LRT Updates: 2022 Update Using DALY Benchmark

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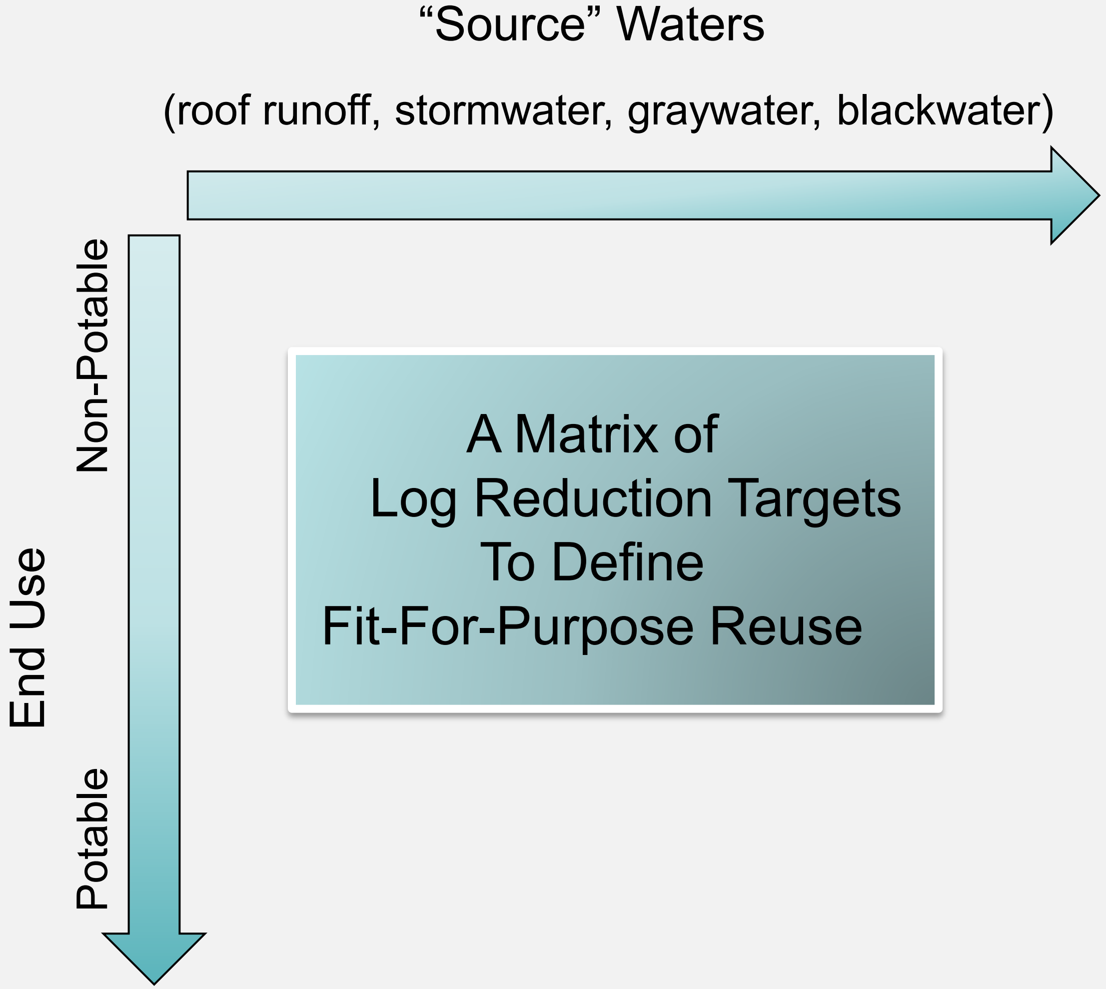
The Projected Path

- New data/knowledge, and the presence of alternative treatment targets (LRTs), suggests that the NBRC should develop an updated recommendation document
  - Continue our role in providing clear and defensible guidance to interested stakeholders across the nation
- EPA ORD has drafted an updated set of LRTs based on our synthesis of the current state of the science
  - Present to NBRC in Sept to get initial feedback
- Finalize this new LRT table and develop related information for an updated NBRC guidance document
  - Document to include
    - LRT tables
    - Potential treatment trains for different alternatives waters
    - Critical control points and associated monitoring guidance
  - Projected completion by end of 2022
    - Correspond to submittal of new LRT table for peer-reviewed publication
- Have overall document undergo external peer review prior to official release in March 2023
  - Virtual panel, preferably of new experts not utilized in the 2017 panel or the CA 2021 effort

Quantitative Microbial Risk Assessment



LRT "State of the Science"

- There were two sets of LRTs for onsite non-potable water systems
  - –2017 WE&RF guidance (and subsequent work by EPA-ORD)
  - –2021 CA review and update

	2017 Guidance	2021 Update*
Onsite Sewage/Blackwater	Scale-based simulation/fecal contamination model	Municipal dataset (DPR-2)
Graywater	Scale-based simulation/fecal contamination model	Dilution of municipal sewage (DPR-2)
Stormwater	Dilution of municipal sewage (literature review)	Dilution of municipal sewage (DPR-2)
Roof runoff	Animal contamination model; bacteria only	Measurement dataset (Alja'fari et al.); protozoa only
Viral Reference pathogens	*Norovirus lower bound*	Adenoviruses

- Neither considered the health burden from infection

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LRT "State of the Science"

- Propose
  - Update 2017 LRTs
    - Pathogen density: municipal wastewater
    - Dose-response relationships: Norovirus and Campylobacter
    - Switch from infection to health burden benchmark
- Annual Health Burden Benchmark
  - 10^{-6} DALYs (Disability Adjusted Life Years) ppy
  - The sum of years of life lost by premature mortality and years lived with disability
  - WHO benchmark for water reuse and drinking water
  - Allows comparison across hazards

DALYs allow comparison across hazards

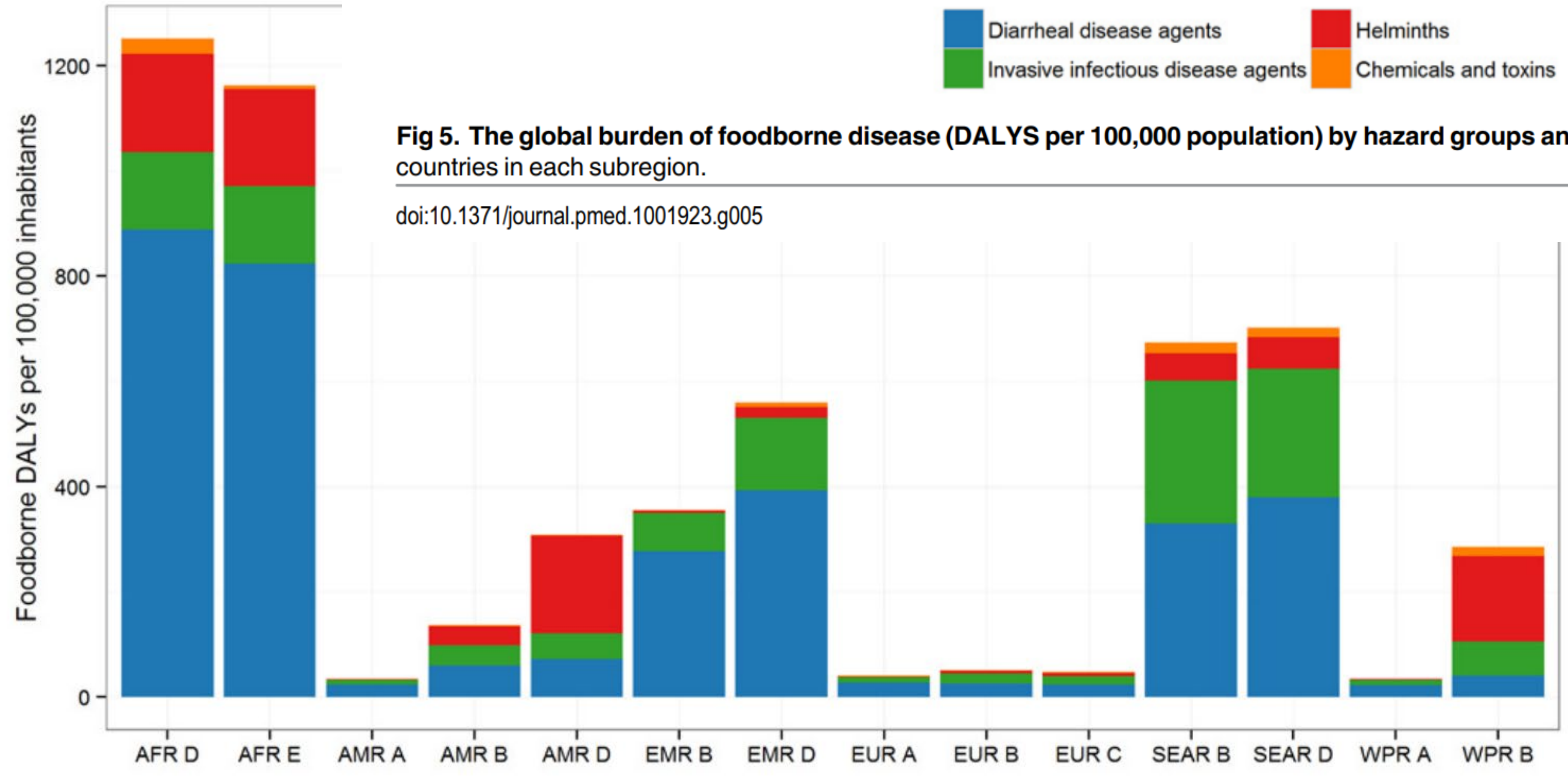

Fig 5. The global burden of foodborne disease (DALYS per 100,000 population) by hazard groups and by subregion for 2010. countries in each subregion.

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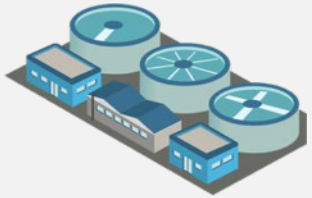
LRT Calculation – What changed?

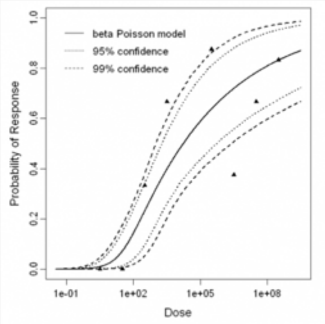

Source Water Pathogen Concentrations


Treatment


Concentration in treated water


Exposure Types & Volumes


Exposure



Dose-response

years lost by premature mortality and years lived with disability

DALY per case illness



Health Burden

Same

Same exposure assumptions

Changes

New LRTs developed

Updated Municipal Wastewater

Updated dose-response assumptions

Updated Goal: 10^{-6} annual DALY

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Update Municipal Wastewater Pathogen Density

Pathogen	Source	Unit	log10 transformed concentration #/L	Reference
Norovirus GII	WW	genome copies	N(4.7,1.5)	Eftim et al. 2018
Cryptosporidium	WW	oocysts	U(-0.5, 4.38)	Soller et al. 2017, 2018; Madore et al. 1987; Yang et al., 2015; Crockett et al., 2007; Nasser et al., 2015; Robertson et al., 2006; Pecson et al., 2022)
Giardia	WW	cysts	U(0.5, 5.0)	Soller et al. 2017, 2018, Walls et al., 1996; Sykora et al, 1991; Harwood et al., 2005 Pecson et al., 2022)
Campylobacter	WW	MPN	U(2.95, 4.6)	No change
Salmonella	WW	MPN	U(0.48, 7.38)	Soller et al., 2017, 2018; Bonadonna et al., 2002; Lemarchand and Lebaron, 2003; Jimenez-Cisneros et. al, 2001

Dose-Response Assumptions

Reference Pathogen	Endpoint	Distributional Form	Parameter	Parameter Values	Reference	Daly/case	Reference
Norovirus GI SE+	Infection Illness	Hypergeometric $1-(1+dose/\eta)^{-r}$	α β r η	0.393 0.767 3.19 0.801	Teunis et al., (2020)	(0.001, 0.002,0.003)	Havelaar 2015
Cryptosporidium spp.	Infection	Exponential	R	0.09	U.S. EPA, 2006	(0.002, 0.006, 0.02)	Havelaar 2015
	Illness	Fractional Poisson	P	0.737	Messner and Berger, 2016		
		Point		U(0.3, 0.7)	U.S. EPA, 2006		

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Dose-Response Assumptions

Reference Pathogen	Endpoint	Distributional Form	Parameter	Parameter Values	Reference	Daly/case	Reference
Giardia lamblia	Infection	Exponential	R	0.0199	Rose and Gerba, 1991	0.003	RIVM 2019
	Illness	Point		U(0.2, 0.7)	Eisenberg et al., 1996		
Campylobacter jejuni	Infection	Hypergeometric[a]	α β	0.44 0.51	Teunis et al., (2018)	(0.02, 0.03, 0.05)	Havelaar 2015
	Illness (challenge)	$1-(1+dose/\eta)^{-r}$	r η	0.06 0.88			
Salmonella enterica	Infection	Beta-Poisson	α β	0.3126 2884	Haas et al., 1999; Fazil, 1996	(0.02, 0.03,0.05)	Havelaar 2015
	Illness	Point		U(0.17,0.4)	Teunis et al., 1999		

Comparison of Results

Water Use Scenario	Human Enteric Viruses				Parasitic Protozoa				Enteric Bacteria			
	2021 Inf	2017 Inf	2022 Inf	2022 DALYs	2021 Inf	2017 Inf	2022 Inf	2022 DALYs	2021 Inf	2017 Inf	2022 Inf	2022 DALYs
Untreated onsite wastewater												
Unrestricted irrigation	7.5	10.5/8.0	10.4	8.4	5.5	7.0	7.0	6.6	n.d. [c]	6.0	7.5	5.3
Indoor use	8.0	11.2/8.5	11.1	9.7	6.5	7.0	7.0	6.5	n.d. [c]	6.0	7.5	5.6
Graywater												
Unrestricted irrigation	5.5	8.4/5.5	8.3	6.4	3.5	4.5	4.5	4.2	n.d. [c]	3.5	5.1	2.9
Indoor use	6.0	8.8/6.0	8.7	7.3	4.5	4.5	4.5	4.2	n.d. [c]	3.5	5.1	3.2
Stormwater (10% wastewater contribution)												
Unrestricted irrigation	6.5	8.0/5.0	9.0	7.1	4.5	4.5	5.1	4.9	n.d. [c]	4.0	5.5	4.2
Indoor use	7.0	8.3/5.5	9.2	7.7	5.5	5.5	6.4	6.0	n.d. [c]	5.0	6.5	5.4
Stormwater (0.1% wastewater contribution)												
Unrestricted irrigation	4.5	6.0/3.0	7.0	5.1	2.5	2.5	3.1	2.9	n.d. [c]	2.0	3.5	2.2
Indoor use	5.0	6.2/3.5	7.2	5.7	3.5	3.5	4.4	4.0	n.d. [c]	3.0	4.5	3.4
Stormwater (0.01% wastewater contribution)												
Unrestricted irrigation	n.d.	n.d.	6.0	4.1	n.d.	n.d.	2.1	1.9	n.d.	n.d.	3.5	1.2
Indoor use	n.d.	n.d.	6.2	4.7	n.d.	n.d.	3.4	3.0	n.d.	n.d.	2.5	2.4
Roof Runoff Water												
Unrestricted irrigation	n/a [a]	n/a [a]	n/a [a]	n/a [a]	1.0	n.d. [b]	1.0	0.4	1.0 [d]	3.5	4.6	3.5
Indoor use	n/a [a]	n/a [a]	n/a [a]	n/a [a]	1.5	n.d. [b]	1.5	1.0	1.5 [d]	3.5	4.8	3.5

2022 Red LRT estimates have not been rounded as done in the previous 2017 and 2021 guidance documents

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Comparison of Results: Viruses

Water Use Scenario	Human Enteric Viruses			
	2021 Inf	2017 Inf	2022 Inf	2022 DALYs
Untreated onsite wastewater		Norovirus		
Unrestricted irrigation	7.5	10.5/8.0	10.4	8.4
Indoor use	8.0	11.2/8.5	11.1	9.7
Graywater				
Unrestricted irrigation	5.5	8.4/5.5	8.3	6.4
Indoor use	6.0	8.8/6.0	8.7	7.3
Stormwater (10% wastewater contribution)				
Unrestricted irrigation	6.5	8.0/5.0	9.0	7.1
Indoor use	7.0	8.3/5.5	9.2	7.7
Stormwater (0.1% wastewater contribution)				
Unrestricted irrigation	4.5	6.0/3.0	7.0	5.1
Indoor use	5.0	6.2/3.5	7.2	5.7
Stormwater (0.01% wastewater contribution)				
Unrestricted irrigation	n.d.	n.d.	6.0	4.1
Indoor use	n.d.	n.d.	6.2	4.7
Roof Runoff Water				
Unrestricted irrigation	n/a [a]	n/a [a]	n/a [a]	n/a [a]
Indoor use	n/a [a]	n/a [a]	n/a [a]	n/a [a]

Upper/lower bound estimates; n.d. not determined; n/a not applicable;

Changes

2022 changes to LRT using infection benchmark:
- Onsite WW/GW: updated Norovirus dose-response
- Stormwater: updated Norovirus dose-response and density in municipal wastewater

2022 additions to calculate LRT using DALY benchmark:
- Probability of illness given infection
- DALY per case of illness

Results

- 2022 LRTs using DALY benchmark are greater than proposed 2017/2021 LRTs using infection benchmark
- 2022 LRTs using infection benchmark for GW/WW roughly equal the 2017 “upper bound” Norovirus estimates
- 2022 LRTs using DALY benchmark are 1.5-2 log10 less than 2022 LRTs using infection benchmark

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Comparison of Results: Protozoa

Water Use Scenario	Parasitic Protozoa			
	2021 Inf	2017 Inf	2022 Inf	2022 DALYs
Untreated onsite wastewater	Cryptosporidium			
Unrestricted irrigation	5.5	7.0	7.0	6.6
Indoor use	6.5	7.0	7.0	6.5
Graywater				
Unrestricted irrigation	3.5	4.5	4.5	4.2
Indoor use	4.5	4.5	4.5	4.2
Stormwater (10% wastewater contribution)				
Unrestricted irrigation	4.5	4.5	5.1	4.9
Indoor use	5.5	5.5	6.4	6.0
Stormwater (0.1% wastewater contribution)				
Unrestricted irrigation	2.5	2.5	3.1	2.9
Indoor use	3.5	3.5	4.4	4.0
Stormwater (0.01% wastewater contribution)				
Unrestricted irrigation	n.d.	n.d.	2.1	1.9
Indoor use	n.d.	n.d.	3.4	3.0
Roof Runoff Water	Giardia			
Unrestricted irrigation	1.0	n.d. [b]	1.0	0.4
Indoor use	1.5	n.d. [b]	1.5	1.0

n.d. not determined

Changes

2022 changes to LRT using infection benchmark:

- Onsite WW/GW: None
- Stormwater: Cryptosporidium density
- Roof Runoff: None

2022 additions to calculate LRT using DALY benchmark:

- Probability of illness given infection
- DALY per case of illness

Summary

- 2022 LRTs using DALY benchmark are similar to the 2017/2021 LRTs
- 2022 LRTs using the infection benchmark for stormwater are greater than 2017 LRTs
- 2022 LRTs using DALY benchmark for Crypto are roughly 0.3 log10 less than 2022 LRTs using infection benchmark

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Comparison of Results: Bacteria

Water Use Scenario	Enteric Bacteria			
	2021 Inf	2017 Inf	2022 Inf	2022 DALYs
Untreated onsite wastewater	Campylobacter			
Unrestricted irrigation	n.d. [c]	6.0	7.5	5.3
Indoor use	n.d. [c]	6.0	7.5	5.6
Graywater				
Unrestricted irrigation	n.d. [c]	3.5	5.1	2.9
Indoor use	n.d. [c]	3.5	5.1	3.2
Stormwater (10% wastewater contribution)				
Unrestricted irrigation	n.d. [c]	4.0	5.5	4.2
Indoor use	n.d. [c]	5.0	6.5	5.4
Stormwater (0.1% wastewater contribution)				
Unrestricted irrigation	n.d. [c]	2.0	3.5	2.2
Indoor use	n.d. [c]	3.0	4.5	3.4
Stormwater (0.01% wastewater contribution)				
Unrestricted irrigation	n.d.	n.d.	3.5	1.2
Indoor use	n.d.	n.d.	2.5	2.4
Roof Runoff Water		Salmonella		Salmonella
Unrestricted irrigation	1.0 [d]	3.5	4.6	3.5
Indoor use	1.5 [d]	3.5	4.8	3.5

n.d. not determined

Changes

2022 changes to LRT using infection benchmark:

- Onsite WW/GW: Campylobacter dose-response
- Stormwater: Campylobacter dose-response
- Roof Runoff: Campylobacter dose-response

2022 additions to calculate LRT using DALY benchmark:

- Probability of illness given infection
- DALY per case of illness

Results

- 2022 LRTs using DALY benchmark for
  - WW/GW are less than
  - stormwater are greater than
  - roof runoff are equal to

  the 2017 LRTs using infection benchmark
- 2022 LRTs using the infection benchmark for Campy are greater than 2017 LRTs using infection benchmark
- 2022 LRTs using DALY benchmark for Campy are ~ 2 log10 less than 2022 LRTs using infection benchmark

Take Home Messages

- Risk-based framework is transparent and adaptable to new data and different assumptions. 2022 changes include:
  - Updated municipal sewage pathogen concentrations
  - Updated dose-response relationships for Norovirus and Campylobacter
  - Recommend 10^{-6} ppy DALY benchmark
    - Focus on illness and disease burden
    - Compare to other hazards like chemicals
- Recommend Norovirus as viral reference hazard using updated dose-response

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Take Home Messages

- Despite different assumptions, 2022 LRTs using the DALY benchmark are similar to what was previously proposed, with the exception of increased viral LRTs for stormwater
- Previous data gaps remain for characterizing pathogens in roof runoff
- New data gaps identified, such as characterizing probability of illness given infection for Salmonella.

Moving Towards a New LRT Table

- **Use estimates based on most recent science**
  - –pathogen characterization, dose response, exposure volumes
- **Move to a more impact focused, comparable health benchmark**
  - –DALYS vs infections

    In other words, the last column in the previous tables

- **Develop different classifications for stormwater risk**
  - –Normal or low (verified) levels of human fecal contamination

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The objective of this project is to synthesize existing research on stormwater microbial quality and treatment processes to provide pragmatic guidance for design and operation of stormwater use systems.

THE Water Research FOUNDATION

Stormwater Capture and Use Roadmap

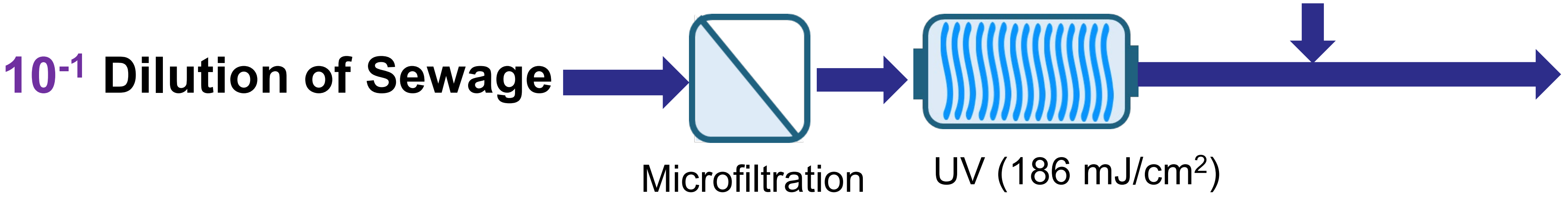
GUIDANCE FOR SELECTION OF LRTS FOR SCU

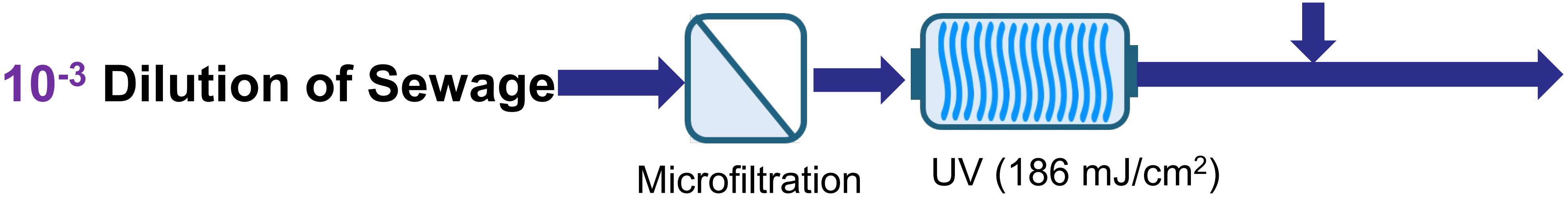
Because there do not exist adequate predictors of stormwater quality, monitoring is needed to justify selection of LRTs based on 10^{-4} HFCA (Human Fecal Contamination Analog)

– 10^{-4} HFCA enables more typical SCU system (microfiltration + UV)

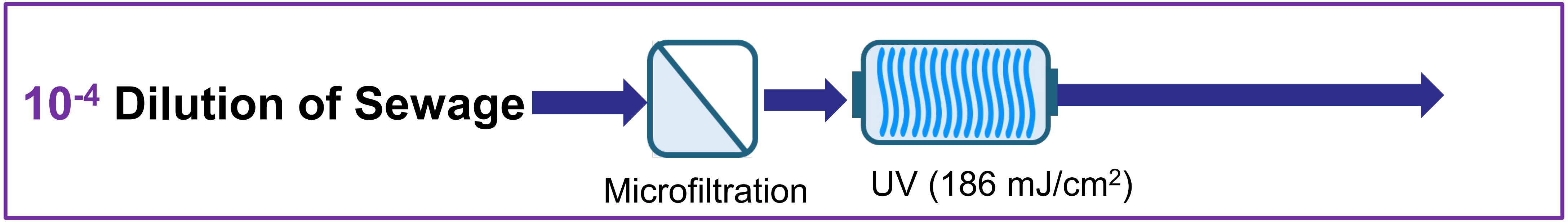
Option 1	Option 2
• Select LRTs and treatment process train based on 10^{-1} dilution of sewage in stormwater	• Monitor for Human MST markers (10^{4} threshold) for treatment consistent with 10^{-4} sewage dilution (discussed in MST breakout session)

SCU Treatment:
Unrestricted Irrigation and Indoor Use





10^{-4} dilution of sewage is where complexity of design decreases



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Next Steps

- Following today's discussion, review the presentation as needed
  - And please feel free to reach out with questions
- A draft table of LRTs will be provided to the NBRC by the end of October
- The NRBC will be reconvened (virtual) sometime in November to reach consensus on new table of LRTs
- The final draft of the guidance document will be circulated for comment before the end of the year to get input prior to the external peer review mentioned earlier
  - Virtual meeting in January to finalize

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Thank you – Questions?