



State Summit Webinar: Treatment Targets and Crediting

Hosted by: ACWA and EPA

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 Nappies, 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 [REUSE Explorer](#).
- ✓ 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



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

Annual State Regulator Summits on Water Reuse

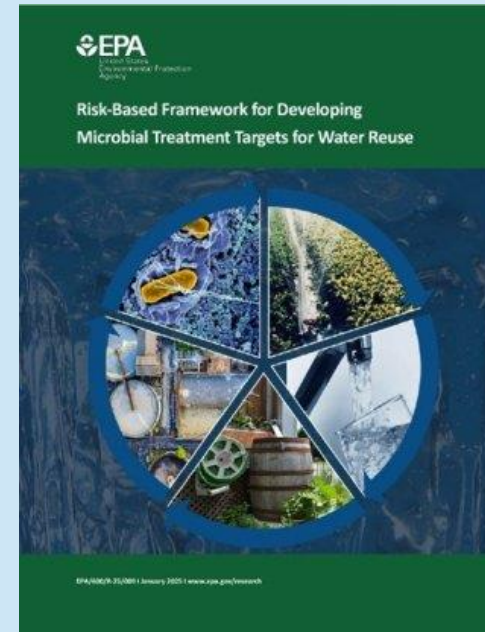


**Support states as they develop
reuse regulations and guidelines**

**CREATED REUSEXPLORER TOOL
SUMMARIZING >185 STATE REUSE POLICIES**



**PUBLISHED FRAMEWORK FOR DEVELOPING
MICROBIAL TREATMENT 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!



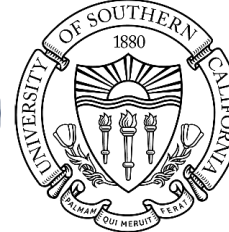
2. Join us at our Annual State Summit Event (in-person with virtual options)

- March 8, full-day event
- Occurs at 41st Annual WaterReuse Symposium in Los Angeles, CA

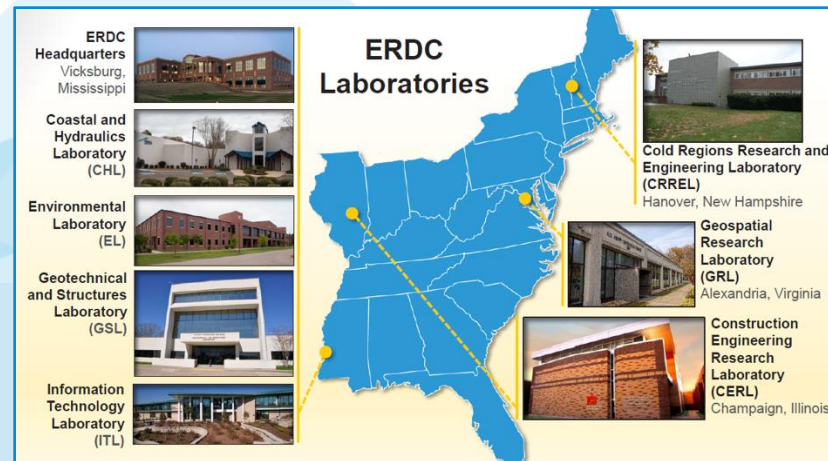
3. Sign up for our monthly updates to receive resources and information on future events!

- 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

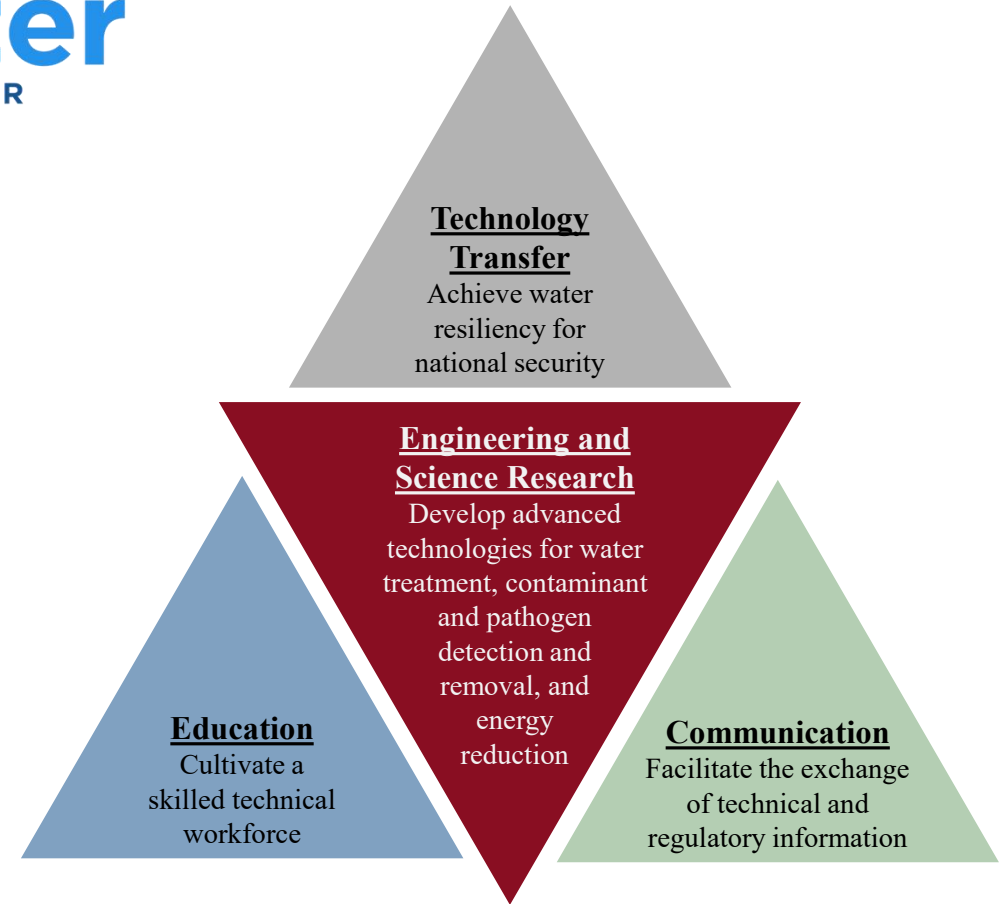


Coordinated research to reduce public health risks and the cost of treatment

University of Southern California Center for Water Reuse and Resource Recovery



- 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



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

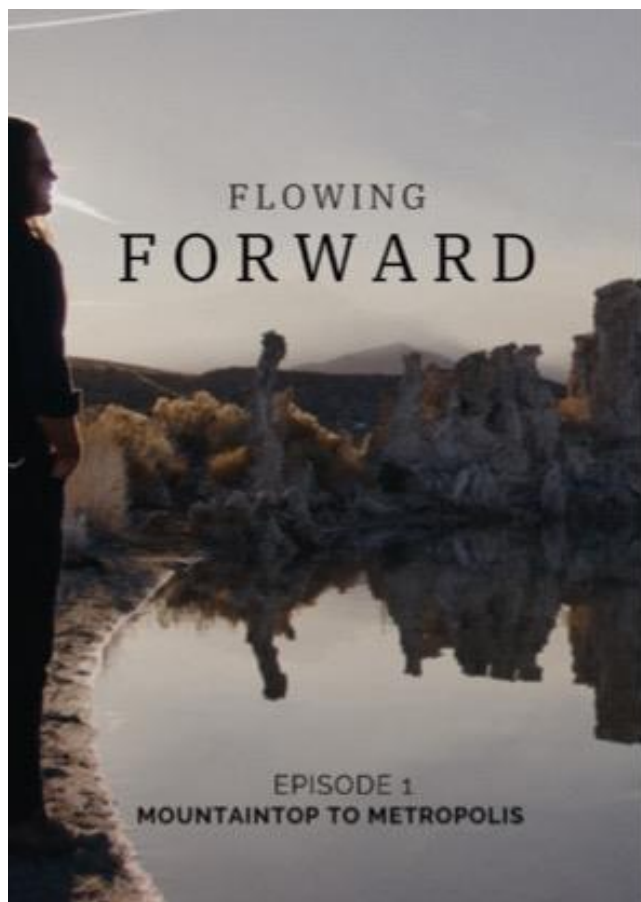


Digital Solutions in Potable Water Reuse
Dr. Billy Raseman



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



Trussell

Brian Pecson and Anya Kaufmann

Jacob Newman

Shane Trussell

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

Welcome to the Potable Water Reuse Report!

A collaboration between the University of Southern California ReWater Center and Trussell, this publication is intended to connect the potable water reuse community – including practitioners, regulators, and academics – to keep them up-to-date with the industry’s rapidly evolving developments.

In this first of three issues focusing on the development of regulations for direct potable reuse (DPR), we examine the development of California’s recently adopted DPR regulations and their implications for the industry at large.

Direct Potable Reuse (DPR): Welcome to Primetime

After an intensive 13-year effort, California recently adopted regulations for DPR, joining Colorado to become the second state with finalized requirements. With the provincial dam now broken, several additional states are considering or actively moving forward with DPR regulatory development.

There is no debating that California has been a national leader in potable reuse, and while many states will likely choose to deviate from the specifics of California’s DPR regulatory requirements, it is an opportune moment to look back at the DPR regulatory development process and reflect on what went well and what could be improved.

Now that California’s DPR regulations are complete, learning the lessons from California’s experience will position other states to more thoughtfully plot their own course to DPR requirements.

1. What Went Well

The California water industry used several legislative mandates (i.e., Senate Bill 574 and 572, Assembly Bill 574) to drive the fast pace of DPR regulatory development from its inception in 2010 to its close in 2023. Throughout this period, California invested in several strategies that played valuable roles in shaping the DPR requirements (Figure 1).

Research Investment

Given the industry’s limited experience with DPR, California pursued an intensive research effort to identify and address knowledge gaps. This took the form of the California DPR Initiative, a research collaboration between WaterSense California and The Water Research Foundation, that provided over \$34 million of funding for 34 research projects. These projects proved fundamental in answering the questions that arose as regulators and experts thought about this new paradigm. The research helped confirm the feasibility of developing DPR regulations in situ and pointed toward a final set of priority research topics. An additional \$4 million was invested for this final phase in support of DPR regulatory development. The massive research investment can be credited with rapidly bringing DPR out of its infancy and informing many of the requirements in the legislation.

Guidance from Other Applications

The impact of California’s 60+ year experience with indirect potable reuse (IPR) cannot be understated. Many of the challenges associated with protecting public health in DPR are also considerations for IPR. The long history and evolution of IPR requirements for the control of pathogens and chemicals, the role of source control and monitoring, treatment, operations, staffing, and governance all informed the DPR requirements.

Potable Water Reuse Report

Published by the University of Southern California ReWater Center in collaboration with Trussell

Series 1, Issue 2

31 June 2024

The Factors Shaping DPR Regulations in the United States

Key Takeaways:

- DPR regulations are being developed on a state-by-state basis in the U.S.
- Between states, there is significant variability in the individual requirements that make up the regulations.
- Despite this variability, there is general consistency in the requirements for public health (i.e., pathogens and chemical control).
- The variability in DPR regulations is often influenced by non-public health factors including:
 - Scale of implementation: finding the appropriate balance between cost and conservation in DPR requirements may be impacted by the scale at which DPR will be implemented.
 - Environmental discharge: restrictions on discharge may impact the type of treatment required (reverse osmosis vs. carbon-based).
 - Statutory scope: states with greater statutory scope have more flexibility to include requirements for contaminants beyond those specified in the Safe Drinking Water Act and Clean Water Act.
 - Political climate: political support (or influence) whether regulations are developed, the speed of development, the funds available for research addressing knowledge gaps, and the resources available to develop, implement, and enforce the regulations.

Introduction

In the absence of a federal regulation for direct potable reuse (DPR), U.S. states are developing their own regulations with Colorado and California leading the way as the first two states to create and adopt regulations. A survey of DPR regulations that have been adopted or proposed nationwide can be insightful for states seeking to develop their own regulations. This survey, however, would immediately shed light on the fact that these regulations are in fact quite different. If the primary goal of DPR is public health protection, how are states ending up with such diversity in their regulations? A deeper analysis of DPR regulations nationwide shows broad similarity in the requirements for control of the two main public health threats: pathogens and chemicals. If the public health requirements are not responsible for the diversity in DPR regulations, then diversity must stem from elements beyond the public health sphere.

To understand the diversity in DPR requirements, we interviewed stakeholders from several states (Figure 1) that are interested in DPR to understand what factors shaped the development of their regulations or guidance. Four location-specific factors emerged: (1) scale of implementation, (2) environmental discharge

restrictions, (3) statutory scope, and (4) political climate. These four factors – which exist outside of the public health sphere – play an important role in determining the strictness, enforceability, and speed of regulatory development. This issue of the Potable Water Reuse Report focuses on these location-specific factors to help prospective reuse stakeholders tailor the development of their own DPR requirements.

1. Scale of Implementation

The scale at which DPR will be implemented in each state varies significantly and can impact how stakeholders think about regulatory requirements. While all states we interviewed confirmed the criticality of potable reuse for their future water supplies, most interviewees predicted that potable reuse might be a relatively small (<10%) contributor to their overall portfolios. In Florida, where groundwater provides approximately 95% of the water supply, potable reuse may only play a 5-10% role in the near term, according to Bart Weiss from Hillsborough County Public Utilities. In El Paso, Texas – where the next full-scale DPR facility in the U.S. is anticipated to start up

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?

Key Takeaways:

- Potable reuse regulations are not being prioritized at the international scale for several reasons:
 - The urgent need for water supplies can leave insufficient time for regulatory development.
 - The effort to develop regulations is not justified by the low number of anticipated projects.
 - Some countries do not have a culture that favors regulatory development and enforcement.
 - Use of an environmental buffer provides an avenue for pursuing reuse without additional regulatory development.
 - In many countries, existing drinking water frameworks do not explicitly prohibit potable reuse.
- Multiple strategies are used for protecting public health in the absence of potable reuse regulations: leveraging existing frameworks, building off precedents from existing projects, employing risk management approaches and documentation facilities, and engaging experts.
- Three different regulatory approaches are discussed based on the urgency of water supply, the number of projects, and the availability of resources: (1) permitting projects on a case-by-case basis without uniform requirements, (2) developing non-enforceable guidelines, and (3) enacting regulations.

Introduction

This inaugural series of the Potable Water Reuse Report is focused on direct potable reuse (DPR) regulations. The first issue looked at the multi-year effort to develop California’s new DPR regulations while the second explored the state-specific factors leading to regulatory diversity in states across the US. Despite the differences, one unifying element from the first two issues was the important role that regulations (or guidelines) play in advancing DPR implementation in the US. In this third issue of the series, we turn our focus to the international scale.

The distribution of potable reuse projects internationally shows a high density of projects in the US and a relatively low density of projects elsewhere. Outside the US, potable reuse regulations – both indirect and direct – are nearly nonexistent. One obvious question arises: “Should the development of regulations spur additional potable reuse implementation worldwide?” If lack of regulations is an impediment, would investments in regulatory development promote more widespread adoption? To answer this, we interviewed several members of the international potable reuse community and found significant departures from the US perspective (Figure 1). In this issue, we provide a roadmap for countries considering potable reuse by exploring why potable reuse regulations are generally not being developed outside the US and what approaches are being used to protect public health in the absence of reuse regulations.

Guidelines vs. Regulations

Several countries have developed guidelines for potable reuse. Guidelines are useful for providing a consistent roadmap for potable reuse projects, but they are not enforceable. In contrast, regulations grant the power of enforcement to regulatory bodies to implement the law. This key distinction between guidelines and regulations is noted throughout this issue.



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the PWR Report



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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



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Series 1: Direct Potable Reuse Regulations



Series 1, Issue 1

8 March 2024

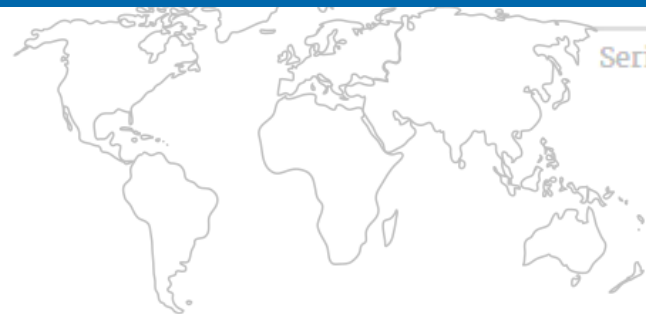
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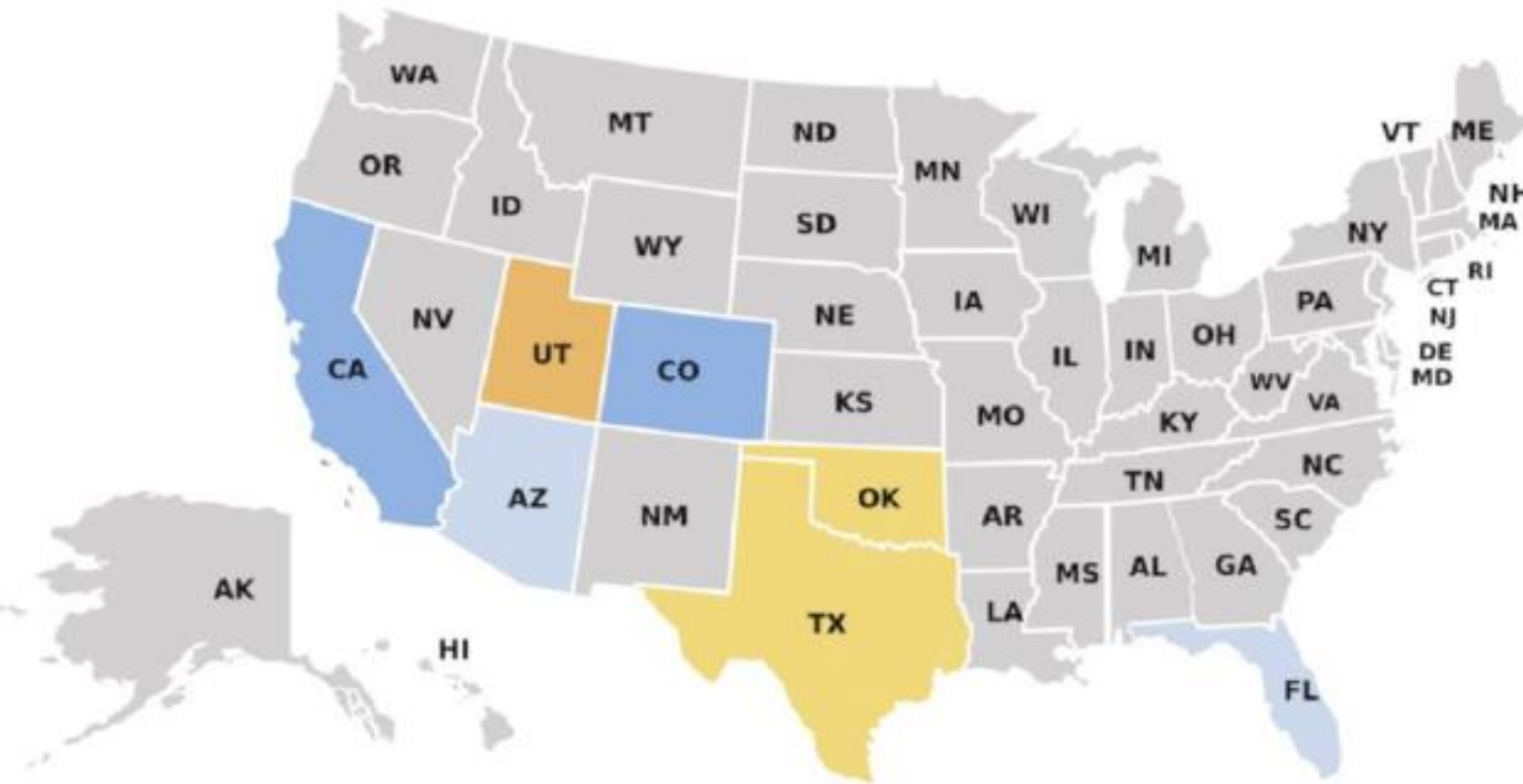


Series 1, Issue 3

13 September 2024

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

DPR Regulations



- Finalized DPR regulations
- Developing DPR regulations
- Considering DPR regulations
- Permitted on a case-by-case basis

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

Nationwide Survey – Interviewed Stakeholders

California



Darrin Polhemus

Deputy Director

CA State Water
Resources Control
Board

Arizona

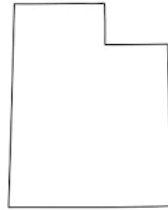


Karthik Kumarasamy

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

Florida



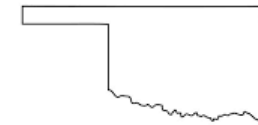
Lynn Spivey
Director of Utilities

City of Plant City

Bart Weiss
Chief Officer for
Innovation & Resiliency

Hillsborough County
Public Utilities

Oklahoma



Shellie Chard

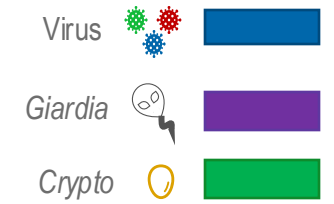
Director

Water Quality Division,
OK Dept. of
Env. Quality

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



Cryptosporidium



California

Colorado

Florida

Arizona

Texas



Raw
Wastewater



Treated
Wastewater



Raw
Wastewater



Raw
Wastewater

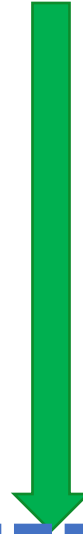


Treated
Wastewater

11-log



10-log



12-log



10-log

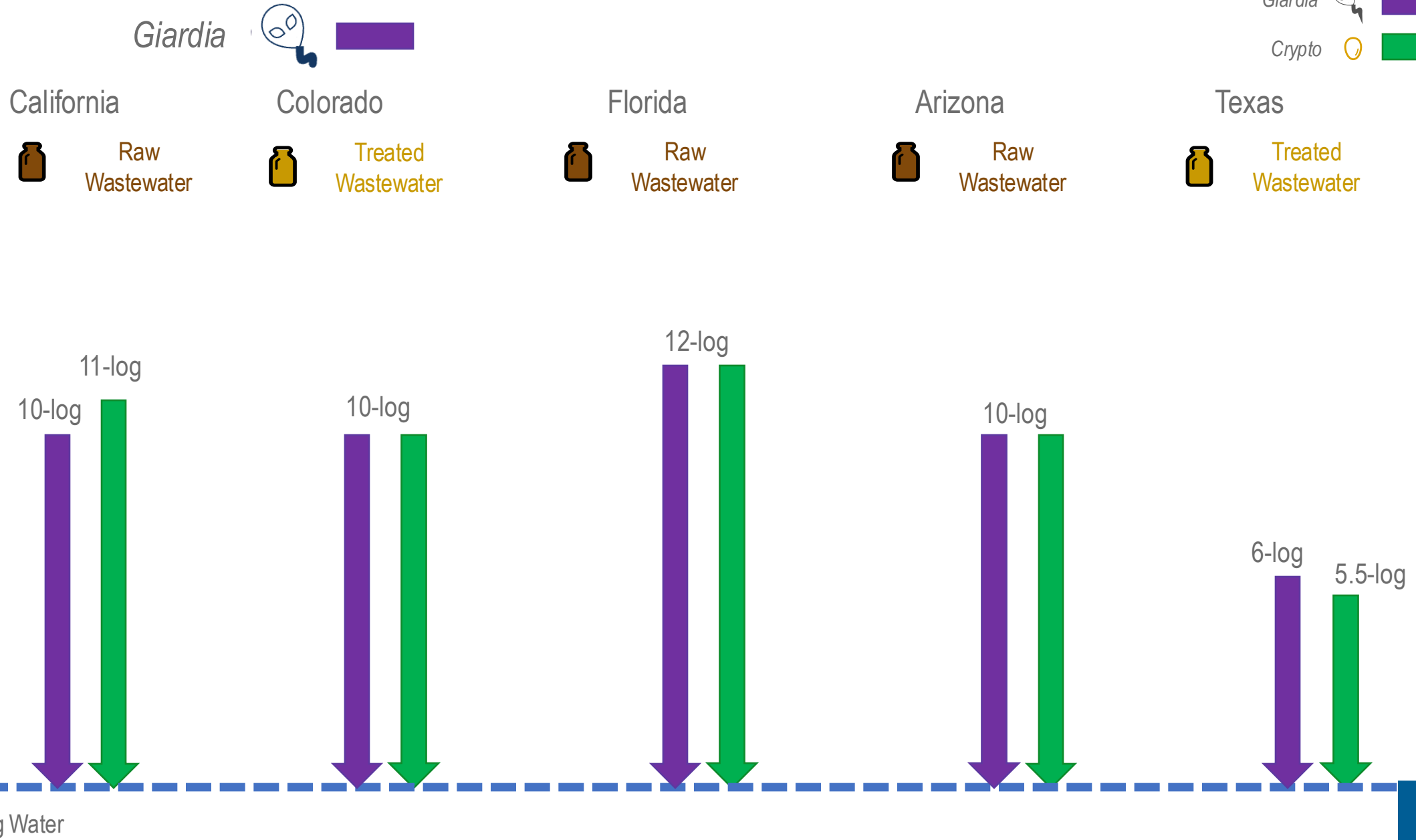
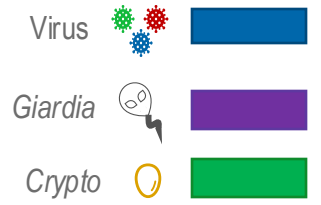


5.5-log



Drinking Water

Public Health Requirements: Pathogens



Public Health Requirements: Pathogens

Virus  

Virus  
Giardia  
Crypto  

California

Colorado

Florida

Arizona

Texas



Raw
Wastewater



Treated
Wastewater



Raw
Wastewater



Raw
Wastewater



Treated
Wastewater

16-log

10-log

11-log

12-log

10-log

14-log

12-log

13-log

10-log

8-log

6-log

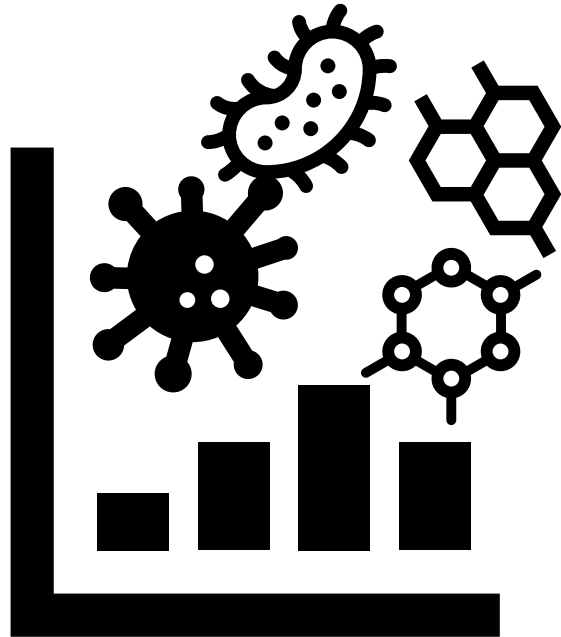
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Drinking Water

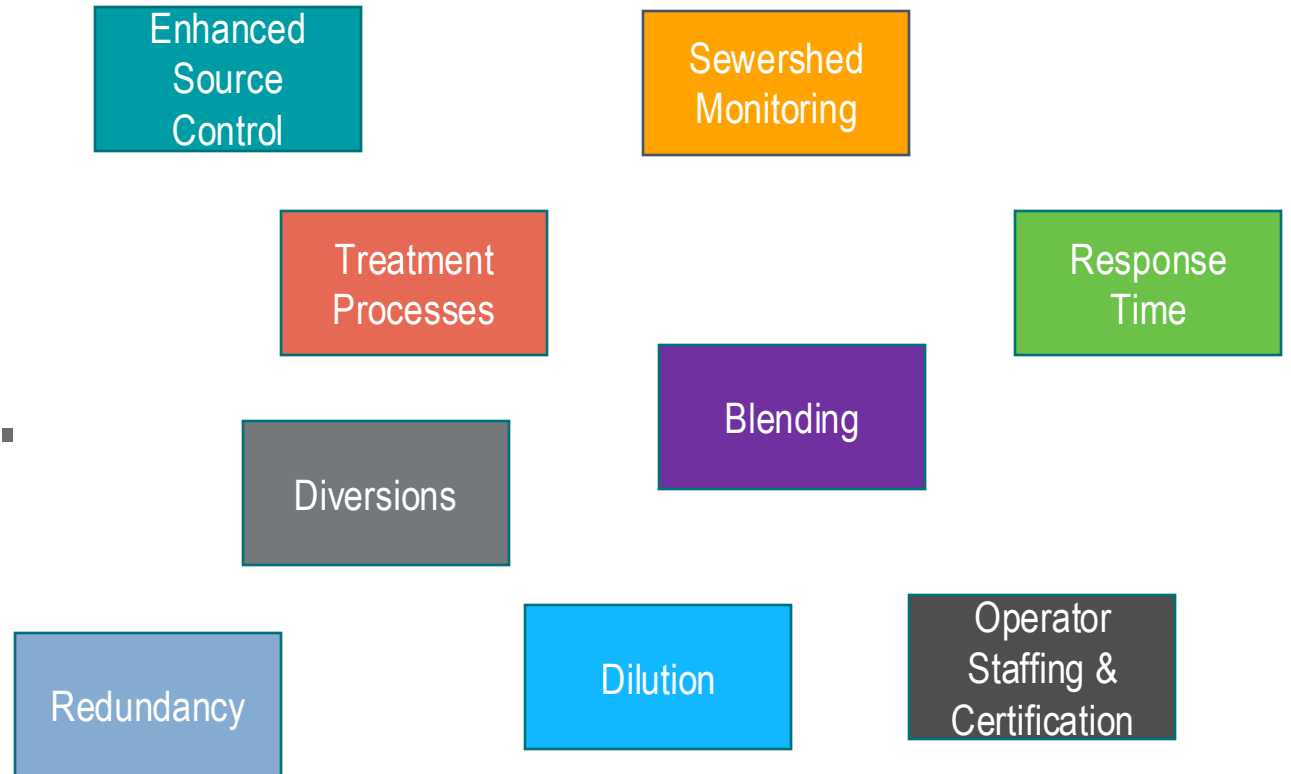
Public Health Requirements: Chemicals

- Compliance with federal drinking water requirements (i.e., Safe Drinking Water Act)
- Monitoring for contaminants with maximum contaminant levels (MCLs)

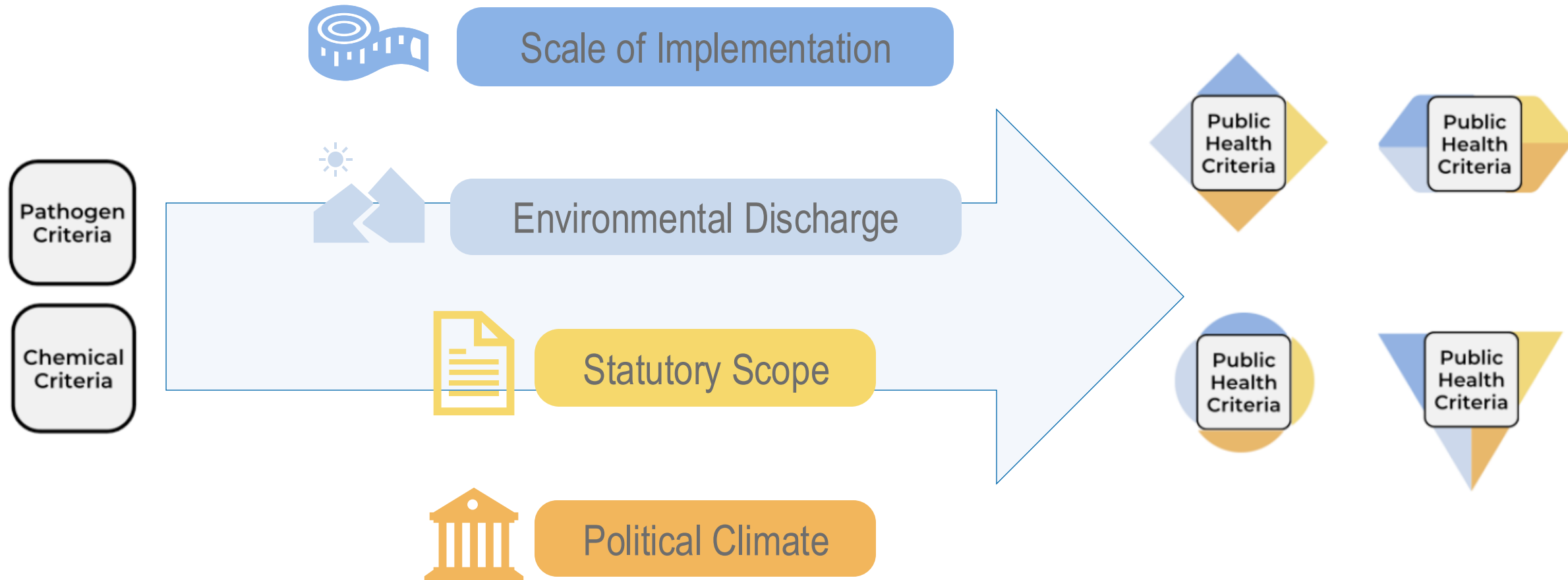
If pathogen and chemical control requirements are similar, what is influencing diversity in regulations?

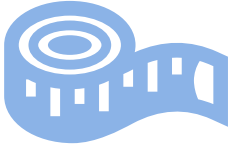


VS.



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



230 MGD

Recycle 100% of
wastewater by 2035

PUREWATER
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



California



Darrin Polhemus

Deputy Director

CA State Water Resources Control Board

“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.”

PURE
SOUTHERN

Water | Our Future

As precious to use just once, the Metropolitan Water District of California is partnering with Los Angeles County Sanitation on Pure Water Southern, a regional water recycling that would purify and reuse wastewater that currently flows into the ocean. At full scale, Pure Water Southern would produce 150 mgd of purified water each day.

Creating a new, climate-resilient source of locally available water, Pure Water Southern would serve 19 million people living within its service area. It also would become one of the world's largest water recycling programs.



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



Nearly **\$100 million** and partnership funds



More than **15 programs** and hundreds of projects



One of the largest programs of its kind

Phase 1

30 mgd

North City

Output

Location

3 mgd

Central Area

Total: **83 mgd** by 2035

*mgd = million gallons per day



Other States - Scale of Implementation



Large cities (e.g. Phoenix, Scottsdale)

&

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

“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



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

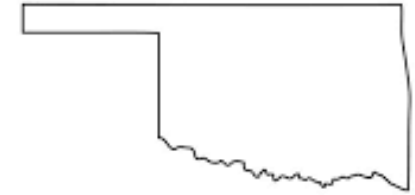
~Gilbert Trejo



5-10% of water supply near term

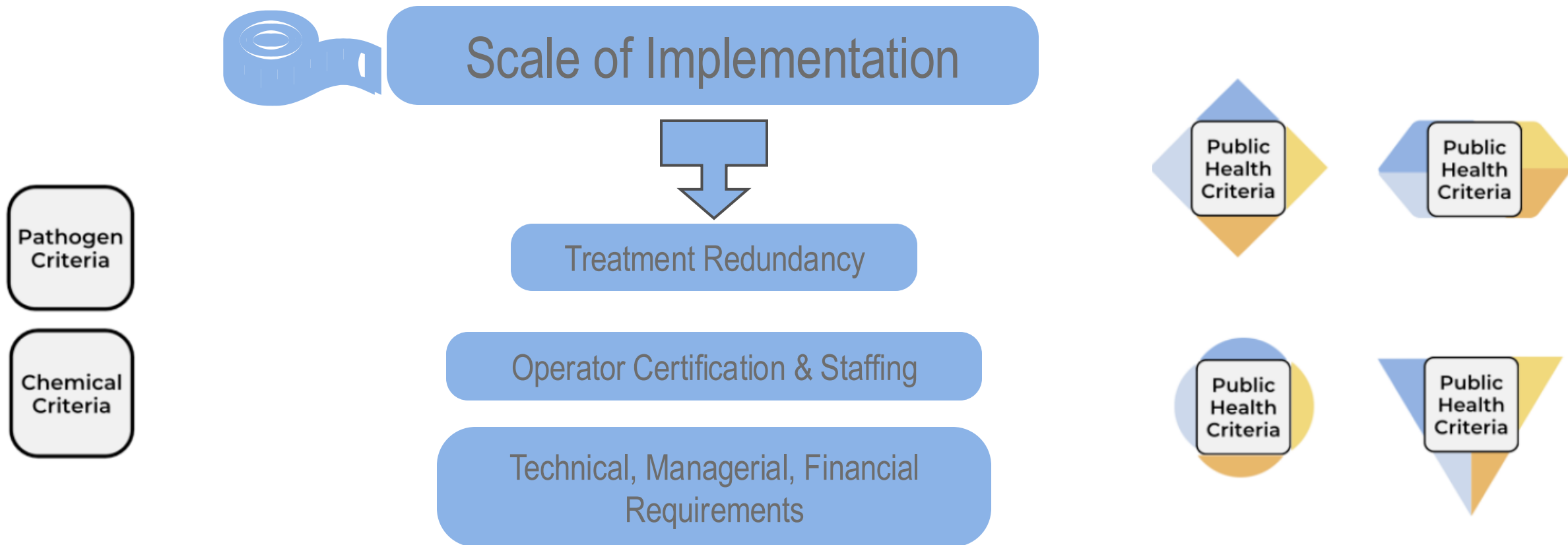
~Bart Weiss

“...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!’”



Cities with greatest need have less than 2,000 people

~Shellie Chard



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)

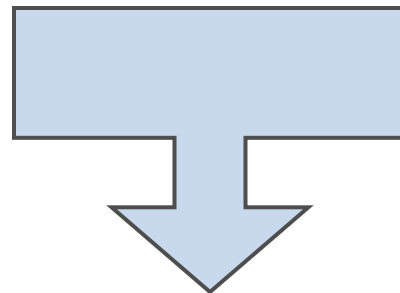
Requirements to Discharge

- 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



Pathogen
Criteria

Chemical
Criteria

RO vs. CBAT Treatment

Public
Health
Criteria

Public
Health
Criteria

Public
Health
Criteria

Public
Health
Criteria

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

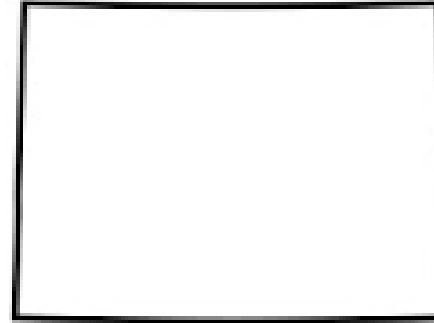
Arizona



Karthik Kumarasamy

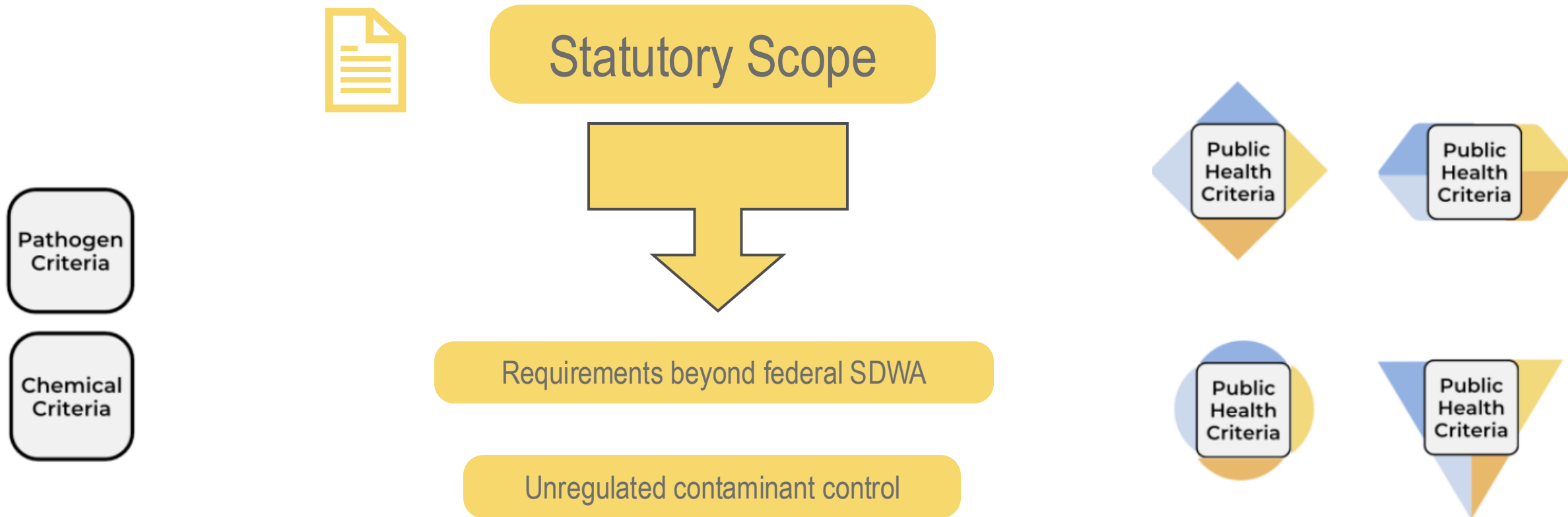
regulations are primarily being shaped to comply with federal SDWA requirements, but some CEC monitoring beyond the SDWA will be required as well.

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

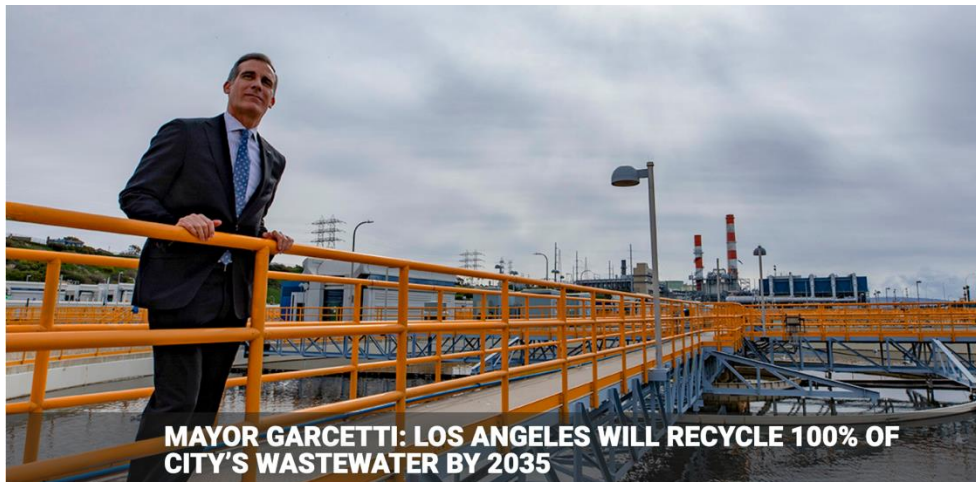


Governor Hickenlooper support and 2015 Colorado Water Plan
+
Aurora Water and Castle Rock as early adopters of potable reuse

California



Governor Newsom support
+

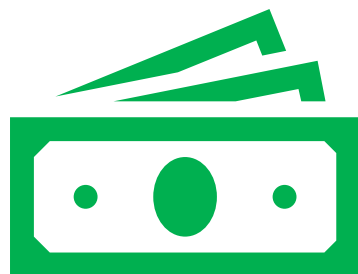


First DPR Regulations





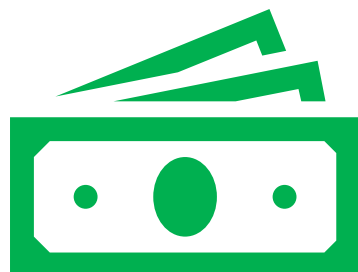
Political Climate



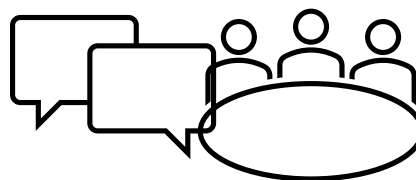
Research



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



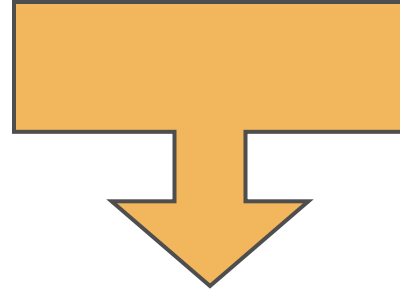
Experts



“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



Political Climate



Pathogen
Criteria

Chemical
Criteria

Speed of Regulatory Development

Funds for Research and Experts

Regulatory Staffing and Enforcement

Public
Health
Criteria

Public
Health
Criteria

Public
Health
Criteria

Public
Health
Criteria

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**

Pathogen
Criteria

Chemical
Criteria

+

**Other Factors
Impacting Regulations**

Scale of
Implementation

Environmental
Discharge

Statutory Scope

Political Climate

**Impact on Specific
Regulatory Requirements**

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

**State-Specific
Requirements**

Public
Health
Criteria

Public
Health
Criteria

Public
Health
Criteria

Public
Health
Criteria

Acknowledgements

💧 Trussell

- 💧 *Brian Pecson*
- 💧 *Shane Trussell*

💧 University of Southern California

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- 💧 *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 what went well and what could be improved
- Lessons learned from California may help other states to thoughtfully plot their own course to DPR regulations



What Went Well

A person in a white shirt and dark pants stands on the edge of a large, layered rock formation. The rock face is rugged and brownish-orange. The background is a vast, hazy landscape with a blue sky and a yellowish horizon. The overall mood is contemplative and challenging.

DPR Requirements

**Public Health
Protection**

Research Investment

California DPR
Initiative
(2012-2016)



\$24 Million
34 Projects



THE
Water
Research
FOUNDATION®

Research Investment

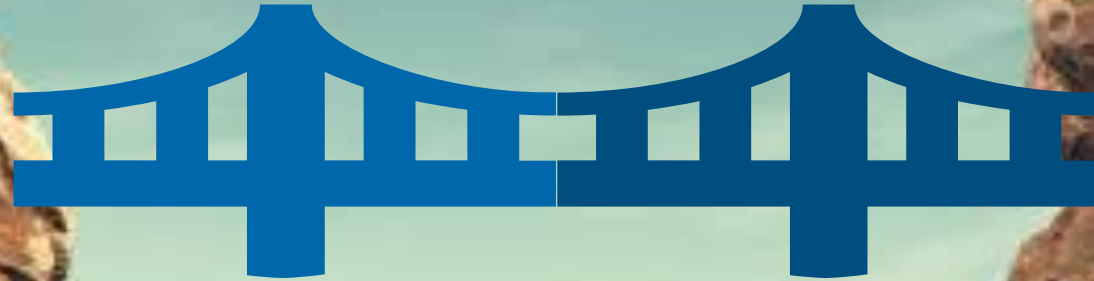
California DPR
Initiative
(2012-2016)



Key outcome:
*California regulators
conclude it is feasible
to develop DPR
regulations*

Research Investment

**Priority DPR
Research
(2018-2021)**



**\$2 Million
5 Projects**

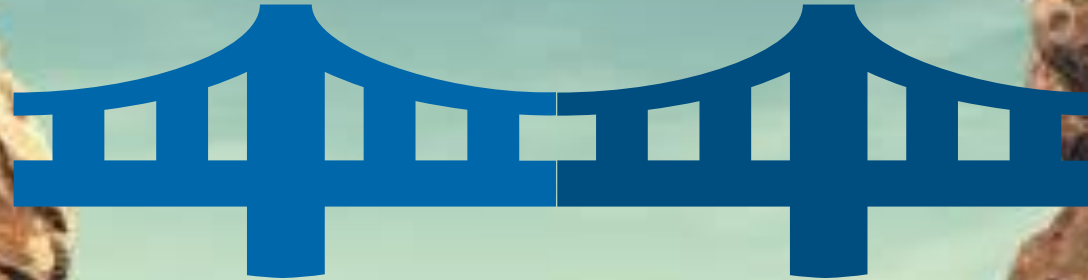


THE
**Water
Research
FOUNDATION®**

Research Investment



DPR Requirements



*Public Health
Protection*

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



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DPR Experience:



Leveraging Potable Reuse Experience



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 - *Pathogen control*
 - *Chemical control*
 - *Source control*
 - *Monitoring*
 - *Operator staffing and certification*



Injection at Orange County Water District

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

Windhoek.

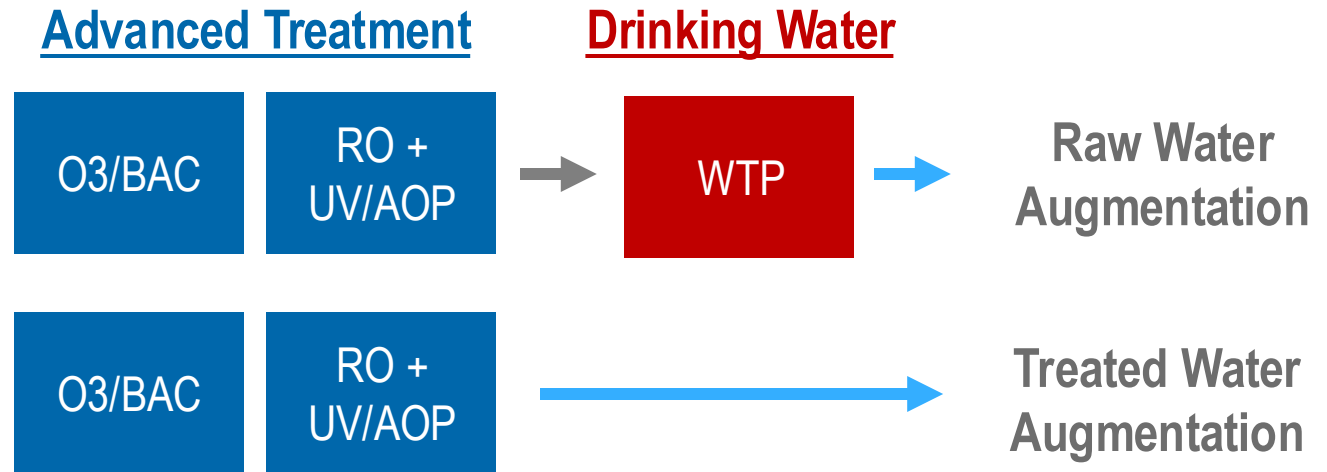
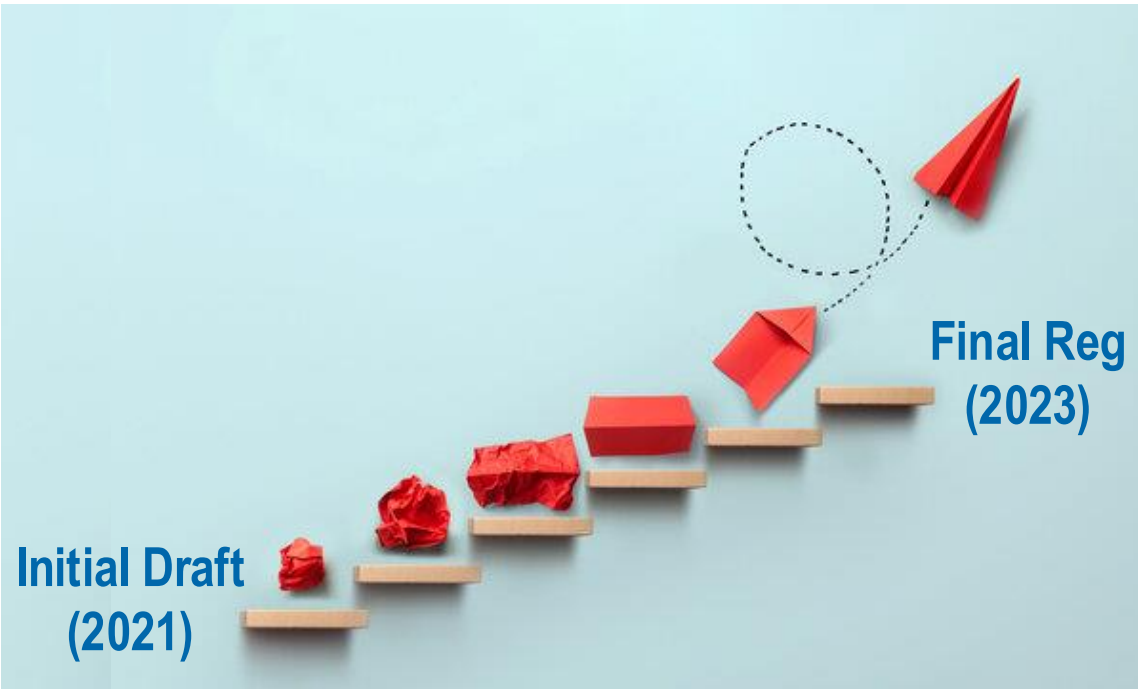
ng,

Ground-truthing from Early Adopters

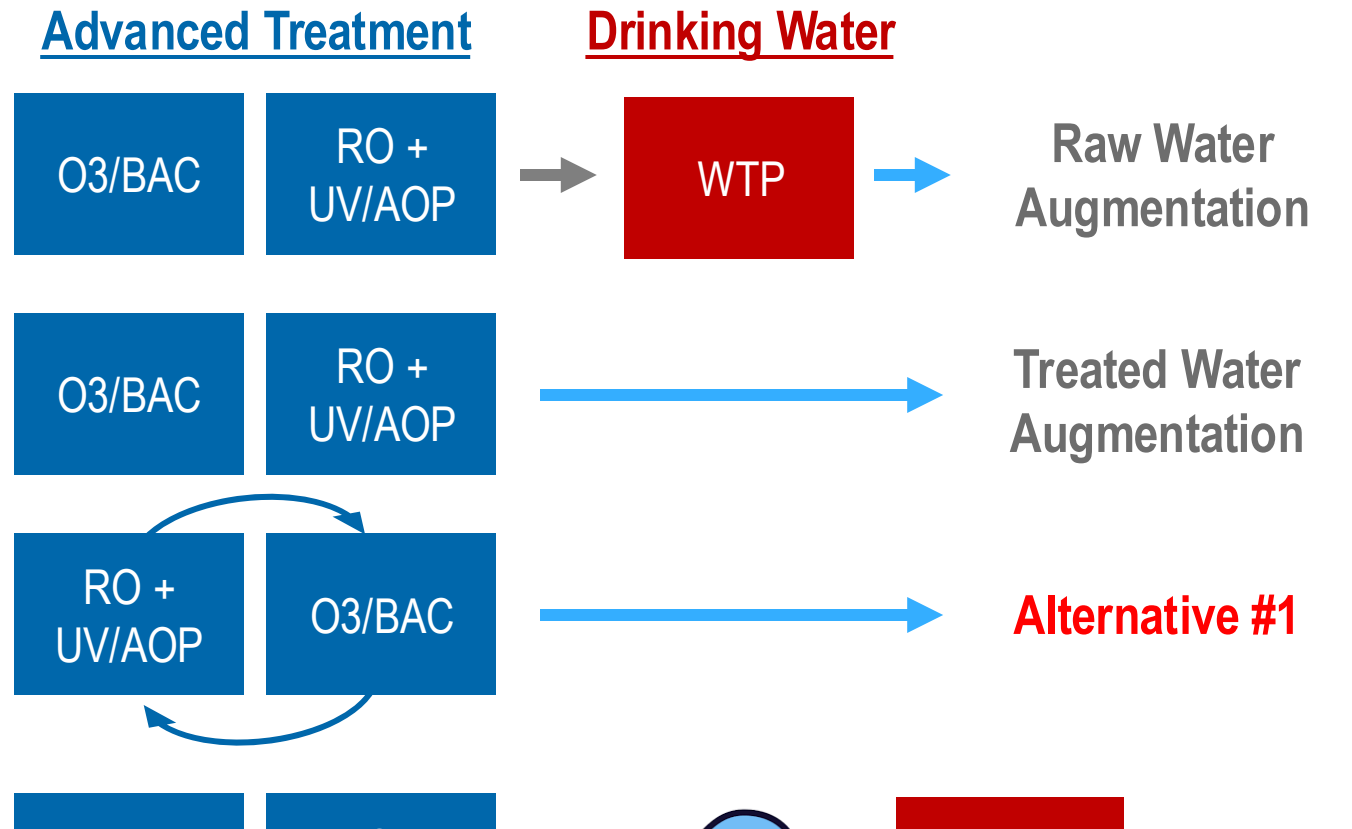


- Why changes if research was completed before 2021?

Ground-truthing from Early Adopters



Ground-truthing from Early Adopters

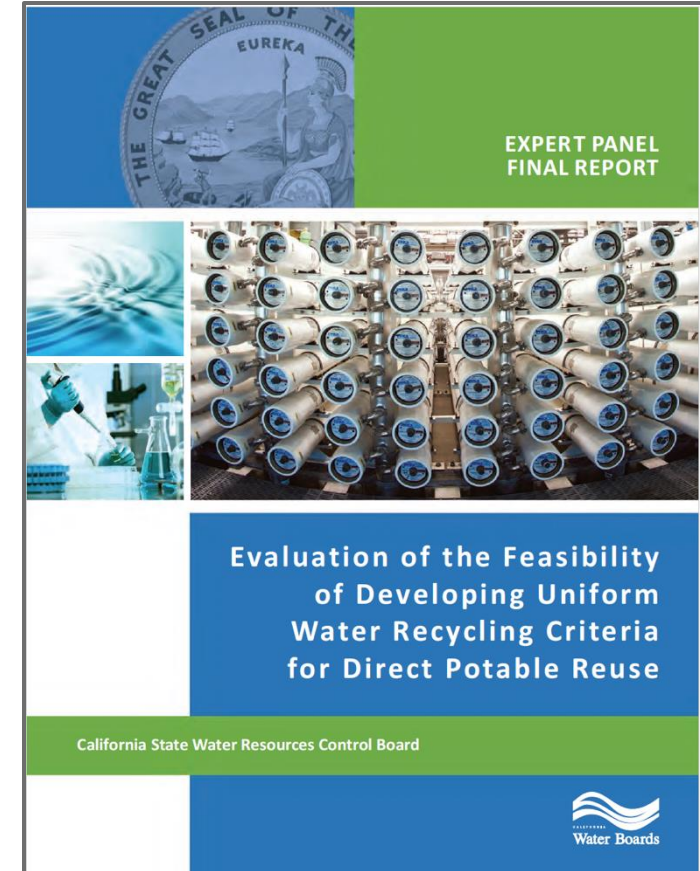


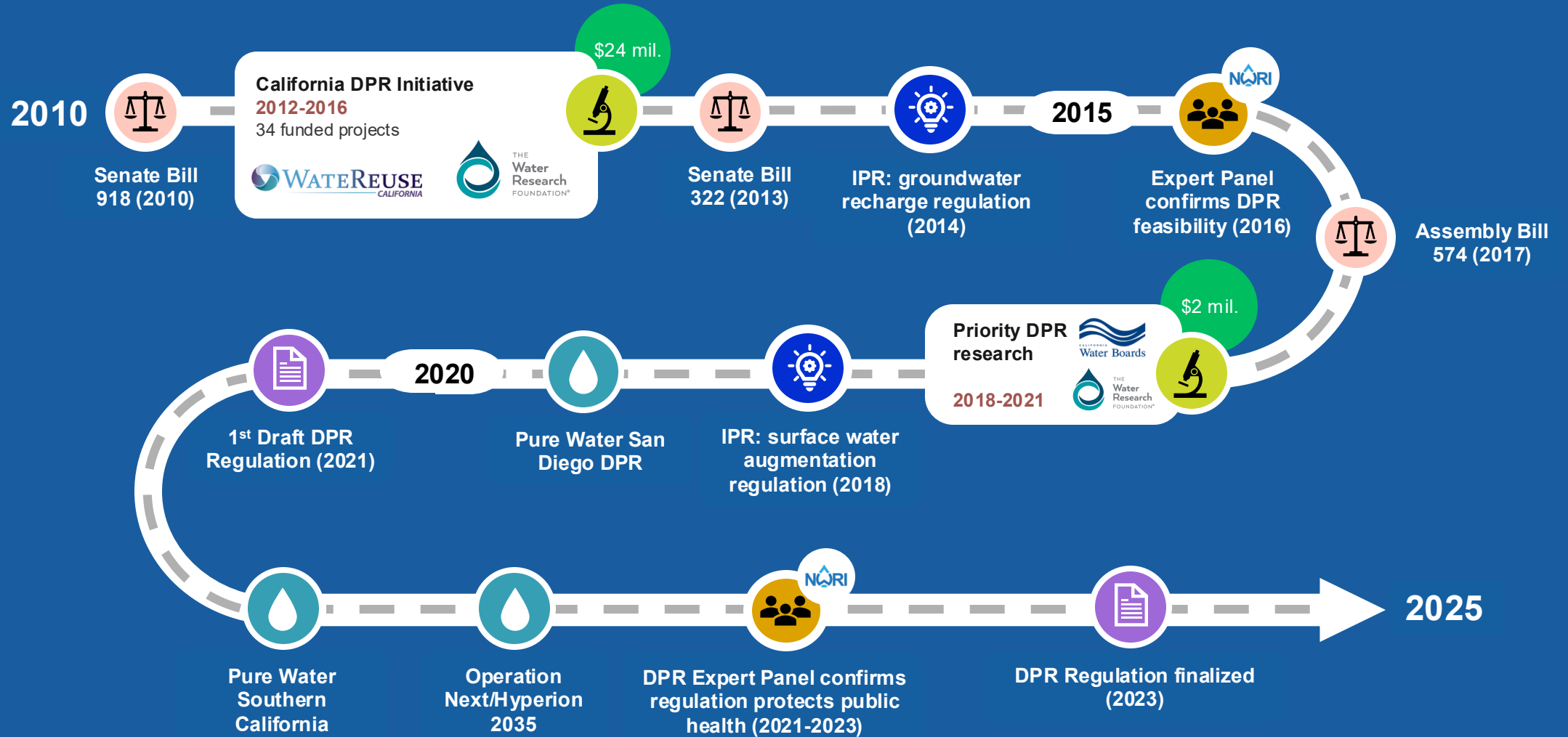
Importance: Early adopters showed that regulations needed more flexibility for diverse project types

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





Legend.





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



Groundwater Recharge: Learning Over 40 years

1962

Filtration

Disinfection



Groundwater Spreading

1974

RO



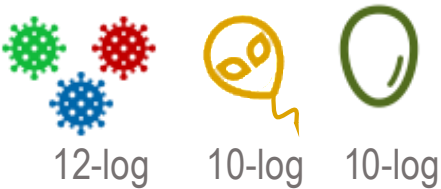
Groundwater Injection

Pathogen Control



Risk-Based LRTs

2011



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

1974

Chemical Control

RO

UV
Photolysis



Groundwater Injection

NDMA

2000s

Pathogen Control



Coliform Standard

Risk-Based LRTs

2011



12-log

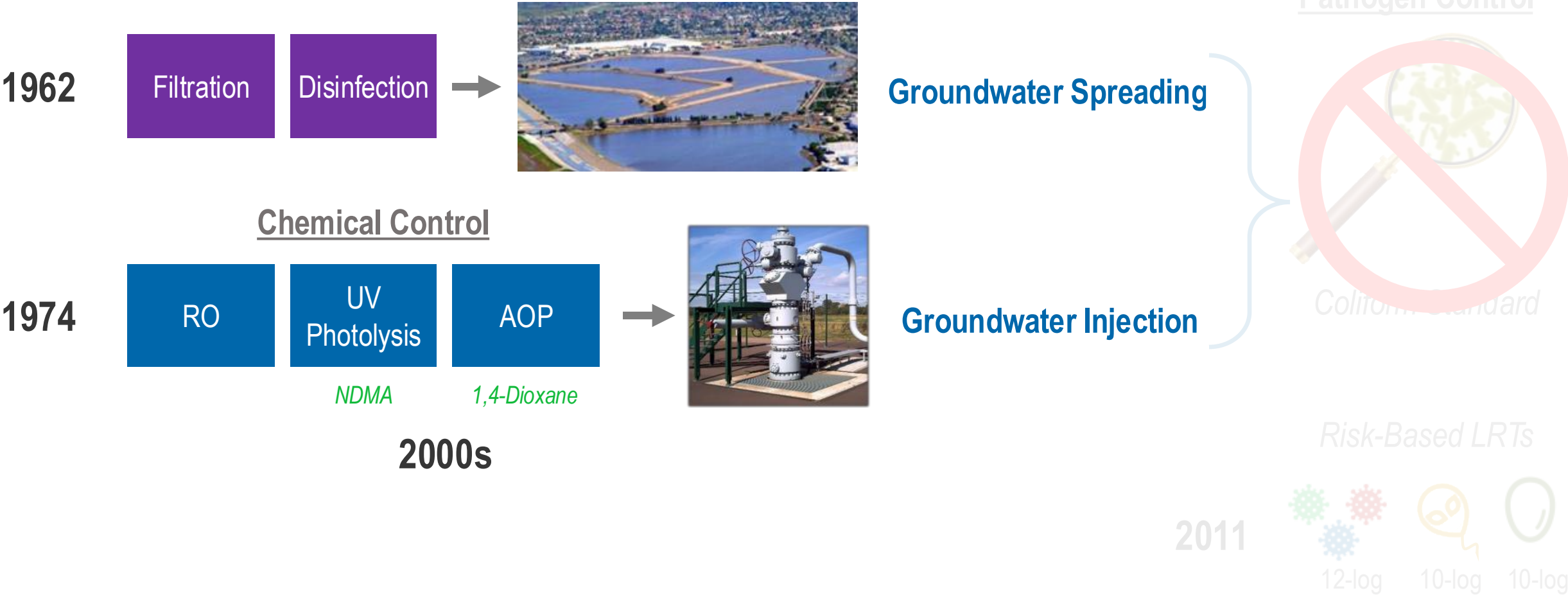


10-log



10-log

Groundwater Recharge: Learning Over 40 years



IPR Regulations Without Experience...

1962

Filtration

Disinfection



Groundwater Spreading

Pathogen Control



Coliform Standard

IPR Regulations With Experience

1962

Filtration

Disinfection



Groundwater Spreading

1974

RO

UV
Photolysis

AOP



Groundwater Injection

Chemical Control

NDMA

1,4-Dioxane

2000s

Pathogen Control



Coliform Standard

Risk-Based LRTs

2011



12-log



10-log



10-log

IPR Regulations With Experience



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*

ReWater
CENTER

HOMEABOUT USRESEARCHCOMMUNICATION AND OUTREACHCOURSEPARTNERSHIPSCONTACT USUSC Viterbi

POTABLE WATER REUSE REPORT

The ReWater Center, in collaboration with Trussell Technologies, Inc., published the first issue of the Potable Water Reuse Report in spring 2024, with future issues being published quarterly. The publication is intended to connect the potable water reuse community – including practitioners, regulators, and academics – to keep them up-to-date with the industry's rapidly evolving developments.

PWR Report Series 1: Direct Potable Reuse Regulations

Potable Water Reuse Report

The Factors Shaping DPR Regulations in the United States

Issue 2

The Factors Shaping DPR Regulations in the United States

June 14, 2024

Potable Water Reuse Report

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

Issue 1

Direct Potable Reuse Regulations and the Importance of Adapting to a Rapidly Changing World: A California Case Study

March 8, 2024





Why don't we just measure the pathogens?



The background of the entire image is a dense, chaotic pile of hundreds of Pokémon trading cards. The cards are of various colors (yellow, blue, green, red, purple) and feature different Pokémon characters. In the center of the pile, a blue Pokémon box with a Poké Ball logo is visible. Overlaid on top of this pile is the Pokémon logo in its characteristic yellow and blue font, with the slogan 'Gotta catch 'em all!' written below it in a blue, outlined font. Both the logo and slogan have a small 'TM' trademark symbol.

POKÉMON

Gotta catch 'em all!

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

POKÉMON

Gotta catch 'em all!



Giardia

Cryptosporidium



Enteric Viruses

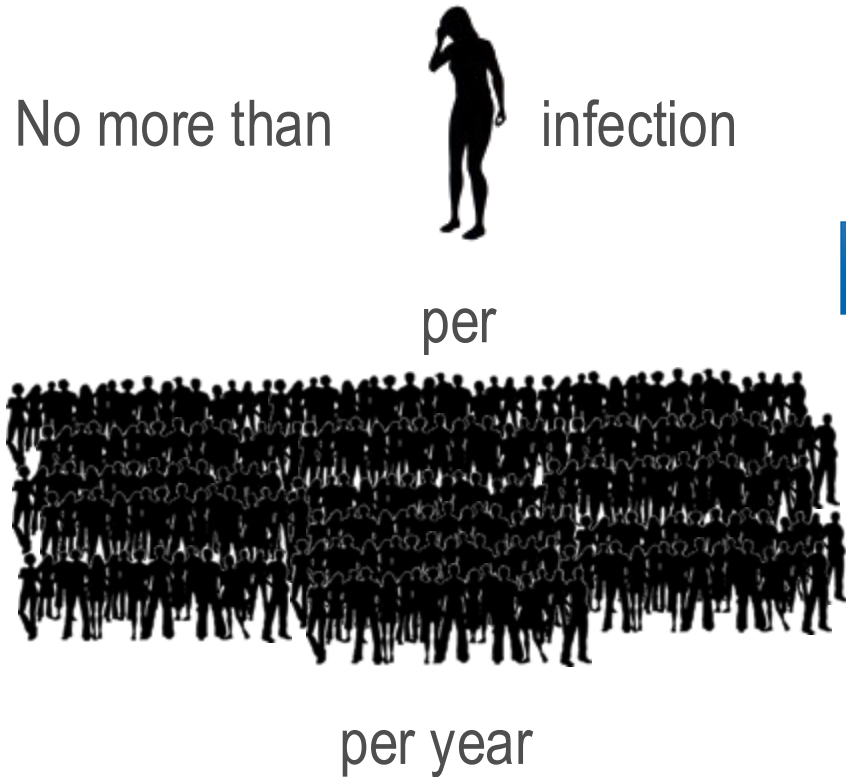


Campylobacter

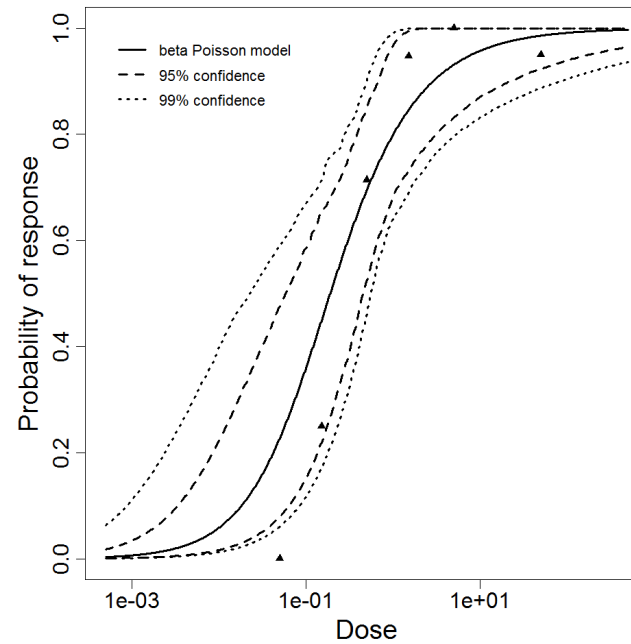
We focus on a small group of resistant pathogens (reference pathogens)

What concentrations are “safe”?

Infection Benchmark

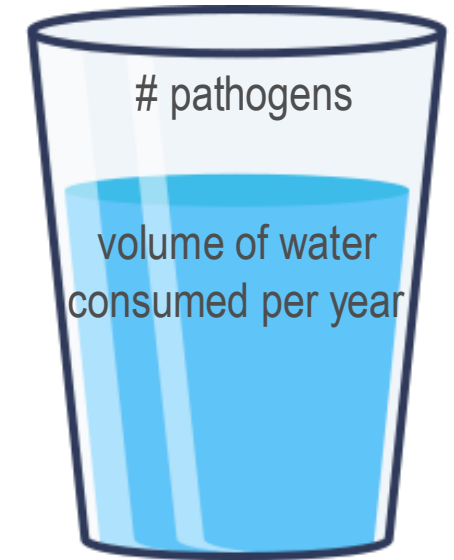


Dose-Response



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

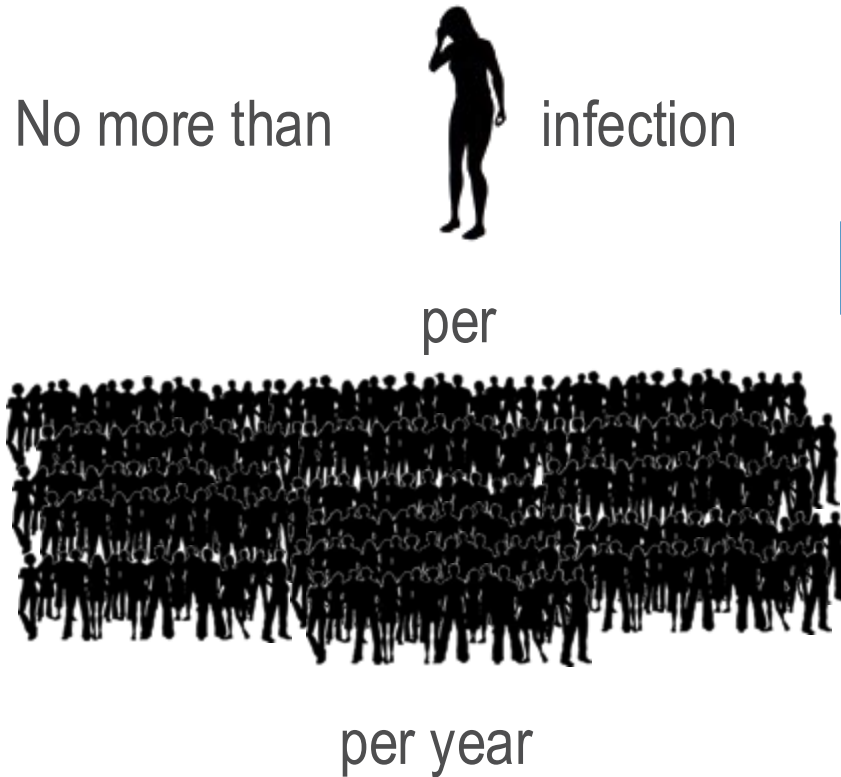
Safe Levels



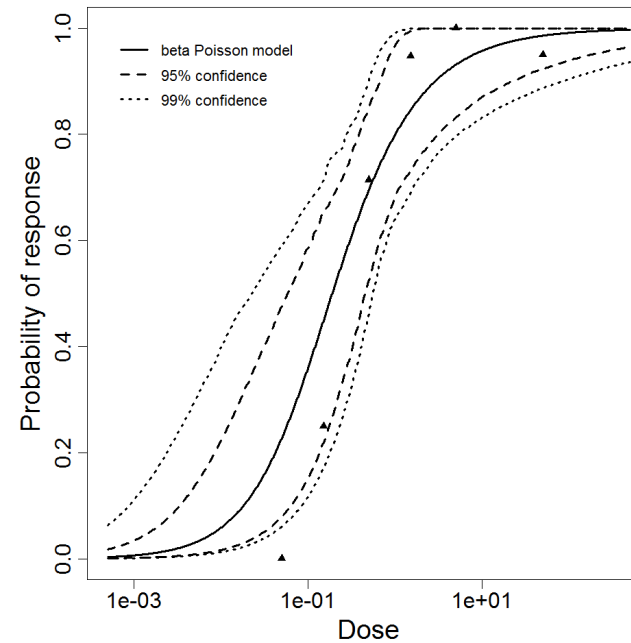
Acceptable virus
concentration:
 2.2×10^{-7} MPN/L

What concentrations are “safe”?

Infection Benchmark

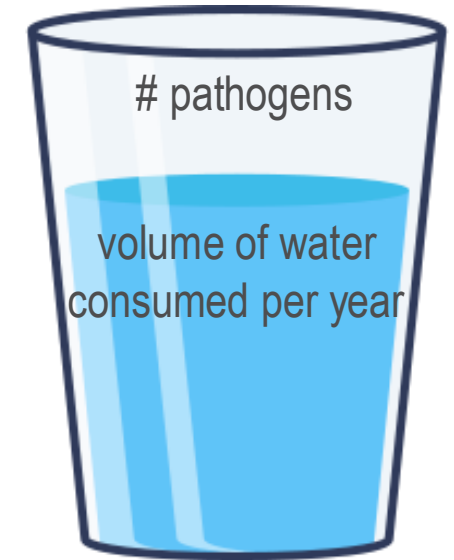


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Safe Levels

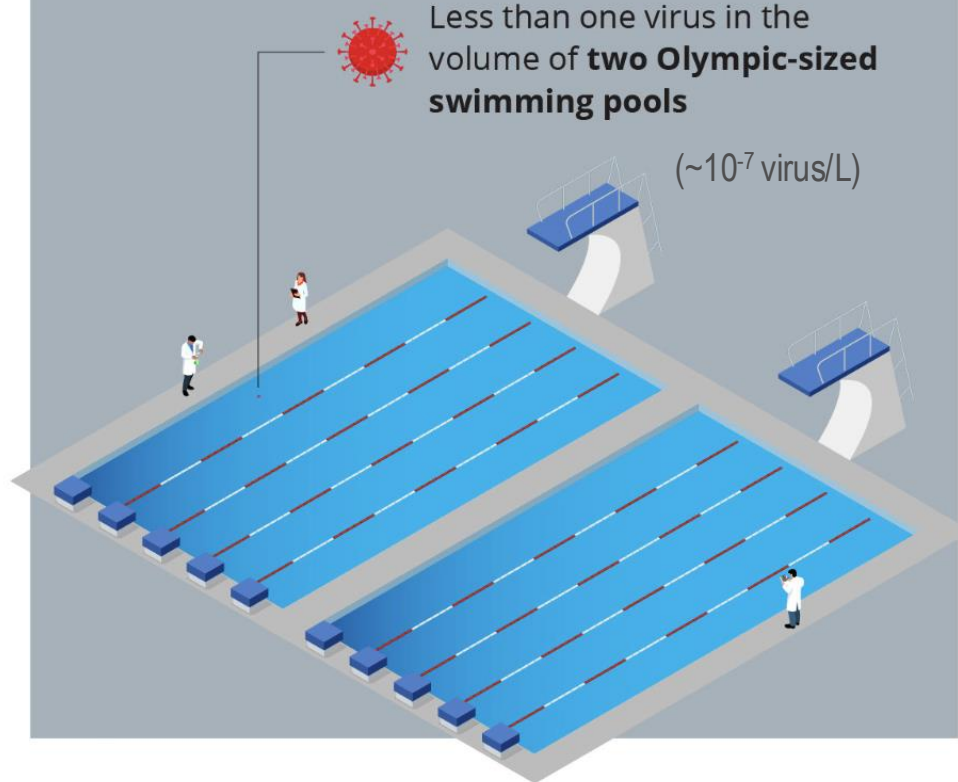


Acceptable virus
concentration:
 2.2×10^{-7} MPN/L

So, why don't we just measure them?

Why don't we just measure the treated water?

What drinking water regulations require

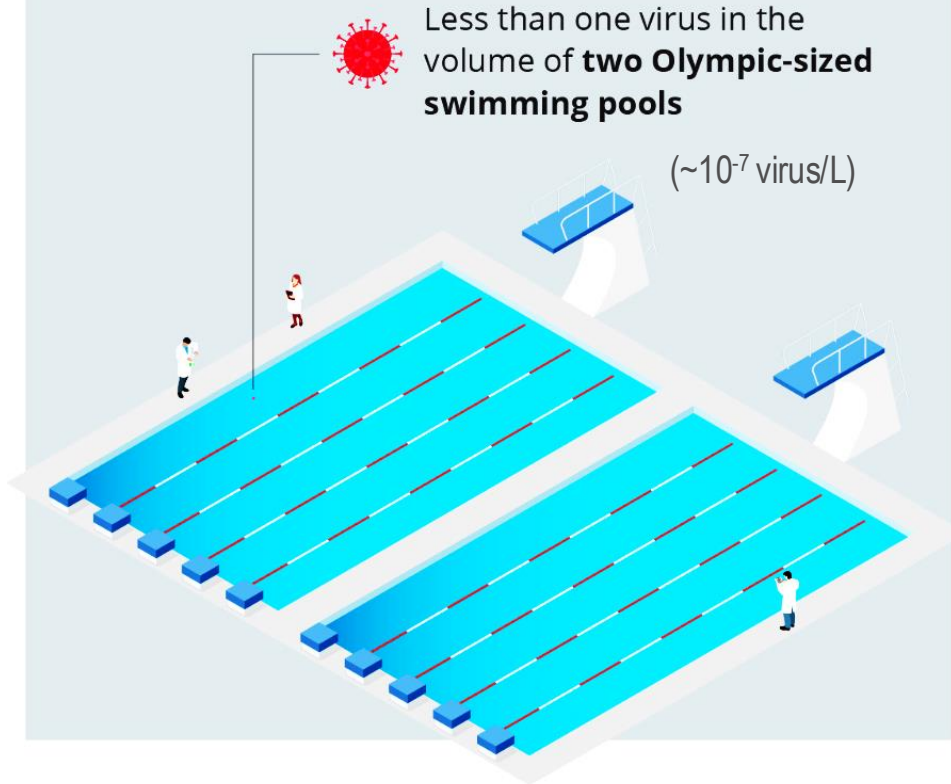


What labs can detect



Why don't we just measure the treated water?

What drinking water regulations require



What labs can detect



We are technically incapable of doing this!

Key Takeaway Message:

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



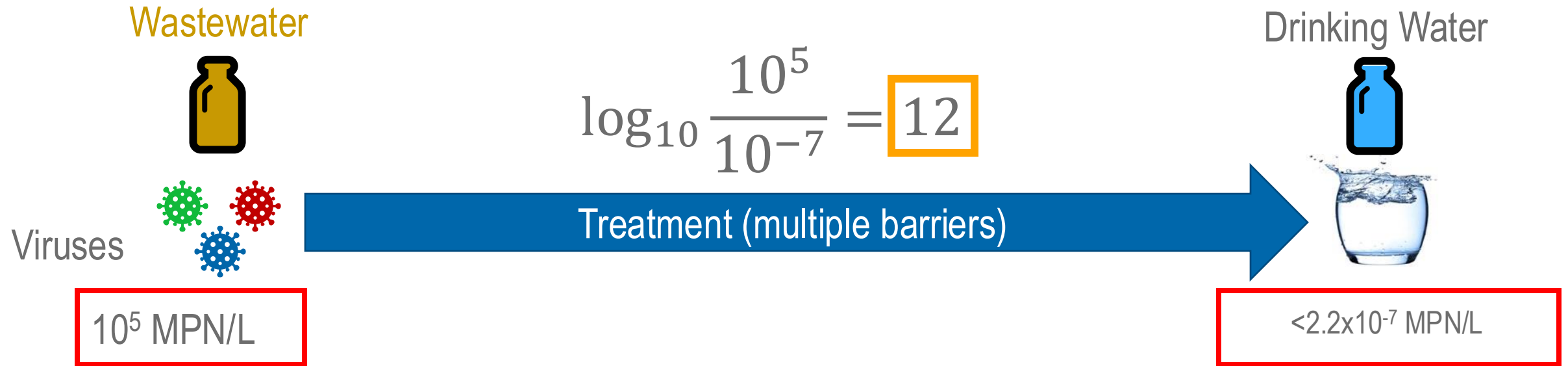
What is the alternative to end-point monitoring?



Plan B: define pathogen log reduction targets



Plan B: define pathogen log reduction targets



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

Potable Reuse Requires High Pathogen LRTs

Surface
water



4-LOG REQ'D

SWTRs



Drinking
water



Wastewater

1 2 - L O G R E Q U I R E D



Drinking
water

Key Takeaway Message:

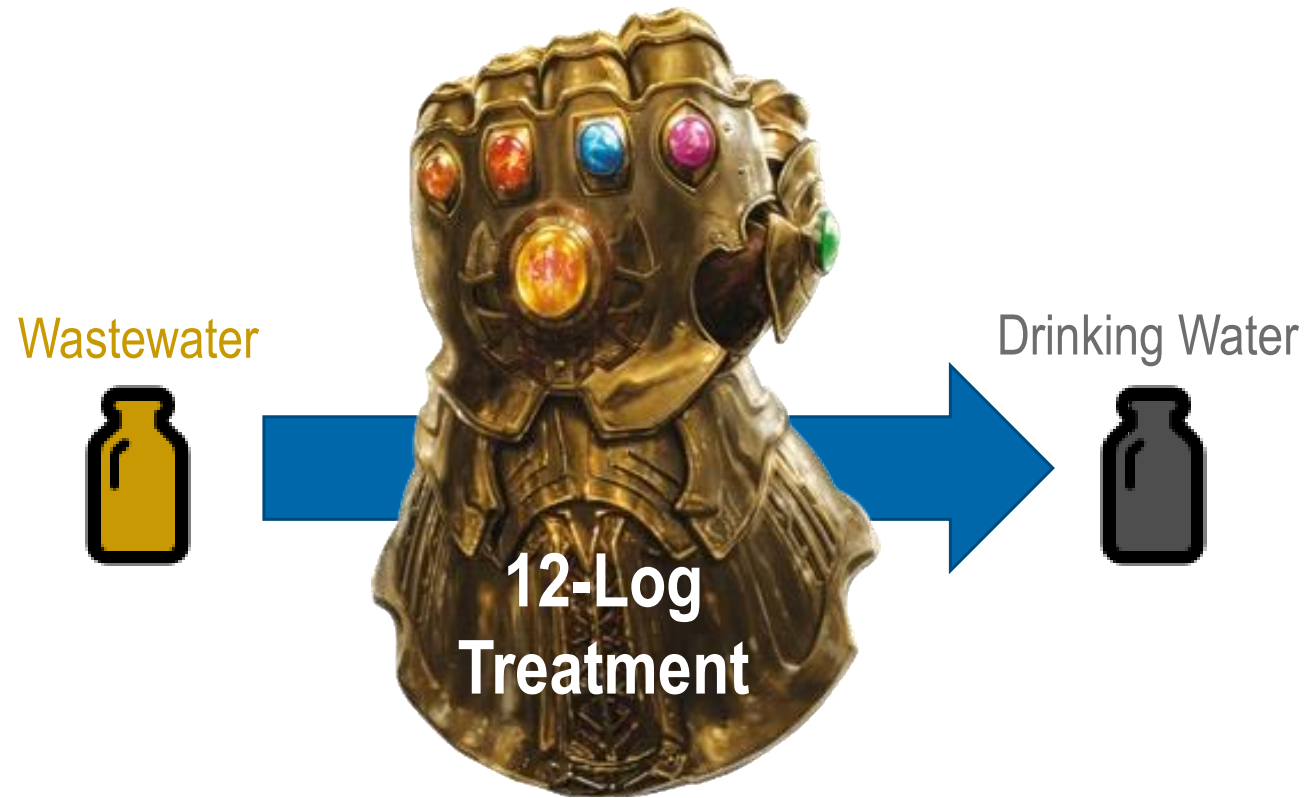
- *Potable water reuse requires much higher pathogen reduction than conventional drinking water treatment*



Why do we need pathogen crediting frameworks?

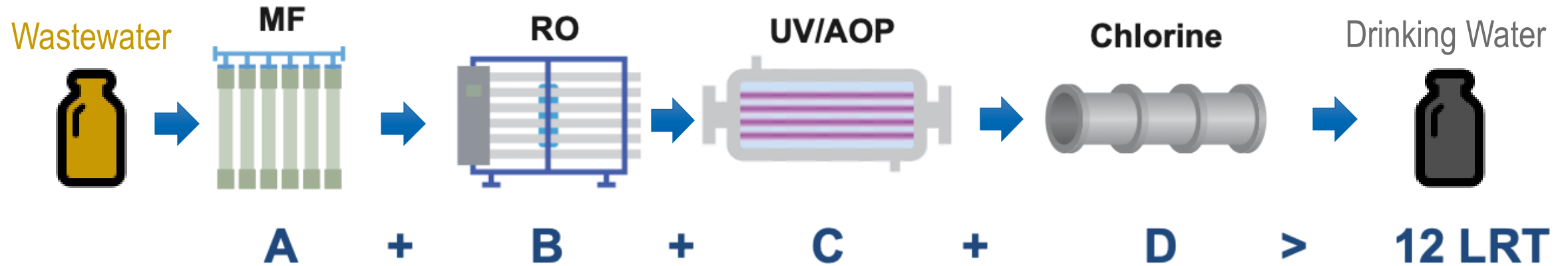


No single process allows us to meet our goals

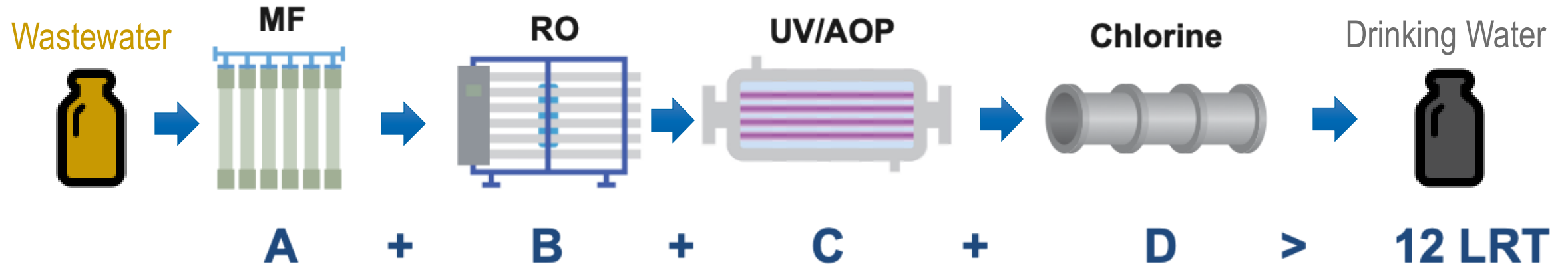


Doesn't exist.

Create trains that collectively meet LRTs



Create trains that collectively meet LRTs

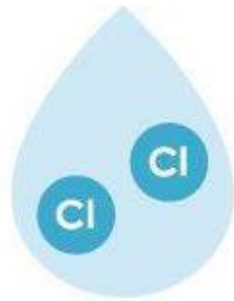


We need crediting frameworks to assign a log reduction value (LRV) to each unit process.

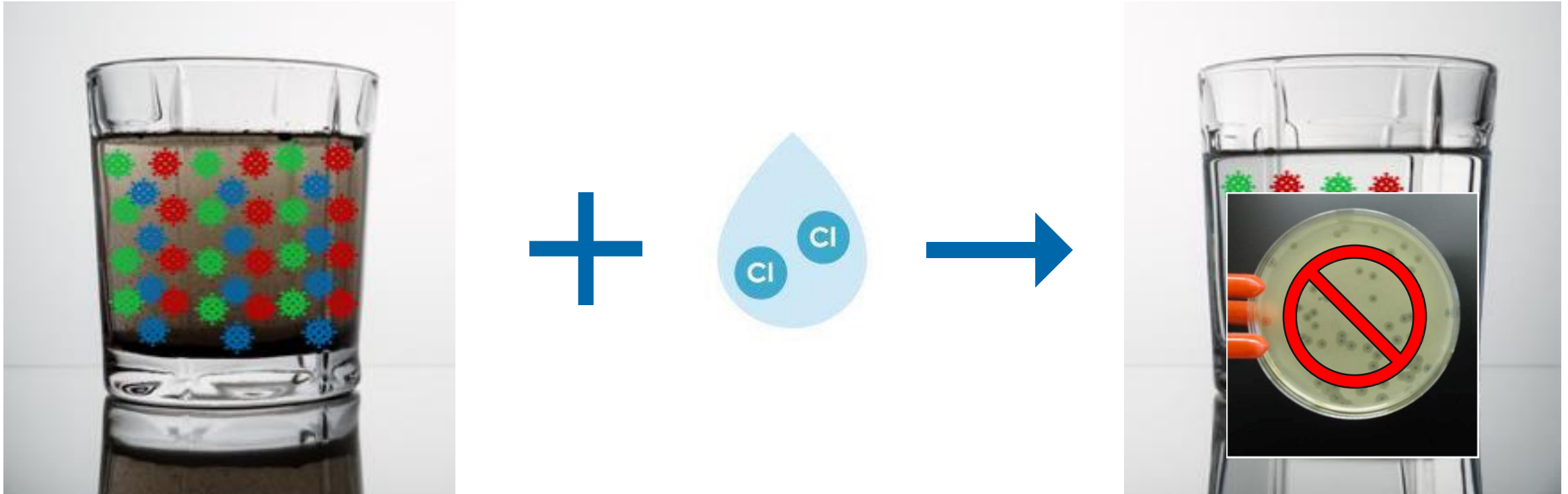
Crediting framework example: chlorine



+

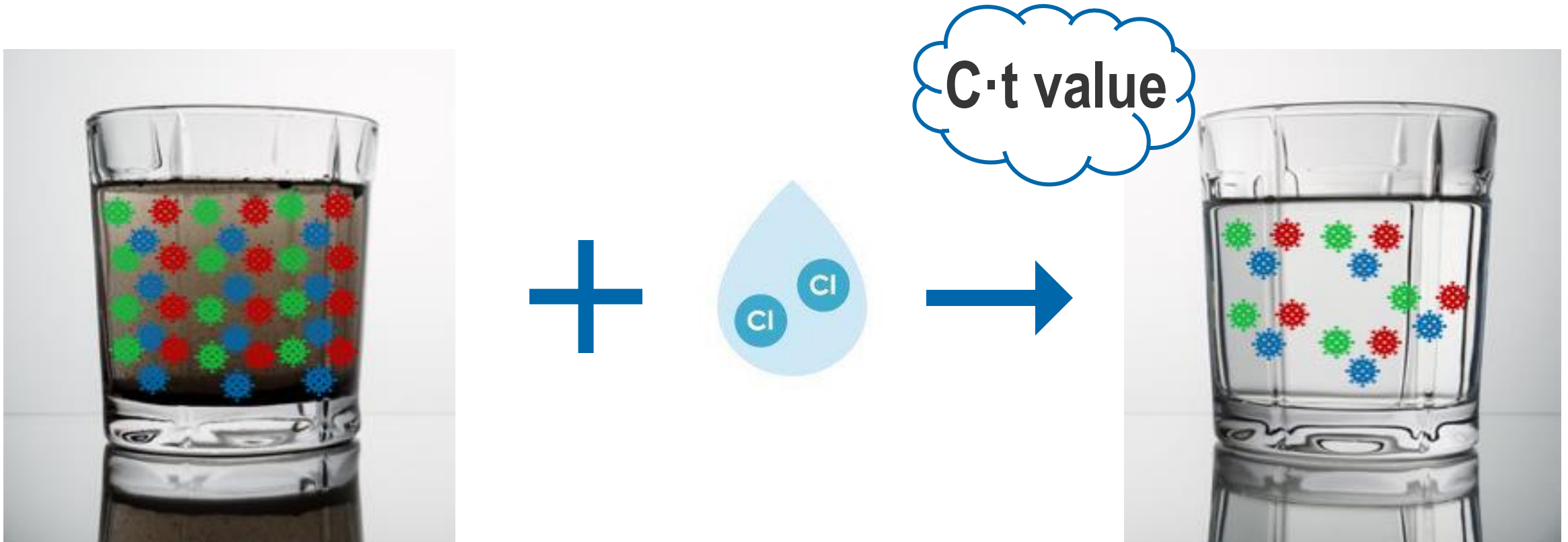


Crediting framework example: chlorine



Do not rely on direct measurement of pathogens

Crediting framework example: chlorine

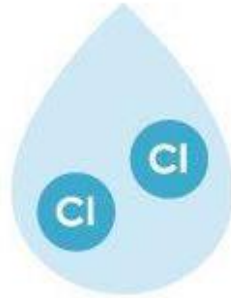


Identify a surrogate that is directly tied to pathogen inactivation

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 temperature

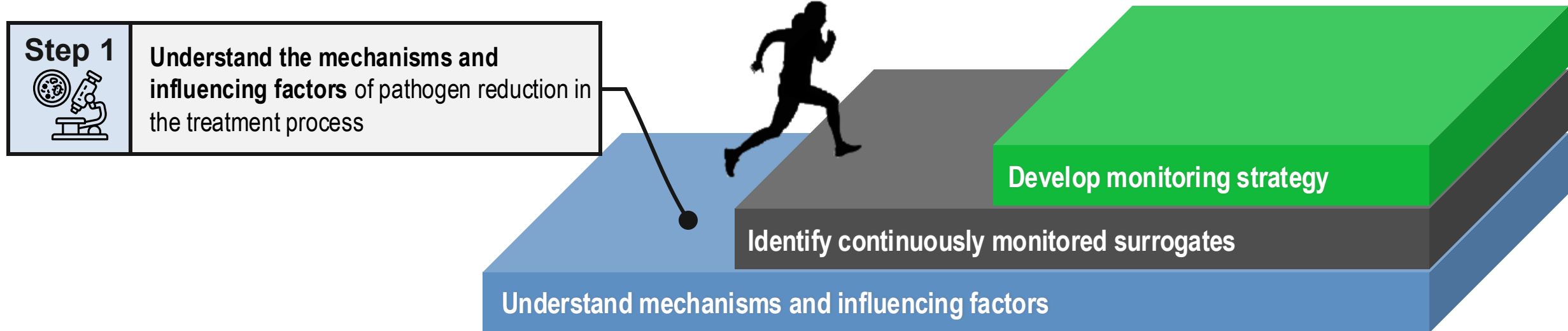
pH	Log ₁₀ inactivation	≤0.2 NTU					≤2 NTU				
		5 °C	10 °C	15 °C	20 °C	25 °C	5 °C	10 °C	15 °C	20 °C	25 °C
≤7	1	4	3	2	2	1	4	3	2	2	1
	2	5	4	3	2	2	5	4	3	2	2
	3	7	5	4	3	2	7	5	4	3	2
	4	8	6	4	3	2	9	6	4	3	2
≤7.5	1	7	5	4	3	2	7	5	4	3	2
	2	10	7	5	4	3	10	7	5	4	3
	3	13	9	7	5	4	13	9	7	5	4
	4	16	11	8	6	4	16	11	8	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

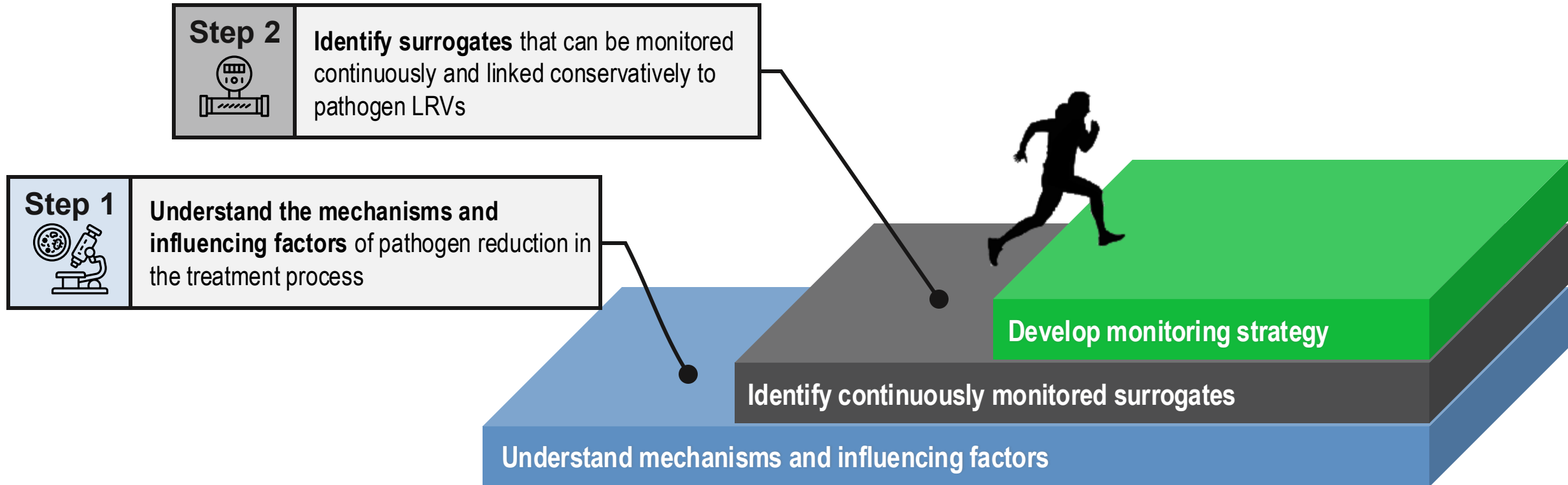


...and where factors influencing performance are well understood.

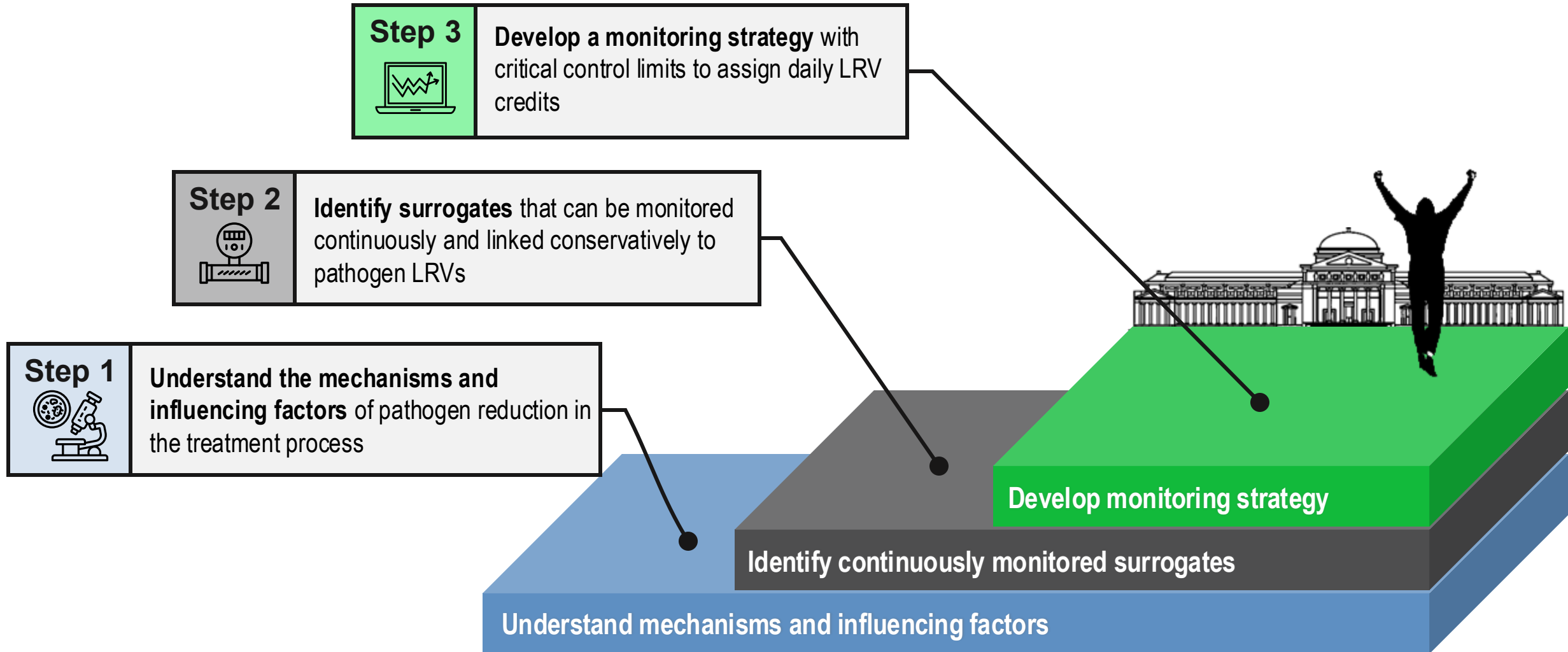
Crediting Frameworks: General Approach



Crediting Frameworks: General Approach



Crediting Frameworks: General Approach



Key Takeaway Message:

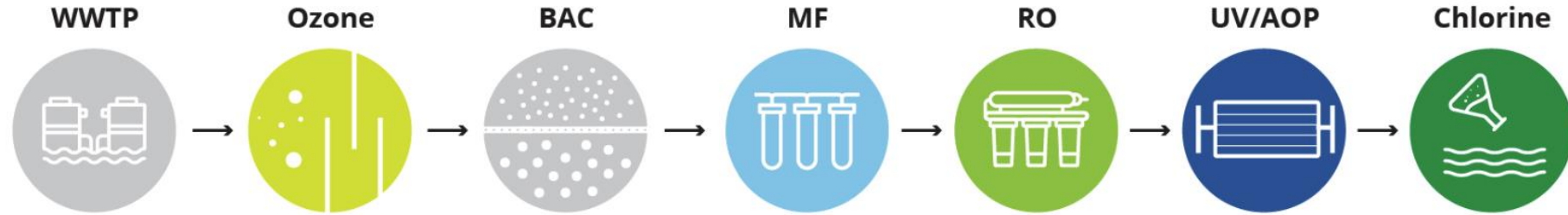
- *Regulations compare pathogen reduction requirements with “credits” that can be achieved by individual processes, but these must be verified continuously using surrogates*



Why do we need new crediting frameworks?

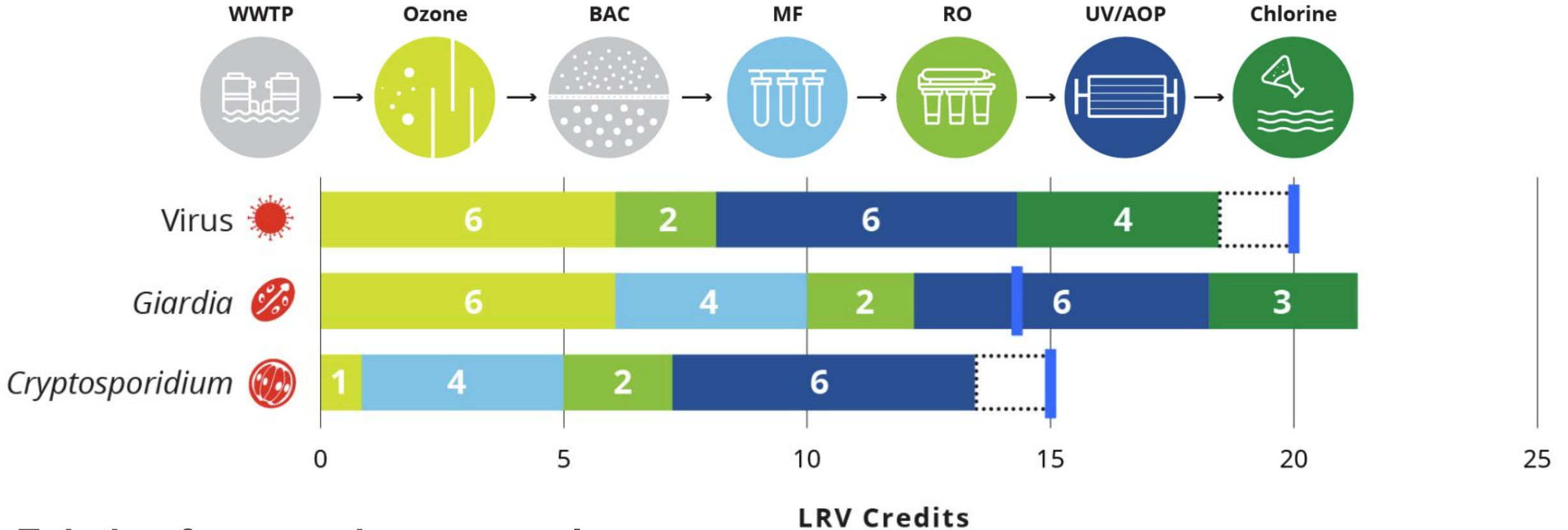


Review of Unit Process Crediting



Which processes have existing pathogen crediting frameworks?

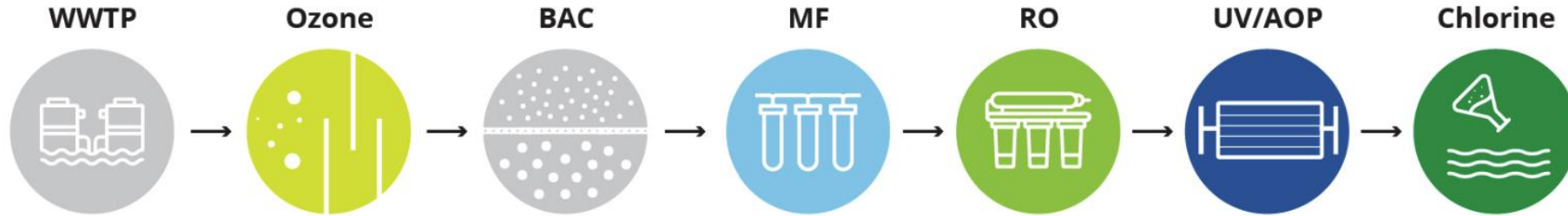
Review of Unit Process Crediting



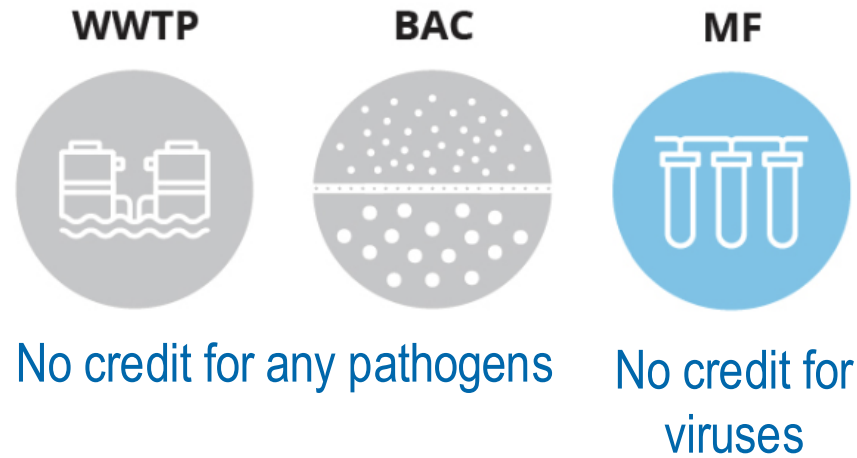
Existing frameworks cover only a fraction of the unit processes

Example LRV Requirements for California Direct Potable Reuse: 20/14/15 for V/G/C

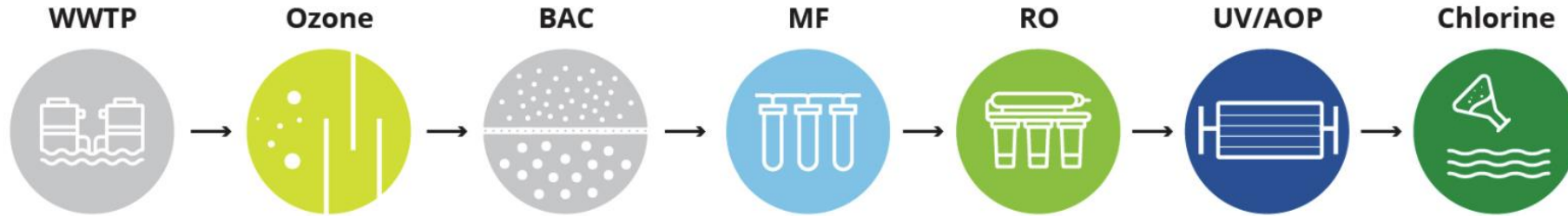
Review of Unit Process Crediting



Some treatment processes are completely uncredited



Review of Unit Process Crediting



Some are under-credited

RO



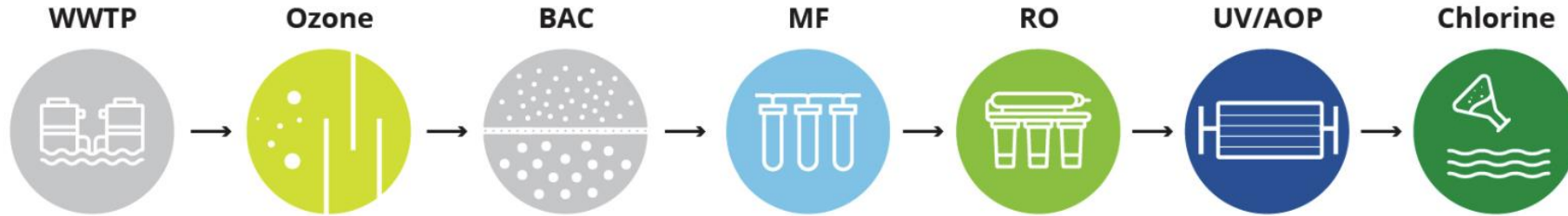
Only 2-log credit for
all pathogens

Chlorine



Only 4-log credit for
viruses

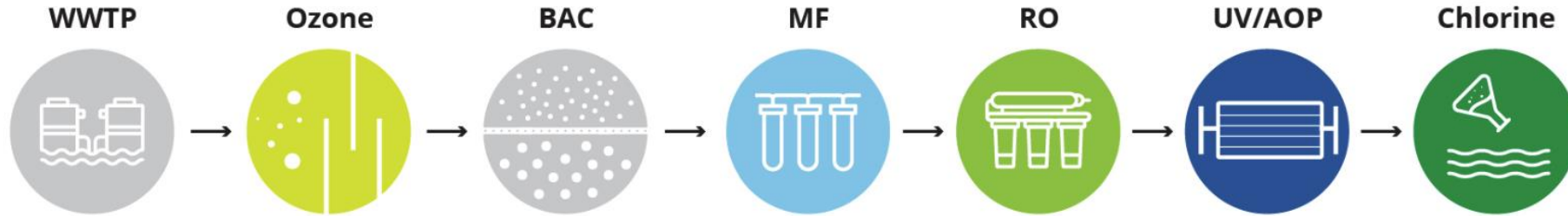
Review of Unit Process Crediting



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

Extremely robust treatment trains can't meet DPR requirements!

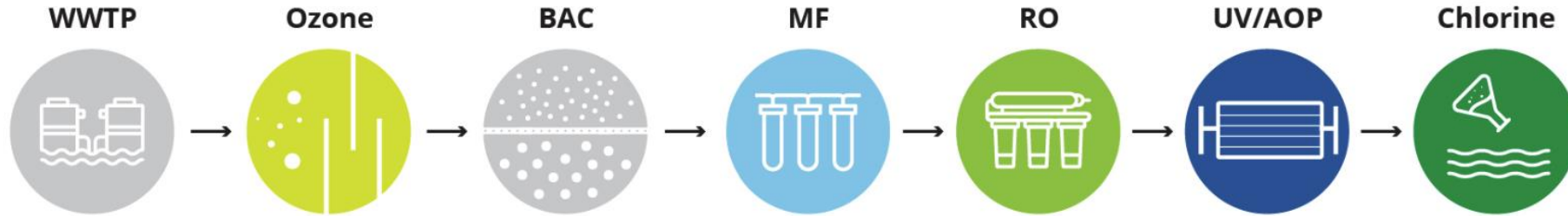
Review of Unit Process Crediting



Pathogen	WWTP	Ozone	BAC	MF	RO	UV/AOP	Cl ₂	Total	Required (CA)
Virus	-	6	-	-	2	6	4	18	20
<i>Giardia</i>	-	6	-	4	2	6	3	19	14
<i>Crypto</i>	-	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
<i>Giardia</i>	1	6	1	4	3	6	3	19	14
<i>Crypto</i>	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.



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**

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POTABLE WATER REUSE REPORT

The ReWater Center, in collaboration with Trussell Technologies, Inc., published the first issue of the Potable Water Reuse Report in spring 2024, with future issues being published quarterly. The publication is intended to connect the potable water reuse community – including practitioners, regulators, and academics – to keep them up-to-date with the industry's rapidly evolving developments.

PWR Report Series 1: Direct Potable Reuse Regulations



Issue 2

The Factors Shaping DPR Regulations in the United States

June 14, 2024



Issue 1

Direct Potable Reuse Regulations and the Importance of Ada
A California Case Study

March 8, 2024



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

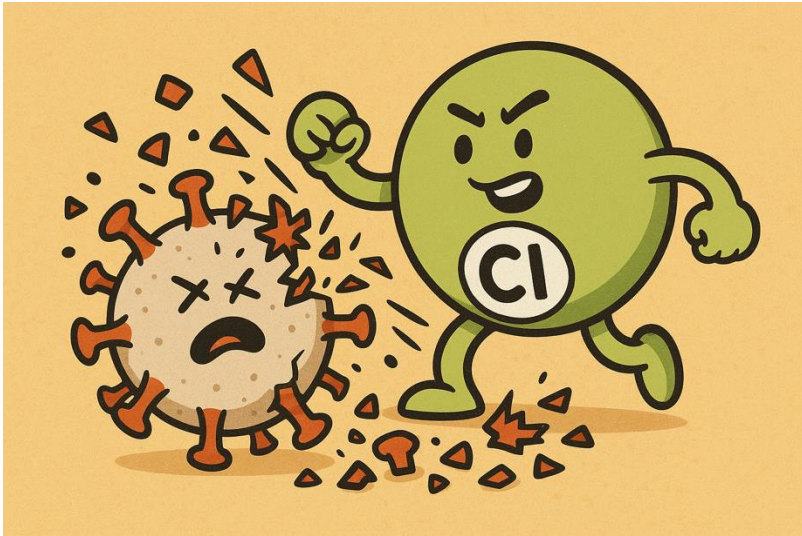
“Ideally, you prove that you are controlling pathogens via continuous monitoring of a relevant parameter—such as a surrogate or an indicator—to justify the credit in real-time and to enable rapid corrective actions in the event of a treatment failure.”

Amos Branch, Carollo Engineers

Scientific Understanding of Pathogen Reduction

Modeling Approach

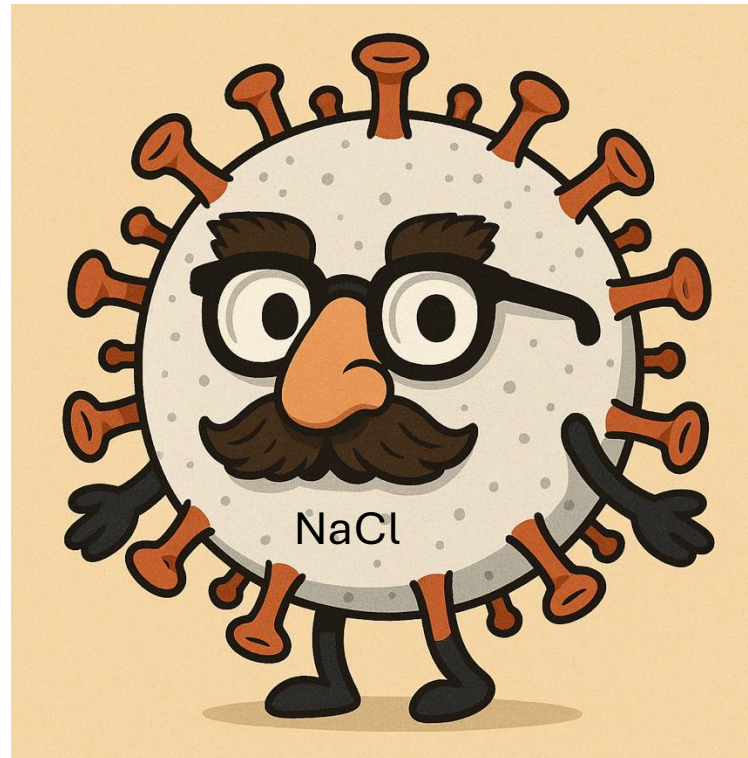
We really understand the mechanisms well (e.g., chlorination)



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
C E N T E R

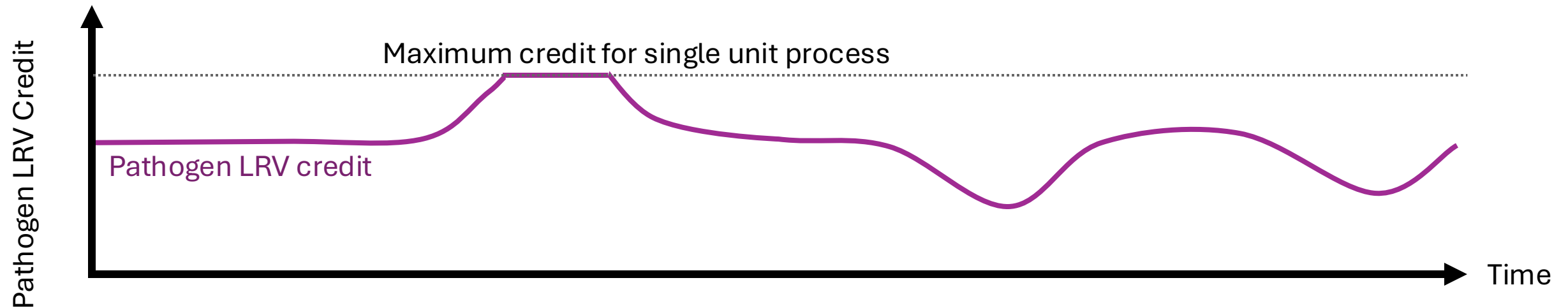
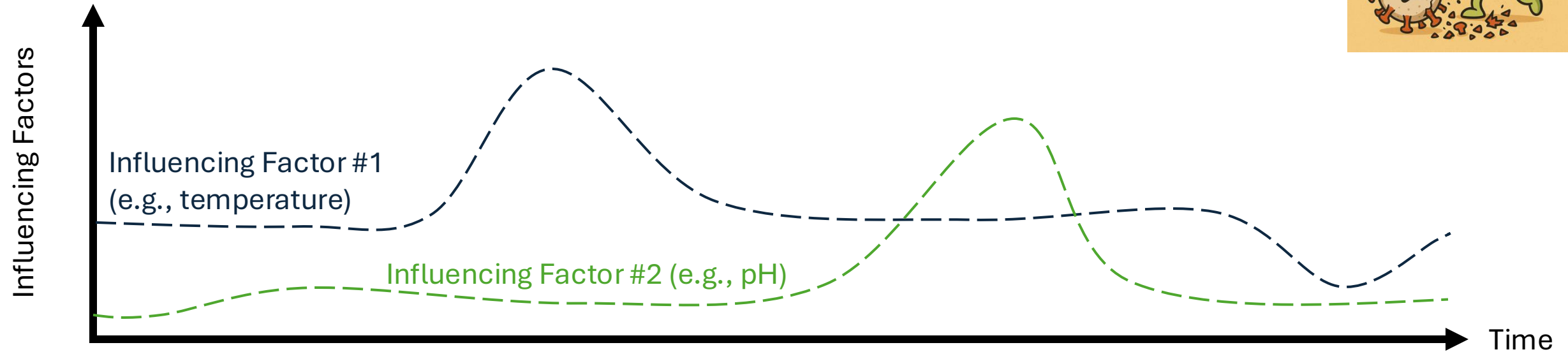
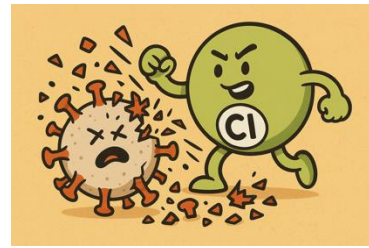
Operational Envelope

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



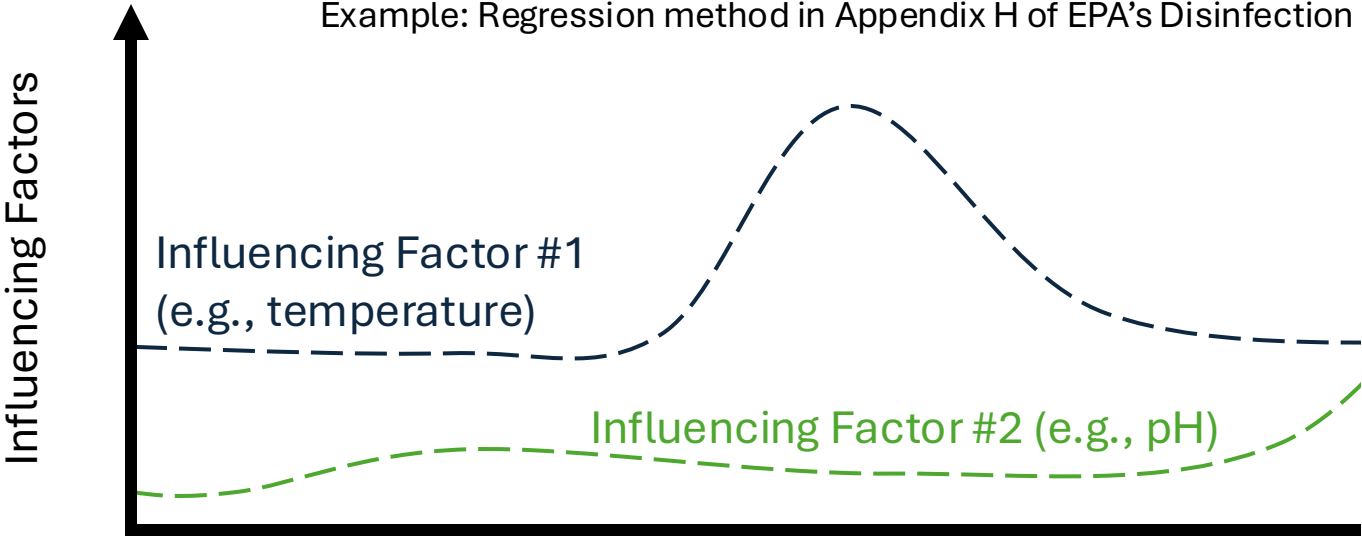
“Let’s just do a study.”

Approach #1: Modeling the Pathogen LRV



Approach #1: Modeling the Pathogen LRV

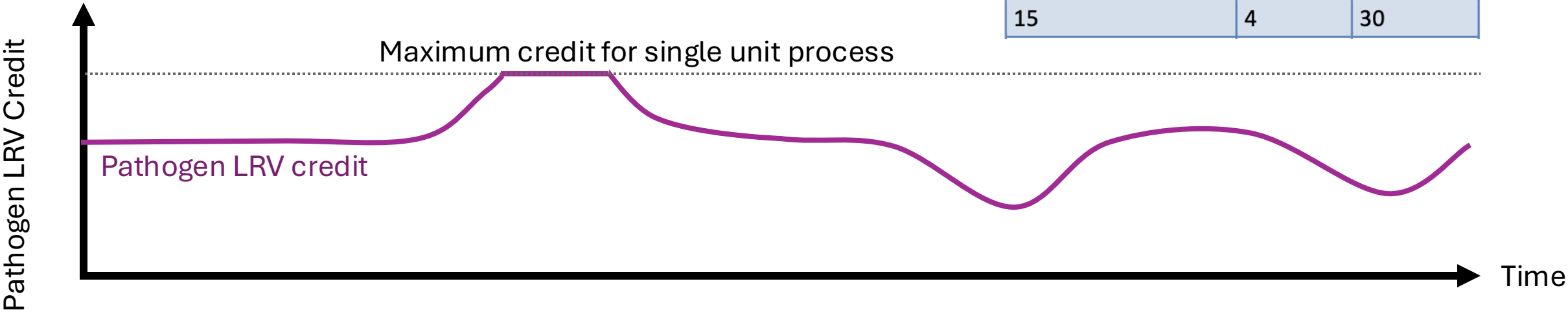
Example: Regression method in Appendix H of EPA’s Disinfection Profiling and Benchmarking Technical Guidance Manual (2020)



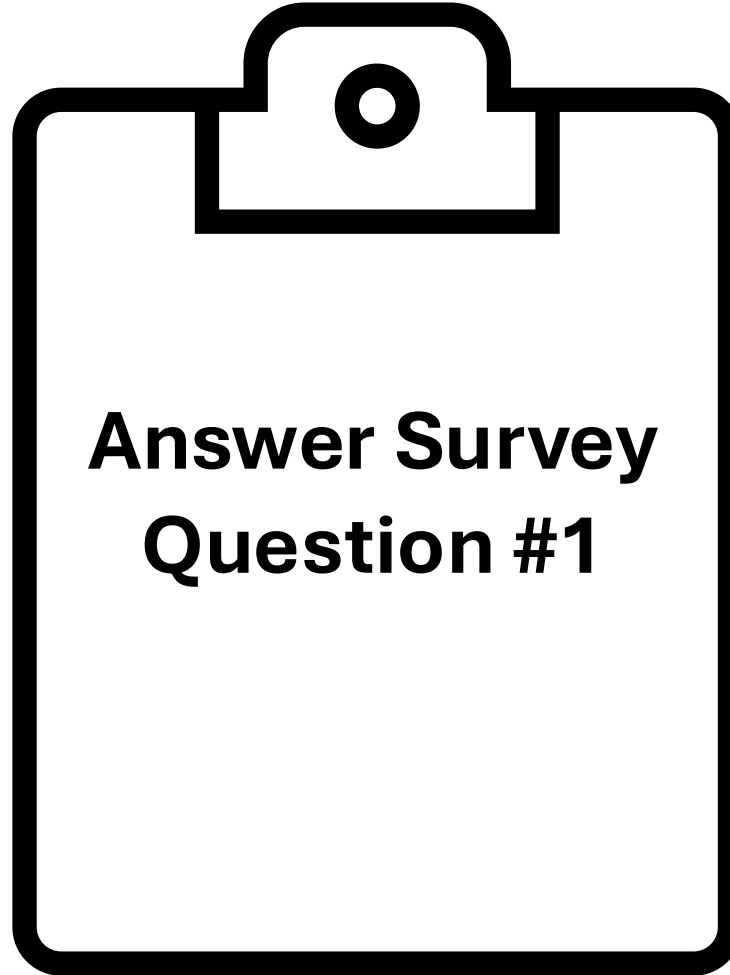
$$LRV = \frac{CT}{0.361(-2.261 + e^{(2.69-0.065T+0.111C+0.361(pH))})}$$

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

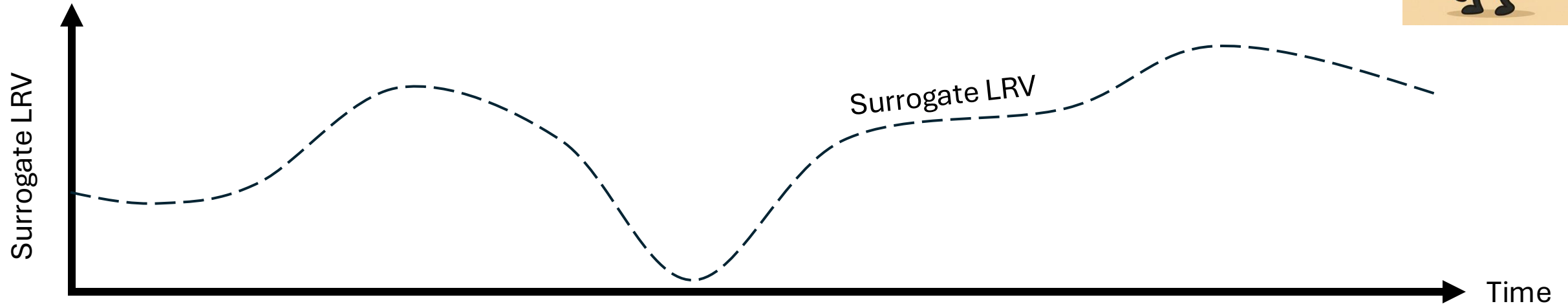
	pH	
Temperature (°C)	6-9	10
0.5	12	90
5	8	60
10	6	45
15	4	30



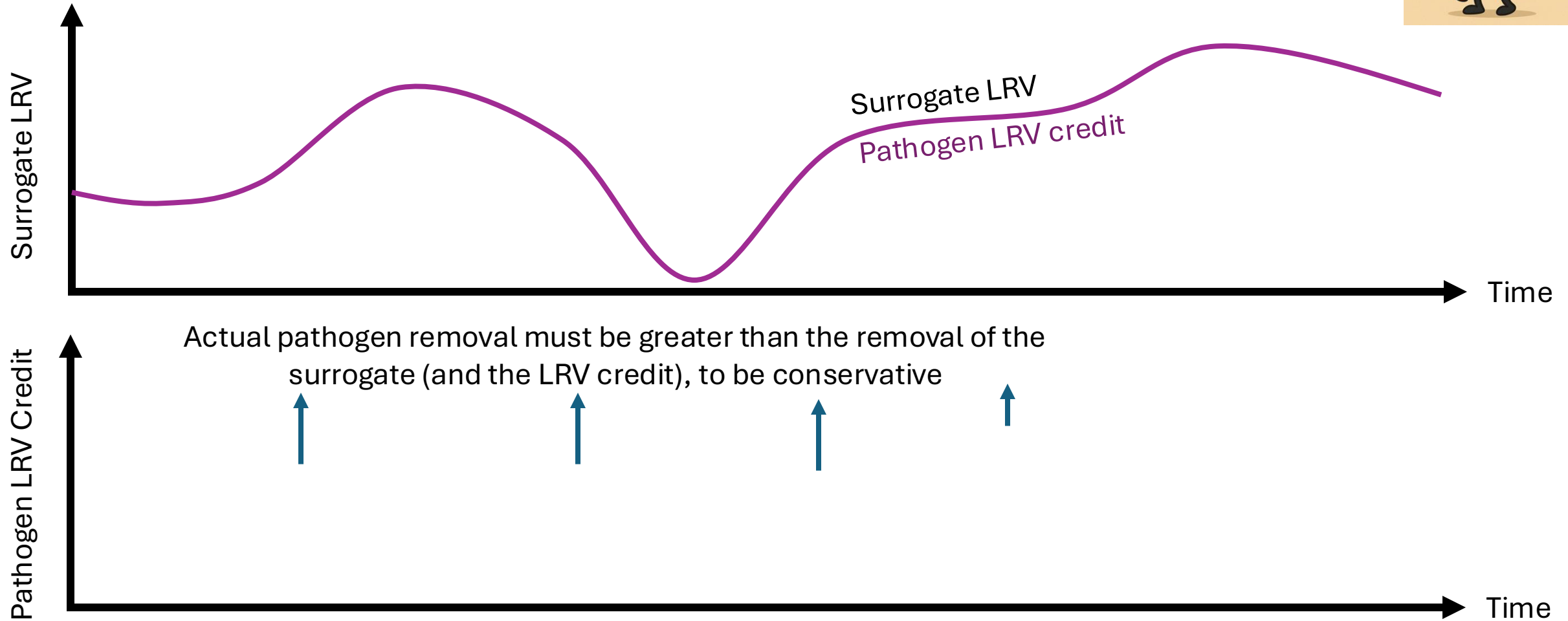
Approach #1: Modeling the Pathogen LRV



Approach #2: Conservative Surrogate

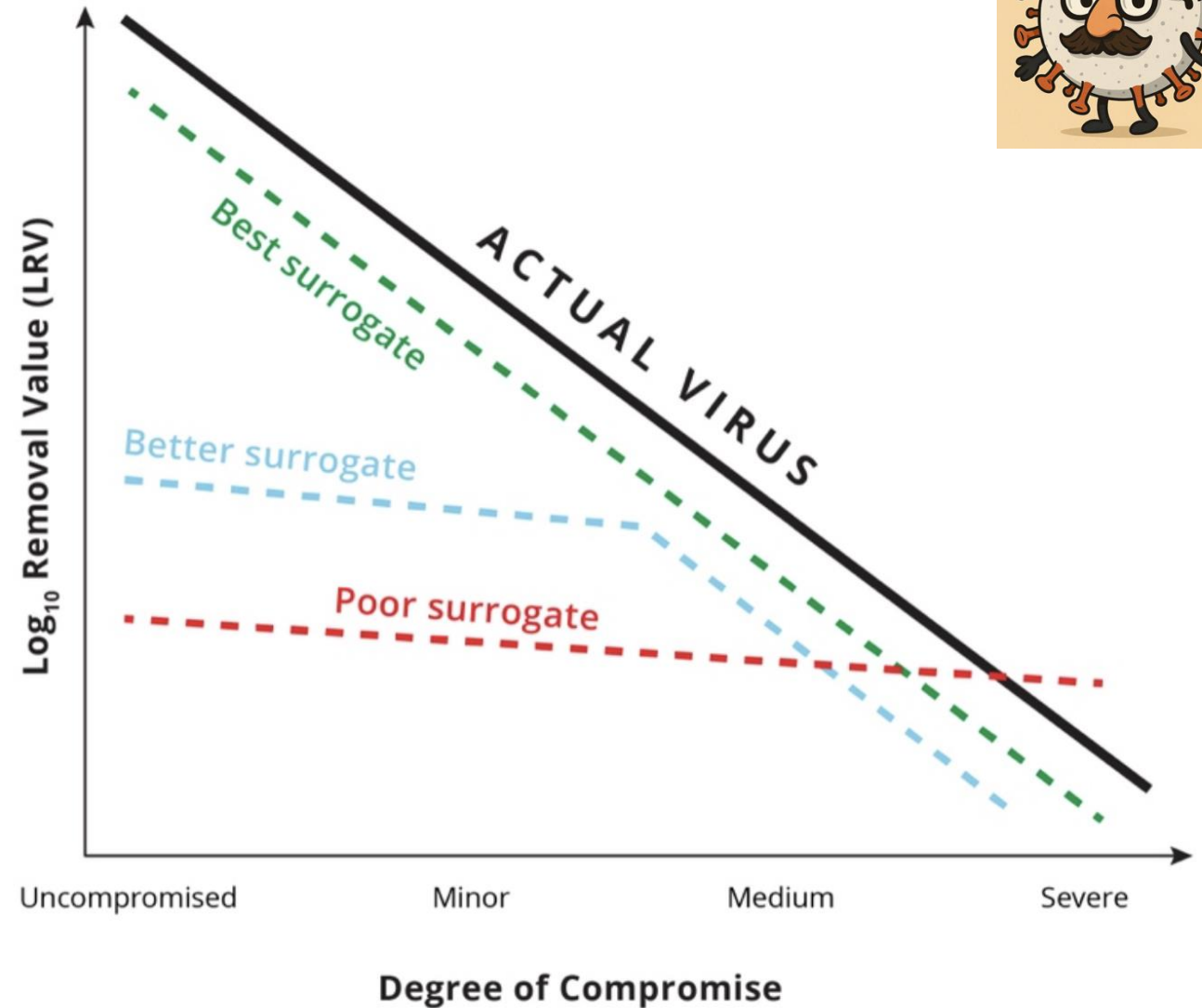


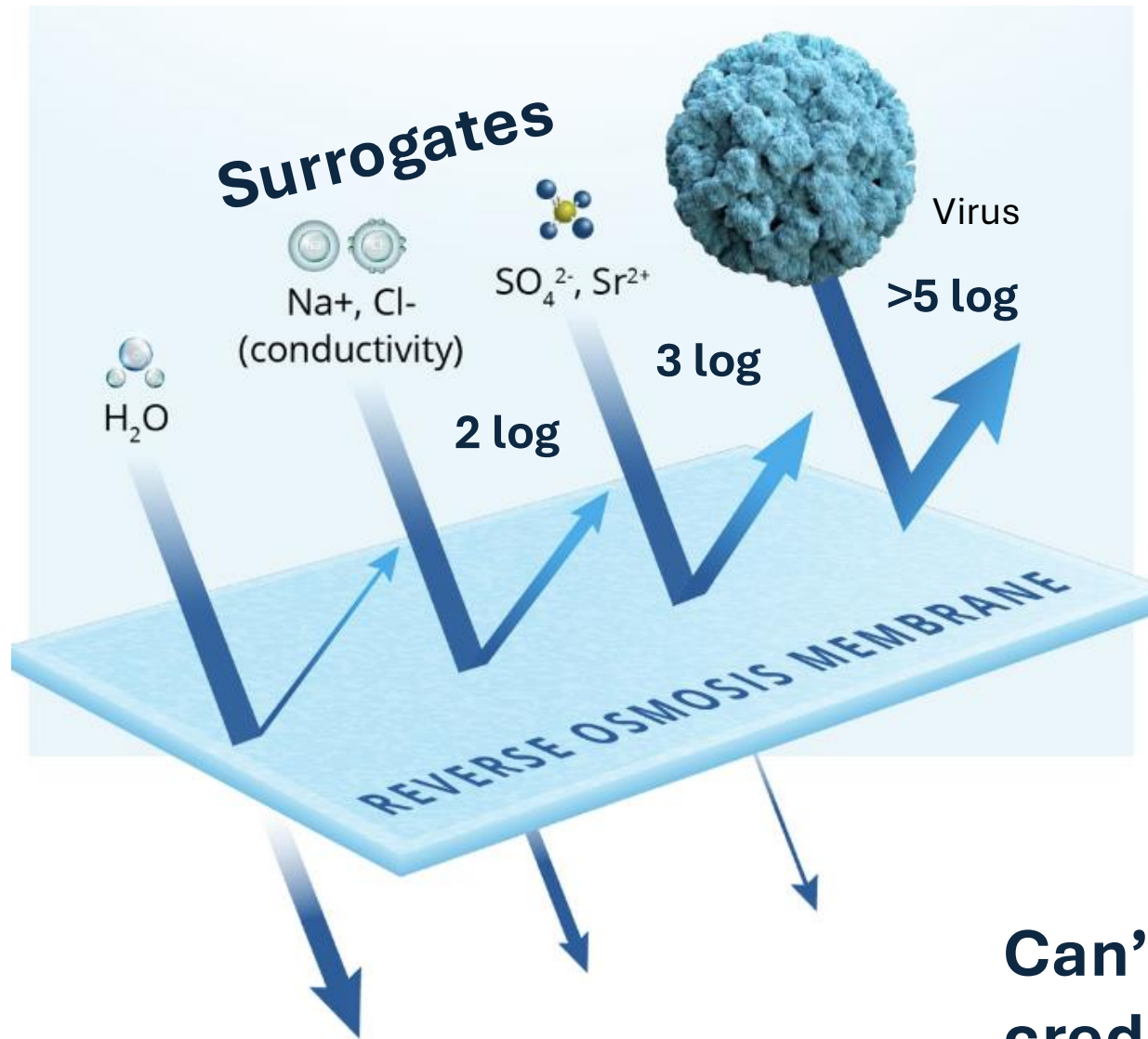
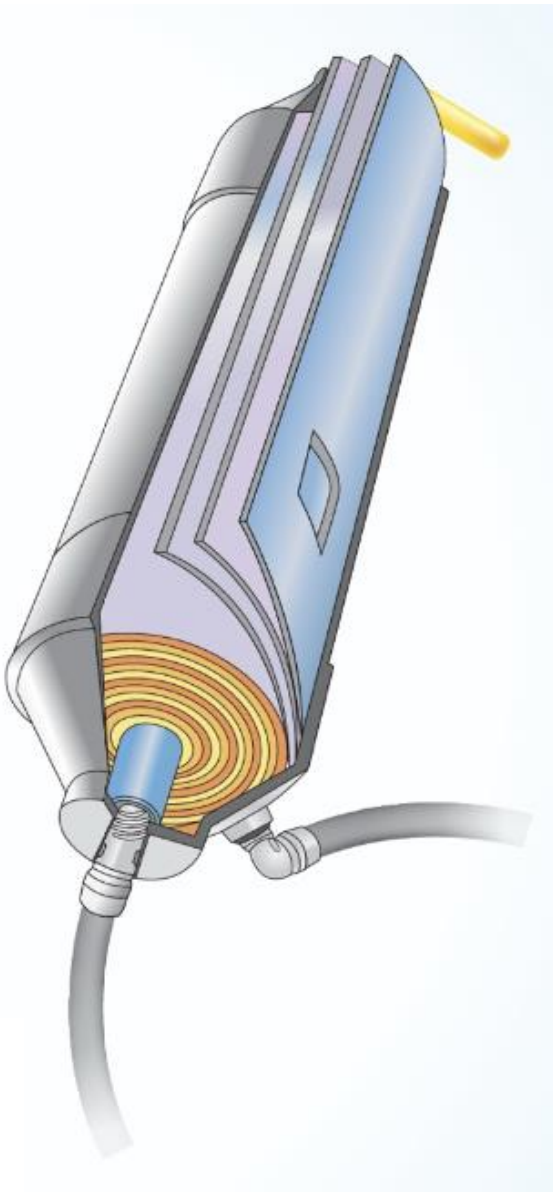
Approach #2: Conservative Surrogate



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)





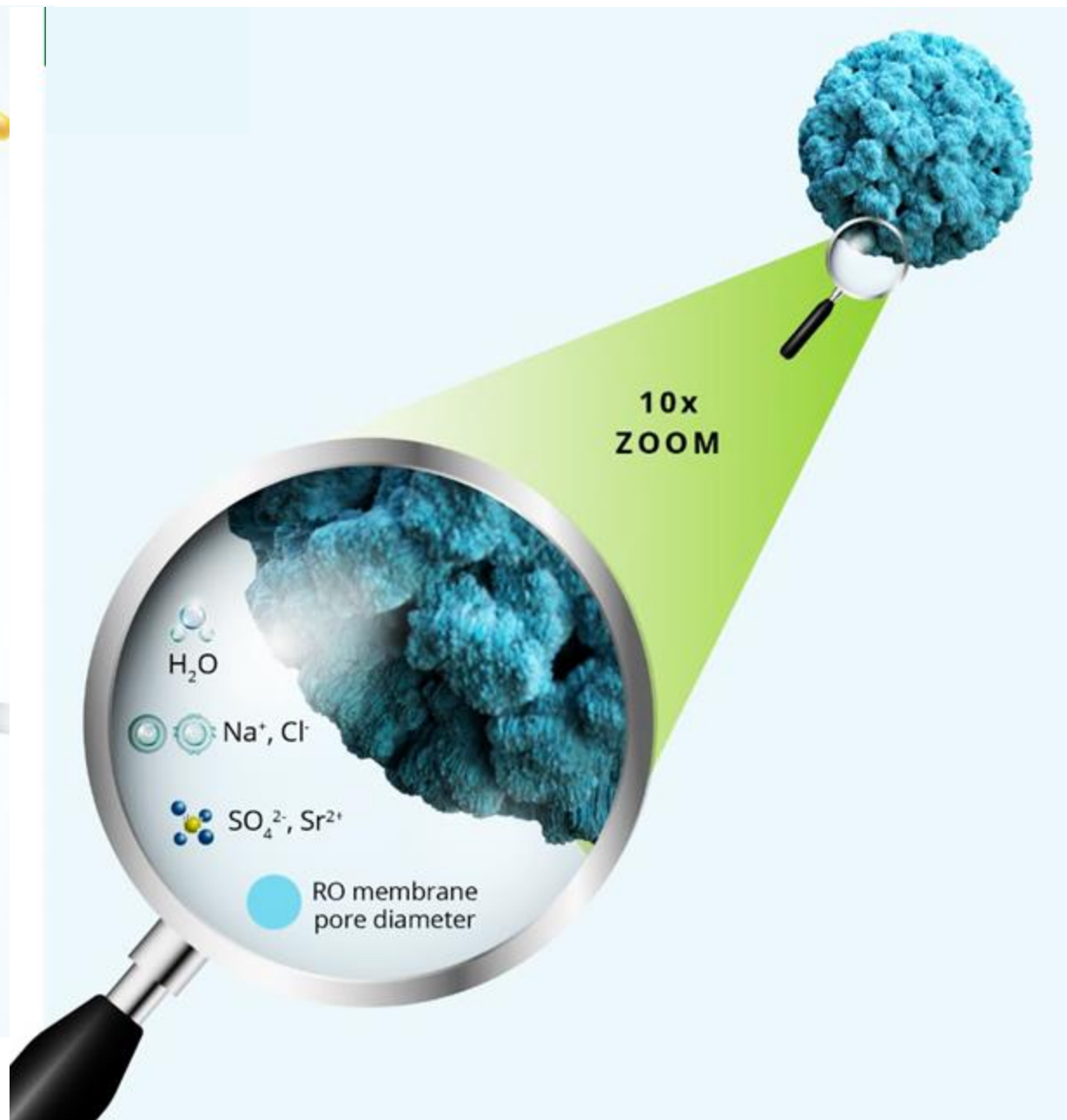
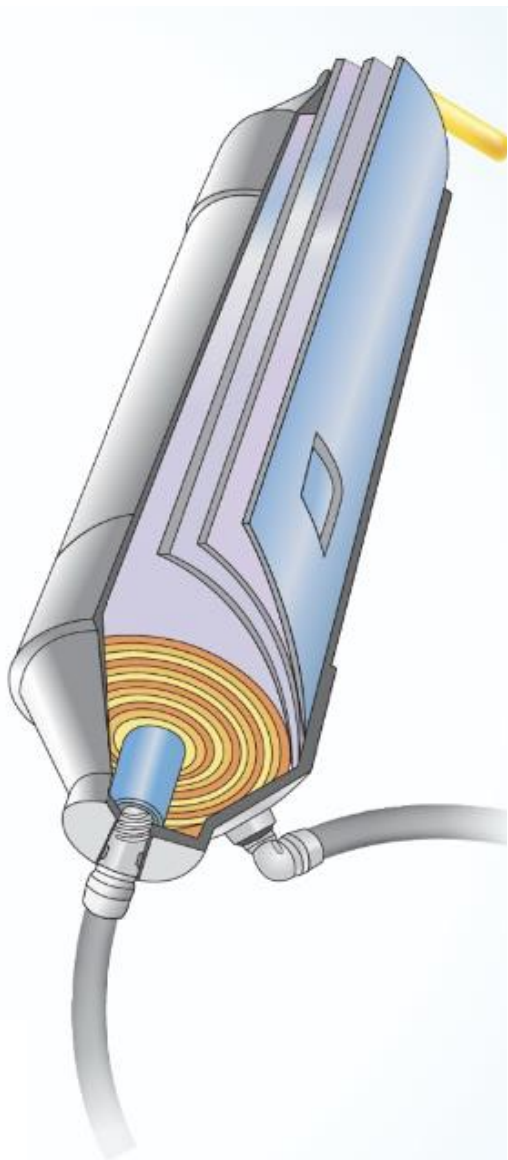
RO



Pathogen	LRV Credit
Virus	2
<i>Giardia</i>	2
<i>Crypto</i>	2

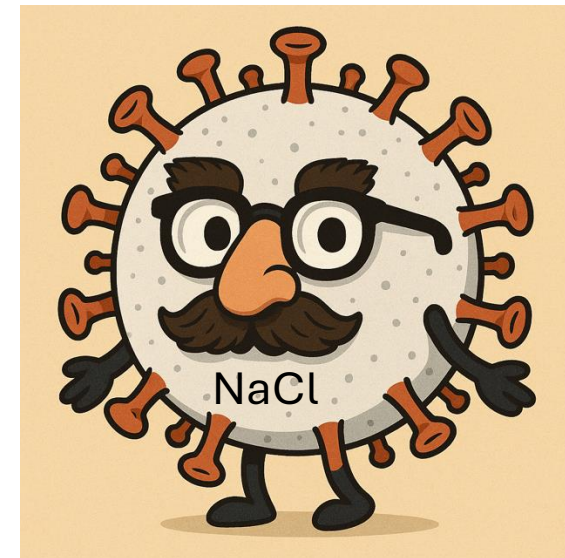
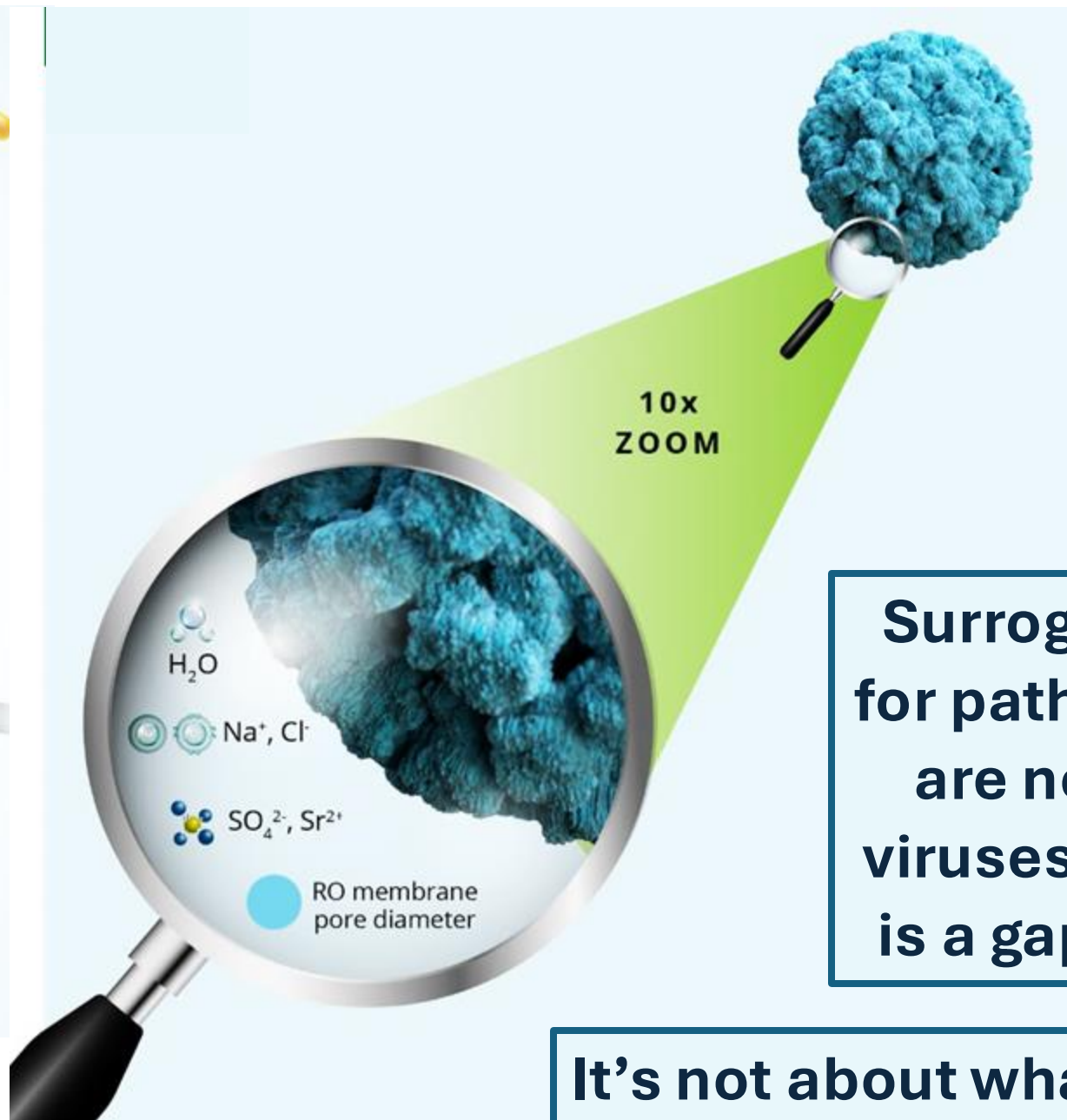
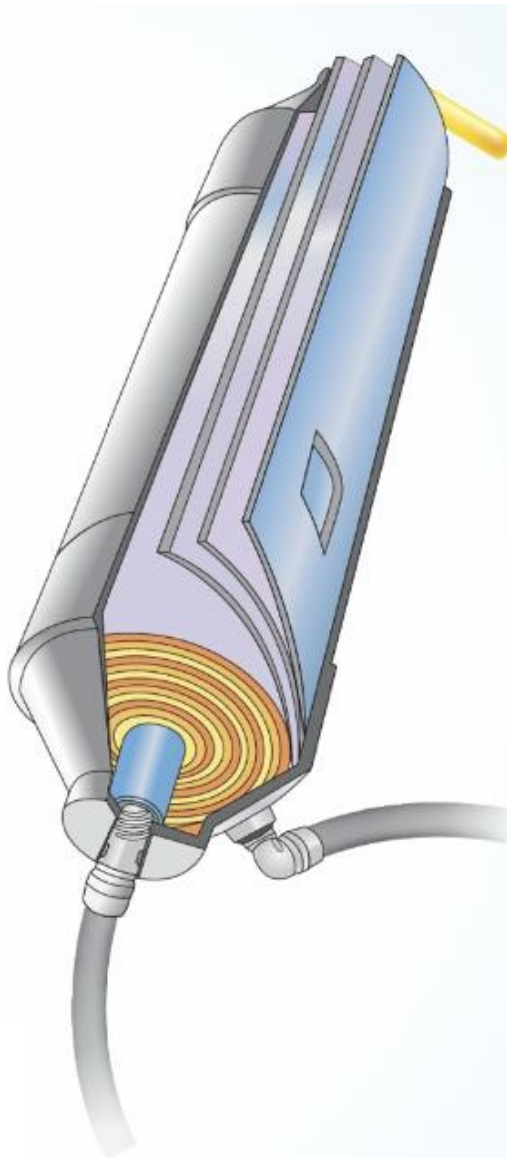
Can't we get more credit for RO?

It's removing SALT!



Can't we get more credit for RO?

It's removing SALT!

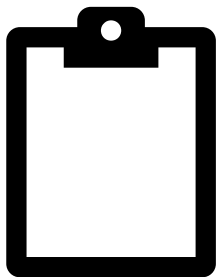
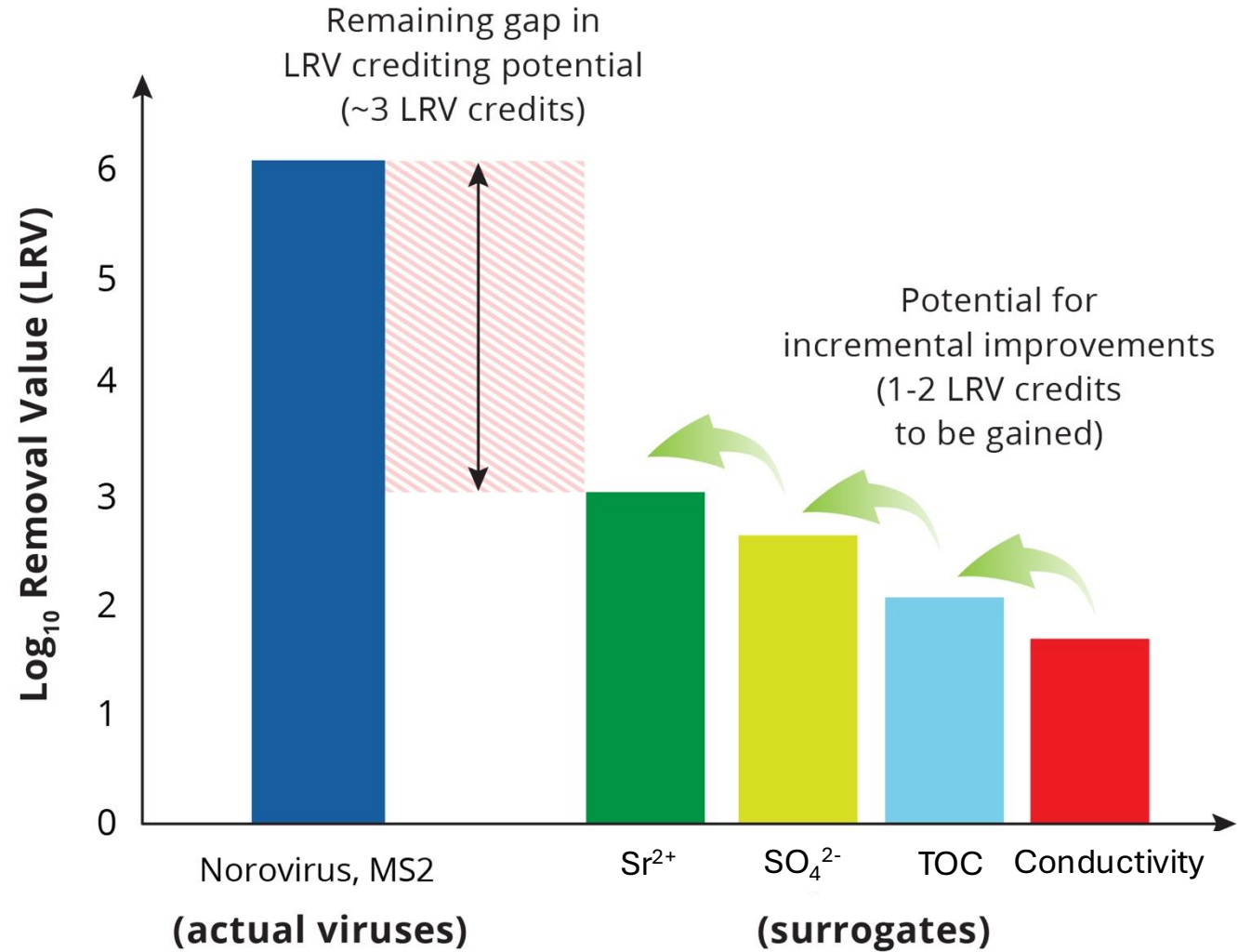


Surrogates currently used for pathogen crediting in RO are not similar to actual viruses, so that's why there is a gap in their reductions

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

Reverse Osmosis: Credit Where Credit is Due

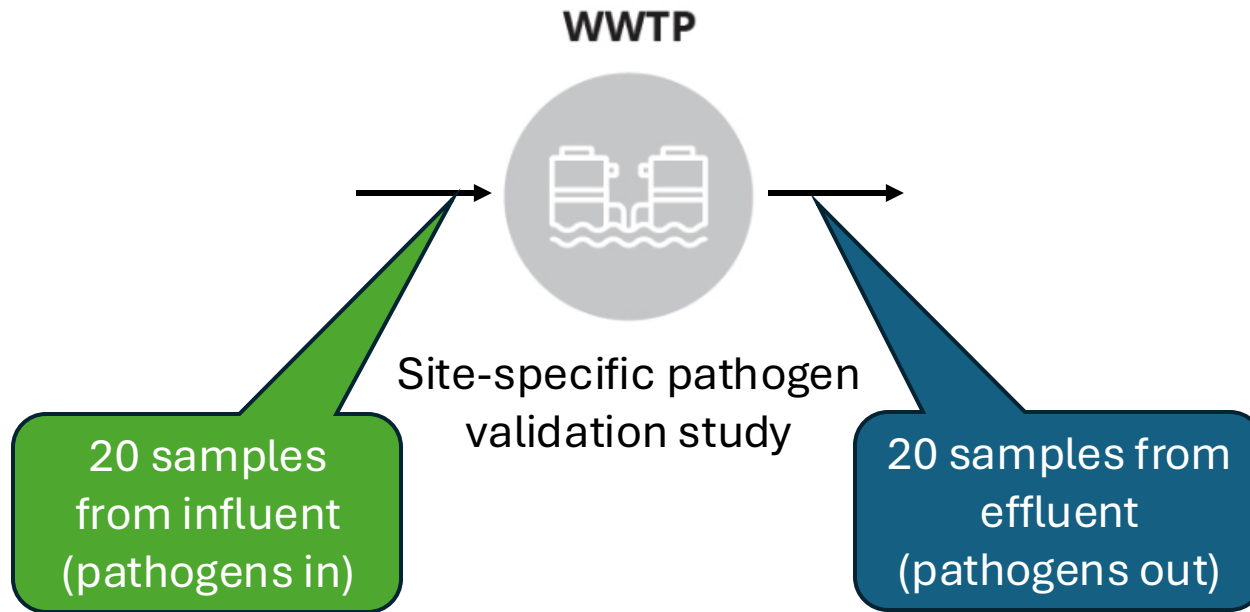
- There is potential to get more credit for pathogen reduction in RO systems using different surrogates:
 - SO_4^{2-}
 - Sr^{2+}
- While these incremental improvements are possible right now, there is still a gap in the LRV credit potential



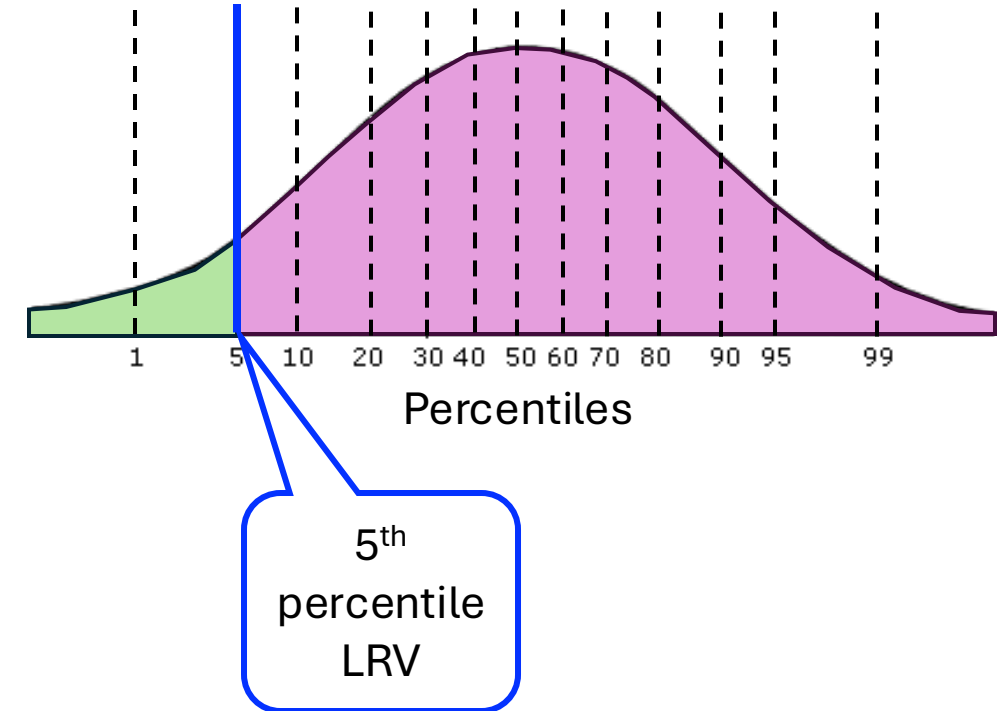
**Answer Survey
Question #2**

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

Approach #3: Operational Envelope Approach

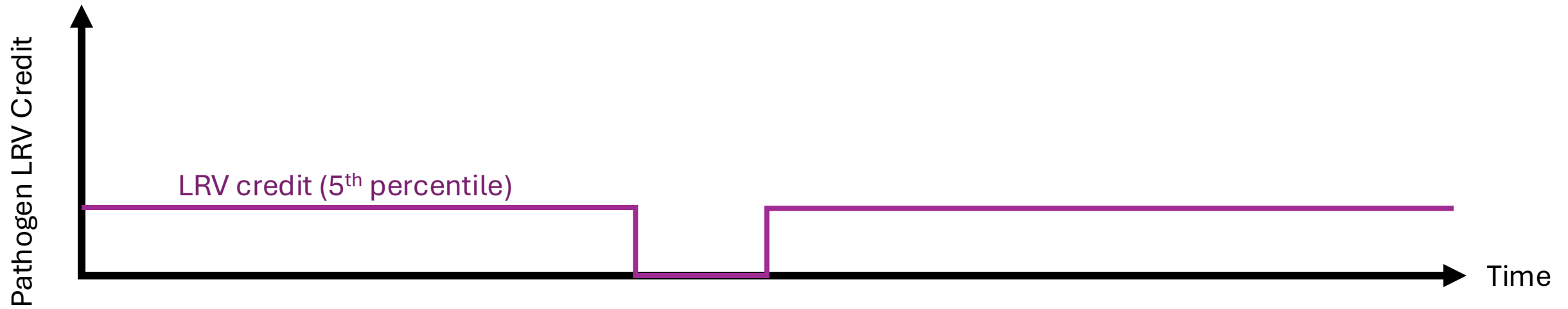
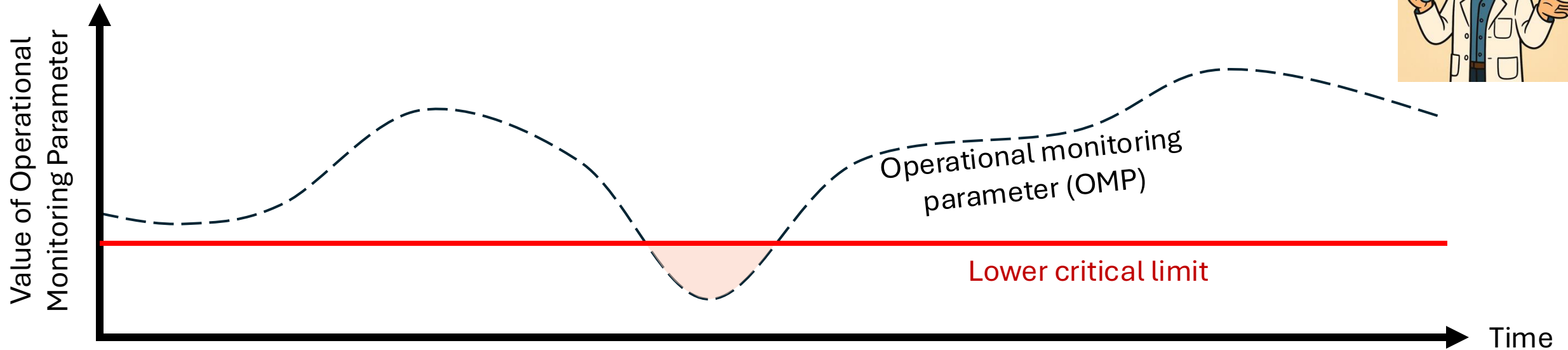


$$LRV = \log_{10} \left(\frac{\text{Pathogens}_{\text{in}}}{\text{Pathogens}_{\text{out}}} \right)$$

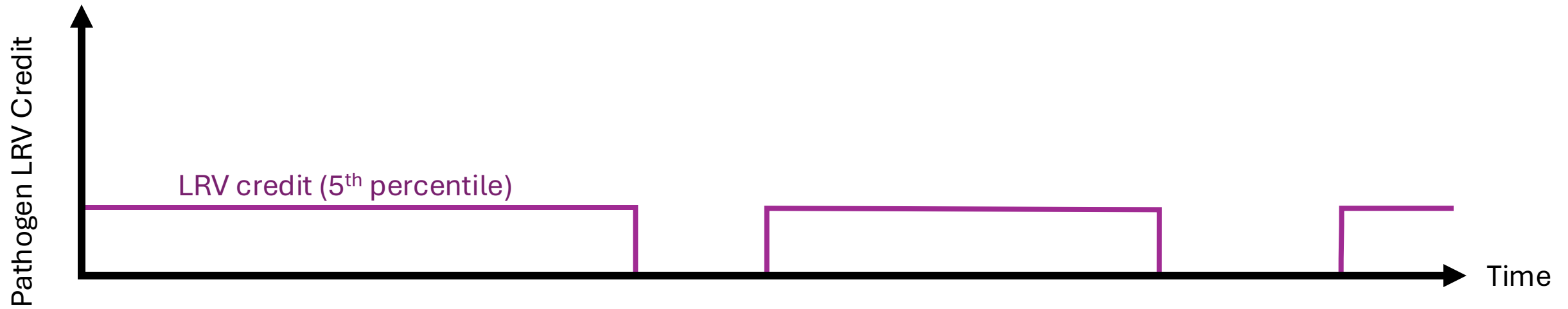
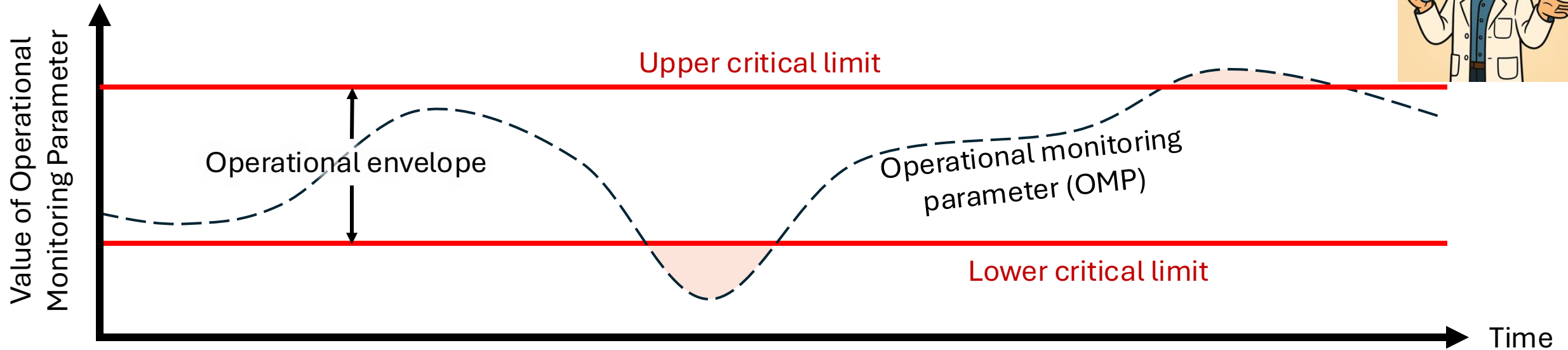


95% of the time (~345 days per year), the actual pathogen reduction will be greater than this value

Approach #3: Operational Envelope Approach



Approach #3: Operational Envelope Approach

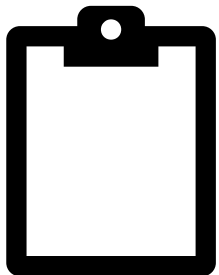


Example Operational Monitoring Parameters for Activated Sludge Wastewater Treatment Systems

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

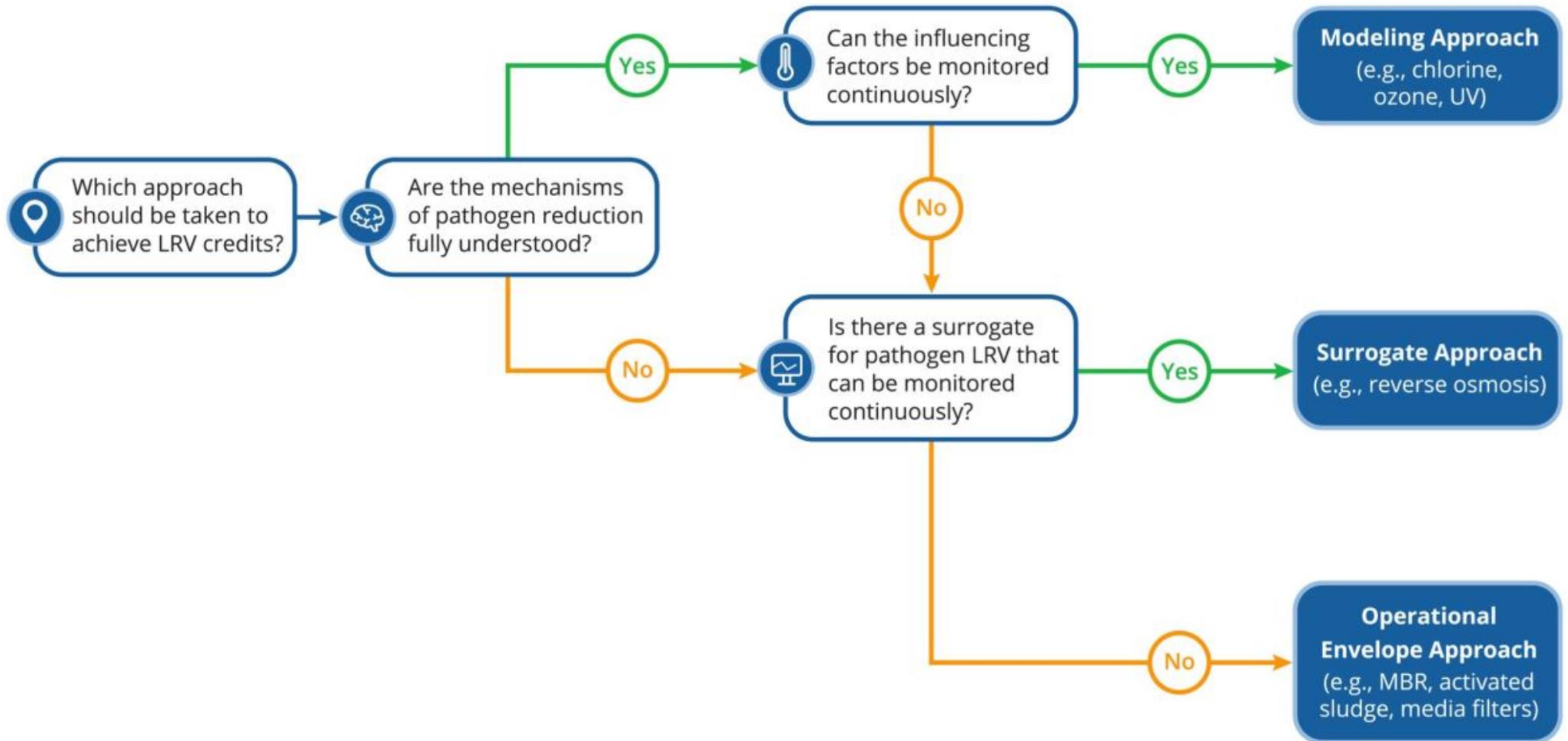
Operational Monitoring Parameters for Other Treatment Processes

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?

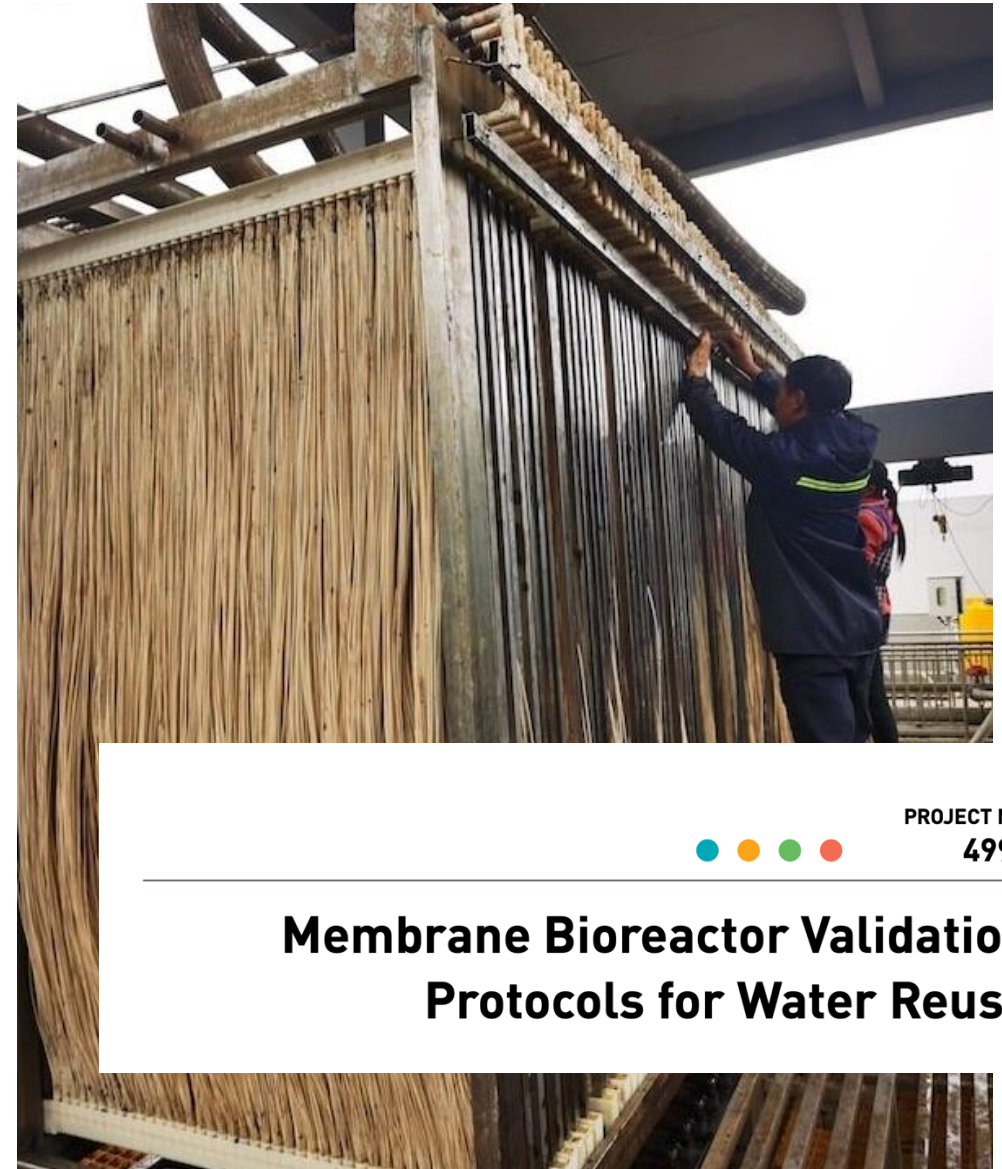


Industry impact of a new pathogen crediting framework

“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



PROJECT NO.
4997

**Membrane Bioreactor Validation
Protocols for Water Reuse**

Example: Membrane bioreactors

Please subscribe to the PWRR!

Thank you!

Matthew E. Verbyla
mverbyla@sdsu.edu

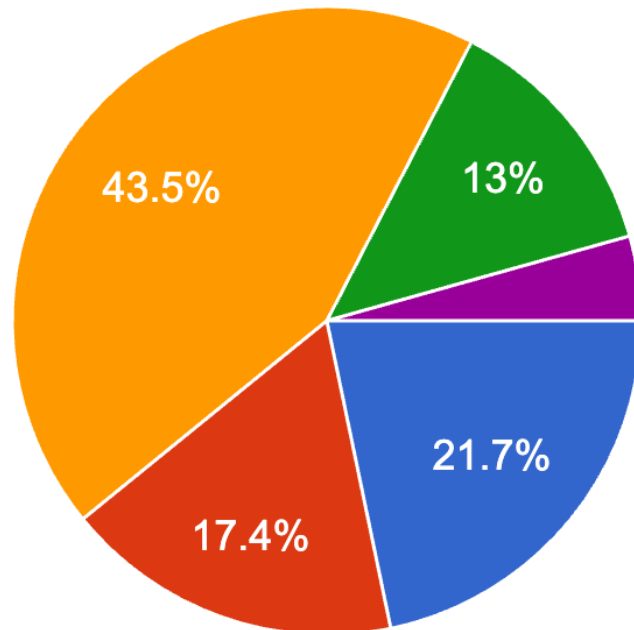
[Summary of Activity Responses](#)



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

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?

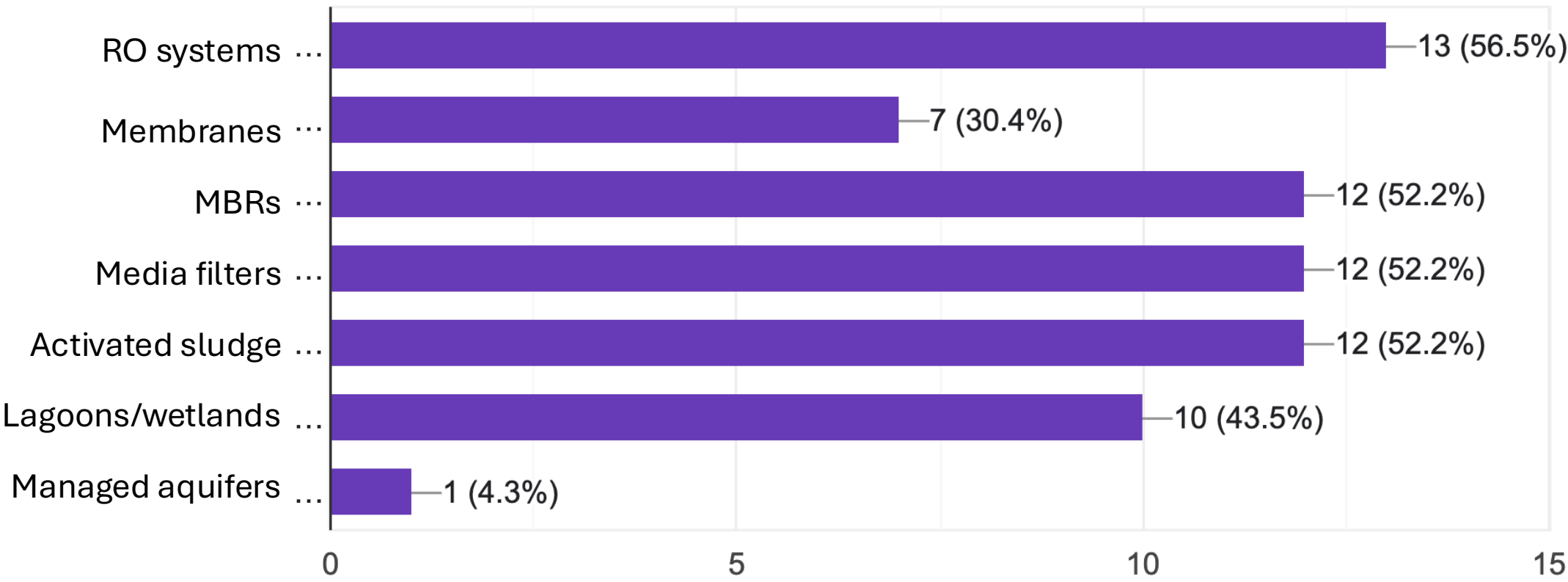
23 responses



- Sure, why not?
- I'm not sure right now
- No, different look-up tables would be needed for water reuse.
- I'm not familiar with these "look-up" tables.
- If the water quality is similar - probably can't use them for raw wastewater.

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

