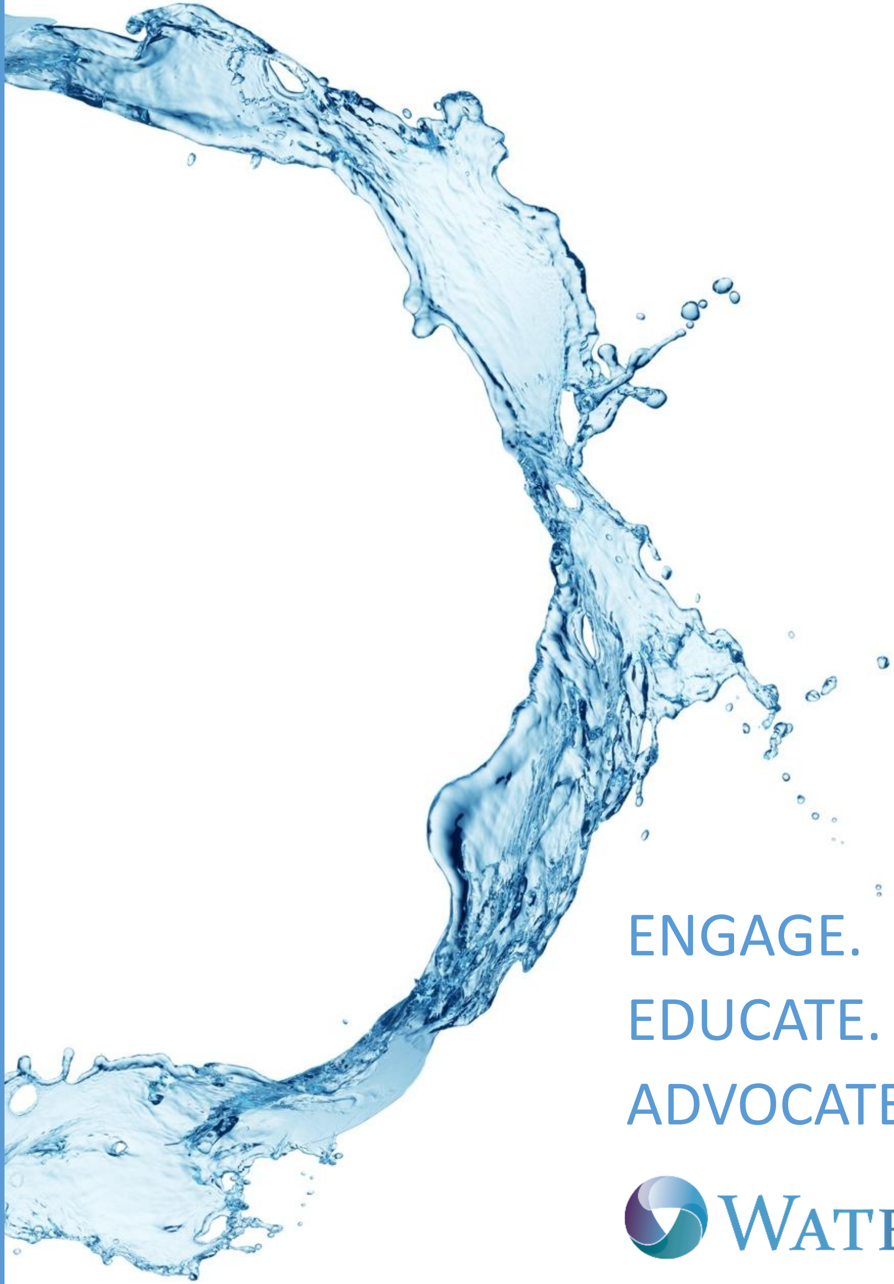
DEFINING, MONITORING, AND ASSESSING DIFFERENT WATER REUSE APPROACHES: A RESEARCH AND DEVELOPMENT PERSPECTIVE

PRESENTED BY: WATEREUSE OHIO

JULY 17, 2025

10:00 AM ET | 7:00 AM PT

WATEREUSE ASSOCIATION WEBCAST SERIES



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- A PDF of this presentation will be shared afterwards via email
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- There is one (1) Professional Development Hour (PDH) available for this webcast. Please email the PDH form to webcasts@watereuse.org

Upcoming Webinar:

Risk-Based Approach to Water Reuse

U.S. EPA Office of Research and Development

Thursday, September 11, 2025
10 a.m.

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LA InterContinental Downtown | March 8-11

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Call for Presentations

- Deadline August 11, 2025
- Posters, Presentations, and Panels
- **New**: Interactive Workshops

Moderator:

Jessica Langdon
Asst. Policy Director
Ohio EPA

Today's Presenters

Jay Garland
U.S. EPA
Office of Research and Development

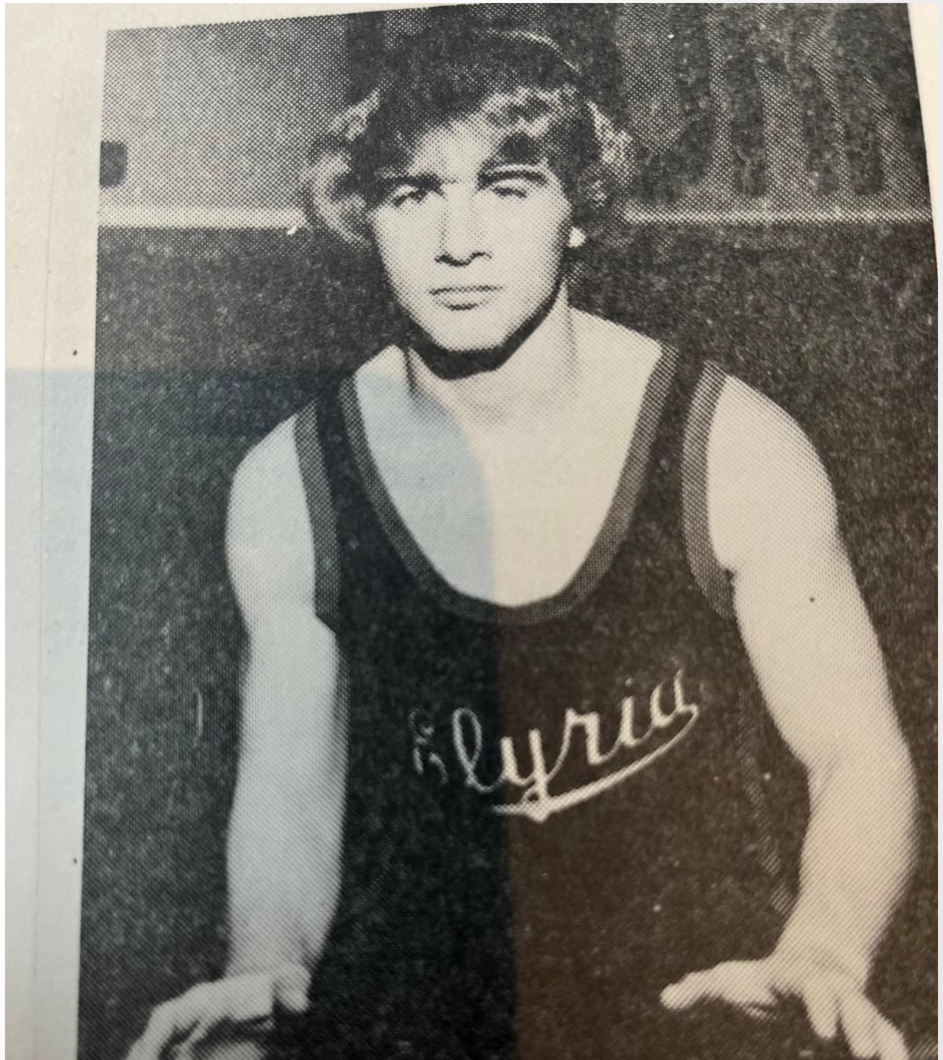
Michael Jahne
U.S. EPA
Office of Research and Development

Defining, Monitoring, and Assessing Different Water Reuse Approaches: A Research & Development Perspective

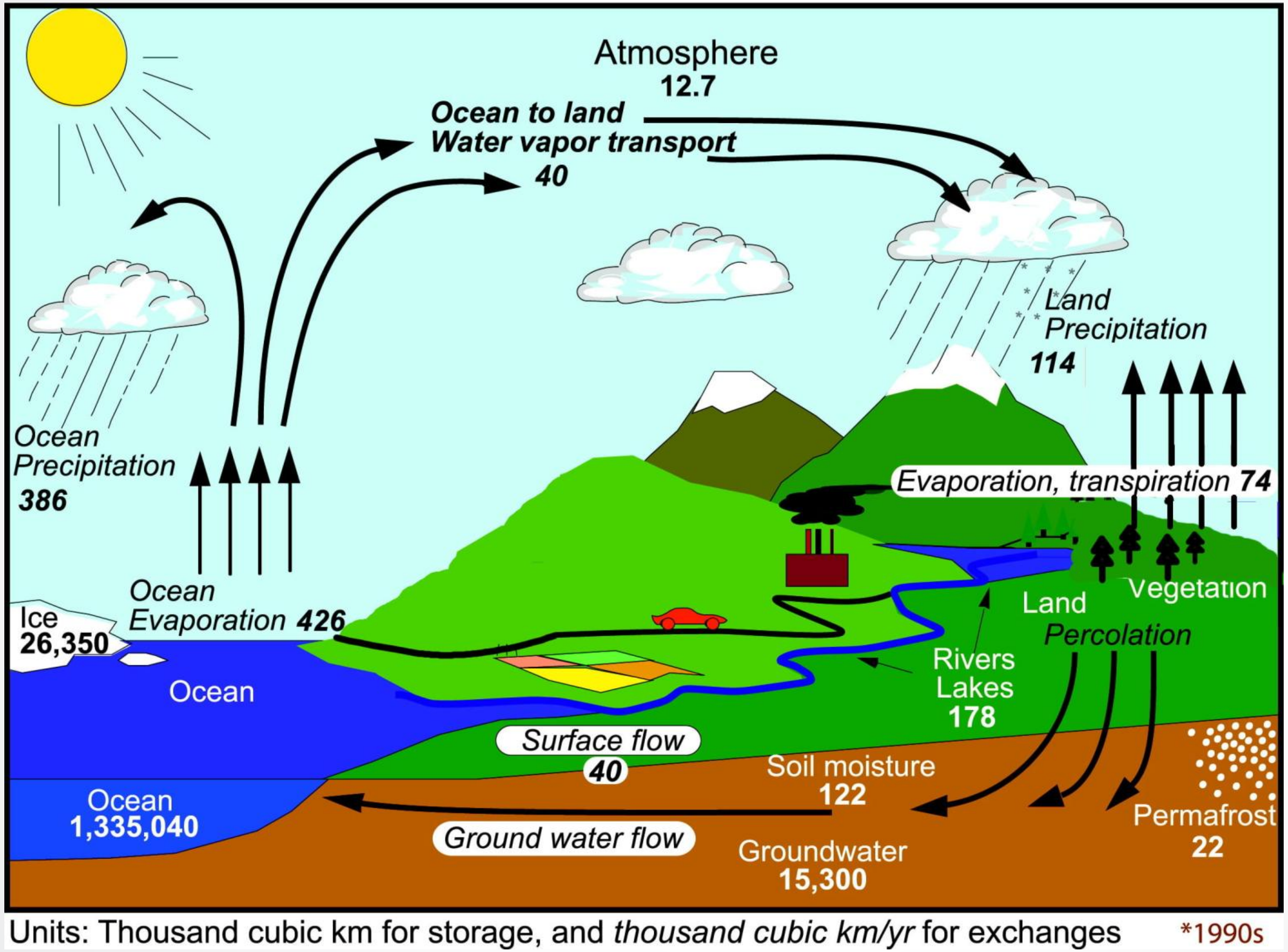
Jay Garland
US EPA Office of Research and Development

WateReuse Ohio Webinar
July 17, 2025

Ohio Roots

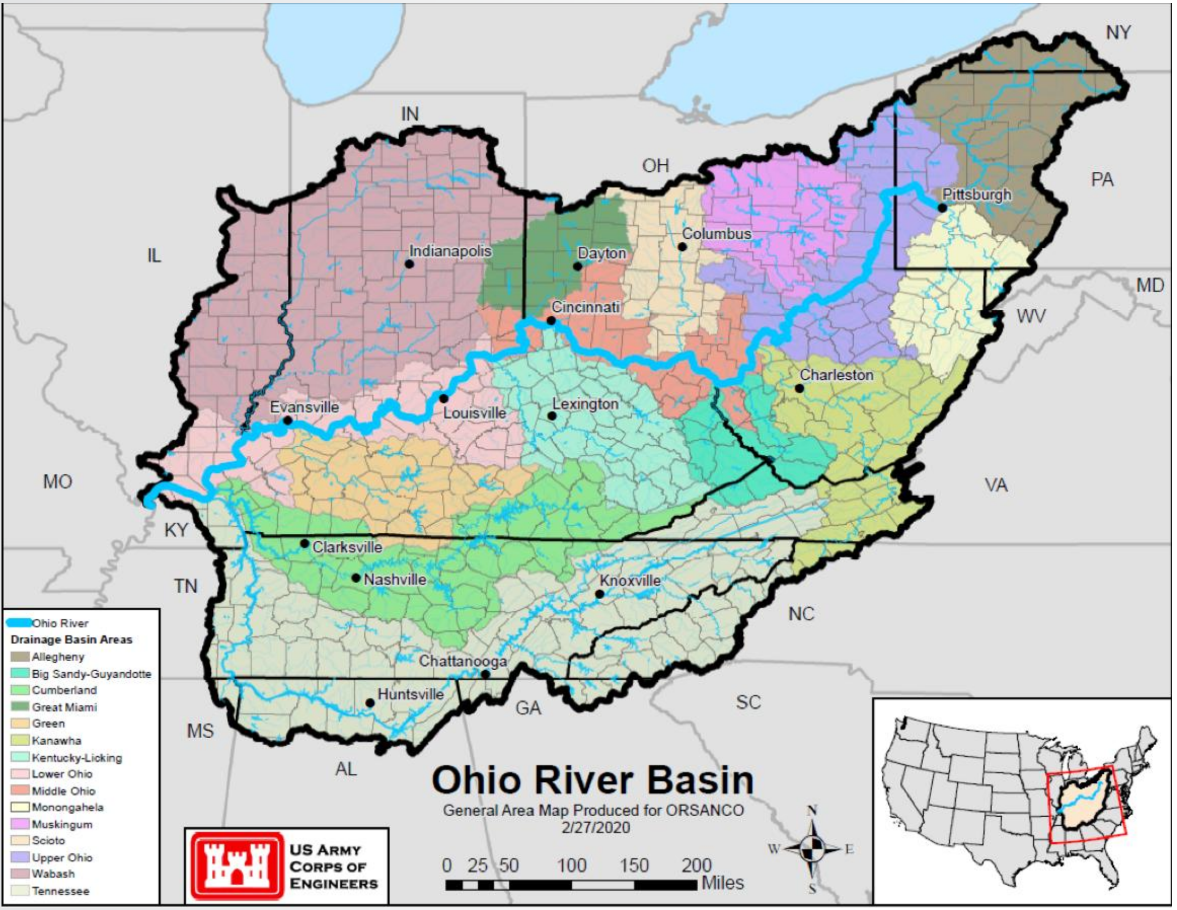


We Tap into the Existing Water Cycle

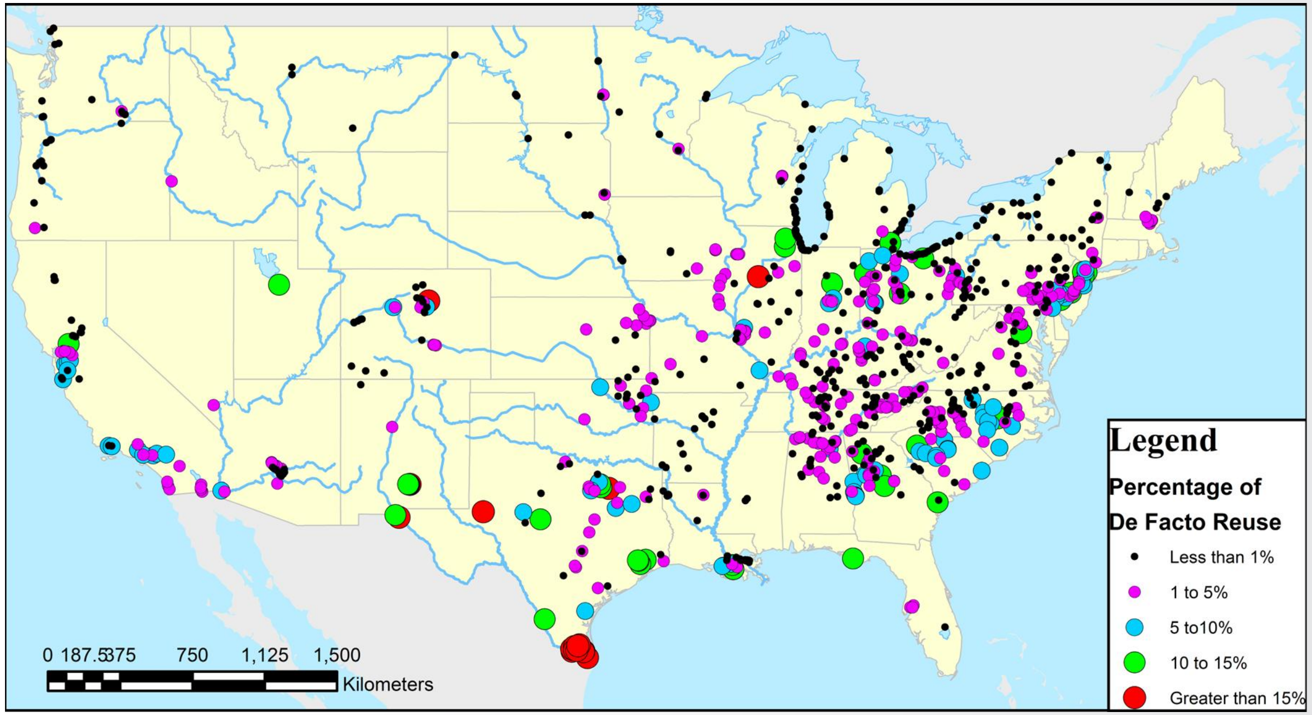


Trenbeth et al. 2011, 24, 4907-4924

Sometimes, We Tap into Our Own Water Cycles

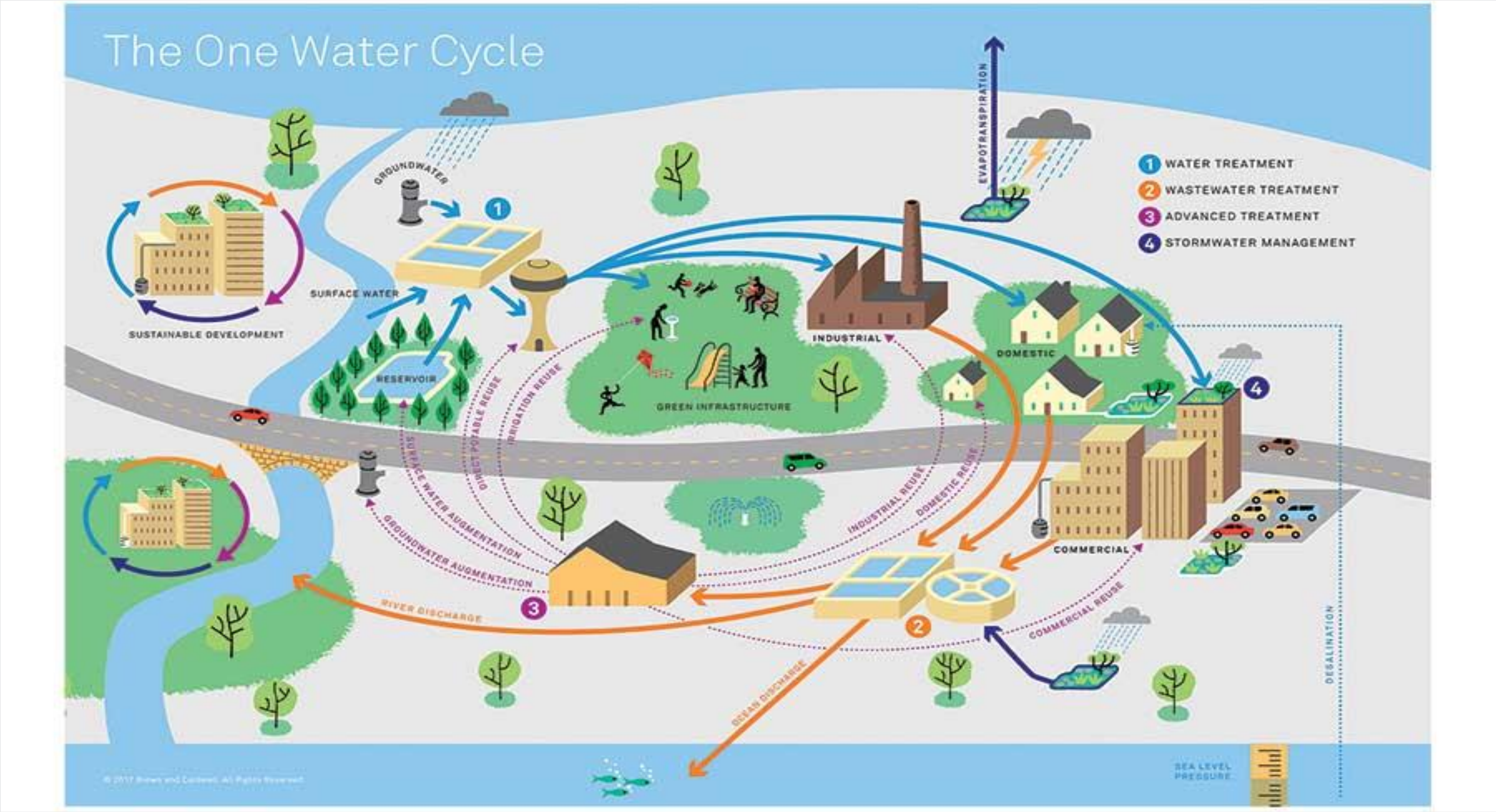


De facto reuse: occurs when a community draws water from a river or reservoir that includes wastewater from upstream communities



Rice J. and P. Westerhoff. 2015. Spatial and temporal variation in de facto Wastewater reuse in drinking water systems across the USA ES&T 49, 982

How Do we Plan Water Cycles?



"The main factors that resulted in the development of the current urban water management system no longer exist."

↓

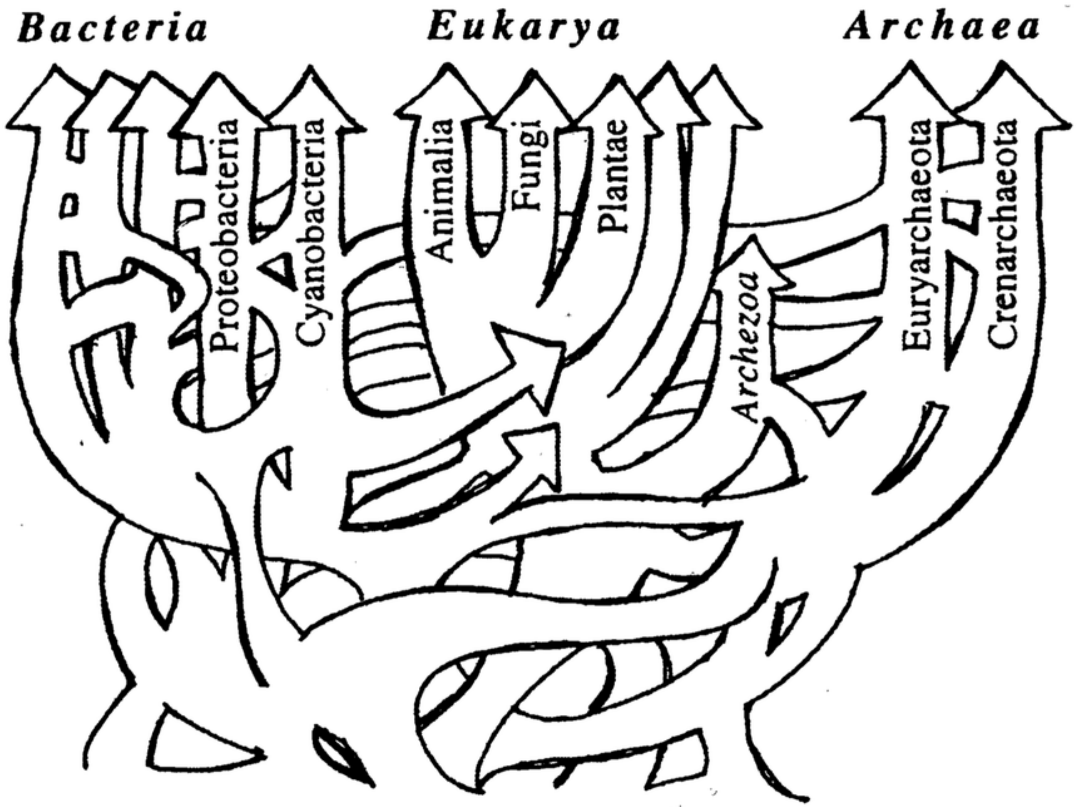
"General availability of water and other materials, relative to demand, and the general lack of treatment technologies and monitoring/autonomous control capabilities"

G.T. Daigger, S. Sharvelle, M. Arabi, and N.G. Love. 2019. Progress and Promise Transitioning to the One Water/Resource Recover Integrated Urban Water Management Systems J. Environ. Eng. 145(10):04019061

Transitions in the Water Sector

	Historic	*Future*
Relationship to Economy	Provide cost-effective water services	Part of circular economy
Functional Objective	Comply with regulations	Produce useful products
Optimization Functions	Infrastructure Cost	Water, energy, materials
Water Supply	Remote	Local
Systems Components	Separate drinking, storm, waste	Integrated, multipurpose
System Configuration	Centralized	Hybrid (C & Distributed)
Financing	Volume Based	Service Based
Institutions	Single-purpose utilities	Water cycle utilities
System Planning	“Plumb up” the planned city	Linked to city planning

G.T. Daigger, S. Sharvelle, M. Arabi, and N.G. Love. 2019. Progress and Promise Transitioning to the One Water/Resource Recovery Integrated Urban Water Management Systems J. Environ. Eng. 145(10):04019061



Ford Dooltttle's Reticulated Tree Of Life

Overview

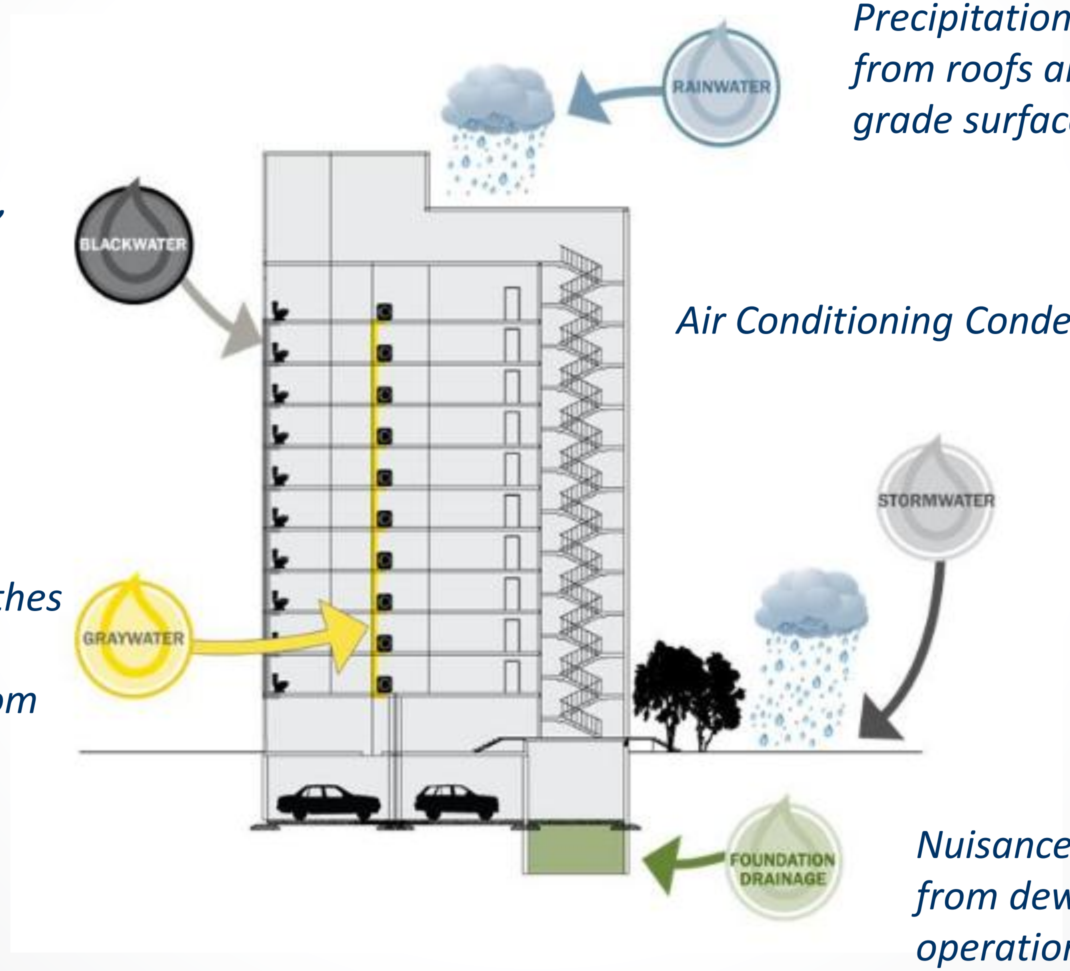
- Expand (and sustain) available water by using alternative waters based on risk-based fit-for-purpose treatment
  - Define necessary treatment for safe use (defining)
  - Verify treatment performance (monitoring)
  - Examine life cycle costs/impacts of different strategies (assessing)

- ORD has applied the same scientific framework to various alternative waters
  - Building-scale reuse of domestic "wastewater" done initially, most developed
    - Combined wastewater, source separated graywater, roof collected rainwater, stormwater
  - More recently involved with food processing wastewater, produced water

Onsite Non-Potable Water Systems

Wastewater from toilets, dishwashers, kitchen sinks, and utility sinks

Wastewater from clothes washers, bathtubs, showers, and bathroom sinks



Precipitation collected from roofs and above-grade surfaces

Air Conditioning Condensate

Precipitation collected at or below grade

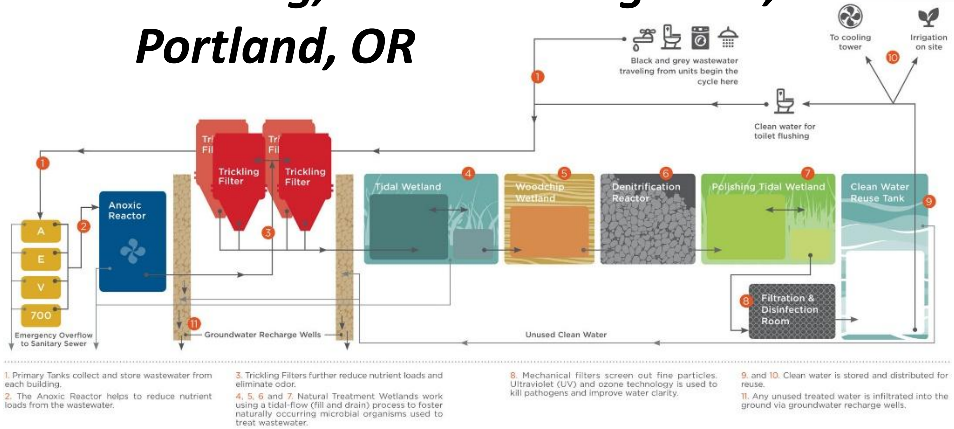
Nuisance groundwater from dewatering operations

Increasing Building Scale Reuse across US

The Solaire apartment building, Battery Park, NYC

25,000 gpd (gallons per day) of wastewater
Membrane Bioreactor
Toilet flushing, cooling, irrigation

Hassalow on Eighth multi-building, mixed-use high rise, Portland, OR



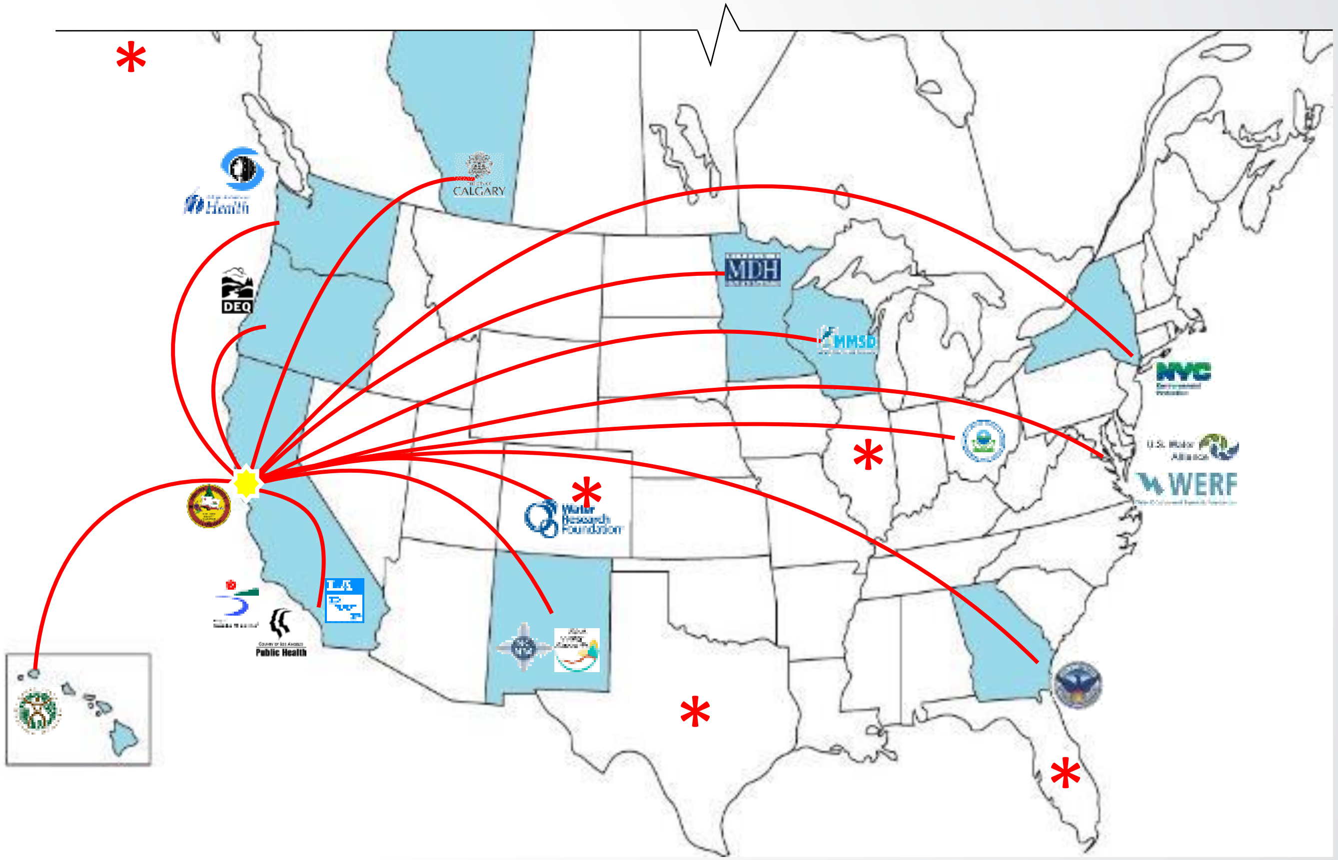
60,000 gpd wastewater
Treatment includes landscaping
Toilet flushing, cooling, irrigation

181 Fremont mixed-use skyscraper, San Francisco, CA

5,000 gpd greywater
Membrane bioreactor
Toilet flushing

Problem Formulation

- Stakeholder (utilities & public health agencies) meeting in 2014
- Local management programs are needed
- Water quality parameters and monitoring are needed to protect public health



National Blue Ribbon Commission for Onsite Water Systems

US Water Alliance

The Need for Standardization: Variation in Graywater Guidance

	BOD_5 (mg L^{-1})	TSS (mg L^{-1})	Turbidity (NTU)	Total Coliform (cfu/ 100ml)	*E. Coli* (cfu/ 100ml)	Disinfection
California	10	10	2	2.2	2.2	0.5 – 2.5 mg/L residual chlorine
New Mexico	30	30	-	-	200	-
Oregon	10	10	-	-	2.2	-
Georgia	-	-	10	500	100	-
Texas	-	-	-	-	20	-
Massachusetts	10	5	2	-	14	-
Wisconsin	200	5	-	-	-	0.1 – 4 mg L^{-1} residual chlorine
Colorado	10	10	2	-	2.2	0.5 – 2.5 mg/L residual chlorine
Typical Graywater	80 - 380	54 -280	28-1340	$10^{7.2}$ – $10^{8.8}$	$10^{5.4}$ – $10^{7.2}$	N/A

National Sanitation Foundation 350 Water Quality for Graywater Use for Toilet Flushing

Parameter	Class R[a]		Class C[b]	
	Test Average	Single Sample Maximum	Test Average	Single Sample Maximum
$CBOD_5$ (mg/l)	10	25	10	25
TSS (mg/l)	10	30	10	30
Turbidity (NTU)	5	10	2	5
E. coli (MPN/100 ml)	14	240	2.2	200
pH (SU)	6.0-9.0		6.0-9.0	
Storage vessel residual chlorine (mg/l)	≥ 0.5 - ≥ 2.5		≥ 0.5 - ≥ 2.5	

[a] Class R: Flows through graywater system are less than 400gpd
[b] Class C: Flows through graywater system are less than 1500gpd

Useful approach to standardization…..but not risk-based

What is the Risk-Base Approach?

A risk-based approach to water reuse focuses on identifying, assessing, and managing potential hazards associated with using reclaimed water for various purposes. This involves evaluating the likelihood and severity of risks related to human health and the environment, then implementing appropriate treatment and monitoring strategies to minimize those risks. It moves beyond simply meeting pre-defined water quality standards and tailors treatment to the specific intended use and potential exposure pathways. Google AI, July 2025

Treatment guidance needs to address the difference in susceptibility between bacteria and other microbial pathogens of concern (i.e., virus, protozoan)

Quantitative Microbial Risk Assessment (QMRA)

Sources of Water

(roof runoff, stormwater, graywater, blackwater)

End Use

Non-Potable

Potable

Structured Framework

Transparent Underlying Assumptions

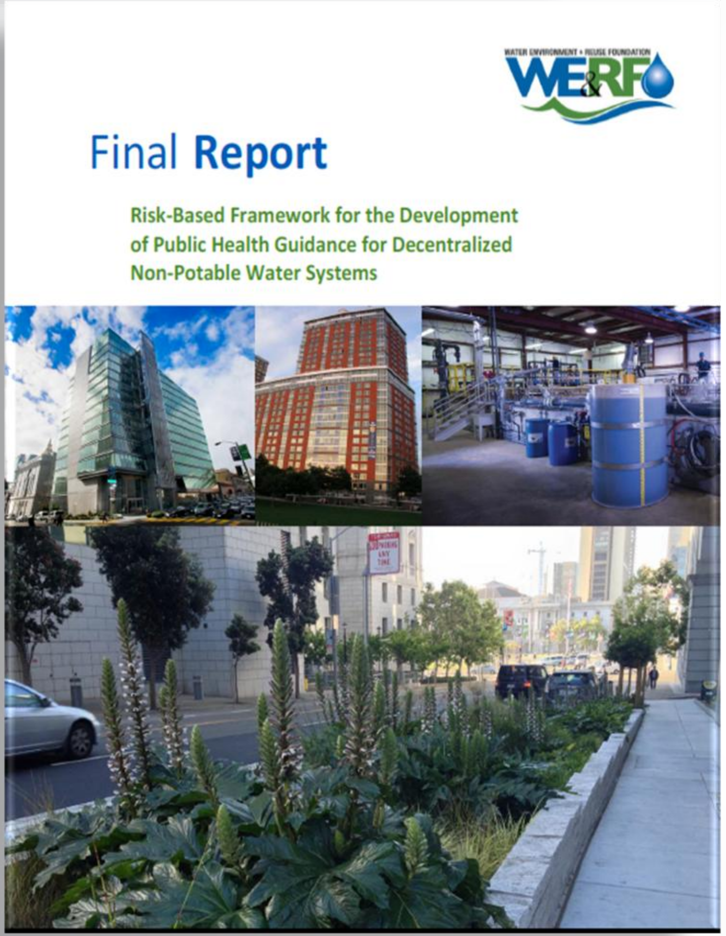
Flexible and Adaptable

Approach: Developing Risk-Based Pathogen Reduction Targets

- “Risk-based” targets attempt to achieve a specific level of protection (aka tolerable or acceptable risk)
  - 1:10,000 infections per person per year (ppy)
  - 1:100 illnesses ppy
  - 1:1,000,000 disability adjusted life years (DALY) ppy

- Pathogen log reduction targets (LRTs)
  - 10-fold removal needed by treatment to meet selected health benchmark

EPA



Sharvelle et al. (2017) Risk-Based Framework for the Development of Public Health Guidance for Decentralized Non-Potable Water Systems

Water Use Scenario	Log_{10} Reduction Targets for 10^{-4} (10^{-2}) Per Person Per Year Benchmarks[b,i]		
	Enteric Viruses[c]	Parasitic Protozoa[d]	Enteric Bacteria[e]
Domestic Wastewater or Blackwater			
Unrestricted irrigation	8.0 (6.0)	7.0 (5.0)	6.0 (4.0)
Indoor use[f]	8.5 (6.5)	7.0 (5.0)	6.0 (4.0)
Graywater			
Unrestricted irrigation	5.5 (3.5)	4.5 (2.5)	3.5 (1.5)
Indoor use[g]	6.0 (4.0)	4.5 (2.5)	3.5 (1.5)
Stormwater (10^{-1} Dilution)			
Unrestricted irrigation	5.0 (3.0)	4.5 (2.5)	4.0 (2.0)
Indoor use	5.5 (3.5)	5.5 (3.5)	5.0 (3.0)
Stormwater (10^{-3} Dilution)			
Unrestricted irrigation	3.0 (1.0)	2.5 (0.5)	2.0 (0.0)
Indoor use	3.5 (1.5)	3.5 (1.5)	3.0 (1.0)
Roof Runoff Water[h]			
Unrestricted irrigation	Not applicable	No data	3.5 (1.5)
Indoor use	Not applicable	No data	3.5 (1.5)

Water Use Scenario	Log_{10} Reduction Targets for 10^{-4} (10^{-2}) Per Person Per Year Benchmarks[b,i]		
	Enteric Viruses[c]	Parasitic Protozoa[d]	Enteric Bacteria[e]
Domestic Wastewater or			

Risk-based approach increasingly adopted

California, Colorado, Washington State

Austin (TX), San Francisco CA)

Or actively considered

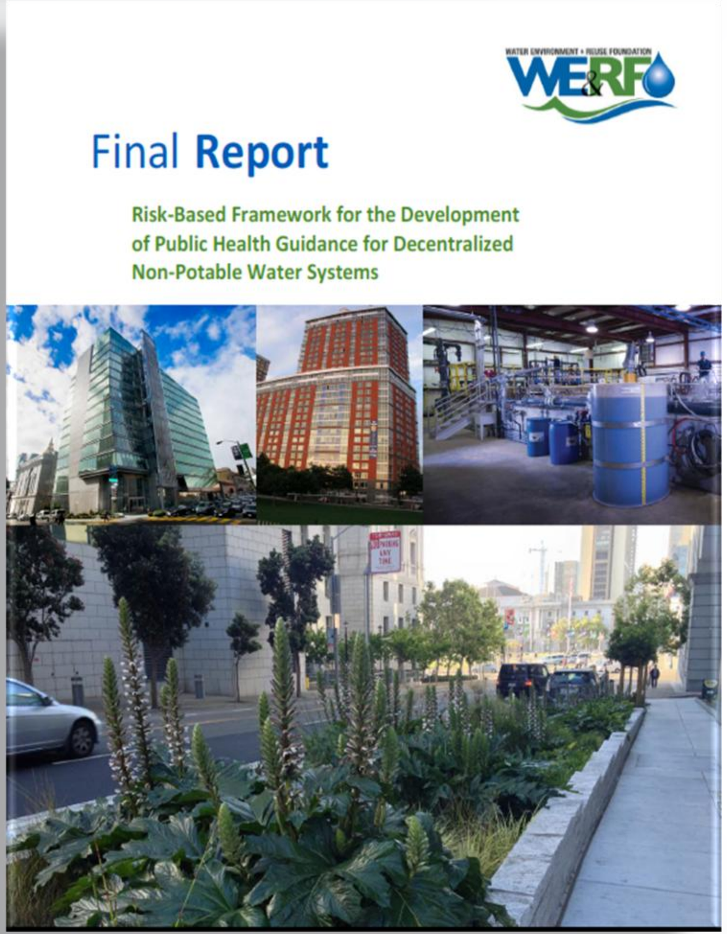
Arizona, Hawaii, Oregon

Potential integration with building codes

International Code Council (ICC)

International Association of Plumbing & Mechanical Officials (IAPMO)

National Sanitation Foundation (NSF)

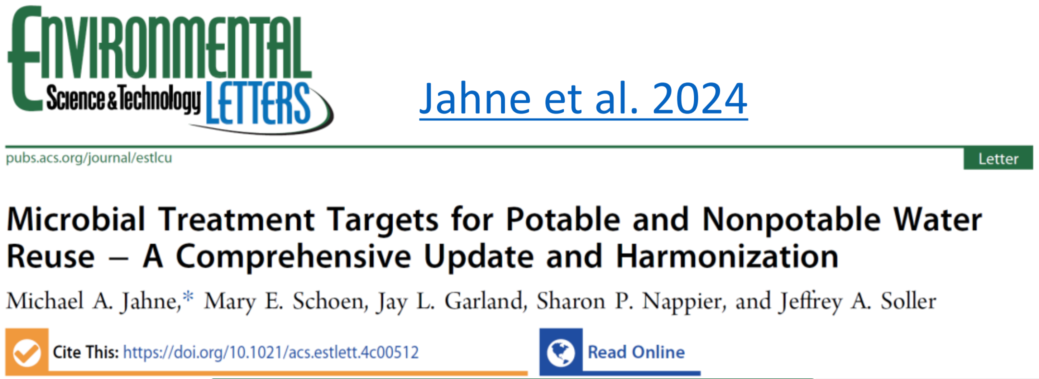


Sharvelle et al. (2017) Risk-Based Framework fo

Schoen et al. (2017) Microbial Risk Analysis 5, 32-43

State of the Science Report

- New scientific resource for states adopting risk-based reuse
  - Joint product of ORD and OW Water Reuse Program
- Describes QMRA framework for water reuse and current parameter assumptions
  - Reference pathogens to consider
  - Pathogen density characterizations in reuse sources of water (municipal and onsite)
  - Exposure estimates for potable and non-potable uses
  - Pathogen dose-response models
  - Risk characterization approaches
- Includes computed log-reduction targets, and information needed for new calculations
- Summarizes related policy decisions and future research needs


Environmental Science & Technology Letters

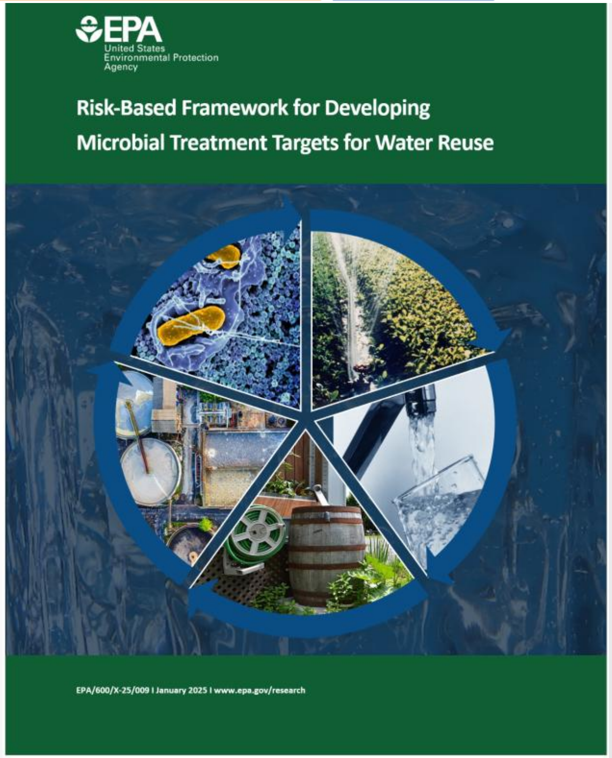
pubs.acs.org/journal/estlcu — Letter

Microbial Treatment Targets for Potable and Nonpotable Water Reuse – A Comprehensive Update and Harmonization

Michael A. Jahne,* Mary E. Schoen, Jay L. Garland, Sharon P. Nappier, and Jeffrey A. Soller

Cite This: https://doi.org/10.1021/acs.estlett.4c00512 — Read Online

Jahne et al. 2024



Risk-Based Framework for Developing Microbial Treatment Targets for Water Reuse

Water *Reuse* in Protein Processing

- Broad water reuse for most purposes, including in processes that involve product contact (but not in product formulation), is also allowed provided:
  - *"Reconditioned water that has never contained human waste and that has been treated by an **onsite advanced wastewater treatment facility**"*
  - *"complies with National Primary Drinking Water Standards" – i.e.*, that the reconditioned water is **potable**
  - and that contacted products and surfaces undergo a final rinse with non-reconditioned water
- **However, treatment requirements for potable reuse of this unique source of water have not been clearly defined**
  - Microbial regulations tied to source water – e.g., Surface Water Treatment Rule
  - Similar challenges to direct potable reuse of municipal wastewater (DPR)

9 CFR Part 416

Tyson Project Objectives

- **Task 1: Source Characterization**
  - Focus on microbial contaminants likely to drive treatment train
  - Include conventional contaminants (biochemical oxygen demand, solids, oil & grease, nitrogen)
  - Since moving towards potable use, secondary assessment of industry-specific chemicals (antibiotics, hormones, cleaning compounds
- **Task 2: Treatment Target Development**
  - Based on microbial contaminants: quantitative microbial risk assessment (QMRA) to develop pathogen log reduction targets (LRTs)
- **Task 3: Treatment Train Configurations**
  - Identify unit processes to meet LRTs
  - Additional consideration of conventional contaminants and chemicals; does treatment train for microbials manage these or need additional unit process(es)
  - Will not provide actual engineering design

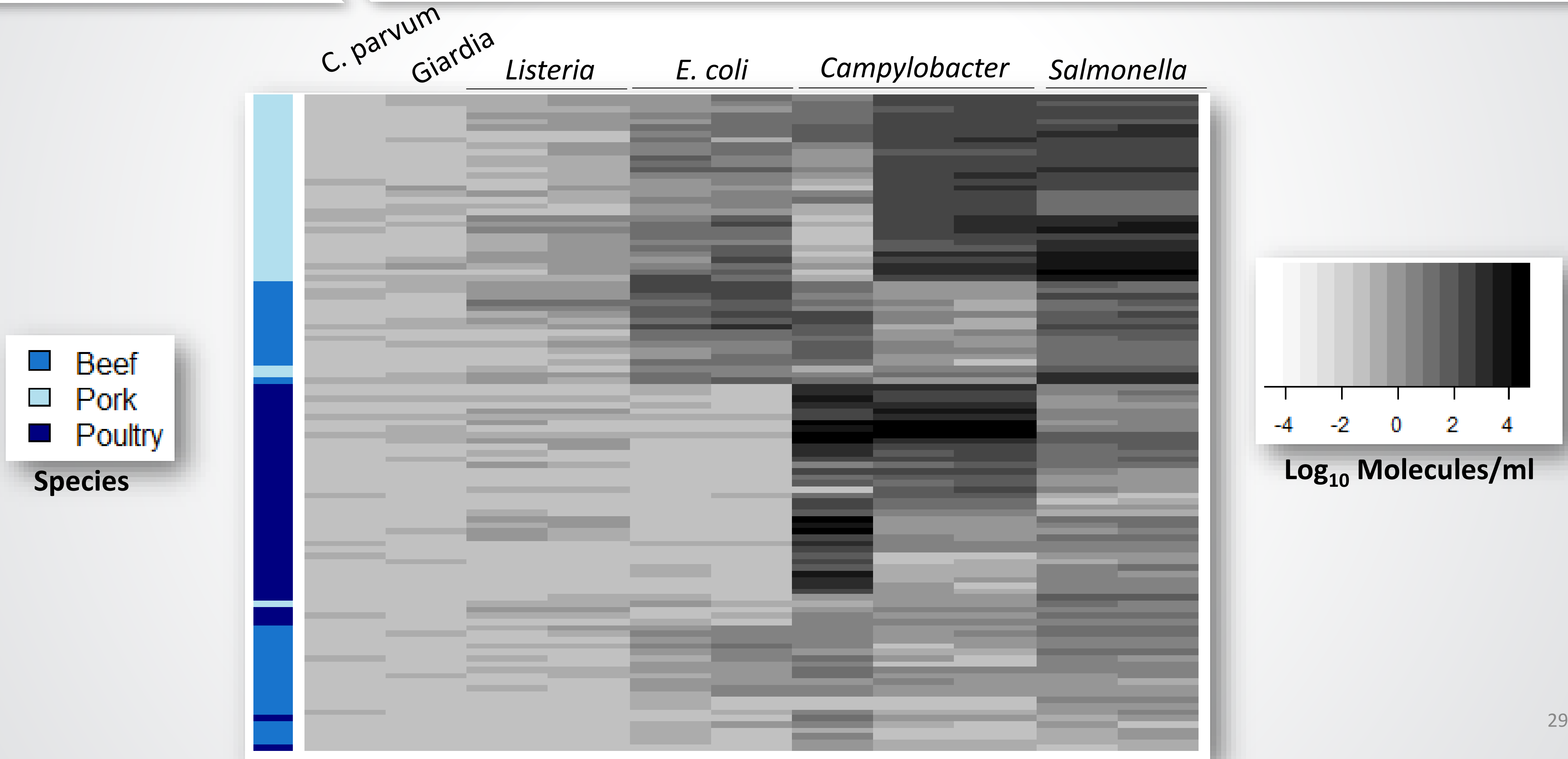
Study Design

- **Facilities**:
  - 3 beef sites
  - 3 pork sites
  - 4 poultry sites
- **Sampling**:
  - Post-DAF (dissolved air flotation)
  - 2 sites rotating weekly
  - Separate microbial and chemical phases
- **Samples**:
  - 8-12 each for microbial
  - 3 each for chemical screening

Microbial Targets

- **Fecal Indicator Bacteria (culture):**
  - Enterococci
  - *E. coli*
- **Pathogens (molecular):**
  - *Listeria*
  - *Salmonella*
  - *Campylobacter*
  - Pathogenic *E. coli*
  - *Cryptosporidium*
  - *Giardia*

Microbial Loads



LRT Results

	Salmonella	*Campylobacter*	Pathogenic *E. coli*	*Listeria*	*Giardia*	*Cryptosporidium*	Norovirus
Beef	8.2	11.4	6.8	*8.9*	*6.5*	*7.7*	n/a
Pork	10.7	13.3	7.1	*8.7*	*7.3*	*7.7*	n/a
Poultry	8.7	15.8	*2.8*	*9.2*	*0*	*0*	n/a
Combined	10.3	14.7	7.2	*9.3*	*7.1*	*7.5*	n/a
WW-DPR	9.5	11	n/a	n/a	9.5	10.5	14.5

Chemical Detections

- **Antibiotics**
  - Tylosin
  - Lincomycin
  - Sulfadimethoxine
  - Trimethoprim
  - Ampicillin
  - Sulfamethazine
  - Sulfanilamide
  - Monensin sodium
  - Erythromycin
  - Virginiamycin
  - Dicyclohexylcarbodiimide
  - Clarithromycin
  - Tiamulin
  - Thiabendazole
  - Penicillin G
  - Novobiocin
  - Azithromycin
  - Oxolinic acid
- **Hormones**
  - Progesterone
  - Testosterone
  - Equilin
  - Equilenin
  - Medroxyprogesterone
  - Levonorgestrel
  - Estrone
  - Genistein
  - Norethindrone
  - Estriol
  - Hydrocortisone
  - Drospirenone
  - Gestodene
  - Triclocarban
  - Formononetin
  - Prednisone
  - Diethylstilbestrol
  - Coumestrol
  - 4-Androstene-3,17-dione
  - 17beta-Estradiol
  - 7,4'-Dihydroxyisoflavone
  - Nomegestrol acetate
  - 17beta-Estradiol
  - 5alpha-Dihydrotestosterone
  - 17alpha-Ethinylestradiol
- **Plant use chemicals**
  - Cyclohexylamine
  - (S)-Lactic acid
  - Didecyldimethylammonium

Typically trace concentrations (ng – µg/L)

Variable occurrence

Hazard Comparison

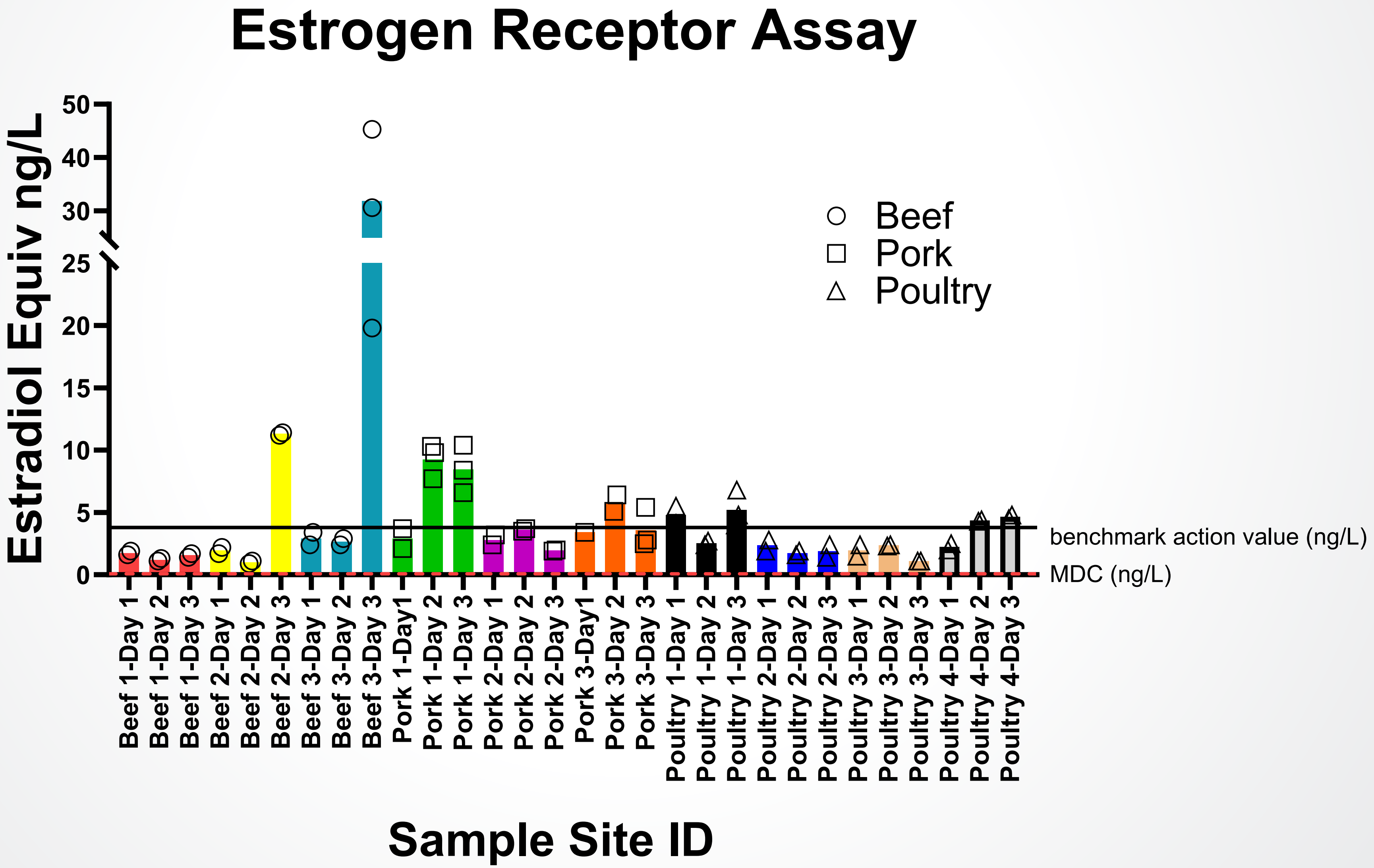
VH - Very High	H - High	M - Medium	L - Low	I - Inconclusive	No Data	Authoritative	Screening	QSAR Model

Name	Human Health Effects															Ecotoxicity		Fate	
	Acute Mammalian Toxicity								Neurotoxicity		Systemic Toxicity								
	Oral	Inhalation	Dermal	Carcinogenicity	Genotoxicity Mutagenicity	Endocrine Disruption	Reproductive	Developmental	Repeat Exposure	Single Exposure	Repeat Exposure	Single Exposure	Skin Sensitization	Skin Irritation	Eye Irritation	Acute Aquatic Toxicity	Chronic Aquatic Toxicity	Persistence	Bioaccumulation
Norethindrone	L			VH	VH	H	H	H								L	VH		L
Didecyldimethylammonium	H	I	I	I	L	L	I	L	I	I	I	I	I	I	I	I		M	H
7,4'-Dihydroxyisoflavone	M				L	H		H	M							H	VH		L
Estrone	L	I	L	VH	VH	H	H	H	H	I	H	I	I	I	I	H	VH	M	M
(S)-Lactic acid	M	L	L	I	L	L	I	H	L	I	L	I	I	VH	VH	L	L	L	L
17beta-Estradiol	L			VH	VH		H				H					VH	VH		L
Estriol	L				L	H	H	H								H	VH		L
Levonorgestrel	L				L	H	H	H								VH			I
Medroxyprogesterone	M				L	L	M	H								H	M		L
17alpha-Ethinylestradiol	M			VH	VH		H				H					H	VH	H	H
Diethylstilbestrol	M	I	I	VH	VH	H	H	H			H	M	H	I	I	H	H		M

U.S. EPA CompTox Cheminformatics Modules
https://www.epa.gov/comptox-tools/cheminformatics

Next step: Assess removal needs by comparing observed concentrations to reported toxicity thresholds

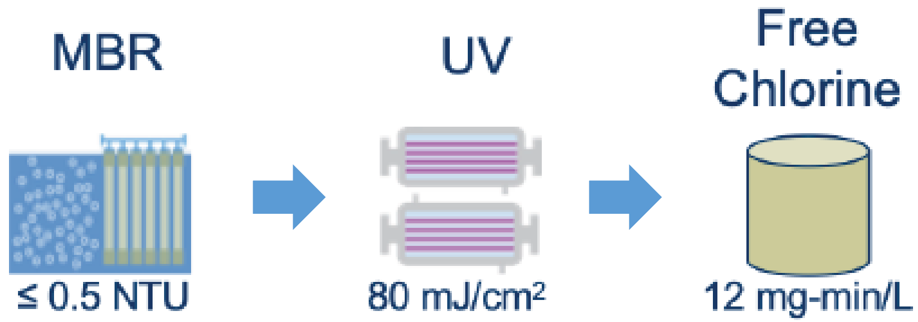
Bioassays



Estrogen Receptor Assay
Estradiol Equiv ng/L
50
40
30
25
20
15
10
5
0
Beef
Pork
Poultry
benchmark action value (ng/L)
MDC (ng/L)
Beef 1-Day 1
Beef 1-Day 2
Beef 1-Day 3
Beef 2-Day 1
Beef 2-Day 2
Beef 2-Day 3
Beef 3-Day 1
Beef 3-Day 2
Beef 3-Day 3
Pork 1-Day1
Pork 1-Day 2
Pork 1-Day 3
Pork 2-Day 1
Pork 2-Day 2
Pork 2-Day 3
Pork 3-Day1
Pork 3-Day 2
Pork 3-Day 3
Poultry 1-Day 1
Poultry 1-Day 2
Poultry 1-Day 3
Poultry 2-Day 1
Poultry 2-Day 2
Poultry 2-Day 3
Poultry 3-Day 1
Poultry 3-Day 2
Poultry 3-Day 3
Poultry 4-Day 1
Poultry 4-Day 2
Poultry 4-Day 3
Sample Site ID

Risk-Based Treatment: Putting it Together

Example Treatment Trains for Indoor Use of Onsite Wastewater/Blackwater



Pathogens	LRV Achieved by Treatment Process			Total LRV Achieved	LRV Required for Indoor Use
	MBR	UV	Free Cl_2		
Enteric Virus	1.0	3.5[b]	4.0	8.5	8.5
Giardia	2.5	6.0	--	8.5	7.0
Crypto	2.5	6.0	--	8.5	7.0
Bacteria	4.0	6.0[d]	4.0	14	6.0

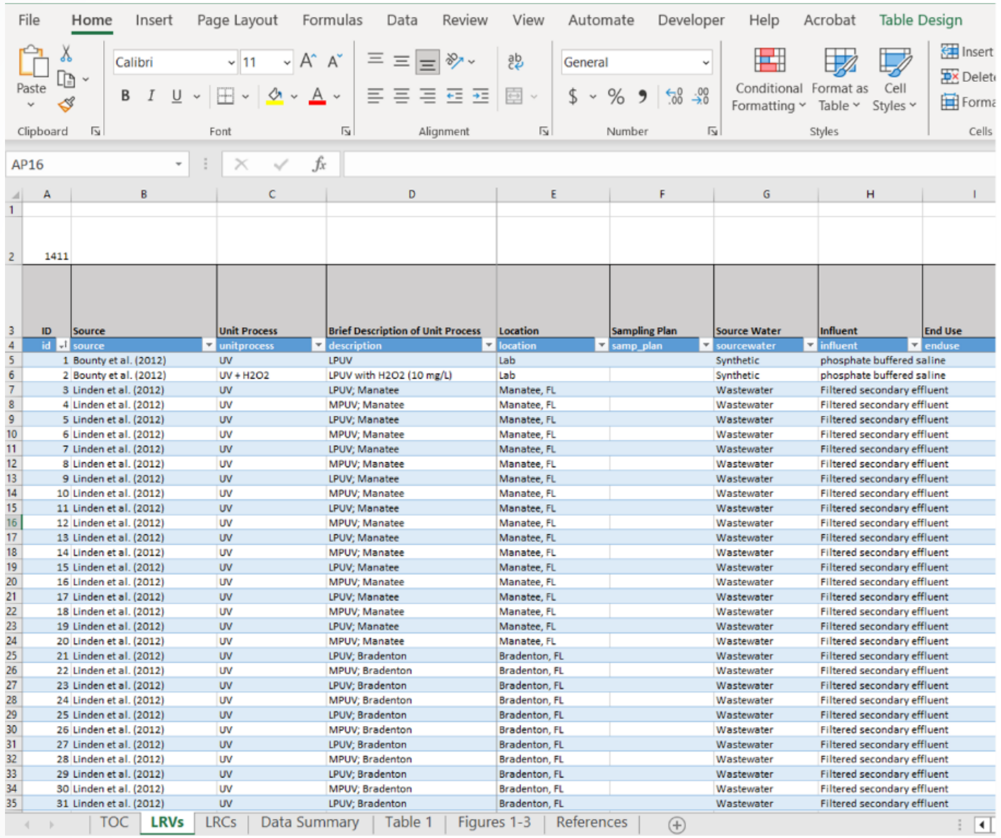
Sum of reduction values must meet LRTs

MBR = Membrane bioreactor (compact biological treatment)
UV = Ultraviolet disinfection
LRV = Log reduction value (pathogen removal achieved by process)

NBRC (2023) “Health Risk-based Benchmarks for Onsite Treatment of Water”

A Unit Process Log Reduction Value (LRV) Database for Water Reuse Practitioners

- Intended as a quick access resource
- LRCs and LRVs compiled for unit processes typical of onsite reuse systems
- Also compiled extensive list of process attributes
- Database available in the publication link



ID	Source	Unit Process	Brief Description of Unit Process	Location	Sampling Plan	Source Water	Influent	End Use
id	source	unitprocess	description	location	samp_plan	sourcewater	influent	enduse
1	Bounty et al. (2012)	UV	LPUV	Lab		Synthetic	phosphate buffered saline	
2	Bounty et al. (2012)	UV + H2O2	LPUV with H2O2 (10 mg/L)	Lab		Synthetic	phosphate buffered saline	
3	Linden et al. (2012)	UV	LPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
4	Linden et al. (2012)	UV	MPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
5	Linden et al. (2012)	UV	LPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
6	Linden et al. (2012)	UV	MPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
7	Linden et al. (2012)	UV	LPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
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10	Linden et al. (2012)	UV	MPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
11	Linden et al. (2012)	UV	LPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
12	Linden et al. (2012)	UV	MPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
13	Linden et al. (2012)	UV	LPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
14	Linden et al. (2012)	UV	MPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
15	Linden et al. (2012)	UV	LPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
16	Linden et al. (2012)	UV	MPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
17	Linden et al. (2012)	UV	LPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
18	Linden et al. (2012)	UV	MPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
19	Linden et al. (2012)	UV	LPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
20	Linden et al. (2012)	UV	MPUV; Manatee	Manatee, FL		Wastewater	Filtered secondary effluent	
21	Linden et al. (2012)	UV	LPUV; Bradenton	Bradenton, FL		Wastewater	Filtered secondary effluent	
22	Linden et al. (2012)	UV	MPUV; Bradenton	Bradenton, FL		Wastewater	Filtered secondary effluent	
23	Linden et al. (2012)	UV	LPUV; Bradenton	Bradenton, FL		Wastewater	Filtered secondary effluent	
24	Linden et al. (2012)	UV	MPUV; Bradenton	Bradenton, FL		Wastewater	Filtered secondary effluent	
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27	Linden et al. (2012)	UV	LPUV; Bradenton	Bradenton, FL		Wastewater	Filtered secondary effluent	
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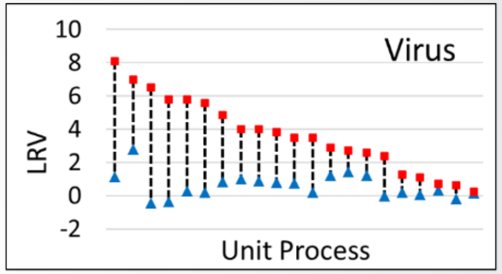
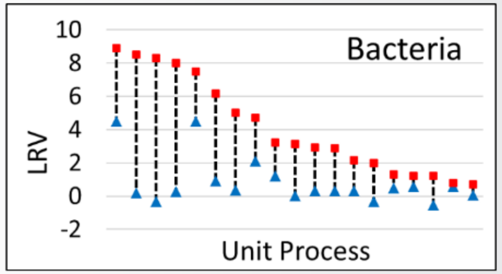
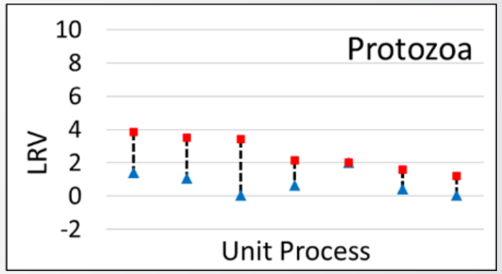
31	Linden et al. (2012)	UV	LPUV; Bradenton	Bradenton, FL		Wastewater	Filtered secondary effluent	







[Science Direct publication]

Monitoring Approach

- Moving away from end point, water quality monitoring
  - Costly, slow response time
  - Low, variable pathogen levels provide difficult analytical challenges

- Toward unit process performance metrics as key critical control points
  - Process-specific surrogates (i.e. transmembrane pressure, UV levels, etc.)
  - More real time data for rapid, remote response

- More operational testing needed to develop and validate surrogate approaches

Continuous Process Monitoring

Example Treatment Process	Available Pathogen Reduction Credits Virus / Protozoa / Bacteria	Example Information Included in an Engineering Report	Example Continuous Monitoring Methods
Microfiltration or Ultrafiltration	0 / 4 / 0	Description and calculation of how the system defines an acceptable pressure decay test value per the US EPA's Membrane Filtration Guidance Manual to detect 3.0 μm breach	• Daily pressure decay test • Effluent turbidity
Membrane Biological Reactor	1.5 / 2 / 4	Operation within the Tier 1 operating envelope as defined in the AWRCE Membrane bio-reactor, WaterVal validation protocol	• Effluent turbidity
Reverse Osmosis	Up to 2 / 2 / 2	Demonstration of ability to meet salt rejection criteria and a description of surrogate parameter used to calculate pathogen reduction credits	• Influent and effluent total organic carbon (TOC) • Influent and effluent electrical conductivity
Ultraviolet Light Disinfection	Up to 6 / 6 / 6	UV reactor's validation report following US EPA UV Disinfection Guidance Manual or NSF/ANSI 55 Class A validation and demonstration of ability of system to meet criteria to achieve specified UV dose	• UV intensity • Flow rate
Chlorine Disinfection	Up to 5 / 0 / 5	Demonstration of ability to achieve a target CT[1] including description of chlorine contactor, contact time provided, and monitoring of chlorine residual	• Chlorine residual • Flow rate
Ozone Disinfection	Up to 4 / 3 / 4	Demonstration of ability to achieve a target CT[1] including description of ozone contactor, contact time provided, and monitoring of ozone residual	• Ozone residual • Flow rate

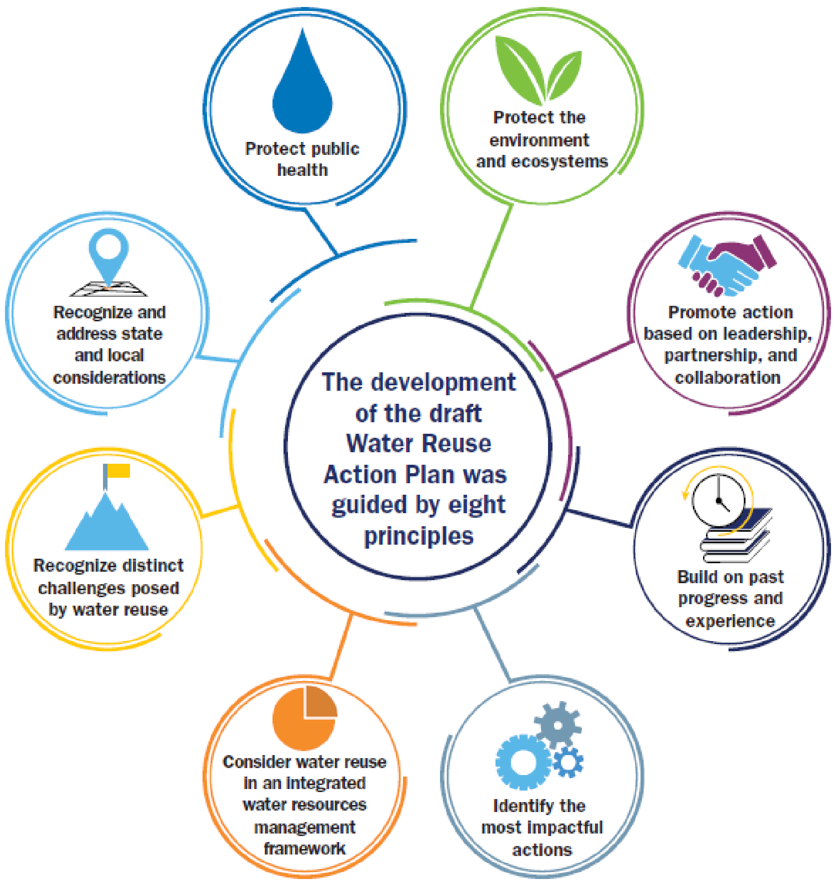
SFPUC (2022) "Onsite Water Reuse Program Guidebook"

Next Steps in Making the Risk Based Approach Whole

- Standard protocols for validating performance consistent with the risk-based approach
- Define critical control point monitoring for different unit processes
- Developing a better library of removal credits for different unit processes

Why do this? (Assessing)

Guiding Principles of the Water Reuse Action Plan



Source: www.epa.gov/sites/production/files/2019-09/documents/water-reuse-action-plan-draft-2019.pdf

- Avoid burden-shifting with respect to economic and environmental impacts
- System level assessment of decentralized systems, including impacts on existing centralized infrastructure

When the well runs dry, we know the value of water.

Benjamin Franklin

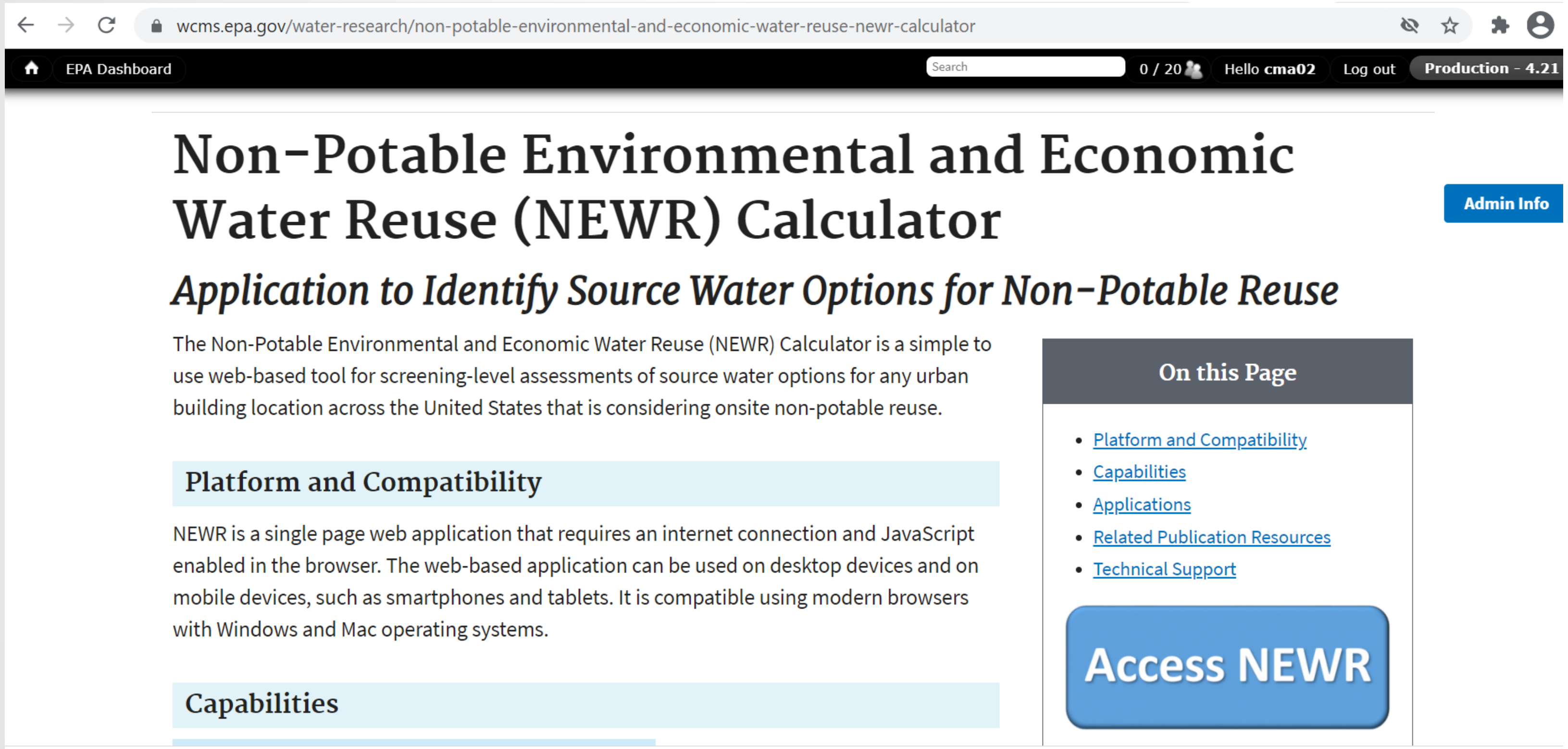
Poor Richard's Almanack 1747

Chance favors the prepared mind

Louis Pasteur

Remarks as new Dean of Faculty of Sciences at Lille 1854

Non-potable Environmental and Economic Water Reuse (NEWR) Calculator



Research Questions:

What is the most environmentally and cost-effective source water(s) to meet large building non-potable water needs?

Target audiences:

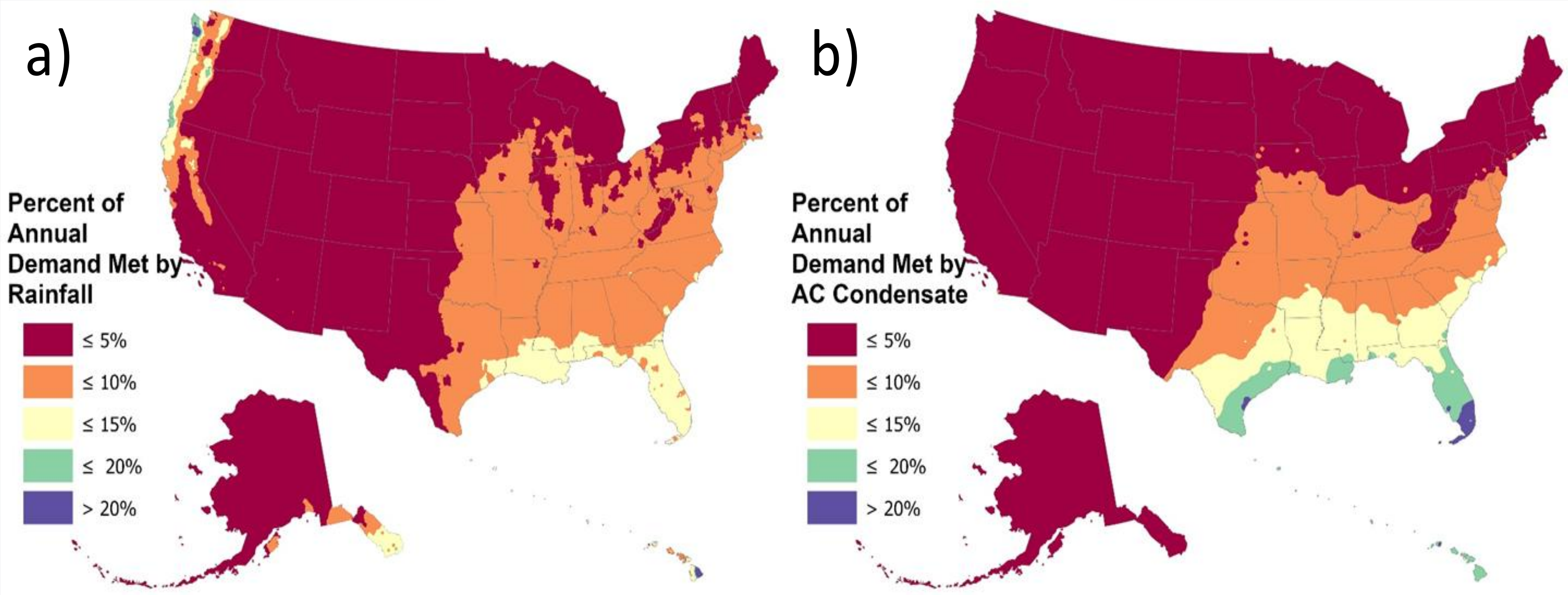
Planners and Developers

Impact:

Inform effective reuse strategies

[Access NEWR]

Percent of Annual Non-Potable Demand Met



Mixed wastewater and graywarer systems always meet non-potable demand under modeled conditions

Scale influence impacts, cost
Reuse in larger building a viable option

Water Research 191 (2021) 116635

Contents lists available at ScienceDirect

Water Research

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

Onsite Non-potable Reuse for Large Buildings: Environmental and Economic Suitability as a Function of Building Characteristics and Location

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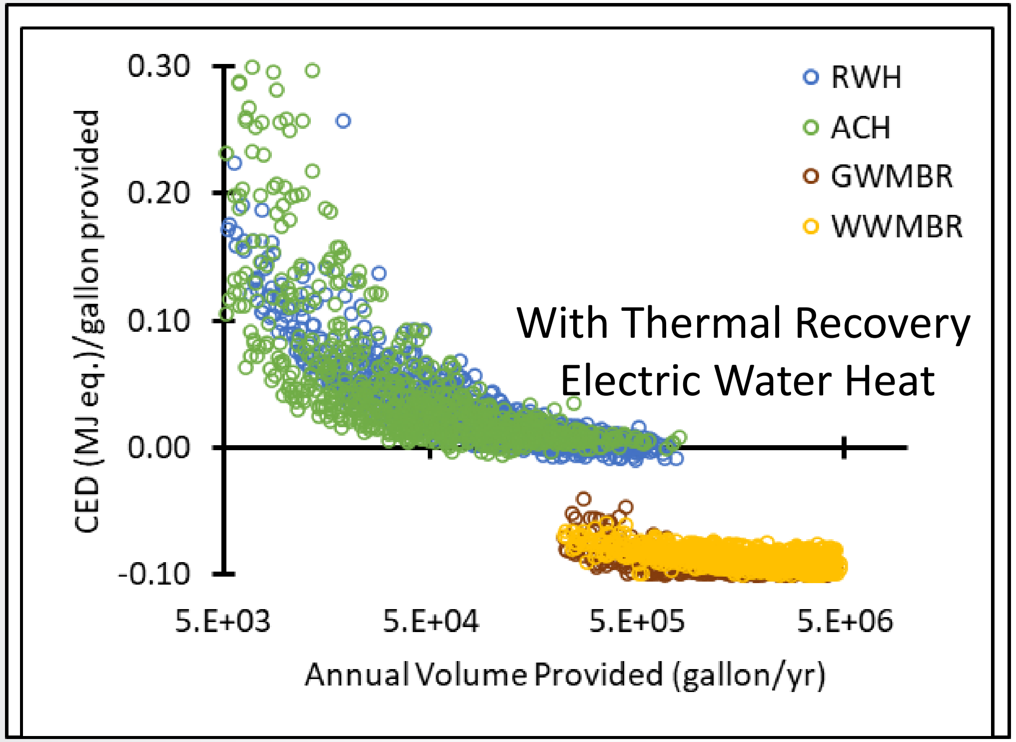
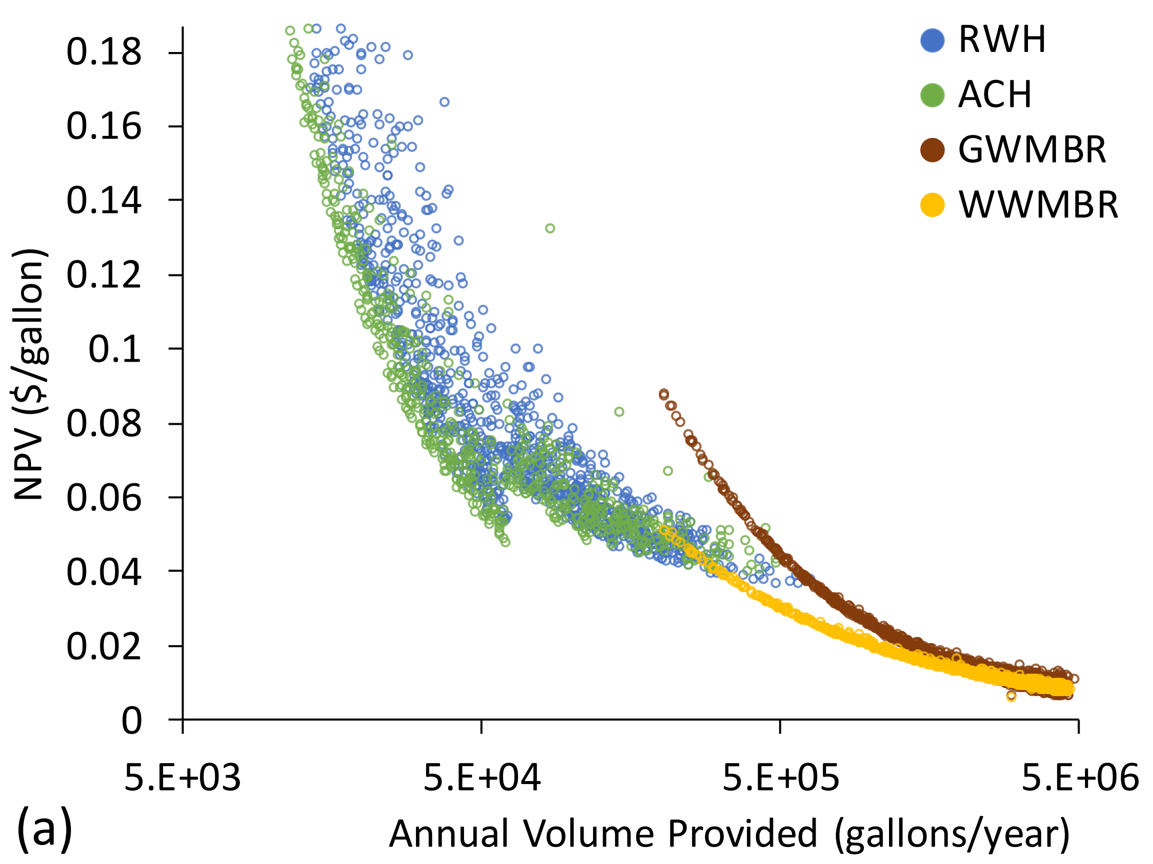
[a] Eastern Research Group, Lexington, Massachusetts USA
[b] United States Environmental Protection Agency, Center for Environmental Solutions and Emergency Response, Cincinnati, Ohio USA





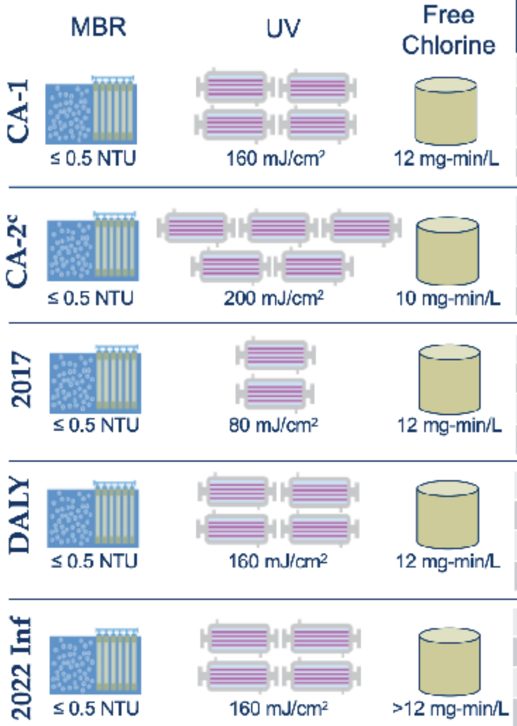
LRT Analysis – Effect of Treatment Train Design

Table 3. Indoor Use LRT Summary

Source Water	Virus[1]				Protozoa					Bacteria			
	2017	CA	DALY	2022	2017	CA (Giardia)	CA (Crypto)	DALY	2022	2017	CA	DALY	2022
Onsite Wastewater	8.5	8.0	10.0	11.5	7.0	6.5	5.5	6.5	7.0	6.0	n/a	5.5	7.5
Graywater	6.0	6.0	7.5	9.0	4.5	4.5	3.5	4.0	4.5	3.5	n/a	3.5	5.5
Stormwater (10^{-1} dilution)	5.5	7.0	8.0	9.5	5.5	5.5	4.5	6.0	6.5	5.0	n/a	5.5	6.5
Stormwater (10^{-3} dilution)	3.5	n/a	6.0	7.5	3.5	n/a	n/a	4.0	4.5	3.0	n/a	3.5	4.5
Stormwater (10^{-4} dilution)	n/a	n/a	5.0	6.5	n/a	n/a	n/a	3.0	3.5	n/a	n/a	2.5	3.5
Roof Runoff	n/a	n/a	n/a	n/a	n/a	1.5	n/a	1.0	2.0	3.5	n/a	3.5	5.0

[1] Norovirus is the reference viral pathogen for 2017, DALY, and 2022; adenovirus is the reference viral pathogen for CA.

Example Treatment Trains for Indoor Use of Onsite Wastewater/Blackwater



Train	Pathogens	LRV Achieved by Treatment Process: MBR	UV	Free Cl_2	Total LRV Achieved	LRV Required for Indoor Use
CA-1	Enteric Virus	1.0	3.0[a]	4.0	8.0	8.0
	Giardia	2.5	6.0	--	8.5	6.5
	Crypto	2.5	6.0	--	8.5	5.5
	Bacteria	n/a	n/a	n/a	n/a	n/a
CA-2[c]	Enteric Virus	1.0	4.0[a]	3.0	8.0	8.0
	Giardia	2.5	6.0	--	8.5	6.5
	Crypto	2.5	6.0	--	8.5	5.5
	Bacteria	n/a	n/a	n/a	n/a	n/a
2017	Enteric Virus	1.0	3.5[b]	4.0	8.5	8.5
	Giardia	2.5	6.0	--	8.5	7.0
	Crypto	2.5	6.0	--	8.5	7.0
	Bacteria	4.0	6.0[d]	4.0	14	6.0
DALY	Enteric Virus	1.0	6.0[b]	4.0	11.0	10.0
	Giardia	2.5	6.0	--	8.5	6.5
	Crypto	2.5	6.0	--	8.5	6.5
	Bacteria	4.0	6.0	4.0	14.0	5.5
2022 Inf	Enteric Virus	1.0	6.0[b]	5.0	12.0	11.5
	Giardia	2.5	6.0	--	8.5	7.0
	Crypto	2.5	6.0	--	8.5	7.0
	Bacteria	4.0	6.0	5.0	15.0	7.5

[a] Credit achieved using adenovirus as reference pathogen

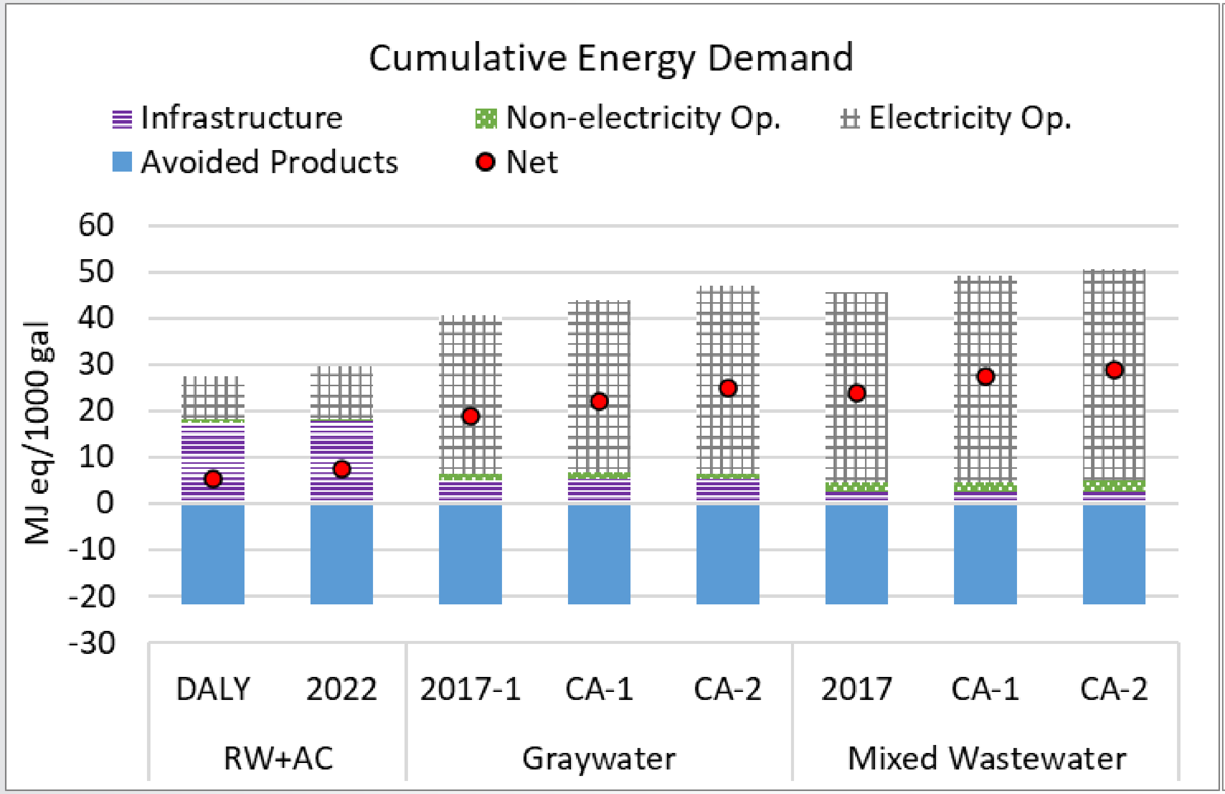
[b] Credit achieved using norovirus as reference pathogen

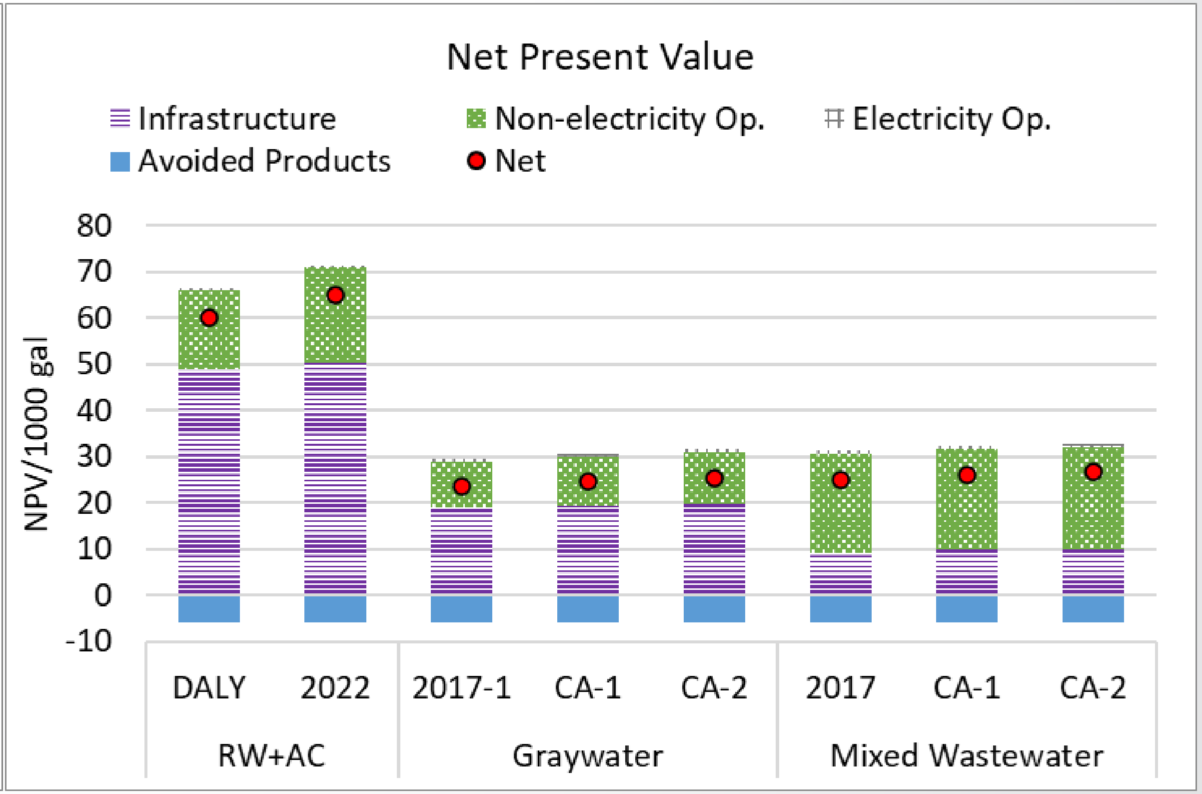
[c] California regulators have specified one model treatment train (CA-1) for wastewater, but may allow alternatives that meet the LRTs including train CA-2

[d] Assumes 3-4 LRV bacterial credit per 40 mJ/cm² UV reactor based on WaterVal

LRT Analysis – Contributions

- Little influence of changing LRTs, source water more important
- MBR treatment, not disinfection, the main driver of energy use for wastewater
- Infrastructure dominant source of energy and costs with rainwater (RW) and AC condensate





Summary

- Significant development and impact of risk-based modeling to inform treatment
  - Harmonized set of pathogen log-reduction target values for **domestic related potable, nonpotable reuse**
  - Risks characterization developed for **food processing wastewater**, and treatment trains drafted in preparation for pilot studies
  - Developing/applying chemical risk assessment tools for potable reuse applications and produced water

- Increasing focus on validating and defining system performance
  - Standard protocols for validating performance consistent with the risk-based approach
  - Define critical control point monitoring
  - Developing a better library of removal credits for different unit processes

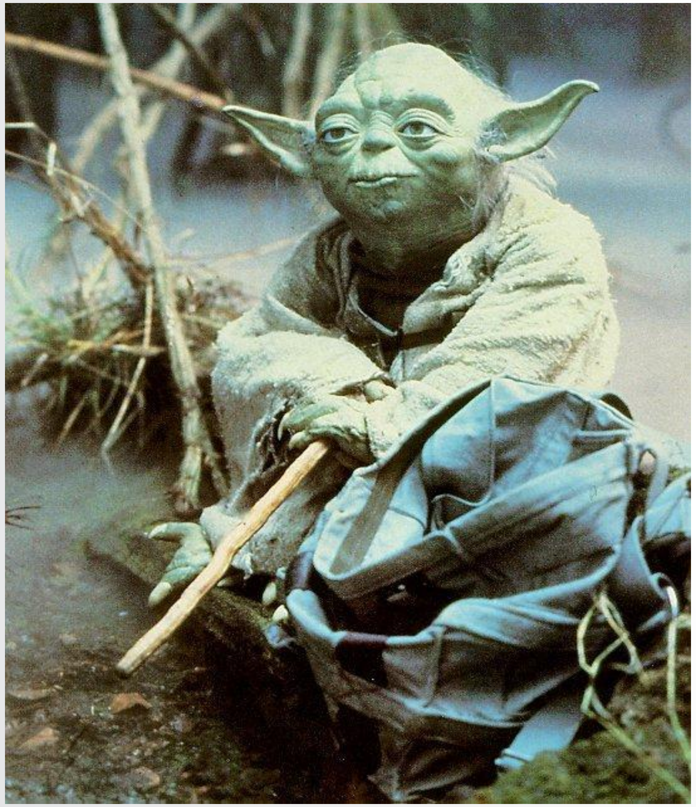
- System level tools are available to help planners and developers
  - Regional differences are important consideration for most efficient approaches
  - Primary treatment (oxidation of organic matter, removal of nutrients) remains a large driver of energy use and cost
  - Heat recovery systems to reduce costs and improve efficiency
  - Defining/quantifying resiliency?

BILD

BUILDING INFRASTRUCTURE LOCALLY FOR DECENTRALIZED WATER SYSTEMS

https://watereuse.org/educate/national-blue-ribbon-commission-for-onsite-non-potable-water-systems/bild/

- Goal is to accelerate the adoption and implementation of decentralized water systems while protecting public health
  - Develop a road map that drives us towards that goal
- Broad participation from product manufacturers, utilities, public health regulators, designers, codes & standards orgs, academia, research orgs, international orgs, and NGOs
- 4 working groups formed: Public Health, Sustainable Technology/Innovation, Capacity Development, and Communications
- Applicable scales – appliance, single-family home, building, and district/campus
- Applicable types of DWS - residential, commercial, and industrial



"Size matters not. Look at me. Judge me by my size, do you? Hmm? Hmm. And well you should not"

Yoda

EPA

Impact

- Collaborations with key stakeholder groups
  - New Mexico Produced Water Research Consortium
  - National Blue-Ribbon Commission for Onsite Water Systems
- Partnerships with industry
  - CRADAs: Tyson Foods, WaterGen
  - Produced water: NGL, PWR, Exxon
- State technical support
  - CA, CO, ID, KS, MN, NM, OH, WA
- Working with code agencies
  - IAPMO, NSF, ARCSA

National Blue Ribbon Commission for Onsite Water Systems

NM STATE NEW MEXICO PRODUCED WATER RESEARCH CONSORTIUM

PWR

ExxonMobil

watergen

mn DEPARTMENT OF HEALTH

NGL Energy Partners LP

Ohio Environmental Protection Agency

Kansas Department of Health and Environment

Idaho Department of Environmental Quality

NSF

Washington State Department of HEALTH

California Water Boards | State Water Resources Control Board

ARCSA International

IAPMO

COLORADO Department of Public Health & Environment (CDPHE)

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Thank You
Jay and Michael!

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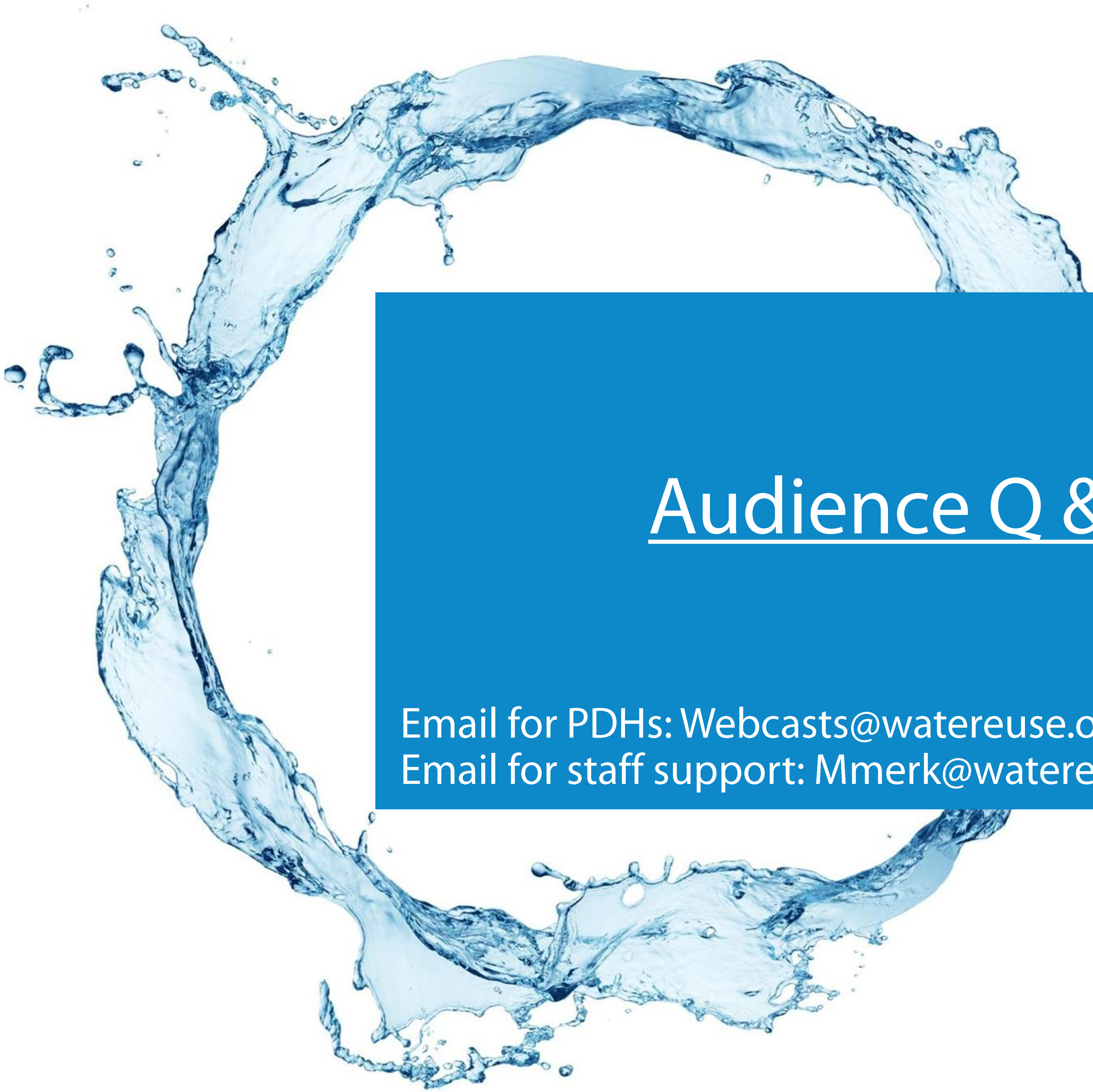

Audience Q & A

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