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NATIONAL BLUE RIBBON COMMISSION FOR ONSITE NON-POTABLE WATER SYSTEMS

Health Risk-based Benchmarks for Onsite Treatment of Water

National Blue Ribbon Commission for Onsite Non-potable Water Systems

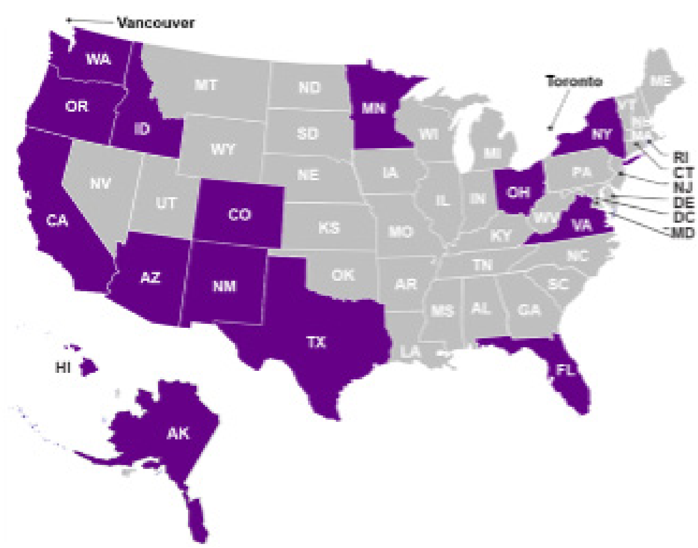
CONTENTS

Emory University in Atlanta, Georgia incorporates a blackwater water treatment system to produce water for toilet flushing and make up water for cooling towers and boilers (image courtesy of Sustainable Water).

INTRODUCTION

The National Blue Ribbon Commission for Onsite Non-potable Water Systems (NBRC) advances best management practices to support the use of onsite water treatment systems for non-potable water end uses within single or multiple buildings. The NBRC is committed to protecting public health and the environment, and sustainably managing water, now and for future generations.

The NBRC builds upon years of work started in 2012 by several municipalities, water utilities, public health officials, the Water Environment & Reuse Foundation, the Water Research Foundation, and the US Water Alliance. At the White House Water Summit in 2016, the NBRC announced its commitment to accelerate the development of onsite non-potable water systems (ONWS) to treat and reuse alternative water sources, including blackwater (onsite wastewater), graywater, rainwater and stormwater for non-potable uses such as toilet flushing and irrigation.

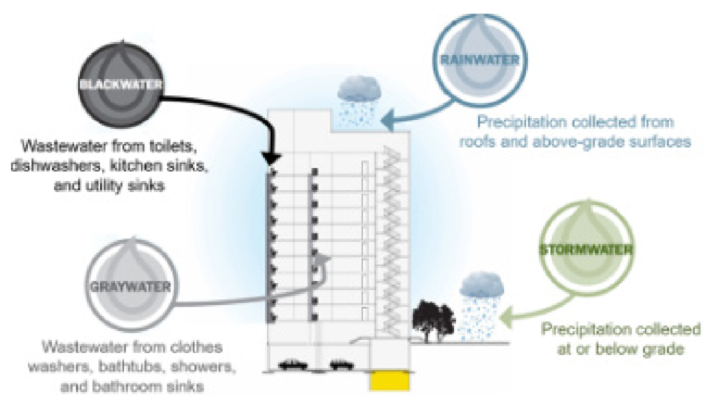


Map of states participating in the NBRC.
More information on the NBRC is available at: *watereuse.org/nbrc*.

Today, the NBRC is comprised of representatives from municipalities, water utilities and public health agencies from 15 states, the District of Columbia, US EPA, US Army Engineer Research and Development Center, the city of Vancouver, and the city of Toronto. The NBRC is convened by the WateReuse Association and chaired by the San Francisco Public Utilities Commission. The NBRC has made significant research contributions and developed technical resources as well as advanced policies and regulations for onsite water reuse.

This document outlines the current state of the science for determining the level of treatment required for ONWS. It includes four approaches to calculate the level of treatment required to achieve a health benchmark. The level of treatment is expressed as a log reduction target (LRT) and example treatment trains for ONWS that can achieve the LRTs are included.

The NBRC embraces a risk-based framework to ONWS by addressing not only LRTs and appropriate treatment trains, but critical control point monitoring, permitting, and oversight and management. For utilities and state and local regulators looking to implement ONWS programs, this document provides examples of actions being taken by communities advancing onsite reuse.



Collection and Treatment of Water Onsite for Non-potable Reuse in Buildings and Districts

Onsite non-potable water system is defined as a system in which water from local sources is collected, treated, and used for non-potable uses at the building - to district/neighborhood-scale at a location near the point of generation.

The New School in New York City, NY reuses blackwater for toilet flushing, cooling tower make-up, irrigation, and clothes washing (image courtesy of NSU).

NBRC Guiding Principles

1. **Protect public health.**
   In order to secure a sustainable water future, we need diverse approaches to water management. In all of the work we do, we are committed to protecting public health and ensuring safe, secure, and reliable water use and reuse.
2. **Develop science-based policy.**
   As the NBRC develops policy recommendations and guidance, it will be driven by risk-based science and research.
3. **Utilize a consensus-based approach.**
   If we align our diverse experiences and expertise, we can achieve the best outcomes. The NBRC will seek consensus across all of the work we do together.
4. **Integrate best practices.**
   The work of the NBRC is informed by the best practices in the management, operations, and oversight of onsite non-potable water systems.
5. **Honor local context.**
   The NBRC sees great value in the development of policy and business models to support the effective adoption of ONWS. At the same time, the NBRC recognizes and respects that policy and program implementation will vary based on needs and context at the local and state level.
6. **Commit to continuous learning.**
   As the adoption of ONWS is evolving, the commission is committed to staying abreast of new science and new approaches. We are inclusive of input from interested stakeholders as we learn together.

Protecting Public Health

One of the most challenging aspects of ONWS is to ensure the appropriate water quality to protect public health. In 2017, the NBRC's landmark report Risk-based Framework for the Development of Public Health Guidance for Decentralized Non-potable Water Systems established a scale-appropriate, risk-based framework for defining and monitoring ONWS treatment systems.

Using Quantitative Microbial Risk Assessment (QMRA), the 2017 report centered on risk-based LRTs for the treatment of pathogens including viruses, protozoa, and bacteria. With the report, the NBRC reached consensus to develop an LRT table for a variety of alternative water sources (using an infection-based benchmark), including combined wastewater or blackwater, graywater, rainwater and stormwater for indoor and outdoor non-potable end uses.

In 2017, the NBRC reached consensus and developed an LRT table for a variety of alternative water sources, including blackwater, graywater, rainwater and stormwater for indoor and outdoor non-potable end uses. The 2017 LRT table has been referenced by communities across the United States.

The recommended standard for pathogen removal and/or inactivation is to require a treatment train in which unit processes are collectively credited to meet selected LRTs. During operation, the performance of each treatment process is continuously monitored using microbial, chemical, or physical indicator(s) or surrogate parameter(s) that verify their ability to achieve the credited pathogen removal and/or inactivation. Along with treatment processes needed for sufficient log reduction credits, other treatment goals include the reduction of organics, particulates, and nutrients and the need to deliver aesthetically acceptable water. In addition to establishing LRTs and monitoring requirements, the health risk-based framework includes establishing structures for ongoing regulatory oversight to ensure compliance of ONWS.

The health risk-based framework represents a significant shift from the typical end-point fecal indicator bacteria monitoring approach common in the United States to determine whether water is suitable for drinking, swimming, or other recreational uses with respect to the risk of infection from microbial contaminants (virus, protozoa, or bacteria).

Denver Water collects and treats 100% of its blackwater for toilet flushing (image courtesy of Denver Water).

Four Different Sets of LRTs

Since 2017, the health risk-based approach has been used to generate four different sets of LTs. While all four efforts used a risk-based approach and are scientifically defensible, their differences in assumptions can result in different LRTs for the same end uses. To date, there is no scientific consensus on which approach to making assumptions is “best”. The four risk-based sets of LRTs available for ONWS are as follows:

1. The original LRT set developed in 2017 (“2017” herein)
2. An infection-based framework LRT set developed for the state of California in 2021 (“CA”)
3. An updated version of the 2017 LRT set developed in 2022 by the EPA Office of Research and Development to incorporate more recent data (“2022”)
4. An extension of the 2022 EPA Office of Research and Development approach using a DALY-based health benchmark to develop an LRT set (“DALY”)

A summary of the four approaches including the source water assumptions, reference pathogens, exposure and risk goals are presented in Table 1. Each recommendation was assembled by scientific experts and is supported by peer reviewed research.

Table 1. Summary of LRT Approaches

	2017 (1)	CA (2)	2022 (3)	DALY (4)
Source water assumptions				
Onsite Wastewater/ Blackwater	Modeled onsite blackwater	Municipal wastewater (DPR-2 dataset)	Modeled onsite blackwater (same as 2017)	
Graywater	Modeled graywater	Dilution of municipal wastewater (DPR-2 da-taset)	Modeled graywater (same as 2017)	
Stormwater	Dilution of municipal wastewater (literature re-view)	Dilution of municipal wastewater (DPR-2 da-taset)	Dilution of municipal wastewater (updated literature review)	
Roof runoff	Modeled roof runoff	Empirical dataset	Modeled roof runoff and new empirical data	
Reference pathogens				
Virus	Norovirus (lower bound dose-response) (adenovirus, rotavirus and norovirus upper bound also considered)	Adenovirus and enterovirus (norovirus also considered)	Norovirus (updated dose-response)	
Protozoa	Giardia and Cryptosporidium			
Bacteria	Campylobacter and Salmo-nella	N/A (Campylobacter and Salmonella considered)	Campylobacter (updated dose-response) and Salmonella	
Exposure				
	Based on Schoen et al. 2017	Based on Schoen et al. 2017 with new exposures for additional end uses	Based on Schoen et al. 2017	
Risk goal				
	10-4 infection pppy	10-4 infection pppy	10-4 infection pppy	10-6 DALY pppy

1: Sharvelle et al. 2017, Schoen et al. 2017
2: Olivieri et al. 2021, Pecson et al. 2022
3: Schoen et al 2023
4: Schoen et al 2023

Infection vs. DALY Health Benchmarks

Risk-based frameworks identify a health benchmark, such as an acceptable level of infections in a population and use that benchmark to calculate a level of treatment needed to achieve the goal. The most prominent works in the field of ONWS have utilized two benchmarks based on limiting either infections or disability adjusted life years (DALYs). Both the infection-based and DALY-based frameworks calculate the log reduction in treatment that is needed to meet a certain benchmark. The infection-based benchmark and DALY health benchmark are both considered to be protective of public health. A comparison of the two frameworks is presented in Table 2 and Figure 1.

The infection-based benchmark (on which the NBRC's 2017 recommendations were based) seeks to limit the number of infections in the exposed population to levels that are so low that they can be considered negligible. By preventing infections, it reduces the risk of illness for all populations including sensitive populations who may have worse outcomes from an illness (Macler and Regli 1993). During development of the Surface Water Treatment Rule (SWTR), the EPA assumed that a 1 in 10,000 probability of infection per person per year (pppy) would represent an acceptably low level of infection (Macler and Regli 1993, Regli et al. 1991). The 1 in 10,000 annual risk of infection has been used as a de facto or explicit benchmark for several state-level regulations.

The DALY-based benchmark looks not only at the level of infection, but the degree of human health impairment resulting from those infections. The DALY framework evaluates how microbial risks impact the quality and quantity of life. Because different infections can have different health outcomes, the DALY framework includes a metric to differentiate various health outcomes. These outcomes are quantified in terms of DALYs where one DALY is equivalent to one healthy year of life lost. DALYs are calculated by considering the years of life lost (YLL) and the years lived with a disability or illness (YLD). The WHO has defined the tolerable burden of disease with an upper limit of 10-6 DALY pppy for waterborne pathogens from drinking water. This is approximately equivalent to a 10-5 excess lifetime risk of cancer which is the risk level the WHO uses to determine guidelines for genotoxic carcinogens (WHO 2022).

49 South Van Ness is a City and County of San Francisco office building collecting and treating graywater for toilet flushing (image courtesy of SOM)

Figure 1. Comparison of Infection and DALY Health Benchmarks and their Goals for Limiting Infections or DALY-based Health Burden

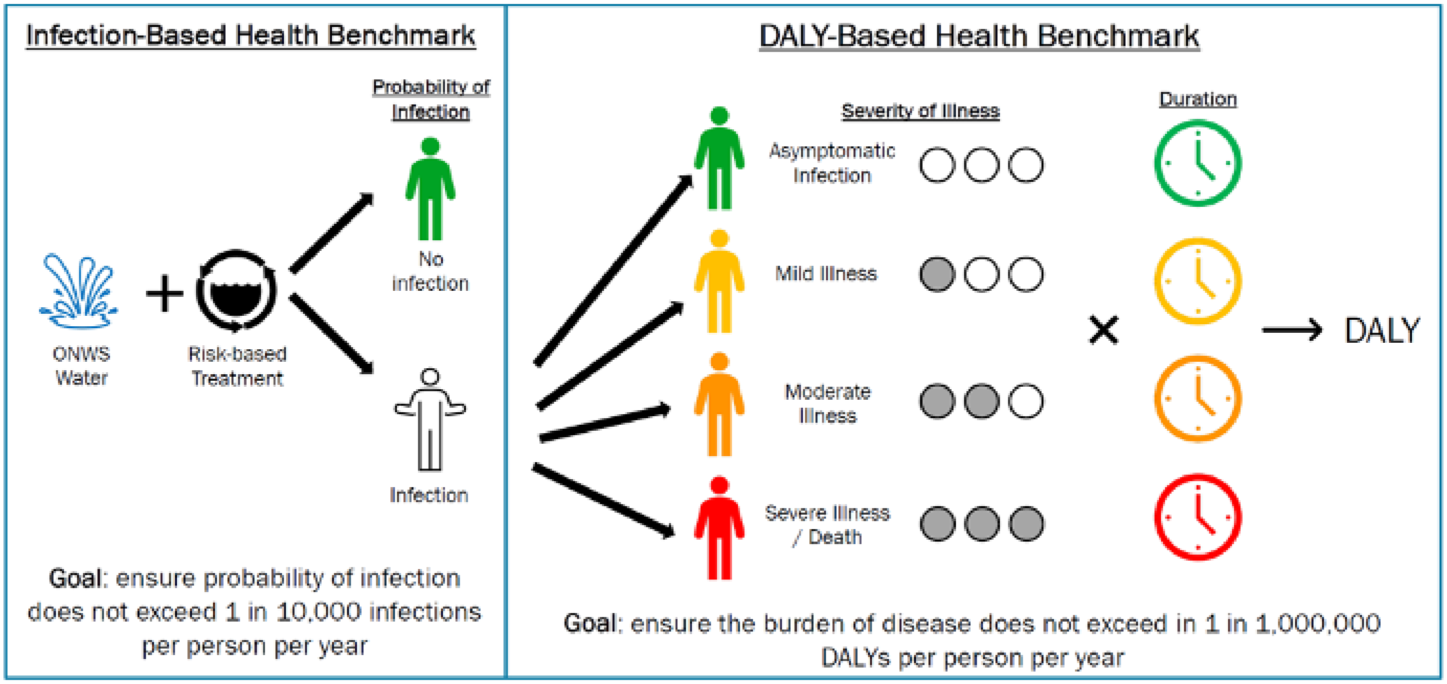


Table 2. Pros and Cons of Infection vs. DALY Health Benchmarks

Pros	Cons
Infection-based framework	
Conservative in that it manages both infection and illness from microbial contaminants	Different from risk framework used by WHO and several other countries
Risk framework underlying several state regulations and guidance documents on microbial risk	Does not account for differences in severity of illness from different pathogens
DALY-based framework	
Accounts for differences in likelihood and severity of illness from different pathogens given an infection occurs	Requires additional assumptions regarding disability weights and the likelihood of illness given infection
Used by several countries to set treatment requirements for drinking water and potable/non-potable reuse.	Requires additional assumptions regarding disability weights and the likelihood of illness given infection
Can be used to evaluate multiple contaminants of concern including different pathogens	Not consistent with risk framework used in some state regulations such as California's development of potable reuse criteria for microbial contaminants and Colorado's direct potable reuse framework.
Can be used to evaluate multiple contaminants of concern including different pathogens	

Assumptions for LRTs

For all source waters and both end uses (indoor use and unrestricted irrigation), the LRTs were consistent in approach (i.e. risk-based QMRA), yet different assumptions were used (Jahne, et al. 2023). The 2022 analysis results in higher LRTs for virus than the 2017 and CA efforts, owning to its use of updated dose-response data for norovirus. For protozoa, the different assumptions result in only a 1-log difference in LRTs. For bacteria, the 2022 analysis results in higher infection-based LRTs than the 2017 due to updated dose-response data for Campylobacter whereas DALY-based results were similar.

One important distinction with the California approach was the elimination of LRTs for pathogenic bacteria. The rationale for the removal of these LRTs was the assumption that the virus and protozoa requirements in conjunction with the California criteria for multibarrier treatment would provide a high degree of control over bacterial pathogens as well, making the bacterial LRTs unnecessary. This assumption is in line with existing regulatory approaches in California for both drinking water and potable reuse, as well as the US EPA's approach in the SWTR that focuses on "Giardia and viruses rather than bacteria because Giardia and viruses are more resistant to treatment" (EPA 1991, Regli et al. 1991). This assumption is supported by several studies showing that viruses are more resistant to treatments including free chlorine disinfection, ultraviolet light (UV) disinfection, and membrane bioreactors (MBR) (LeChevallier and Au 2004, WaterSecure 2017a, b).

It is also important to note that norovirus was used as the reference viral pathogen for all but the California approach, which used adenovirus as the reference viral pathogen. Norovirus is used as the reference pathogen for the 2017, DALY, and 2022 frameworks in part due to its epidemiological significance as the leading cause of viral acute gastroenteritis in the United States and globally. The selection of reference viral pathogens is significant because it impacts treatment design.

Indoor and Outdoor LRTs

A summary of the LRTs for indoor use is presented in Table 3 and a summary of the LRTs for unrestricted irrigation is presented in Table 4.

1550 Mission is a residential building in San Francisco. Graywater collection and treatment for toilet flushing and irrigation. (Image courtesy of Epic CleanTec).

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.

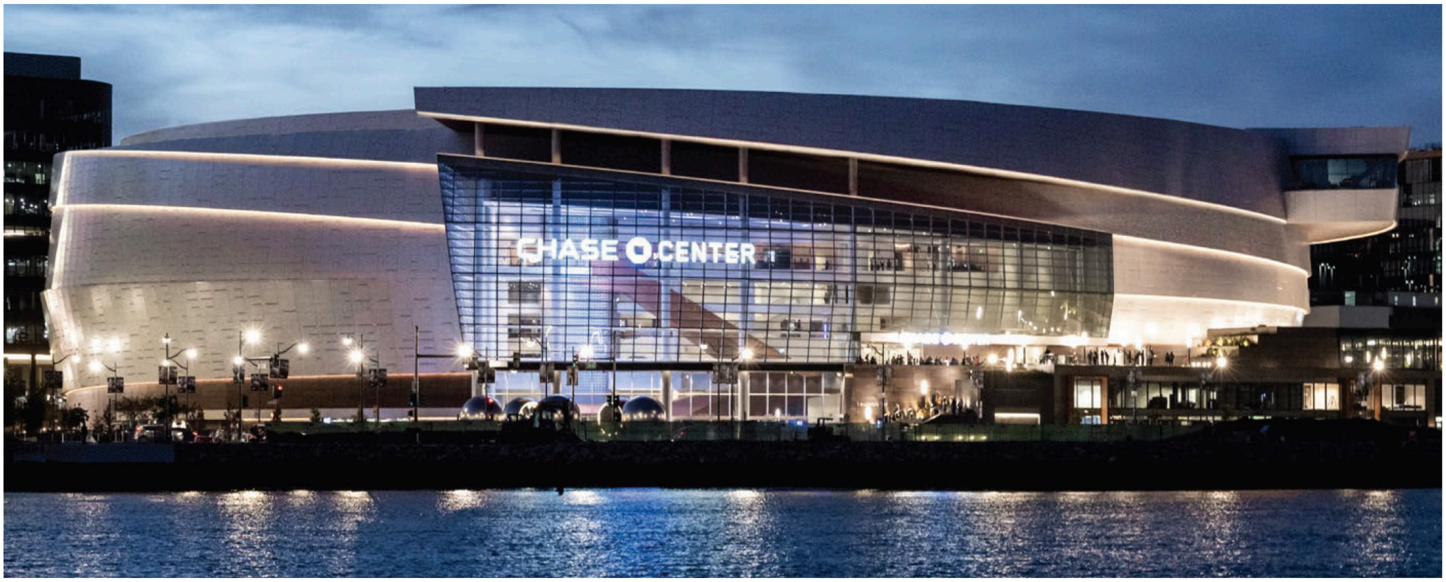
California Natural Resources Agency Headquarters in Sacramento, CA treats graywater for toilet flushing (image courtesy of HTEC).

Table 4. Unrestricted Irrigation 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	8.0	7.5	8.5	10.5	7.0	5.5	5.0	6.5	7.0	6.0	n/a	5.5	7.5
Graywater	5.5	5.5	6.5	8.5	4.5	3.5	3.0	4.0	4.5	3.5	n/a	3.0	5.5
Stormwater (10^{-1} dilution)	5.0	6.5	7.5	9.0	4.5	4.5	4.0	5.0	5.5	4.0	n/a	4.5	5.5
Stormwater (10^{-3} dilution)	3.0	n/a	5.5	7.0	2.5	n/a	n/a	3.0	3.5	2.0	n/a	2.5	3.5
Stormwater (10^{-4} dilution)	n/a	n/a	4.5	6.0	n/a	n/a	n/a	2.0	2.5	n/a	n/a	1.5	2.5
Roof Runoff	n/a	n/a	n/a	n/a	n/a	1.0	n/a	0.5	1.5	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.*

Installation of Underground Rainwater Storage Tank for irrigation of Allianz Field in St. Paul, MN (image courtesy of City of St. Paul).



Chase Center in San Francisco collects and treats graywater, rainwater, stormwater and condensate for toilet and urinal flushing and irrigation (image courtesy of Chase Center).

Example Treatment Trains to Achieve LRTs

Given the diversity of LRT results, it can be helpful to understand how the differences in LRT recommendations impact the level of treatment required. Example treatment trains capable of achieving the LRTs for the four risk-based frameworks are presented for systems treating onsite wastewater, graywater, roof runoff, and stormwater. These are examples and there are other treatment processes capable of achieving the LRTs. Professional engineers, local, and/or state regulators should be consulted on the design and installation of an ONWS that best satisfies local conditions and regulations.

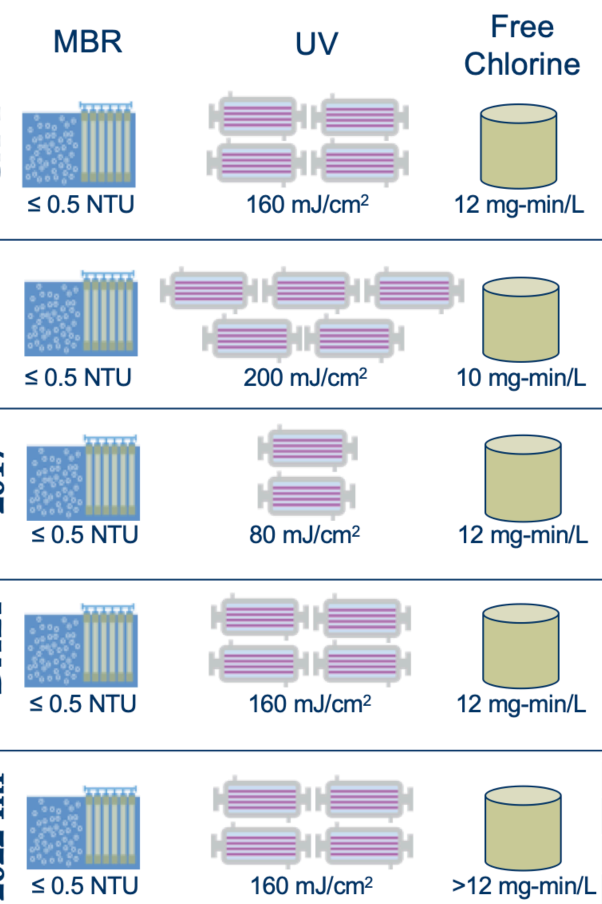
Note that while the virus LRTs for California are lower than those based on the 2022 assessment, the model trains require similar levels of treatment for onsite wastewater, graywater, and stormwater. This is due primarily to the difference in the reference virus: California is based on adenovirus, which belongs to a group of DNA viruses that are much more resistant to UV than norovirus. Consequently, the UV dose required to achieve 1-log inactivation of norovirus is approximately half of what is required for adenovirus. As a result, higher UV doses are required for treatment trains that must control for adenovirus compared to those controlling norovirus, even though the LRTs themselves are lower. This results in the California treatment trains being essentially equivalent to the 2022 DALY- and infection-based trains for these source waters.

For roof runoff, treatment to meet California LRTs is lower than the other frameworks due primarily to the absence of a bacterial LRT, which drives the treatment sizing for the 2017, 2022 Infection, and DALY frameworks. However, the CA assessment did consider bacterial targets in its analysis which, although not ultimately selected, were lower than the other models and are anticipated to be met by the treatment train shown.

In addition to treatment processes needed for log reduction credits, there are several other treatment goals for ONWS including the reduction of organics (e.g., BOD), particulates (e.g., turbidity), nutrients (e.g., ammonia), and the production of an aesthetically acceptable water. To achieve these goals, treatment systems often rely on the use of multiple different barriers including both filtration and disinfection.

Monitoring is another important consideration to ensure that the treatment processes are continuously meeting their performance goals. Frequently, treatment systems rely on surrogate monitoring, i.e., the measurement of different water quality parameters that are correlated to pathogen removal through the process. Monitoring surrogates are specific to each treatment process and are measured at high frequency (e.g., online or every 15 min) to ensure that the process remains within an operational window that has been demonstrated to achieve its credited LRTs.

Example Treatment Trains for Indoor Use of Onsite Wastewater/Blackwater



Train	Pathogens	LRV Achieved by Treatment Process: MBR	LRV Achieved by Treatment Process: UV	LRV Achieved by Treatment Process: 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

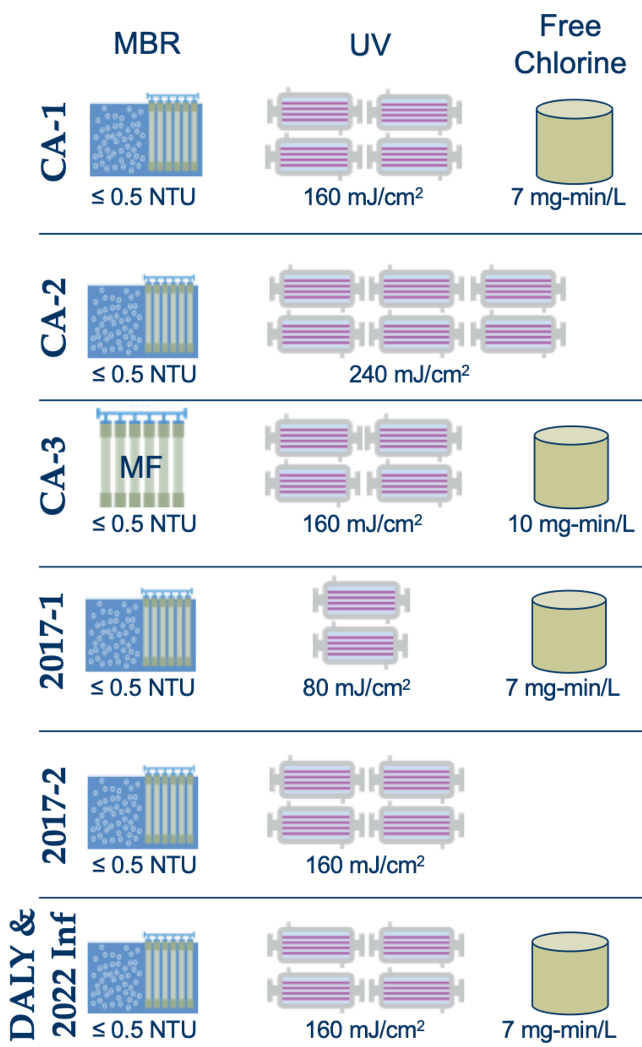
[a] Credit achieved using adenovirus as reference pathogen

[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/cm^2 UV reactor based on WaterVal

Example Treatment Trains for Indoor Use of Graywater



Pathogens	LRV Achieved by Treatment Process			Total LRV Achieved	LRV Required for Indoor Use
	MBR	UV	Free Cl_2		
Enteric Virus	1.0	3.0[a]	2.0	6.0	6.0
Giardia	2.5	6.0	--	8.5	4.5
Crypto	2.5	6.0	--	8.5	3.5
Bacteria	n/a	n/a	n/a	n/a	n/a
Enteric Virus	1.0	5.0[a]	--	6.0	6.0
Giardia	2.5	6.0	--	8.5	4.5
Crypto	2.5	6.0	--	8.5	3.5
Bacteria	n/a	n/a	n/a	n/a	n/a
Enteric Virus	--	3.0[a]	3.0	6.0	6.0
Giardia	--	6.0	--	6.0	4.5
Crypto	--	6.0	--	6.0	3.5
Bacteria	n/a	n/a	n/a	n/a	n/a
Enteric Virus	1.0	3.5[b]	2.0	6.5	6.0
Giardia	2.5	6.0	--	8.5	4.5
Crypto	2.5	6.0	--	8.5	4.5
Bacteria	4.0	6.0[d]	2.0	12	3.5
Enteric Virus	1.0	6.0[b]	--	7.0	6.0
Giardia	2.5	6.0	--	8.5	4.5
Crypto	2.5	6.0	--	8.5	4.5
Bacteria	4.0	6.0	--	10.0	3.5
Enteric Virus	1.0	6.0[b]	2.0	9.0	7.5 / 9.0[c]
Giardia	2.5	6.0	--	8.5	4.0 / 4.5[c]
Crypto	2.5	6.0	--	8.5	4.0 / 4.5[c]
Bacteria	4.0	6.0	2.0	12.0	3.5 / 5.5[c]

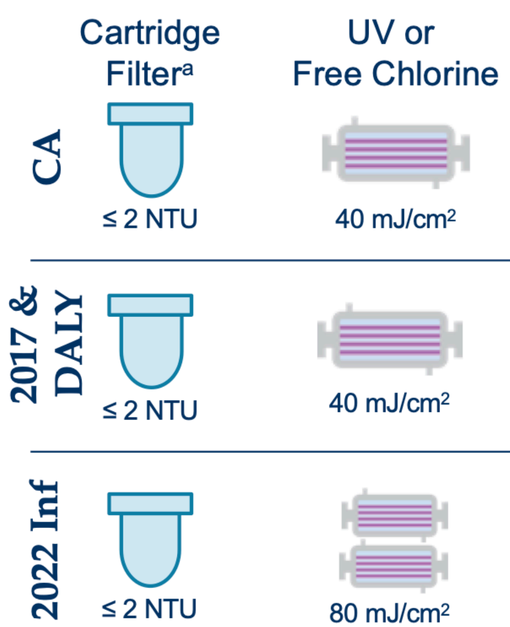
[a] Credit achieved using adenovirus as reference pathogen

[b] Credit achieved using norovirus as reference pathogen

[c] LRVs listed as DALY/2022 Inf

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

Example Treatment Trains for Indoor Use of Roof Runoff



Pathogens	LRV Achieved by Treatment Process			Total LRV Achieved	LRV Required for Indoor Use
	CF	UV	Free Cl_2		
Enteric Virus	--	--	--	--	n/a
Giardia	--	3.5	--	3.5	1.5
Crypto	--	3.5	--	3.5	n/a
Bacteria	n/a	n/a	n/a	n/a	n/a
Enteric Virus	n/a	n/a	n/a	n/a	n/a
Giardia	--	3.5	--	3.5	n/a / 1.0[b]
Crypto	--	3.5	--	3.5	n/a / 1.0[b]
Bacteria	--	3.5	--	3.5	3.5 / 3.5[b]
Enteric Virus	n/a	n/a	n/a	n/a	n/a
Giardia	--	6.0	--	6.0	2.0
Crypto	--	6.0	--	6.0	2.0
Bacteria	--	6.0[c]	--	6.0	5.0

[a] Cartridge filter or other filtration may be required to meet influent turbidity requirements for pathogon crediting: 24-hr average of ≤ 2 NTU, ≤ 5 NTU 95% of the time, and always < 10 NTU.

[b] LRVs listed as 2017/DALY

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

Example Treatment Trains for Indoor Use of Stormwater (10% Wastewater Contribution)

Train	MBR or MF	UV	Free Chlorine	Pathogens	LRV Achieved by Treatment Process: MBR/MF	LRV Achieved by Treatment Process: UV	LRV Achieved by Treatment Process: Free Cl_2	Total LRV Achieved	LRV Required for Indoor Use
CA-1	MBR ≤ 0.5 NTU	120 mJ/cm²	16 mg-min/L	Enteric Virus	1.0	2.0[a]	4.0	7.0	7.0
				Giardia	2.5	6.0	--	8.5	5.5
				Crypto	2.5	6.0	--	8.5	4.5
				Bacteria	n/a	n/a	n/a	n/a	n/a
CA-2[d]	MBR ≤ 0.5 NTU	160 mJ/cm²	13 mg-min/L	Enteric Virus	1.0	3.0[a]	3.0	7.0	7.0
				Giardia	2.5	6.0	--	8.5	5.5
				Crypto	2.5	6.0	--	8.5	4.5
				Bacteria	n/a	n/a	n/a	n/a	n/a
2017 & DALY	MBR ≤ 0.5 NTU	80 mJ/cm²	12 mg-min/L	Enteric Virus	1.0	3.5[b]	4.0	8.5	5.5 / 8.0[c]
				Giardia	2.5	6.0	--	8.5	5.5 / 6.0[c]
				Crypto	2.5	6.0	--	8.5	5.5 / 6.0[c]
				Bacteria	4.0	6.0[e]	4.0	14	5.0 / 5.5[c]
2022 Inf	MBR ≤ 0.5 NTU	160 mJ/cm²	12 mg-min/L	Enteric Virus	1.0	6.0[b]	4.0	11.0	9.5
				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	6.5
2017	MF ≤ 0.5 NTU	160 mJ/cm²		Enteric Virus	--	6.0[b]	--	6.0	5.5
				Giardia	--	6.0	--	6.0	5.5
				Crypto	--	6.0	--	6.0	5.5
				Bacteria	--	6.0	--	6.0	5.0
DALY	MF ≤ 0.5 NTU	160 mJ/cm²	7 mg-min/L	Enteric Virus	--	6.0[b]	2.0	8.0	8.0
				Giardia	--	6.0	--	6.0	6.0
				Crypto	--	6.0	--	6.0	6.0
				Bacteria	--	6.0	2.0	8.0	5.5
2022 Inf	MF Validated	160 mJ/cm²	12 mg-min/L	Enteric Virus	--	6.0[b]	4.0	10.0	9.5
				Giardia	4.0	6.0	--	10.0	6.5
				Crypto	4.0	6.0	--	10.0	6.5
				Bacteria	--	6.0	4.0	10.0	6.5

[a] Credit achieved using adenovirus as reference pathogen

[b] Credit achieved using norovirus as reference pathogen

[c] LRVs listed as 2017/DALY

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

[e] Assumes 3-4 LRV bacterial credit per 40 mJ/cm^2 UV reactor based on WaterVal

States Proceeding with LRTs

In line with the NBRC's guiding principle of honoring local context, some states such as Colorado, California and Washington are proceeding with LRTs that have slight variations. The NBRC recognizes and respects that policy and program implementation will vary based on needs and context at the local and state level. While there may be differences in regulatory perspectives and risk assumptions, it is important to acknowledge that the approaches are each guided by risk-based science. Additional states and jurisdictions are currently preparing or have adopted guidance including, San Francisco, Austin, TX, New York City, Minnesota, Hawaii, Texas, Arizona, New Mexico and Washington, D.C.

Colorado:
Colorado is a leader and early adopter of progressive regulations to promote water reuse. Colorado was the first state to modify its blackwater regulations (Regulation 84) following the publication of the NBRC's report Risk-based Framework for the Development of Public Health Guidance for Decentralized Non-potable Water Systems to incorporate the 2017 LRTs. The 2017 LRTs are based on the same overall framework as Colorado's regulations for direct potable reuse, allowing the requirements to be compared easily and understood by technical and non-technical stakeholders alike. Furthermore, the infection-based approach for risk characterization is widely accepted in Colorado as adequate and appropriate for establishing risk in reuse applications.

California:
California is currently developing an infection-based framework as a result of Senate Bill 966 (SB 966). SB 966 directed the State Water Resources Control Board to develop regulations that included risk-based LRTs for enteric virus, parasitic protozoa, and enteric bacteria for several source waters (blackwater, graywater, rainwater, and stormwater) and end uses (toilet and urinal flushing, irrigation, clothes washing, and dust suppression). An independent advisory panel was convened to help the State Board evaluate more recent studies published that might warrant a re-evaluation of the 2017 LRTs. Since 2017, several key studies have been conducted to characterize pathogen concentrations in ONWS source waters by utilizing pathogen monitoring of untreated municipal wastewater data from five wastewater treatment plants. The use of the new and different pathogen data resulted in a different set of LRT requirements for indoor uses and irrigation; the panel also considered additional end-uses including fire suppression, car washing, and indoor decorative fountains. Important distinctions with the California approach were the elimination of the requirement of an LRT for pathogenic bacteria and the selection of adenovirus rather than norovirus as a reference pathogen.

Washington:
The Washington State Department of Health (WSDOH) is currently developing ONWS regulations and has benefited from the experience of its sister states leading the way. However, WSDOH is concerned that the exclusion of bacteria pathogens from the LRTs could lead to future scenarios where bacteria pathogens are not properly accounted for. Continuing climate change and an increasing understanding of environmental bacterial pathogens as significant potential health risks warrant those bacterial pathogens to be explicitly accounted for. WSDOH's involvement with the bacterial inactivation study led by the Minnesota Department of Health has also called into question the assumption that virus and protozoa inactivation requirements for all disinfectants and filter treatments always ensure sufficient bacterial inactivation. With an eye to the future, the Washington regulations will embrace the DALY framework as a new and different method of quantifying risk. Incorporation of DALYs will allow a more ready comparison of health risks and benefits from non-microbial concerns associated with both ONWS and other public health activities moving forward.

While states are proceeding with LRTs that have slight variations, there is general consistency with the example treatment trains regardless of infection- or DALY-based frameworks in terms of the type of technologies used in ONWS (i.e., filter, MBR, UV, chlorine). Generally, some frameworks may require more or less chlorine dose or more or less UV units.

Oversight and Management Strategies

The NBRC supports oversight and management programs for ONWS for ongoing protection of public health. Oversight and management programs can be implemented at the local or state level and depends on the local context.

In California, SB 966 requires local jurisdictions to adopt local programs to permit ONWS and prohibits the state to take over a local program. On the other hand, Colorado and Washington plan to take a statewide approach to oversight. The pathway to implementation will depend on the circumstances in each state and locality.

Future Research Priorities

The NBRC plans to re-visit the health risk- based frameworks and associated LRTs discussed within this document during the next three years. While these risk assessment efforts have provided new insights since 2017, there are several inputs that remain uncertain across them. As a result, all four approaches require the use of multiple assumptions. There is agreement that the collection of additional data would reduce the uncertainty of the assumptions needed for LRT refinement.

Ongoing research by the NBRC includes addressing single family applications, researching pathogen crediting for natural treatment systems, and aligning plumbing codes and standards with the health risk-based approach. Future work will include assessing how onsite water systems can play a role in equity and climate change issues, conducting life cycle assessments evaluating the environmental and economic effects of community-scale onsite water reuse adoption, collecting pathogen data and identifying improved approaches for defining stormwater treatment.

Learn more about the NBRC at **watereuse.org/nbrc**

City of Austin Permitting and Development Center in Austin, TX collecting and treating blackwater for toilet and urinal flushing (image courtesy of Austin Water).

NBRC Policy Impacts and Resources

The NBRC has made significant research contributions and advanced policies and regulations for onsite non-potable water reuse over the past several years.

Blueprint for Onsite Systems: A Step-by-Step Guide for Developing a Local Program to Manage Onsite Water Systems (2014): Describes ten key steps for considering and implementing an ONWS program.

Risk-based Framework for the Development of Public Health Guidance for Decentralized Non-potable Water Systems (2017): This landmark report establishes scale-appropriate LRTs and monitoring for ONWS. The research was funded by WRF and led by the National Water Research Institute (NWRI).

A Guidebook for Developing and Implementing Regulations for Onsite Non-potable Water Systems (2017): To help develop LRTs and monitoring for ONWS and present pathways for implementation and management of these systems at the local and/or state level.

Model State Regulation for Onsite Non-potable Water Programs (2017): Provides a template for state legislation for establishing regulatory programs for ONWS.

Model Local Ordinance for Onsite Non-Potable Water Programs (2017): Provides a template for local ordinance for establishing regulatory programs for ONWS.

Model Program Rules for Onsite Non-potable Water Systems (2017): Provides specific details on implementation of an ONWS, including system design criteria, permitting, cross-connection control, reporting, notification, and enforcement.

Making the Utility Case for Onsite Non-potable Water Systems (2018): A report to help utilities and other stakeholder understand the benefits and drivers behind onsite reuse, how other utilities have addressed potential challenges, and best practices for the ongoing operation of these systems.

Guidance Manual and Training Materials for Onsite Non-potable Water Systems (2020): Develops a design and permitting training for onsite non-potable water systems to identify the skills and knowledge required to design and permit treatment systems that meet the LRTs.

Assessing the Microbial Risks and Impacts from Stormwater Capture and Use to Establish Appropriate Best Management Practices (2023)

This WRF sponsored project synthesizes existing research on stormwater microbial quality and addresses the selection of appropriate log reduction targets based on quality of stormwater and intended end use.

Operator Certificate Program for Onsite Non-potable Water Systems (2024, anticipated): Develop an operator certificate program to safely operate and maintain onsite non-potable water systems.

Hassalo on Eighth in Portland, Oregon collecting and treating blackwater for toilet flushing. (Image courtesy of Jim G. Maloney/Biohabitats, Inc.).

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