Interreg Baltic Sea Region

Co-funded by the European Union

KWB

SUSTAINABLE WATERS WaterMan

The WaterMan project
Feasibility study on reuse of water from large-scale WWTP

Pia Schumann, Elisa Rose, Wolfgang Seis, Ulf Miehe

Berlin Centre of Competence for Water (KWB)

Final concept, 31 Dec 2025

Content

- The opportunity
- **(Industrial) water reuse at WWTP Ruhleben**
  - Context
  - Concept & approach
  - Water quantity
  - Water quality
  - Pipeline costs
- **(Agricultural) water reuse at WWTP Stahnsdorf**
  - Context
  - Stakeholders
  - Technical solution
- Quantitative microbial risk assessment
- Key findings, transferability & final reflections

The challenge

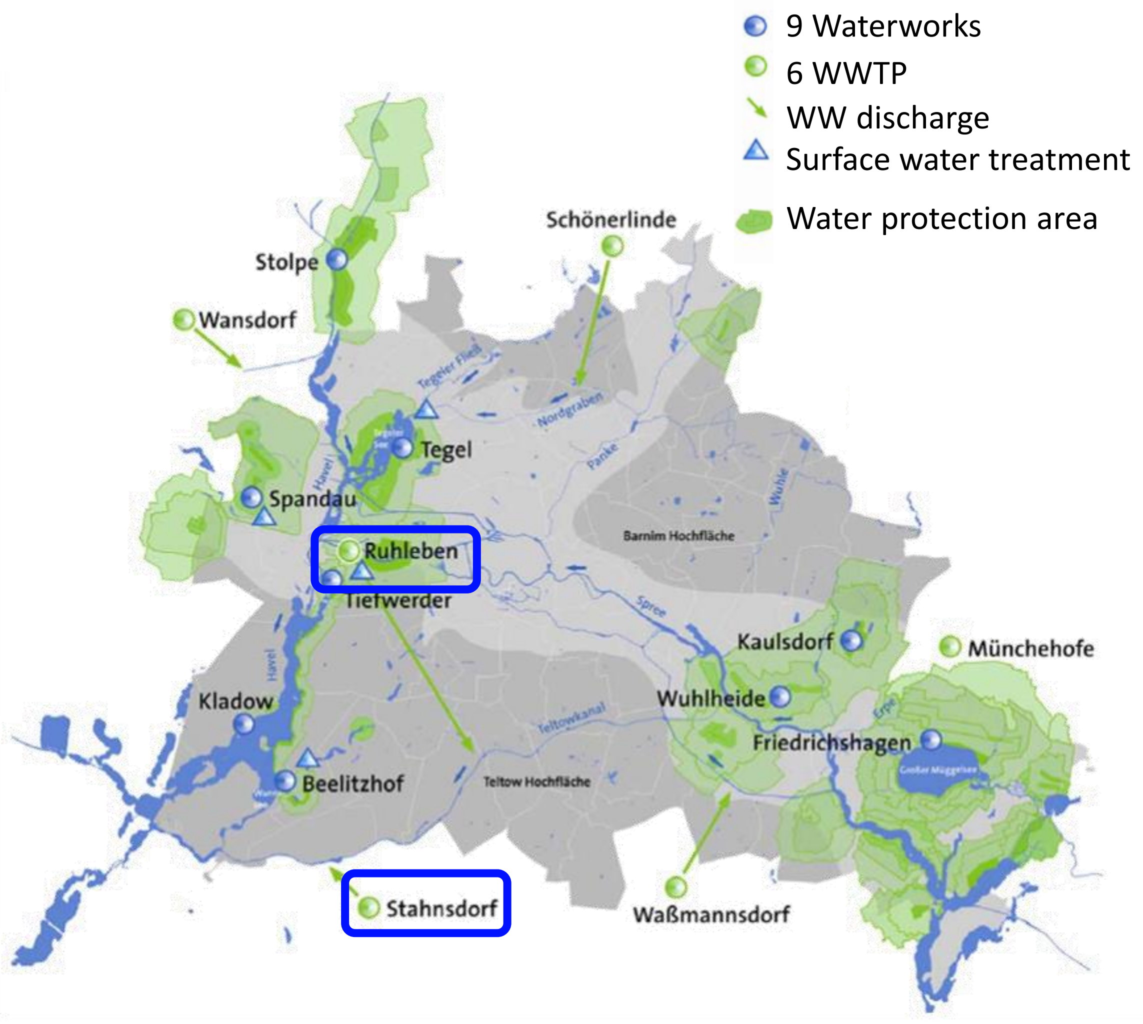
Future challenges of water supply in the Berlin Brandenburg Metropolitan Region

- Population Growth: Rising demand due to increasing population
- Climate Change: Reduced water availability (e.g., the dry five-year period 2018–2022)
- Decline in Spree River Flow: End of lignite mining and related mine drainage inflows
- Decline in Havel River Flow: Lower precipitation levels

The opportunity

1. (Industrial) water reuse at WWTP Ruhleben
   - There is a large wastewater treatment plant (WWTP) in the city, in close proximity of a commercial zone
   - More detailed assessment of industrial reuse potential, building upon the study by Heinrich and Wilmes (2022)

2. (Agricultural) water reuse at WWTP Stahnsdorf
   - High interest of Berlin water utility and the local mayor in water reuse opportunities



Berlin water utilities (BWB)

Heinrich & Wilmes: Potenziale der Wasserwiederverwendung am urbanen Klärwerk Ruhleben (2022)

WWTP Ruhleben

The context – WWTP Ruhleben

- Aim to assess the potential of reuse of municipal wastewater at WWTP Ruhleben
  - Focus on industrial & commercial reuse
  - Urban irrigation may be included as well
- large urban WWTP near industrial/commercial zone
- Discharge of treated WW:
  - Winter period: Spree river
  - Summer period: Teltowkanal (16 km distance)
- Current capacity of 247,500 m³/day
- Planned extentions:
  - Coagulation filtration for nutrient removal + full-stream UV disinfection (until 2027)
  - Advanced treatment for micropollutant removal (e.g. activated carbon, ozonation)

The context - WWTP Ruhleben Upgrade

Secondary effluent → Ozonation → Coagulation → Dual media filtration → UV → Water for potential reuse

The context - WWTP Ruhleben Upgrade

Secondary effluent	Ozonation	Coagulation	Dual media filtration	UV	Water for potential reuse
Target compounds	Organic micropollutants	Nutrients (P)	Suspended solids, DOC, ozonation transformation products	Pathogens	

The context - WWTP Ruhleben Upgrade

Secondary effluent	Ozonation	Coagulation	Dual media filtration	UV	Water for potential reuse
Target compounds	Organic micropollutants	Nutrients (P)	Suspended solids, DOC, ozonation transformation products	Pathogens	
Implemented by	2045 at the latest (UWWTD)	2027 (planned)	2027 (planned)	2027 (planned)	

The context - WWTP Ruhleben Upgrade

Secondary effluent → Ozonation → Coagulation → Dual media filtration → UV → Water for potential reuse

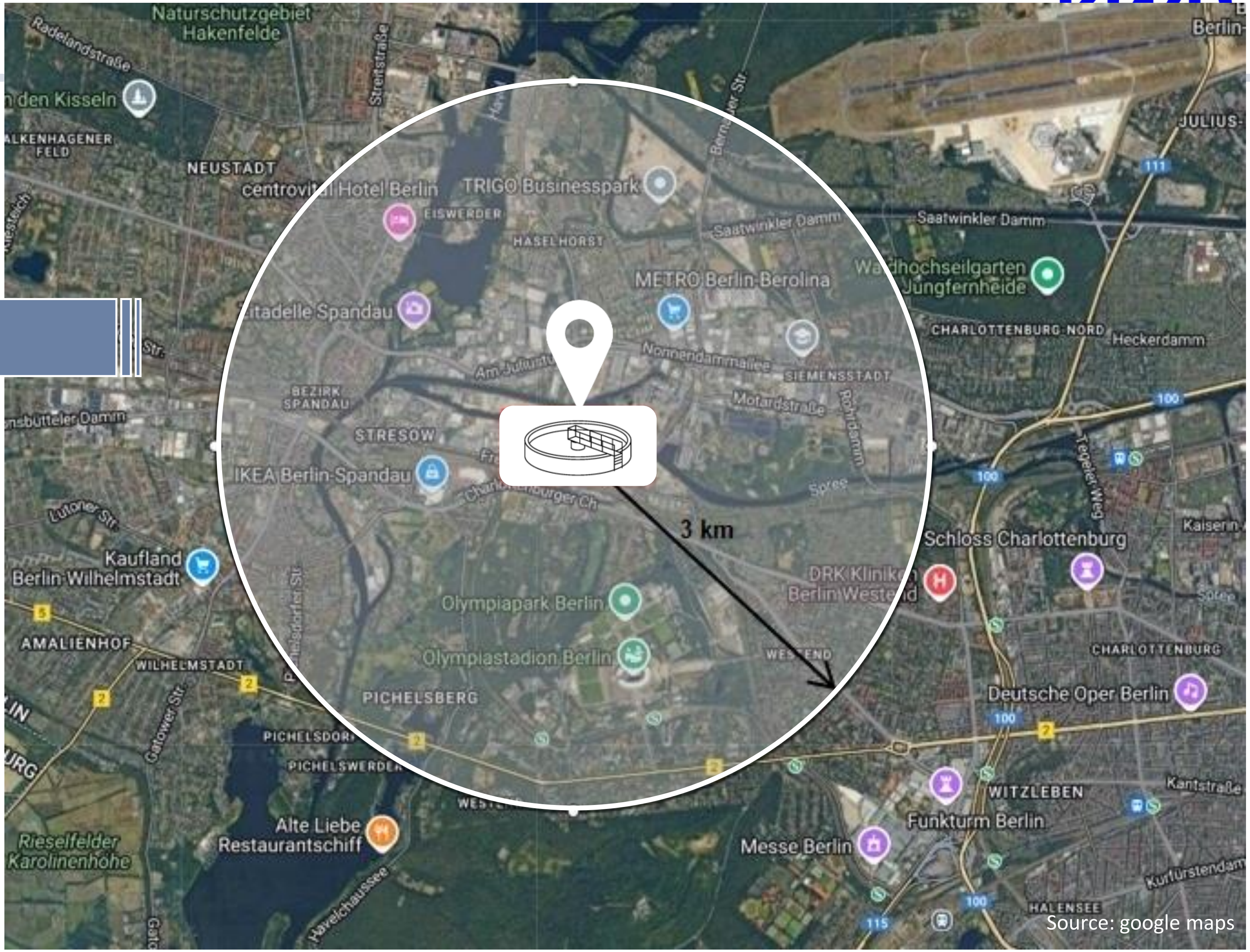
	Ozonation	Coagulation	Dual media filtration	UV
Target compounds	Organic micropollutants	Nutrients (P)	Suspended solids, DOC, ozonation transformation products	Pathogens
Implemented by	2045 at the latest (UWWTD)	2027 (planned)	2027 (planned)	2027 (planned)
Treatment target	UWWTD 80% removal of indicator OMP		Water Framework Directive: TSS < 1 mg/L TP < 0.1 mg/L	Bathing water quality („good“ status)

Concept & approach

189 industries / businesses

- water consumption
- non-food

25 priority industries / businesses



Source: google maps

Concept & approach – WWTP Ruhl

189 industries / businesses

- water consumption
- non-food

25 priority industries / businesses

@

Name of Industry	Category	Distance from Ruhleben in km
Aks Dasis Dommermuth GmbH & Co KG	Cooling and air conditioning	1.53
Aladdin Auto Werkstatt	Car repair shop	0.78
ATU Berlin - Spandau	Car repair shop	0.74
Auto-Eid Autoverwertung	Car repair shop	0.47
Automobile D.A.H West	Car repair shop	1.36
Autoservice Müller	Car repair shop	0.35
BERGER BETON SE	Ready mix concrete supplier	0.46
Berlin Recycling GmbH Recycling company	Waste management service	0.33
BeST Berliner Sensortechnik GmbH	Electronic manufacturer	3.06
BMW spez. DREIMW Fahrzeugtechnik GmbH	Car repair shop	0.63
BSR Biogasanlage West	Waste management service	0.68
BSR Müllheizkraftwerk Ruhleben	Waste management service	1.12
BTB - Werkstatt für Mobilkrane und Nutzfahrzeuge	Truck repair shop	1.90
Clean Car	Car wash	0.56
Feigel umwelt-service gmbh	Environmental services or waste management	0.37
Gerken GmbH - Arbeitsbühnenvermietung Niederlassung Berlin	Construction machine rental service	1.13
Graf Baustoffe | Berlin - Brandenburg	Building material store	0.85
Halter Spreng- und Umwelttechnik	Demolition contractor	0.43
Hasan Solmaz - Autoservice	Car repair shop	0.85
KEL CAR Karsli UG	Car repair shop	0.23
MAN Truck & Bus Center Berlin	Truck repair shop	0.73
MAN Truck & Bus Germany GmbH	Truck repair shop	1.45
Mr. Wash Berlin Spandau	Car wash	0.69
RUWE Gruppe | Betriebshof Nord-West	service provider for street cleaning and green areas	0.46
The GARAGE auto repair shop	Car repair shop and maintenance service	1.45
Vattenfall Wärme Berlin AG, Heizkraftwerk Reuter	Power station	0.99

- Received responses from 2 businesses
- Discussed potential areas for cooperation
- No concrete opportunities identified

Concept & approach – WWTP Ruhl

189 industries / businesses

- water consumption
- non-food

25 priority industries / businesses

- Most relevant

2 priority categories

Name of Industry	Category	Distance from Ruhleben in km
Aks Dasis Dommermuth GmbH & Co KG	Cooling and air conditioning	1.53
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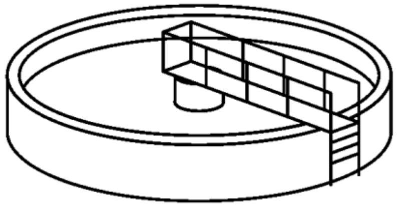
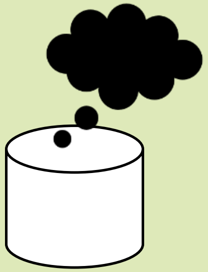
Water quantity – Car wash and cooling



247,500 m^3/day treated wastewater

4 – 44 m^3/day[1]



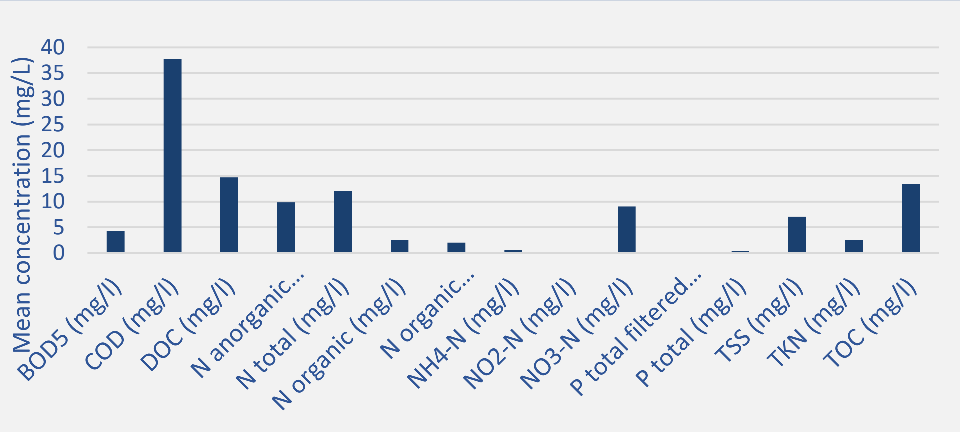
3,500 – 18,000 m^3/day[2]

Max. 7% of the daily wastewater volume of the WWTP Ruhleben

[1]Löffler et al., 2024 doi 10.2166/wst.2024.300; personal communication, [2]based on average yearly energy production and water consumption according to Pan et al., 2018: https://doi.org/10.1016/j.wen.2018.04.002

Water quality[1]

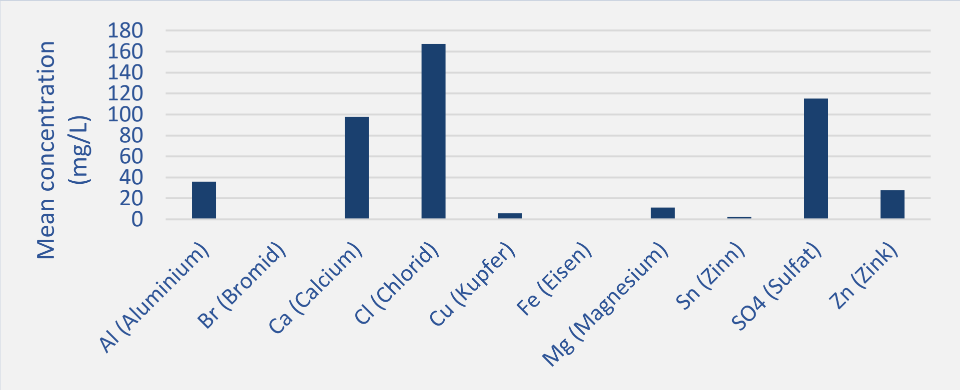
organics & nutrients



parameter	value	SD	n
pH ( )	7.9	0.3	76
conductivity (µS/cm)	1200	0	1
UVA254 (1/m)	29.1	2.9	637

- Standard parameters on organics and nutrients
- Important for all water reuse end-uses

ions

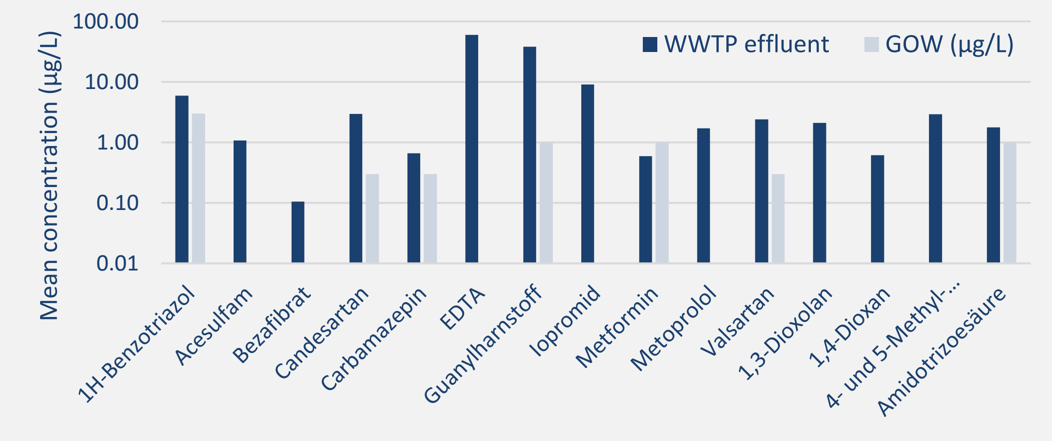


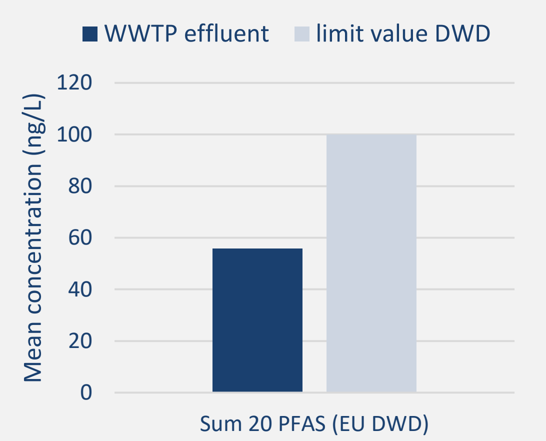
- Important for industrial ww reuse (e.g. H_2 production or steam production)

[1] Berlin water utilities, WWTP Ruhleben effluent data from 2019 - 2024

Water quality[1]

Organic micropollutants





- Important for agricultural or urban irrigation
- Other applications where reclaimed water is released into the environment (e.g. aquifer recharge)

Note:

- Effluent values are **within all legal regulatory limits**; **full compliance** with current requirements is ensured
- **Quaternary treatment for organic micropollutant removal is planned**, commissioning is expected between 2035 and 2038
- Reported values do not include quaternary treatment, which is expected to substantially **enhance the removal of organic micropollutants**

- **GOW[2] does not apply to wastewater shown here** (defined for drinking-water)**, but was used as a conservative benchmark** (due to the potential for transfer to groundwater)
- Regulatory context: National regulations for water reuse for irrigation propose **PFAS limit values** aligned with drinking water standards, **which are already met**

[1] Berlin water utilities, WWTP Ruhleben effluent data from 2019 – 2024, [2] GOW: Health Guideline Value for drinking water purposes given by the German Environment Protection Agency (Umweltbundesamt), considering toxicological data, DWD: Drinking Water Directive

Water quality

Requirements for car wash and cooling towers according to European guidelines

Parameter	Unit	Car wash[1]	Cooling tower[2]
Aluminium	µg/L		< 500
Calcium	mg/L		>20 / <500
Carbon hardness	°dH		< 4 /< 20
Chloride	mg/L		< 50 / < 250
Conductivity	µS/cm		50 - < 3000
Copper	µg/L		< 500
E. Coli	CFU/100 mL; MPN/100mL	200	Absence
Intestinal nematodes	eggs/10L	<1	<1
Iron	mg/L		< 0.1 / < 0.5
Legionella	CFU/L		<100
Magnesium	mg/L		<100
pH			7 - 9
Sulphate	mg/L		< 50 / < 600
TDS	g/L		<1.8
Total Hardness	°dH		<8
TSS	mg/L	<20	< 5
Turbidity	NTU	<10	< 1

[1]Royal Decree (1620/2007) (2007) Spanish Regulations for Water Reuse – Royal Decree 1620/2007 of 7 December. Madrid: Spanish Association for Sustainable Water Reuse ASERSA, Universitat Politècnica de Catalunya, UPC and Consorci de la Costa Brava, CCB.

[2]Royal Decree (1620/2007) (2007) Spanish Regulations for Water Reuse – Royal Decree 1620/2007 of 7 December. Madrid: Spanish Association for Sustainable Water Reuse ASERSA, Universitat Politècnica de Catalunya, UPC and Consorci de la Costa Brava, CCB.

VDI 2047 Blatt 2 (2015) Rückkühlwerke – Sicherstellung des hygienegerechten Betriebs von Verdunstungskühlanlagen, Rule Number: VDI 2047 Blatt 2 2015 Düsseldorf: Verein Deutscher Ingenieure e.V.

VDI 3803 Blatt 1 (2019) Raumlufttechnik – Bauliche und technische Anforderungen Zentrale raumlufttechnische Anlagen (VDILüftungsregeln). Rule Number: VDI 3803 Blatt 1 2019 Düsseldorf: Verein Deutscher Ingenieure e.V.

Niewersch, C., Arias, A., Sukopova, M. & Gilron, J. (2016) Deliverable 1.3 - Report on Innovative Membrane Technologies and Schemes for Water Reuse. Tarragona, Spain: Dow Chemical Ibérica.

Water quality

Requirements for car wash and cooling towers according to European guidelines

Comparison to secondary effluent of WWTP Ruhleben

Parameter	Unit	Car wash[1]	Cooling tower[2]	WWTP effluent
Aluminium	µg/L		< 500	36
Calcium	mg/L		>20 / <500	98
Carbon hardness	°dH		< 4 /< 20	
Chloride	mg/L		< 50 / < 250	167
Conductivity	µS/cm		50 - < 3000	1200
Copper	µg/L		< 500	6
E. Coli	CFU/100 mL; MPN/100mL	200	Absence	
Intestinal nematodes	eggs/10L	<1	< 1	
Iron	mg/L		< 0.1 / < 0.5	0.24
Legionella	CFU/L		< 100	
Magnesium	mg/L		< 100	11
pH			7 - 9	7.9
Sulphate	mg/L		< 50 / < 600	115
TDS	g/L		< 1.8	
Total Hardness	°dH		< 8	
TSS	mg/L	<20	< 5	7.1
Turbidity	NTU	<10	< 1	

[1]Royal Decree (1620/2007) (2007) Spanish Regulations for Water Reuse – Royal Decree 1620/2007 of 7 December. Madrid: Spanish Association for Sustainable Water Reuse ASERSA, Universitat Politècnica de Catalunya, UPC and Consorci de la Costa Brava, CCB.

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Pipeline costs – Example cooling tower

- Estimation for pipeline construction costs incl. Pavement works, excavation, material costs
- Cost estimate per m pipeline: 410€[1]
- Pipeline length: approx. 1550 m
- Estimated costs: 640,000€
- Excluding maintenance, pumping, operation

[1]Based on Wilmes & Heinrich (2022), considering a prize increase of 30%

Pipeline costs – Example cooling tower

- Estimation for pipeline construction costs incl. Pavement works, excavation, material costs
- Cost estimate per m pipeline: 410€[1]
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- Estimated costs to Clean Car facility: 450,000€

Proximity is a key aspect for viable water reuse!

[1]Based on Wilmes & Heinrich (2022), considering a prize increase of 30%

WWTP Stahnsdorf

The context – WWTP Stahnsdorf

- Aim to assess the potential of reuse of municipal wastewater at WWTP Stahnsdorf
  - Focus on agricultural reuse
  - Urban irrigation may be included as well
- Close cooperation with Berlin water utility (BWB)
- Boundary conditions:
  - New WWTP will replace old WWTP by 2037
  - Assessment shall include current and future WWTP
  - Capacity current WWTP 410,000 p.e./50,000 m^3/a
  - Capacity future WWTP 900,000 p.e./100,000 m^3/a


Berlin water utilities (BWB)

Interreg Baltic Sea Region | Co-funded by the European Union | SUSTAINABLE WATERS WaterMan | KWB

Stakeholders – WWTP Stahnsdorf

1. **Operators of the Treatment Facility & Municipal Wastewater Treatment Plant (public/private):**
   - BWB: Stahnsdorf Wastewater Treatment Plant
   - Water and Wastewater Association (WAZV) "Der Teltow“
   - Mittelmärkische Wasser- und Abwasser GmbH (Service provider for WAZV "Der Teltow")
2. **Operators of Facilities for the Storage and Distribution of Treated Water (if applicable):**
   - See references (1) or (3).
3. **Operators Responsible for Irrigation** (Farmers/Agricultural Associations/Irrigation Associations):
   - e.g., Agro Saarmund GmbH
4. **Relevant Authorities:**
   - Water, Health & Environmental Authorities:
     - Primary responsible authority: Lower Water Authority – Landkreis Potsdam Mittelmark
     - Upper Water Authority – State Office for the Environment (LfU) Brandenburg
     - Health Department – Potsdam-Mittelmark District
   - Lower Nature Conservation Authority
   - Lower Soil Protection Authority
   - State Office for Rural Development, Agriculture, and Land Reorganization (Plant Protection)
5. **Other Stakeholders:**
   - Entities responsible for parts of the water and wastewater system or located within the affected area.
     - E.g. land users users close to agricultural land to be irrigated

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     - Health Department – Potsdam-Mittelmark District
   - Lower Nature Conservation Authority
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   - State Office for Rural Development, Agriculture, and Land Reorganization (Plant Protection)
5. **Other Stakeholders:**
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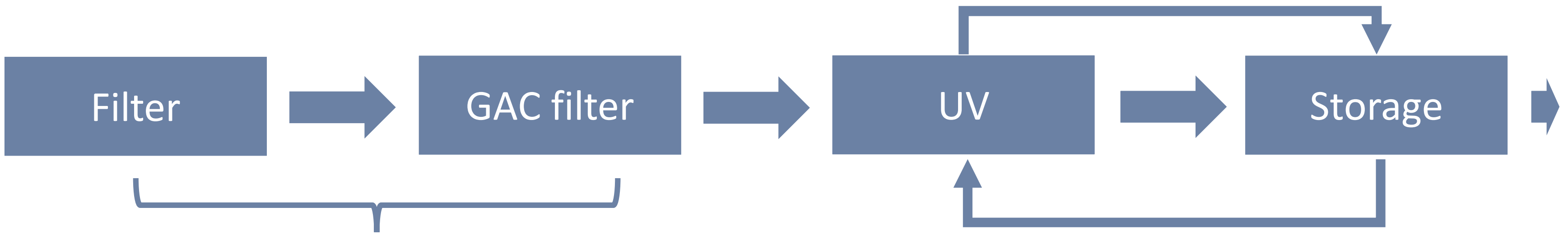
Technical solution – favored option status quo

- Aim: Class B according to the Water reuse regulation 2020/741



- Agricultural irrigation
- Urban irrigation
- Process water for WWTP
- Discharge

Treatment capacity:
Q = 115 m³/h
Number of filters:
first stage = 2
Second stage GAC filter = 4

Treatment capacity:
Q = 115 m³/h

Storage:
V = 8000 m³
Number of storage tanks:
4 tanks

Process concept enables continuous operation
- Lower maintenance requirements
- Lower operating costs

Buffer storage tanks enable a reduction in treatment units
- 2 sand/solids filters and 4 GAK filters
- 1 UV disinfection

Treated water can be used for various purposes

Quantitative microbial risk assessment

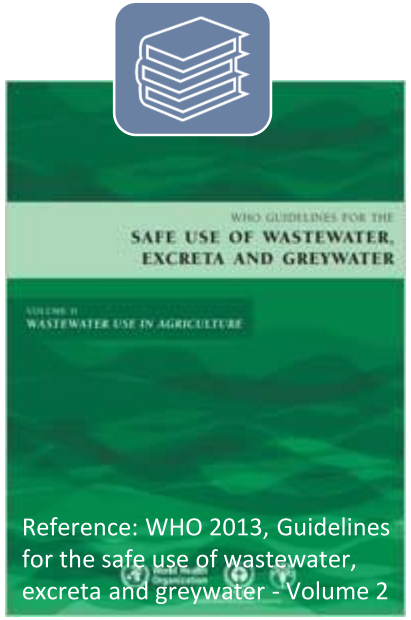
Quantitative microbial risk assessment

Aims & scope within WaterMan

1. Data collection of missing local data for real pathogens in wastewater to provide local data for a QMRA
2. Compare default data with local data and evaluate added value
3. Carry out a QMRA with local data for selected use cases with the QMRA tool
   - Industrial/commercial applications: car wash
   - Urban irrigation
   - Agricultural irrigation at WWTP Stahnsdorf assuming similar *Campylobacter jejuni* concentrations

Quantitative microbial risk assessment

Default data



Reference: WHO 2013, Guidelines for the safe use of wastewater, excreta and greywater - Volume 2

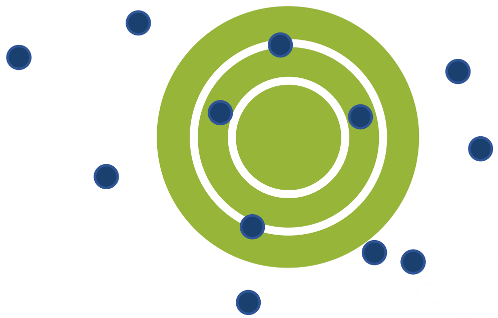
VS.

Local data

Reference: google maps

Quantitative microbial risk assessment

Default data



VS.

Local data

Is the effort for local data collection worth it?

Quantitative microbial risk assessment

Default data

Pros

- Low effort & quick access
- Cost-efficient (no lab analysis needed)
- Standardized, widely accepted
- Good starting point for feasibility studies

Cons

- Not site-specific → may not reflect local conditions
- Static values → no insight into variability or dynamics
- Risk of under/overestimating risks
- May reduce accuracy of decision-making
- Can weaken credibility if questioned by stakeholders

Local data

Pros

- Site-specific: reflects actual effluent characteristics
- Captures variability (seasonal, operational)
- Improves reliability of decisions and designs
- Stronger credibility with stakeholders/ regulators

Cons

- Higher effort (sampling, analysis) & more costly (lab fees, staff time)
- Requires planning & expertise
- Data may still be uncertain if sampling is limited
- Effort may not be justified if values are close to literature defaults
- Microbial analysis of real pathogens is challenging

Quantitative microbial risk assessment

Default data

- WWTP influent matrix: highly complex accompanying microbial flora
- Lab capacities; often methods need to be developed or fine tuned
- Costly: not standard parameters; e.g. 100-500€ per sample for *C. jejuni*
- Results are often not straight forward to interpret

Local data

Pros

- Site-specific: reflects actual effluent characteristics
- Captures variability (seasonal, operational)
- Improves reliability of decisions and designs
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- Higher effort (sampling, analysis) & more costly (lab fees, staff time)
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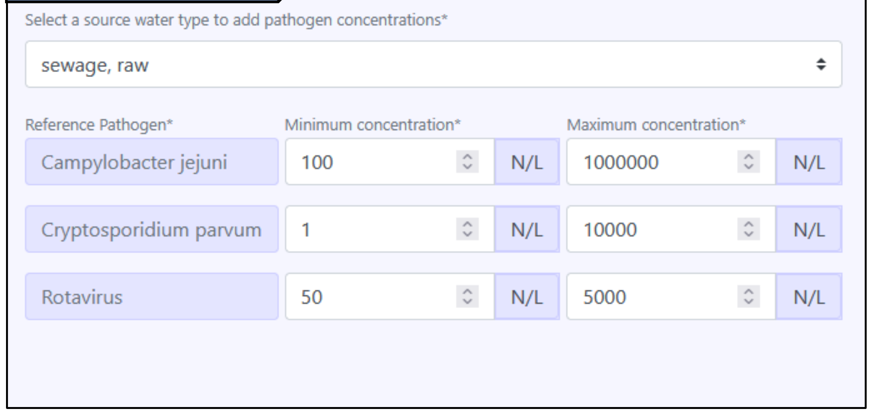
Quantitative microbial risk assessment

Default data

QMRA tool



Pathogen	Range (gene copies/L)	Reference
Norovirus	90 – 200,000,000[1] (9E+01 – 2E+08)	Eftim et al., 2017

Local data

Pathogen	Range (n/L)	Reference	
Campylobacter jejuni	<1,000 – 850,000	Own measurements	≈
Cryptosporidium parvum	10 – 700	Selinka et al., 2019	≈
Norovirus	100,000 – 100,000,000[1] (1E+05 – 1E+08)	Selinka et al., 2019	

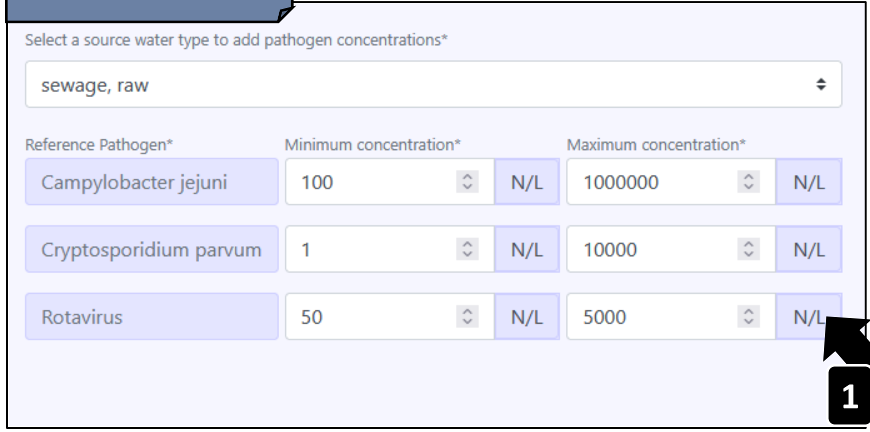
[1]Conservative estimate: norovirus measured as gene copies/L; not all detected genes are infectious.

Eftim et al., 2017: Occurrence of norovirus in raw sewage - A systematic literature review and meta-analysis; http://dx.doi.org/10.1016/j.watres.2017.01.017
Selinka et al., 2019: Viren und Parasiten in Abwasser und Flüssen sowie Handlungsempfehlungen für Flüsse mit kurzzeitigen Verschmutzungen, Abschlussbericht Flusshygiene, Umweltbundesamt
Seis et al.,2024: Bayesian estimation of seasonal and between year variability of norovirus infection risks for workers in agricultural water reuse using epidemiological data; https://doi.org/10.1016/j.watres.2022.119079

Quantitative microbial risk assessment

Default data

QMRA tool



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[1]Conservative estimate: norovirus measured as gene copies/L; not all detected gene copies equal an infectious virus

1 Rotavirus default vs. local norovirus data:

- not directly comparable due to higher norovirus infectivity
- even assuming equal infectivity, local norovirus values are substantially higher than QMRA default data
- **supports the use of local data in the assessment**

2 Norovirus literature vs. local norovirus data:

- local concentrations are within the same range of literature values
- note: norovirus concentrations are seasonal (Seis et al, 2022); should be considered in sampling campaigns
- Local data tend toward the upper concentration range reported in the literature
- **literature data represent local conditions**

Eftim et al., 2017: Occurrence of norovirus in raw sewage - A systematic literature review and meta-analysis; http://dx.doi.org/10.1016/j.watres.2017.01.017
Selinka et al., 2019: Viren und Parasiten in Abwasser und Flüssen sowie Handlungsempfehlungen für Flüsse mit kurzzeitigen Verschmutzungen, Abschlussbericht Flusshygiene, Umweltbundesamt
Seis et al.,2024: Bayesian estimation of seasonal and between year variability of norovirus infection risks for workers in agricultural water reuse using epidemiological data; https://doi.org/10.1016/j.watres.2022.119079

Quantitative microbial risk assessment at WWTP Ruhleben

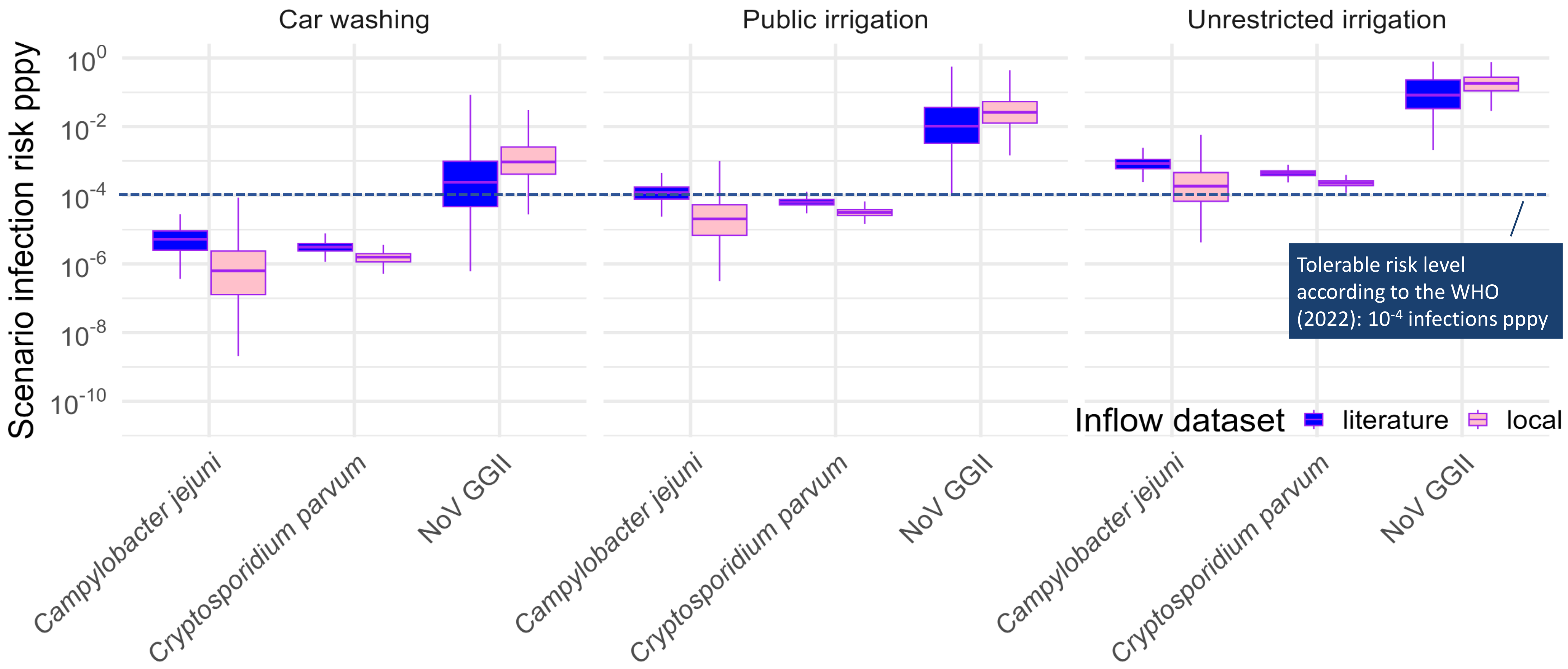
- Water reuse scenarios:
  - Commercial use in a car wash („car wash“)
  - Urban irrigation („public irrigation“)
  - Agricultural use („unrestricted irrigation“): for WWTP Stahnsdorf, assuming similar microbial water quality of the WWTP effluent
- Assumed water treatment: existing treatment + planned WWTP upgrade:

Primary treatment → Secondary treatment → Ozonation → Coagulation filtration → UV disinfection

- Evaluation: The risk of a water reuse scenario can be compared to two commonly applied health-based targets (WHO 2022):
  - 1 in 10,000 infections per person per year (pppy)
  - 0.000001 Disability Adjusted Life Years (DALY)

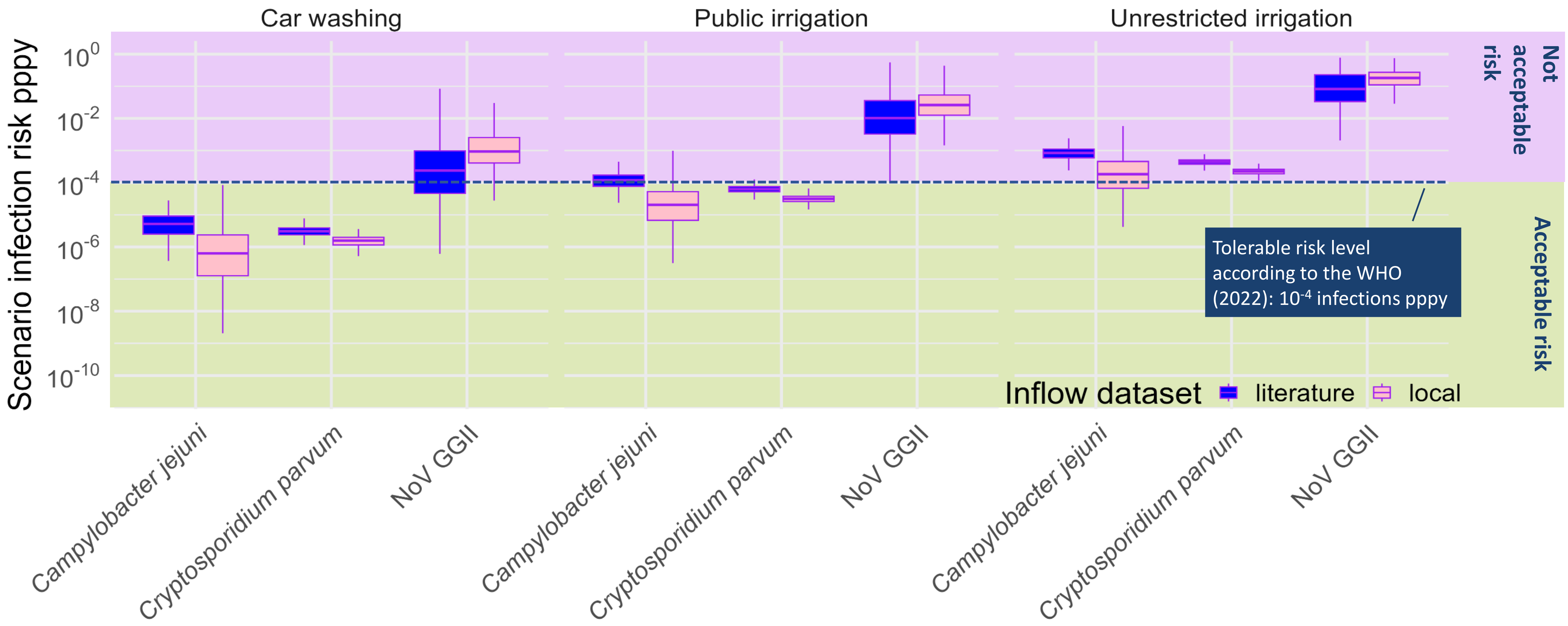
WHO 2022: Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. Geneva: World Health Organization; 2022. Licence: CC BY-NC-SA 3.0 IGO.

Quantitative microbial risk assessment at WWTP Ruhleben



WHO 2022: Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. Geneva: World Health Organization; 2022. Licence: CC BY-NC-SA 3.0 IGO.

Quantitative microbial risk assessment at WWTP Ruhleben



WHO 2022: Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. Geneva: World Health Organization; 2022. Licence: CC BY-NC-SA 3.0 IGO.

Quantitative microbial risk assessment at WWTP Ruhleben: QMRA Tool

- Exemplary tool results on the right
- Differences in QMRA results are rooted in different default values and virus types (rotavirus vs. norovirus)

QMRA TOOL BY KWB

https://qmra.org/

Quantitative microbial risk assessment at WWTP Ruhleben: Evaluation

- The planned WWTP upgrade (ozonation, coagulation, filtration, and UV disinfection) does not achieve acceptable risk levels for any of the three indicator pathogens across the investigated reuse scenarios
- Additional treatment steps (e.g. membrane filtration) are required to ensure acceptable risk levels for safe water reuse
- Risk assessment outcomes differ with used default data and indicator pathogens

Overall key findings & transferability

- Be flexible: adapt project scope change over time and in discussion with local stakeholders
- Differing level of interest depending on location
- Proximity is a key parameter for economic water reuse
- Creation of incentives is key: Difficult to find non-public large-scale end-users

! **Think local, apply broadly. Success depends on context, but lessons transfer widely.**

Apendix

Underlying data of QMRA

Dosis-Response Relationships

Pathogen	Model type	Model formula (per exposure)	Parameters	Dose unit
NoV GGII	Beta–Poisson (hypergeometric form)	$P_I(d, a, \alpha, \beta) = {}_2F_1\left(\alpha; \frac{-d}{\log(1-\alpha)}, \alpha+\beta, \frac{-a}{1-a}\right)$	α = 0.23; β = 5.04	GC (genome copies)
Cryptosporidium parvum	Exponential	$P_{I,}(d, r) = 1 - e^{-r*d}$	k = 0.0572	Oocysts (N)
Campylobacter jejuni	Beta–Poisson	$P_{I,}(d, N_{50}, \alpha) = 1 - [1 + \frac{d}{N_{50}}(2^{\frac{1}{\alpha}} - 1)]^{-\alpha}$	α = 0.145; N_{50} = 896	CFU (KBE)

Inflow: literature data

Pathogen	Distribution / formula	Parameter values	Units
NoV GGII	$log_{10}C \sim N(\mu, \sigma)$	μ= 5.1, σ = 1.6	GC/L
Cryptosporidium parvum	$C \sim uniform(min, max)/1000$	min = 1, max = 10 000	N/mL
Campylobacter jejuni	$C \sim uniform(min, max)/1000$	min = 100, max = 1 000 000	CFU/mL

Inflow: local data

Pathogen	Distribution/formula	Parameter values	Units
NoV GGII	$log_{10}C \sim N(\mu, \sigma)$	μ= 5.63, σ = 0.78	GC/mL
Cryptosporidium parvum	$C \sim uniform(min, max)/100$	min = 1, max = 500	N/mL
Campylobacter jejuni	$C \sim NegBinomial(\mu, \phi)$	$\mu = 147, \phi = 8{,}4$	CFU/mL

Log-removal value

Indicator row	Primary	Secondary	Ozonation	Coagulation–filtration	UV	Total LRV (sum)
bacteria_min	0.0	1.0	2.0	0.2	2.0	**5.2**
bacteria_max	0.5	3.0	6.0	2.0	4.0	**15.5**
virus_min	0.0	0.5	3.0	0.1	1.0	**4.6**
virus_max	0.1	2.0	6.0	2.0	3.0	**13.1**
proto_min	0.0	0.5	0.0	1.0	3.0	**4.5**
proto_max	1.0	1.5	0.0	2.0	3.0	**7.5**

Log-removal value

Indicator row	Primary	Secondary	Ozonation	Coagulation–filtration	UV	Total LRV (sum)
bacteria_min	0.0	1.0	2.0	0.2	2.0	**5.2**
bacteria_max	0.5	3.0	6.0	2.0	4.0	**15.5**
virus_min	0.0	0.5	3.0	0.1	1.0	**4.6**
virus_max	0.1	2.0	6.0	2.0	3.0	**13.1**
proto_min	0.0	0.5	0.0	1.0	3.0	**4.5**
proto_max	1.0	1.5	0.0	2.0	3.0	**7.5**

Scenarios

Scenario label (plot)	Description/code name	Number of exposure events (nexposure)	Volume per event (volume_mL)	Total volume per scenario
Car washing	"Car washing"	25	0.1 mL	2.5 mL
Public irrigation	"Public irrigation"	50	1.0 mL	50 mL
Unrestricted irrigation	„unrestricted irrigation"	70	5 mL	350 mL

Monte Carlo simulation

Element	Value/description
Influent draws	10 000 per pathogen per dataset
Effluent draws	10 000 per pathogen per dataset (after LRV)
Scenario simulations	1 000 per (dataset × scenario × pathogen)
Sampling of individuals	Sample effluent concentrations with replacement
Per-scenario infection risk	$P_{I,total} = 1 - \prod_{i=1}^{N}(1 - P_{i,n})$

Interreg Baltic Sea Region
Co-funded by the European Union

KWB

SUSTAINABLE WATERS
WaterMan

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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.