Plant pathogen removal by managed aquifer recharge to provide safe irrigation water

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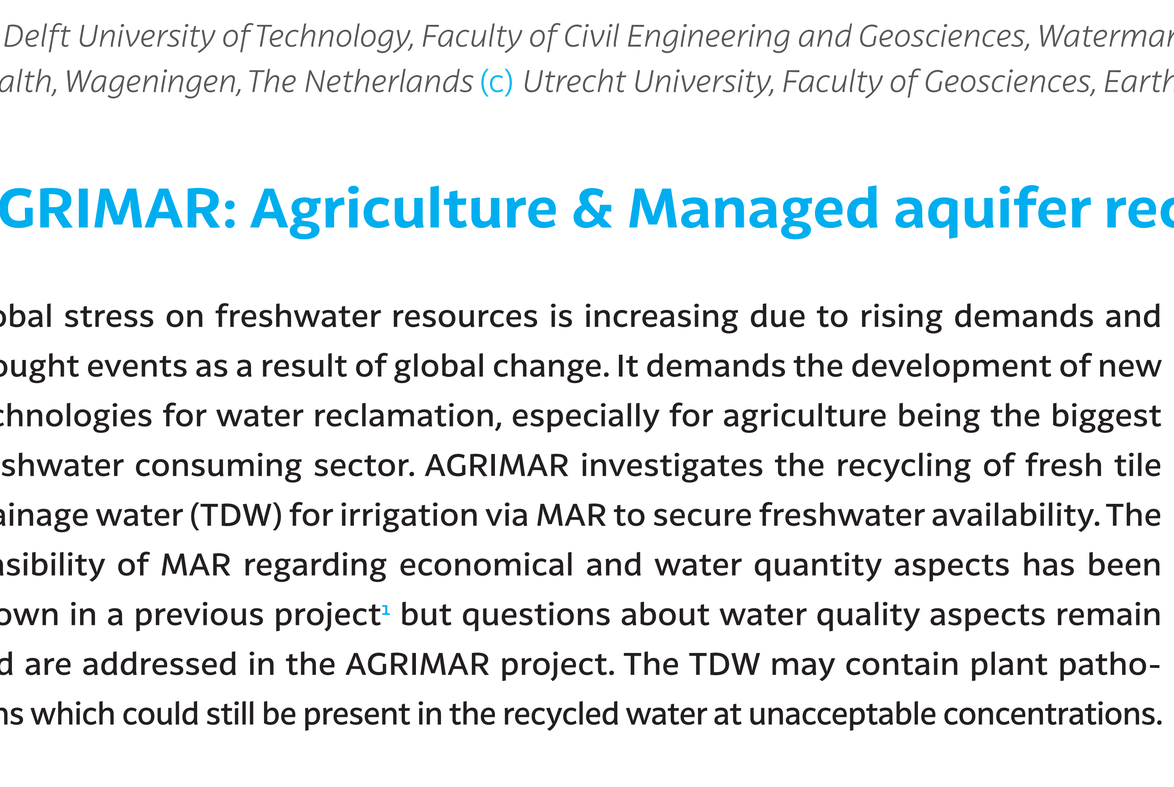
AGRIMAR: Agriculture & Managed aquifer recharge (MAR)

Global stress on freshwater resources is increasing due to rising demands and drought events as a result of global change. It demands the development of new technologies for water reclamation, especially for agriculture being the biggest freshwater consuming sector. AGRIMAR investigates the recycling of fresh tile drainage water (TDW) for irrigation via MAR to secure freshwater availability. The feasibility of MAR regarding economical and water quantity aspects has been shown in a previous project[1] but questions about water quality aspects remain and are addressed in the AGRIMAR project. The TDW may contain plant pathogens which could still be present in the recycled water at unacceptable concentrations.

Does MAR provide safe irrigation water?



1. Storage

> Based on aquifer storage transfer and recovery system[2]

> Excess rainwater is collected via tile drains which are buried under the agricultural field

> Infiltration into naturally brackish aquifers to create a freshwater 'bubble'

> Brackish and fresh water mix at the fringes of the 'bubble' due to dispersion and density differences

> Loss of water in the aquifer by evaporation does not occur

2. Soil Passage

> The water extraction well is at a distance of six meters from the injection well to create a water flow and soil passage in the subsurface

> The soil passage acts as a natural filtration step

> Water quality is enhanced and plant pathogens and (agro)chemicals are removed

> Removal potential can be increased by increasing the residence time of injected TDW in the aquifer

3. Use

> In coastal areas where brackish groundwater prevails and surface water carries pathogens

> During droughts to supply irrigation water

> To avoid groundwater exploitation

> On a local scale; self-supplying

1. Objectives

Main objective:

Quantitative microbial risk assessment (QMRA) of using MAR water to irrigate crops

Specific objectives:

a) Determine die-off rates of plant pathogenic bacteria in MAR water using batch experiments

b) Estimate attachment/detachment of plant pathogenic bacteria in the subsurface from breakthrough curves in (i) soil column experiments under (an)oxic saturated conditions; (ii) *in-situ* at field scale at MAR pilot site (in the Netherlands)

c) Develop dose-response relationships between target crops and plant pathogenic bacteria over a range of inoculum concentrations (10^1 - 10^3 CFU/L)

Selected plant pathogens:

Ralstonia solanacearum phylotype IIb (brown rot)
Dickeya solani (blackleg)
Pectobacterium carotovorum sp. carotovorum (soft rot, blackleg)

Worldwide present, with a broad host range including potato and ornamental plants[3,4]. Survive and spread in the environment in soil and water or by alternative host plants. Irrigation water is a potential source for plant disease outbreaks[5].

2. Results of batch experiments

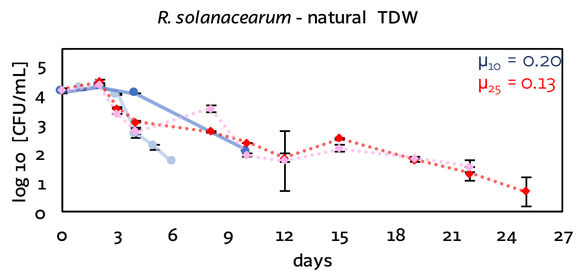
a) All three pathogens were below the detection limit (10^1 CFU/mL) after 14 days at 10 °C in natural TDW, corresponding to a 3 $\log_{10}$ reduction by die-off

b) *D. solani* and *P. carotovorum sp. carotovorum* were no longer detected within 6 days at 25 °C, whereas *R. solanacearum was* detectable up to 25 days in natural TDW

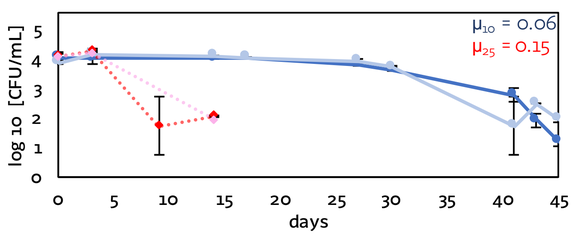
Die-off in natural and 0.22 µm filtered TDW

> Inoculation concentration: 10^4 CFU/mL
> 0.1 mL samples taken to enumerate by viable cell counting on semi-selective media
> Decay rates are calculated as $\mu = \frac{-\log C(t)/C(0)}{t}$
> Red points show die-off at 25 °C
> Blue plots show die-off at 10 °C
> Lines represent one biological replicate and error bars represent standard deviation of enumeration in duplicates; detection limit: 10^1 CFU/mL

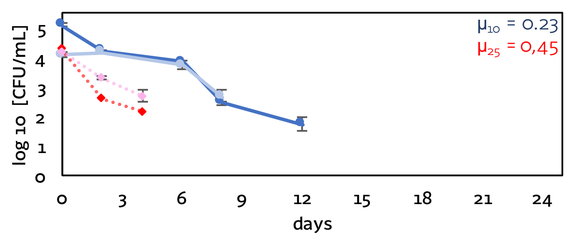
R. solanacearum - natural TDW



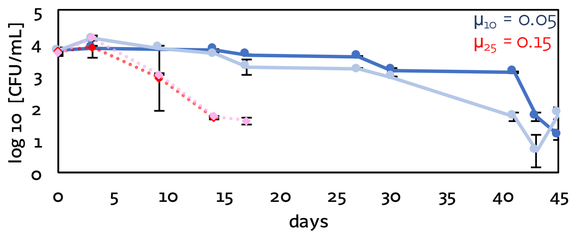
D. solani - 0.22 µm filtered TDW



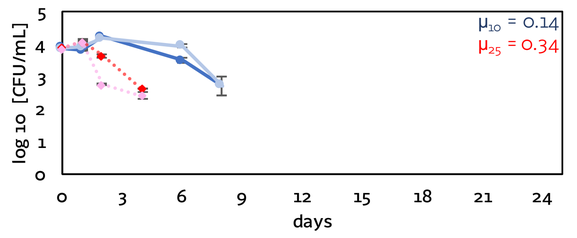
D. solani - natural TDW



P. carotovorum sp. carotovorum - 0.22 µm filtered TDW



P. carotovorum sp. carotovorum - natural TDW



c) Biotic interactions in natural TDW are higher at 25 °C which has a greater influence on the die-off of *D. solani* and *Pectobacterium carotovorum sp. carotovorum* compared to *R. solanacearum*, indicating that it competes better against the prevailing microbiota

d) The influence of microbiota is also notable when comparing natural TDW and 0.22 µm filtered TDW where most of the microbiota is removed and the persistence of the bacteria is about three times longer

e) Temperature had different effects on the bacteria; *R. solanacearum* persisted three times longer at a higher temperature in natural TDW but the persistence of all three bacteria was similar at 10 °C

3. Outlook

a) Batch experiments show that the survival of the bacteria in natural TDW is limited; their decay rates can be related to determine appropriate residence times during MAR treatment

b) Results of batch and column experiments will be used to construct a transport model based on the advection-dispersion equation[6] to predict the fate of plant pathogenic bacteria during MAR

c) The collected quantitative data will be used in QMRA to determine the feasabiltiy and the risks related to recycling freshwater for agriculture by MAR

d) The risk assessment is a basis to set guidelines for the safe application of MAR to improve water quality by reducing pathogen concentrations

References
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(2) Dillon, 2005, Hydrogeol J, 13 (1)
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(4) Czajkowski, 2015, Ann Appl Biol, 166 (1)
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Acknowledgement:
This work is financially supported by the NWO Topsector Water AGRIMAR project and Acacia Water B. V.

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