quality reports
  - Routine inspections
  - Enforcement actions for systems that violate regulations
- Regulators define the types of violations, the associated penalties, and the corresponding reference in the regulations

Problem Solving Exercises

What are the benefits of early and frequent communication with regulators:

Select all that apply:

- A. Avoid costly last-minute revisions to ONWS design
- B. Minimize start-up delays due to permitting issues
- C. Decrease risk of designing a non-compliant system
- D. Reduce risk of non-compliance from insufficient monitoring capabilities
- E. None of the above

When is the appropriate time in the design process to submit an Engineering Report:

- A. 100% design
- B. 10 – 30% design
- C. 60% design
- D. 90% design
- E. (A) and (B)

What tool can assist both Design Engineers and Regulators with developing/reviewing Engineering Reports:

- A. Operations Plan
- B. Engineering Report Template
- C. Preliminary Engineering Report
- D. Commissioning Plan
- E. None of the above

What does the Project Team need to complete to receive a Permit to Operate:

- A. Final Engineering Report
- B. Operations and Maintenance Plan
- C. Construction
- D. Inspections
- E. All the above

True or False:

A Permit to Operate allows the System Owner to distribute ONWS water for its intended use

What are some of the items that are confirmed during an installation inspection:

- A. Installation of proper monitoring at specified locations
- B. Use of specified chemicals and treatment processes
- C. Presence of flow diversions
- D. Provision of back-up wastewater disposal and supply options
- E. All the above