Trussell

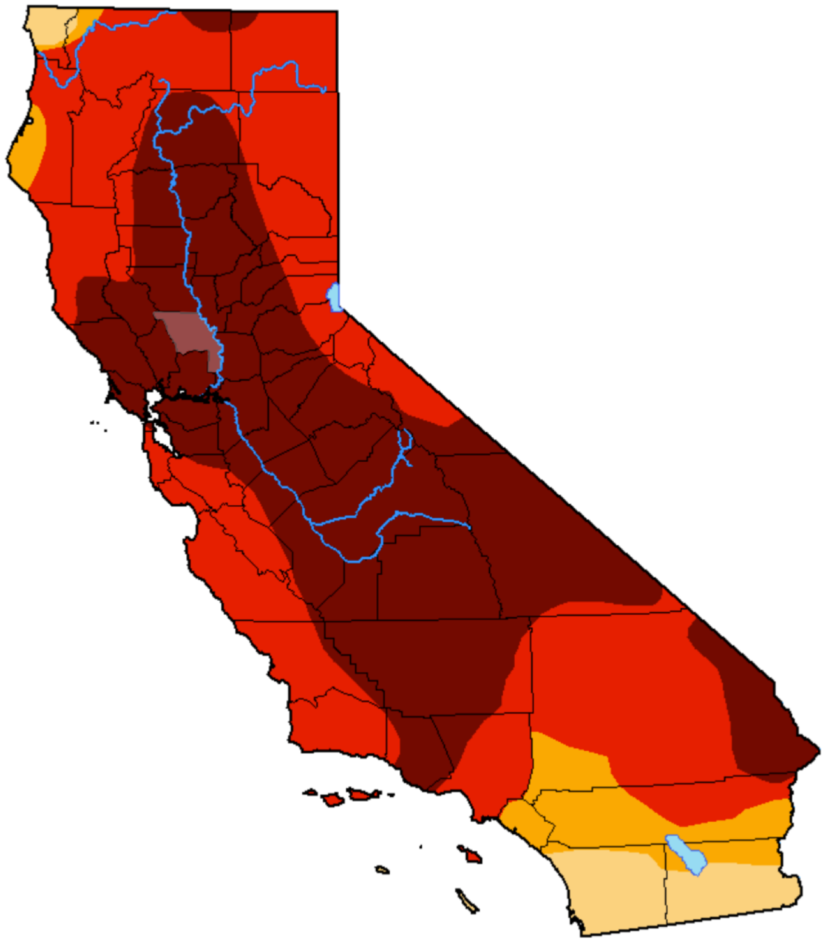
California Potable Reuse Regulations

Shane Trussell, Ph.D., P.E., BCEE

Why Pursue Local Water Supplies

- Climate Change Adaptation
- Local Sustainability
- Water Supply Certainty
- Cost Control

California



Map released: Thurs. August 5, 2021

Data valid: August 3, 2021 at 8 a.m. EDT

Intensity

- None
- D0 (Abnormally Dry)
- D1 (Moderate Drought)
- D2 (Severe Drought)
- D3 (Extreme Drought)
- D4 (Exceptional Drought)
- No Data

Authors

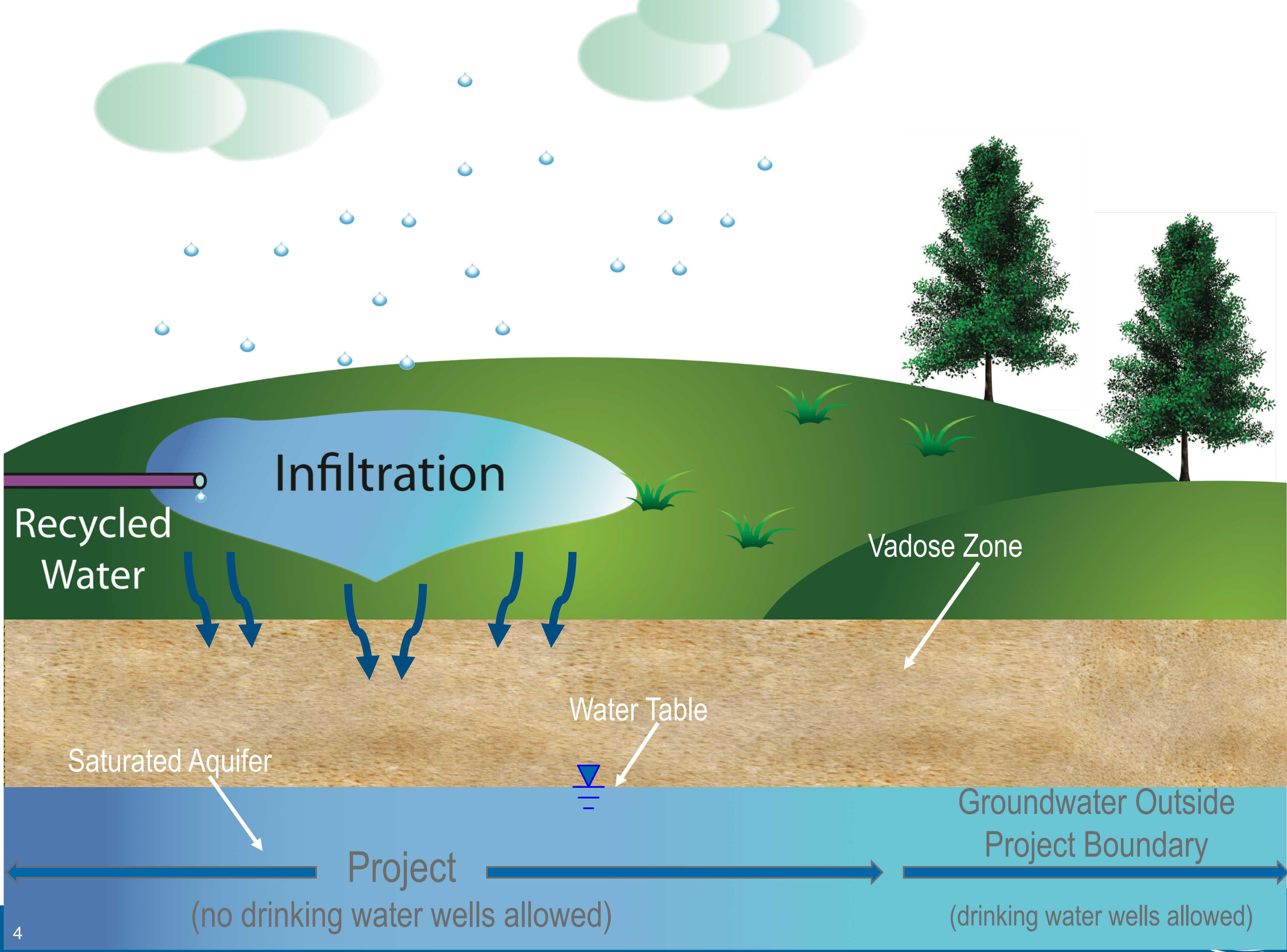
United States and Puerto Rico Author(s):
Richard Tinker, NOAA/NWS/NCEP/CPC

Pacific Islands and Virgin Islands Author(s):
Richard Heim, NOAA/NCEI

California Has Deep Roots in Potable Reuse

- Montebello Forebay project began operating in 1962 and is a joint project between the Water Replenishment District of Southern California and Los Angeles County Sanitation Districts
- Replenishes groundwater basin with more than 150 ML/d
- Utilizes infrastructure that was primarily designed for storm water management and captures recycled water in dry seasons

Potable Reuse with Disinfected Tertiary Recycled Water Depends on Soil Aquifer Treatment



Groundwater Injection Requires Advance Treatment

Advent of Integrated Membrane Systems in Late 90s

Indirect Potable Reuse - Surface Water Augmentation

Direct Potable Reuse – Coming Soon!

2010 — **SB 918** defines **DPR,** mandates DPR **feasibility assessment**, and establishes **Expert Panel**

2013 — **SB 322** tasks Expert Panel with **identifying DPR research needs**

2014 — **Final Groundwater Recharge Regulations**

2016 — Expert Panel identifies **6 priority research topics**

Expert Panel **confirms DPR feasibility**

2017 — **AB 574** mandates DPR regulatory development

2018 — **DPR Regulatory Framework Ed. 1**

Final Surface Water Augmentation Regulations

2019 — **DPR Regulatory Framework Ed. 2**

2021 — **Draft DPR Criteria version 1**

DPR priority research complete

Draft DPR Criteria version 2

2023 — **Draft DPR Criteria version 3**

DPR Regulations due

Pathogen Risk, Treatment and Drinking Water

Drinking Water

Pathogen Risk and Treatment

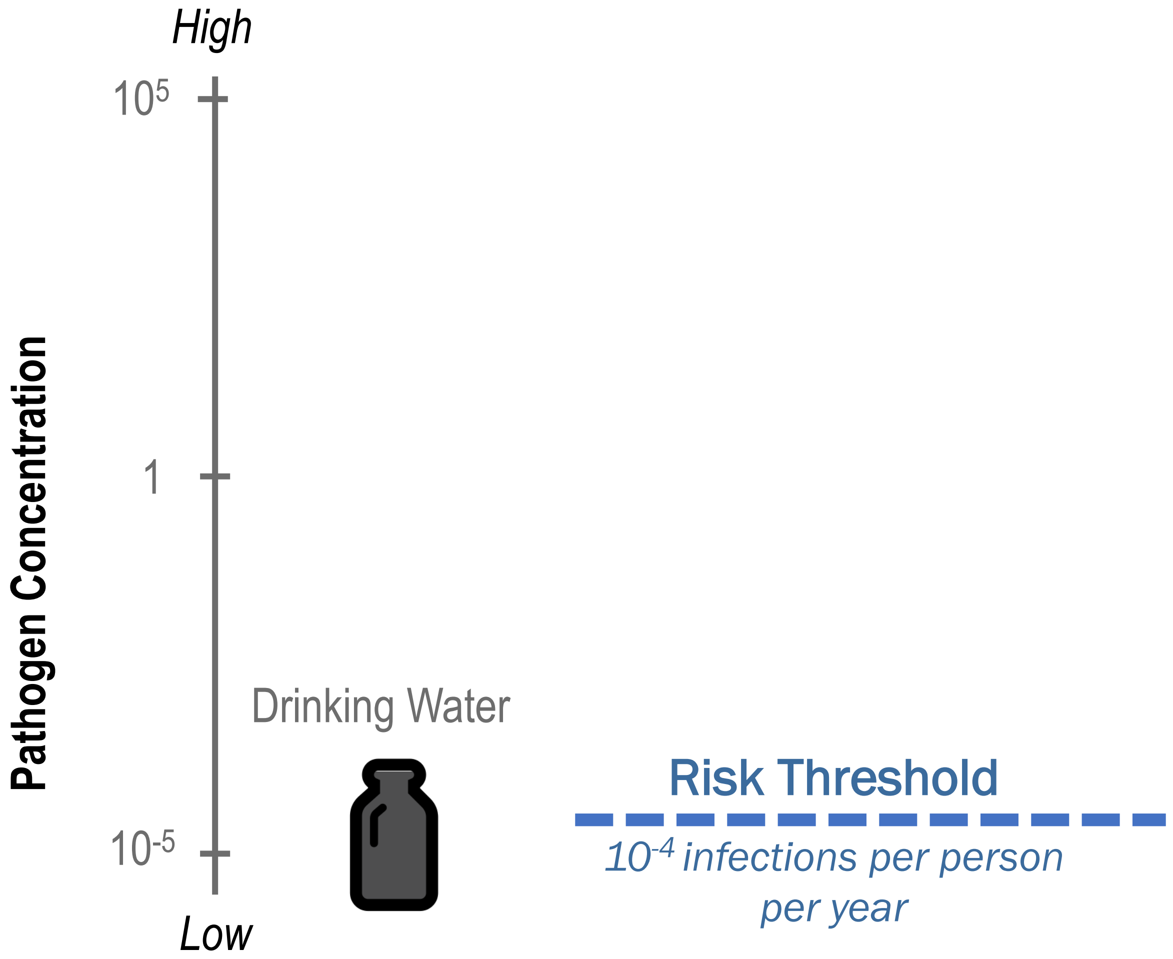
Drinking Water

Risk Threshold

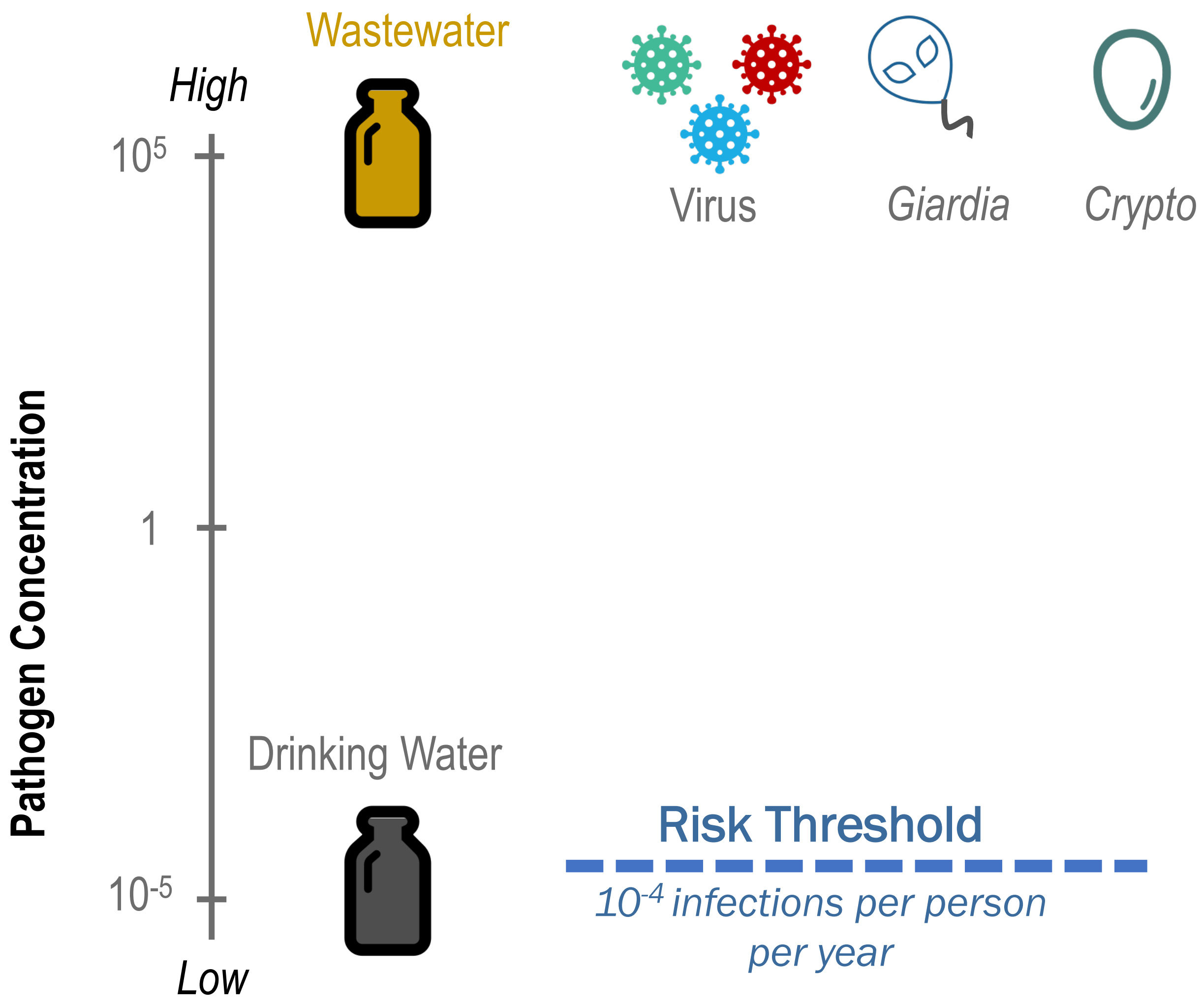
10^{-4} infections per person per year

Trussell

Pathogen Risk and Treatment



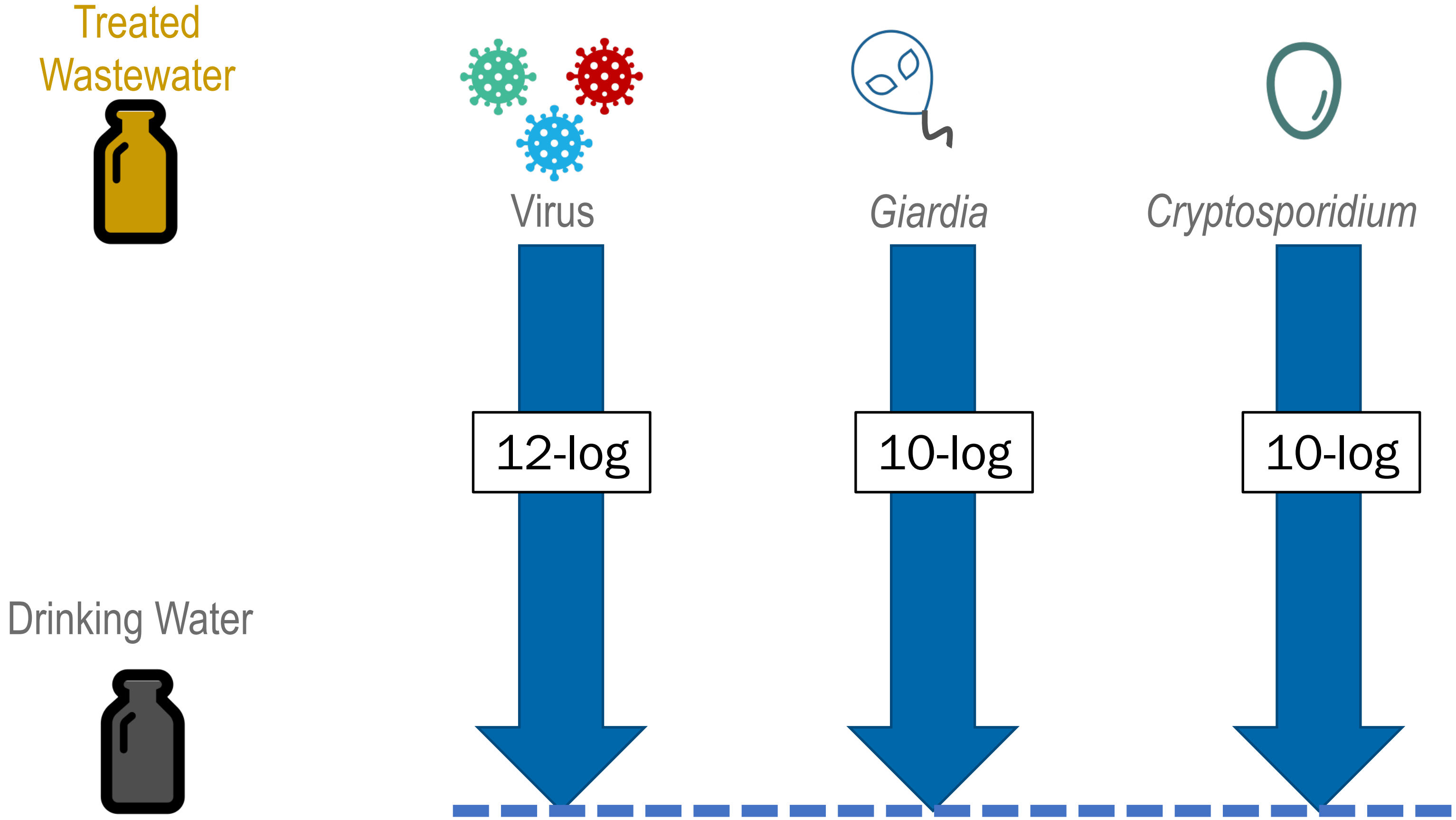
Pathogen Risk and Treatment



Trussell

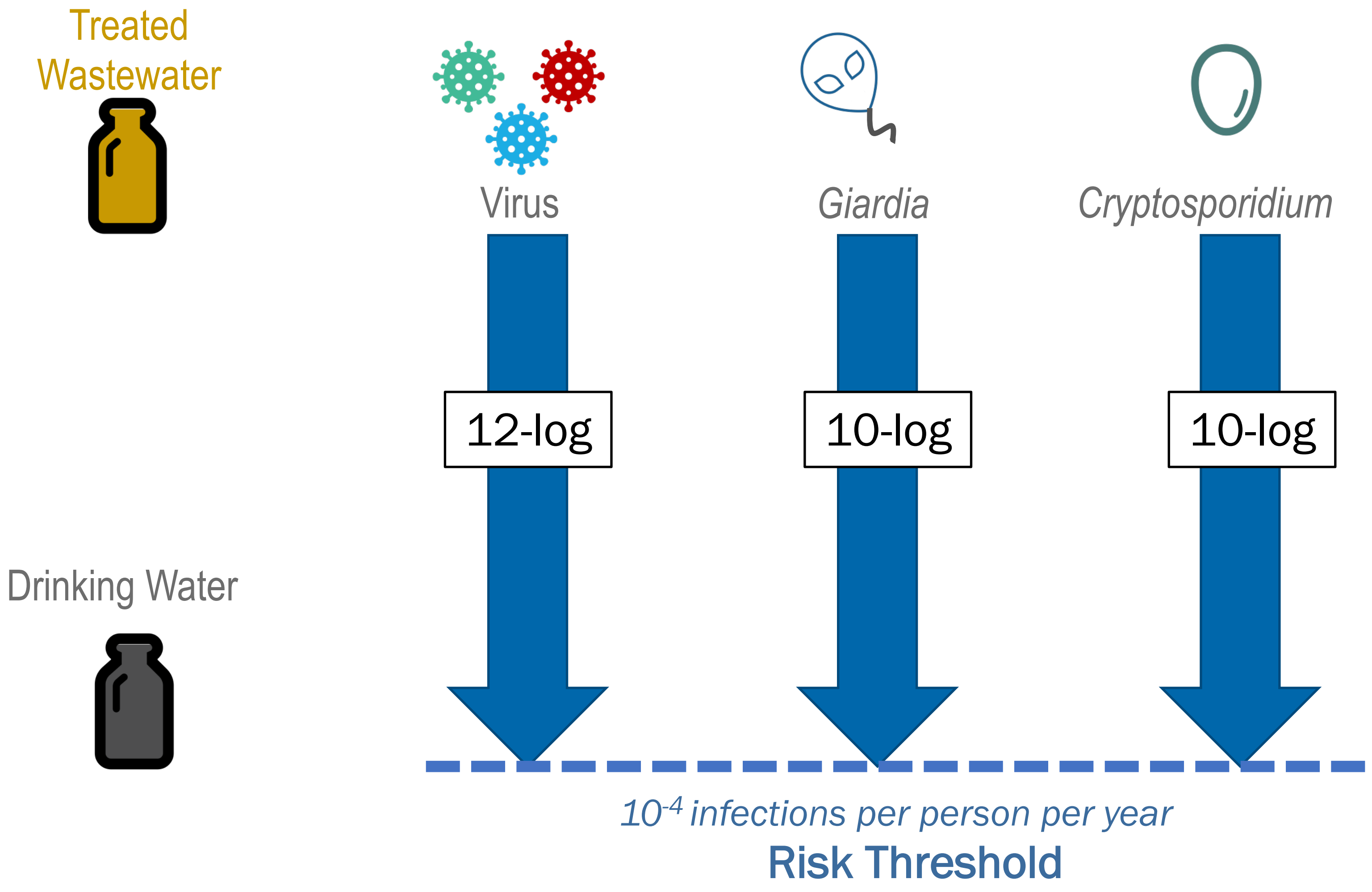
Pathogen Risk and Treatment

California Indirect Potable Reuse (IPR) Requirements for Pathogen Reduction

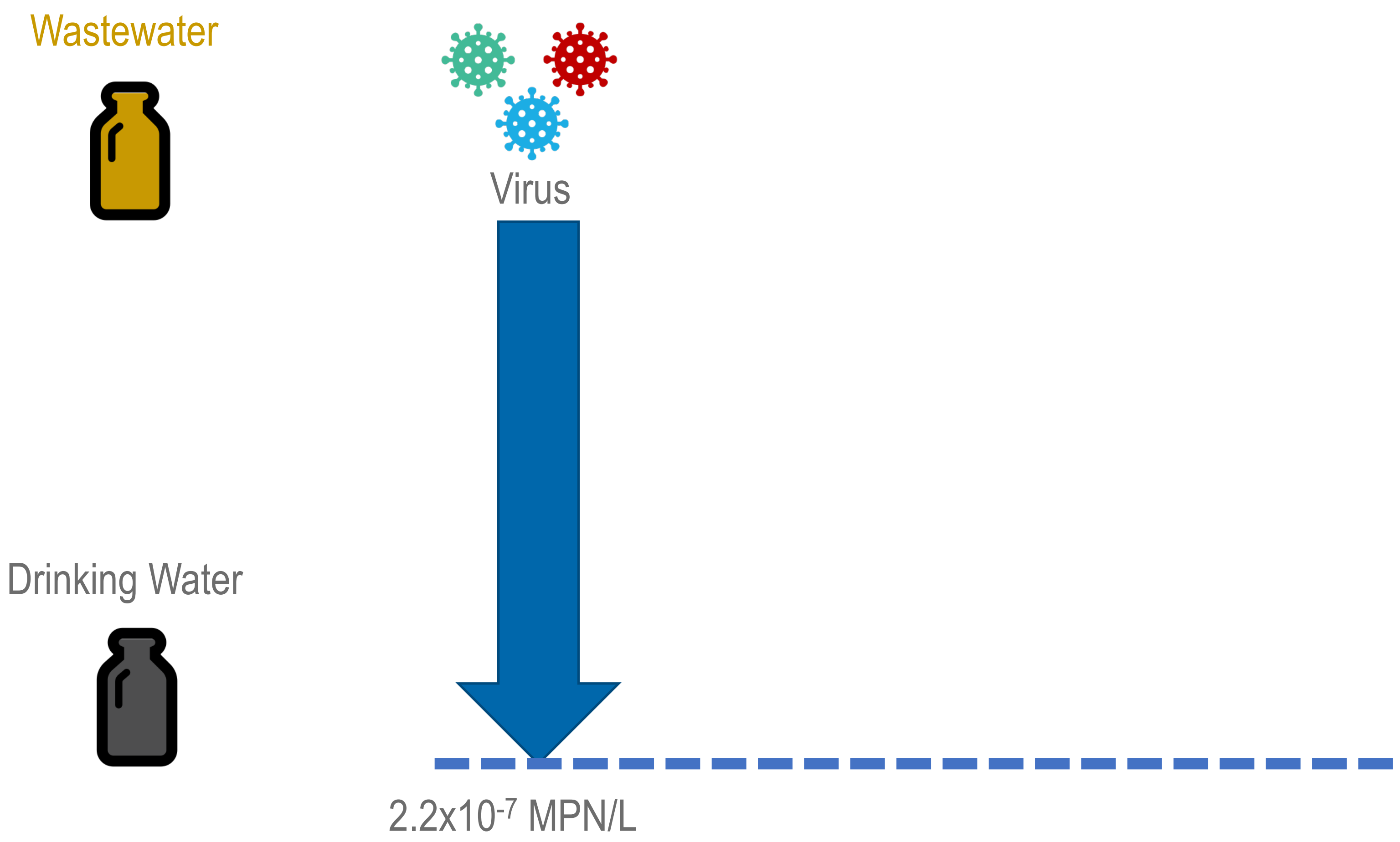


- 3 treatment barriers with at least 1-log for each pathogen
- No single barrier can be credited with more than 6-log
- Groundwater basin can serve as one of these treatment barriers

Where does 12/10/10 come from?



Where does 12-log Virus come from?



Dose-Response: Beta-Poisson Model for Rotavirus[1]

Dose-response functions tell us the tolerable level in drinking water

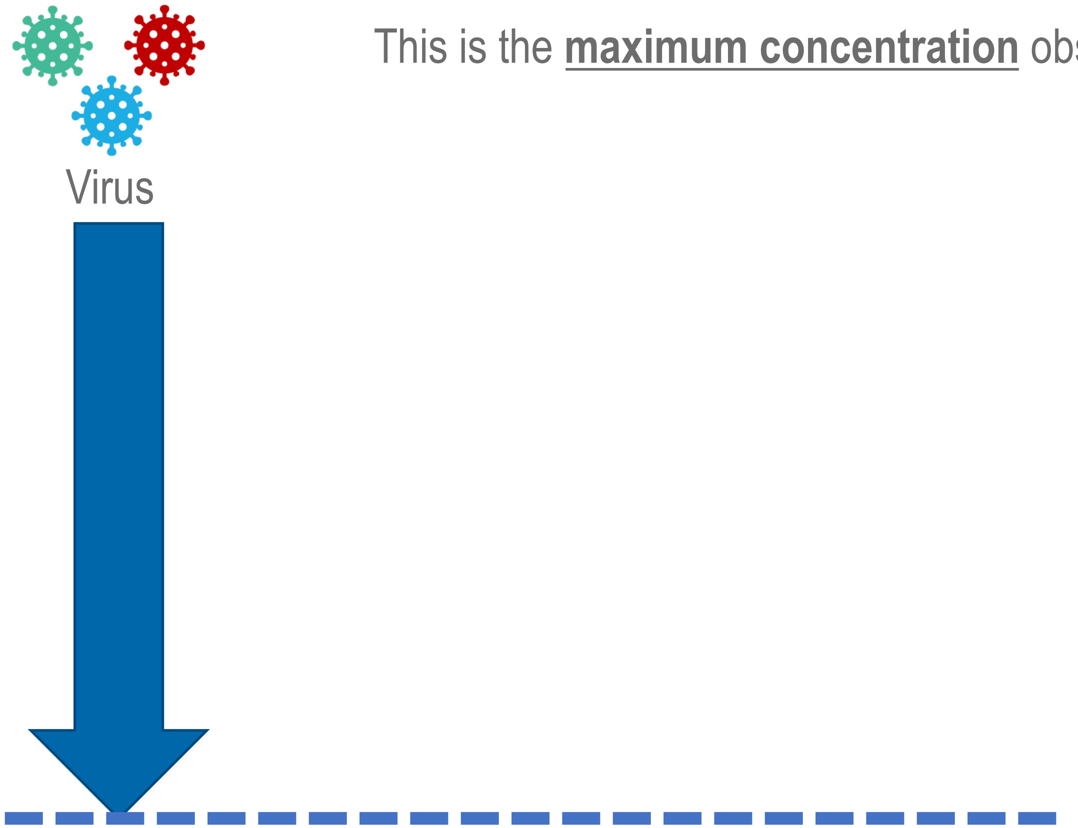
[1] Regli et al, 1991

Where does 12-log Virus come from?

Wastewater

10^5 MPN/L **enterovirus**

This is the **maximum concentration** observed in raw wastewater



Drinking Water

2.2×10^{-7} MPN/L

Dose-Response: Beta-Poisson Model for Rotavirus[1]

Dose-response functions tell us the tolerable level in drinking water

[1] Regli et al, 1991

Where does 12-log Virus come from?

Wastewater

10^5 MPN/L **enterovirus**

Virus

This is the **maximum concentration** observed in raw wastewater

$$\log_{10} \frac{10^5}{2.2x10^{-7}} = 12$$

Drinking Water

2.2x10^{-7} MPN/L

Dose-Response: Beta-Poisson Model for Rotavirus[1]

Dose-response functions tell us the tolerable level in drinking water

[1] Regli et al, 1991

Trussell

Where does 10-log *Giardia* come from?

Wastewater

10^5 cysts/L

Giardia

This is the **maximum concentration** observed in raw wastewater

$$\log_{10} \frac{10^5}{6.8x10^{-6}} = 10$$

Drinking Water

$6.8x10^{-6}$ cysts/L

Dose-Response:

Exponential Model for *Giardia*[1]

Dose-response function

[1] Regli et al, 1991

Where does 10-log *Crypto* come from?

Wastewater

10^5 oocysts/L

Cryptosporidium

This is the **maximum concentration** observed in raw wastewater

$$\log_{10} \frac{10^5}{3.0x10^{-5}} = 10$$

Drinking Water

$3.0x10^{-5}$ oocysts/L

Dose-Response: Exponential Model for *Cryptosporidium*[1]

Dose-response function

[1] Messner et al, 2001

Where does 10-log *Crypto* come from?

Wastewater

10^5 oocysts/L

Cryptosporidium

Based on a literature review, CA regulators found that the maximum concentration in wastewater was actually…

10^4 oocysts/L

$$\log_{10} \frac{10^4}{1.7x10^{-6}} = 10$$

Drinking Water

…but they also changed their assumption about the dose-response function such that the "safe" concentration in drinking water was…

$3.0x10^{-5}$ oocysts/L

Dose-Response: Exponential Model for *Cryptosporidium*[1]

$1.7x10^{-6}$ oocysts/L

Exponential Model for *Cryptosporidium*[2]

[1] Messner et al, 2001

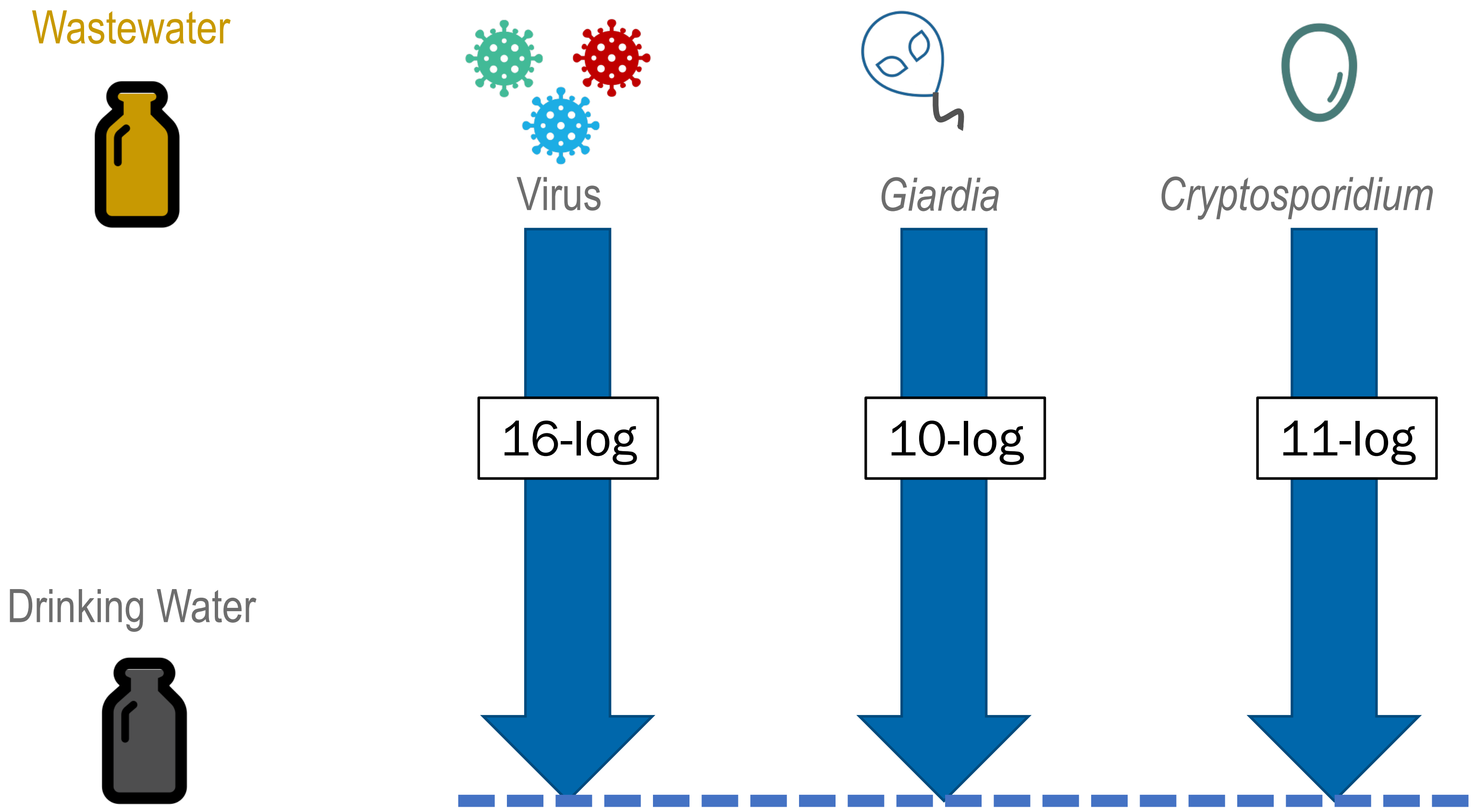
[2] US EPA, 2005

Trussell

Assumptions for 12/10/10

Pathogen	Reference Pathogen	Dose-Response	Tolerable Drinking Water Density	Max. Concentration in Wastewater	Resulting Log Reduction
Virus	Enterovirus	Beta-Poisson for Rotavirus (Regli et al, 1991)	2.2×10^{-7} MPN/L	10^5 MPN/L	**12**
Giardia	*Giardia*	Exponential (Regli et al, 1991)	6.8×10^{-6} cysts/L	10^5 cysts/L	**10**
Cryptosporidium	*Cryptosporidium*	Exponential (Messner et al, 2001)	3.0×10^{-5} oocysts/L	10^5 oocysts/L	**10**
		Exponential (USEPA, 2005)	1.7×10^{-6} oocysts/L	10^4 oocysts/L	

California Direct Potable Reuse (DPR) Requirements for Pathogen Reduction



- 4 processes providing at least 1-log for <u>*each*</u> pathogen
- 3 *mechanisms* for <u>each</u> pathogen including:
  - *UV disinfection*
  - *Physical separation*
  - *Chemical disinfection*

Where does 16-log Virus come from?

Wastewater

10^9 GC/L **norovirus**

Virus

This is the **maximum concentration** observed in raw wastewater

$$\log_{10}\frac{10^{9}}{3.3x10^{-7}} = 16$$

Shift from enterovirus to norovirus!

Drinking Water

3.3×10^{-7} virus/L

Dose-Response: **Hypergeometric Model for norovirus[1]** Dose-response function

[1] Teunis et al, 2008

Where does 10-log *Giardia* come from?

Wastewater

10^5 cysts/L

Giardia

This is the **maximum concentration** observed in raw wastewater

$$\log_{10} \frac{10^5}{6.8x10^{-6}} = 10$$

This is the same as before!

Drinking Water

$6.8x10^{-6}$ cysts/L

Dose-Response: Exponential Model for *Giardia*[1] Dose-response function

[1] Regli et al, 1991

Trussell

Where does 11-log *Crypto* come from?

Wastewater

10^4 oocysts/L

Cryptosporidium

This is the **maximum concentration** observed in raw wastewater

$$\log_{10}\frac{10^4}{1.4x10^{-7}} = 11$$

Drinking Water

1.4x10^{-7} oocysts/L

Dose-Response: **Beta-Poisson Model** for *Cryptosporidium*[1]

Dose-response function

[1] Messner and Berger, 2016

Assumptions for 16/10/11

Pathogen	Reference Pathogen	Dose-Response	Tolerable Drinking Water Density	Max. Concentration in Wastewater	Resulting Log Reduction
Virus	**Norovirus**	Hypergeometric for Norovirus (Teunis et al, 2008)	$3.3\text{x}10^{-7}$ virus/L	10^{9} GC/L	**16**
Giardia	*Giardia*	Exponential (Regli et al, 1991)	$6.8\text{x}10^{-6}$ cysts/L	10^{5} cysts/L	**10**
Cryptosporidium	*Cryptosporidium*	**Beta-Poisson** (Messner and Berger, 2016)	$1.4\text{x}10^{-7}$ oocysts/L	10^{4} oocysts/L	**11**

California requires redundant treatment

- "For the treatment train to reliably provide microbiologically safe drinking water, the treatment train must be designed to include extra log reduction capacity beyond the required log reductions."
  - *California DDW, LRV Derivation*
    (https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/direct_potable_reuse/lrvderivation.pdf)

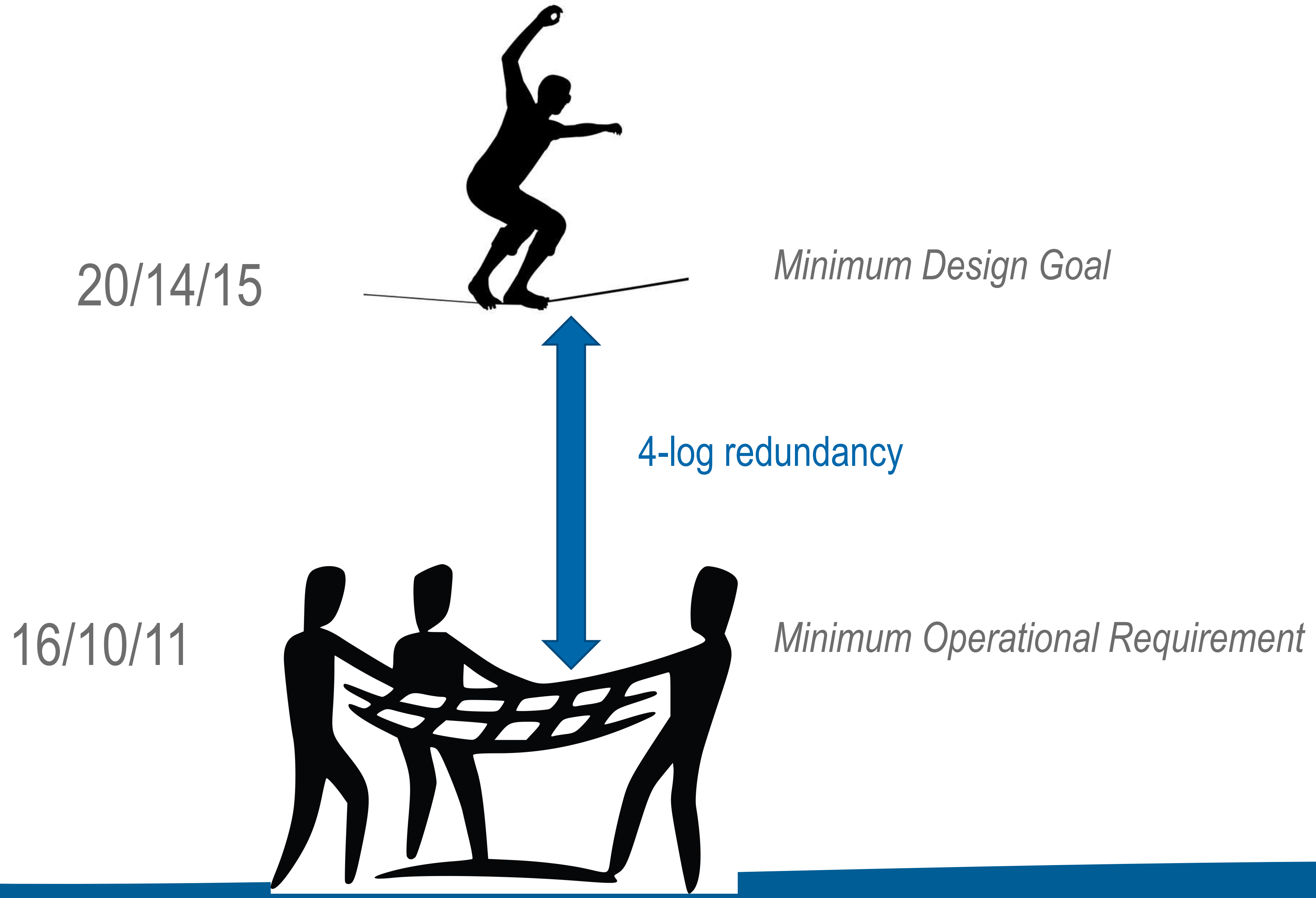
- California regulators want to ensure that if an undetected failure occurs, the water produced is still protective of public health.

Why is redundancy important?

16/10/11

No redundancy = no safety net

Redundancy provides buffer against failures



Basis for 20/14/15

Public Health Criteria:

Pathogen	Reference Pathogen	Dose-Response	Tolerable Drinking Water Density	Max. Concentration in Wastewater	Resulting Log Reduction
Virus	**Norovirus**	Hypergeometric for Norovirus (Teunis et al, 2008)	$3.3x10^{-7}$ virus/L	**10^9** GC/L	**16**
Giardia	*Giardia*	Exponential (Regli et al, 1991)	$6.8x10^{-6}$ cysts/L	10^5 cysts/L	**10**
Cryptosporidium	*Cryptosporidium*	**Beta-Poisson** (Messner and Berger, 2016)	$1.4x10^{-7}$ oocysts/L	10^4 oocysts/L	**11**

Redundancy Criteria:

+4-log redundancy to protect against failure

Trussell

DPR Research Informed CA DPR Log Reductions

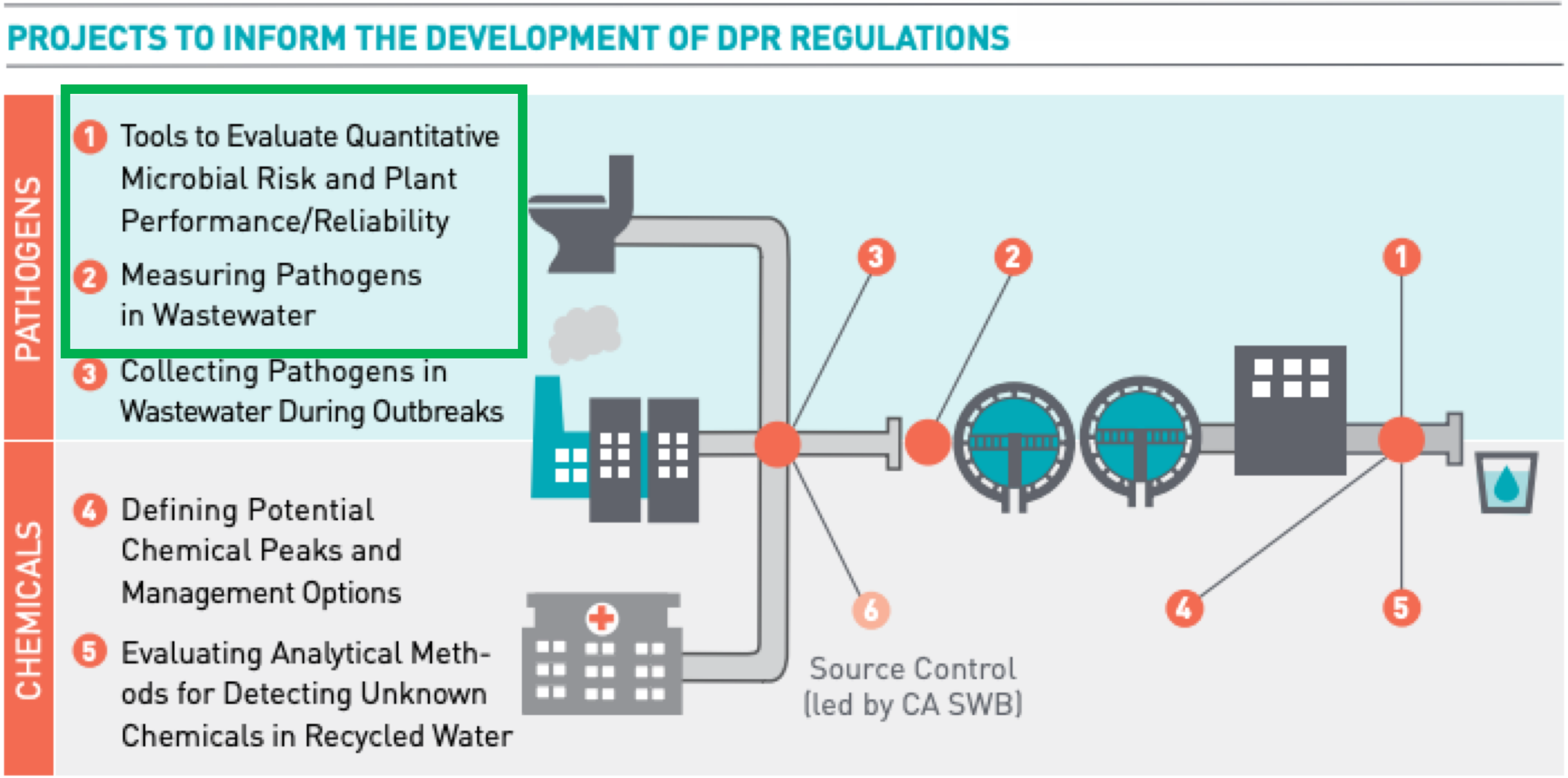


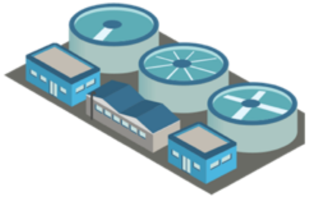
Figure credit: Water Research Foundation

DPR-1 and DPR-2 Research

Wastewater

What concentration of pathogens are we starting with?

DPR-2: Raw Wastewater Pathogen Monitoring



How much treatment is needed?

DPR-1: Pathogen Treatment and Risk

Drinking Water

Can we meet our risk goals?

DPR-1: DPRisk Tool and Guidance Document

DPRisk: QMRA Tool

DPRisk

version 1.0.1 (11.05.2020)
Sponsored by: The Water Research Foundation

THE Water Research FOUNDATION

Introduction

- Background
- How to use the tool
- License

Model Specification

- Raw Wastewater Pathogen Concentrations
- Treatment Train
- Treatment Failure
- Management Barriers
- Exposure
- Dose-Response

Results

- PATTP Output
- QMRA Output
- Summary of PATTP and QMRA Output
- Comparison of Risk Curves

Quantitative Microbial Risk Assessment and Probabilistic Assessment of Treatment Train Performance for Direct Potable Reuse Scenarios

This tool is intended to facilitate quantitative microbial risk assessment (QMRA) and probabilistic assessment of treatment train performance (PATTP) for various direct potable reuse (DPR) scenarios. There are many possible analyses that you can conduct with this tool, including:

There are many possible analyses that you can conduct with this tool, including:

- Developing a distribution of treatment train performance for different potential DPR treatment trains.
- Evaluating daily and annual risks of infection for multiple microbial pathogens for different potential DPR treatment trains.
- Comparing different DPR treatment trains in terms of treatment performance and risk.
- Evaluating the impact of failures on treatment performance and risk.

The accompanying Guidance Document provides useful context for this tool, including:

- The background motivation for the creation of the tool.
- The historical context for the use of PATTP and QMRA in DPR.
- The project process that resulted in this tool.
- Detailed descriptions of each step of the tool, including references for default assumptions.
- Details on the computations implemented by the tool.
- Example case studies to help you get started with using the tool.

This tool was developed in the R statistical language.

DPRisk: Guidance Document

Guidance Document for DPRisk

Table of Contents

Also: User Input Files for 3 Case Studies

DPRisk Tool

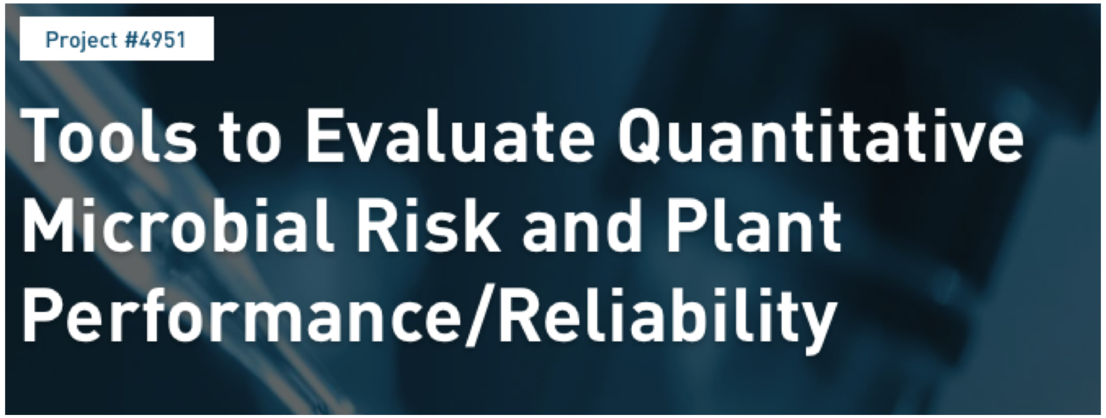
- Developed in **R** using the **R Shiny** web-based platform (Dr. Seto at UW)
- Quantitative Microbial Risk Assessment (QMRA)
- Probabilistic Assessment of Treatment Train Performance (PATTP)

California State Water Board:

The QRMA tool, DPRisk, is a Shiny web-based application. A copy of DPRisk is available at cawaterdatadive.shinyapps.io/DPRisk with an approved shinyapps.io account. To obtain authorization, please send an email to DDWrecycledwater@waterboards.ca.gov with your name, phone number, organization, and project (if any) with your request. Please include “DPRisk” in the subject of your email. DDW will review all requests after TWRF posts the guidance document for the DPRisk tool.

Source: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/direct_potable_reuse.html

Water Research Foundation:



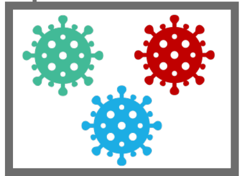
Source: https://www.waterrf.org/research/projects/tools-evaluate-quantitative-microbial-risk-and-plant-performancereliability

DPRisk Inputs: Risk Assessment

Raw WW Pathogen Concentration

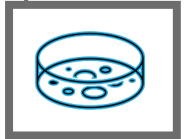
Select the pathogen:

Enterovirus



The recommended enumeration for Enterovirus is Culture.
Select the enumeration method:

Culture



Select how raw wastewater pathogen concentrations are provided:

Lognormal distribution

Provide parameters for the lognormal distribution:

Lognormal Log Mean:

3.19

Lognormal Log SD:

1.74

Exposure

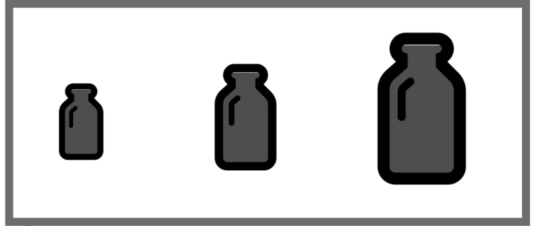
Ingestion rate in mL/day per person.

Use the default exposure assumptions, or specify an exposure distribution:

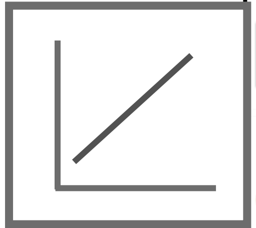
Use default

Options:

- (selected) Lognormal distribution (mu = 7.492 mL/day sigma = 0.407 mL/day (Roseberry and Burmaster 1992))
- Point Estimate: 1 L/day (used by State Expert Panel, Oliveri et al. 2016)
- Point Estimate: 2 L/day



Dose Response



Use the default dose-response for this pathogen, or specify a dose-response:

Use default

Rotavirus to be used for Enterovirus

Options:

- (selected) Beta-Poisson (Ward et al., 1986; alpha=0.253, beta=0.426)

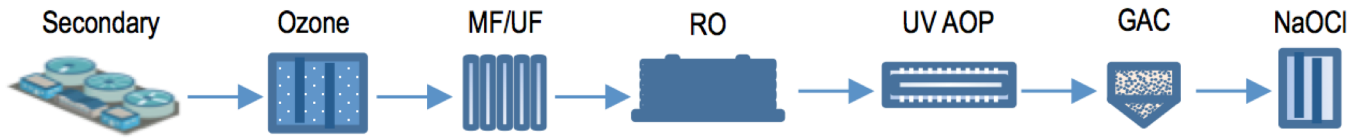
DPRisk Inputs: Treatment Train Performance

Treatment Train Performance

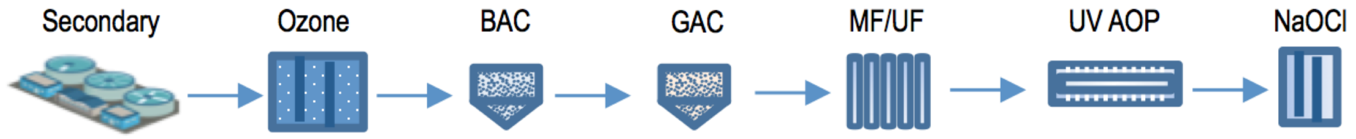
Overall Treatment Train LRV

20 logs

Full Advanced Treatment (RO + AOP)



Carbon Based Treatment (w/o RO)



Failures

Failure Type 1:

Does this failure type apply to all processes?

Yes

Global vs. Process-Specific

Magnitude: Specify a percentage, representing the reduction in log removal to 4x(100-50)/100 = 2).

Percentange failure (0 - 100):

50

Magnitude

Duration: Select how long it will last (in hours. max is 24 hrs)

Specify hours:

0.25 8 24

0.25 2.75 5.25 7.75 10.25 12.75 15.25 17.75 20.25 22.7524

Duration

Frequency:

Should the frequency be applied as a daily probability of a failure or as a deterministic number of failure days per year:

Deterministic

Frequency

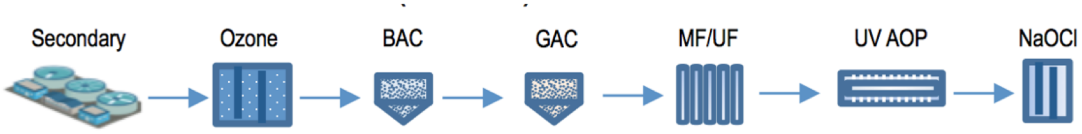
Select how many failures per process per year

Number of failures:

12

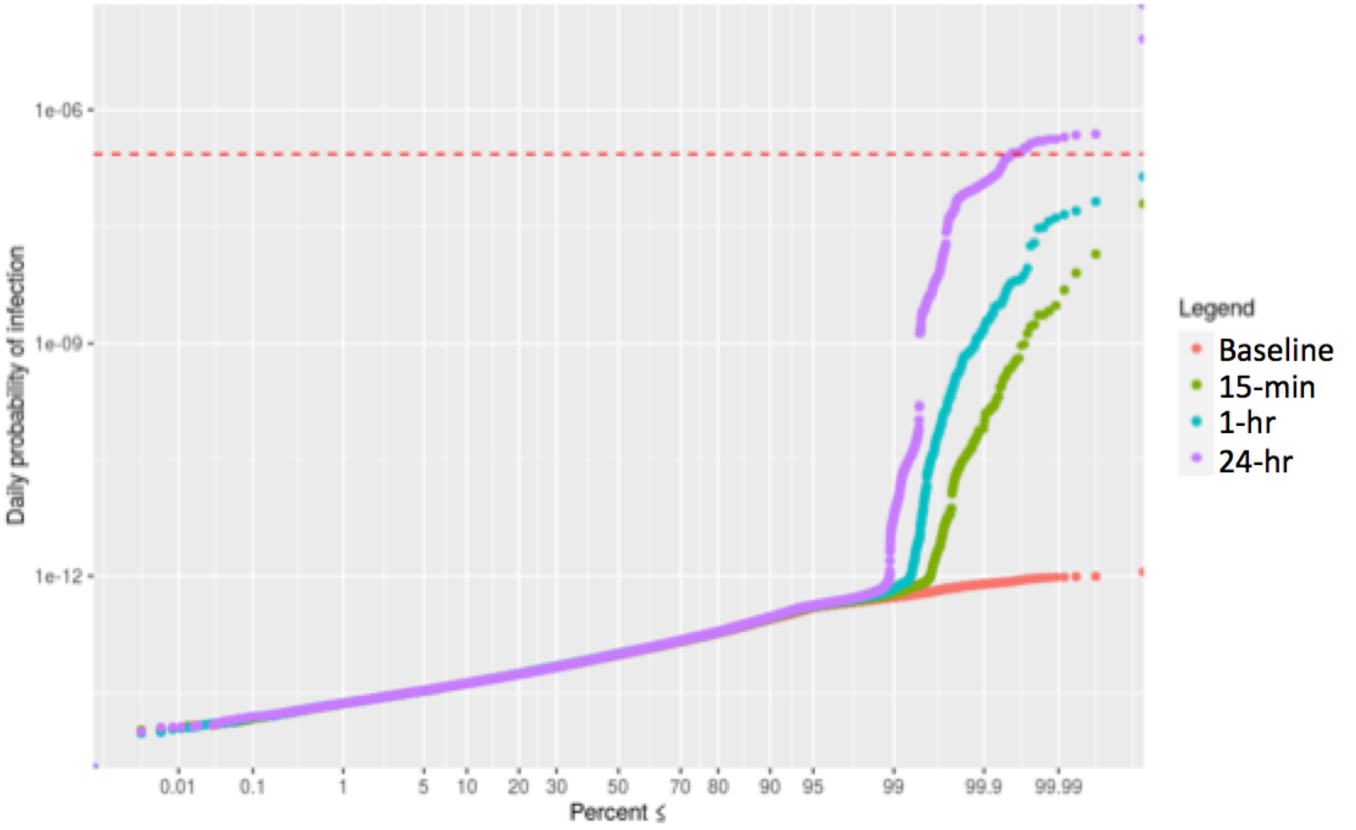
DPRisk Outputs

Probabilistic Assessment of Treatment Train Performance



Model the performance of treatment trains in terms of pathogen log reduction reliability

Quantitative Microbial Risk Assessment



Understand microbial risk with and without failures

Why is this helpful?

- Allows different States and countries to develop their own log reduction requirements based on inputs that are agreed upon with the scientific community performing the work
- DPRisk allows you to perform QMRA with your own data!
- How to get high-quality pathogen data in treated wastewater?

DPR-2: Quality Assurance Project Plan sets bar for quality

- SOPs optimized to minimize non-detects
  - 94% detection rate for all culture and microscopy assays
- Extensive QA/QC requirements
  - Matrix spikes provide ability to correct for recovery
- Effective in wastewater from 5 different facilities
- Reproducible across 3 different labs

QAPP Analytical Microbiology Supporting
Version 4.0.

WRF Contract No: 4952
Date: 05.06.20

Quality Assurance Project Plan

Analytical Microbiology Services

Water Research Foundation
Contract #4952

Prepared for:

The Water Research Foundation

Prepared by:

cel analytical, inc.
water, wastewater, and soil laboratory services

82 Mary Street Suite 2
San Francisco, CA 94103
Yeggie Dearborn Ph.D.
Program Manager
Email: yeggie@celanalytical.com

ugust; October
Version 1.0, Rev.01
November
Version 2.0, Rev.02
Version 2.0, Rev.03
Version 3.0
Version 4.0

Extensive new dataset from 14-month campaign

San Francisco Water Power Sewer
Services of the San Francisco Public Utilities Commission

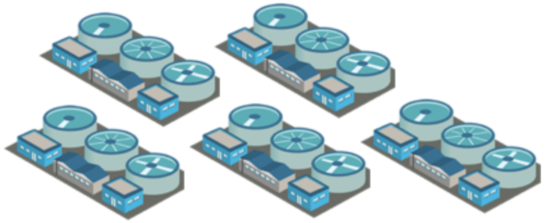
SANITATION DISTRICTS OF LOS ANGELES COUNTY

environment LA SANITATION
CITY OF LOS ANGELES

ORANGE COUNTY SANITATION DISTRICT
PROTECTING THE ENVIRONMENT

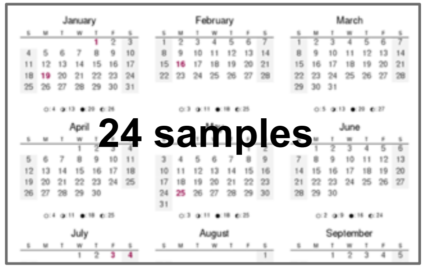
ORANGE COUNTY WATER DISTRICT

The City of SAN DIEGO

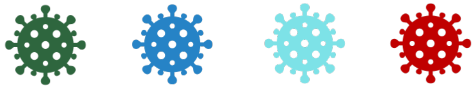


Five facilities

×



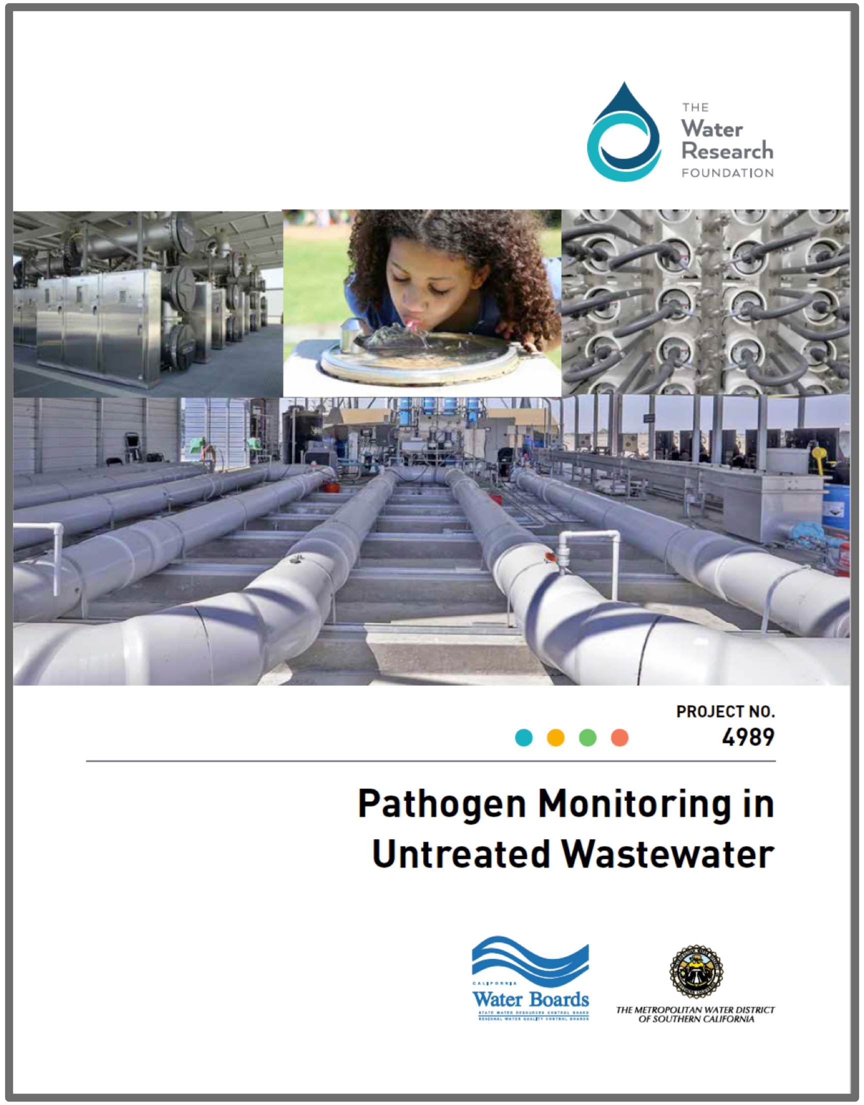
120 Samples of Pathogens & Indicators



- Enterovirus (culture)
- Enterovirus (PCR)
- Adenovirus (culture)
- Adenovirus (PCR)
- Norovirus (PCR)
- SARS-CoV-2 (PCR)

- *Giardia*
- *Crypto*

DPR-2 Results are available – Open Access!




Water Research 213 (2022) 118170

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

Distributions of waterborne pathogens in raw wastewater based on a 14-month, multi-site monitoring campaign

Brian M. Pecson [a,*,1], Emily Darby [a,*,1], Richard Danielson [b], Yeggie Dearborn [b], George Di Giovanni [c], Walter Jakubowski [d], Menu Leddy [e], George Lukasik [f], Bonnie Mull [f], Kara L. Nelson [g], Adam Olivieri [h], Channah Rock [i], Theresa Slifko [c]

[a] Trussell Technologies, Oakland, CA, USA
[b] Cel Analytical Inc., San Francisco, CA, USA
[c] Metropolitan Water District of Southern California, Los Angeles, CA, USA
[d] WaltJay Consulting, Spokane, WA, USA
[e] Essential Environmental & Engineering Systems, Huntington Beach, CA, USA
[f] BCS Laboratories Inc., Gainesville, FL, USA
[g] Department of Civil and Environmental Engineering, University of California, Berkeley, CA, USA
[h] EOA, 1410 Jackson Street, Oakland, CA 94612, USA
[i] Department of Environmental Science, University of Arizona, Maricopa, AZ, USA

ARTICLE INFO

Keywords:
Pathogen concentrations
Wastewater monitoring
Potable reuse
Enterovirus
Cryptosporidium

ABSTRACT

The California State Water Resources Control Board is the first regulatory body in the United States to develop statewide regulations for direct potable reuse (DPR). To support this effort, a pathogen monitoring campaign was undertaken to develop and implement an optimized standard operating protocol to better characterize the concentration of human pathogens in raw wastewater. Methods to detect relevant viral and protozoan pathogens in raw wastewater were optimized and implemented during a 14-month monitoring campaign. Over 120 samples were collected from five wastewater treatment plants treating a quarter of California's population. Samples were analyzed for two protozoa (*Cryptosporidium* and *Giardia*) using microscopy methods, three enteric viruses (enterovirus, adenovirus, and norovirus) using culture and/or molecular methods, and male-specific coliphage using culture methods. The method recovery efficiency was measured in every protozoa sample and every other virus sample to confirm minimum recovery efficiencies were achieved and to correct the concentrations for pathogen losses during sample processing. The results from this study provide the industry with a large, high-quality dataset as demonstrated by the high degree of method sensitivity, method recovery, and QA/QC steps. Such high-quality data on pathogen concentrations in raw wastewater are critical for confirming the level of treatment needed to reduce pathogen concentrations down to acceptable levels for potable water in DPR projects.

1. Introduction

In the face of increasing water supply deficits and historic droughts, communities across the American West are implementing bold plans to maximize the use of recycled water. For instance, the City of Los Angeles is pursuing efforts to recycle 100% of its wastewater by 2035, allowing it to produce 35% of its total supply through water reuse (City of Los Angeles, 2019). The City of San Diego's Pure Water program will produce 40% of the City's supply through potable reuse projects by 2035 (City of San Diego, 2021). One element that will aid in the widespread implementation of potable reuse is the regulatory flexibility to pursue the full spectrum of reuse types, which would allow communities to tailor projects to address their local constraints. The California State Water Resources Control Board (State Board) has already completed regulations for groundwater recharge and reservoir water augmentation, both of which are deemed indirect potable reuse (IPR) because the water must pass through an environmental buffer before distribution (DDW, 2018). The State Board is also under legislative mandate to

* Corresponding authors.
E-mail addresses: brianp@trusselltech.com (B.M. Pecson), emilyd@trusselltech.com (E. Darby).
[1] These authors contributed equally to this work.

https://doi.org/10.1016/j.watres.2022.118170
Received 30 September 2021; Received in revised form 5 February 2022; Accepted 7 February 2022
Available online 9 February 2022
0043-1354/

Conclusions

- California has a long history successfully implementing potable reuse through groundwater recharge
- Projects are under construction that make use of the new indirect potable reuse regulations for reservoirs and will be online in 2025
- Different log reduction requirements were developed for DPR vs IPR:
  - *Reference pathogens (enterovirus vs. norovirus)*
  - *Dose-response functions (exponential vs. beta-poisson)*
  - *Redundancy*
- California WRF DPR research projects DPR-1 and DPR-2 are valuable tools for performing QMRA and pathogen monitoring campaigns

Trussell

Thank you for listening!

shanet@trusselltech.com