Safe wastewater reuse in the United Arab Emirates; safety assessment from concept to realisation

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Introduction

In the Middle East fresh water is scarce and often produced from seawater at high costs. Currently, used drinking water is regarded as wastewater and, after treatment, discharged to the sea. Recently the Government of Fujairah (UAE) has developed a water distribution system to facilitate wastewater reuse for irrigation. Before putting this system into use, the TANQIA wastewater treatment company has performed a safety assessment of the existing and planned water reclamation system. Together with KWR Watercycle Research Institute a stepwise approach to reach safe water reuse has been developed and executed.

Stepwise approach to safe water reuse

The water reuse project is part of various developments at the TANQIA wastewater treatment site. The capacity of the existing system will be increased to match the increased wastewater flow. At the same time the treatment process will be extended with processes for reclamation of wastewater. In addition, two container systems for small scale decentralized wastewater reuse have been developed. KWR and TANQIA took a phased approach to reach safe water reuse as shown in Figure 1.

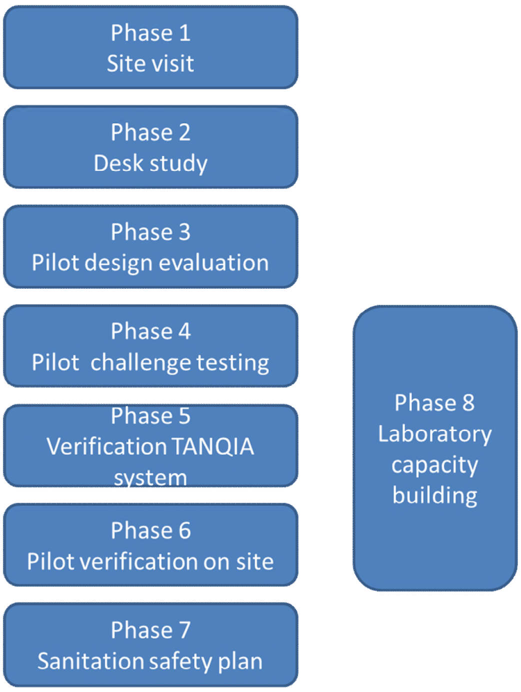

Figure 1 Stepwise approach to safe water reuse

The site visit in phase 1 created mutual understanding of the project goals and of the actual system. It included an inspection of technical status, operation, procedures, monitoring and record keeping. Inspection results were included in the desk study risk assessment of the current and planned system in phase 2. The designs of the pilot systems were evaluated in phase 3, leading to improvements. The pilot systems will be validated by challenge testing (phase 4) before shipment to the UAE, making use of advanced laboratory capacities in the Netherlands. Local laboratory capacities in the UAE will be developed in phase 8, since these will be needed for verification of performance of the full scale and pilot treatment systems in operation. Close collaboration with the KWR laboratory during the verification phases 5 and 6 allows for effective and practical knowledge exchange and training. Finally, in phase 7 all experiences will be captured in a Sanitation Safety Plan (SSP), including procedures for operation and monitoring that secure safe reclaimed water.

Results of safety assessment

The safety of the current and extended treatment system were assessed based on the WHO guidelines for safe use of wastewater in agriculture. In phase 2 the microbial wastewater composition and effect of treatment were estimated based on literature. Using minimal and maximum expected performance, the 'worst' and 'best' situation were estimated. Figure 2 shows the total performance for viruses, bacteria and protozoa, evaluated against various health-based targets for restricted and unrestricted irrigation and even potable reuse. In the worst case the system won't meet safety targets for viruses and protozoa, but with proper design and operation the extended system could even reach potable water quality. Figure 2 illustrates the various challenges per organism. Chlorination is important for controlling viruses and bacteria, while the inspection revealed that operation, monitoring and record keeping for chlorination needs improvement. Verification through on-site microbial monitoring is needed in phase 5 to verify that the system is meeting the targets.

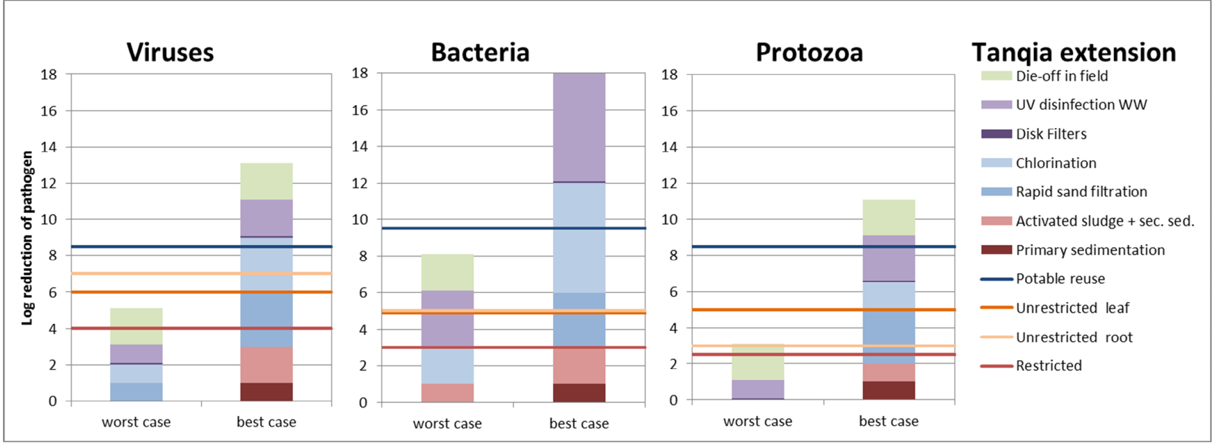

Figure 2 Expected treatment performance under worst and best case assumptions and health based targets as log removal values.

Outlook

At the moment of writing (October 2018) phase 4, validating the pilot container systems, is on-going. At the time of the conference (June 2019) we expect to present the results of phase 4, 5 and 6 (full scale verification) and to report on phase 8.

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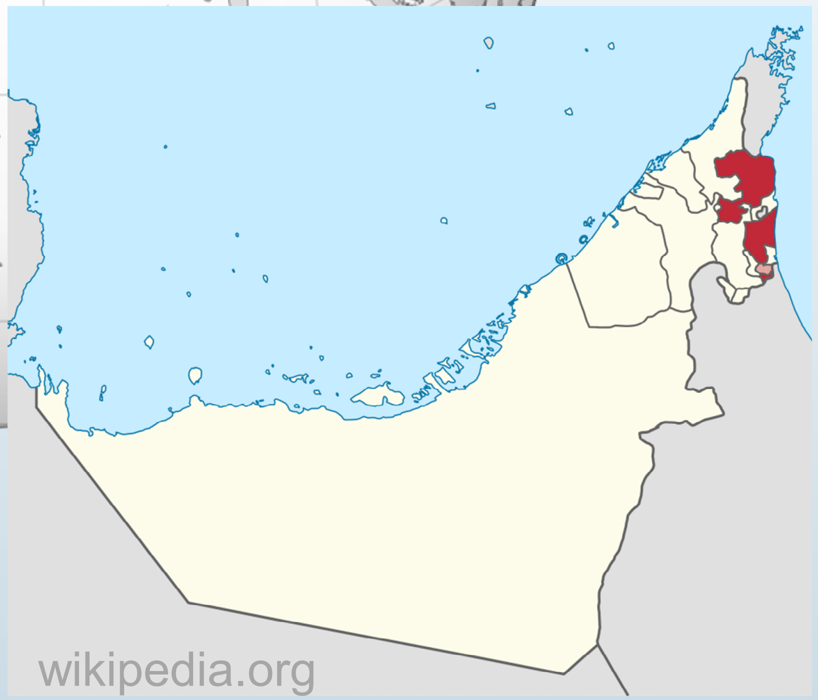
Dr. Ibrahim Elwan (TANQIA)

17 June 2019, IWA Water Reuse Conference, Berlin

Current situation in Fujairah
United Arab Emirates

- Fresh water mostly desalination
- Currently used once, then treated and discharged to the ocean
- This is not efficient or sustainable
- TANQIA is the wastewater service provider

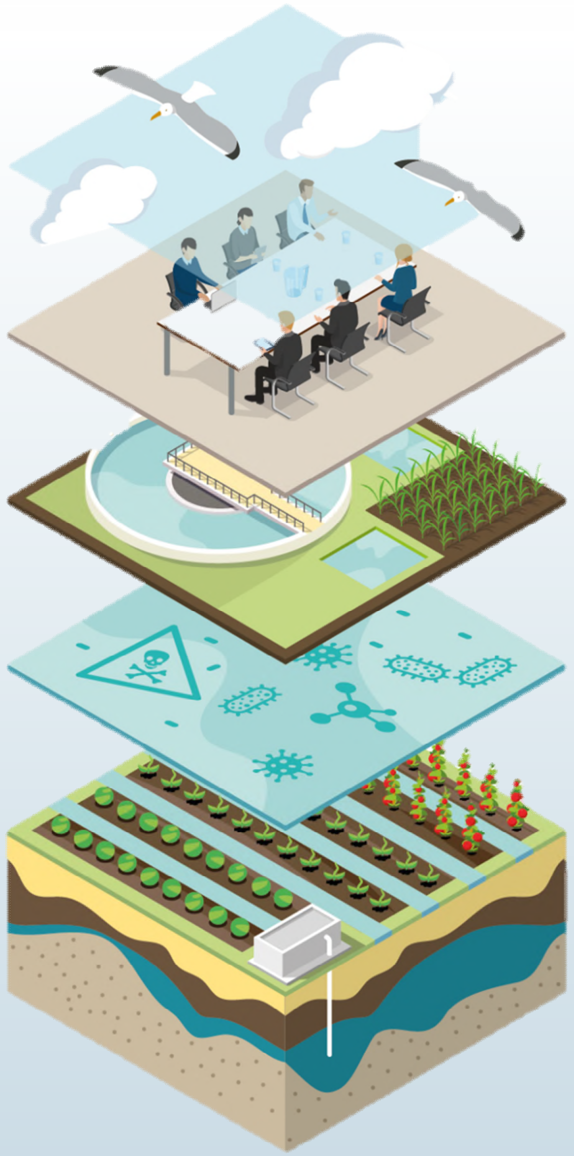
TANQIA Entered into a Cooperation with KWR in the Process of Implementing save Re-Use of treated Effluent for both technical and organizational support.



TANQIA

- TANQIA is first of its kind Developer having implemented a wastewater-based BOOT-Project in the Gulf Region;
- 33-year Concession granted in 2004 by the Government of Fujairah (one of seven Emirates in the United Arab Emirates) to TANQIA;
- Exclusive Right during the Concession Period to design, finance, construct, own, operate, maintain and expand the Wastewater Treatment System, and market the treated Effluent produced by the Wastewater Treatment System in the Concession Area;

Water reuse, many aspects to consider



Sustainability (contaminants into environment, energy and materials treatment)

Legislation and regulations (WHO guidelines, California Title 22)

Water treatment technologies (current, upgrade, UF and NF pilot)

Health and safety (microbial and chemical risks)

Reuse application (irrigation, potable)

Matching availability and demand (water storage)

Municipal wastewater reuse for irrigation

Risk assessment of treament options

Municipal wastewater treatment plant

1. Current treatment:
   - Primary sedimentation
   - Activated sludge
   - Secondary sedimentation
   - Sand filtration
   - Chlorination
2. Extension planned: ~~SF~~→disk filters+UV
3. Pilot ~~CL_2~~ → Ultrafiltration-GAC-UV
4. Pilot ~~CL_2~~ → Nanofiltration-GAC-UV

CURRENT SECONDARY SEDIMENTATION

Risk assessment at various levels/stages of project

Stage	Goal	Information
Desktop risk assessment Current	Could safety be achieved?	Standards guidelines

Reuse applications

Intended use

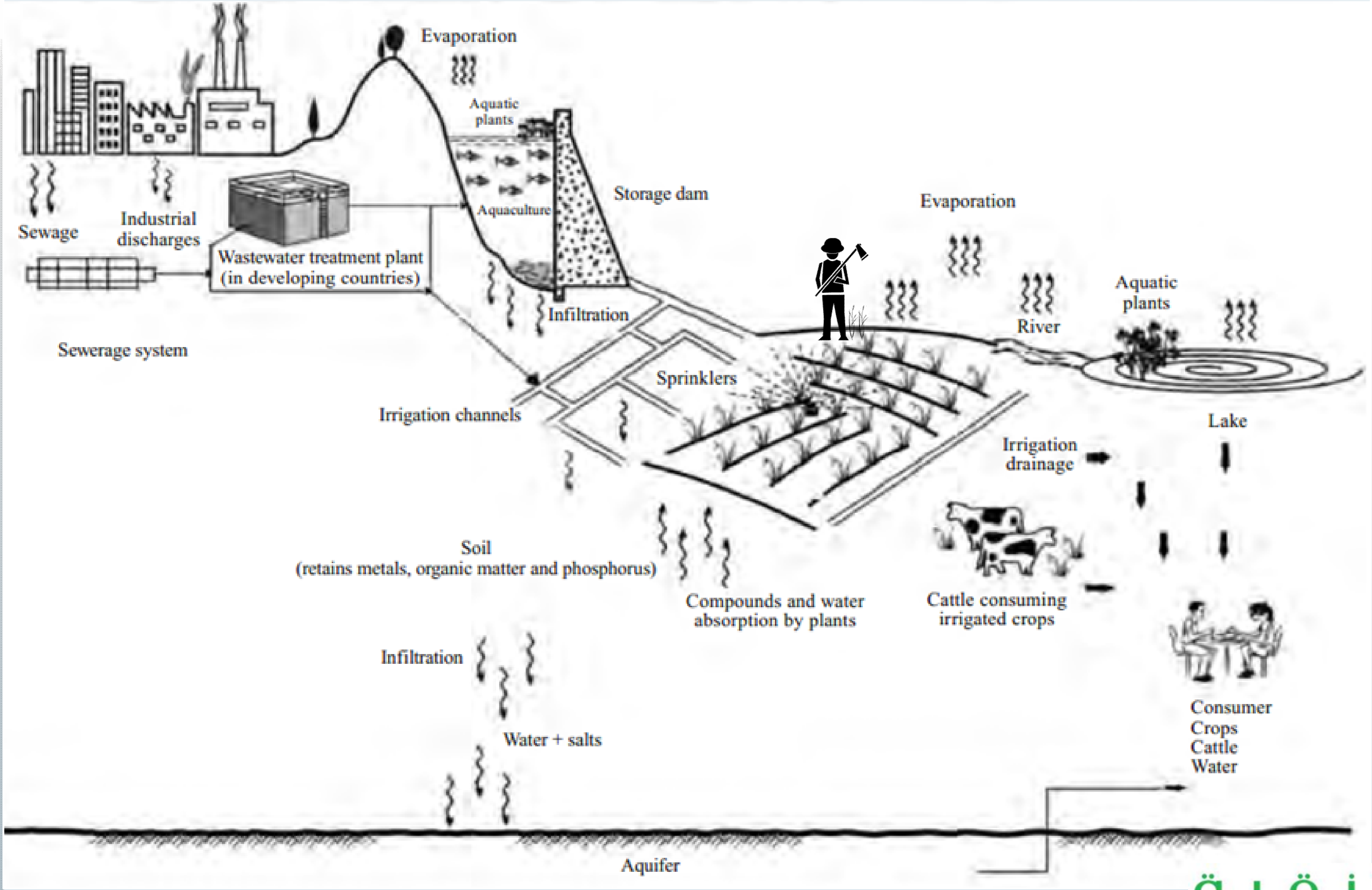
- restricted irrigation
- unrestricted irrigation
- drinking

Method of application

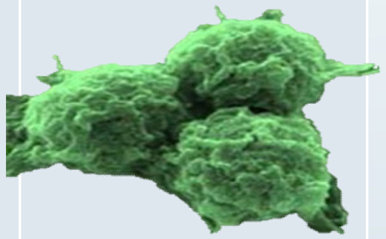
- drip or spray irrigation
- root or leafy crops

Exposure:

- consumers (crops, water)
- workers and public
- plant health/crop yield
- environment



Types of pathogens pose various challenges of occurence, persistance, treatment, health impact

Index pathogen	Origin	Characteristics	
Viruses *enterovirus*	Human	Very small (25 nm), hard to filter, variable resistance against UV, Cl_2	
Bacteria *Campylobacter*	Human+ Animal	Bacteria, high numbers in feces, Easily removed by treatment	
Protozoa *Cryptosporidium* *Giardia*	Human+ Animal	Very persistent, not affected by chlorine, but sensitive to UV	
Helminths (worms) *Ascaris*	Human+ Animal	Very persistent, especially in agriculture. No dose-response	

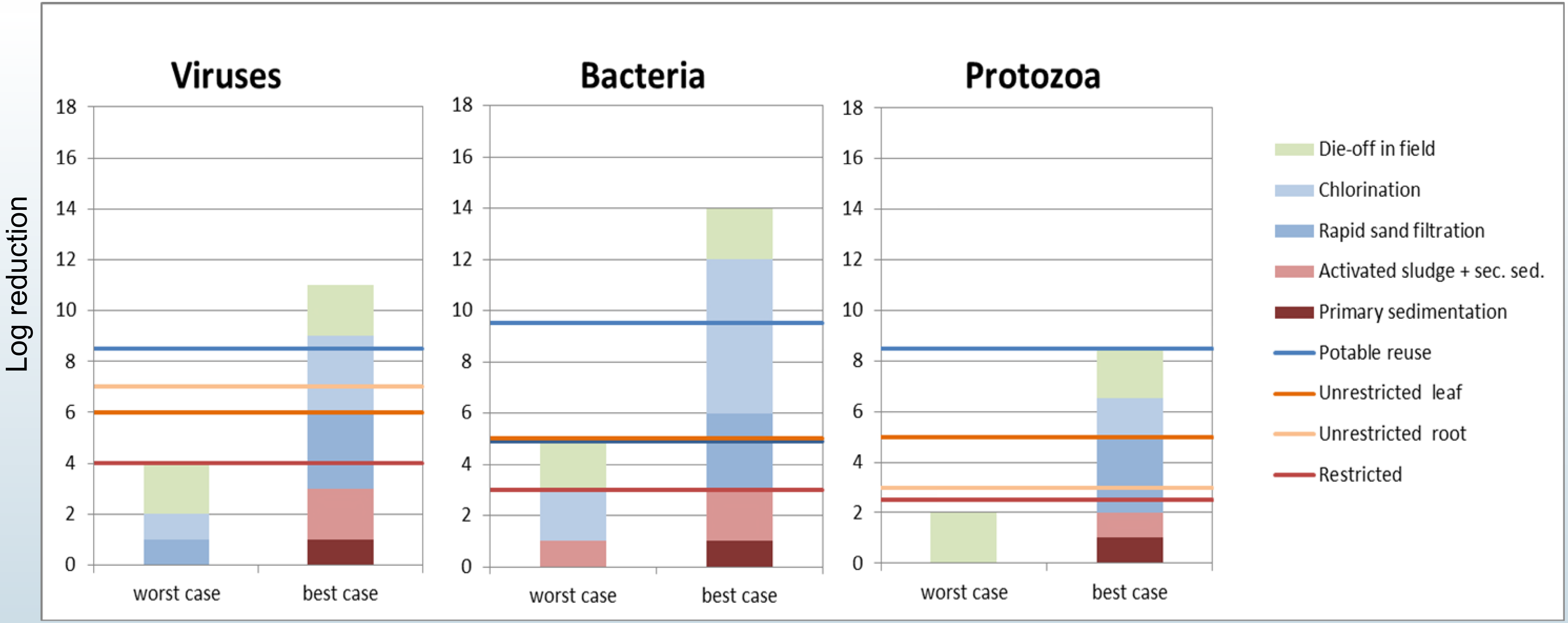
Desktop study risk assessment based on literature

Worst case and best case conditions

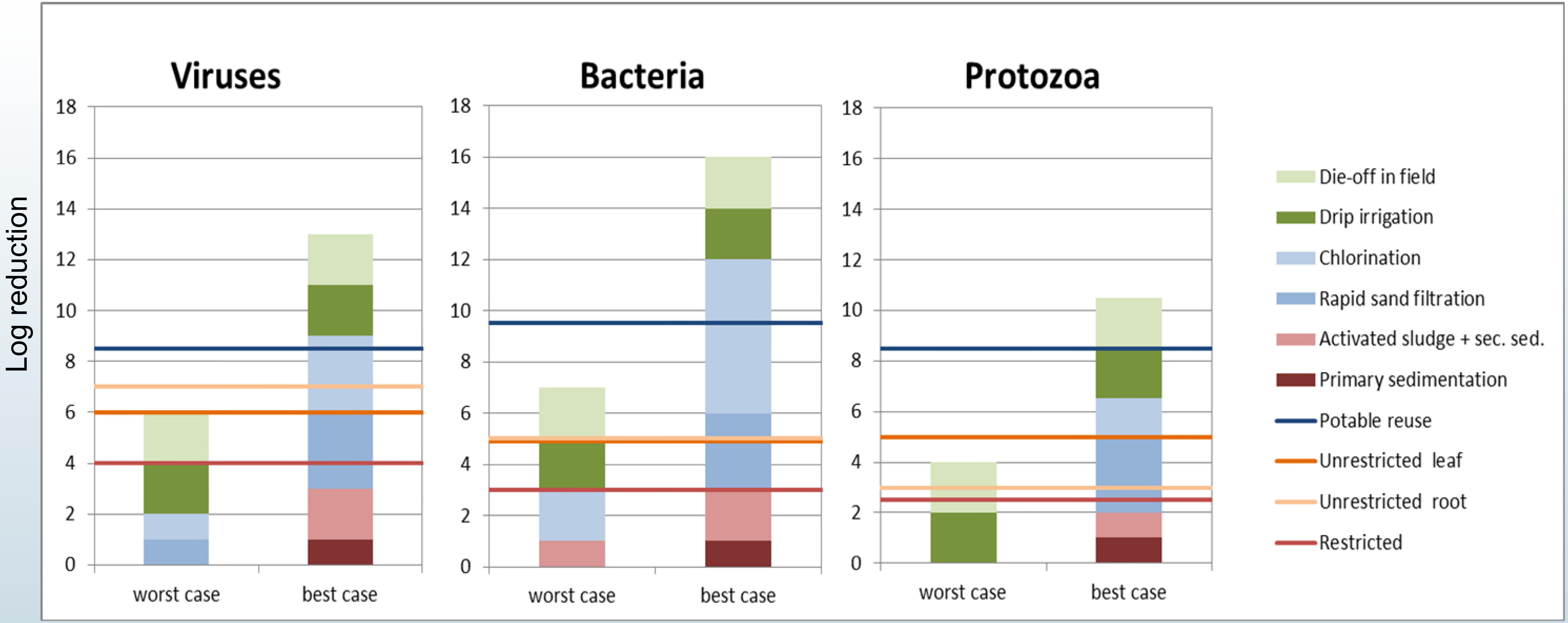
	Viruses		Bacteria		Protozoa		Helminth eggs	
	worst	best	worst	best	worst	best	worst	best
(Waste)water composition (log10 #/L)	6	5	5	1	5	2	3	0
Wastewater treatment effect (log10)								
Primary sedimentation	0	1	0	1	0	1	0	1
Activated sludge and sec. sedimentation	0	2	1	2	0	1	1	2
Reclamation treatment effect (log10)								
Rapid sand filtration	0[7]	3	0	3	0	3	1	3
Chlorination	1	3	2	6	0	1,5	0	1
Disk Filters[1]	0	0	0	0	0	0	2	2
UV disinfection WW [2]	1	2	3	6	1	2,5	0	0
Ultrafiltration[3]	4	4	6	6	6	6	6	6
Nanofiltration[4]	4	4	6	6	6	6	6	6
Activated Carbon Filtration[5]	0	0	0	0,5	0	2	0	2
UV disinfection DW[6]	3	5	3	6	2	2,5	0	0

	Pathogens		
	Enteric bacteria (*Campylobacter*)	Enteric viruses (noroviruses)	Enteric protozoa (*Cryptosporidium*)
Default concentration (per litre) in source wastewater	7000	20 000	2700

Current system with spray irrigation (WHO guidelines)



Current system with drip irrigation (WHO guidelines)



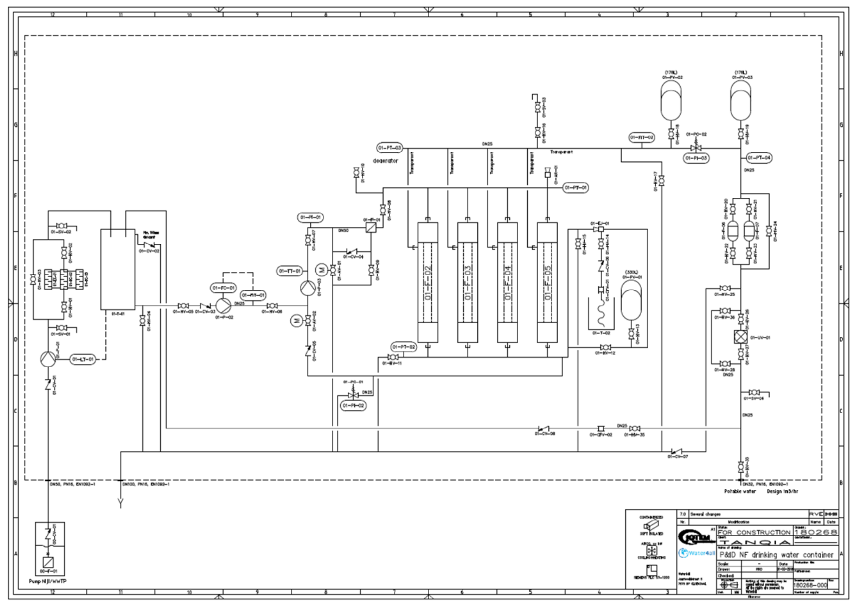
Risk assessment at various levels/stages of project

Stage	Goal	Information
Desktop risk assessment	Could safety be achieved?	Standards guidelines
Design evaluation of pilots	Could design, equipment and operation achieve safety?	Equipment data, PID's operation and monitoring plan

Design evaluation (extension and pilots)

Based on technical design (e.g. PID) and selected equipment

- Standards, certified? e.g. UV-disinfection DVGW or USEPA
- Equipment tested? e.g. membrane challenge testing
- Correct (online) monitoring equipment?
- Options for operational testing?
  e.g. membrane pressure hold test
- Risk of short circuiting?
- Risk of recontamination?



MEMBRANE CHARACTERISTICS

- Hydrophilic membrane composed of a blend of polyvinylpyrrolidone and polyethersulfone
- A nominal pore size of 20 nm
- Structure asymmetric/microporous
- High performance and a very good anti-fouling behaviour
- Typical permeate quality SDI<3, turbidity <0,1 NTU
- Membrane filtration provides 99.9999% (LOG6) reduction of bacteria (Pseudomonas diminuta) and 99.99% (LOG 4) reduction of virus (MS2 colifages) by mechanical means. EPA Est. No. 090374-NLD-001

Risk assessment at various levels/stages of project

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Design evaluation of pilots	Could design, equipment and operation achieve safety?	Equipment data, PID's operation and monitoring plan
Validation of pilots	Does the system (or parts) achieve performace?	Challenge testing Water quality testing

Validation: what is the system capable of?

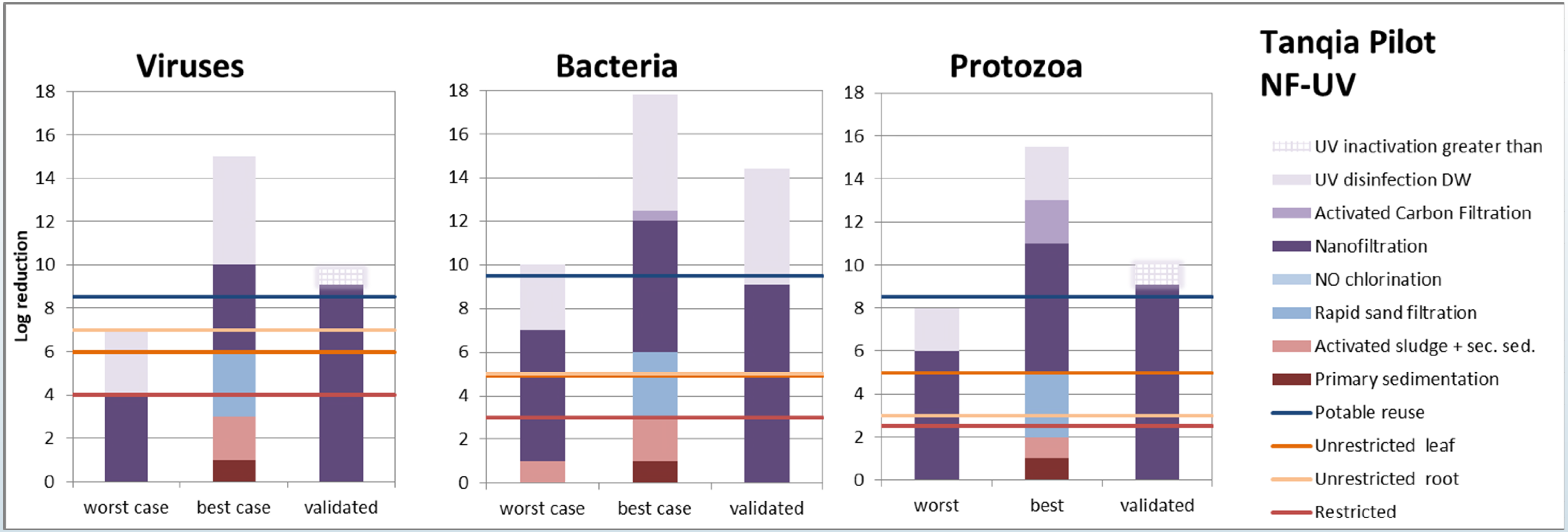
- Controlled conditions
- Challenge testing of equipment in built system
- Testing (automated) operation
  - normal conditions
  - startup, failure etc.

10^12 VIRUSES DOSED

TREATMENT

SAMPLING AFTER EACH PROCESS

Validated safety Nanofiltration pilot



Risk assessment at various levels/stages of project

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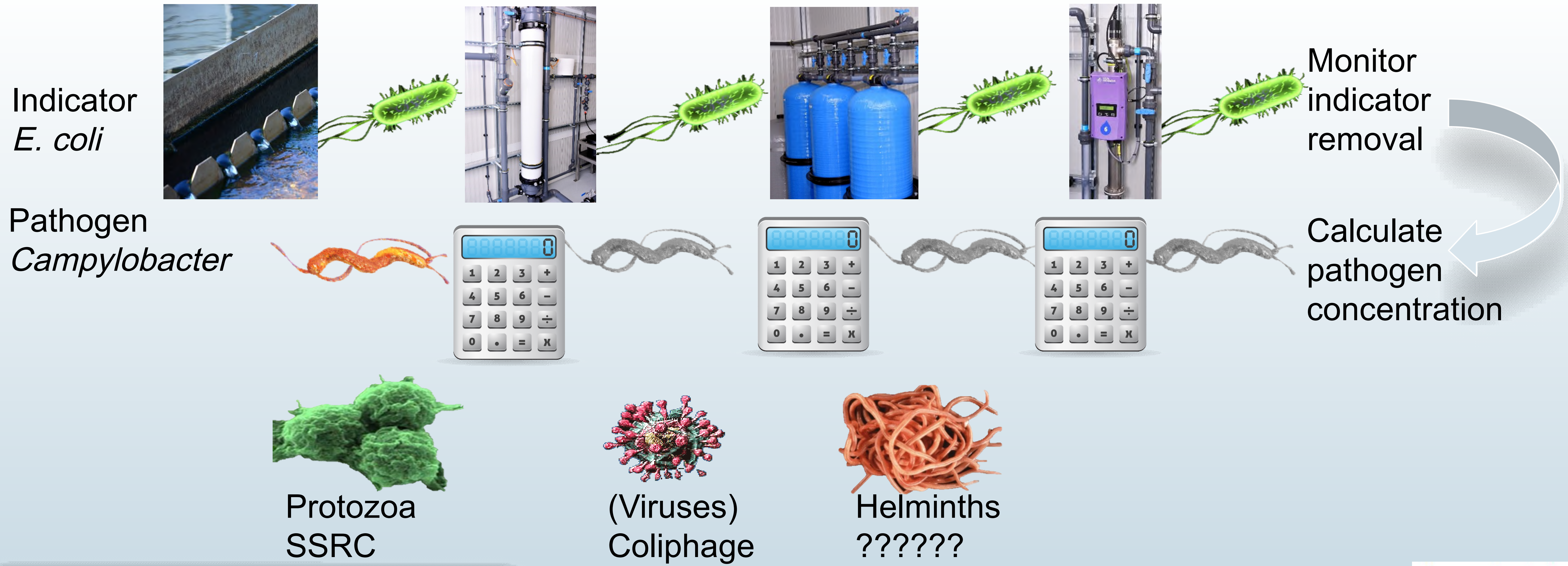
Design evaluation of pilots	Could design, equipment and operation achieve safety?	Equipment data, PID's operation and monitoring plan
Validation of pilots	Does the system (or parts) achieve performace?	Challenge testing Water quality testing
Verification of existing plant and pilots	Is the system performing as expected?	Water quality monitoring (indicators)

Verification, microbial

Monitoring indicators in practice



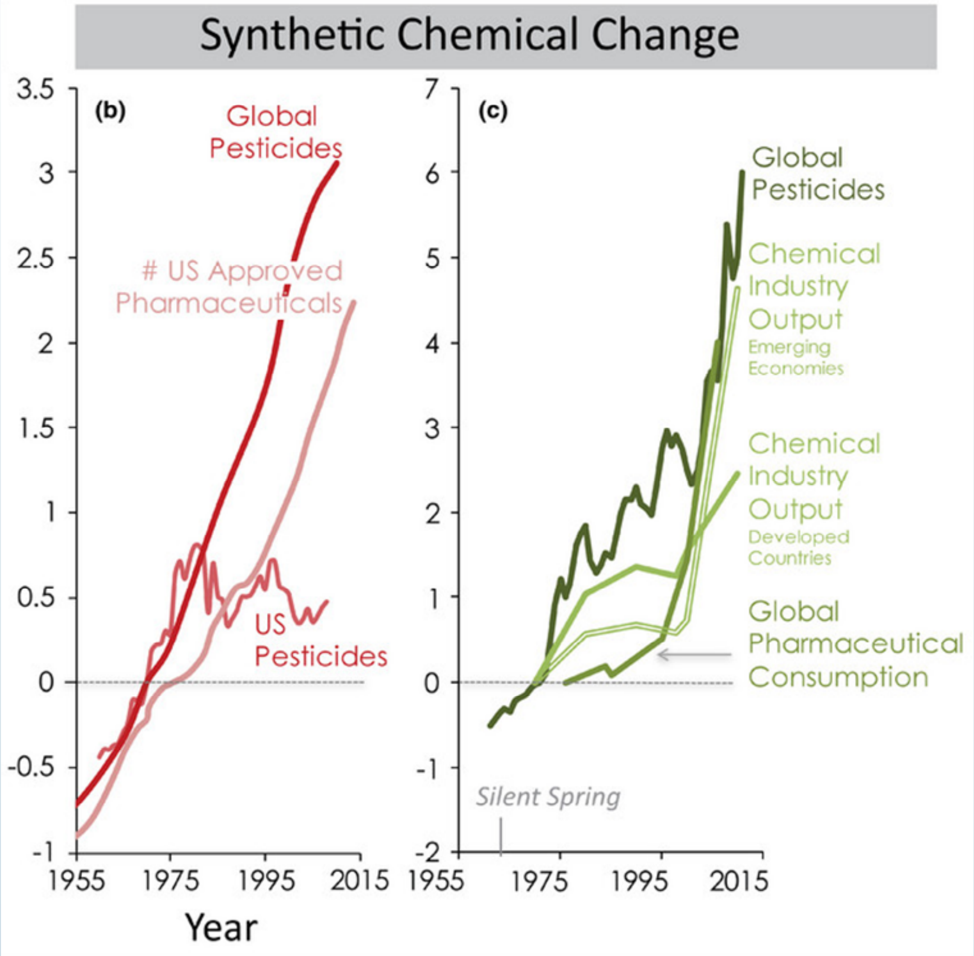
Verification, chemical

Water

Millions of new chemicals yearly

Monitor key known contaminants

Removal of indicator chemicals



Soil

Water quality not the only issue

Effect of soil type, climate, irrigation practice

Monitor irrigated versus non-irrigated soil

Results to date

Microbial:

- Few pathogens/indicators in influent, highly variable (remarkable)
- No indicators after treatment (two incidents in existing and UF pilot)
- Verification of validated performace isn't feasible

Chemical:

- Salt level limits irrigation (select tolerant crops)
- Few contaminants slightly above guideline
- Limited lab capability for contaminants of concern
- Very limited lab capability for indicator chemicals
- Nitrate issue for drinking water

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Desktop risk assessment	Could safety be achieved?	Standards guidelines
Design evaluation of pilots	Could design, equipment and operation achieve safety?	Equipment data, PID's operation and monitoring plan
Validation of pilots	Does the system (or parts) achieve performace?	Challenge testing Water quality testing
Verification of existing plant and pilots	Is the installed system performing as expected?	Water quality monitoring (indicators)
Operational monitoring, laboratory development	Is the system operating within specifications?	Operational monitoring (equipment+condition+WQ)

Operational monitoring and SOPs

Develop during pilot as preparation for full scale

- Part of WSP, SSP etc.
- Can consist of:
  - visual inspections
  - online sensors
    - UV intensity sensor
    - chlorine monitoring (+pH + Temperature + Flow)
    - turbidity after (sand) filtration
    - particle counting (UF)
  - Lab analysis

MANUAL SAMPLING TO CHECK CL2 SENSOR

UV INTENSITY ONLINE MONITOR

Conclusions and challenges

Risk assessment at various stages:

- Provides confidence for the next step
- Provides basis for adequate design and monitoring of next step
- Allows operations and challenge testing not feasible at full scale

Challenges:

- Many unknowns and large uncertainties in desktop study
- Variability of wastewater quality
- Availability of adequate lab capacity
- On-site lab will be developed for some parameters, but capacities are limited

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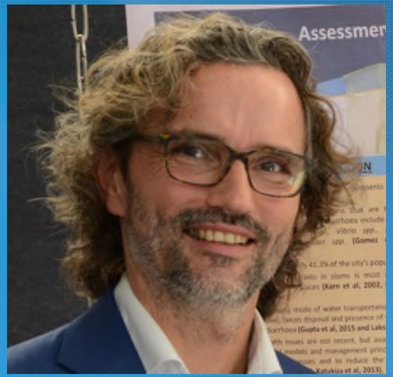

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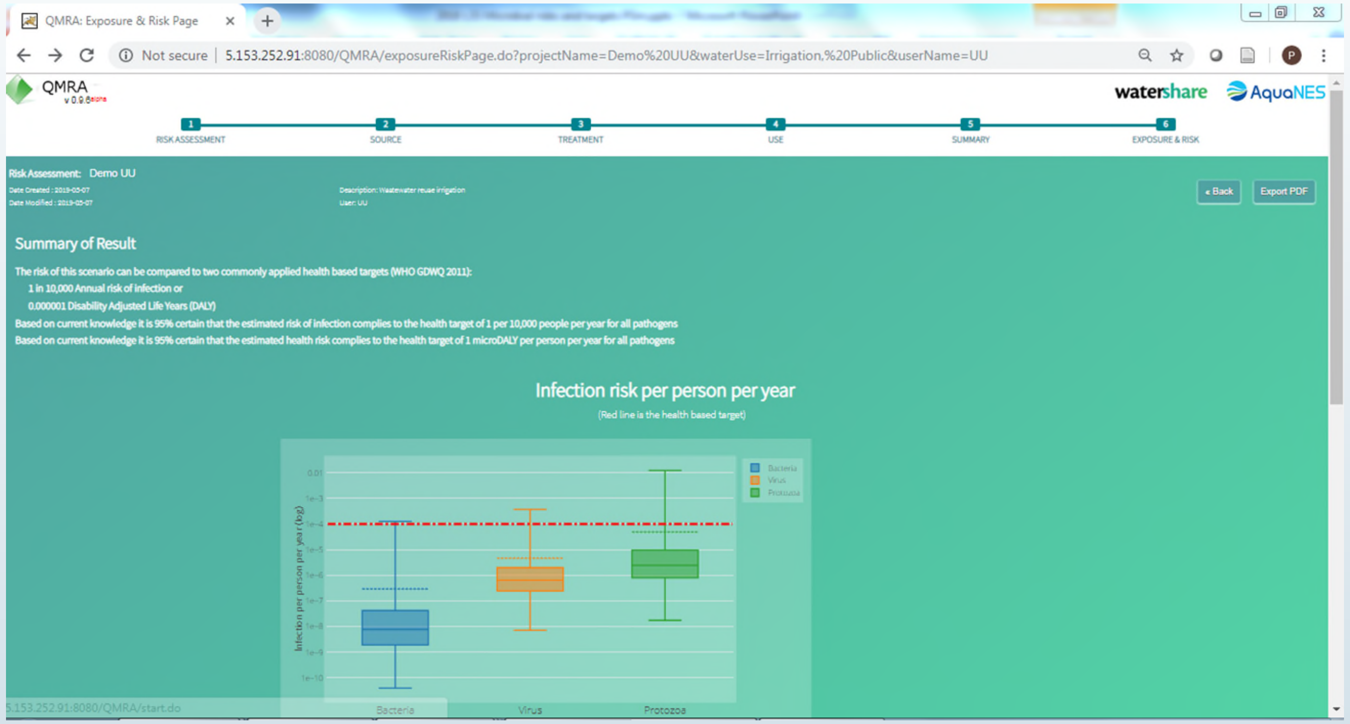
Current developments

AquaNES QMRA tool (values from guidelines)



IWA Water Reuse Berlin: Workshop Sunday 17-6-2019

QMRA reference document (Meta study of literature)

IWA Water Reuse Berlin: Presentation Tuesday 18-6-2019