State Summit Webinar: Treatment Targets and Crediting

Hosted by: ACWA and EPA

National Water Reuse Action Plan

WRAP

Sign up for the next State Summit Webinar on December 3

Water Reuse for Data Centers

Use QR code to register

Introductory Speakers

Dr. Sharon Nappier, U.S. EPA
National Program Leader
For Water Reuse

Nicholas M. Josefik, DOD
ERDC-CERL
Industrial Engineer

Dr. Amy Childress, USC
Dean's Professor and
Director of USC's ReWater Center

Water Reuse and Recycling
Water Where You Need it, When You Need it

Water reuse or recycling is treating an alternative supply of water to reuse for a beneficial use.

- Treating wastewater and cleaning it to drinking water standards
- Treating wastewater for industrial reuse (e.g., data center cooling)
- Treating stormwater for use in buildings, reducing flood events
- Treating industrial wastewater for mining operations

This is a highly planned process that should account for different risks to public health based on the pathogens in the source water and the intended use.

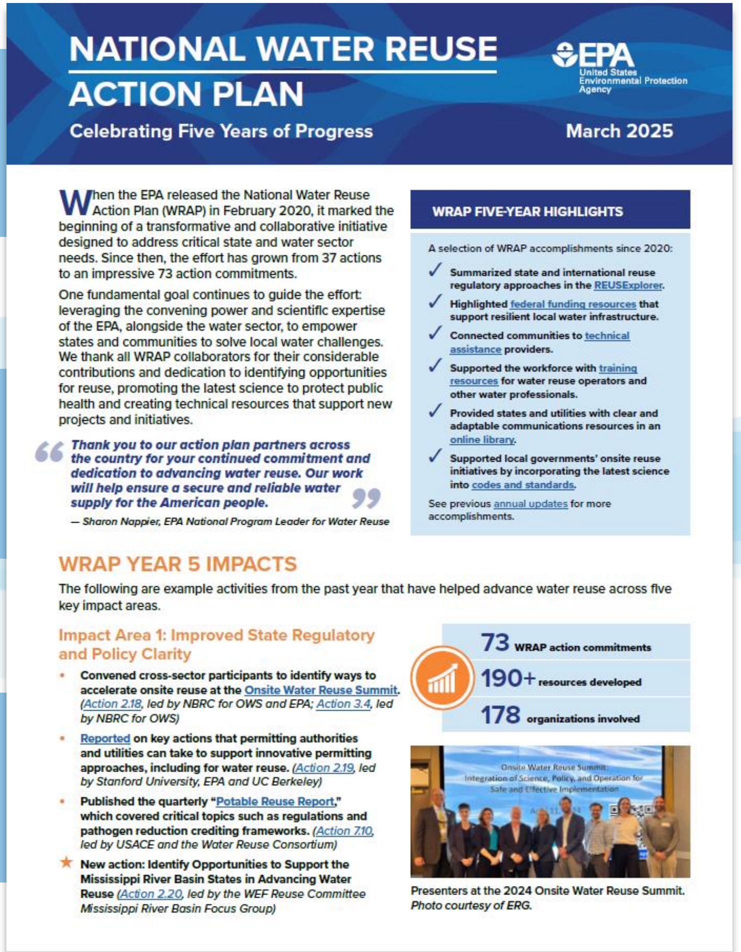
States set requirements for additional treatment; it is not specifically regulated at the federal level.

Celebrating 5 Years of Successful Collaborations to Advance Water Reuse!

74 WRAP action commitments

190+ resources developed

199 organizations involved



NATIONAL WATER REUSE ACTION PLAN

Celebrating Five Years of Progress

March 2025

When the EPA released the National Water Reuse Action Plan (WRAP) in February 2020, it marked the beginning of a transformative and collaborative initiative designed to address critical state and water sector needs. Since then, the effort has grown from 37 actions to an impressive 73 action commitments.

One fundamental goal continues to guide the effort: leveraging the convening power and scientific expertise of the EPA, alongside the water sector, to empower states and communities to solve local water challenges. We thank all WRAP collaborators for their considerable contributions and dedication to identifying opportunities for reuse, promoting the latest science to protect public health and creating technical resources that support new projects and initiatives.

"Thank you to our action plan partners across the country for your continued commitment and dedication to advancing water reuse. Our work will help ensure a secure and reliable water supply for the American people."

— Sharon Nappier, EPA National Program Leader for Water Reuse

WRAP FIVE-YEAR HIGHLIGHTS

A selection of WRAP accomplishments since 2020:

- ✓ Summarized state and international reuse regulatory approaches in the REUSExplorer.
- ✓ Highlighted federal funding resources that support resilient local water infrastructure.
- ✓ Connected communities to technical assistance providers.
- ✓ Supported the workforce with training resources for water reuse operators and other water professionals.
- ✓ Provided states and utilities with clear and adaptable communications resources in an online library.
- ✓ Supported local governments' onsite reuse initiatives by incorporating the latest science into codes and standards.

See previous annual updates for more accomplishments.

WRAP YEAR 5 IMPACTS

The following are example activities from the past year that have helped advance water reuse across five key impact areas.

Impact Area 1: Improved State Regulatory and Policy Clarity

- Convened cross-sector participants to identify ways to accelerate onsite reuse at the Onsite Water Reuse Summit. *(Action 2.18, led by NBRC for OWS and EPA; Action 3.4, led by NBRC for OWS)*
- Reported on key actions that permitting authorities and utilities can take to support innovative permitting approaches, including for water reuse. *(Action 2.19, led by Stanford University, EPA and UC Berkeley)*
- Published the quarterly "Potable Reuse Report," which covered critical topics such as regulations and pathogen reduction crediting frameworks. *(Action 7.10, led by USACE and the Water Reuse Consortium)*
- ★ New action: Identify Opportunities to Support the Mississippi River Basin States in Advancing Water Reuse *(Action 2.20, led by the WEF Reuse Committee Mississippi River Basin Focus Group)*

73 WRAP action commitments

190+ resources developed

178 organizations involved

Onsite Water Reuse Summit: Integration of Science, Policy, and Operation for Safe and Effective Implementation

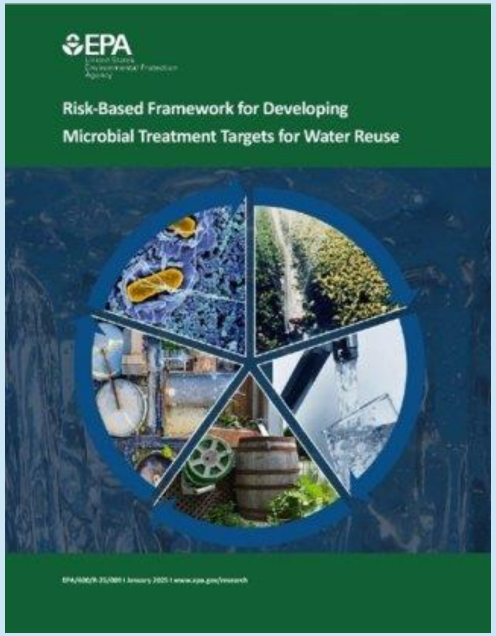
Presenters at the 2024 Onsite Water Reuse Summit. *Photo courtesy of ERG.*

Annual State Regulator Summits on Water Reuse

Support states as they develop reuse regulations and guidelines

CREATED REUSEXPLORER TOOL SUMMARIZING >185 STATE REUSE POLICIES

PUBLISHED FRAMEWORK FOR DEVELOPING MICROBIAL TREAMENT TARGETS



Support states as they develop reuse regulations and guidelines

More ways to Engage and Learn about Water Reuse!

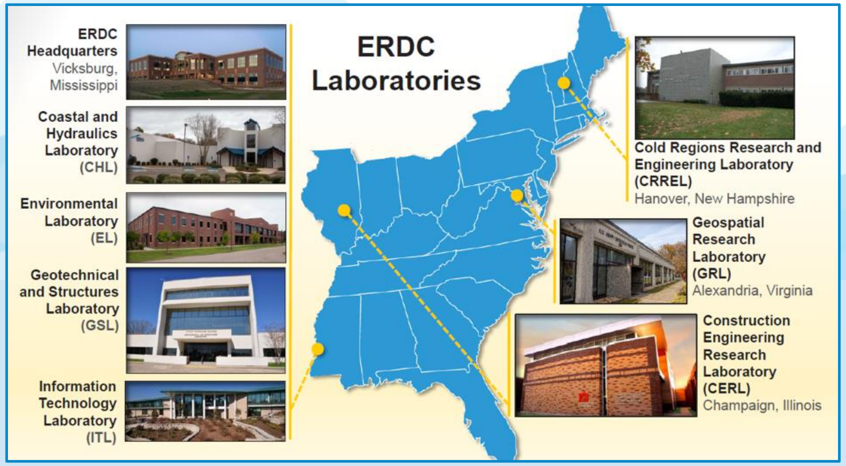
1. Next State Summit Webinar on Water Reuse for Data Centers
   - December 3, 2-4pm EST, REGISTER using the QR code!

2. Join us at our Annual State Summit Event (in-person with virtual options)
   - March 8, full-day event
   - Occurs at 41st Annual WateReuse Symposium in Los Angeles, CA

3. Sign up for our monthly updates to receive resources and information on future events!
   - Email us: waterreuse@epa.gov

WRAP Partners: Awarded millions of dollars in federal research awards for water reuse since 2020

Water Reuse Consortium: Improving resiliency and security for our nation's military

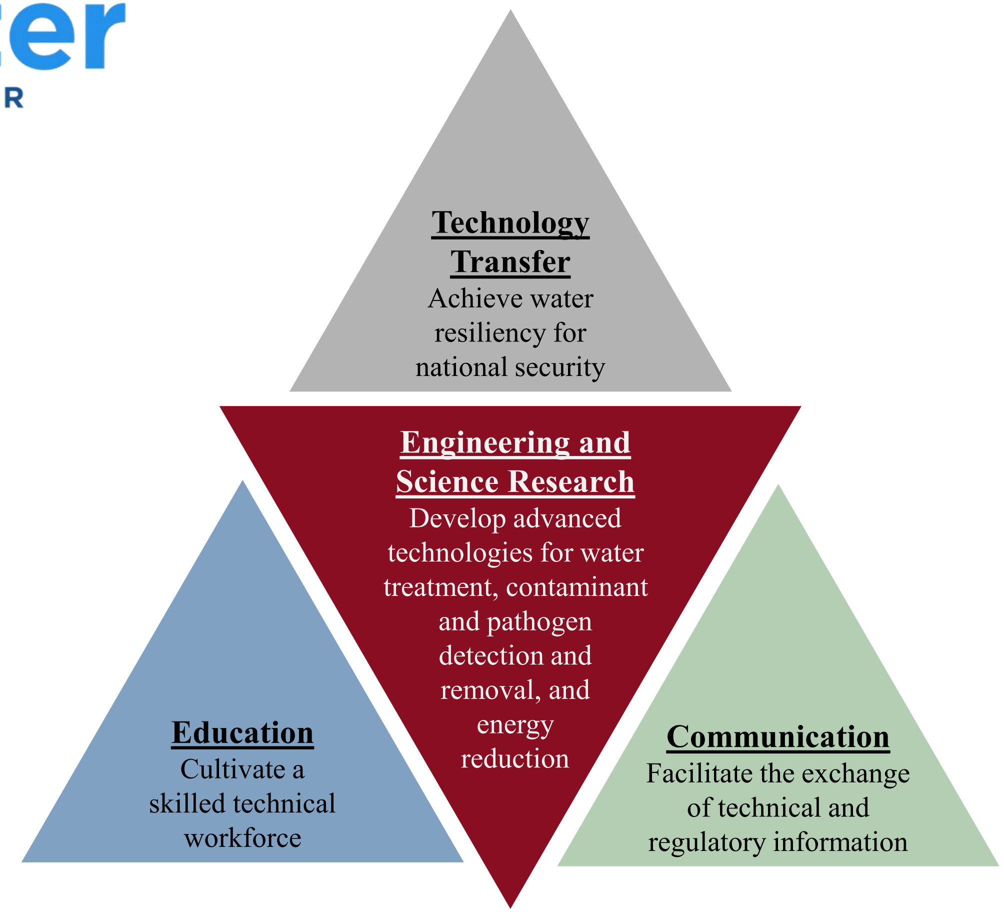


Coordinated research to reduce public health risks and the cost of treatment

University of Southern California
Center for Water Reuse and Resource Recovery

ReWater CENTER

- Research, outreach, and education on water reuse
- Balancing public health objectives with energy, nutrient, and resource extraction, as well as environmental aspects of residuals disposal
- Engaging with practitioners, communicating with the public, and facilitating interaction amongst the water reuse community



USC University of Southern California

ENE 507: Potable Water Reuse

Facilitating academic and industry research exchange; identifying knowledge gaps and determining research priorities

Overview of Risks, Regulations, and Policies
Brian Bernados

Wastewater Based Epidemiology to Inform Potable Reuse Implementation
Dr. Daniel Gerrity

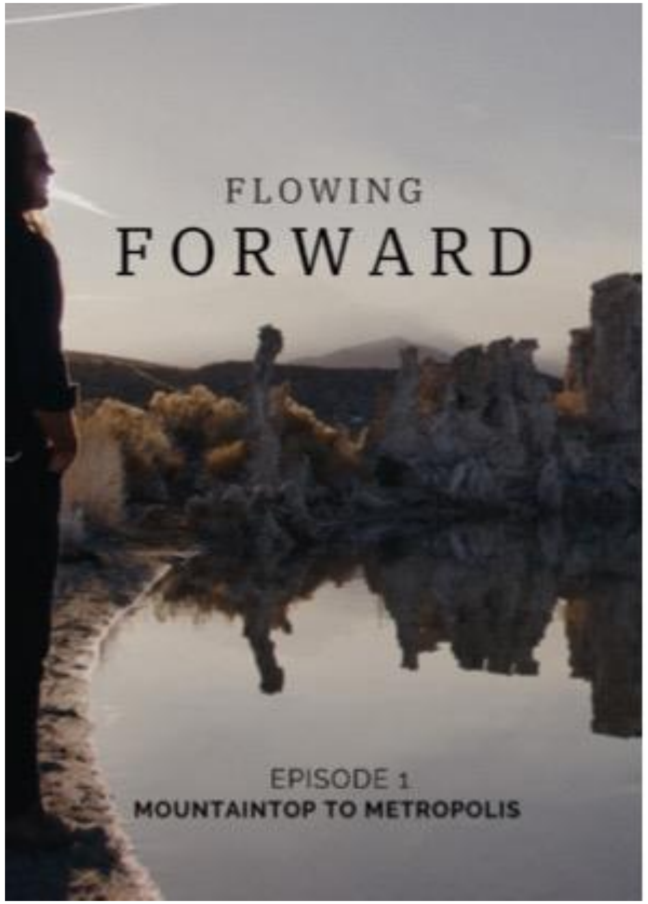
High-Recovery Reverse Osmosis Technologies
Dr. Han Gu

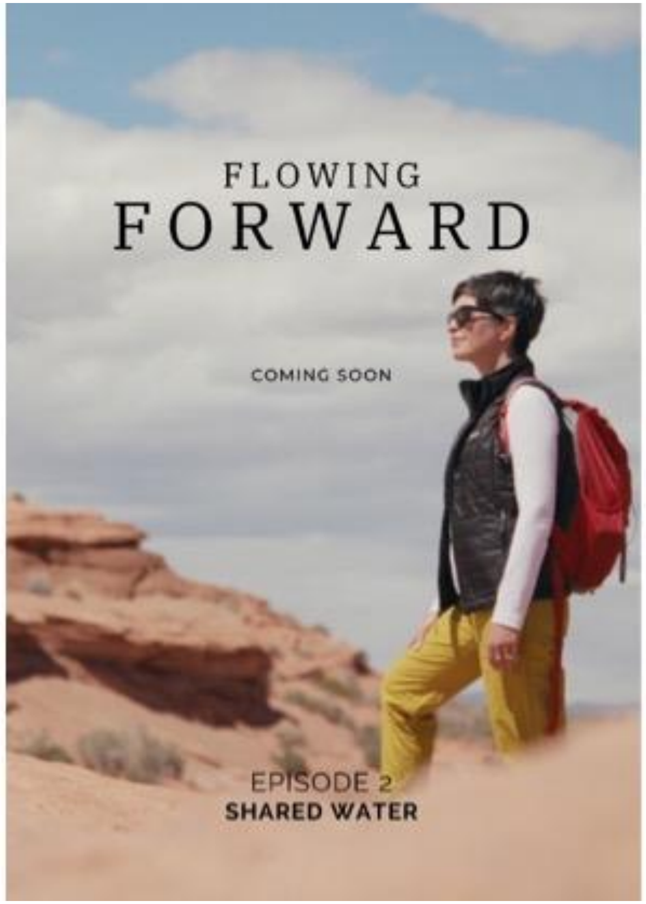
Advances in Wastewater Treatment that Support IPR
Dr. Charles B. Bott

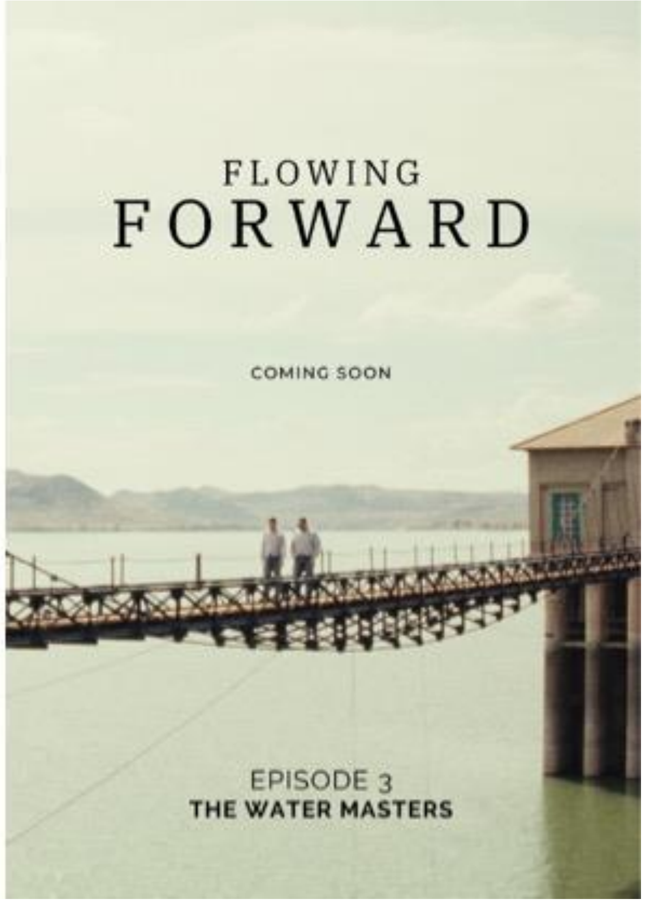
Digital Solutions in Potable Water Reuse
Dr. Billy Raseman

Series of Short Documentaries

Bridging the gap between science and society; connecting stakeholders across sectors







Potable Water Reuse Report

Connecting the potable water reuse community – including practitioners, regulators, and academics – to keep them up-to-date with the industry's rapidly evolving developments

Potable Water Reuse Report
Published by the University of Southern California ReWater Center in collaboration with Trussell
Series 1, Issue 1 — 8 March 2024
Direct Potable Reuse Regulations and the Importance of Adaptability in a Rapidly Evolving World: A California Case Study

Potable Water Reuse Report
Published by the University of Southern California ReWater Center in collaboration with Trussell
Series 1, Issue 2 — 14 June 2024
The Factors Shaping DPR Regulations in the United States

Potable Water Reuse Report
Published by the University of Southern California ReWater Center in collaboration with Trussell
Series 1, Issue 3 — 13 September 2024
Direct Potable Reuse at the Global Scale: Regulations or Bust?

ReWater CENTER

Trussell

Brian Pecson and Anya Kaufmann
Jacob Newman
Shane Trussell

Sign up to receive the PWR Report

Potable Water Reuse Report Advisory Panel

Jeff Mosher

Potable Reuse
Subject Matter Expert
Klir

Tom Pankratz

Editor of
Water Desalination Report
Global Water Intelligence

Sharon Nappier
PhD, MS PH

National Program Leader for
Water Reuse
US EPA, Office of Water

Nicholas Josefik

Industrial Engineer
US Army Corps of Engineers
ERDC-CERL

The Factors Shaping DPR Regulations in the United States

Brian Pecson, *Trussell*

September 11, 2025

Series 1: Direct Potable Reuse Regulations

Series 1, Issue 1 — 8 March 2024

Direct Potable Reuse Regulations and the Importance of Adaptability in a Rapidly Evolving World: A California Case Study

Series 1, Issue 2 — 14 June 2024

The Factors Shaping DPR Regulations in the United States

Series 1, Issue 3 — 13 September 2024

Direct Potable Reuse at the Global Scale: Regulations or Bust?

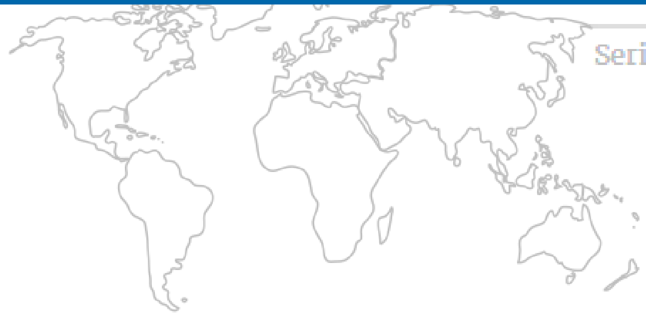
Series 1: Direct Potable Reuse Regulations

Series 1, Issue 1 — 8 March 2024

Direct Potable Reuse Regulations and the Importance of Adaptability in a Rapidly Evolving World: A California Case Study

Series 1, Issue 2 — 14 June 2024

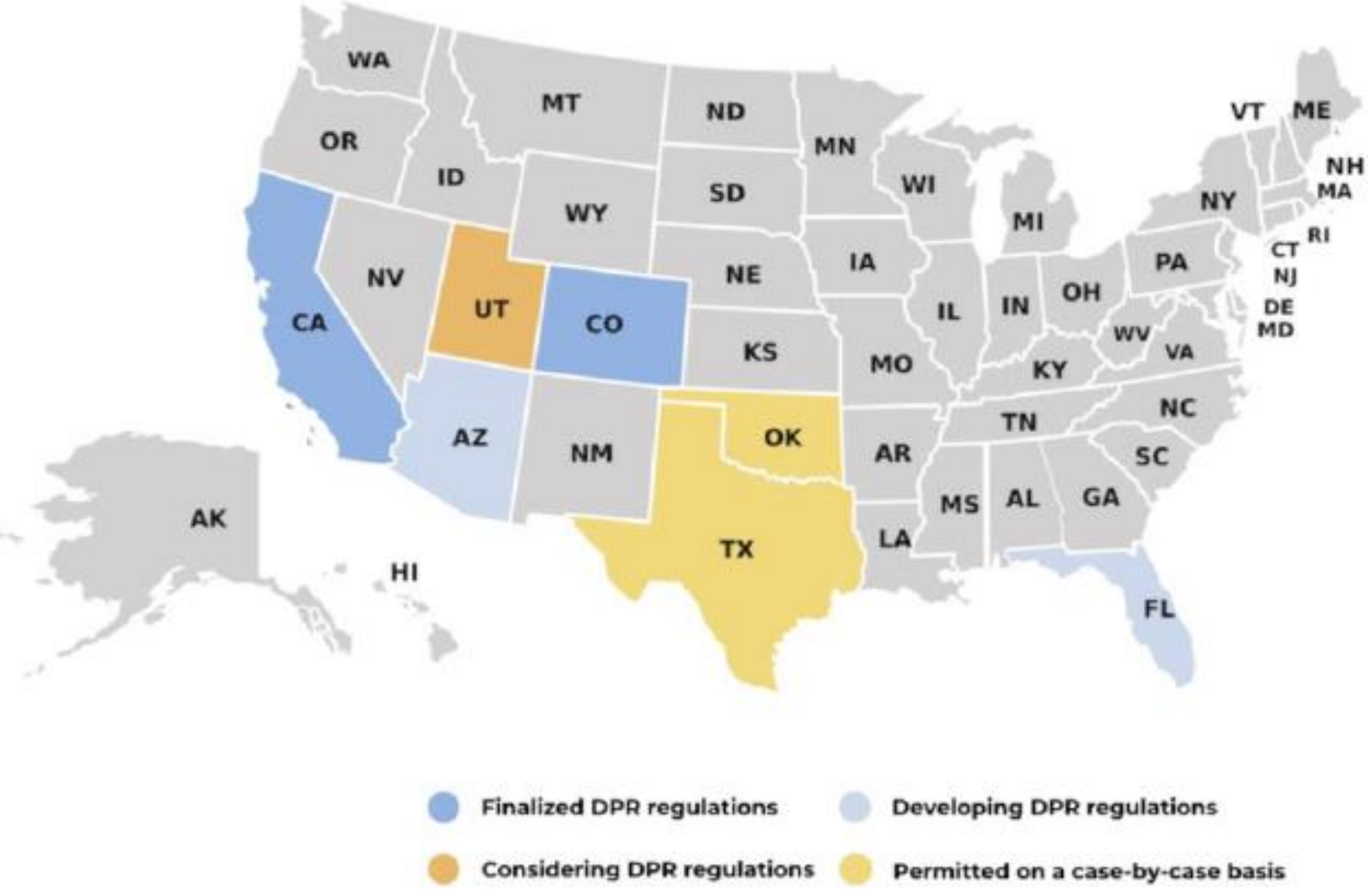
The Factors Shaping DPR Regulations in the United States



Series 1, Issue 3 — 13 September 2024

Direct Potable Reuse at the Global Scale: Regulations or Bust?

DPR Regulations



- No Federal regulation for potable reuse
- Regulations developed state-by-state

*Map developed June 2024

Nationwide Survey – Interviewed Stakeholders

California

Darrin Polhemus

Deputy Director

CA State Water Resources Control Board

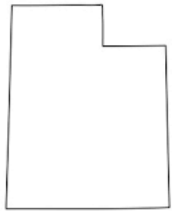
Arizona

Karthik Kumarasamy

Principal Engineer

Water Quality Division AZ Dept. of Env. Quality

Utah

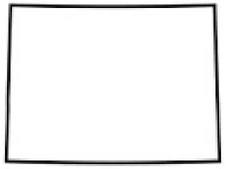


Dani Zebelean

Environmental Engineer

Division of Drinking Water, UT Dept. of Env. Quality

Colorado

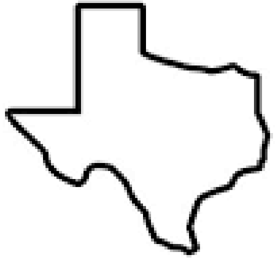


Tyson Ingels

Lead Drinking Water Engineer

Water Quality Control Division, CO Dept. of Public Health & Env.

Texas

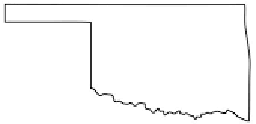


Gilbert Trejo

Vice President Engineering, Operations & Technical Services

El Paso Water

Oklahoma



Shellie Chard

Director

Water Quality Division, OK Dept. of Env. Quality

Florida

Lynn Spivey
Director of Utilities

City of Plant City

Bart Weiss
Chief Officer for Innovation & Resiliency

Hillsborough County Public Utilities

Hypothesis

- Public health requirements are broadly similar between states
  - *Pathogen requirements*
  - *Chemical requirements*
- Factors outside of public health are shaping the diversity in DPR regulations

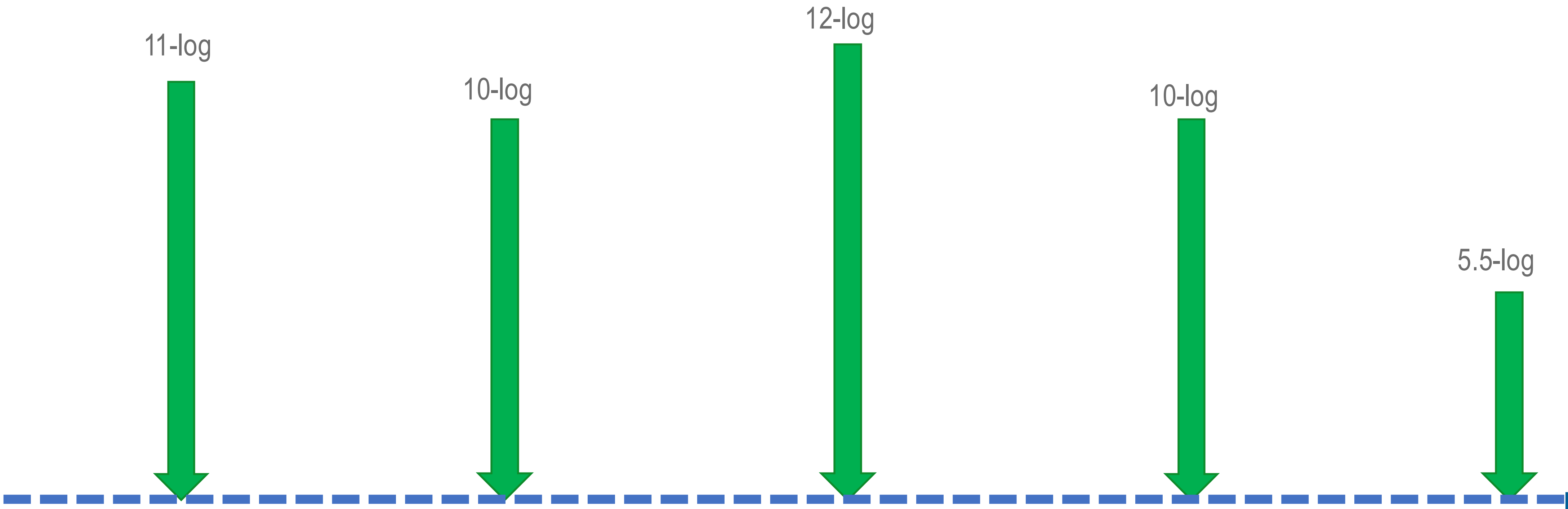
- What are those factors?

Public Health Requirements: Pathogens

Virus
Giardia
Crypto

Cryptosporidium

California	Colorado	Florida	Arizona	Texas
Raw Wastewater	Treated Wastewater	Raw Wastewater	Raw Wastewater	Treated Wastewater

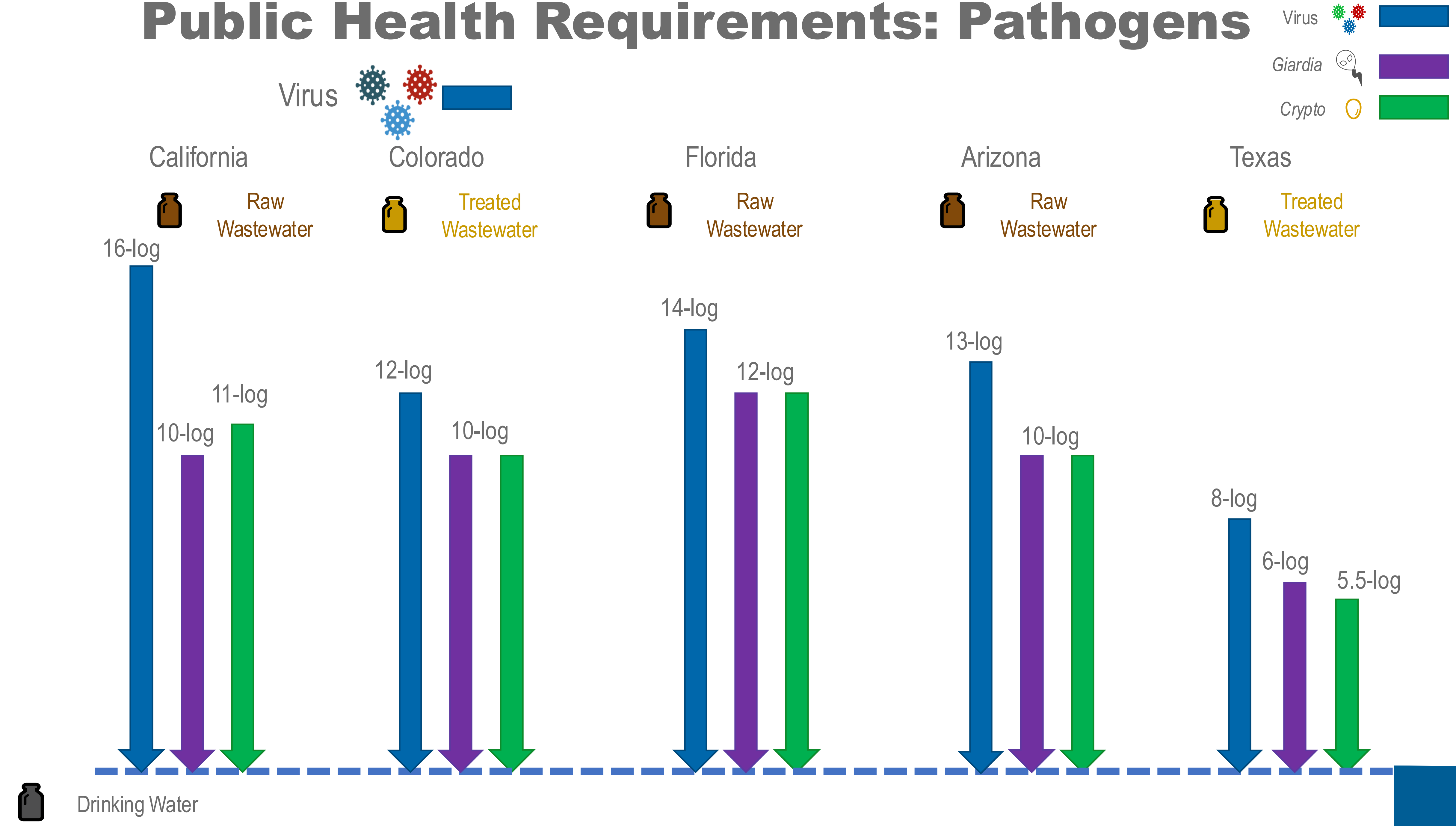


Drinking Water

Public Health Requirements: Pathogens

Virus
Giardia
Crypto

Public Health Requirements: Pathogens

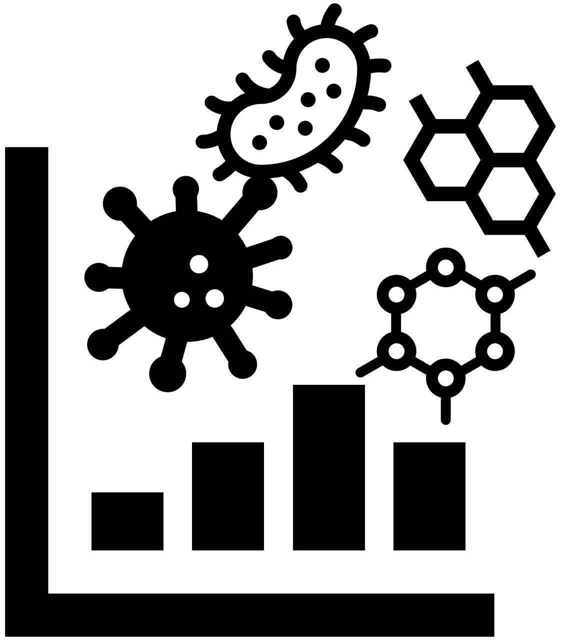


Public Health Requirements: Chemicals

- Compliance with federal drinking water requirements (i.e., Safe Drinking Water Act)

- Monitoring for contaminants with maximum contaminant levels (MCLs)

If pathogen and chemical control requirements are similar, what is influencing diversity in regulations?



VS.

Enhanced Source Control

Sewershed Monitoring

Treatment Processes

Response Time

Blending

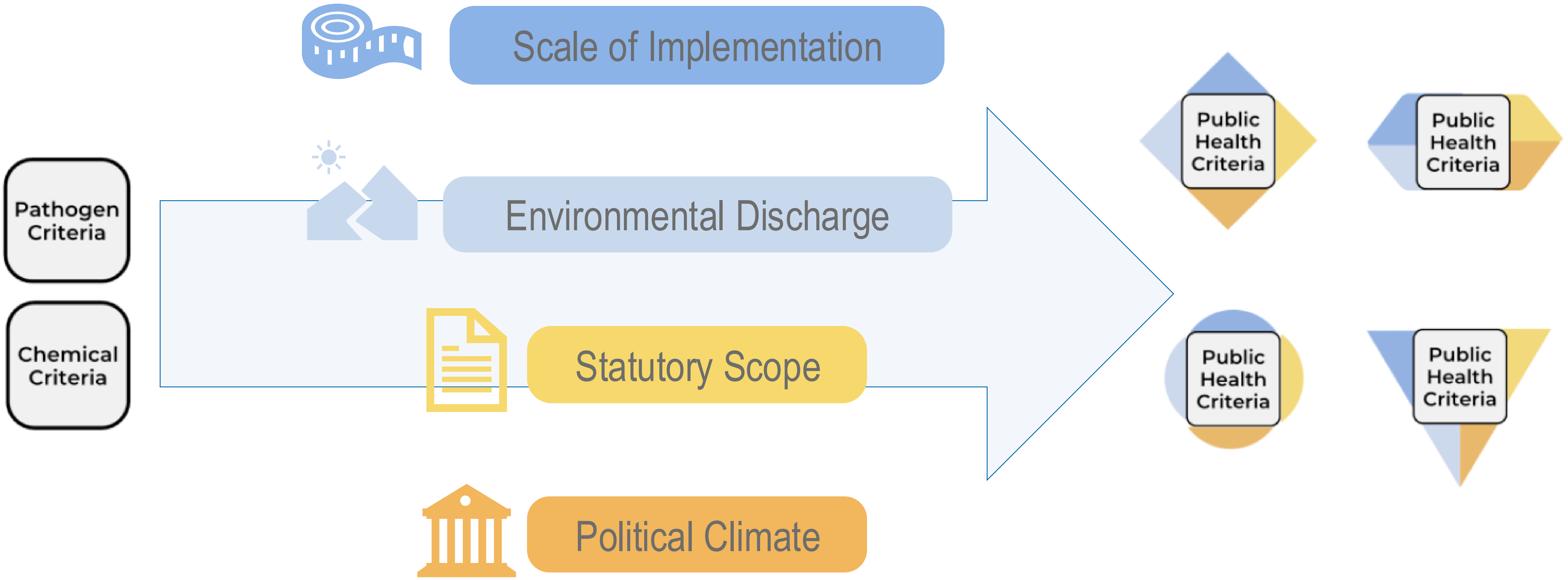
Diversions

Redundancy

Dilution

Operator Staffing & Certification

Four Key Factors Influencing Regulations



Scale of Implementation

- What is the largest planned DPR project in the US?
- What is the smallest planned DPR project in the US?
- What percentage of the water supply in your state will be from potable reuse?

California – Scale of Implementation

PURE WATER LOS ANGELES

Los Angeles Department of Water & Power

LA Sanitation environment, City of Los Angeles, zero waste • zero wasted water

230 MGD

Recycle 100% of wastewater by 2035

PURE WATER SOUTHERN CALIFORNIA

Our Water | Our Future

Water is too precious to use just once. That's why The Metropolitan Water District of Southern California is partnering with the Los Angeles County Sanitation Districts on Pure Water Southern California, a regional water recycling program that would purify and reuse cleaned wastewater that currently flows into the ocean. At full scale, Pure Water Southern California would produce 150 million gallons of purified water each day.

By delivering a new, climate-resilient supply of locally available water, Pure Water Southern California would benefit the 19 million people living within Metropolitan's service area. It also would become one of the world's largest water recycling programs.

Pure Water Southern California in Numbers

Would produce up to **150 million gallons per day**, enough water to meet the annual needs of about 500,000 homes

A new source of drought-resilient water that benefits **19 million people**

Nearly **$100 million** in grant and partnership funds secured

More than **15 program partners** and hundreds of program supporters

One of the largest recycling programs of its kind in the world

Pure Water San Diego

When Will the New Facilities be Built?

Phase	Output	Location
Phase 1	30 mgd	North City
Phase 2	53 mgd	Central Area

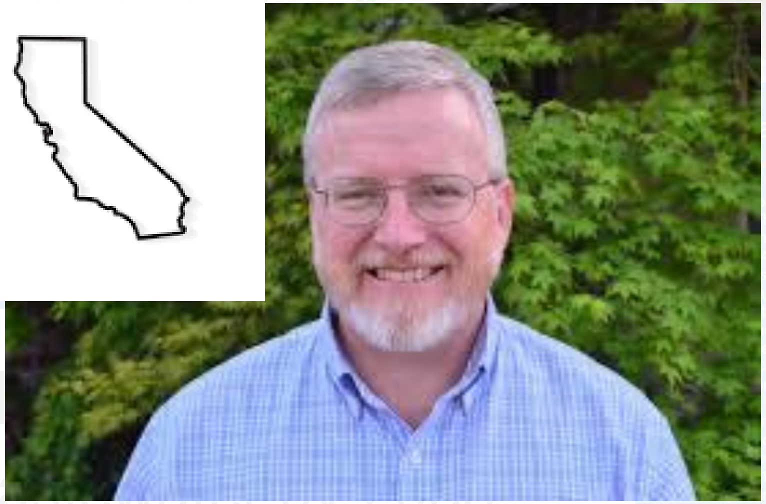
Total: **83 mgd** by 2035

**mgd = million gallons per day*

California – Scale of Implementation

“There’s no way I want to look back after our municipalities pursuing [DPR] have invested tens of billions of dollars to have public opinion make them shut it off. That would be the worst thing.”

California



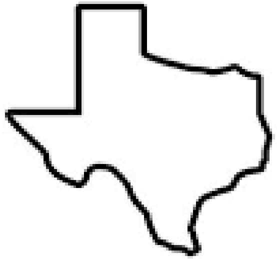
Darrin Polhemus
Deputy Director
CA State Water Resources Control Board

Other States - Scale of Implementation

Large cities (e.g. Phoenix, Scottsdale)

&

Small cities (e.g., Cottonwood < 1 MGD)

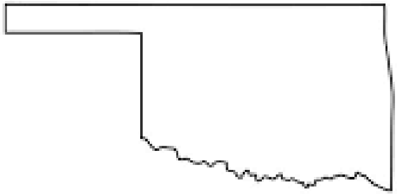


El Paso's project will represent about 5% of the overall supply

~Gilbert Trejo

5-10% of water supply near term

~Bart Weiss

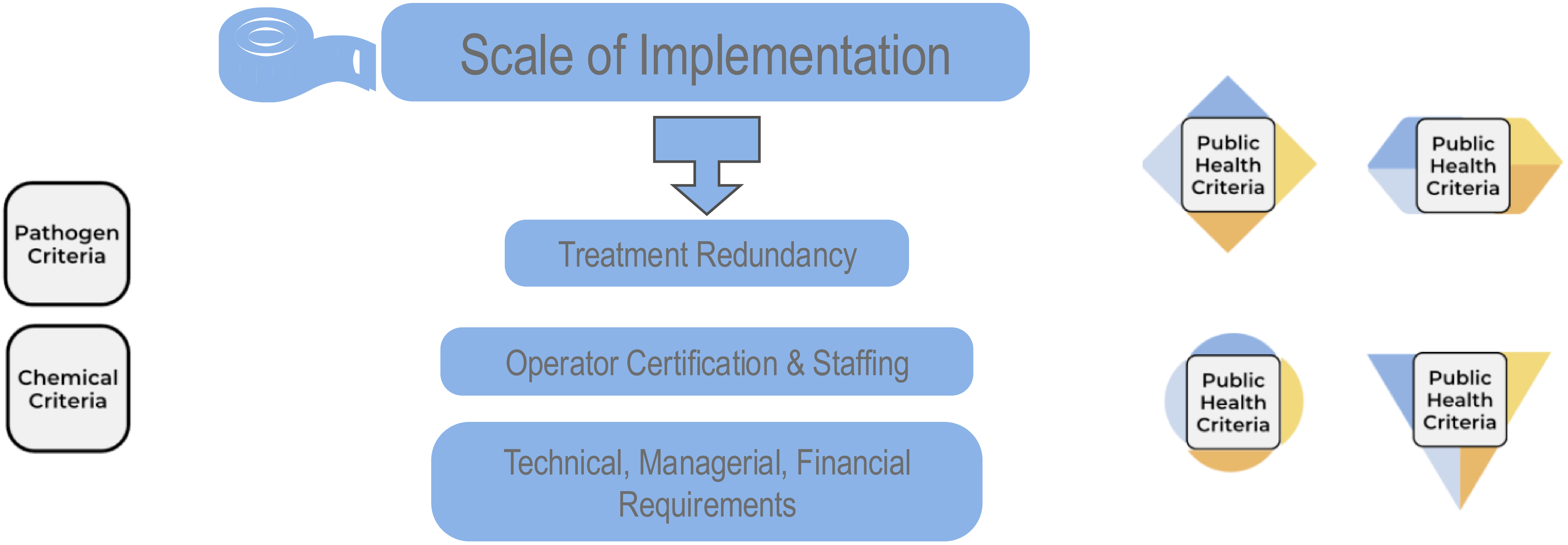


Cities with greatest need have less than 2,000 people

~Shellie Chard

"We're still figuring out what are the right pre-requisites so that we protect public health but make sure that the technology is affordable to all communities."
~Karthik Kumarasamy

"…we're going to end up with a rule that's so draconian that everybody says, 'Well, I'd like to do it, but I can't afford it!'"



States with *smaller scales of implementation* or those with small communities interested in reuse tend to *omit the layers of conservatism and redundancy* that were added by states with larger scales.

Environmental Discharge

Discharge Restrictions

- Florida Senate Bill 64 *prohibits* non-beneficial discharge of effluents into surface waters (including ocean discharges) by 2032
- RO concentrate discharge restrictions/challenges

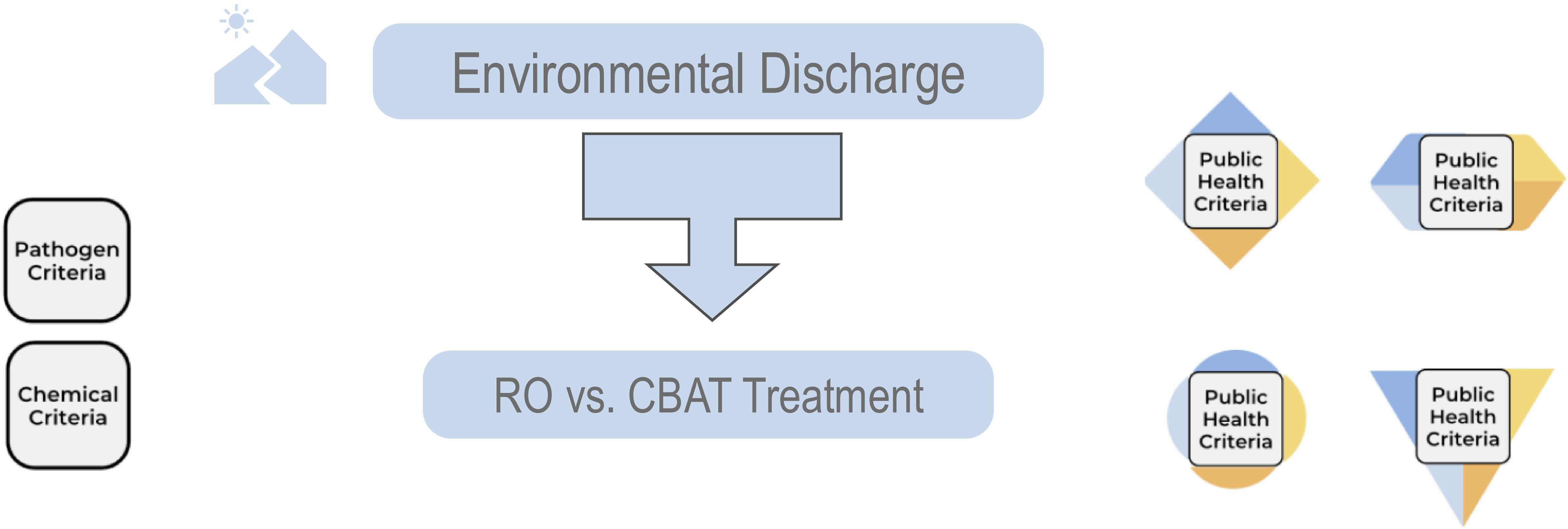
Motivation for potable reuse regulations

Regulations need flexibility in treatment technologies (e.g., RO vs non-RO)

Requirements to Discharge

- Colorado has requirements to return wastewater to the environment
- El Paso, TX also has requirements for minimum flows in the Rio Grande

May limit wastewater availability



Environmental discharge considerations typically have the biggest impact on treatment requirements for DPR – and specifically, whether the use of RO is *mandated*.

Statutory Scope

- Colorado's Primary Drinking Water Regulations require assurance of "the safety of public drinking water supplies"
- Texas's Administrative Code requires public water systems to "supply safe drinking water in adequate quantities"

- How much can state regulators legally require *beyond* federal requirements for drinking water (i.e., Safe Drinking Water Act)?

Statutory Scope

California Safe Drinking Water Act:

"Every resident of California has the right to **pure and safe** drinking water."

"This chapter is intended to ensure that the water delivered by public water systems of this state shall at all times be **pure, wholesome, and potable**."

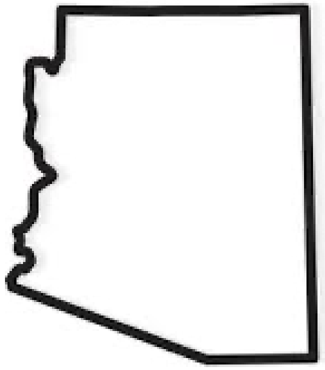
- California regulators have greater flexibility to extend requirements beyond those required only for *safety*.

Statutory Scope

- Impacts the ability to require monitoring of contaminants *beyond* those regulated by the federal SDWA (e.g., MCLs)
- Contaminants with MCLs are determined based on their occurrence and concentration *in conventional supplies* (i.e., groundwaters and surface waters)
- Many *secondary treated wastewater effluents* meet most of the MCLs, while not being of *potable* quality
- Many industry experts endorse an approach that includes monitoring and control of a larger suite of chemicals of emerging concern (CECs) for potable reuse beyond only the regulated MCLs
- Can states *legally* require the monitoring of CECs for potable reuse?

Statutory Scope

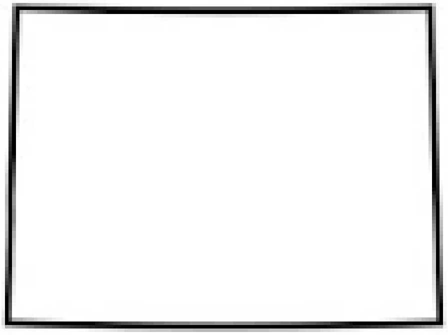
Arizona



Karthik Kumarasamy

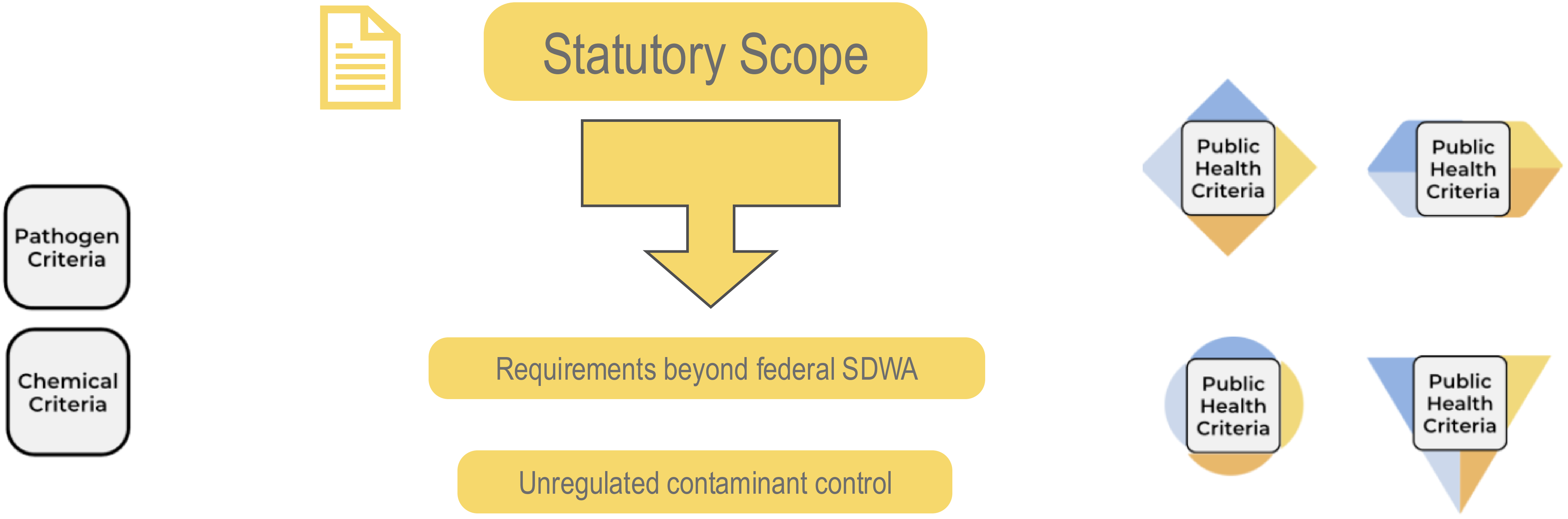
regulations are primarily being shaped to comply with federal SDWA requirements, but some CEC monitoring beyond the SDWA will be required as well.

Colorado



Tyson Ingels

“We knew we needed to right-size [the DPR regulations] for our state and what utilities could reasonably implement under our regulatory structure that was still very protective of public health.”



While California's statutory scope provides a pathway to expand requirements *beyond the federal SDWA*, regulators in other states may experience more resistance.

Political Climate

Colorado

Governor Hickenlooper support and 2015 Colorado Water Plan

+

Aurora Water and Castle Rock as early adopters of potable reuse

California

Governor Newsom support

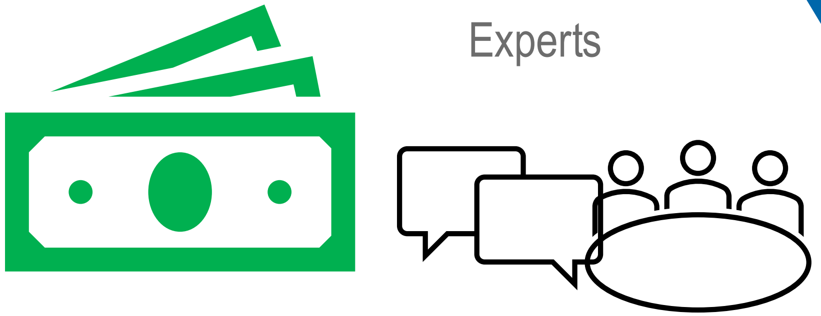
+

First DPR Regulations

Political Climate

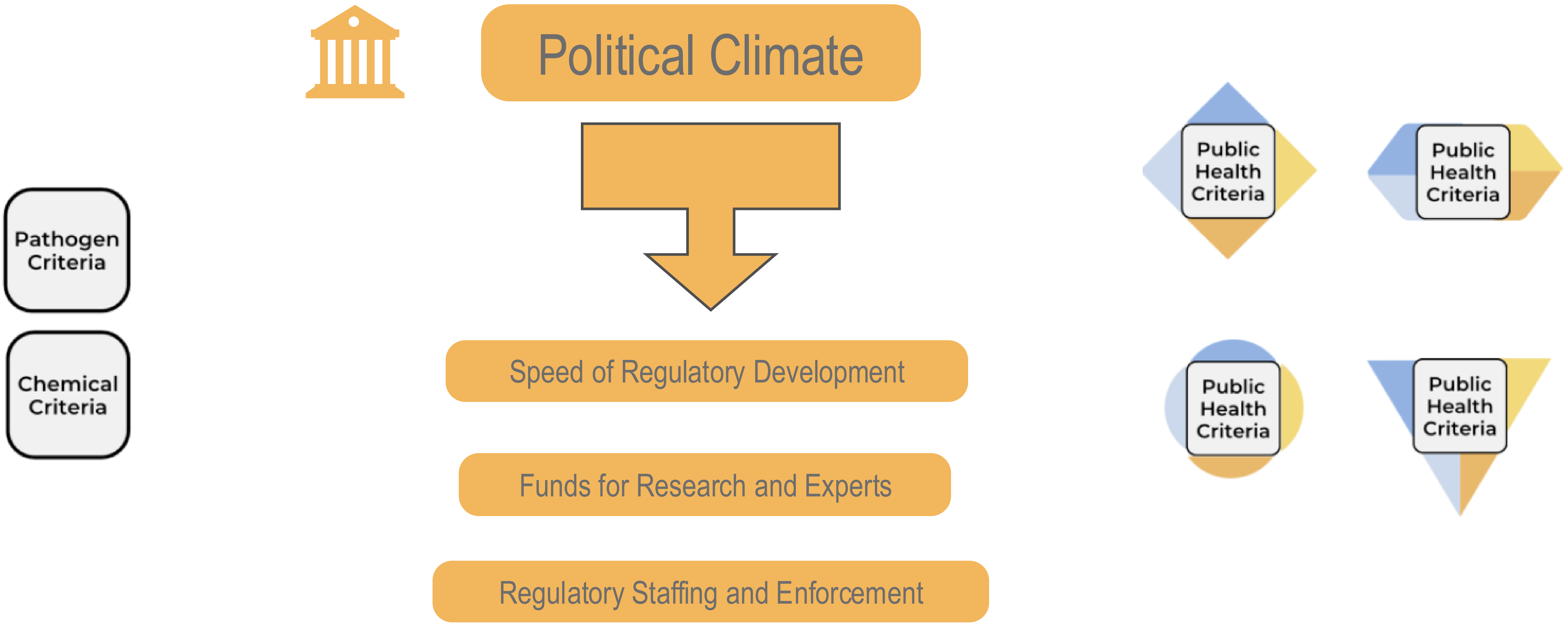
Research

Experts

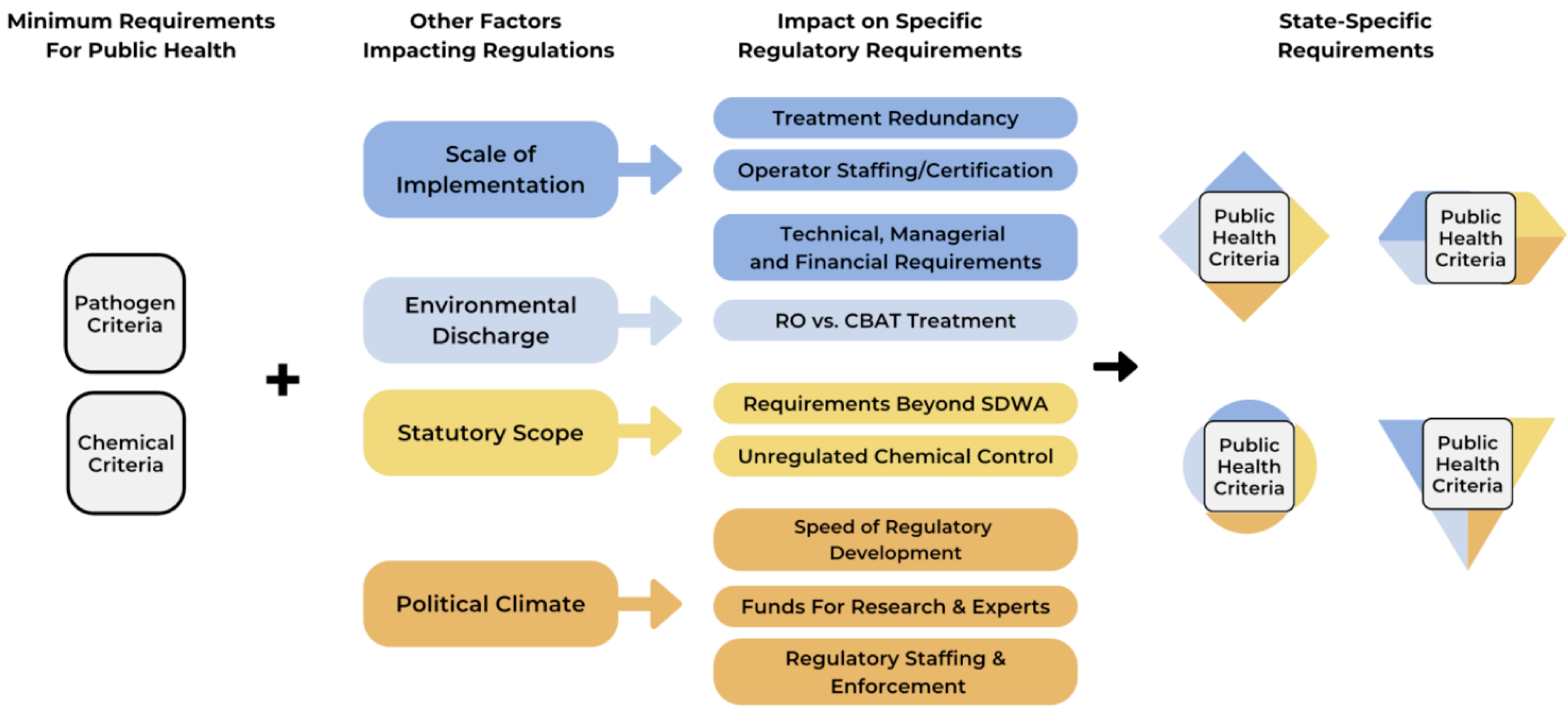


Regulators in Colorado, Arizona, Florida, and California **all cited research** as a critical element for their regulatory development.

"Research made it possible for us to proceed. The work gave us confidence. We were able to clearly see that we could go all the way to DPR."
~Darrin Polhemus



As new states move forward with DPR regulations, one useful lesson from the past is to *seek out and educate advocates in the political sphere who can help build support for reuse.*


Minimum Requirements For Public Health
Other Factors Impacting Regulations
Impact on Specific Regulatory Requirements
State-Specific Requirements
Pathogen Criteria
Chemical Criteria
Scale of Implementation
Environmental Discharge
Statutory Scope
Political Climate
Treatment Redundancy
Operator Staffing/Certification
Technical, Managerial and Financial Requirements
RO vs. CBAT Treatment
Requirements Beyond SDWA
Unregulated Chemical Control
Speed of Regulatory Development
Funds For Research & Experts
Regulatory Staffing & Enforcement
Public Health Criteria
Public Health Criteria
Public Health Criteria
Public Health Criteria

Acknowledgements

- Trussell
  - *Brian Pecson*
  - *Shane Trussell*
- University of Southern California
  - *Amy Childress*
  - *Sarah Philo*
- Advisory Panel
  - *Jeff Mosher*
  - *Tom Pankratz*
  - *Sharon Nappier*
  - *Dawn Morrison*
- Interview Participants
  - *Darrin Polhemus, CA*
  - *Tyson Ingels, CO*
  - *Dani Zebelean, UT*
  - *Karthik Kumarasamy, AZ*
  - *Lynn Spivey, FL*
  - *Bart Weiss, FL*
  - *Shellie Chard, OK*
  - *Gilbert Trejo, TX*

Lessons Learned from California DPR Regulatory Development

Brian Pecson, *Trussell*

September 11, 2025

Premise

- Reflecting on California's DPR regulatory development can identify <u>what went well</u> and <u>what could be improved</u>
- Lessons learned from California may help other states to thoughtfully plot their own course to DPR regulations

What Went Well


DPR Requirements
Public Health Protection


Research Investment
California DPR
Initiative
(2012-2016)
$24 Million
34 Projects
WATEREUSE
CALIFORNIA
THE
Water
Research
FOUNDATION®

Research Investment

California DPR Initiative
(2012-2016)

Key outcome:
California regulators conclude <u>it is feasible</u> to develop DPR regulations

Research Investment

Priority DPR Research
(2018-2021)

$2 Million
5 Projects

CALIFORNIA Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

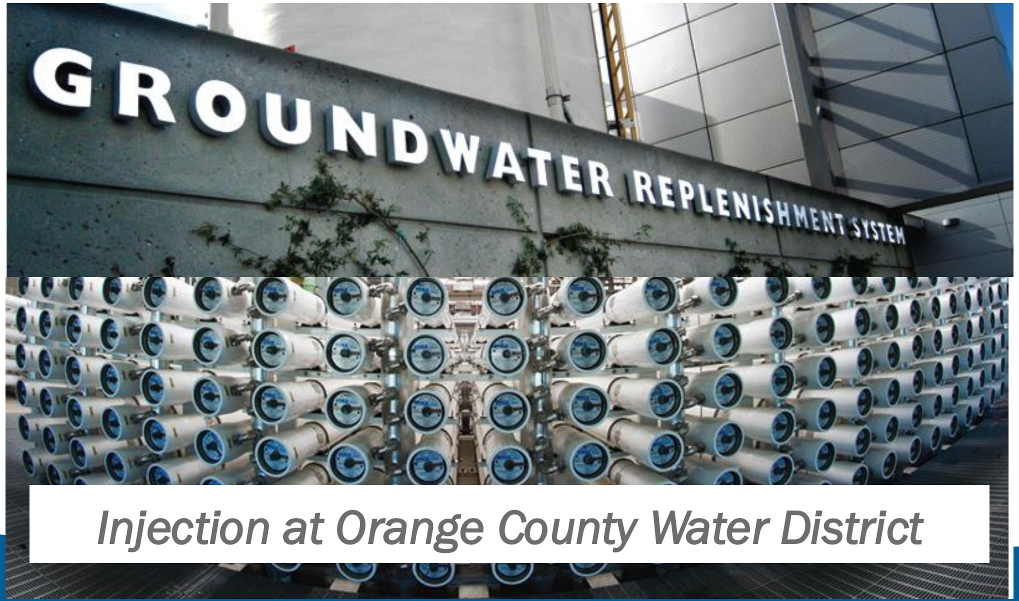
THE Water Research FOUNDATION®

Research Investment

Importance: Research took DPR out of its infancy and informed many requirements for public health protection

Leveraging Potable Reuse Experience

Spreading at LA County Sanitation Districts



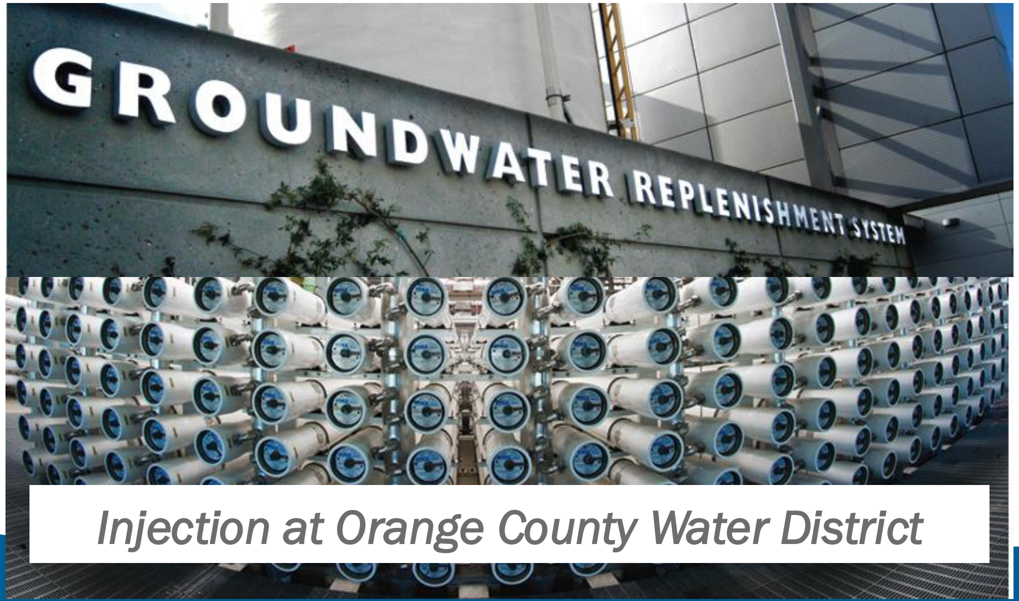
Injection at Orange County Water District

California Experience

- 60+ years of IPR experience inform DPR
- Multiple regulatory topics are similar:
  - *Pathogen control*
  - *Chemical control*
  - *Source control*
  - *Monitoring*
  - *Operator staffing and certification*

Leveraging Potable Reuse Experience

Spreading at LA County Sanitation Districts



Injection at Orange County Water District

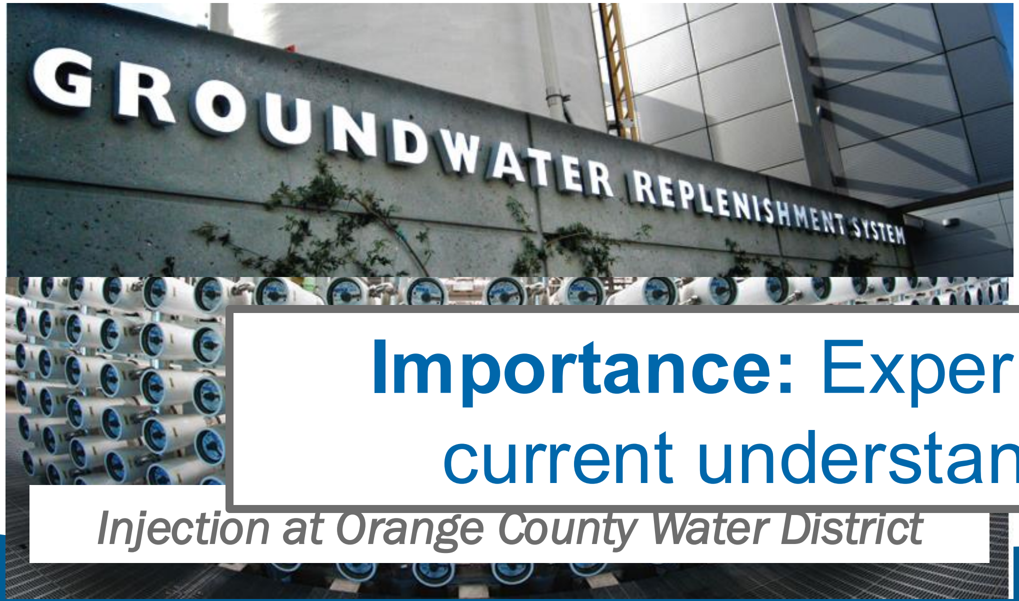
California Experience

- 60+ years of IPR experience inform DPR
- Multiple regulatory topics are similar:
  - *Pathogen control*
  - *Chemical control*
  - *Source control*
  - *Monitoring*
  - *Operator staffing and certification*

DPR Experience:

Leveraging Potable Reuse Experience

Spreading at LA County Sanitation Districts



Injection at Orange County Water District

California Experience

- 60+ years of IPR experience inform DPR
- Multiple regulatory topics are similar:
  - *Pathogen control*
  - *Chemical control*
  - *Source control*
  - *Monitoring*
  - *Operator staffing and certification*

Importance: Experience allowed regulators to build off current understanding to shape DPR requirements

Ground-truthing from Early Adopters

- Why changes if research was completed **before** 2021?

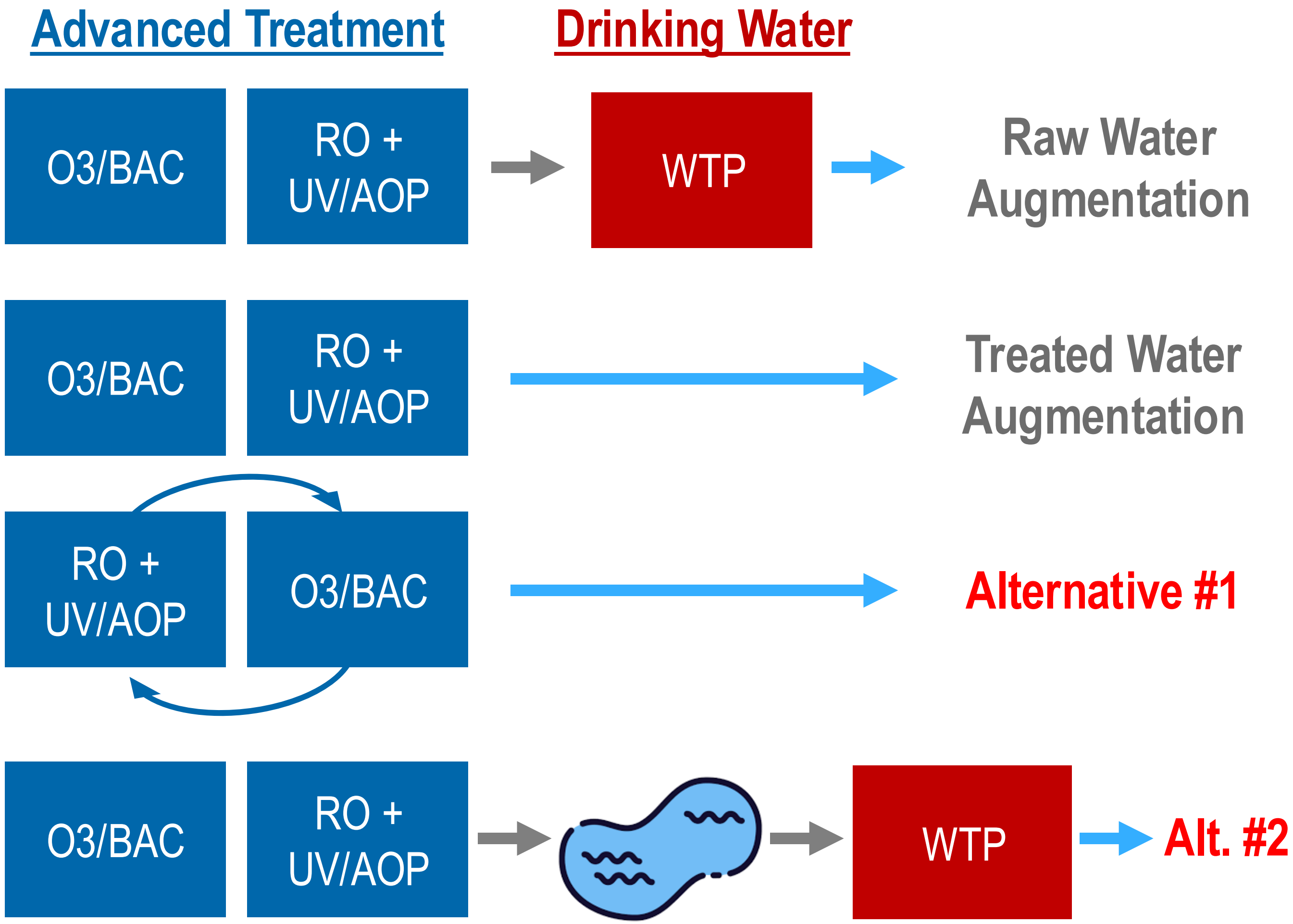
Ground-truthing from Early Adopters

Advanced Treatment | **Drinking Water**

O3/BAC → RO + UV/AOP → WTP → Raw Water Augmentation

O3/BAC → RO + UV/AOP → Treated Water Augmentation

Ground-truthing from Early Adopters



Ground-truthing from Early Adopters

<u>Advanced Treatment</u> | <u>Drinking Water</u>

O3/BAC → RO + UV/AOP → WTP → Raw Water Augmentation

O3/BAC → RO + UV/AOP → Treated Water Augmentation

RO + UV/AOP ⇄ O3/BAC → Alternative #1

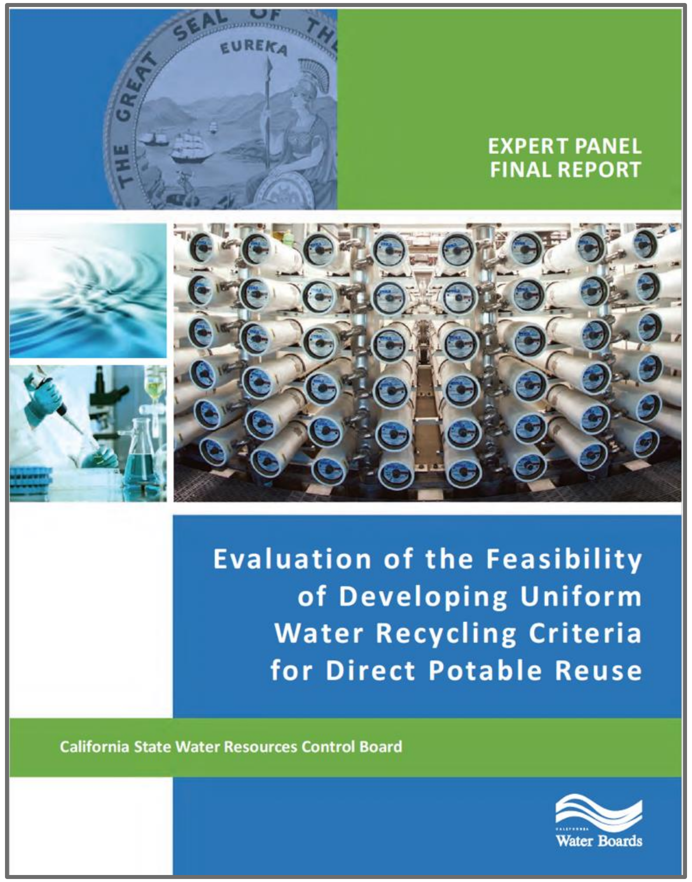
→ Alt. #2

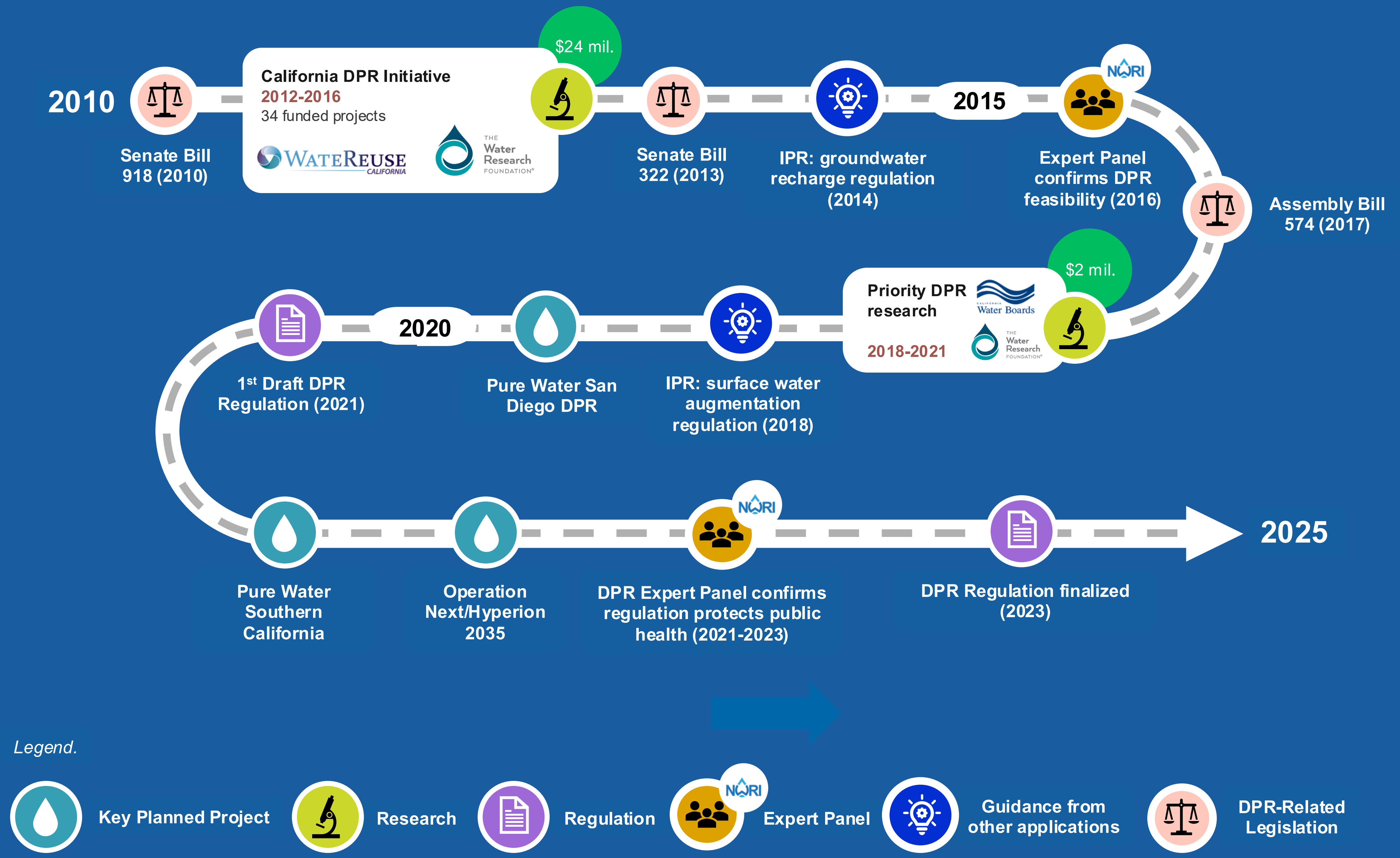
Importance: Early adopters showed that regulations needed *<u>more flexibility</u>* for diverse project types

Support of Independent Advisory Panels

- Expert panels can provide several benefits:
  - *Critical review of public health criteria*
  - *Complementary skillset to help develop scientific rationale*
  - *Input on knowledge gaps and research needs*

- **California approach**: ensured expert panel involvement by requiring IAPs during DPR regulatory development





2010
Senate Bill 918 (2010)
California DPR Initiative
2012-2016
34 funded projects
$24 mil.
WateReuse California
The Water Research Foundation
Senate Bill 322 (2013)
IPR: groundwater recharge regulation (2014)
2015
NWRI
Expert Panel confirms DPR feasibility (2016)
Assembly Bill 574 (2017)
Priority DPR research
2018-2021
$2 mil.
California Water Boards
The Water Research Foundation
IPR: surface water augmentation regulation (2018)
Pure Water San Diego DPR
2020
1st Draft DPR Regulation (2021)
Pure Water Southern California
Operation Next/Hyperion 2035
NWRI
DPR Expert Panel confirms regulation protects public health (2021-2023)
DPR Regulation finalized (2023)
2025
Legend.
Key Planned Project
Research
Regulation
NWRI
Expert Panel
Guidance from other applications
DPR-Related Legislation

What Could Be Improved

Groundwater Recharge: Learning Over 40 years

1962 | Filtration | Disinfection →  Groundwater Spreading

Groundwater Recharge: Learning Over 40 years

1962 | Filtration | Disinfection →

Groundwater Spreading

1974 | RO →

Groundwater Injection

Groundwater Recharge: Learning Over 40 years

1962 Filtration → Disinfection →

Groundwater Spreading

1974 RO →

Groundwater Injection

Pathogen Control

Coliform Standard

Groundwater Recharge: Learning Over 40 years

1962 | Filtration | Disinfection →

Groundwater Spreading

1974 | RO →

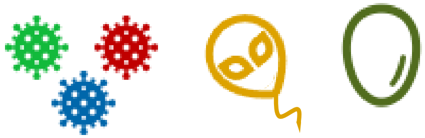
Groundwater Injection

Pathogen Control

Coliform Standard

Risk-Based LRTs

2011



12-log 10-log 10-log

Groundwater Recharge: Learning Over 40 years

1962 | Filtration | Disinfection →

Groundwater Spreading

Chemical Control

1974 | RO →

Groundwater Injection

Pathogen Control

Coliform Standard

Risk-Based LRTs

2011

12-log 10-log 10-log

Groundwater Recharge: Learning Over 40 years

1962 | Filtration | Disinfection →

Groundwater Spreading

Chemical Control

1974 | RO | UV Photolysis →

NDMA

2000s

Groundwater Injection

Pathogen Control

Coliform Standard

Risk-Based LRTs

2011

12-log | 10-log | 10-log

Groundwater Recharge: Learning Over 40 years

1962 Filtration | Disinfection →  **Groundwater Spreading**

Chemical Control

1974 RO | UV Photolysis | AOP →  **Groundwater Injection**

NDMA (UV Photolysis) *1,4-Dioxane* (AOP)

2000s

Pathogen Control

Coliform Standard

Risk-Based LRTs

2011

IPR Regulations Without Experience…

Pathogen Control

1962

Filtration

Disinfection

→

Groundwater Spreading

Coliform Standard

IPR Regulations With Experience

1962 | Filtration | Disinfection →

Groundwater Spreading

Pathogen Control

Coliform Standard

Chemical Control

1974 | RO | UV Photolysis | AOP →

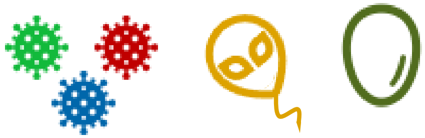
NDMA (UV Photolysis) · *1,4-Dioxane* (AOP)

Groundwater Injection

2000s

Risk-Based LRTs

2011



12-log | 10-log | 10-log

IPR Regulations With Experience

1962 Filtration | Disinfection →

Groundwater Spreading

Pathogen Control

Coliform Standard

Chemical Control

1974 RO | UV | AOP

LRTs

10-log

Takeaway: Expect a rush of new information when we get full-scale operational experience!

Importance: Regulations benefit when they include *flexibility* to adapt to advancements in public health protection

Lack of Flexibility is Main Issue with CA DPR

- We *should* structure DPR regs to account for our lack of experience
- IPR regs allow alternatives to all requirements (**alternatives clause**)
  - *Must prove public health protection is equal or better than default requirements*
- DPR has some flexibility but no broad alternatives clause
  - *This omission was the main concern of California agencies*
- **Outcome**: without flexibility, regs may unnecessarily limit innovation and close door on adaptive approach to public health protection

Summary

- Urgency of water supply issues will demand rapid solutions across the nation
- California's experience provides a template for others developing DPR regs
- California's regulatory development did many things well!

Research

Expert Panel

Guidance from other applications

Learning from Early Adopters

- **Main area for improvement**: allow flexibility to adapt to influx of new knowledge

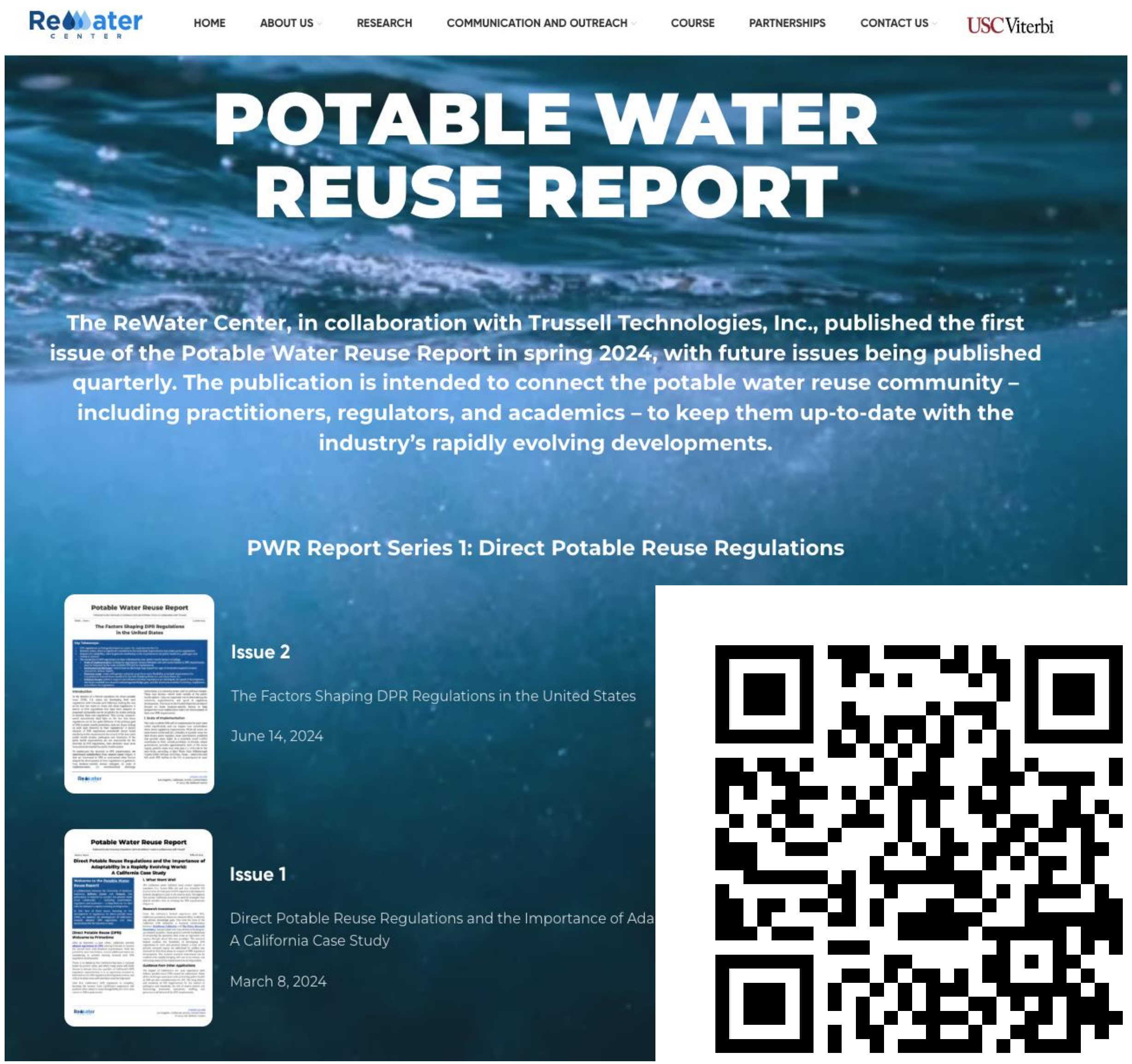
- *Need to ensure regulations allow us to evolve with our future experience*

Pathogen Log Crediting: A Primer

Shane Trussell, *Trussell*

September 11, 2025

- Pathogen Reduction Crediting for Potable Reuse Projects
  - *Issue 1: It's not what you remove, it's what you can prove!*
  - *Issue 2: Pathogen crediting for reverse osmosis: Getting credit where credit is due*
  - *Issue 3: Focus on wastewater treatment processes, especially MBR systems*



Why don’t we just measure the pathogens?

When it comes to pathogens, we just can't measure 'em all!

POKÉMON™

Gotta catch 'em all!™

Giardia

Cryptosporidium

Enteric Viruses

Campylobacter

We focus on a small group of resistant pathogens (**reference pathogens**)

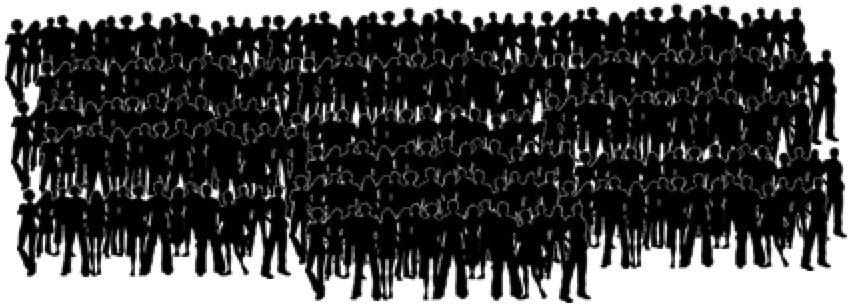
What concentrations are “safe”?

Infection Benchmark

No more than

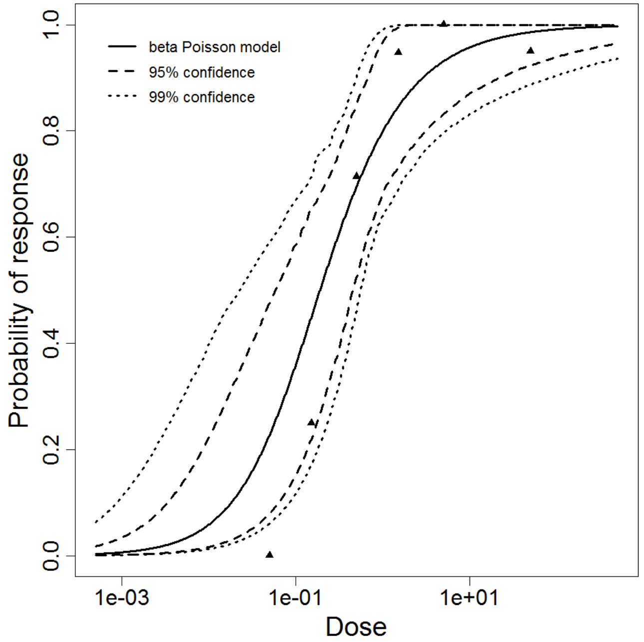
infection

per



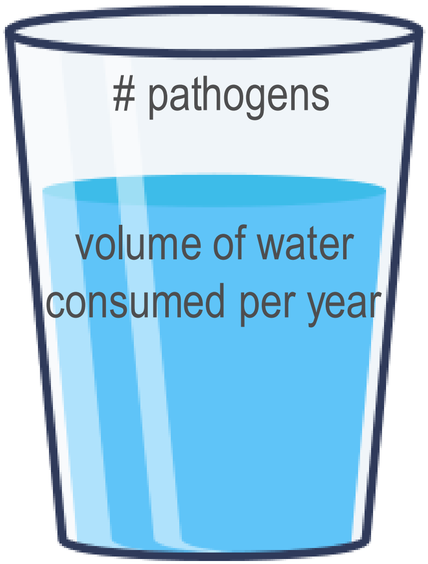
per year

Dose-Response



Tells us the <u>number of viruses</u> that would cause 10^{-4} infections

Safe Levels



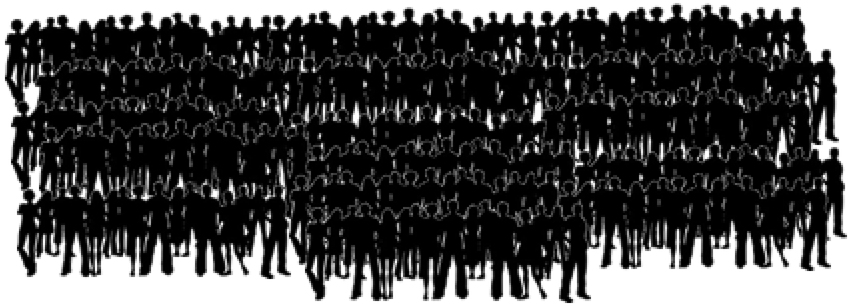
Acceptable virus concentration:
2.2×10^{-7} MPN/L

What concentrations are “safe”?

Infection Benchmark

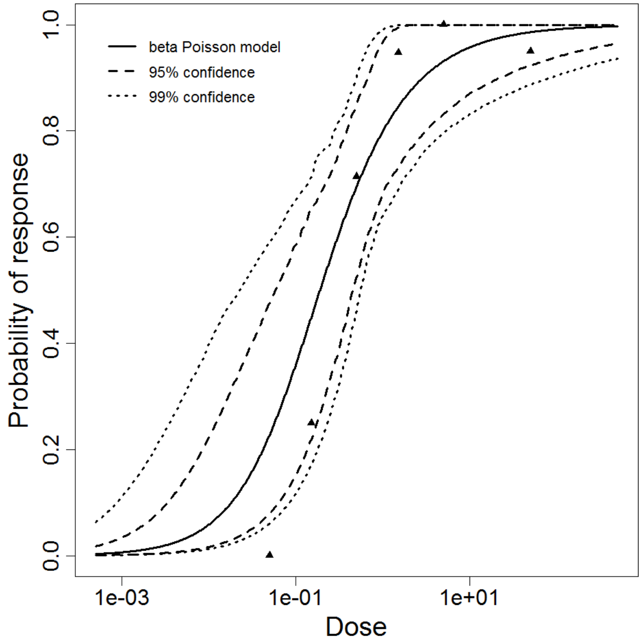
No more than  infection

per



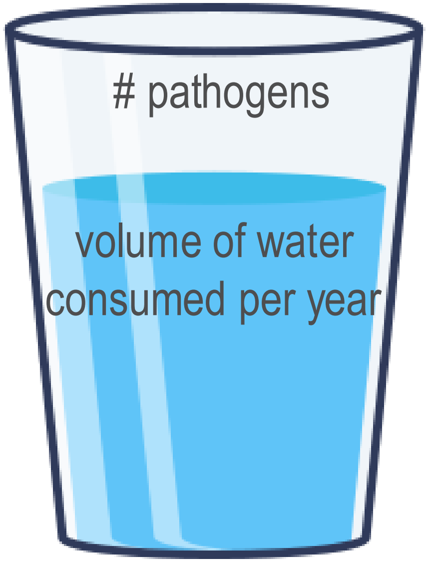
per year

Dose-Response



Tells us the <u>number of viruses</u> that would cause 10^{-4} infections

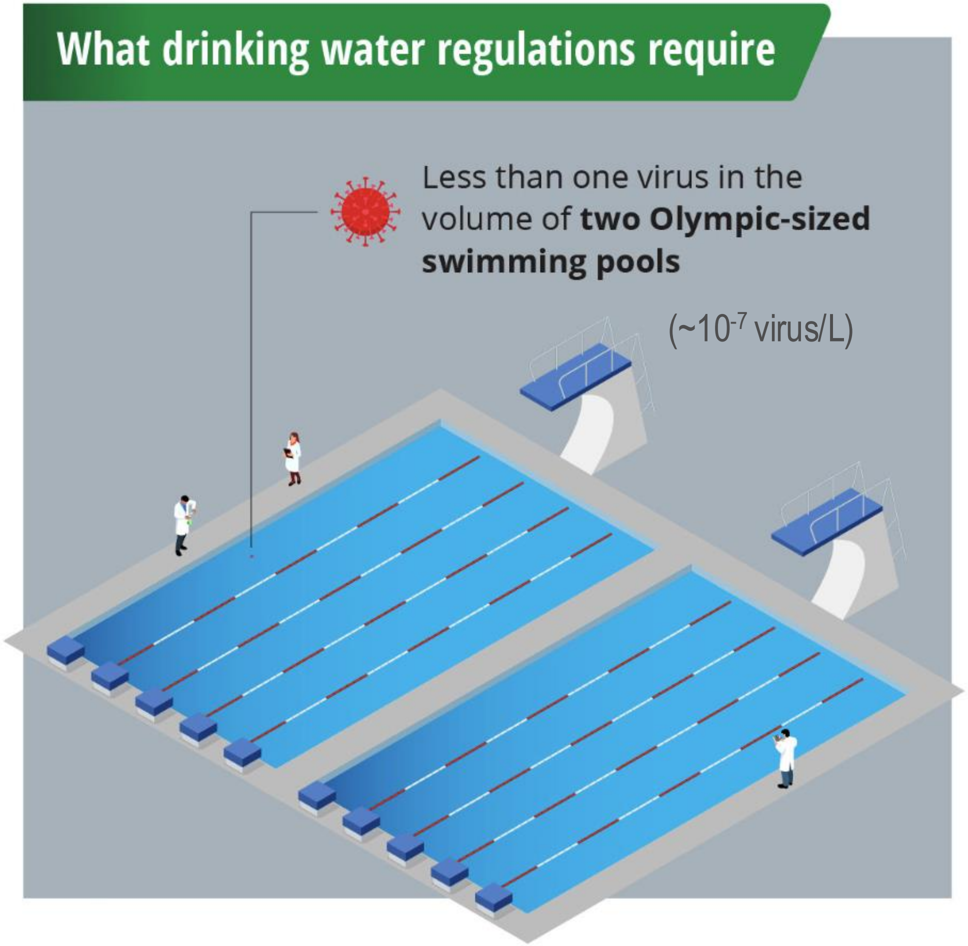
Safe Levels

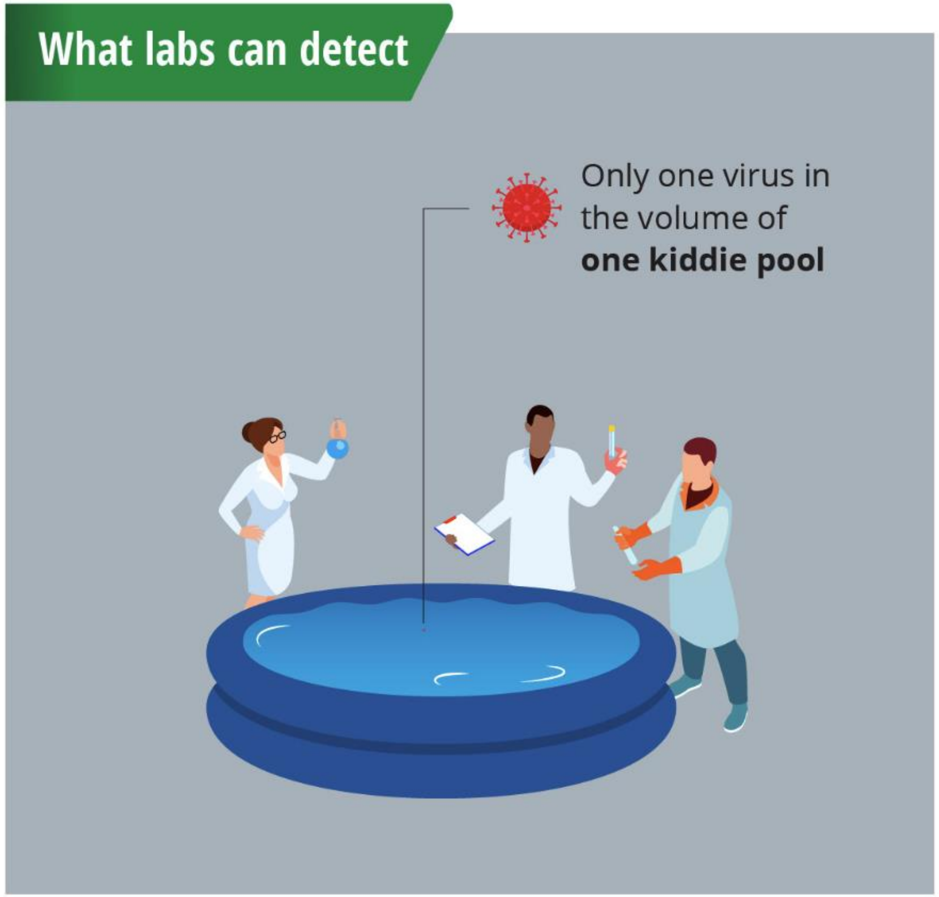


Acceptable virus concentration: **$2.2\text{x}10^{-7}$ MPN/L**

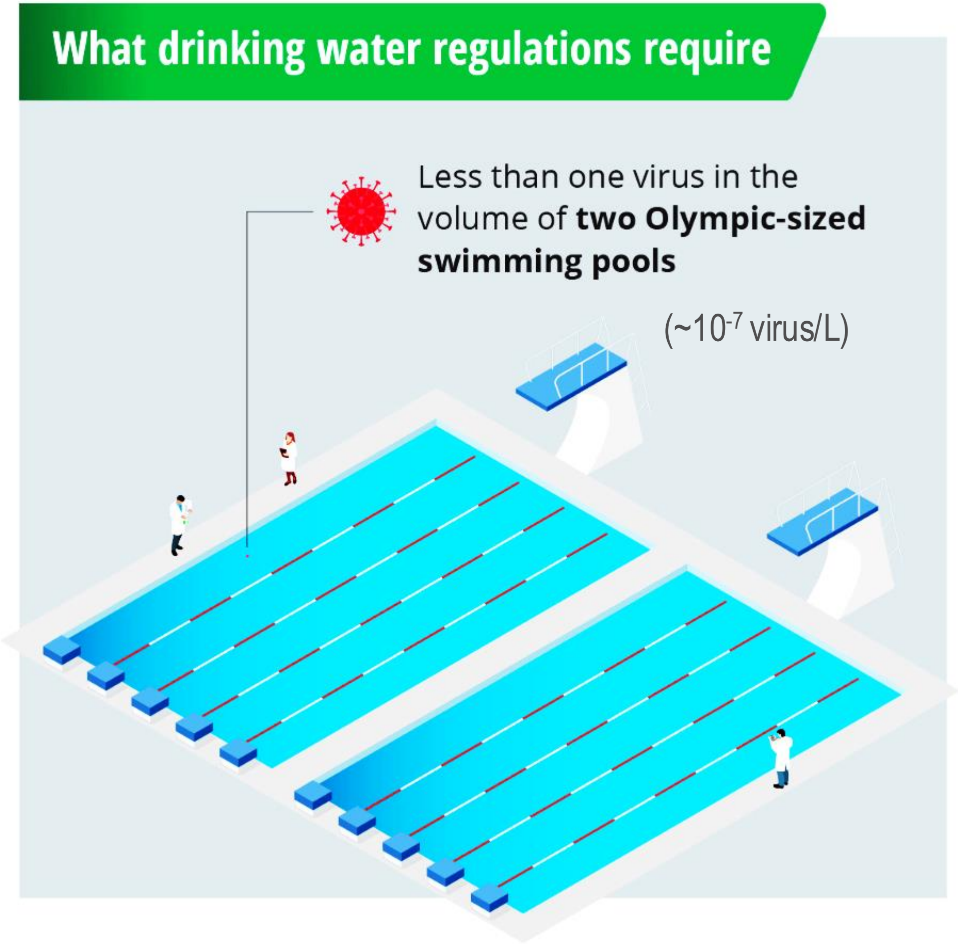
So, why don’t we just measure them?

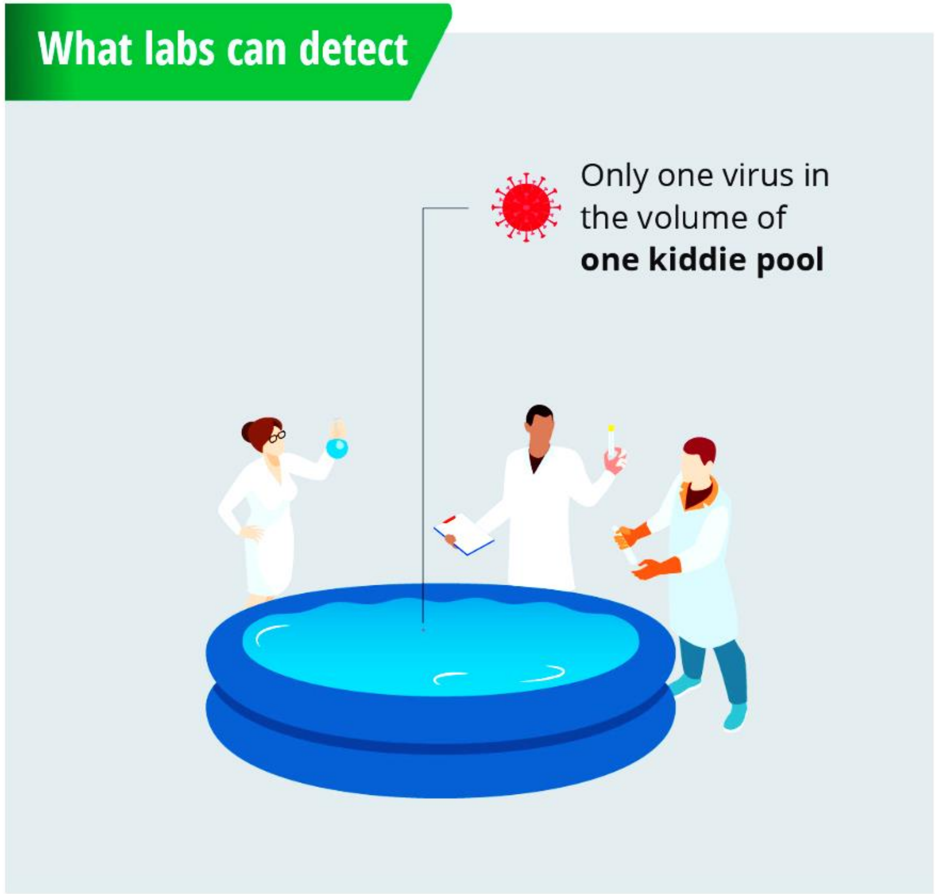
Why don't we just measure the treated water?





Why don't we just measure the treated water?





We are <u>technically incapable</u> of doing this!

Key Takeaway Message:

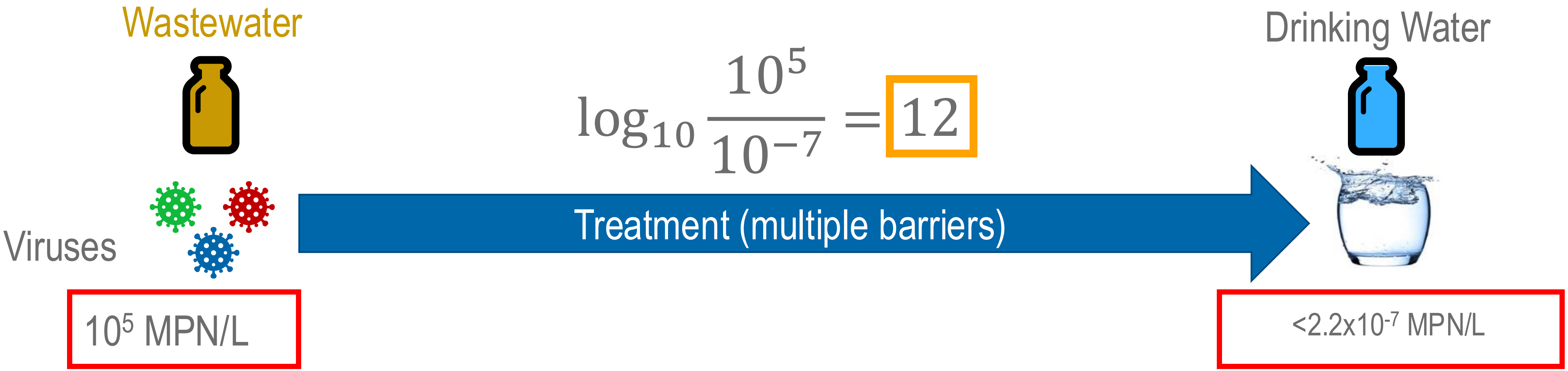
- *We cannot measure all the different types of pathogens down to the low levels needed for drinking water*

What is the alternative to end-point monitoring?

Plan B: define pathogen log reduction targets

Plan B: define pathogen log reduction targets

$$\log_{10}\frac{10^5}{10^{-7}} = \boxed{12}$$



We specify **log reduction targets** (**LRTs**) to confirm we meet our risk goals

Potable Reuse Requires High Pathogen LRTs

Key Takeaway Message:

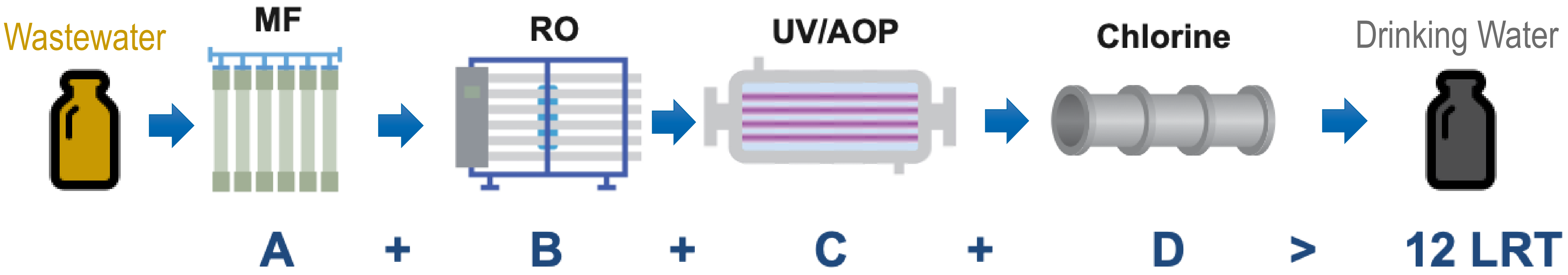
- *Potable water reuse requires much higher pathogen reduction than conventional drinking water treatment*

Why do we need pathogen crediting frameworks?

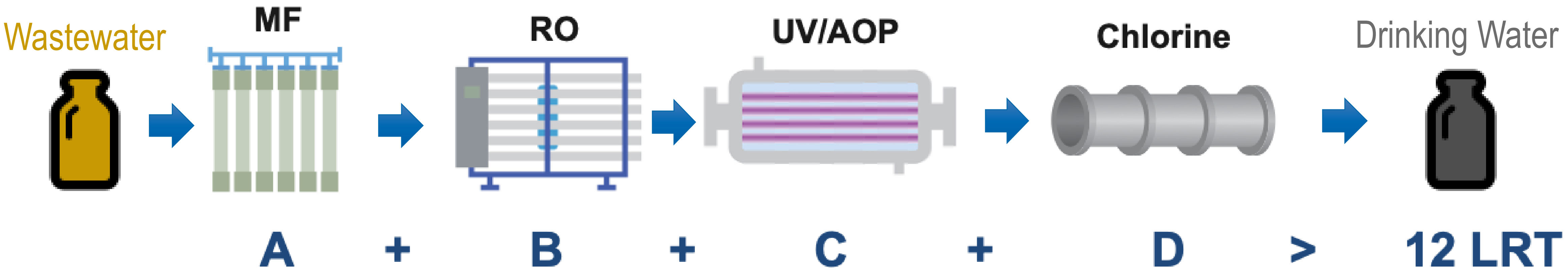
No single process allows us to meet our goals

Doesn’t exist.

Create trains that collectively meet LRTs

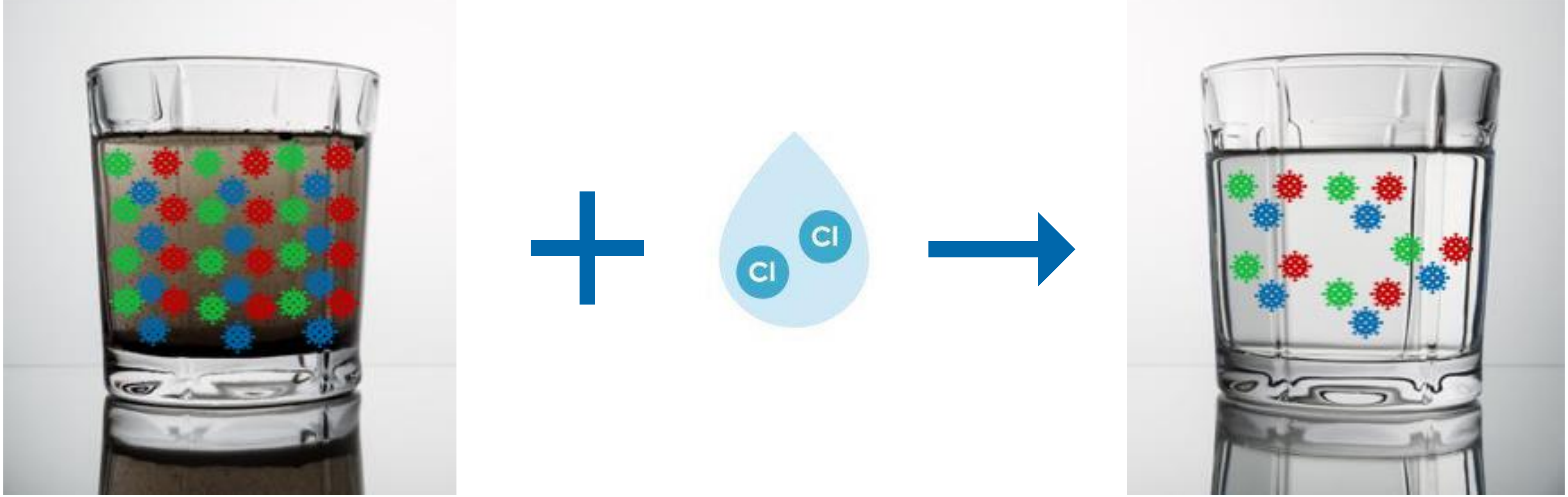


Create trains that collectively meet LRTs

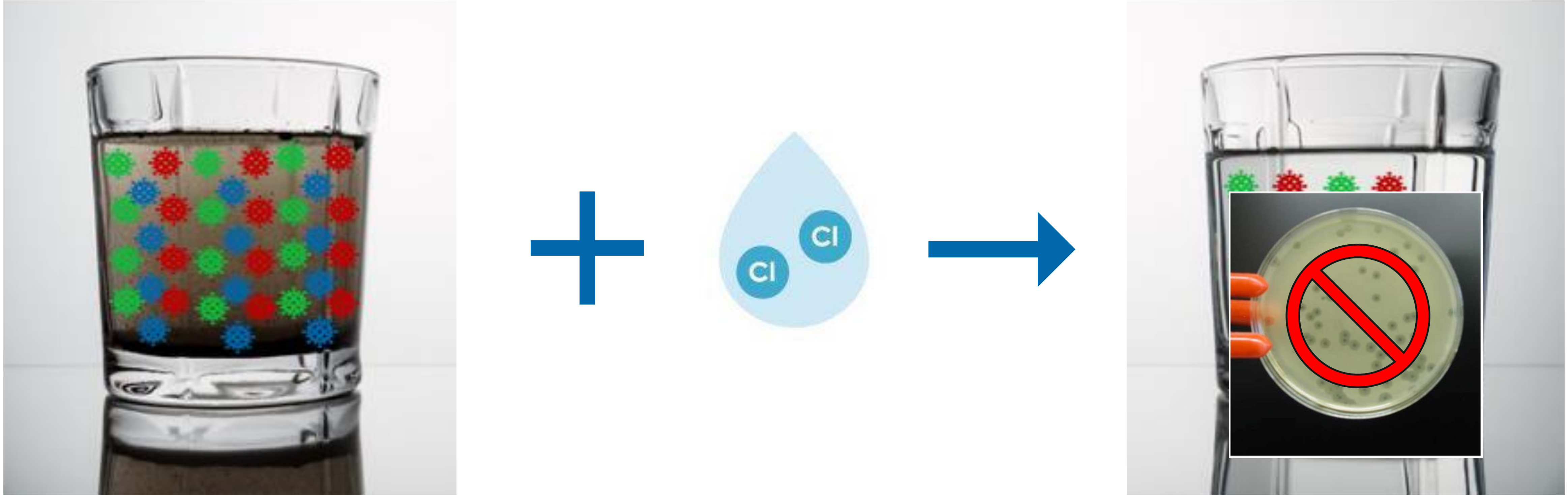


We need <u>crediting frameworks</u> to assign a log reduction value (LRV) to each unit process.

Crediting framework example: chlorine

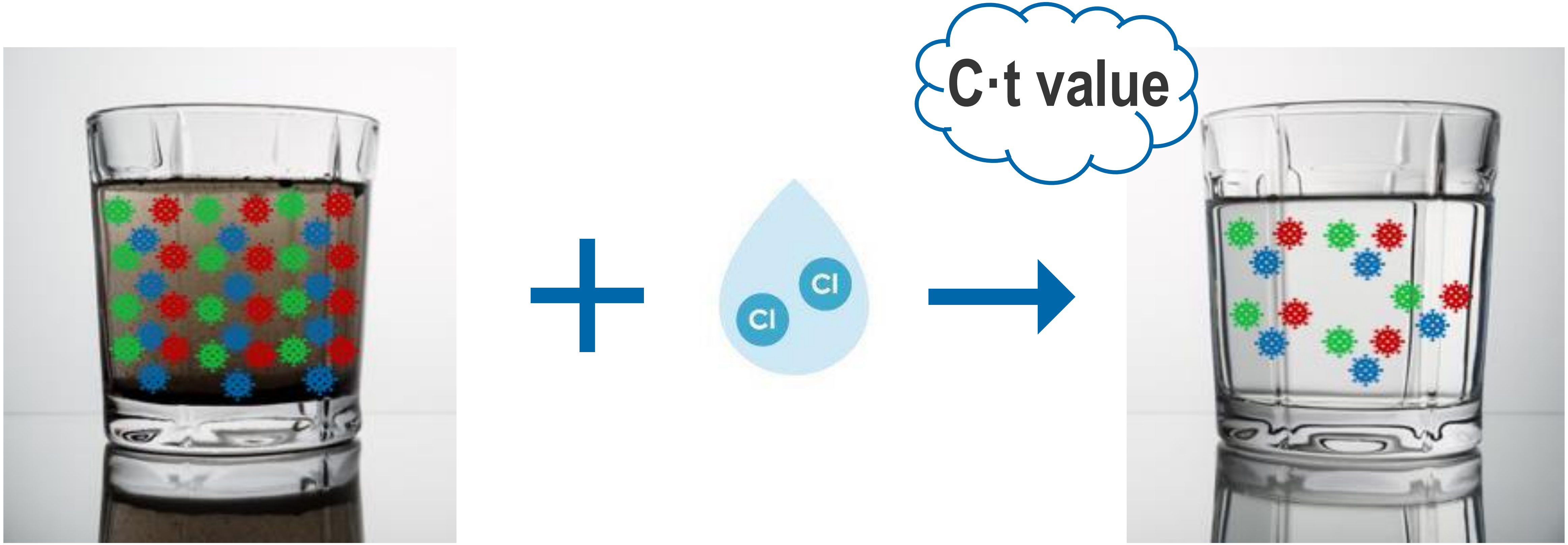


Crediting framework example: chlorine



Do not rely on direct measurement of pathogens

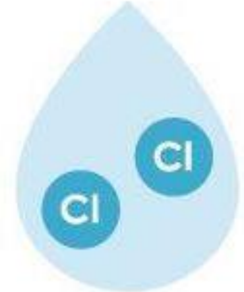
Crediting framework example: chlorine



Identify a <u>surrogate</u> that is directly tied to pathogen inactivation

Crediting framework example: chlorine

+



→

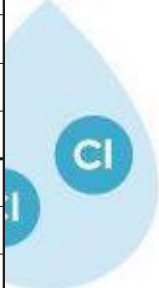
C·t value

…that can be continuously measured with online meters…

Crediting framework example: chlorine

Table 1 CT values for 1 to 4 log reduction values of viruses at a range of turbidity, pH and temperc

pH	Log_{10} inactivation	≤0.2 NTU					≤2 NTU				
		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
	2	5	4	3	2	2	5	4	3	2	2
	3	7	5	4	3	2	7	5	4	3	2
	4	8	6	4	3	2	9	6	4	3	2
≤7.5	1	7	5	4	3	2	7	5	4	3	2
	2	10	7	5	4	3	10	7	5	4	3
	3	13	9	7	5	4	13	9	7	5	4
	4	16	11	8	6	4	16	11	8	6	4
≤8	1	9	7	5	3	3	10	7	5	4	3
	2	14	10	7	5	4	15	10	7	5	4
	3	18	13	9	7	5	19	13	10	7	5
	4	23	16	12	8	6	23	16	12	8	6



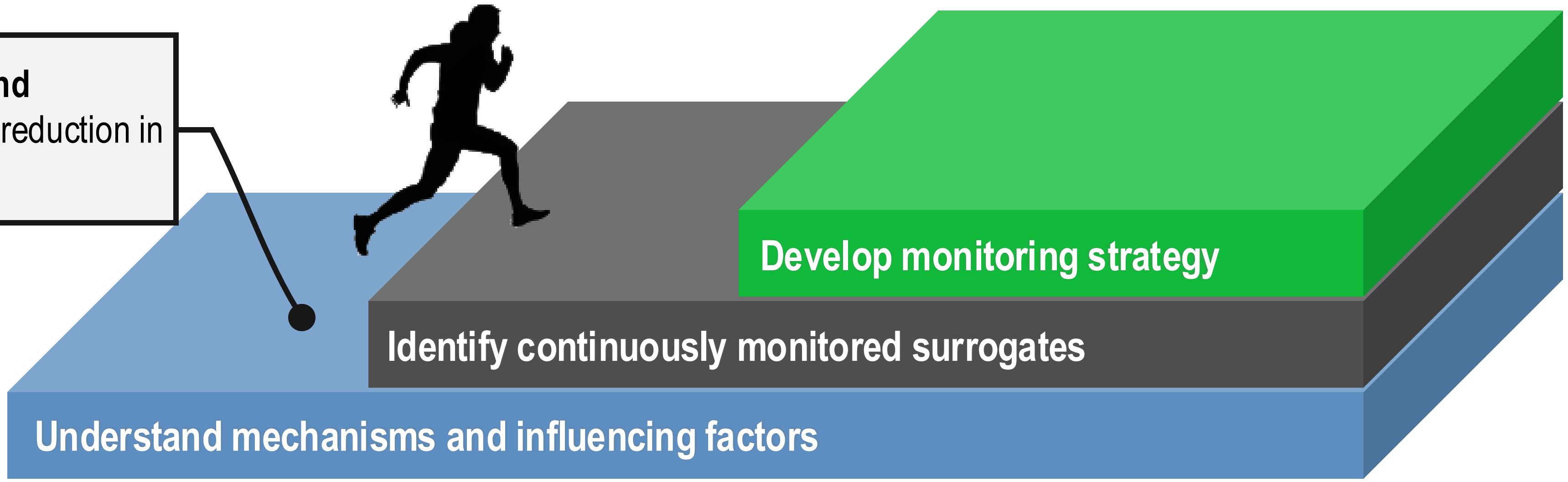
C·t value

…and where factors influencing performance are well understood.

Crediting Frameworks: General Approach

Step 1

Understand the mechanisms and influencing factors of pathogen reduction in the treatment process



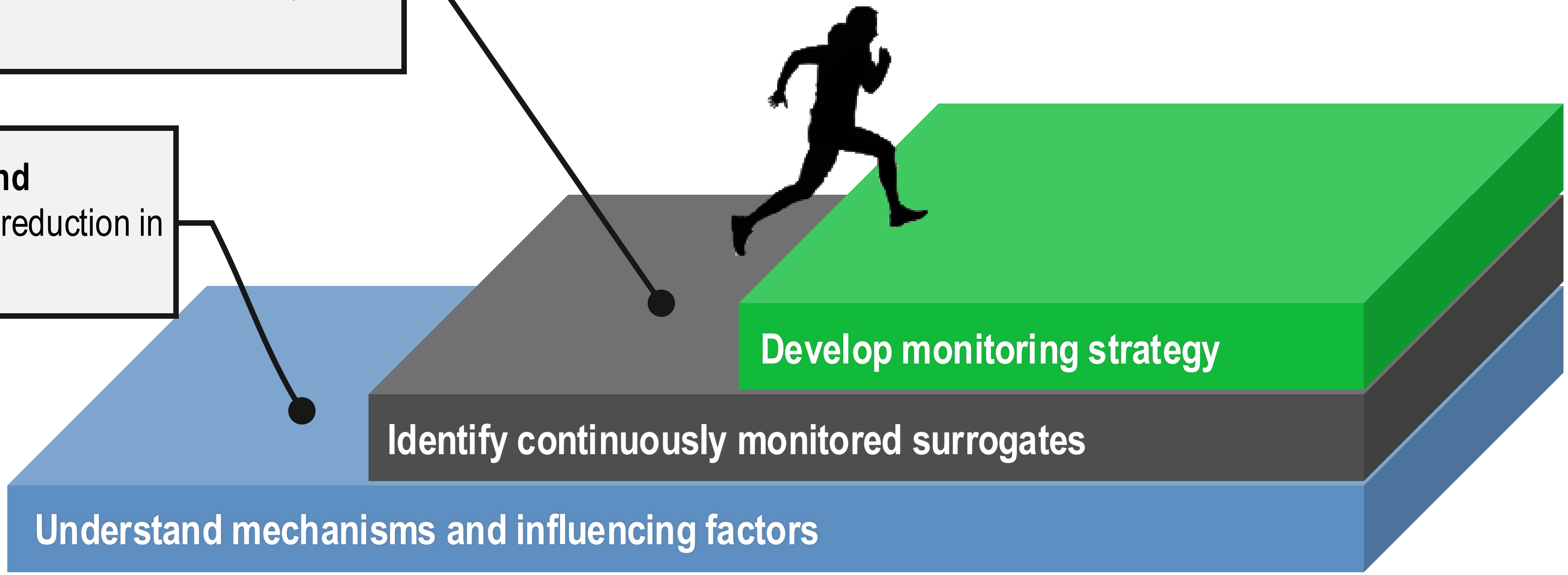
Crediting Frameworks: General Approach

Step 2

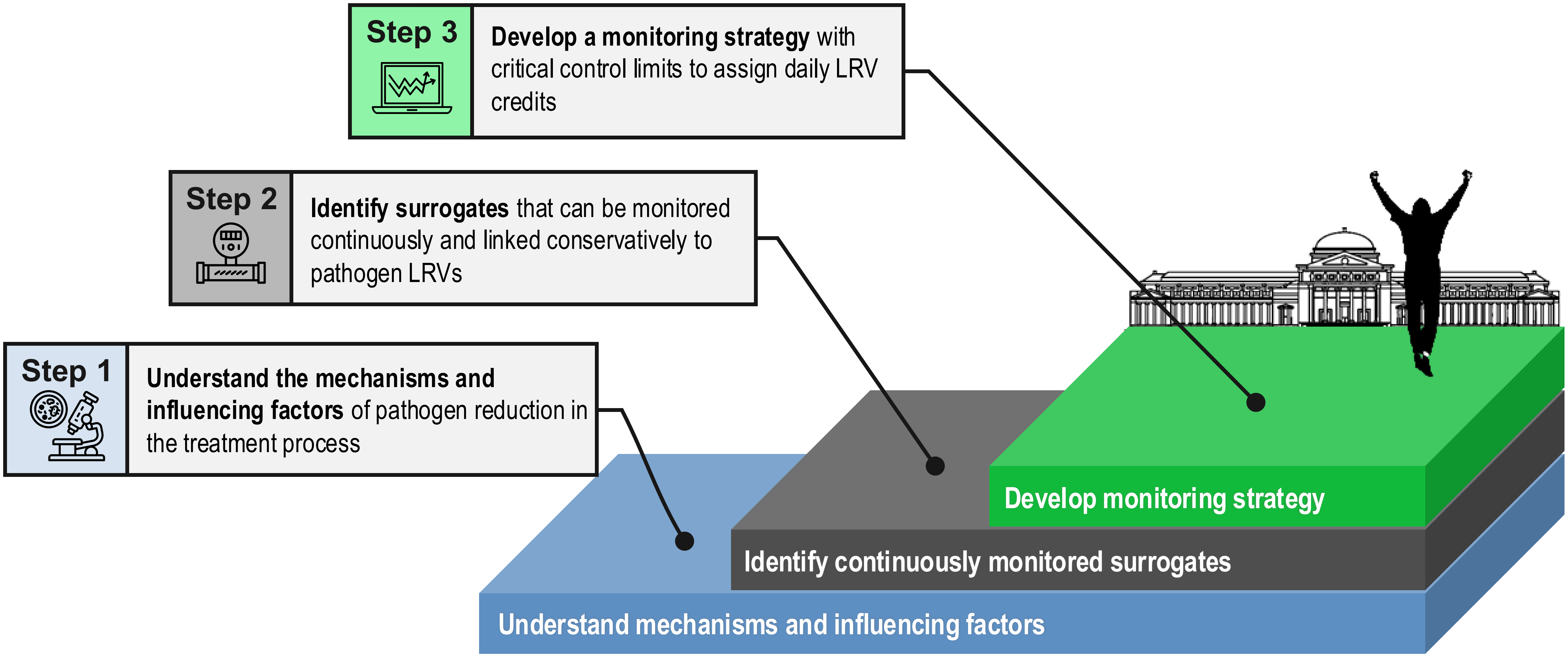
Identify surrogates that can be monitored continuously and linked conservatively to pathogen LRVs

Step 1

Understand the mechanisms and influencing factors of pathogen reduction in the treatment process



Crediting Frameworks: General Approach

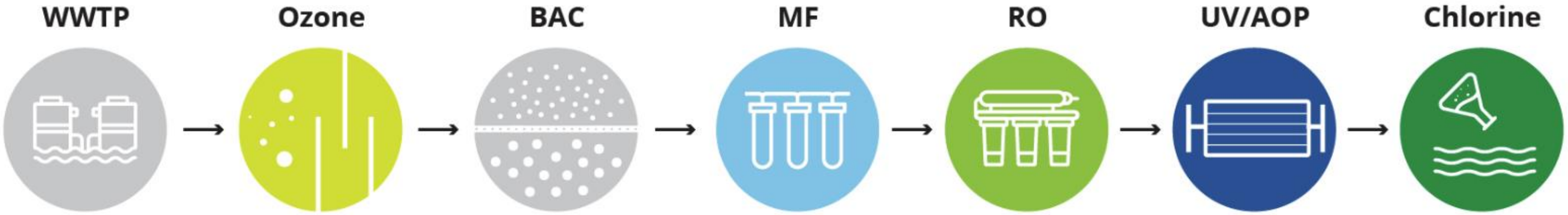


Key Takeaway Message:

- *Regulations compare pathogen reduction requirements with "credits" that can be achieved by individual processes, but these must be verified continuously using surrogates*

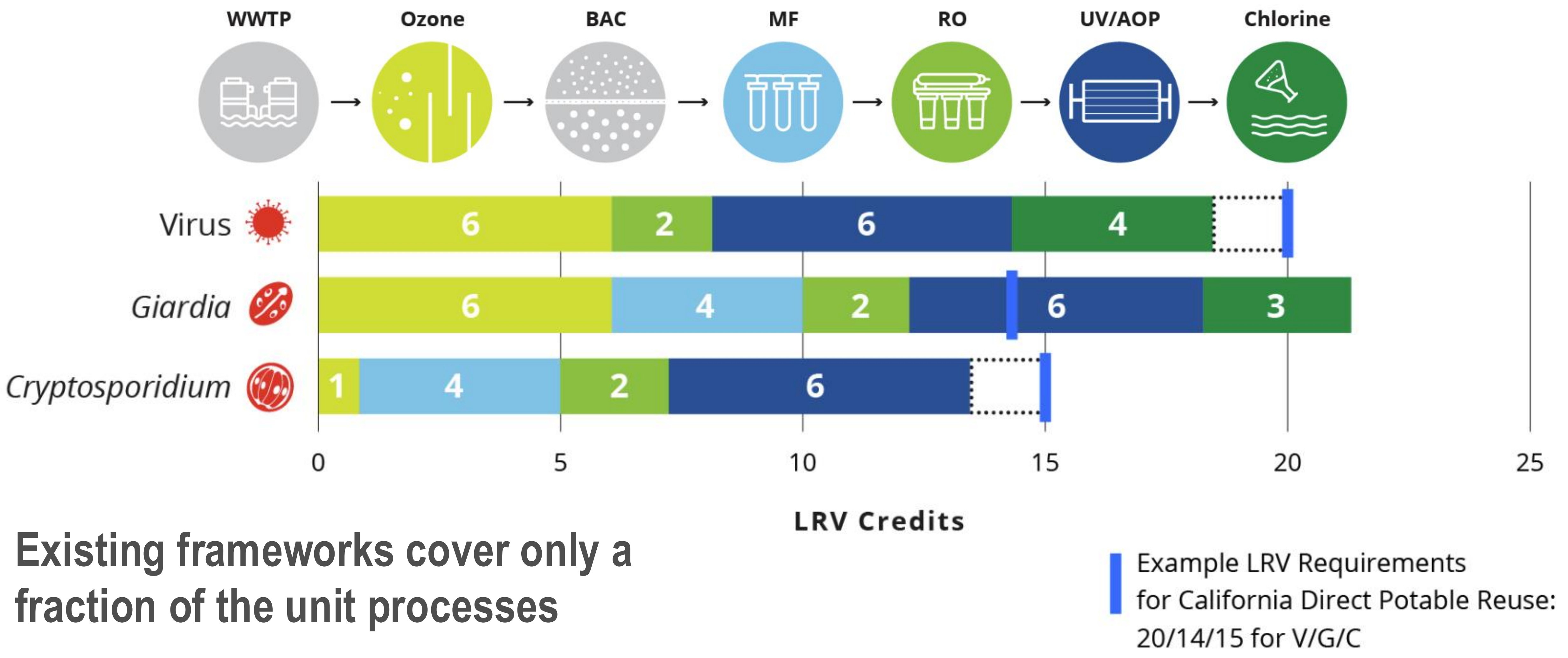
Why do we need new crediting frameworks?

Review of Unit Process Crediting



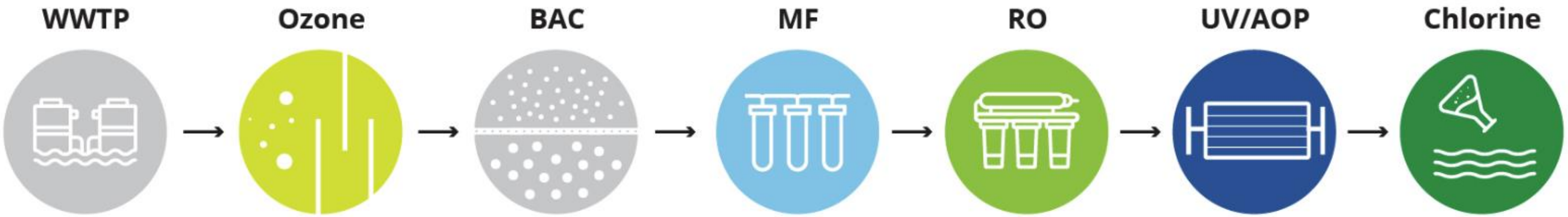
Which processes have existing pathogen crediting frameworks?

Review of Unit Process Crediting

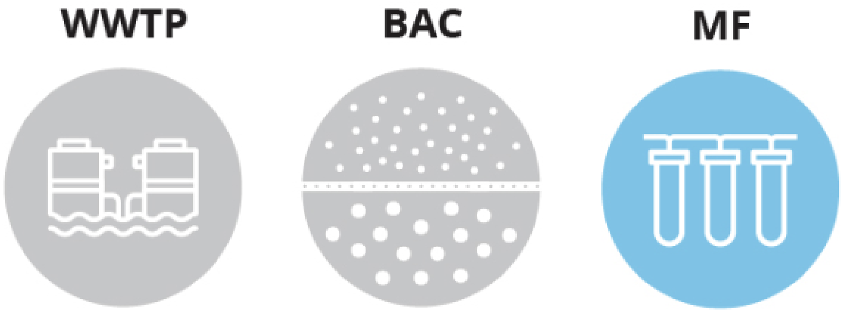


Existing frameworks cover only a fraction of the unit processes

Review of Unit Process Crediting



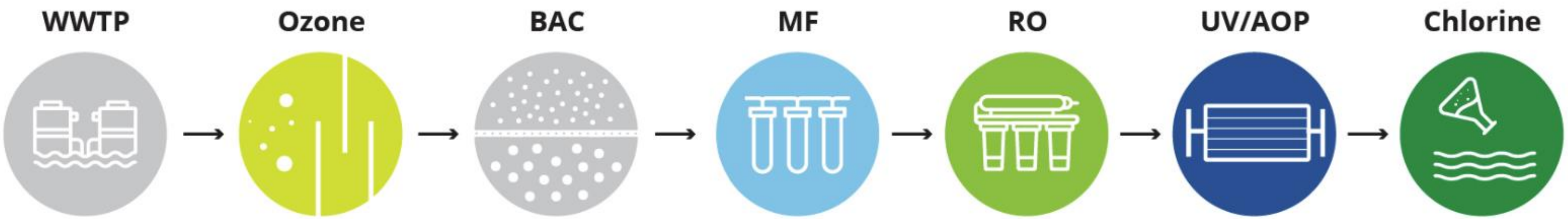
Some treatment processes are completely uncredited



No credit for any pathogens

No credit for viruses

Review of Unit Process Crediting



Some are under-credited

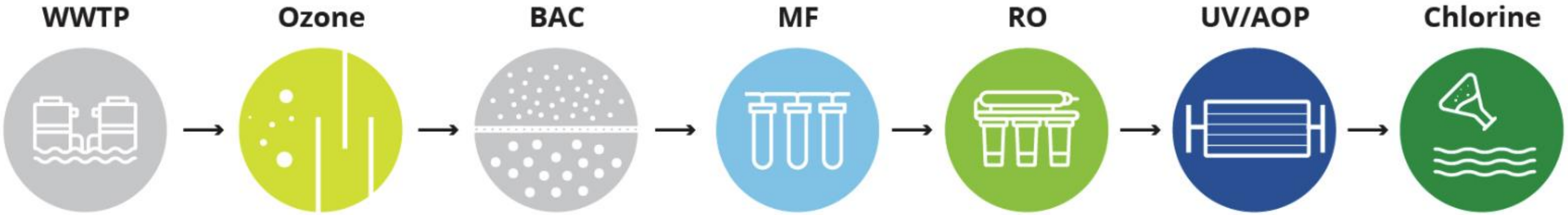
RO

Only 2-log credit for all pathogens

Chlorine

Only 4-log credit for viruses

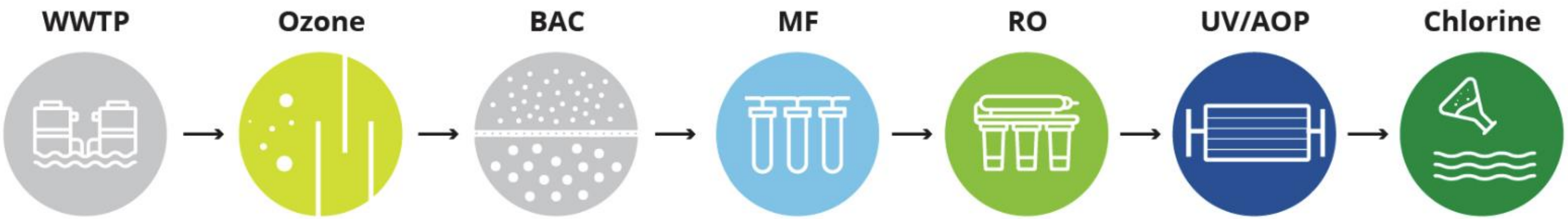
Review of Unit Process Crediting



Pathogen	WWTP	Ozone	BAC	MF	RO	UV/AOP	Cl_2	Total	Required (CA)
Virus	-	6	-	-	2	6	4	18	20
Giardia	-	6	-	4	2	6	3	19	14
Crypto	-	1	-	4	2	6	-	13	15

Extremely robust treatment trains can't meet DPR requirements!

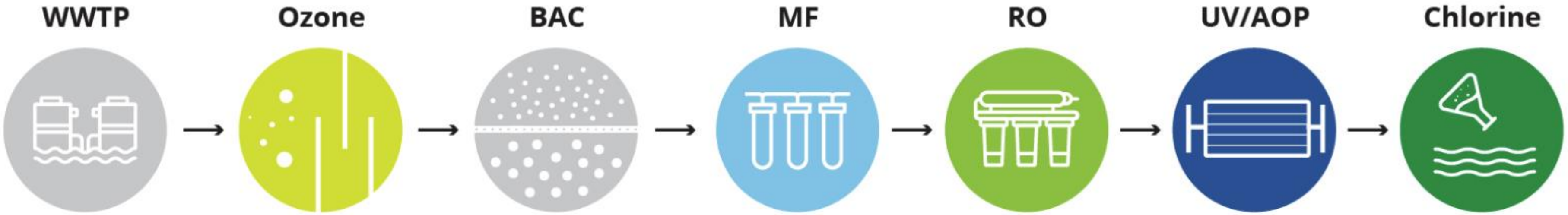
Review of Unit Process Crediting



Pathogen	WWTP	Ozone	BAC	MF	RO	UV/AOP	Cl_2	Total	Required (CA)
Virus	-	6	-	-	2	6	4	18	20
Giardia	-	6	-	4	2	6	3	19	14
Crypto	-	1	-	4	2	6	-	13	15

Should we add on even *MORE* unit processes?

Review of Unit Process Crediting



Pathogen	WWTP	Ozone	BAC	MF	RO	UV/AOP	Cl_2	Total	Required (CA)
Virus	1	6	-	-	3	6	6	**22**	20
Giardia	1	6	1	4	3	6	3	**19**	14
Crypto	1	1	1	4	3	6	-	**16**	15

Or can we get the rightful credit for our existing processes?

Summary

- We cannot measure pathogens at the low levels needed for drinking water
- Potable reuse requires higher LRTs than conventional drinking water treatment
- Pathogen compliance requires log "credits" to meet or exceed the minimum LRTs
- Crediting frameworks typically rely on surrogates to track treatment performance
- To improve the efficiency of potable reuse:
  - *Expand existing frameworks to maximize pathogen credits*
  - *Create new frameworks for under-credited and uncredited processes*

Pathogen crediting for potable reuse: Get credit where credit is due!

Matthew E. Verbyla, Ph.D.

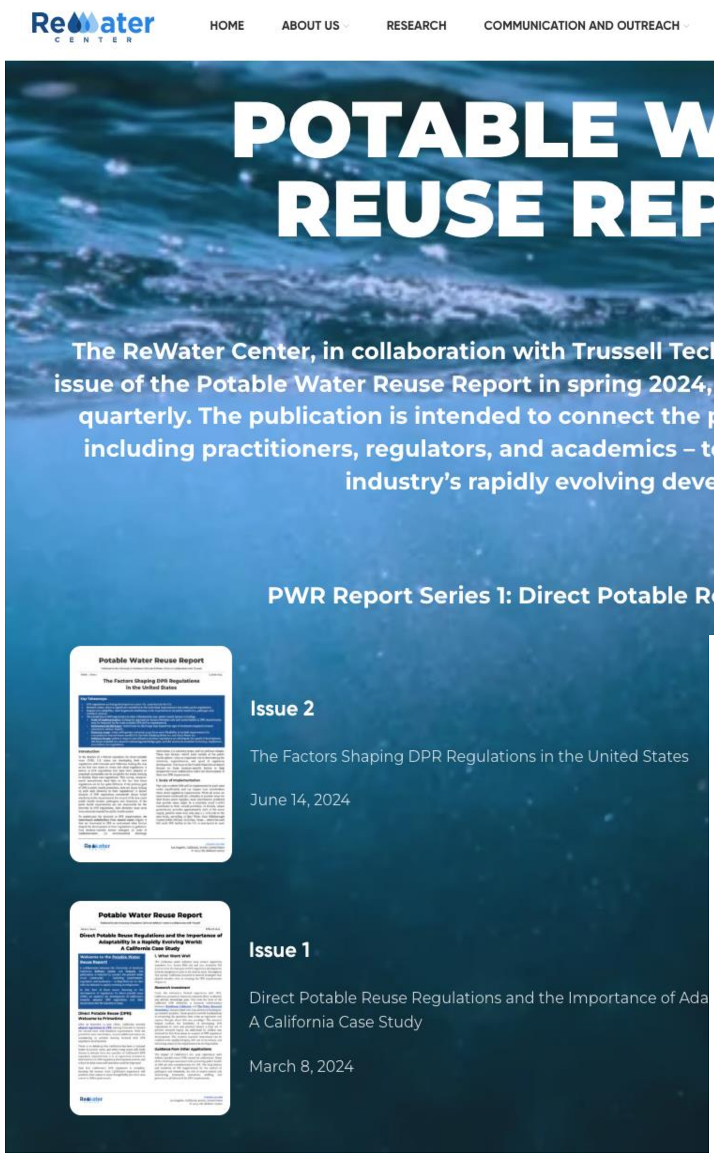
SDSU | San Diego State University

ReWater CENTER

Agenda

Pathogen Reduction Crediting for Potable Reuse Projects

- Issue 1: It's not what you remove, it's what you can prove!
- **Issue 2: Pathogen crediting for reverse osmosis: Getting credit where credit is due with good surrogates**
- **Issue 3: Tapping into untapped potential: Why some treatment processes lack pathogen credits and what to do about it**



ReWater CENTER

This presentation will be interactive!

Your participation is voluntary. Enter your name, email, and organization (if you wish), then wait for my prompt to proceed to each question in the survey.

Three Approaches Currently Used for LRV Crediting

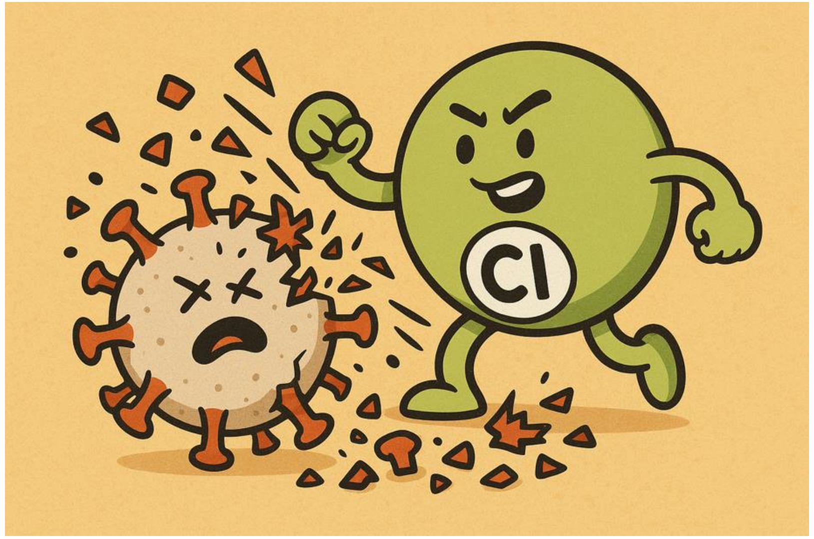
1. Modeling approach
2. Surrogate approach
3. Operational envelope approach

> *"Ideally, you prove that you are controlling pathogens via continuous monitoring of a relevant parameter—such as a surrogate or an indicator—to justify the credit in real-time and to enable rapid corrective actions in the event of a treatment failure."*
>
> Amos Branch, Carollo Engineers

Scientific Understanding of Pathogen Reduction

Modeling Approach

We really understand the mechanisms well (e.g., chlorination)



Free chlorine reacts with cellular components, a reaction that is influenced by the CT value, temperature, and pH

Surrogate Approach

We have a surrogate that is continuously measured (e.g., conductivity for RO)

ReWater CENTER

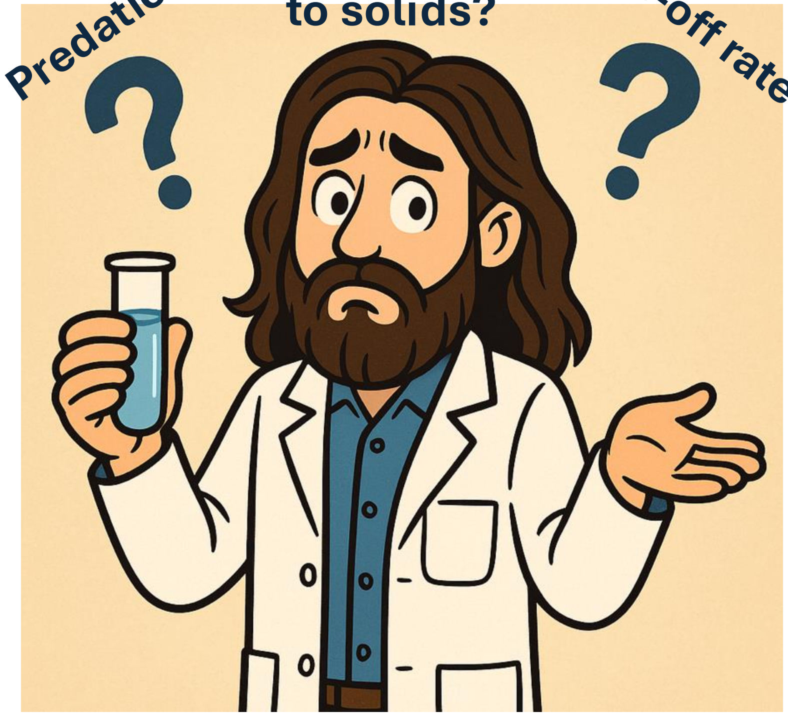
Operational Envelope

At best, we can get an empirical understanding (e.g., activated sludge)

Predation?

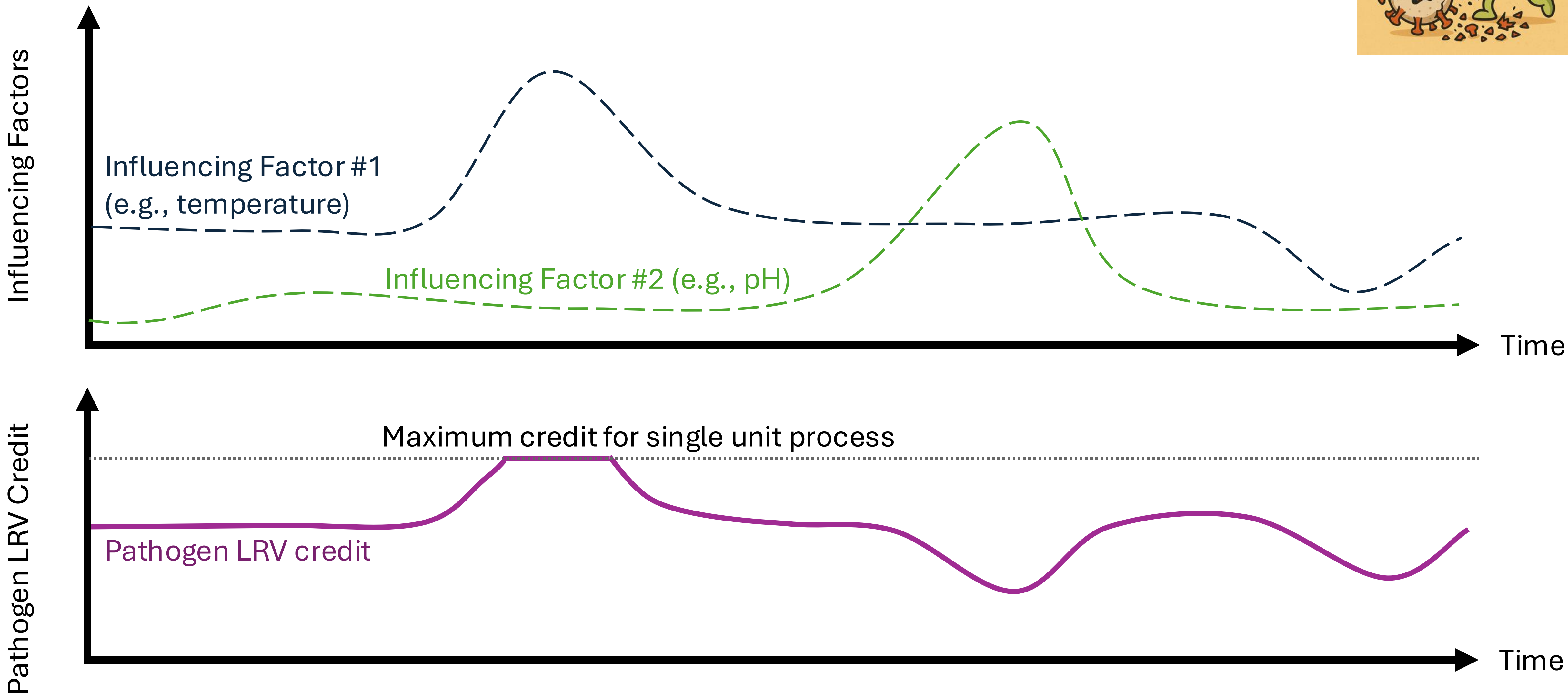
Attached to solids?

Die-off rate?



"Let's just do a study."

Approach #1: Modeling the Pathogen LRV



ReWater CENTER

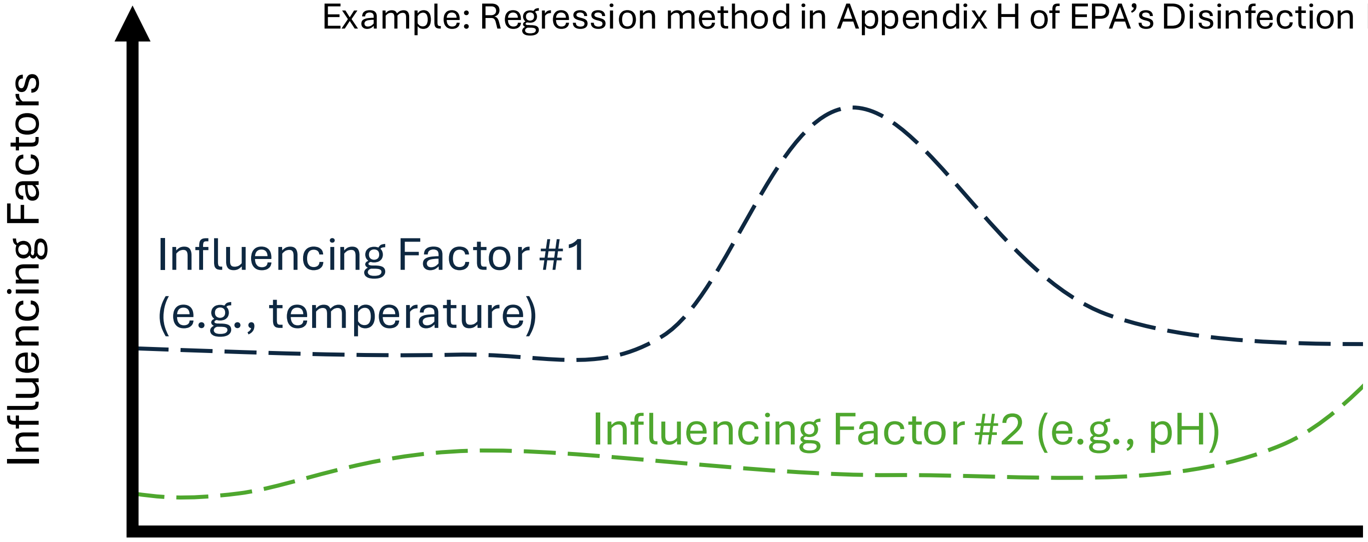
Approach #1: Modeling the Pathogen LRV

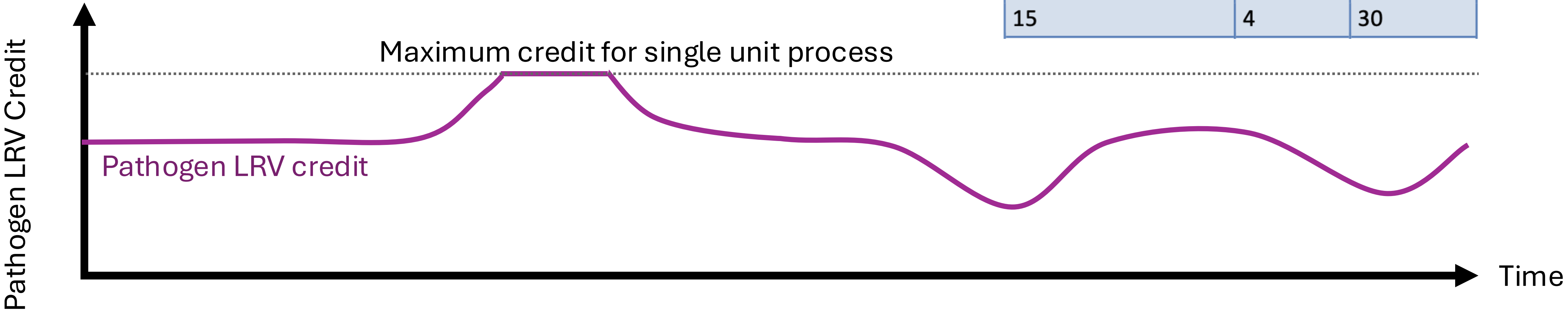
Example: Regression method in Appendix H of EPA's Disinfection Profiling and Benchmarking Technical Guidance Manual (2020)

$$LRV = \frac{CT}{0.361\left(-2.261 + e^{\left(2.69 - 0.065T + 0.111C + 0.361(pH)\right)}\right)}$$

Table B-2. CT Values* for 4-Log Inactivation of Viruses by Free Chlorine

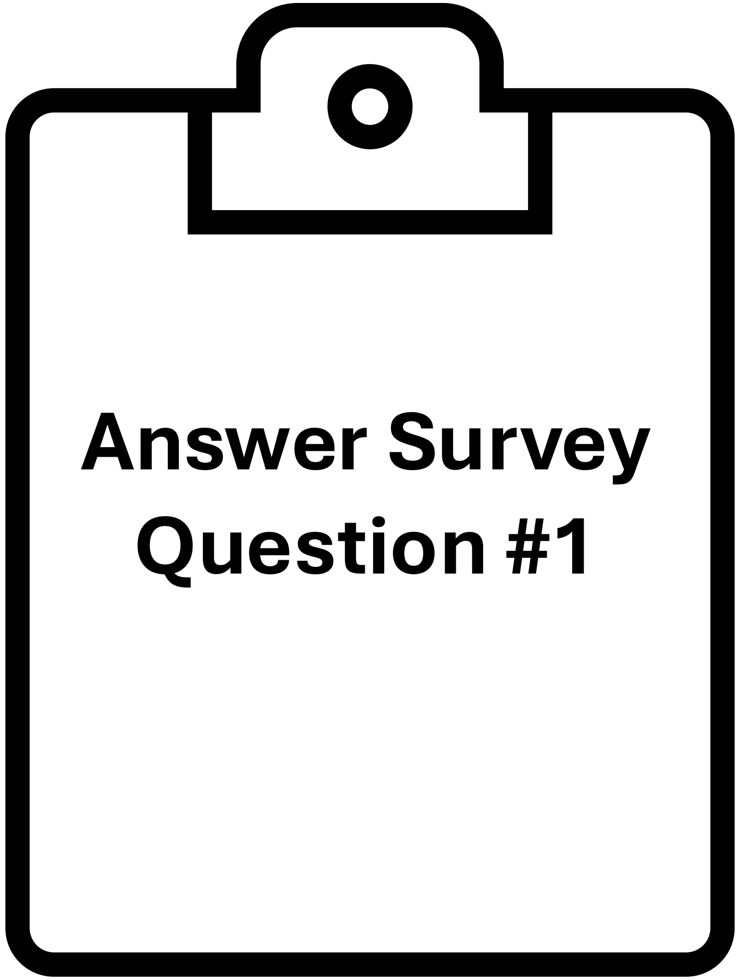
	pH	
Temperature (°C)	**6-9**	**10**
0.5	12	90
5	8	60
10	6	45
15	4	30



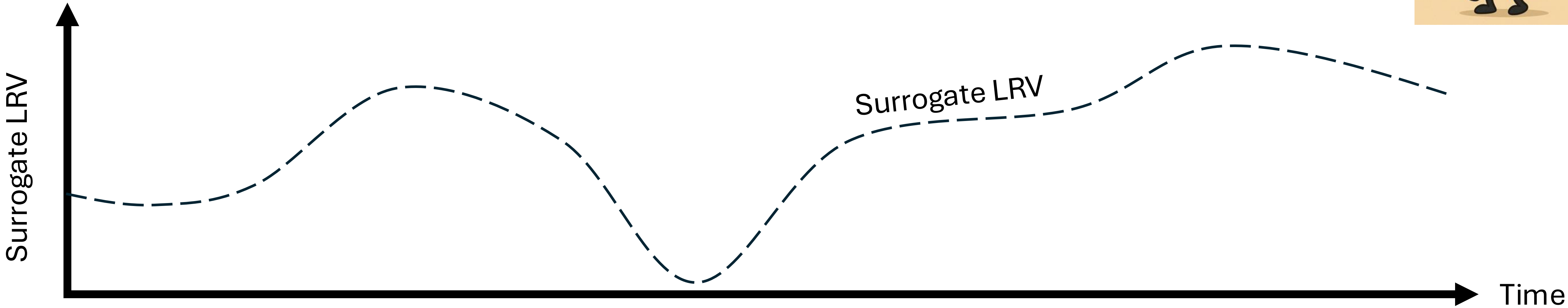


ReWater CENTER

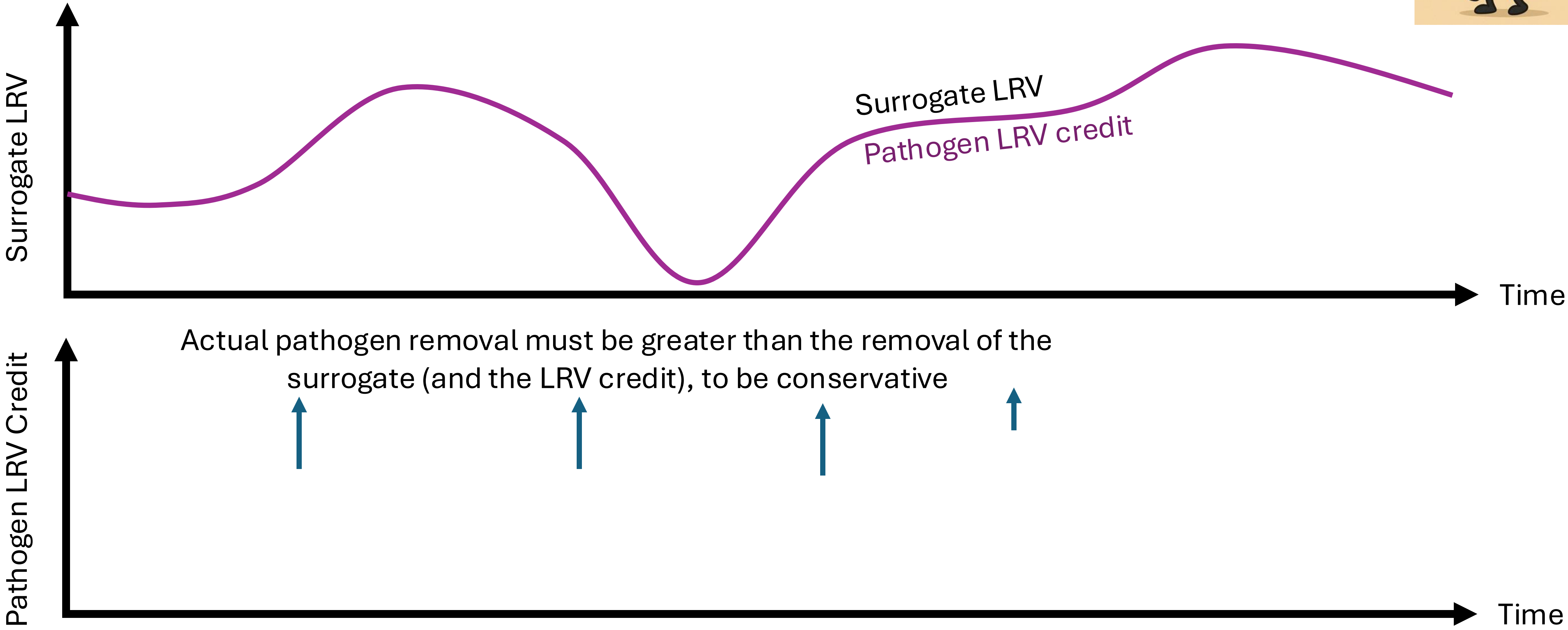
Approach #1: Modeling the Pathogen LRV



Approach #2: Conservative Surrogate



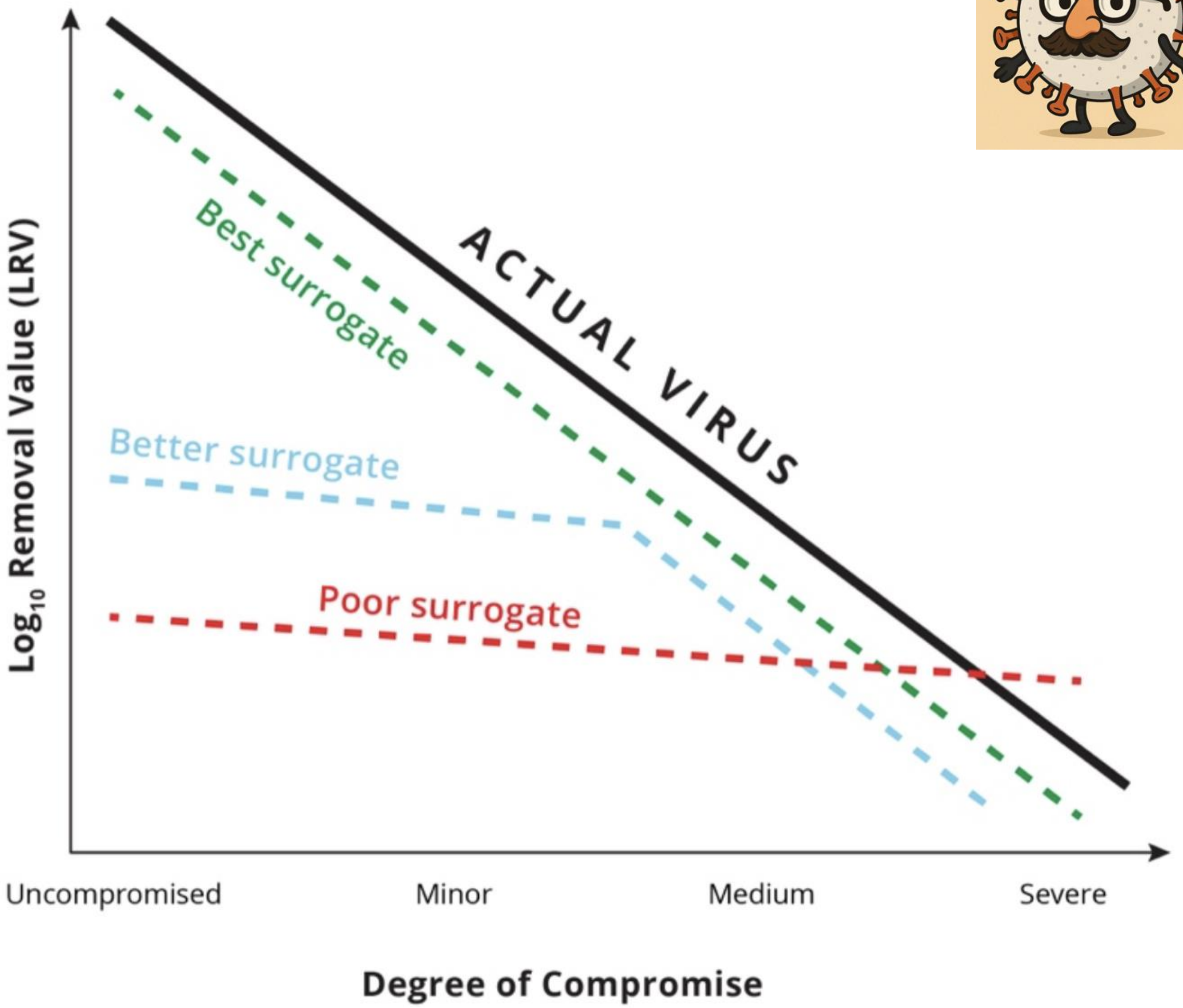
Approach #2: Conservative Surrogate



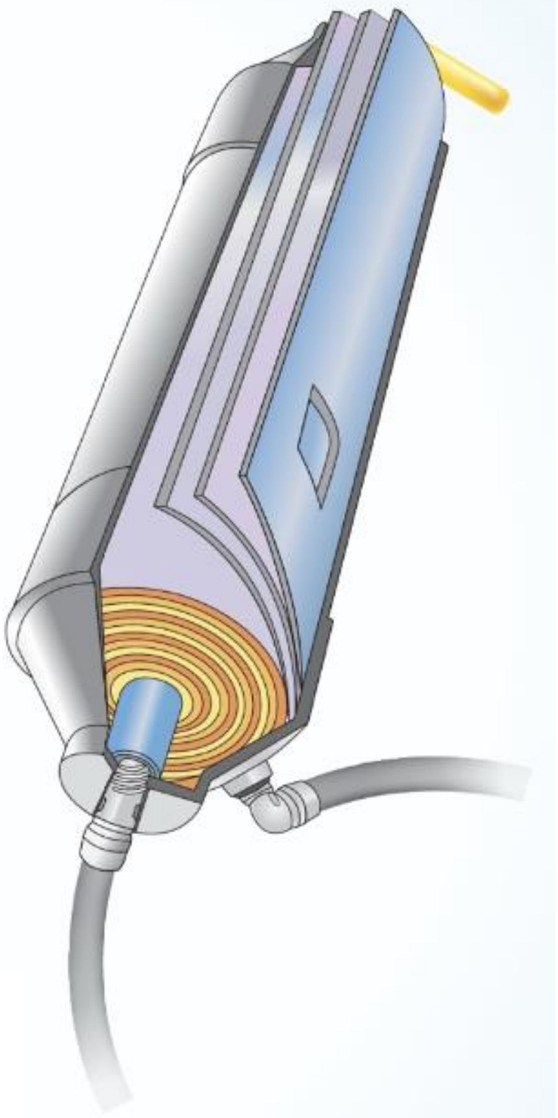
ReWater CENTER

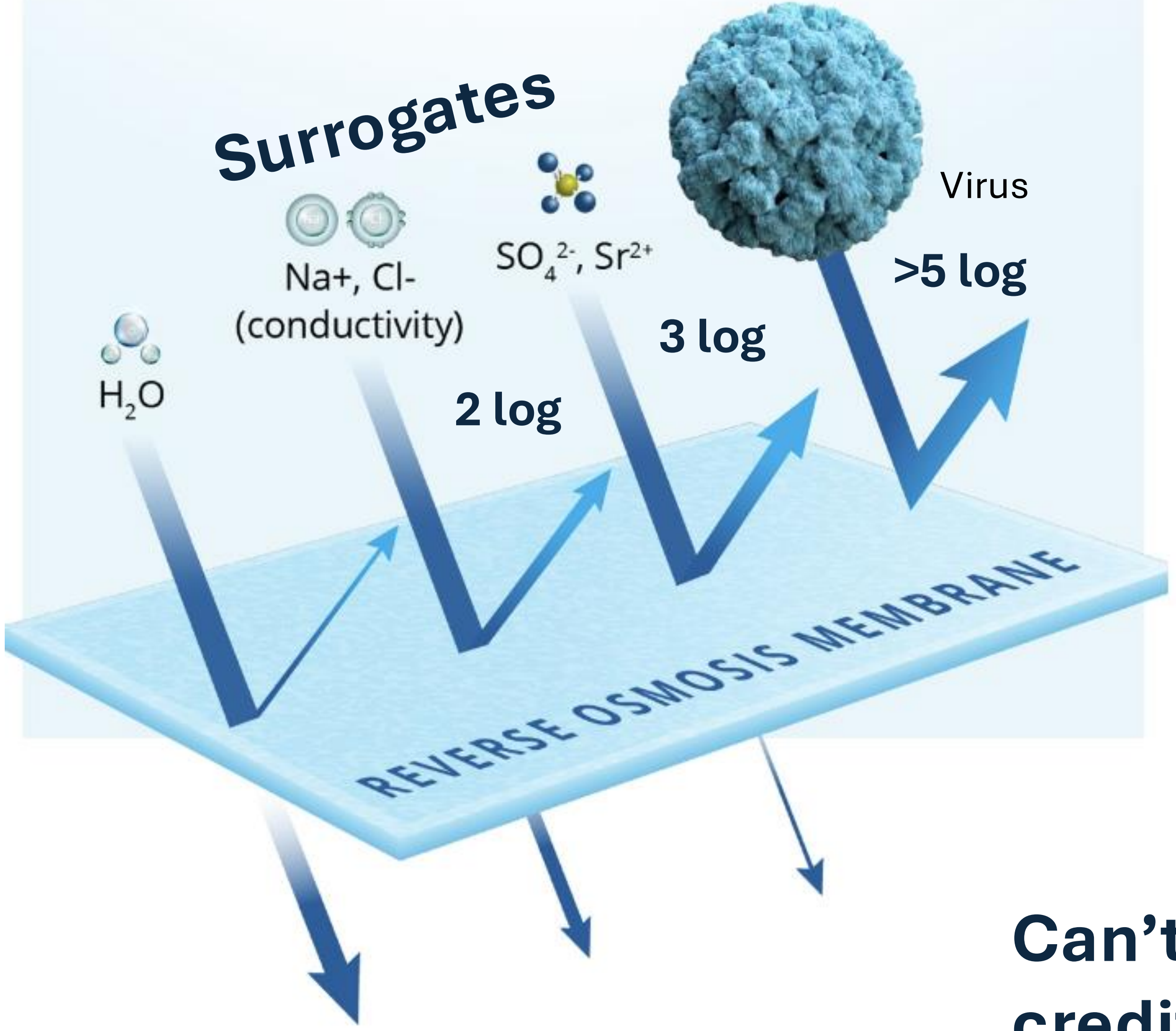
What makes a good surrogate?

- A good surrogate has a similar LRV as the pathogen, under a wide range of values of influencing factors and operational parameters.
- For RO membranes, a key factor is membrane integrity (the degree of compromise)



ReWater CENTER



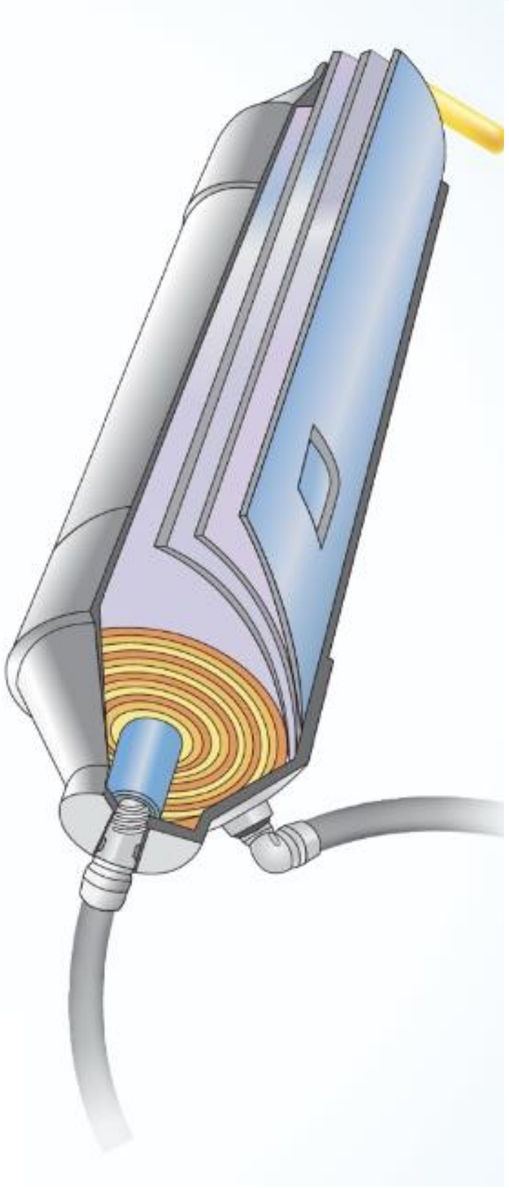


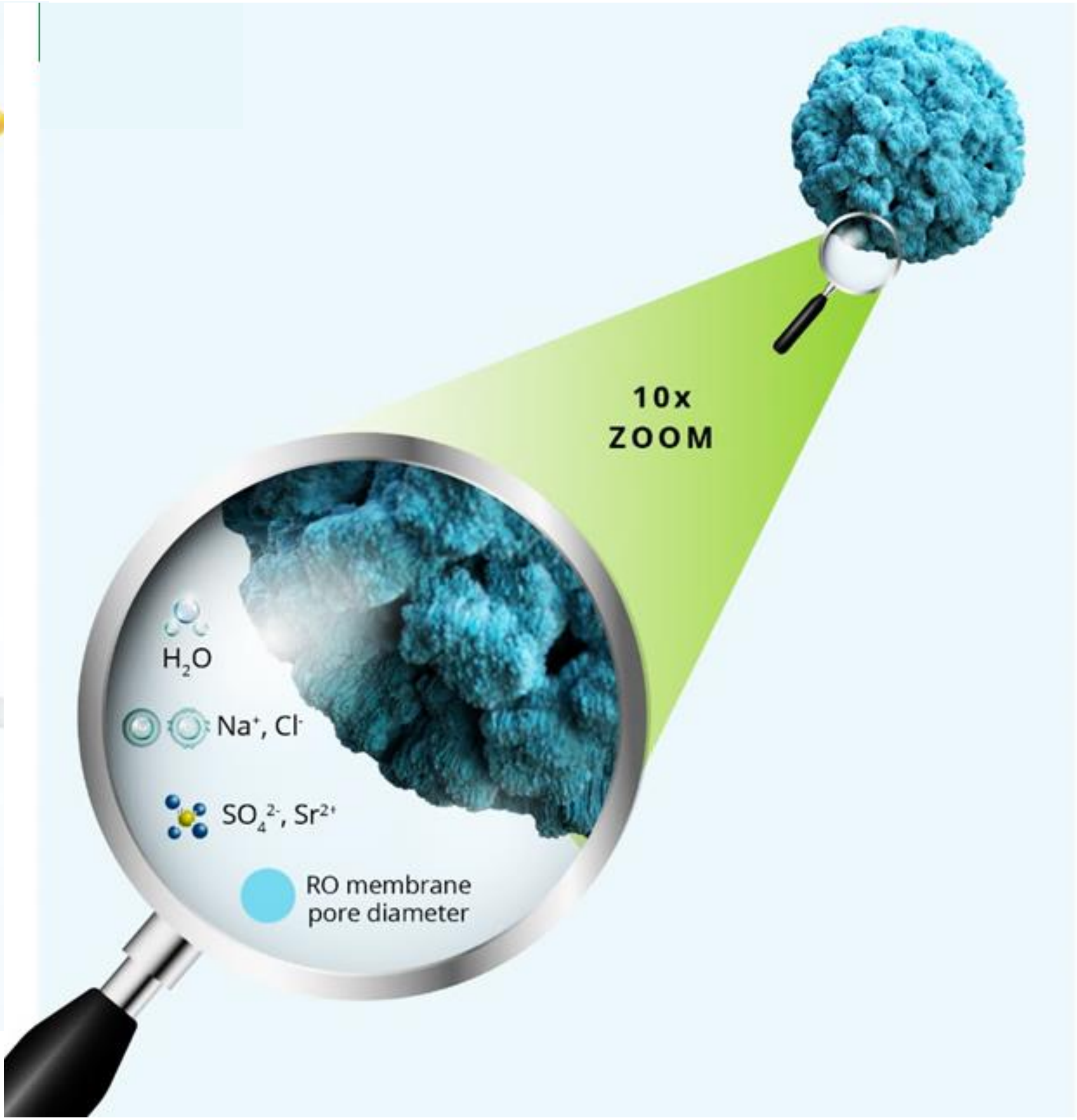
RO

Pathogen	LRV Credit
Virus	2
Giardia	2
Crypto	2

Can't we get more credit for RO?

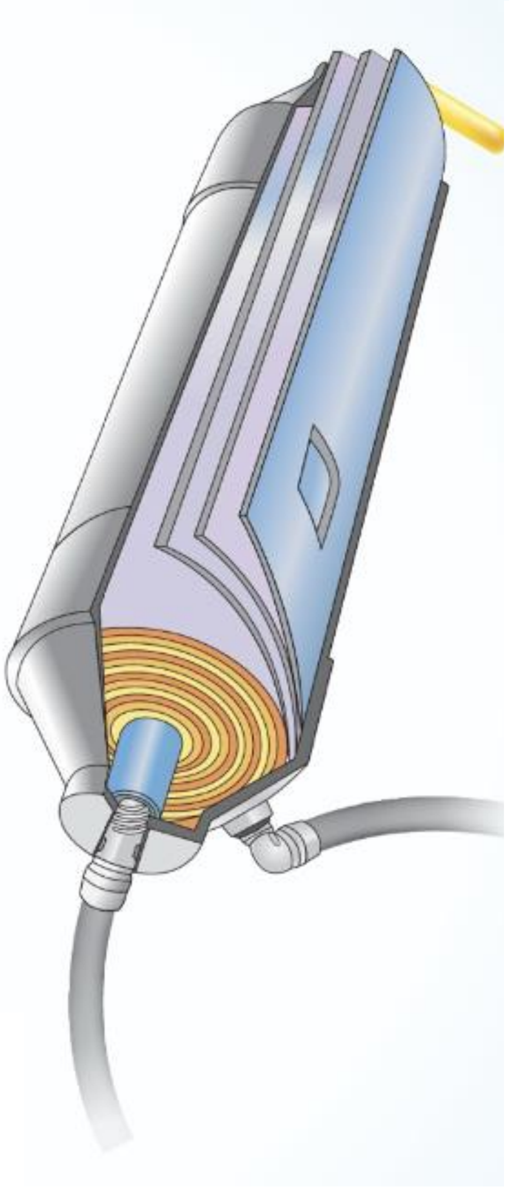
It's removing SALT!

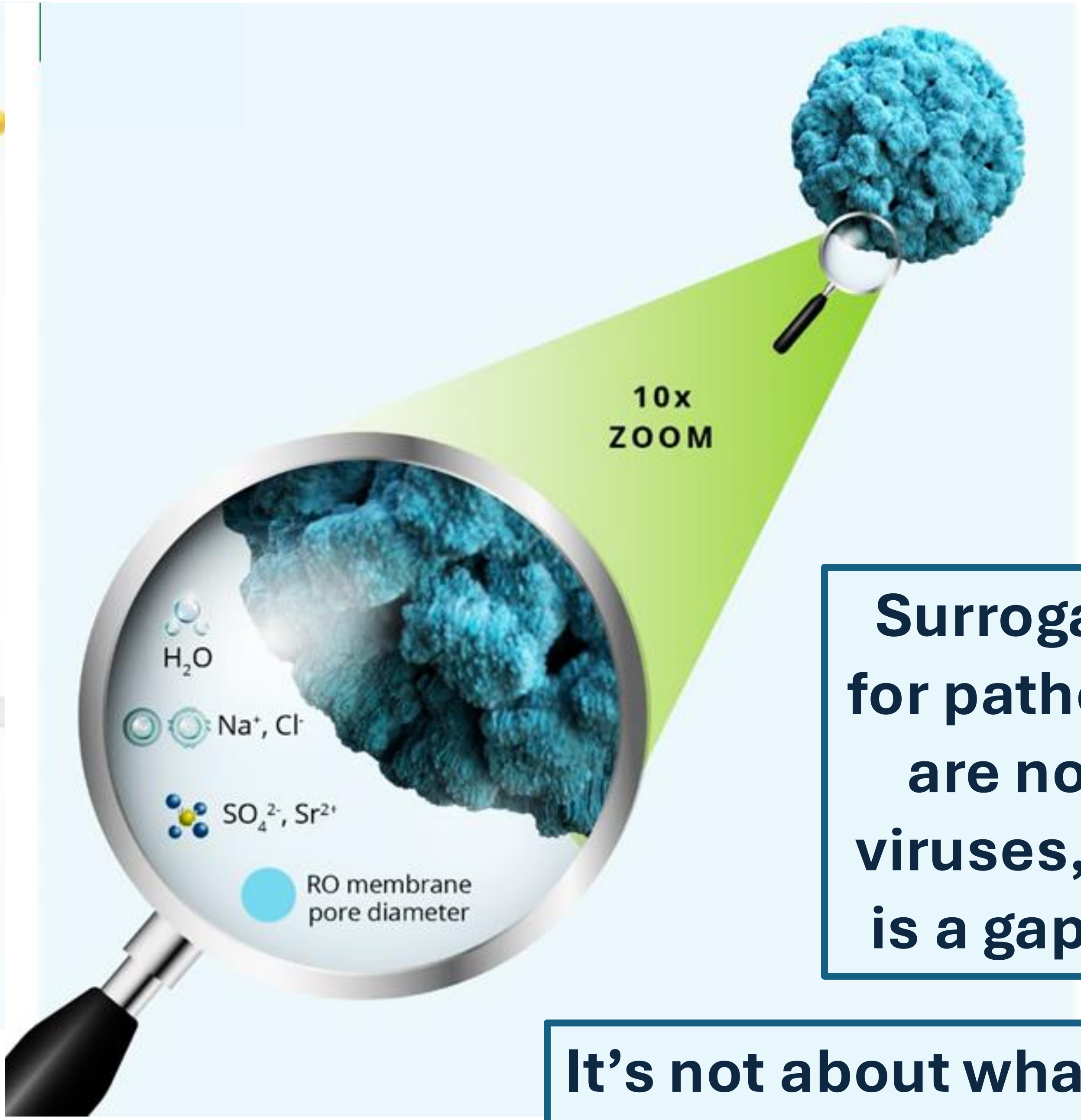


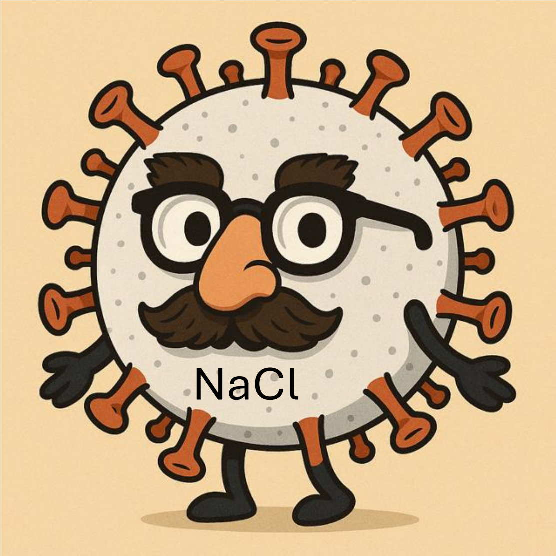


Can’t we get more credit for RO?

It’s removing SALT!





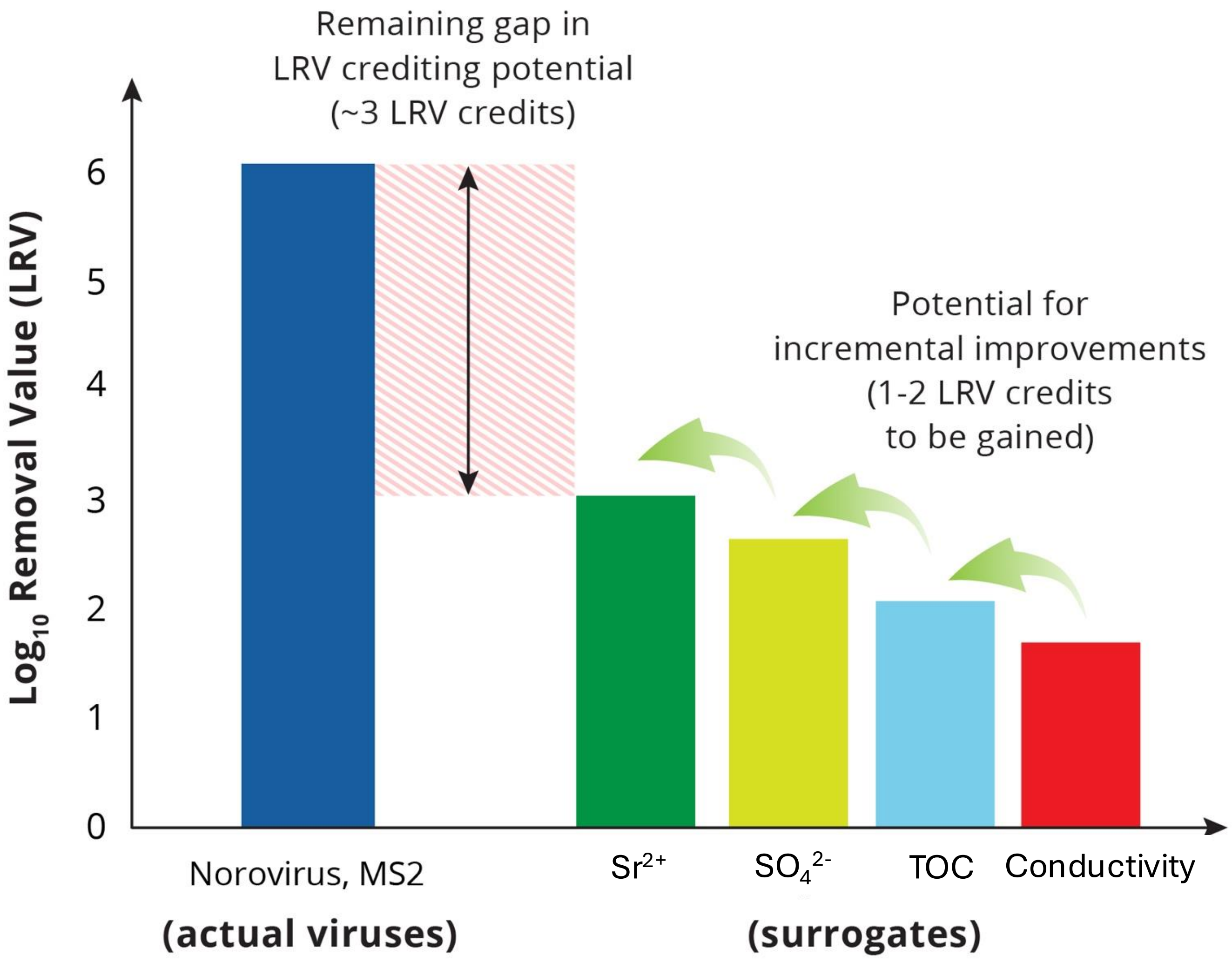


Surrogates currently used for pathogen crediting in RO are not similar to actual viruses, so that's why there is a gap in their reductions

**It's not about what you can remove.
It's about what you can PROVE!**

Reverse Osmosis: Credit Where Credit is Due

- There is potential to get more credit for pathogen reduction in RO systems using different surrogates:
  - SO_4^{2-}
  - Sr^{2+}
- While these incremental improvements are possible right now, there is still a gap in the LRV credit potential

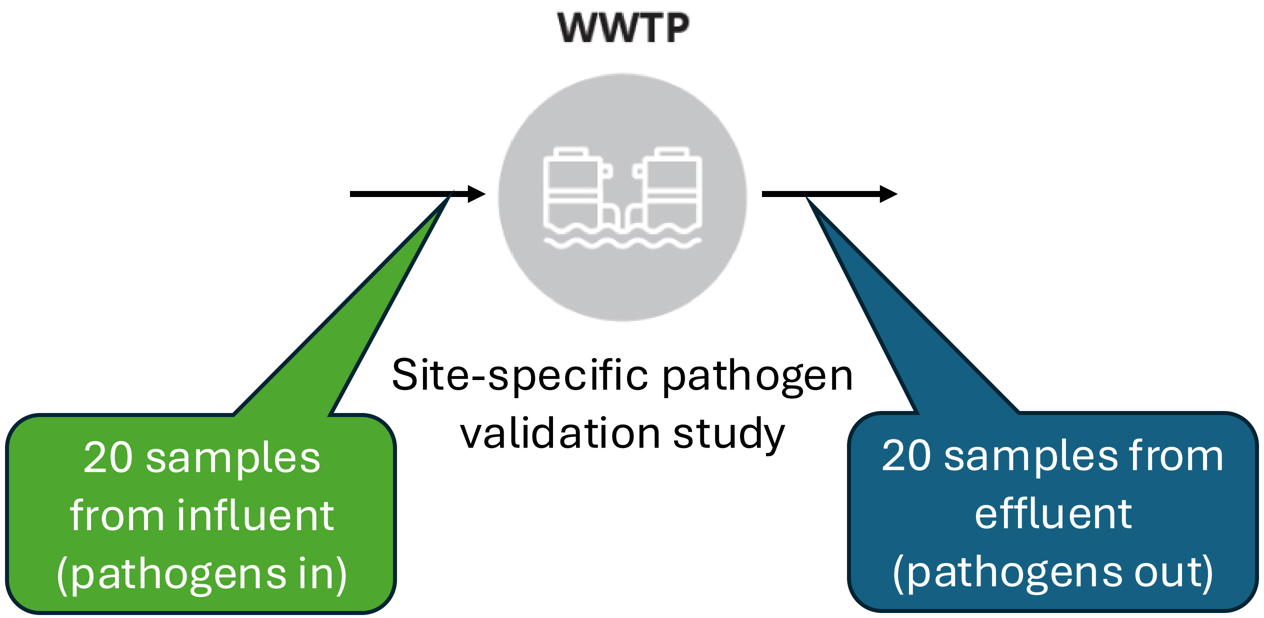


Answer Survey Question #2

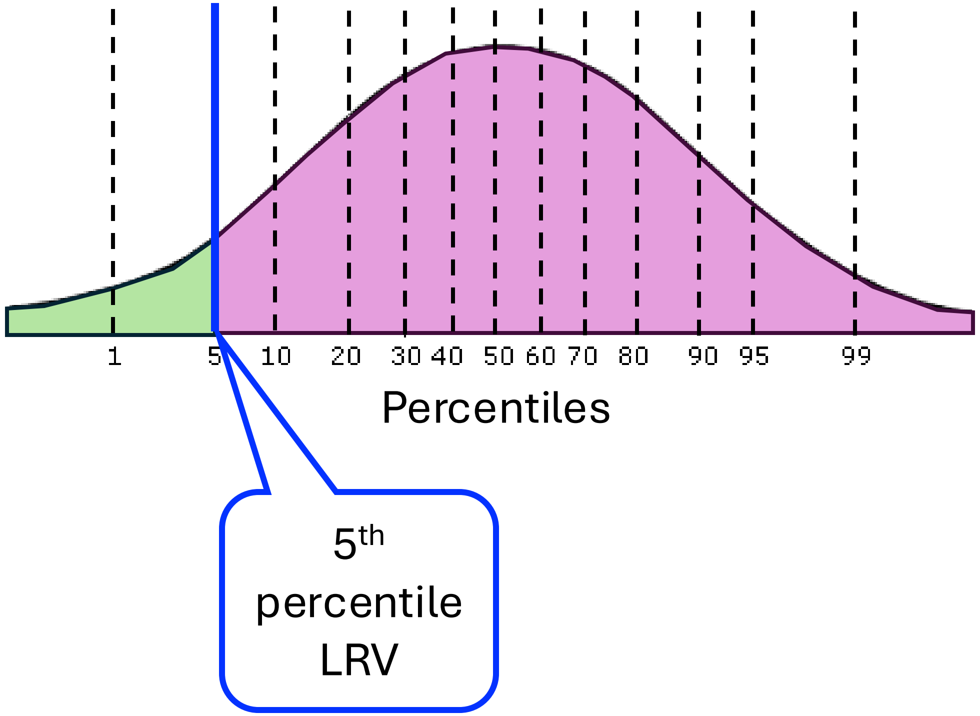
ReWater CENTER

What if we don’t have a good surrogate and we can’t model pathogen reduction using influencing factors?

Approach #3: Operational Envelope Approach

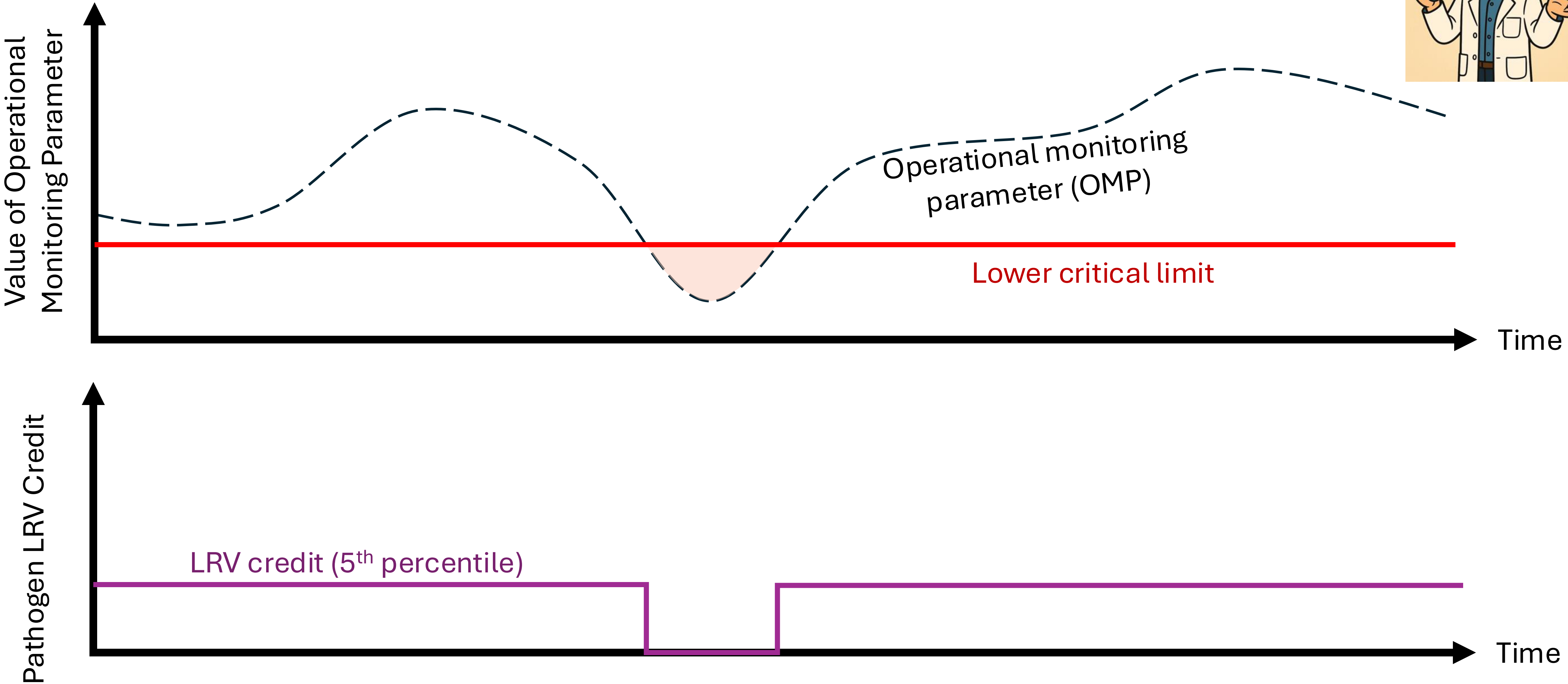


$$LRV = \log_{10}\left(\frac{\text{Pathogens}_{\text{in}}}{\text{Pathogens}_{\text{out}}}\right)$$



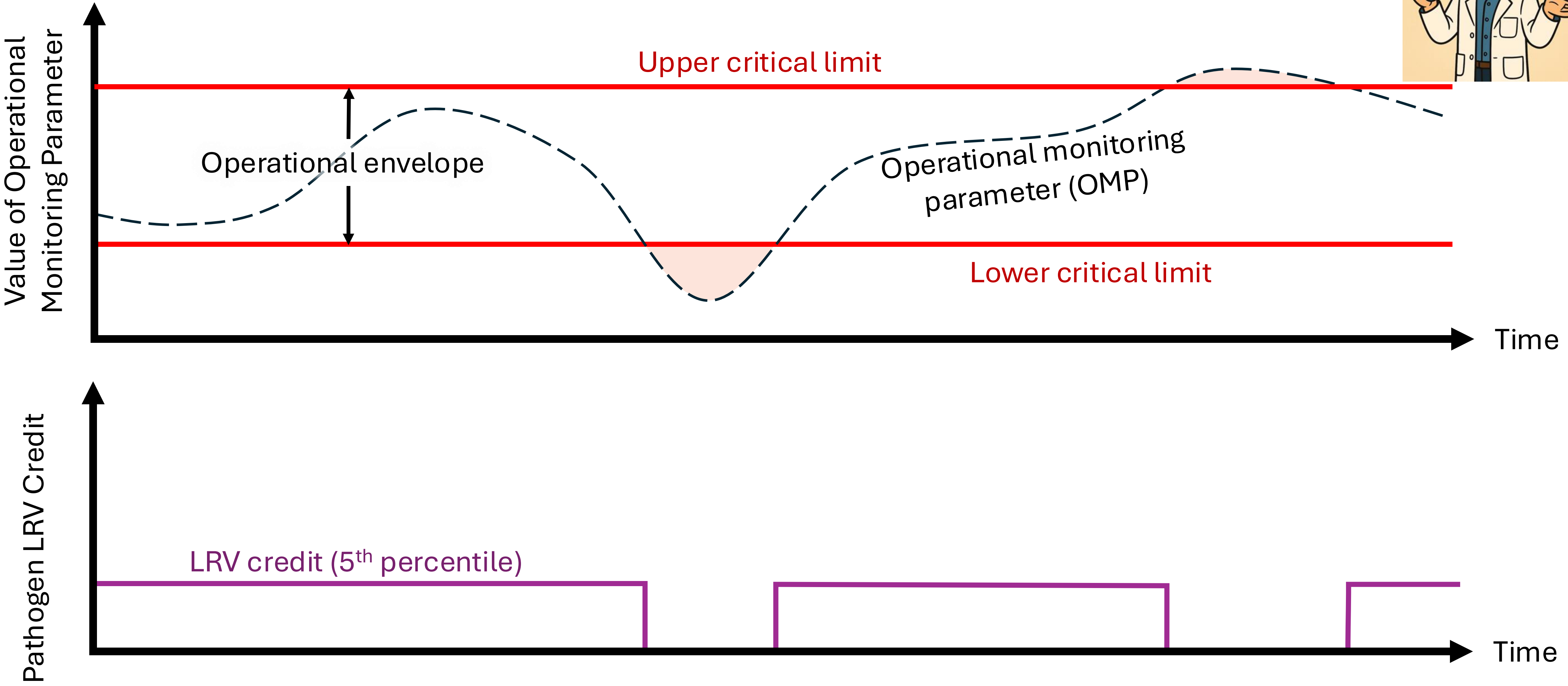
95% of the time (~345 days per year), the actual pathogen reduction will be greater than this value

Approach #3: Operational Envelope Approach



ReWater CENTER

Approach #3: Operational Envelope Approach



ReWater CENTER

Example Operational Monitoring Parameters for Activated Sludge Wastewater Treatment Systems

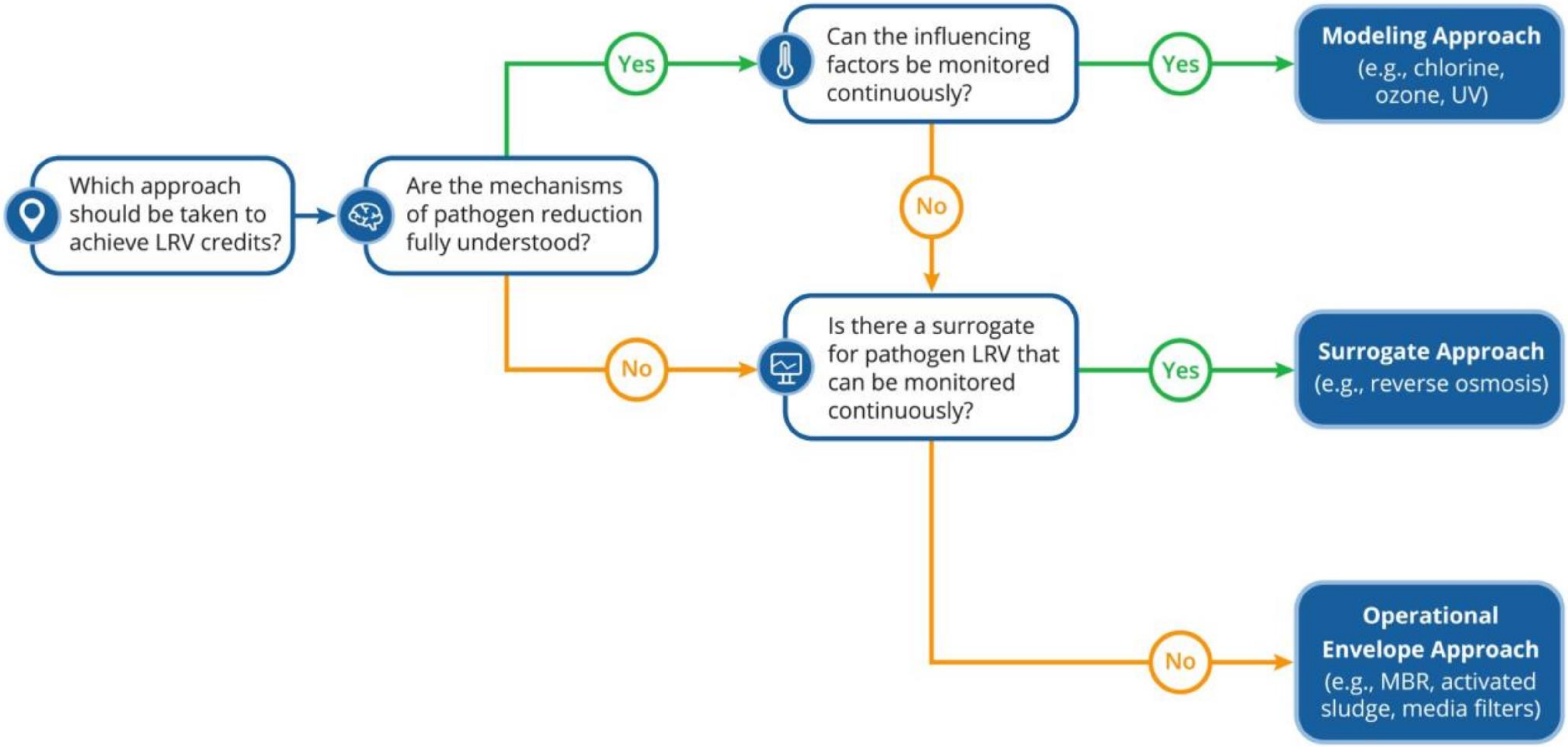
Treatment Process	Monitoring Parameters	Relation to Pathogen Reduction	Type of Critical Limit
Activated sludge	SRT HRT	Shorter retention times might mean lower pathogen LRVs	Lower limits on SRT and HRT
	BOD TSS Ammonia	Higher BOD, TSS, and ammonia in the effluent might mean lower pathogen LRVs	Upper limits on effluent BOD, TSS, and ammonia

Operational Monitoring Parameters for Other Treatment Processes

Treatment Process	Monitoring Parameters	Relation to Pathogen Reduction	Type of Critical Limit
Other processes (media filter, trickling filter, constructed wetlands?)	???	???	???

Answer Survey Question #3

Which approach can be used?



Industry impact of a new pathogen crediting framework

"The development of the crediting framework had a major impact on programs considering MBRs. MBRs have many benefits for potable reuse including footprint and cost savings as well as effluent quality, but they didn't receive any pathogen credit. Having an accepted pathogen credit has allowed programs to confidently move forward with MBR implementation."

Stephen Katz

Municipal Business Development and Large Program Director

Veolia Water Technologies & Solutions

Example: Membrane bioreactors

ReWater CENTER

Thank you!

Matthew E. Verbyla

mverbyla@sdsu.edu

Summary of Activity Responses

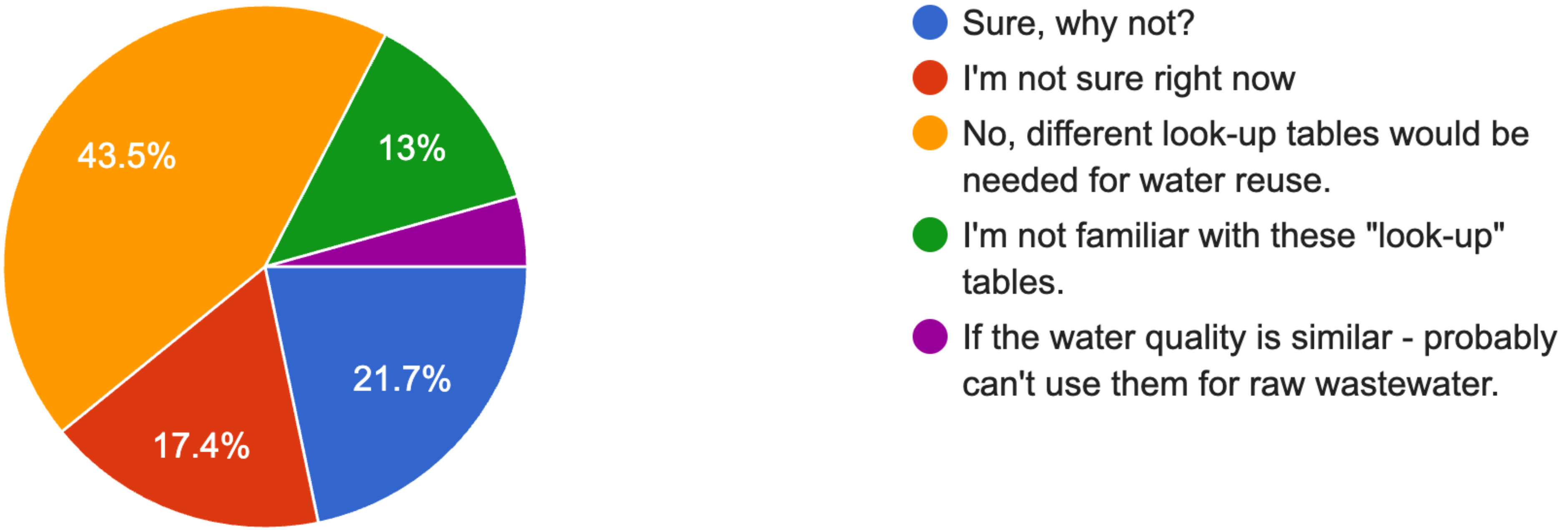
Please subscribe to the PWRR!

https://rewater.usc.edu/potable-water-reuse-report/

ReWater CENTER

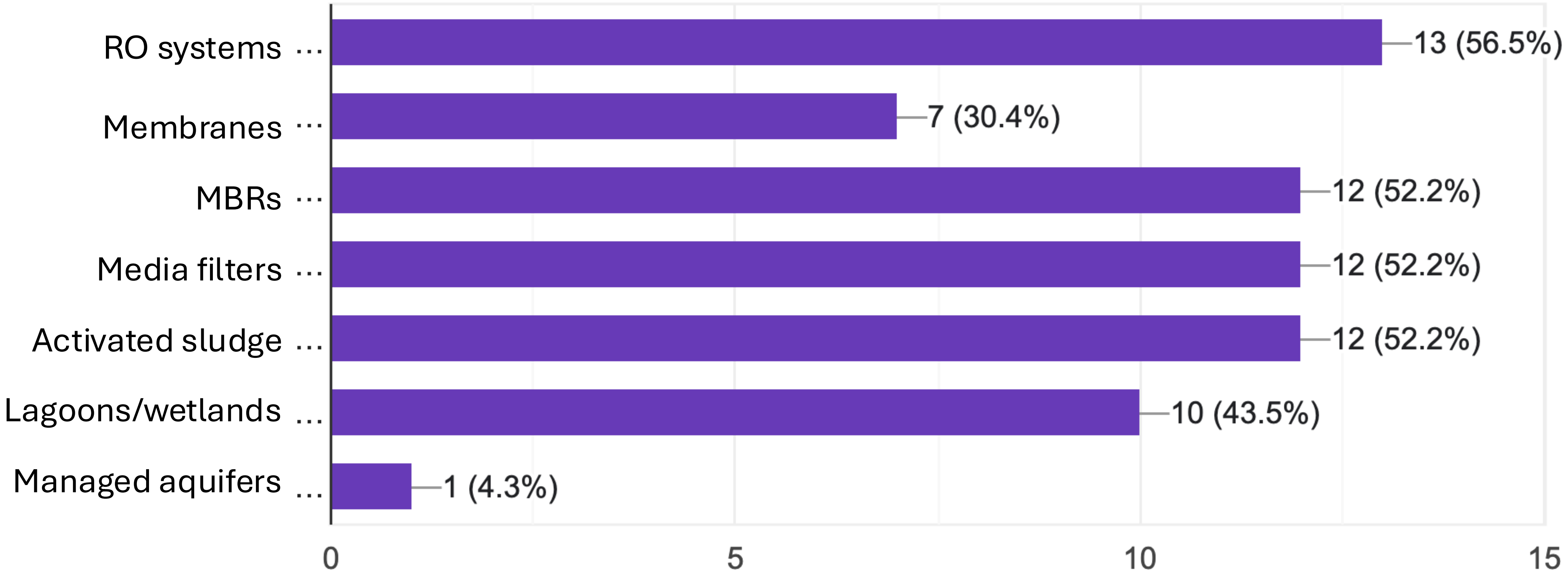
Do you think that the same pathogen "look-up" tables that are used for disinfection in drinking water systems for chlorination, UV, or ozone (e.g., to fin... pathogen LRV crediting in water reuse applications?

23 responses



Which surrogates for pathogen LRV crediting are you most interested in learning more about for water reuse?

23 responses



What is the probability that a site-specific pathogen validation study is completed in your state/jurisdiction to seek pathogen LRV credits for...pe approach) to support a water reuse application?

23 responses