Fate of Agrochemicals and Plant Pathogens during Managed Aquifer Recharge of Tile Drainage Water

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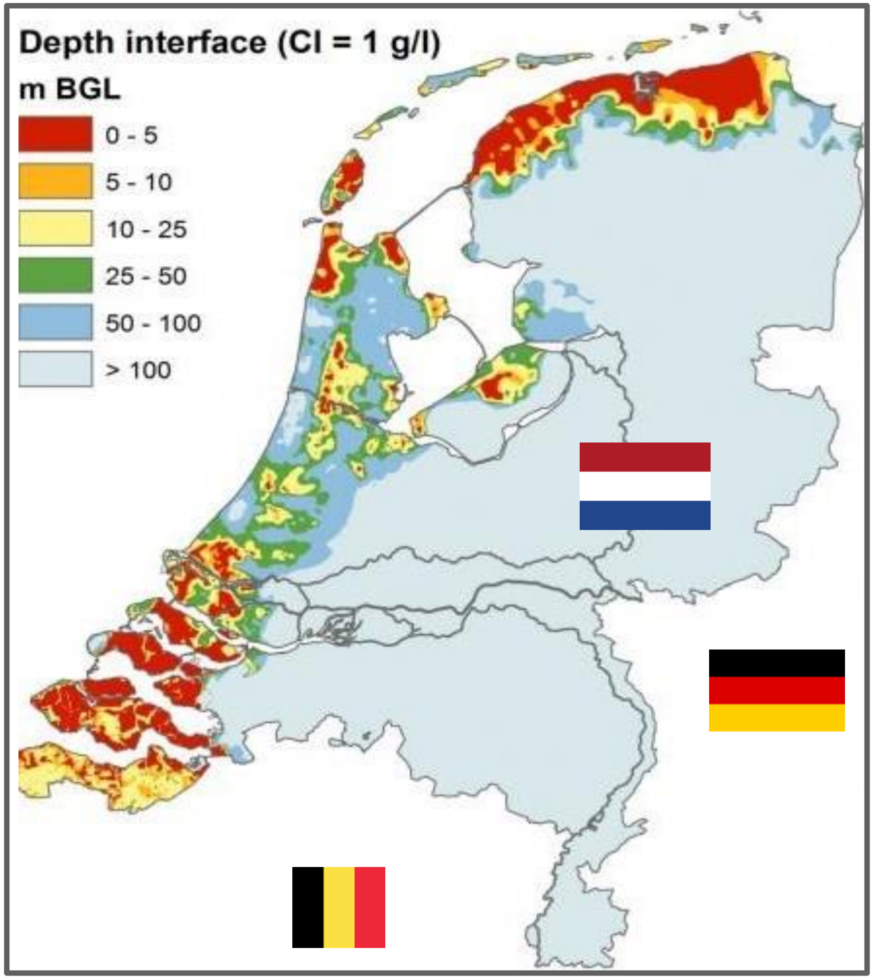
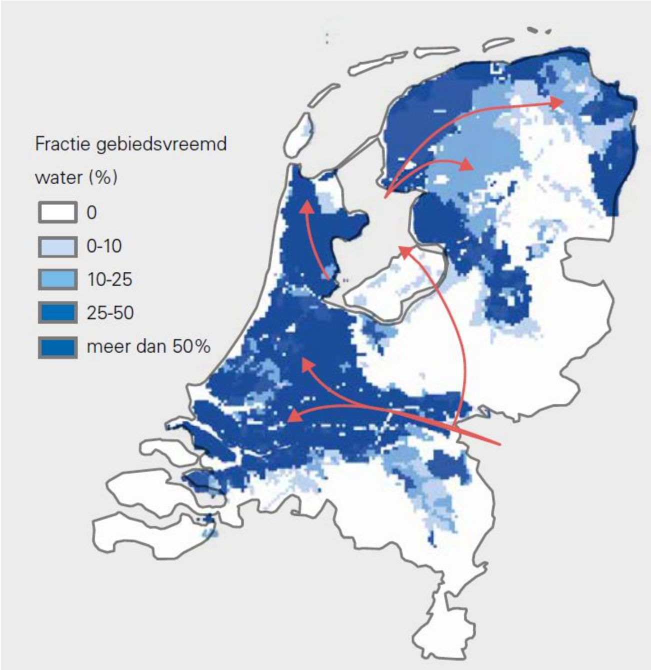
Issue: Lack of irrigation water (1/2)

Brackish groundwater coastal NL



Fresh surface water availability under stress:



Dry summers: need for irrigation water:

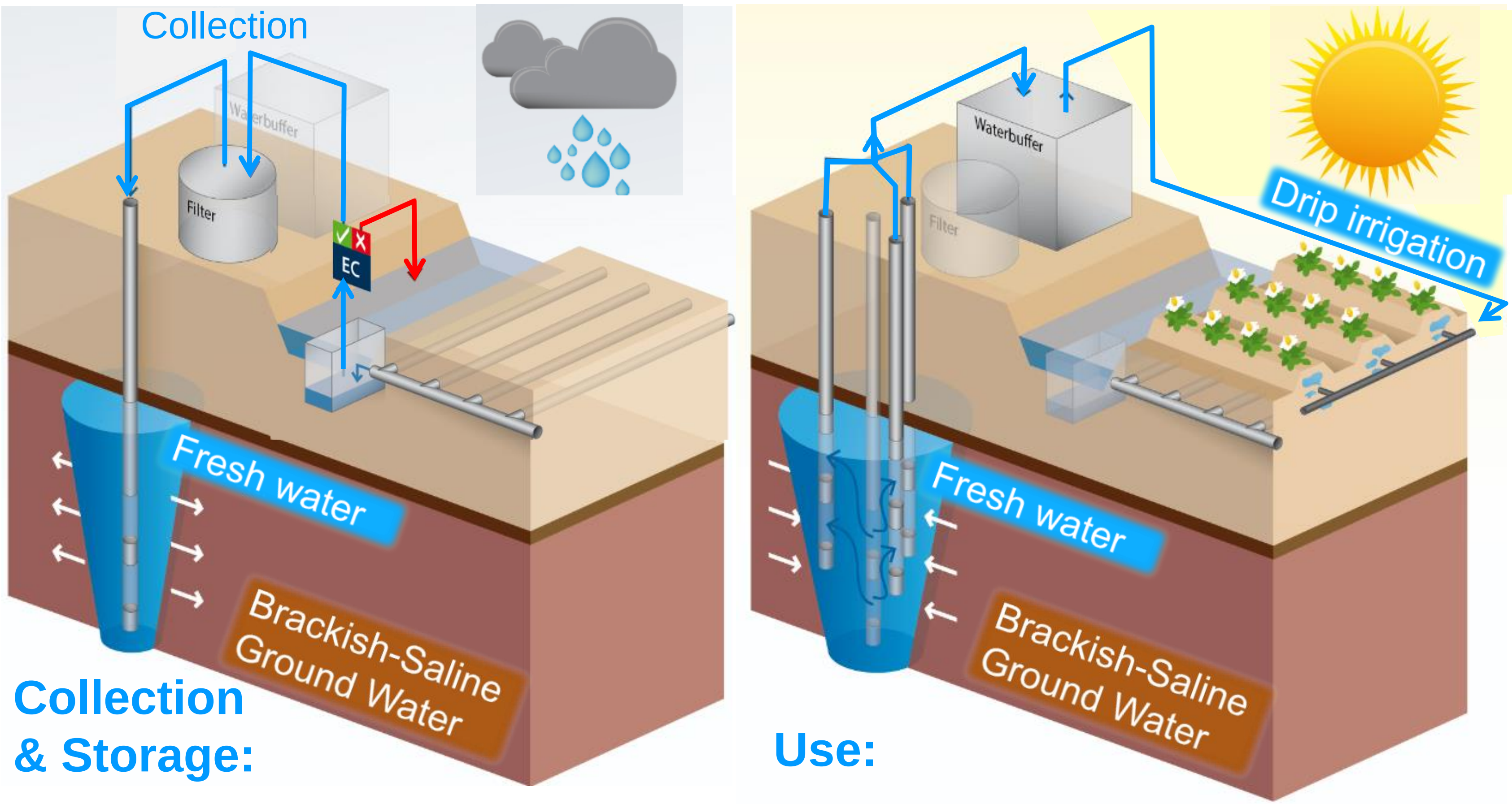
Issue: Lack of irrigation water (2/2)

- *Ralstonia solanacearum* found in Dutch waterways (▲): Restricted irrigation

- Risk of plant disease (brownrot)

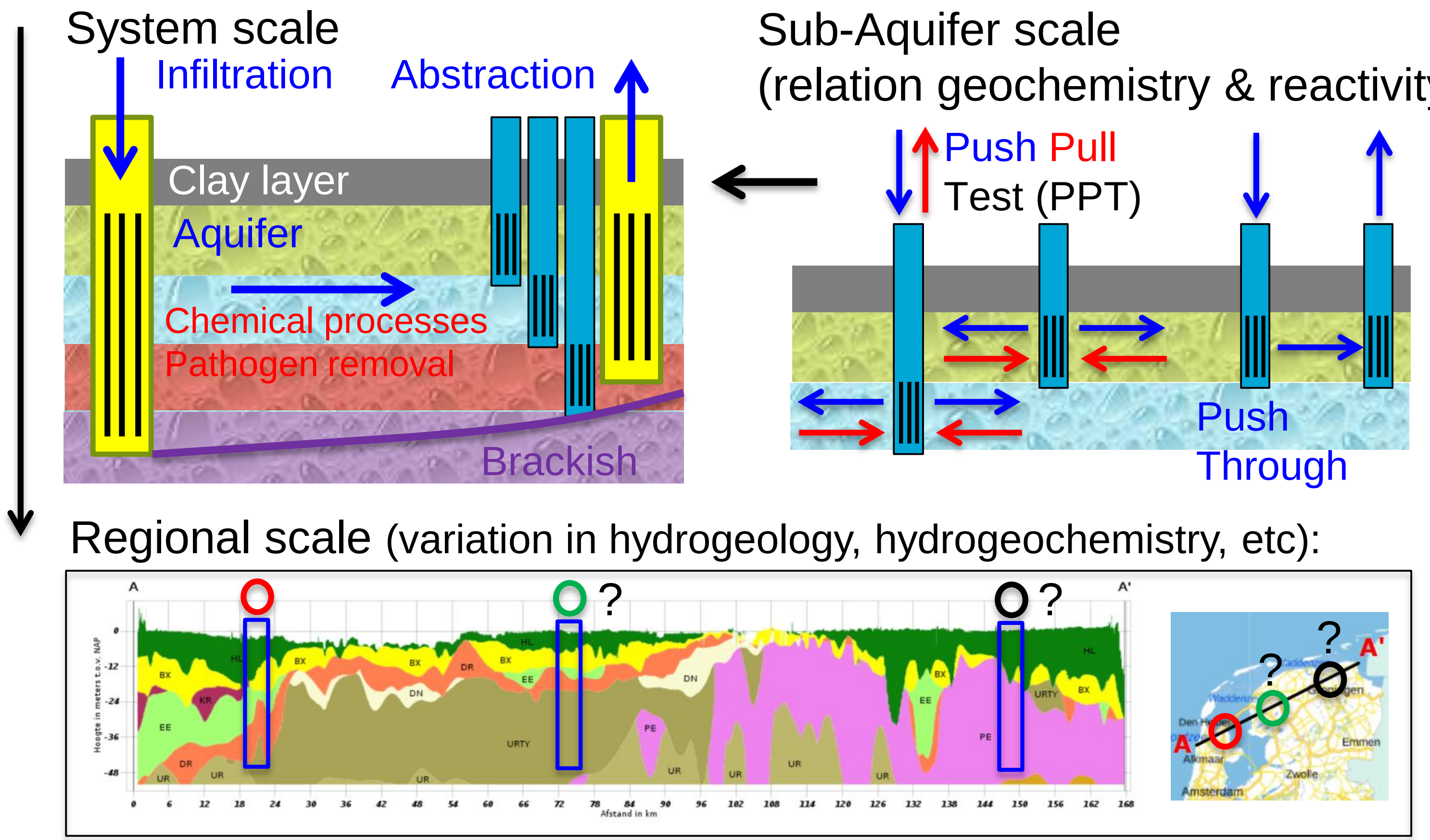
NVWA, Rapport fytosanitaire signaleringen 2016

Aquifer Storage & Recovery as Solution?

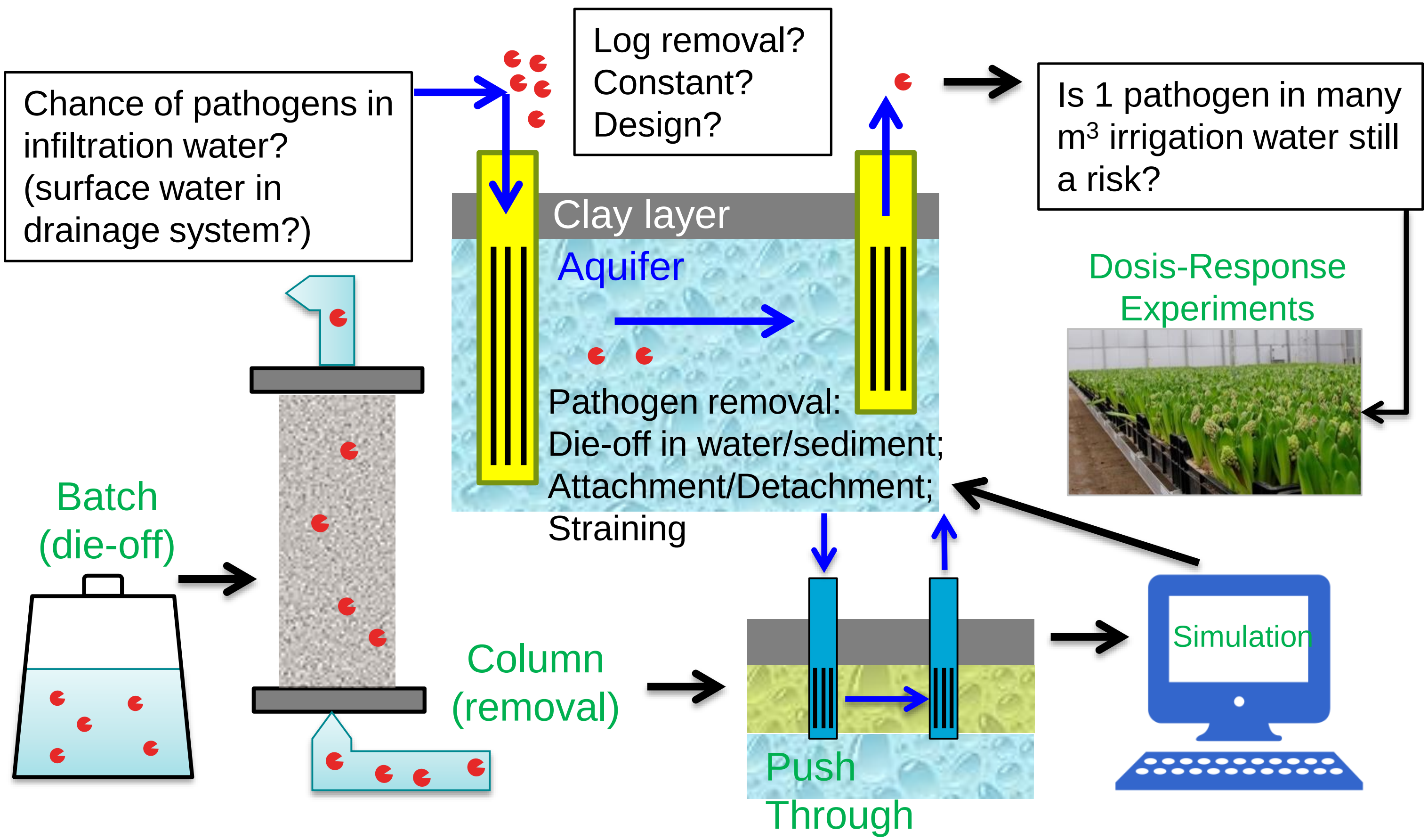


Risk for groundwater pollution (pesticides, nutrients)? Re-use of nutrients? Improvements of surface water quality? Removal of plant pathogens?

Research Approach: Water Quality



Research Approach: Pathogen Risk

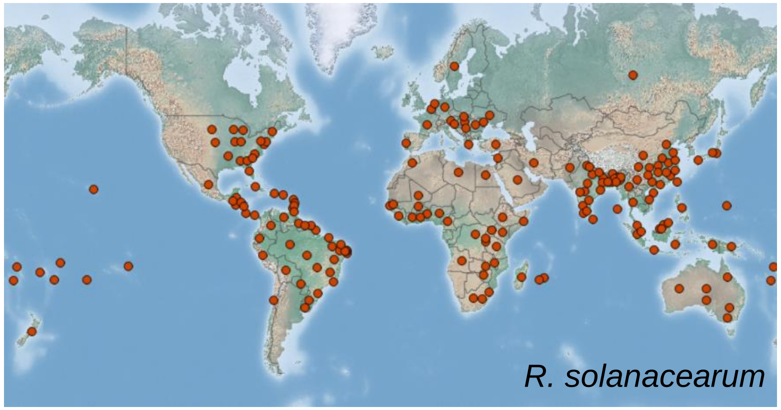


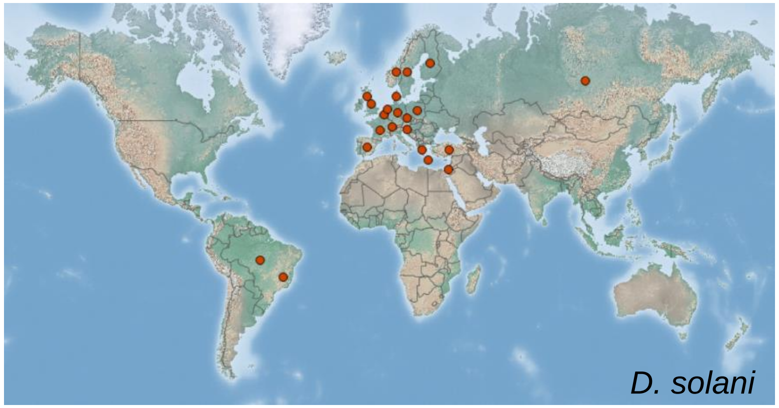
- Quantitative Microbial Risk Assessment (QMRA)

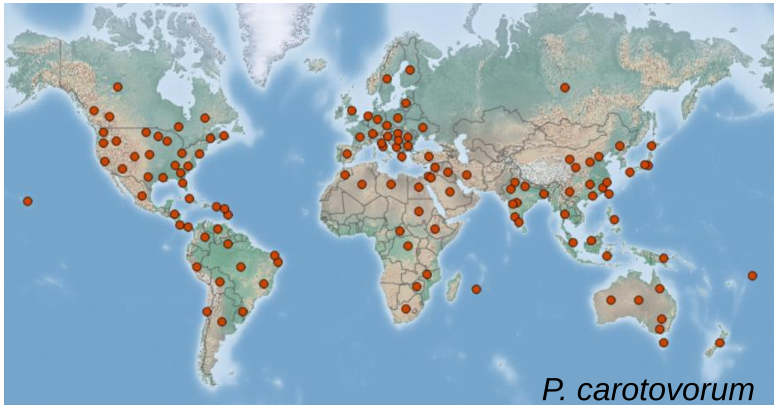
Selected bacterial pathogens

1. *Ralstonia solanacearum* phylotype IIb (IPO1828rif)
2. *Dickeya solani* IPO2266 (strep)
3. *Pectobacterium carotovorum* IPO1990 (strep)

- Broad host range
- Survival in water and soil
- Symptoms: brown rot, blackleg, soft rot

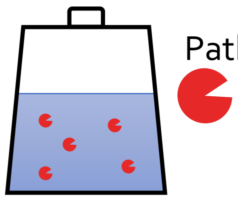




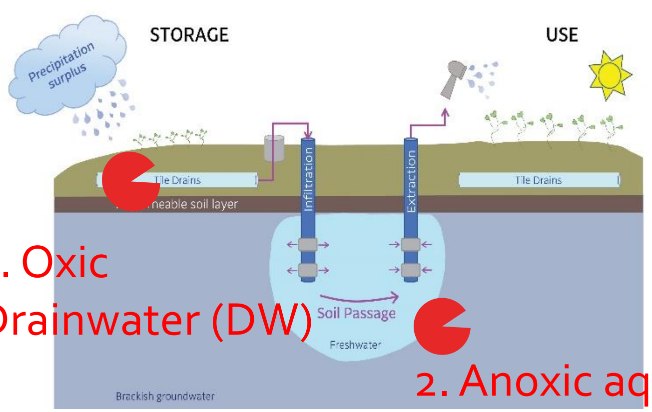


Pathogen die-off rates

Batch: Bacterial survival in water



1. Influence of water type



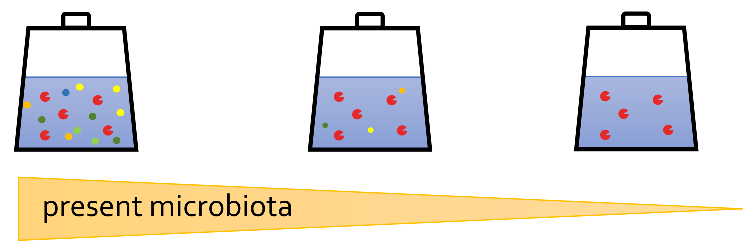
1. Oxic Drainwater (DW)

2. Anoxic aquifer water = mix: DW + natural aquifer

2. Influence of microbiota

Treatment of water before inoculation

Drainwater:	natural	0,22 µm filtered	autoclaved
Anoxic aquifer water:	natural		

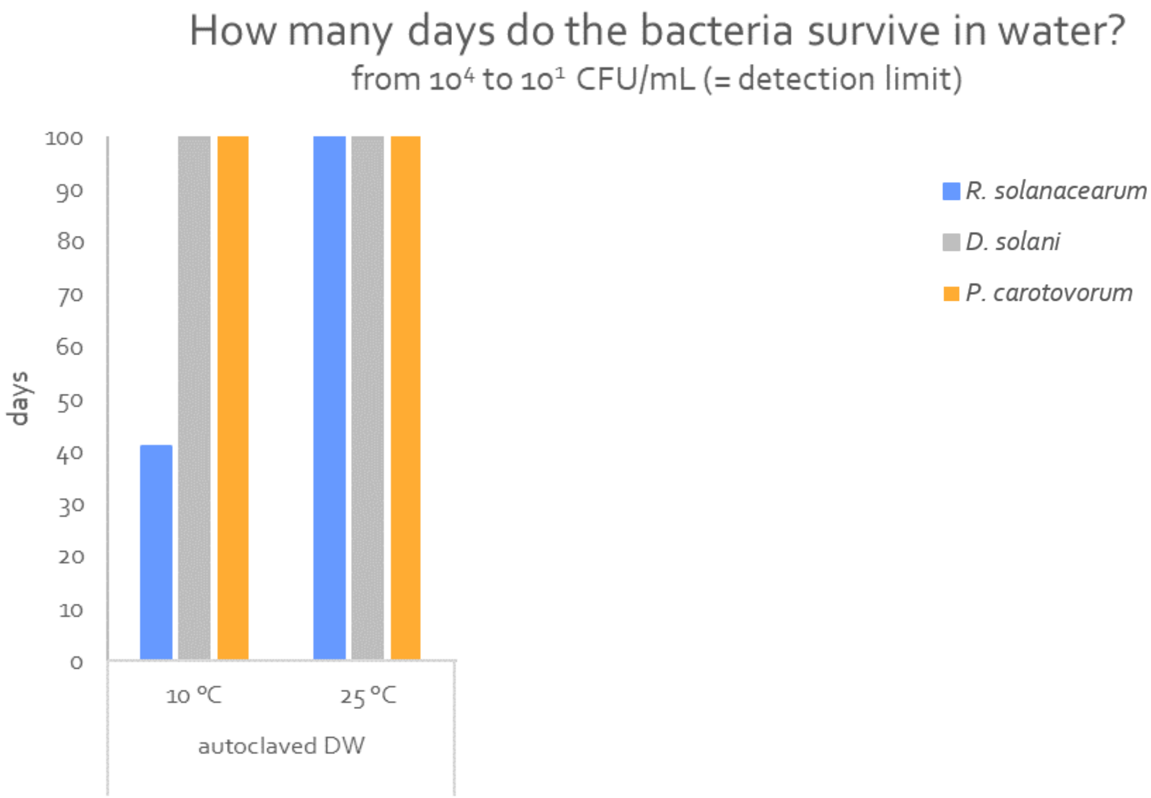


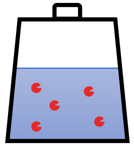
3. Influence of temperature

10 °C Aquifer

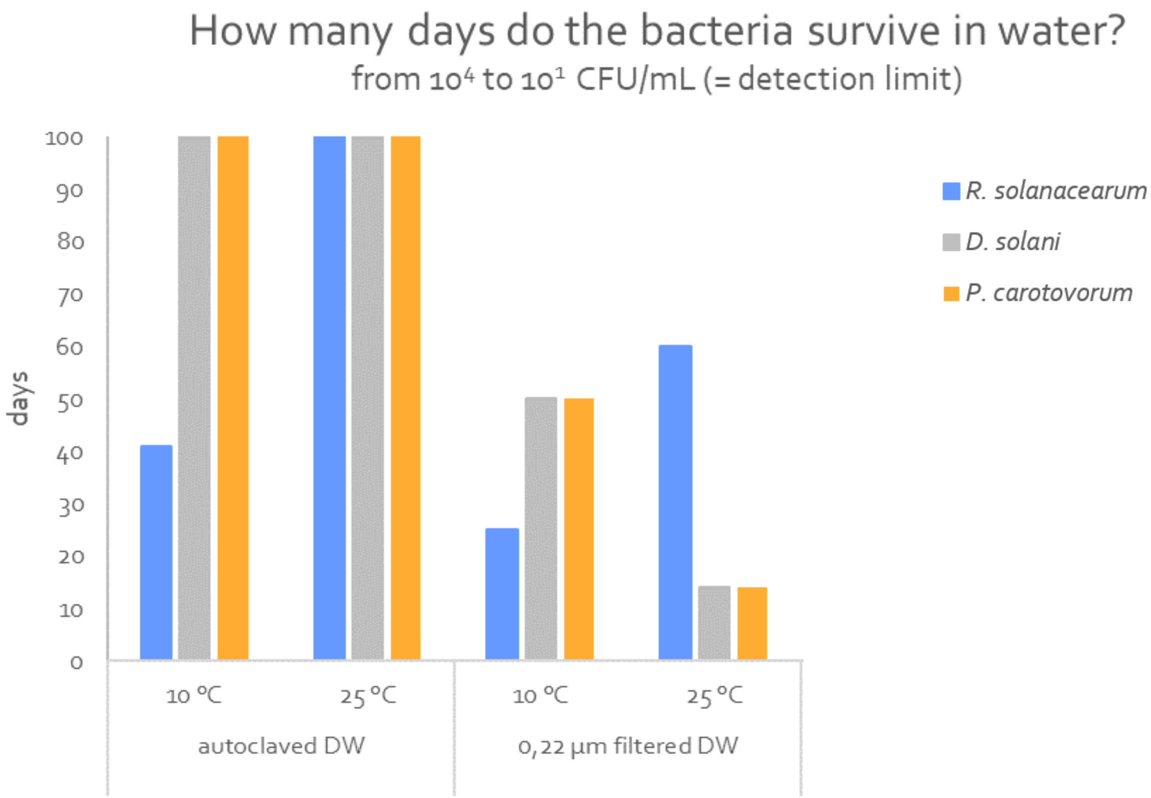
25 °C

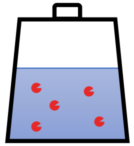
Pathogen die-off rates

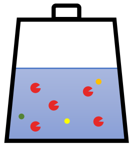




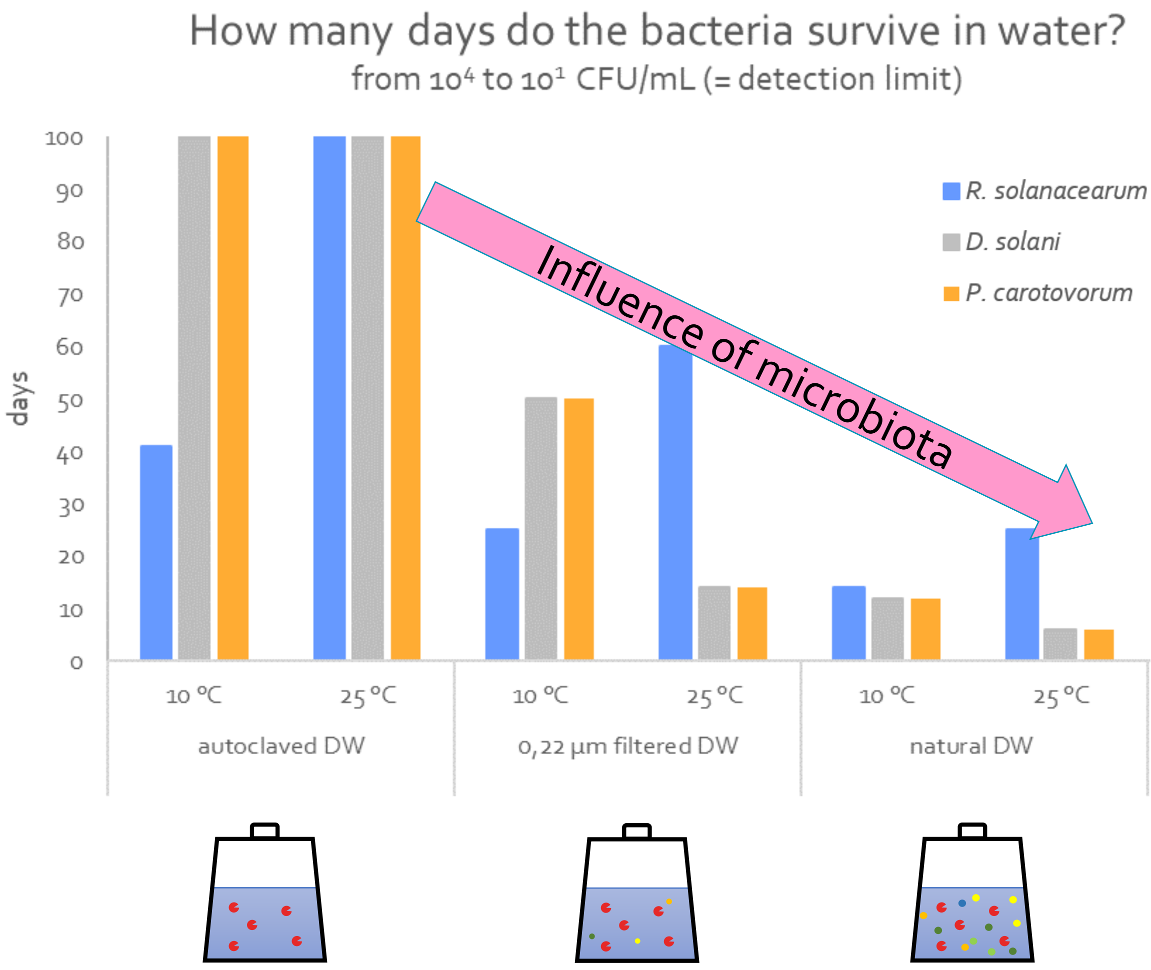
Pathogen die-off rates





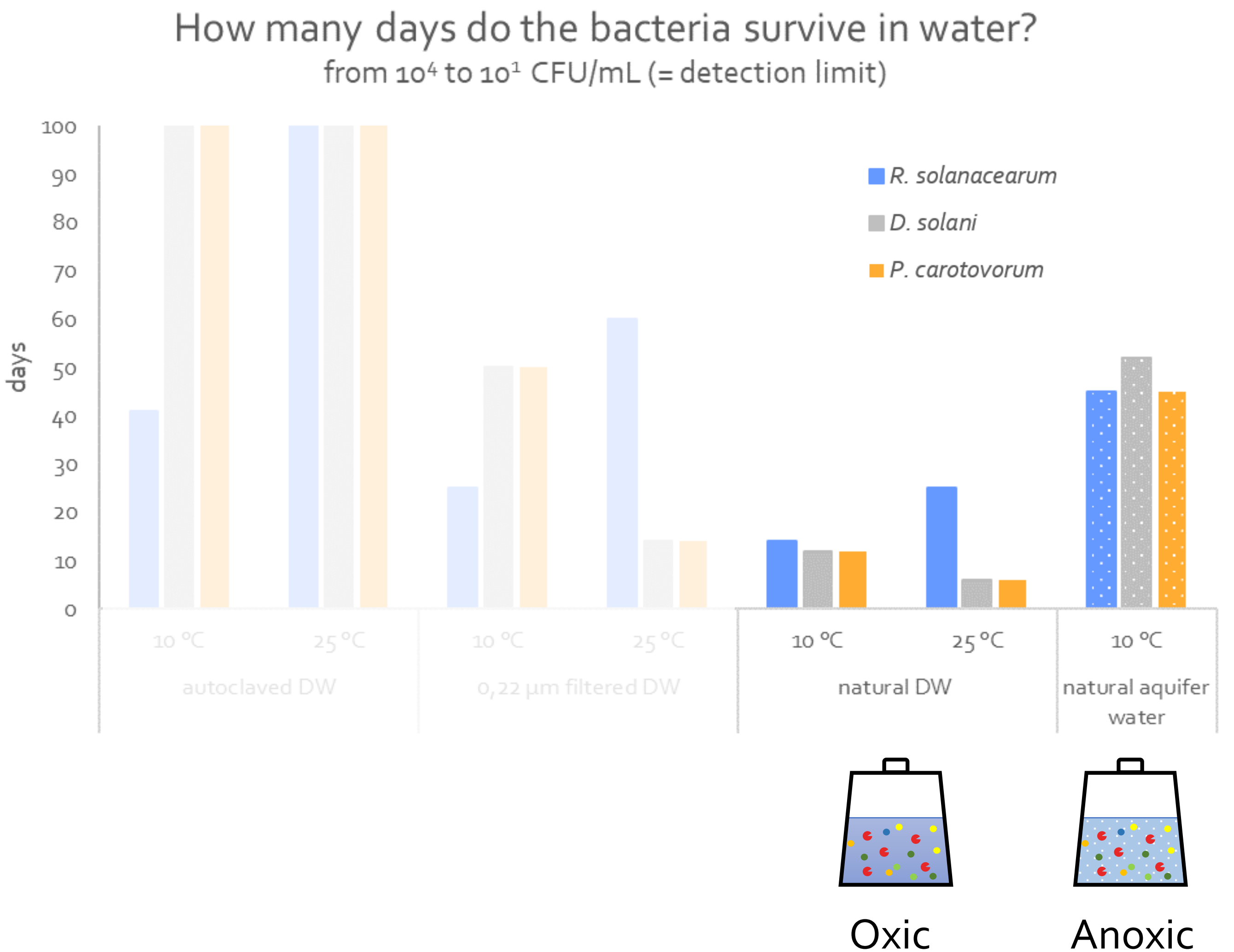


Pathogen die-off rates



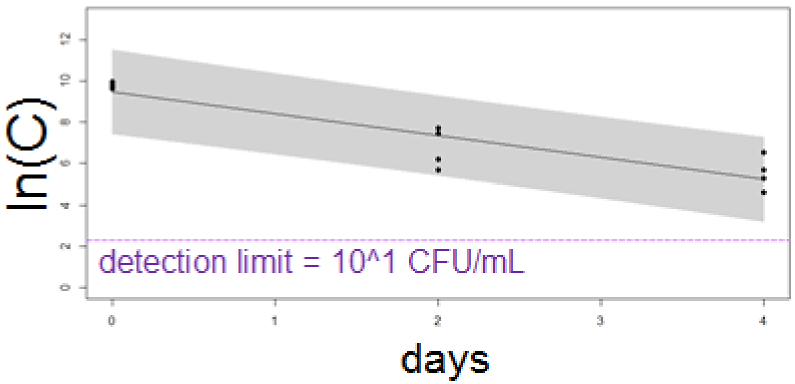
Competition with naturally present microbiota reduces pathogen survival

Pathogen die-off rates



Unexpected result: longer survival in the anoxic aquifer – less competition?

Modeling die-off rates



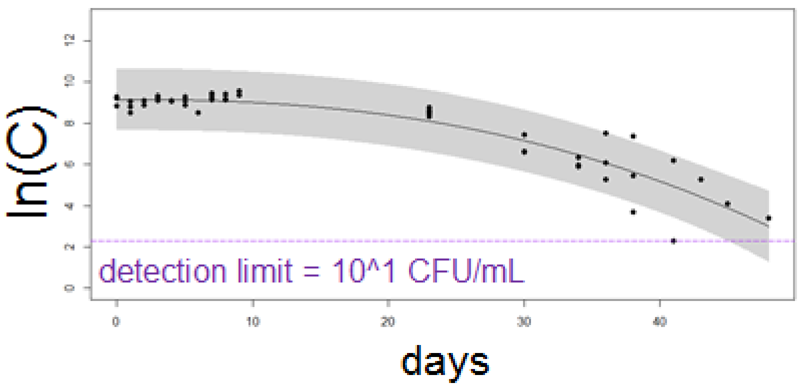
Model 1:

Dickeya solani at 25 °C in drainwater

$$\ln(C) = \ln(C_0) - (a * t)$$

First-order decay

α = inactivation parameter



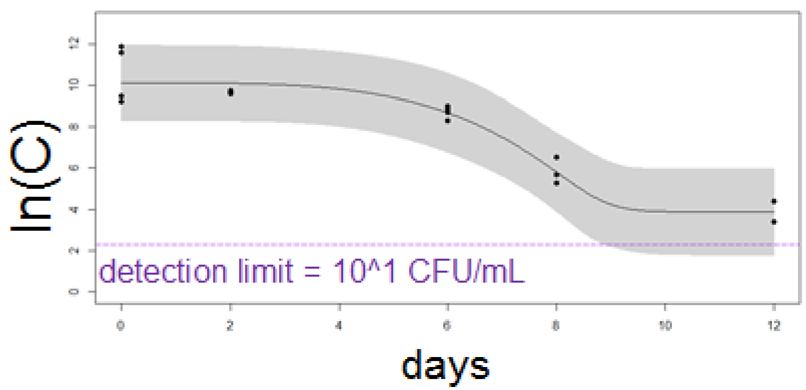
Model 2:

Dickeya solani at 10 °C in anoxic aquifer water

$$\ln(C) = \ln(C_0) - (a * t)^b$$

Weibull model, non-linear decay

b = shaping parameter (< 1 | > 1)



Model 3:

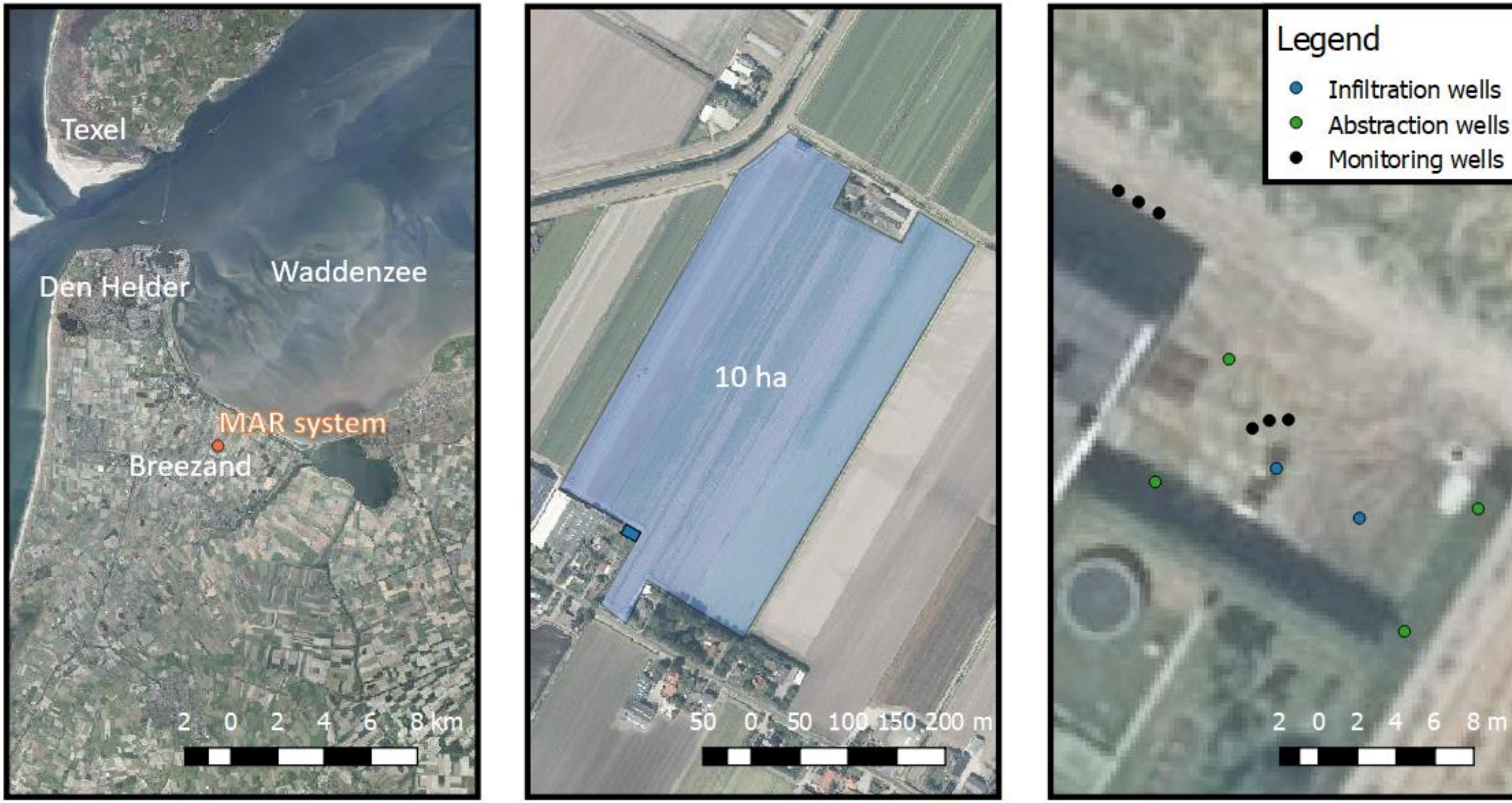
Dickeya solani at 10 °C in drainwater

$$\ln(C) = \ln(C_0) - \ln(C_{res}) - ((a * t)^b + C_{res})$$

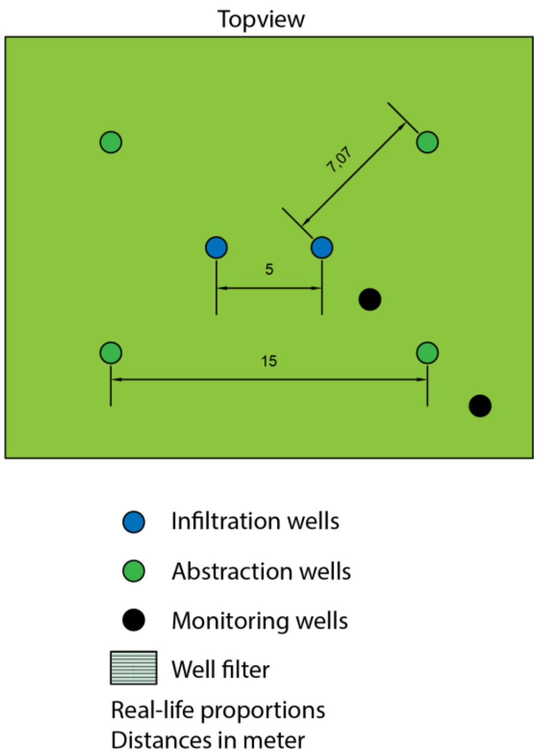
Weibull model with tail

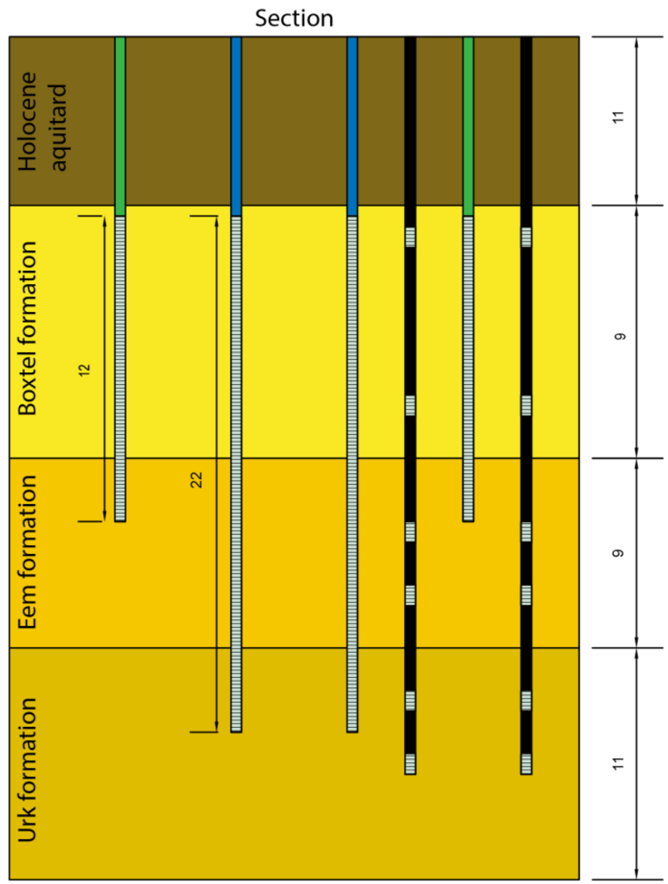
accounts for rest population, C_{res}, causing the tail (and risk)

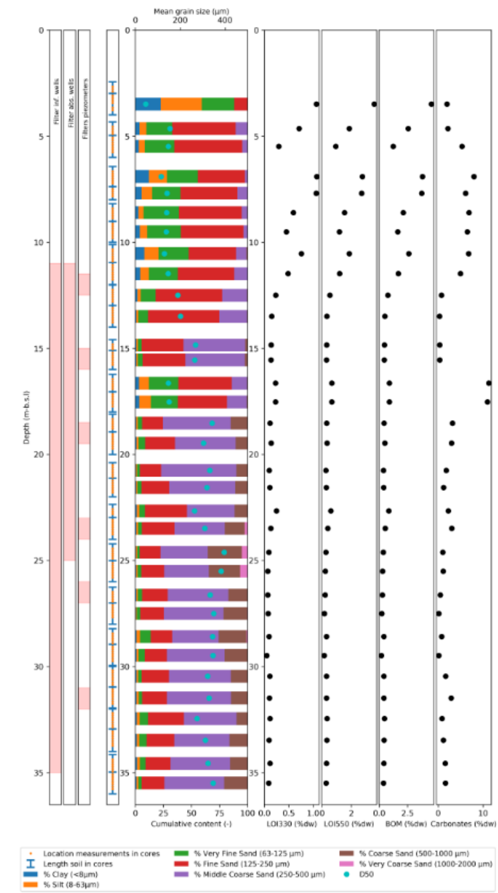
MAR pilot


Texel
Den Helder
Waddenzee
MAR system
Breezand
2 0 2 4 6 8 km
10 ha
50 0 50 100 150 200 m
Legend
Infiltration wells
Abstraction wells
Monitoring wells
2 0 2 4 6 8 m

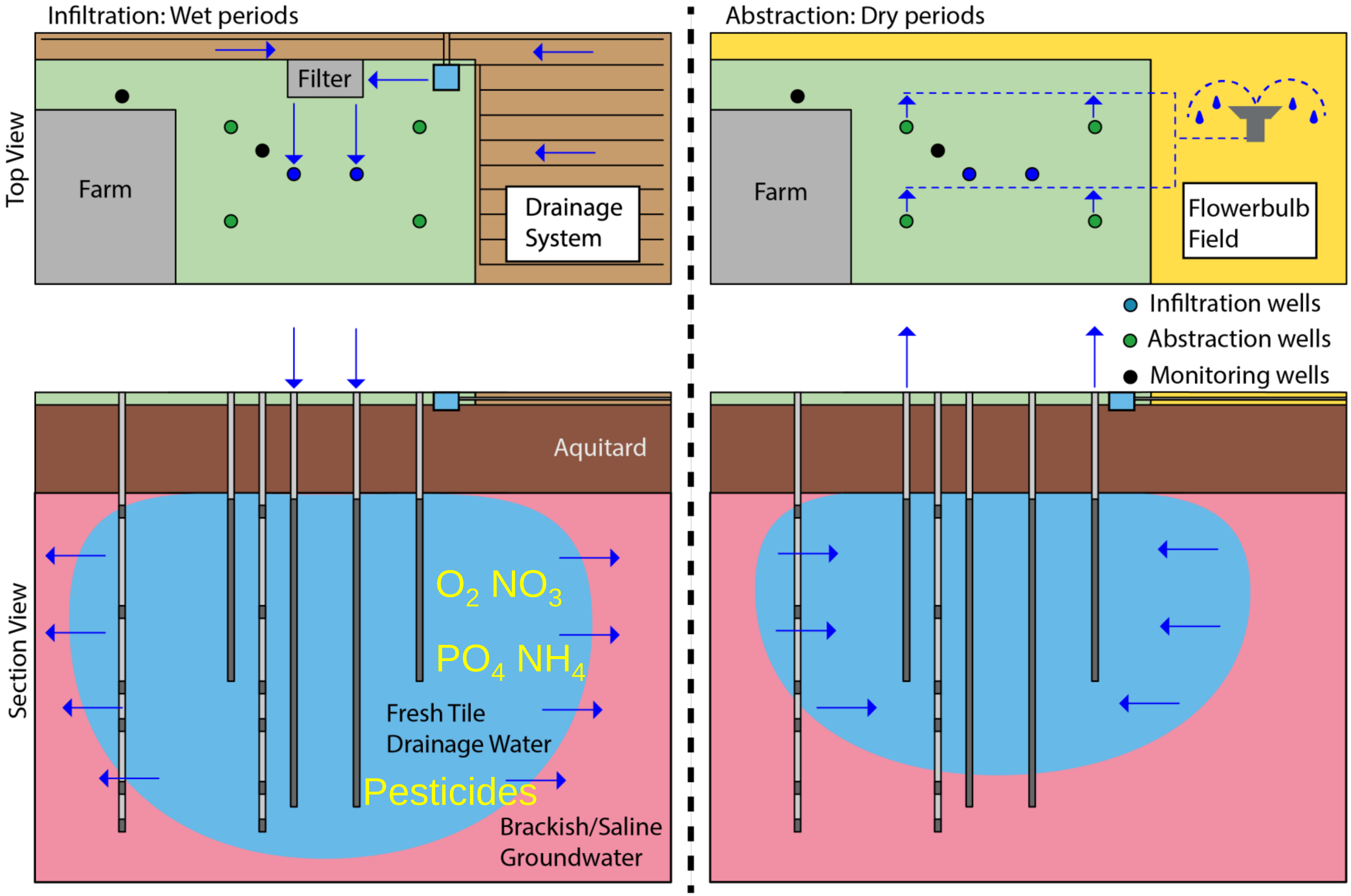
MAR pilot


Topview
7,07
5
15
Infiltration wells
Abstraction wells
Monitoring wells
Well filter
Real-life proportions
Distances in meter


Section
Holocene aquitard
Boxtel formation
Eem formation
Urk formation
12
22
11
9
9
11

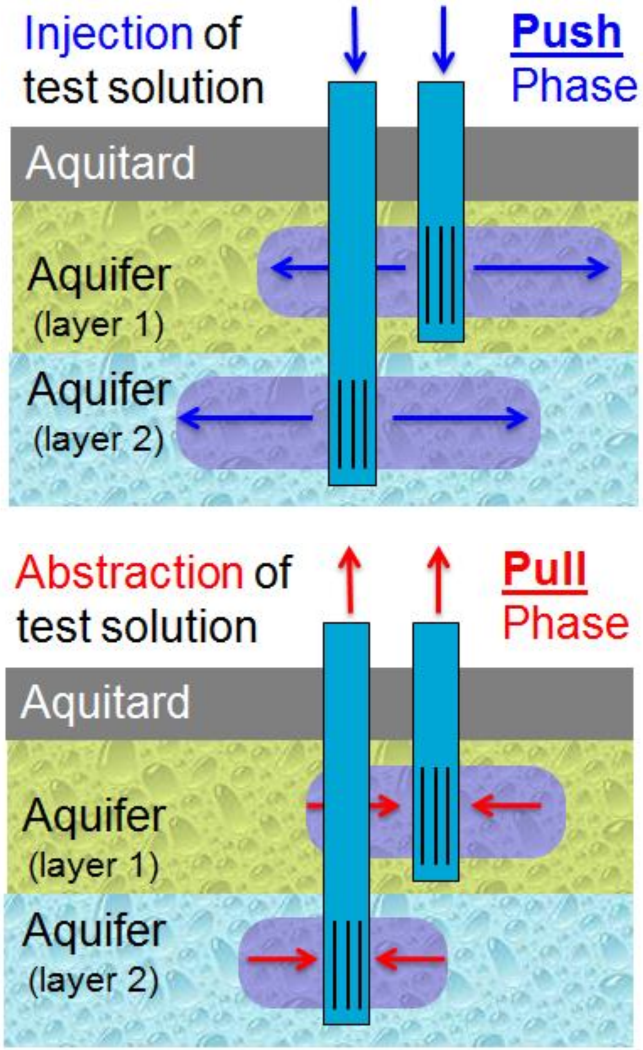

Mean grain size (µm)
Depth (m-b.s.l)
Cumulative content (-)
LOI330 (%dw)
LOI550 (%dw)
BOM (%dw)
Carbonates (%dw)

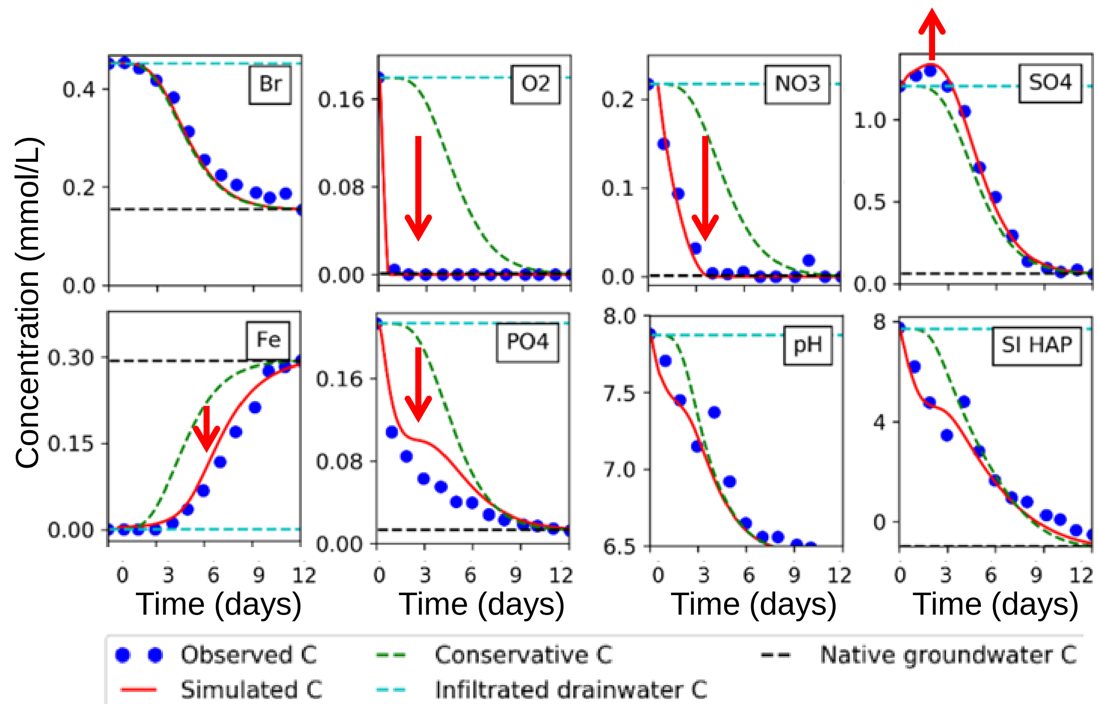
MAR pilot



Infiltration: Wet periods
Abstraction: Dry periods
Top View
Filter
Farm
Drainage System
Farm
Flowerbulb Field
Infiltration wells
Abstraction wells
Monitoring wells
Section View
Aquitard
O2 NO3
PO4 NH4
Fresh Tile Drainage Water
Pesticides
Brackish/Saline Groundwater

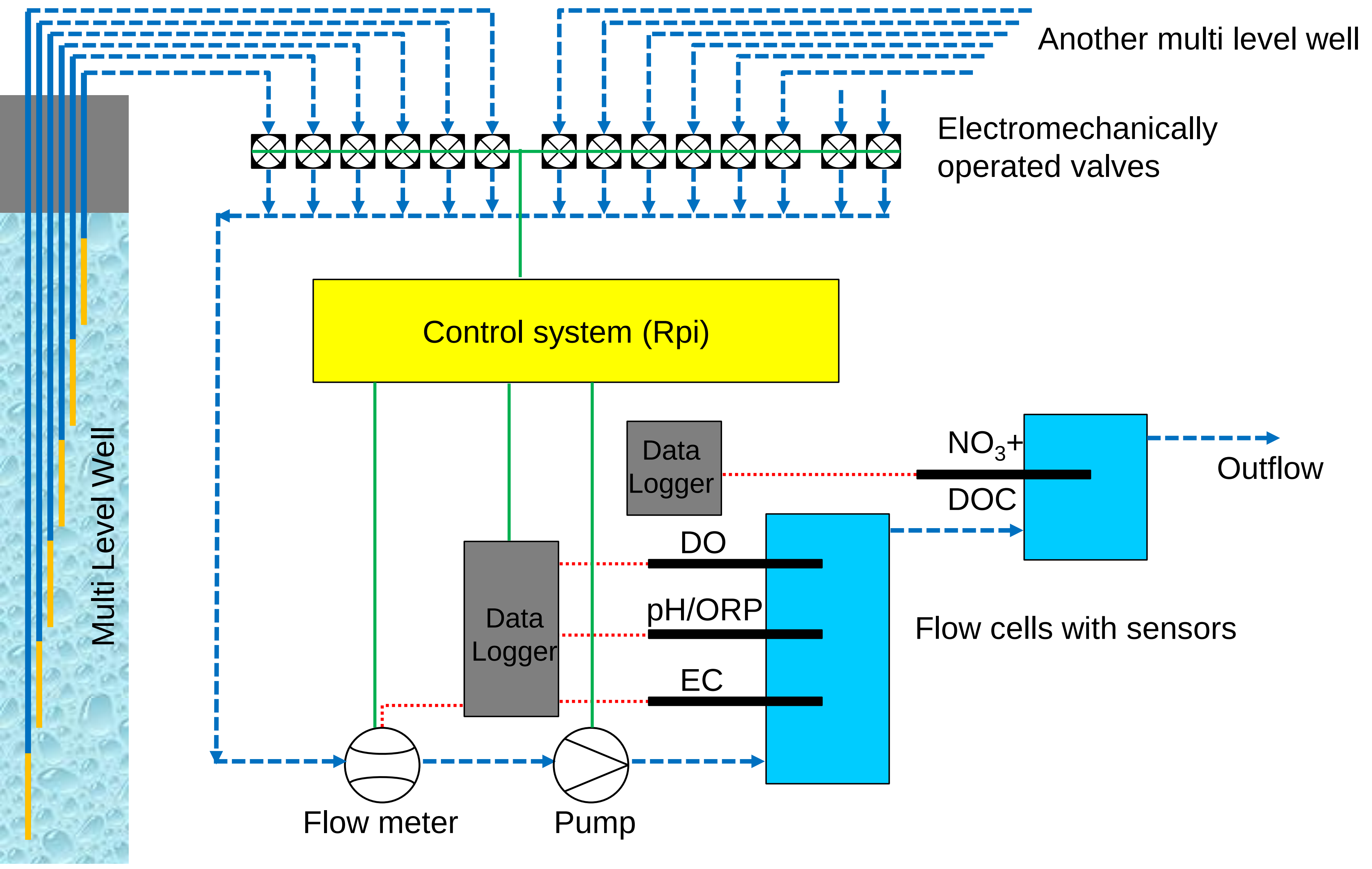
Push-Pull Tests (PPTs)



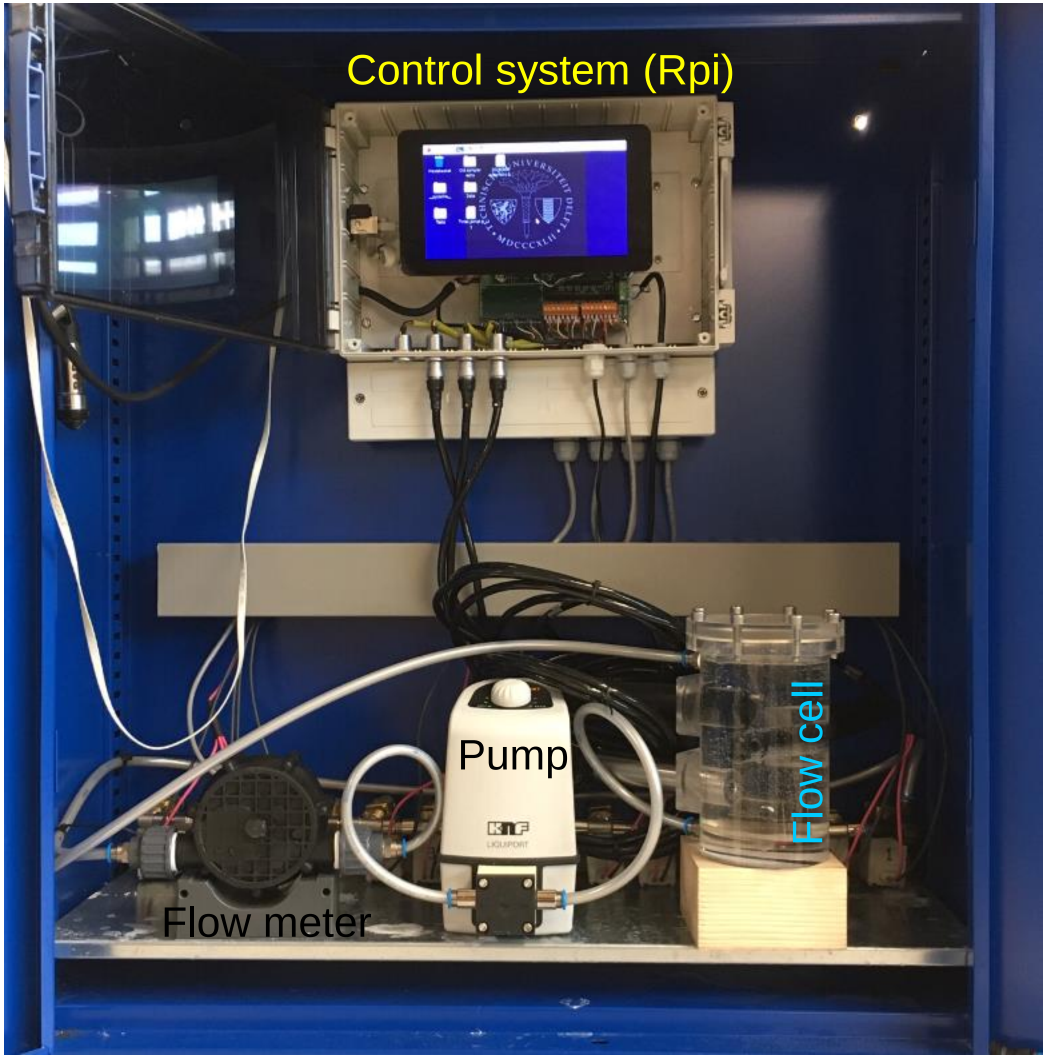


For more: see poster #160 (poster session 3: Wednesday 13:20-14:05)

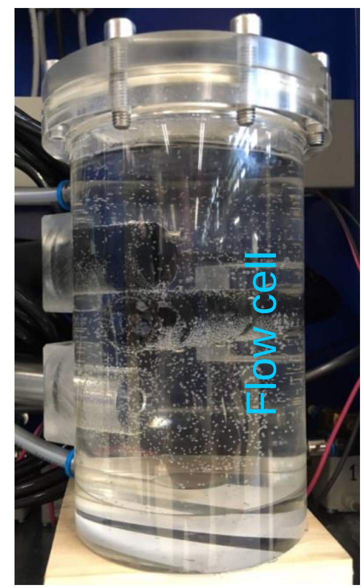
Automated Monitoring System



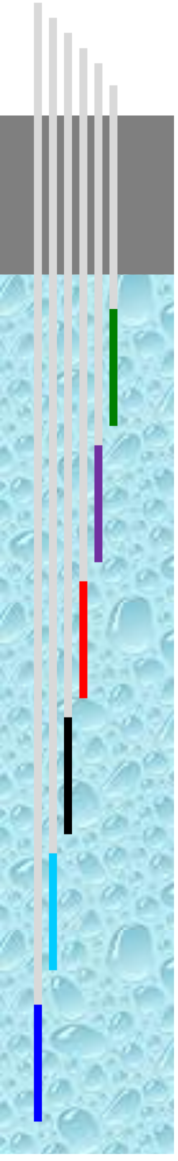
Automated Monitoring System

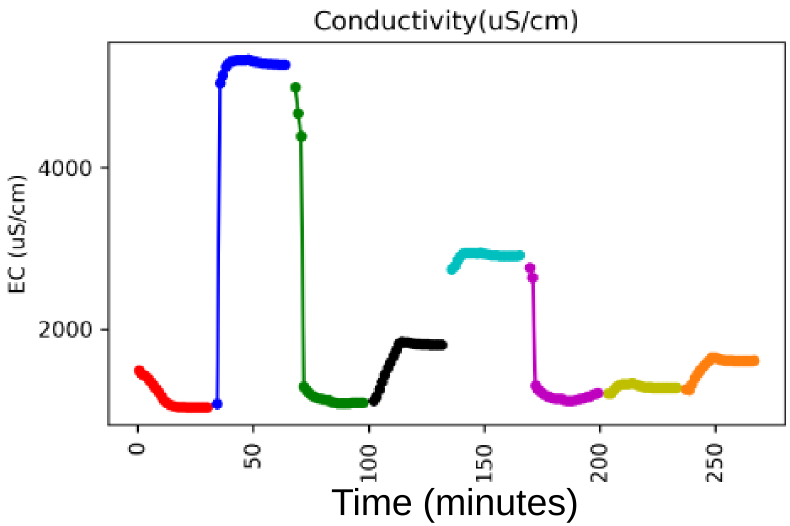


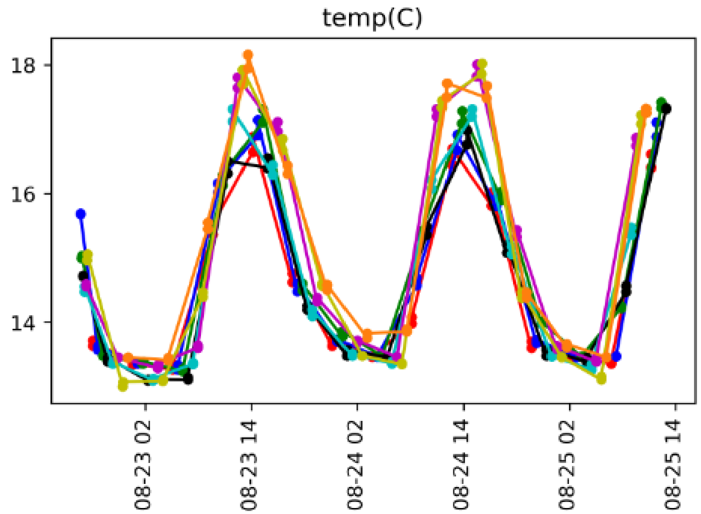
Electromechanically operated valves

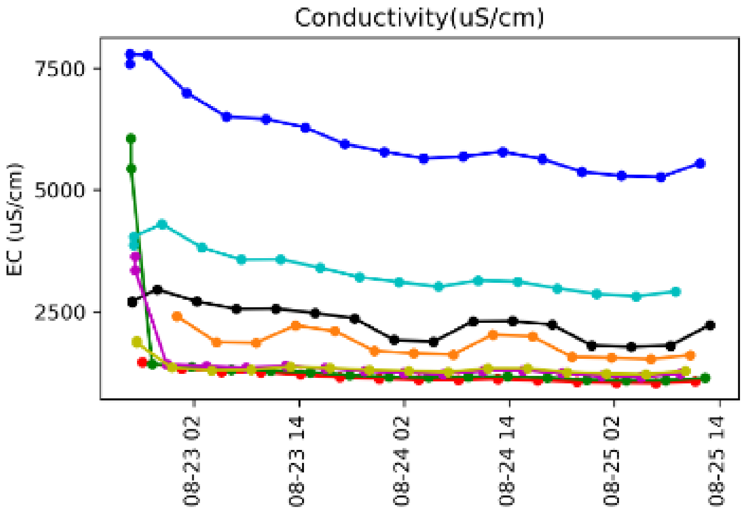


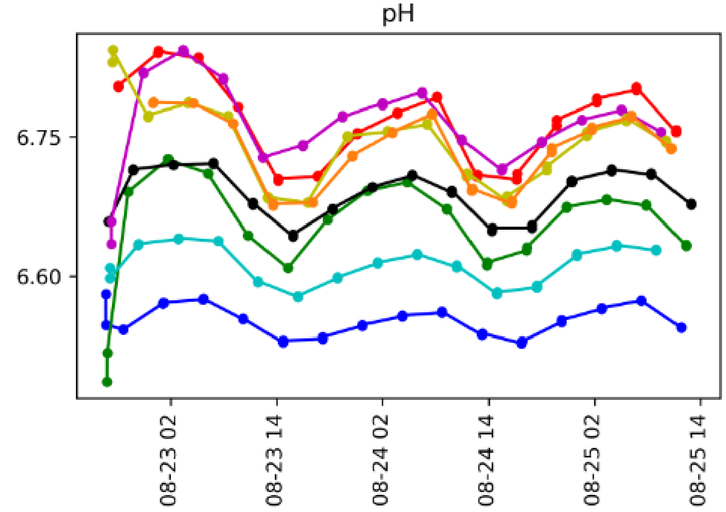
Automated Monitoring System











Summary & Outlook

Summary

- Die-off plant pathogens depends on natural microbiota and rarely follows first-order kinetics. Resistant part of the population caused enhanced risk.
- PPTs yield quantitative insights in biogeochemical processes controlling water quality changes.

Outlook

- MAR system starts infiltrating very soon (finally).
- High expectations of automated monitoring system to quantify redox reactions over time under dynamic conditions.
- RTM: improvements in design (residence times, travel distances) and operation? Expected variation in water treatment performance throughout the region?
- QMRA: will include RTM and complex die-off kinetics

Believe it or not: it works!

2018:
without irrigation

2018:
+ MAR irrigation
180 mm

Acknowledgments

- The AGRIMAR project: Agriculture & Managed Aquifer Recharge: Drainage Water Recycling for Irrigation and Surface Water Quality Protection. www.agrimar.nl
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  - Emiel Kruisdijk: Water Quality
  - Carina Eisfeld: Pathogen Fate
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  - Prof. dr. Pieter Stuyfzand, TU Delft, KWR
  - Prof. dr. Gertjan Medema, TU Delft, KWR
  - Prof. dr. Jack Schijven, Utrecht University, RIVM
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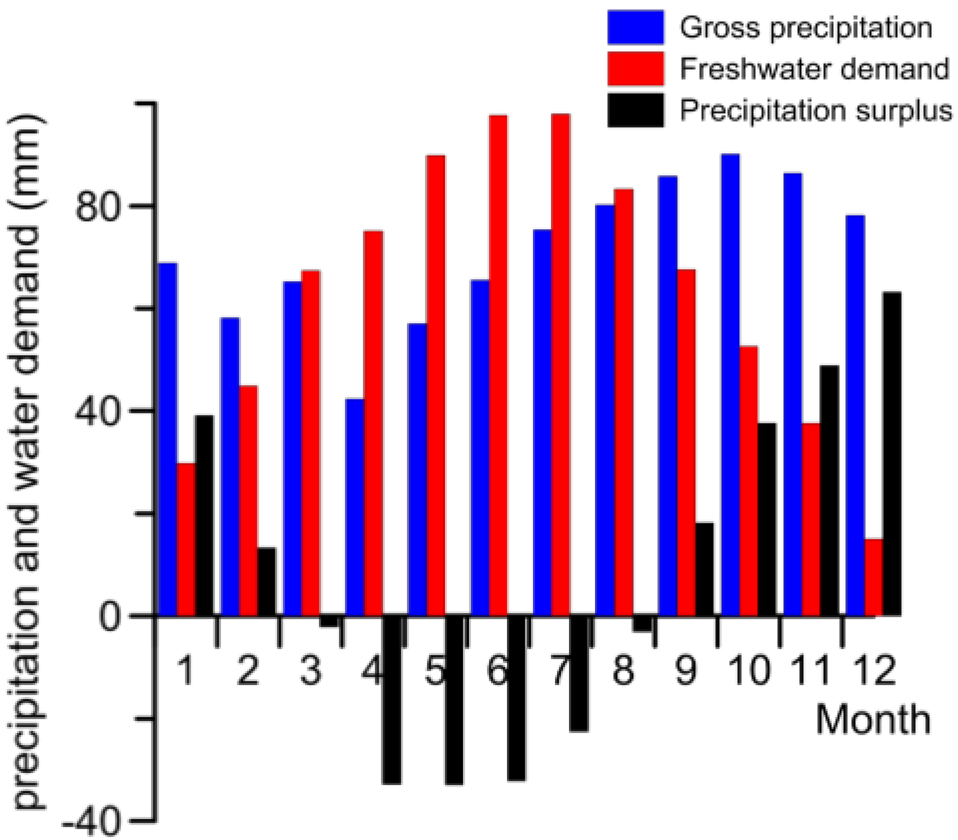
Fig. 1 Illustration of average freshwater availability and demand in a coastal area: mean gross monthly precipitation (1980–2010), estimated monthly water demand of an intensive greenhouse horticulture area (Greenport Westland-Oostland) in the Province of Zuid-Holland in The Netherlands (Paalman et al. 2012), and resulting freshwater surplus/deficit. Source: Zuurbier et al. (2013)



Model Fits Survival Experiments

Pathogen	Condition	Condition	Temp	Weibull + tail	Weibull	1st order
Ralstonia	Natural	Oxic drain	10	37	38	52
Ralstonia	Filtrated	Anoxic aquifer	25	109	108	118
Ralstonia	Filtrated	Oxic drain	10	–	49	62
Ralstonia	Filtrated	Oxic drain	25	121	145	157
Ralstonia	Natural	Anoxic aquifer	10	181	224	223
Ralstonia	Natural	Anoxic + NO3 aquifer	10	188	203	204
Dickeya	Natural	Oxic drain	10	48	53	54
Dickeya	Natural	Oxic drain	25	–	31	33
Dickeya	Filtrated	Oxic drain	10	69	79	128
Dickeya	Filtrated	Oxic drain	25	–	79	37
Dickeya	Natural	Anoxic aquifer	10	–	168	199
Dickeya	Natural	Anoxic + NO3 aquifer	10	111	111	133
Pectobacterium	Natural	Oxic drain	10	–	32	54
Pectobacterium	Natural	Oxic drain	25	–	11	36
Pectobacterium	Filtrated	Oxic drain	10	73	85	110
Pectobacterium	Filtrated	Oxic drain	25	–	46	51
Pectobacterium	Natural	Anoxic aquifer	10	144	148	157