Interreg
Baltic Sea Region

Co-funded by
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SUSTAINABLE WATERS
WaterMan

KWB

The Quantitative microbial risk assessment tool

A hands-on introduction

19.06.2025

Objectives & Content

1. Understand what QMRA is
2. Navigate and use the online QMRA Tool
3. Perform a basic risk assessment scenario
4. Ask questions and discuss applications and limitations

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*W*hat is QMRA?

Quantitative **M**icrobial **R**isk **A**ssessment

What is QMRA? - Risk

Quantitative Microbial Risk Assessment

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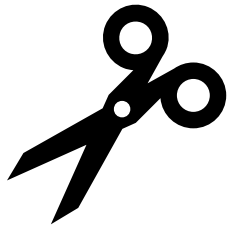
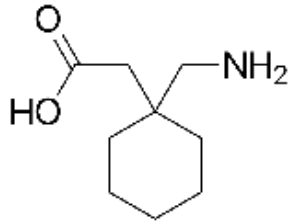
*W*hat is QMRA? - Hazard

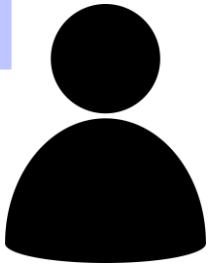
... in daily life



... in *w*ater reuse



Risk is everywhere in daily life, but we can still live safely



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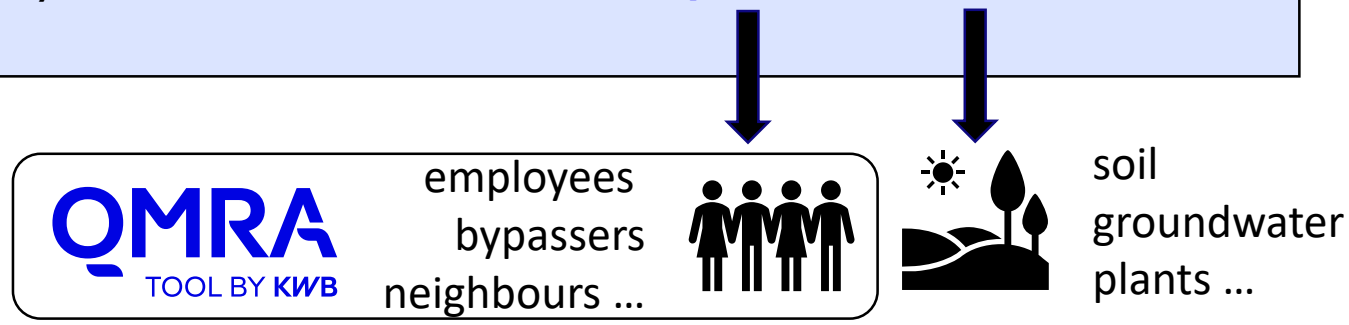

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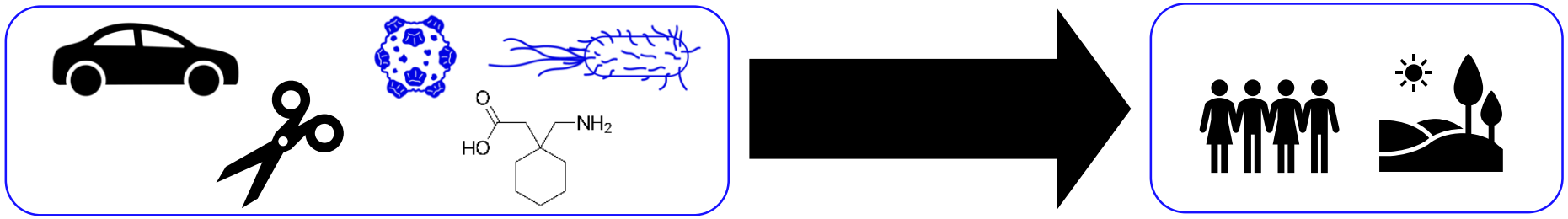

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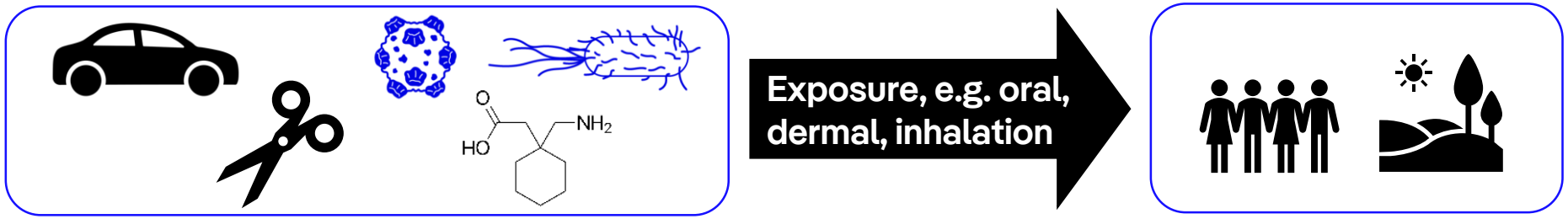

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What is QMRA? - Microbial risk

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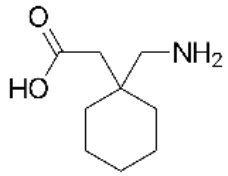
Nature of the hazard

In the *w*ater reuse context: **Chemical** & **microbial** risk



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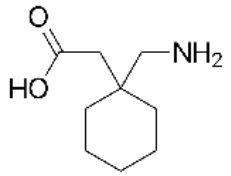
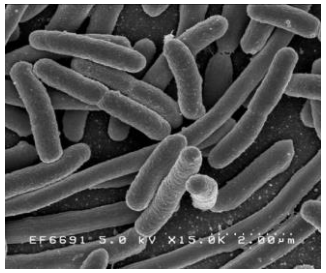


QMRA
TOOL BY KWB

What is QMRA? - Microbial risk

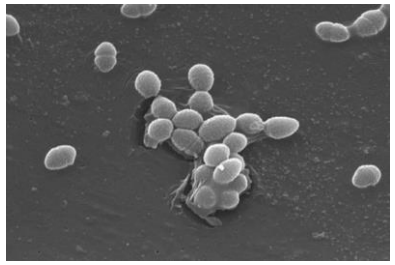
Indicator organisms indicating faecal pollution

Escherichia Coli



Source: Rocky Mountain Laboratories

Intestinal enterococci



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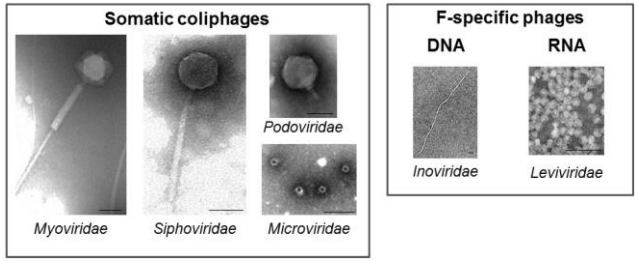
Coliphages



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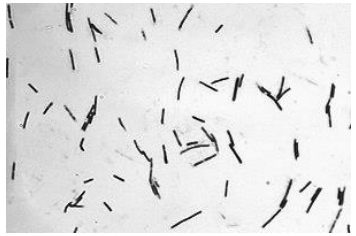
Clostridium perfringens



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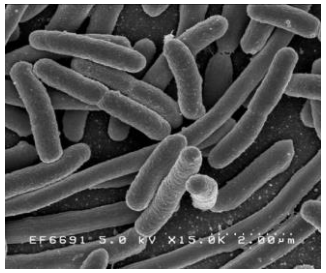

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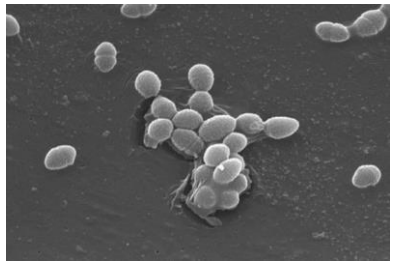

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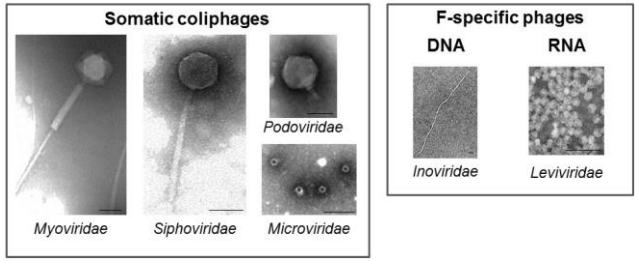

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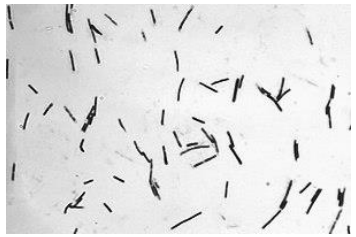

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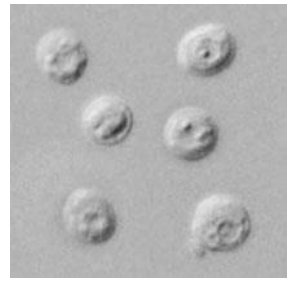
Real pathogens causing illness (e.g. gastroenteritis)

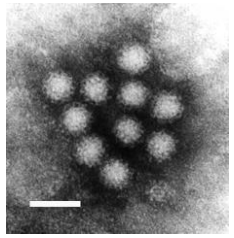
Parasites

Giardia intestinalis

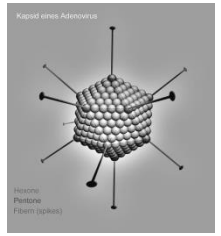


Cryptosporidium parvum

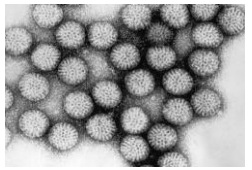
Viruses



Norovirus



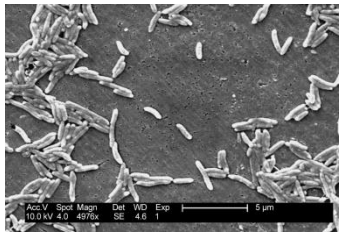
Adenovirus



Rotavirus

Von Gleiberg - Eigenes Werk, CC BY-SA 2.0 de, https://commons.wikimedia.org/w/index.php?curid=11869453

Bacteria



Campylobacter jejuni

What is QMRA? - Microbial risk

World Health Organization — WHO reference pathogens

QMRA TOOL BY KWB — reference pathogens in QMRA tool

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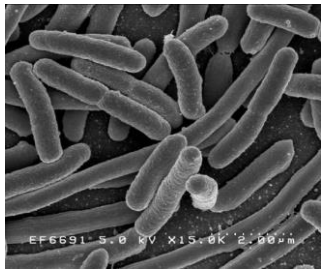

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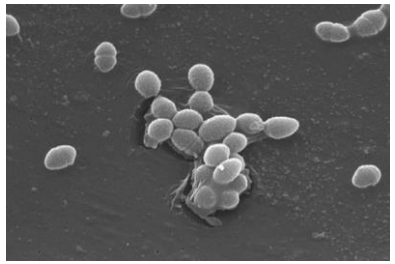

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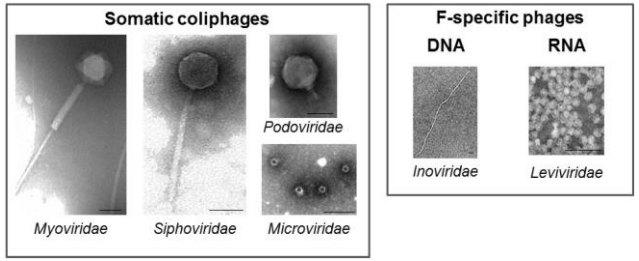

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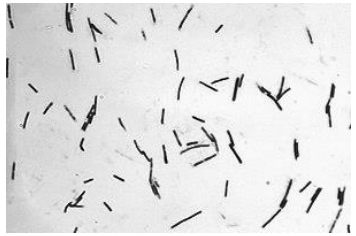

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World Health Organization — QMRA TOOL BY KWB

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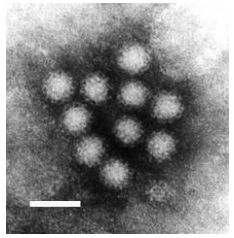

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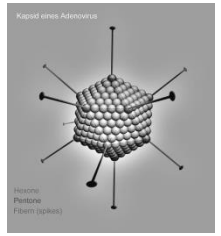

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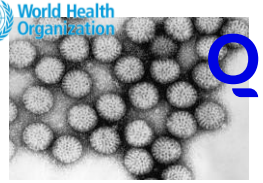

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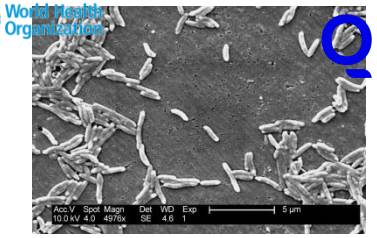

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To collect all available information and quantify the degree of certainty that the *w*ater is „safe“

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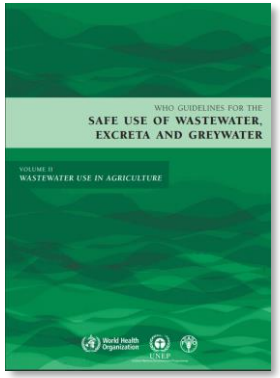
- Measured data
- Epidemiological data
- Scientific literature
- International guideline documents (*W*HO, Australia, US EPA)
- Expert kno*w*ledge

International guidelines for risk assessment

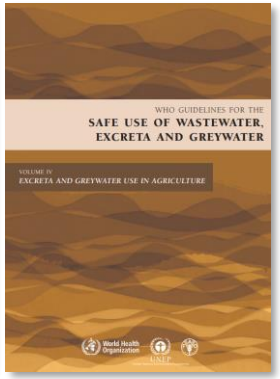
Numerous guidelines and recommendations available (especially from *W*HO, AUS, USA)

2009

2015

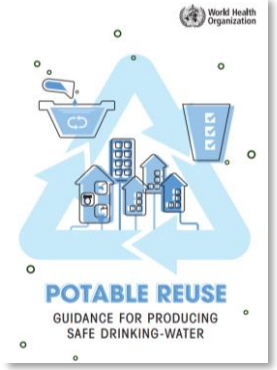


2006

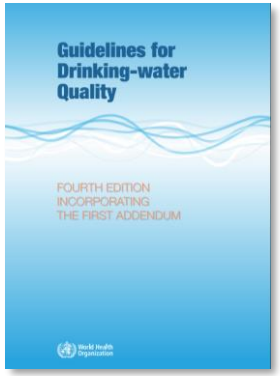


2013

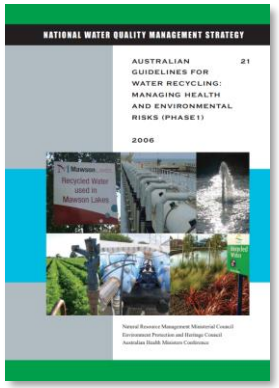
2016



2017



2022



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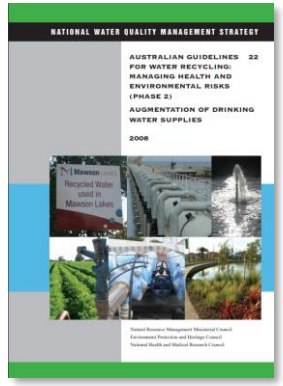
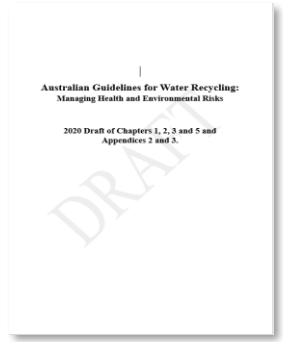
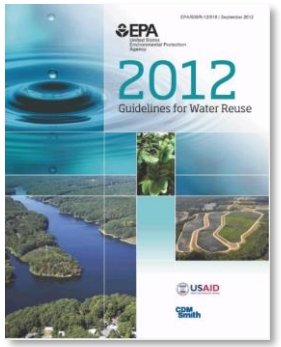


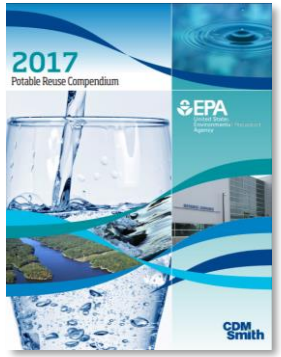
2008



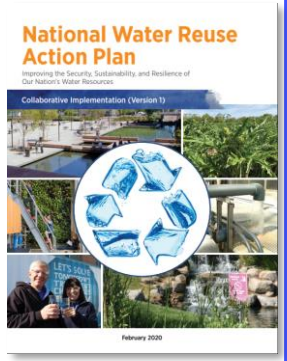
2020



2012



2017



2020

What is QMRA? – Quantitative

Quantitative **M**icrobial **R**isk **A**ssessment

What is QMRA? – Quantitative vs. qualitative

Qualitative / semi-quantitative[1,2]

Risk matrix

Likelihood	Severity of the impact				
	1 – Marginal	2 – Minor	4 – Moderate	8 – High	16 – Catastrophic
Rare (highly unlikely) - 1	1	2	4	8	16
Unlikely – 2	2	4	8	16	32
Possible – 3	3	6	12	24	48
Anticipated – 4	4	8	16	32	64
Almost certain – 5	5	10	20	40	80
Risk score (LxS)	<6	7-12		13-32	>32
Risk level	Low	Moderate		High	Extremely high

Quantitative[3]

Combines scientific knowledge about the

1. presence and nature of pathogens,
2. their potential fate and transport in the water cycle,
3. the routes of exposure of humans and the health effects that may result … and
4. the effect of natural and engineered barriers and hygiene measures.

[1] WHO, 2016. Sanitation Safety Planning Manual for Safe Use of Waste Water; [2] WHO, 2016. Quantitative Microbial Risk Assessment; [3] Zhiteneva et al., 2020. 10.1016/j.mran.2020.100132; WHO, 2016. Quantitative Microbial Risk Assessment.

Different types of QMRAs

Worst-case / point estimate

Deterministic

Assumes only one value for each step of the calculation, e.g.

- Maximum concentration of rotaviruses in raw sewage (or other source water)
- Minimum LRV for all treatment steps
- High level of safety, but also high risk of overcompensation in terms of treatment design
- Result: Quality target achieved, yes or no

Monte Carlo simulation

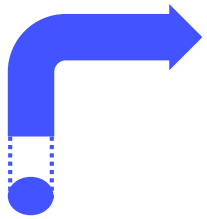
Probabilistic

Generation of probability distributions for raw water quality and removal performance

Uncertainty and variability are considered

QMRA
TOOL BY KWB

- Result: How likely is it that the quality target achieved?

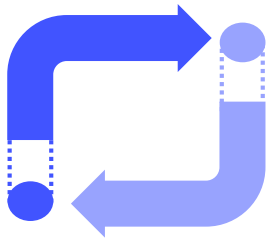


Bayesian network

Probabilistic

Similar to Monte Carlo, but also includes:

- Expert opinions/knowledge is transparently included
- Distributions can be updated with new measured values or findings
- Can be performed forwards or backwards
- Result: How likely is it that the quality target or LRV target will be achieved?



Steps in a QMRA

$$Disability\ adjusted\ life\ years\ (DALY) = Years\ lived\ with\ a\ disability\ (YLD) + Years\ of\ life\ lost\ (YLL)$$

Probability distribution of the pathogen concentrations

- Experimental values or literature values can be fitted to a distribution

Exposure scenarios (exposure)

- What type of exposure pathway? How frequent and how severe is the exposure?

Calculate the infection and disease probabilities

- Dose-response analysis provides a quantitative relationship between the likelihood of adverse effects and the level of microbial exposure

Calculate the DALYs and compare with the health target

- One DALY corresponds to the loss of one year of full health
- Drinking water = 10^{-6} DALY per person per year

Objectives & Content

1. Understand what QMRA is
2. Navigate and use the online QMRA Tool
3. Perform a basic risk assessment scenario
4. Ask questions and discuss applications and limitations

The QMRA tool – use cases

The QMRA tool assesses the microbial risk to human health for a water reuse scenario. It can be useful in two phases of a water reuse project:

1. Planning Phase:

- Estimates if a proposed water treatment process can reduce risks to acceptable levels based on quality of source water and intended use.
- Helps choose:
    - An appropriate end-use for reclaimed water.
    - A suitable source water for a specific end-use.

2. Plant Operation:

- Estimates if an existing treatment process can reduce microbial risks to acceptable levels.
- Allows input of site-specific data, including:
    - Pathogen concentrations.
    - Removal rates of treatment steps.
    - Exposure scenarios.
- Enables a more customized risk assessment.

Please note, **the QMRA tool is not designed for water treatment process design**.

The QMRA tool – modes and input

The tool provides two basic modes of use:

- Use of default data based on literature (e.g. WHO) by choosing from a drop-down menu.
- Use of site-specific data by modifying the inputs manually.

Model Inputs:

- Exposure Scenario: Events per year, volume per event in liters for the intended end-use
- Source Water Quality: Minimum and maximum concentration for rotavirus, Campylobacter jejuni and Cryptosporidium parvum
- (Waste)water Treatment: Log removal values (LRV) for viruses, bacteria and protozoa for each water treatment process

The QMRA tool – outputs and evaluation

Simulation Outputs:

The simulated risk is expressed and visualized in terms of:

- Annual Risk of Infection
- Disability-Adjusted Life Years (DALYs): A measure representing the loss of one year of full health, commonly used to assess human health risks.

The tool evaluates the water reuse scenario by comparing the simulation results with the tolerable risk levels set by the WHO:

- 1/10,000 infections per person per year
- 1 μDALY / 10^{-6} DALY per person per year (WHO 2022)

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https://qmra.org/

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Perform a basic risk assessment in groups

Group 1

Exposure: Domestic use, toilet flushing

Source water type: Rainwater, rooftop harvesting

Treatments: Dual media filtration + UV disinfection (20 mJ/cm²)

Group 2

Exposure: Drinking water

Source water type: Sewage treated

Treatments: Dual media filtration + ultrafiltration + reverse osmosis

Group 3

Exposure: Irrigation, restricted

Source water type: Sewage treated

Treatments: Ozonation wastewater + dual media filtration + UV disinfection wastewater

Group 4

Exposure: Irrigation, unrestricted

Source water type: Sewage treated

Treatments: Ozonation wastewater + dual media filtration + microfiltration + UV disinfection wastewater

… or build your own scenario

Please answer the poll ...

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The QMRA tool - limitations

Simplified Assumptions: The tool uses certain assumptions and simplifications to model complex real-world scenarios.

- The tool assumes constant treatment efficacy: LRV of a treatment is constant regardless of the treatment process order, which does not reflect the variability present in actual systems. The tool estimates the same LRV for two filtration steps in a row, even though after one filtration, the reduction is likely to be much lower as the target contaminants already have been eliminated.
- The tool does not consider operation conditions: Constant treatment LRV are assumed, which does not reflect the variability present in actual systems, for e.g. empty bed contact time during activated carbon fixed-bed filtration, filtration rate of a sand filter.

Do you have any questions?

KWB

THANK YOU

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Interreg Baltic Sea Region

Co-funded by the European Union

SUSTAINABLE WATERS
WaterMan

The „BSR Water Recycling Toolbox" was elaborated as part of the WaterMan project, which is co-financed by the European Union (European Regional Development Fund) and implemented within the Interreg Baltic Sea Region Programme. More information:

eurobalt.org/WaterRecyclingToolbox
interreg-baltic.eu/project/waterman

WaterMan promotes a Baltic Sea Region-specific approach to water recycling, which makes use of the alternation of too much and too little water that has become typical for humid areas in the EU to strengthen the resilience of local water supply. Building on this approach, the project supports municipalities and water companies in adapting their water supply strategies.