Constructed wetlands to remove micropollutants from WWTP effluent

An exploratory study

Mirit Hoek

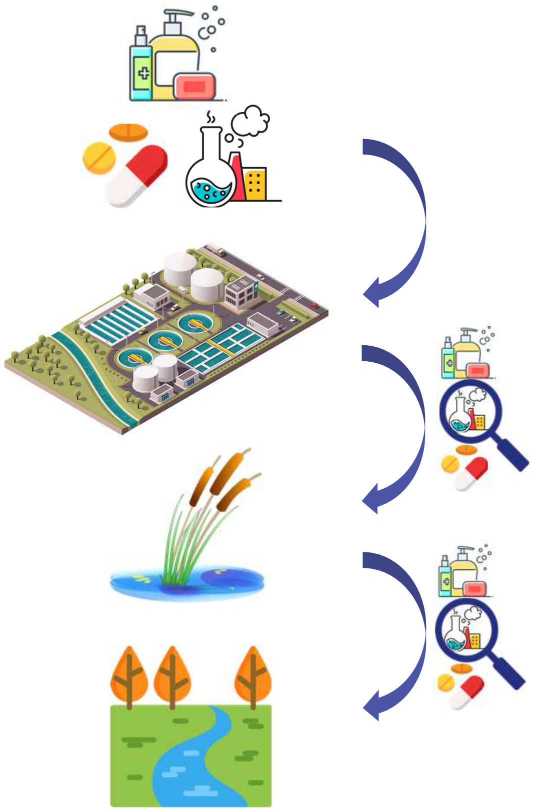
Joost van den Bulk, Fleur Rempe, Johan Blom, Thomas Wagner, Els Schuman, Ruud Kampf, Arnoud de Wilt, Adrie Otte

WWTP = WasteWater Treatment Plant

Introduction

Micropollutants are harmful to ecological and human health

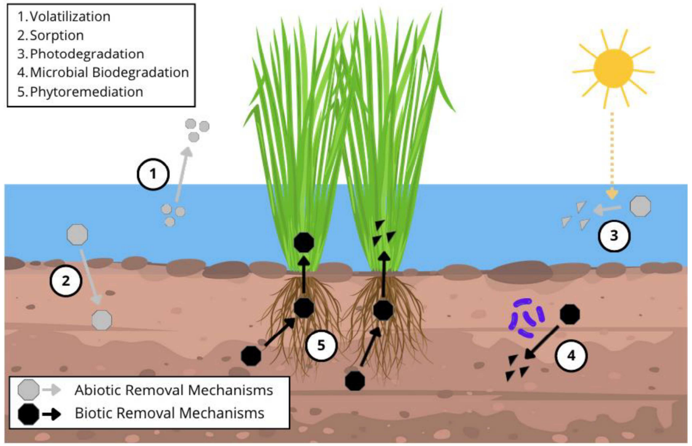
- WWTP as main route
- Constructed wetlands to remove micropollutants
  - 👍 Sustainable post-treatment step
  - 👍 Toolbox of removal mechanisms
  - 👍 Promising results for raw wastewater
  - ? Performance on WWTP effluent



Explore the potential of CWs to remove micropollutants from WWTP effluent

Focus on 16 Dutch indicator micropollutants

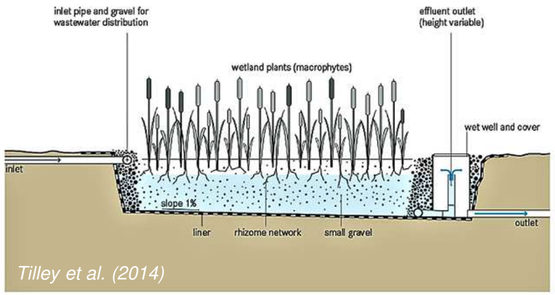
- Data gathering: Scientific literature review and Dutch CWs
- Different types of CWs
  - Dominant removal mechanisms
  - Optimal design and operational parameters



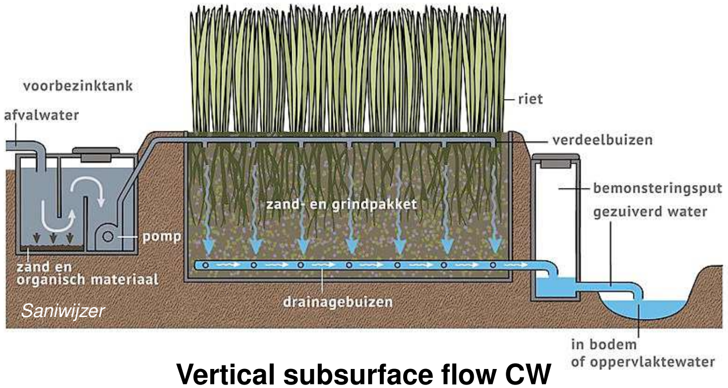
Overton et al. (2023). Wetland removal mechanisms for emerging contaminants. *Land, 12*(2), 472

Explore the potential of CWs to remove micropollutants from WWTP effluent

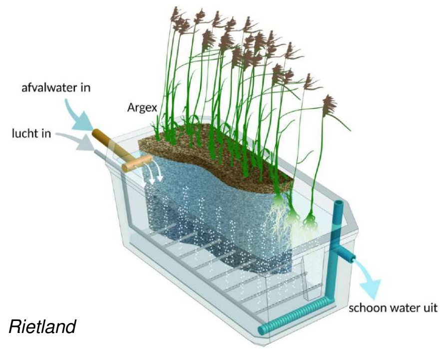
Different types of CWs based on flow design characteristics



Horizontal subsurface flow CW



Vertical subsurface flow CW



Aerated subsurface flow CW

Open water system

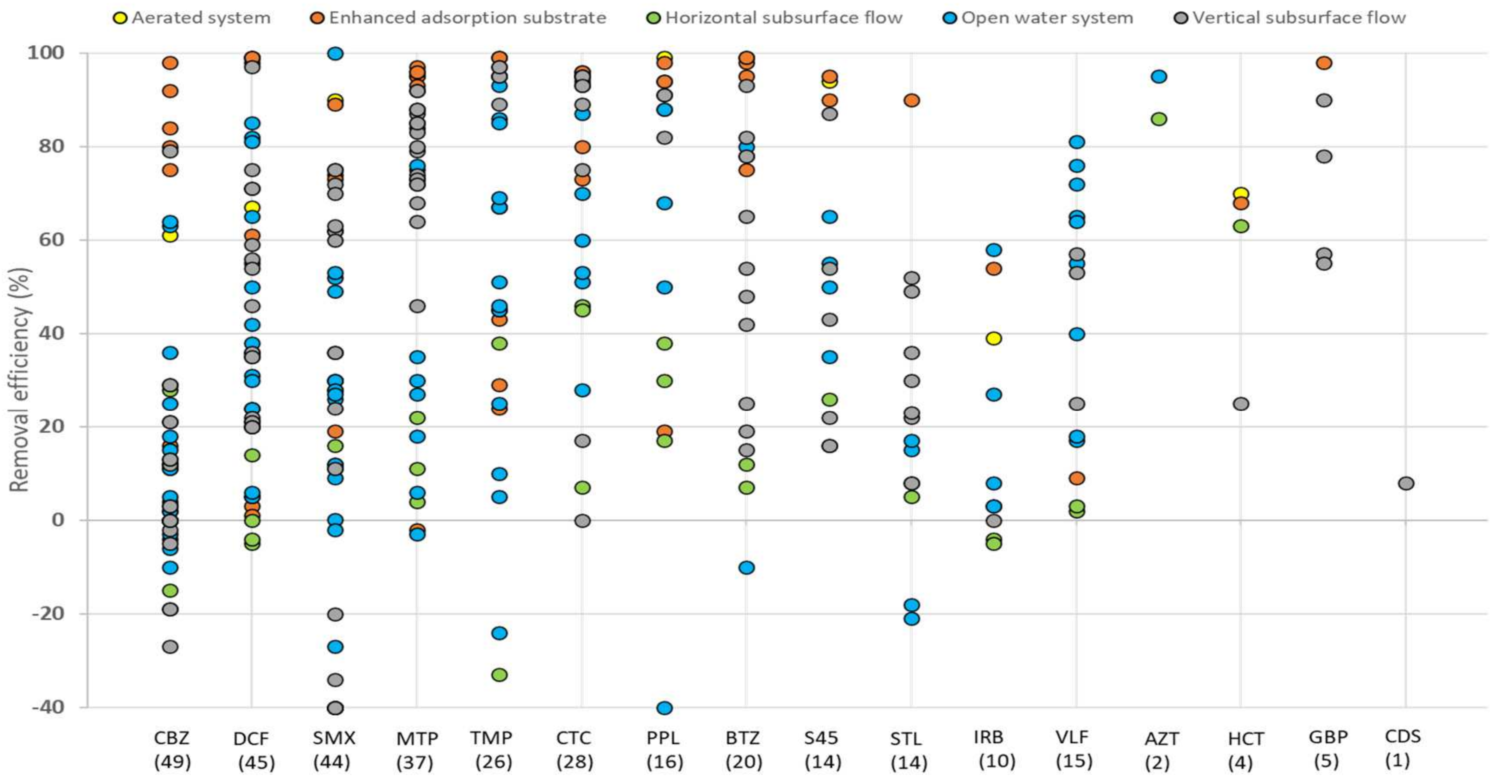
Enhanced adsorption substrate CW

Literature review

Results and discussion

Constructed wetlands can remove micropollutants from WWTP effluent

Determine dominant CW mechanisms to remove micropollutants

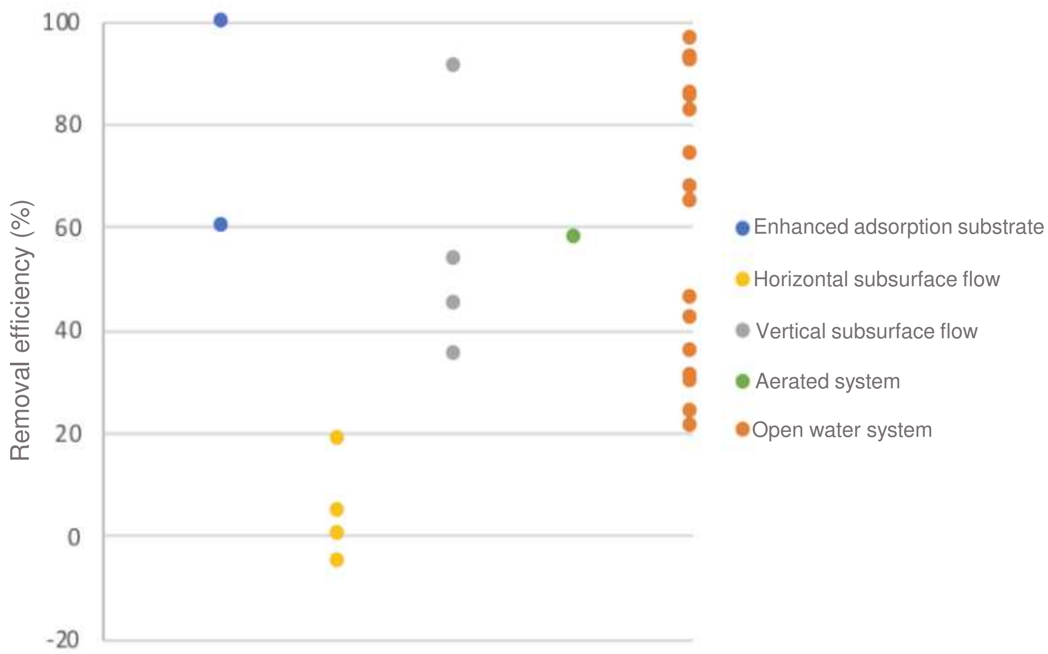


Removal of 16 indicator micropollutants (%) in different CW systems. Each datapoint represents the removal efficiency of 1 micropollutant in 1 distinct system. The number in between brackets corresponds to the number of datapoints obtained from 19 studies (Wagner et al., 2023).

Constructed wetlands can remove micropollutants from WWTP effluent

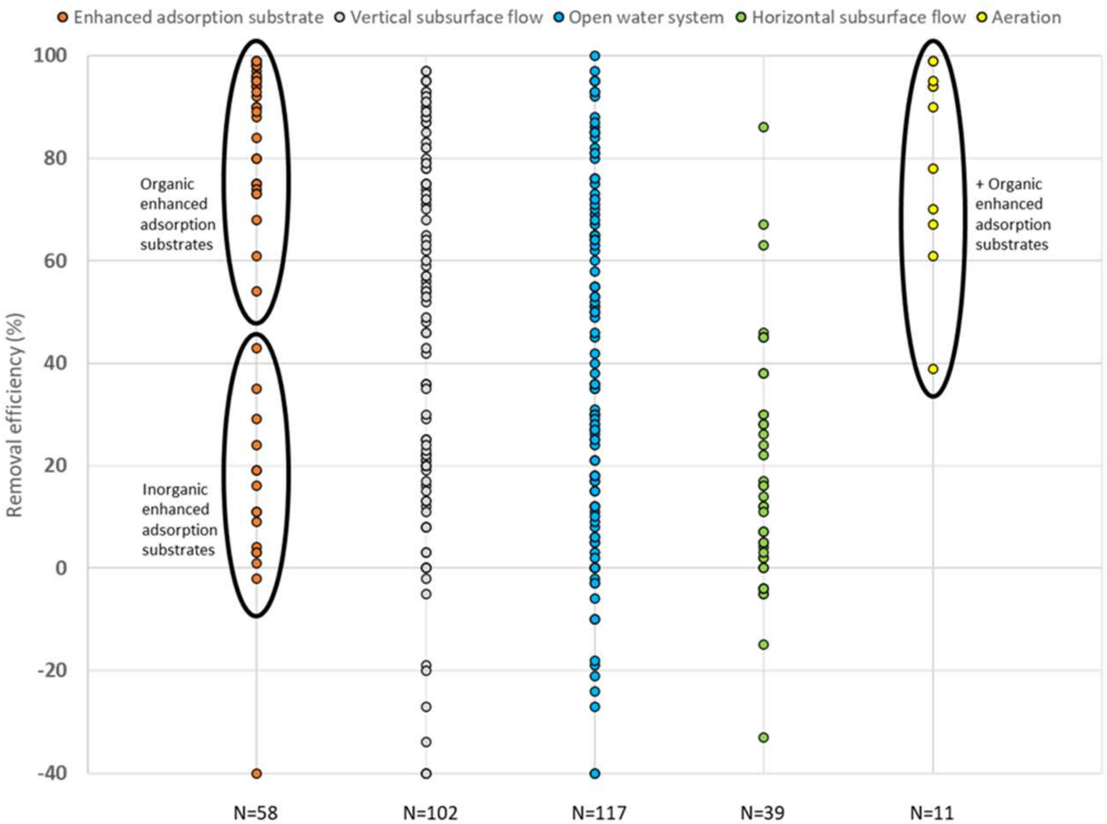
Diclofenac: anti-inflammatory drug

- ✓ Adsorption to organic adsorbents
- ✓ Aerobic biodegradation
- ✓ Photodegradation
- ✗ Anaerobic biodegradation



Constructed wetlands can remove micropollutants from WWTP effluent

Determine CW system with highest micropollutant removal



Micropollutant removal data per constructed wetland system (Wagner et al., 2023)

CWs are promising to remove micropollutants from WWTP effluent

- Most efficient: Enhanced adsorption substrate CWs
    - *Long-term efficiency*
- >75% removal: Vertical subsurface flow CWs
    - *Active aeration & seasonality*
- Wide range in removal: Open water systems
    - *Seasonality*
- <30% removal: Horizontal subsurface flow CWs

Integrating different techniques into the CW to optimize removal

Ecovorms

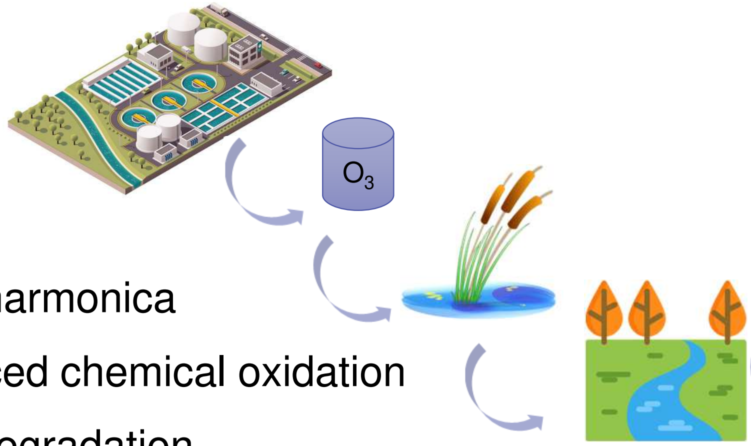
- Enzymatic degradation
- Aerobic biodegradation

NFA

- Adsorption

LECA

- Adsorption
- Aeration



O3-Waterharmonica

- Advanced chemical oxidation
- Photodegradation
- Biodegradation

Conslusion and recommendations

Summary

	Removal Efficiency Dutch guide substances (%)	CO_2 footprint ($g\ CO_2/m^3$ treated)	Costs (ct/m^3 WWTP-effluent)	Surface area needed for 100.000 p.e. (ha)
Natural systems				
Open water systems	40 – 60%[1]	4	9	37,5
Vertical subsurface flow	60 – 80%[1]	5-8	6-19	6,1 – 18,4
Ecovorms	70 – 90%[1]	6	10	9,2
NFA filter	80%[1]	18-136	8-42	3,7 – 7,4
LECA filter	45 – 85%[1]	33-51	8-16	5,4 – 10,8
O_3-Waterharmonica	70 – 90%[1]	40	14	37,5
Reference systems				
PACAS	70-75%[2]	122	5	-
Ozone + Sand Filtration	80-85%[2]	128	17	-

[1] *The removal efficiency is only from the post-treatment step itself and not over the whole WWTP*

[2] *Overall Removal Efficiency of effluent wwtp to influent wwtp (including bypass post treatment) for 7 of 11 guide substances: benzotriazool, carbamazepine, diclofenac, irbesartan, gabapentine, metropolol, hydrochloorthiazide, mixture of 4- en 5-methylbenzotriazool, sotalol, trimethoprim en venlaflaxine in every 24h or 48h flow or time proportional sample. The sampling has to take the hydraulic retention time of the wwtp into account*

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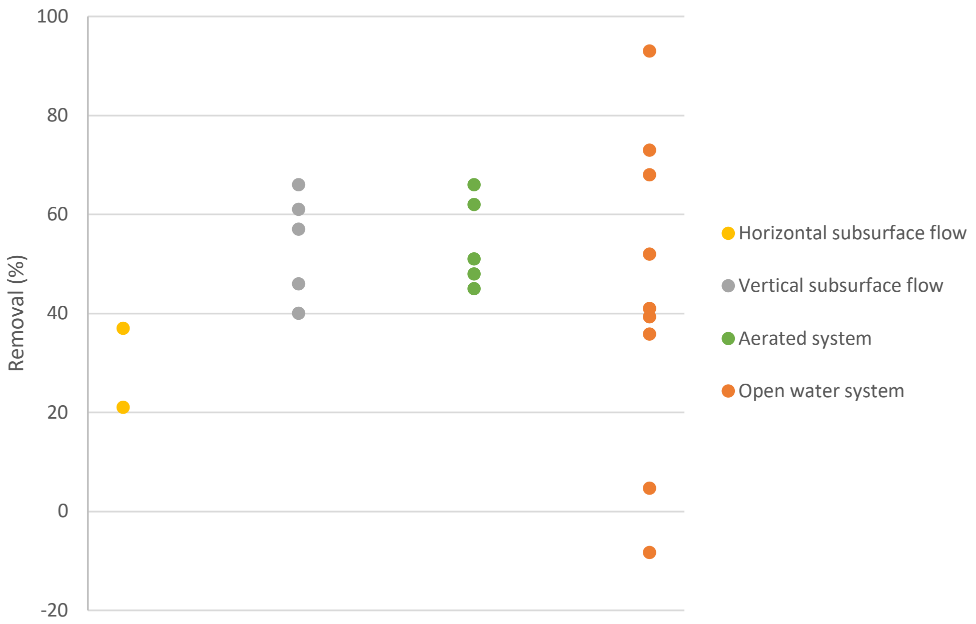
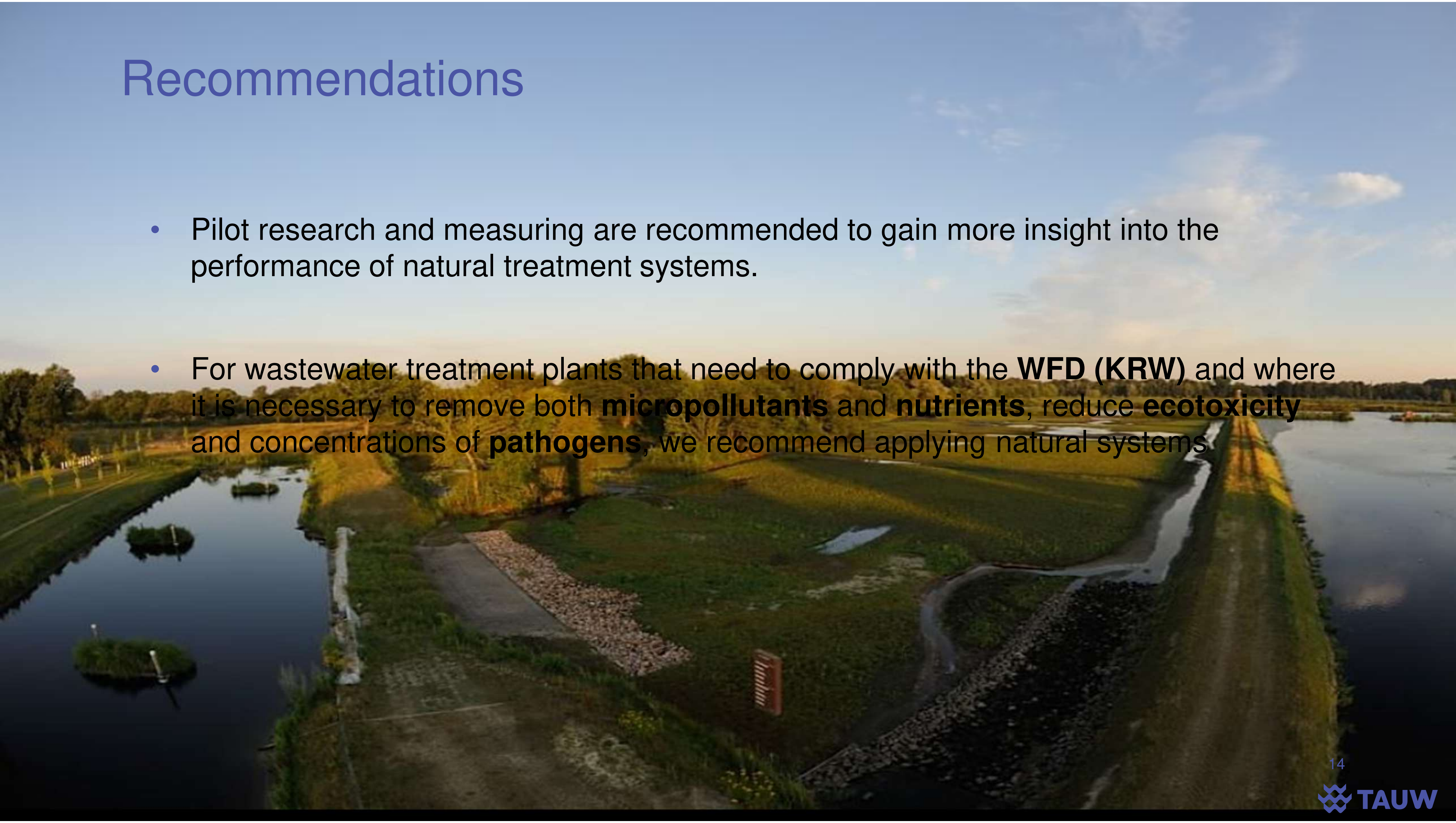
Additional benefits

N-removal



- 50 – 85 % reduction ecotoxicity
- log 1 – log 4 removal of pathogens
- 29 - 62 % N-removal
- 40-90 % P-removal
- Some metals are removed



Recommendations

- Pilot research and measuring are recommended to gain more insight into the performance of natural treatment systems.

- For wastewater treatment plants that need to comply with the **WFD (KRW)** and where it is necessary to remove both **micropollutants** and **nutrients**, reduce **ecotoxicity** and concentrations of **pathogens**, we recommend applying natural systems.

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Thank you for your attention!

Mirit Hoek

mirit.hoek@tauw.com

Further information:
STOWA 2022-42
Wagner et al., 2023

Tackling Micropollutants in Wastewater
Results of the Dutch Innovation and Implementation Program

November 8 and 9 2023
Aquatech Amsterdam

stowa

Ministry of Infrastructure and Water Management

Constructed wetlands can remove micropollutants from WWTP effluent

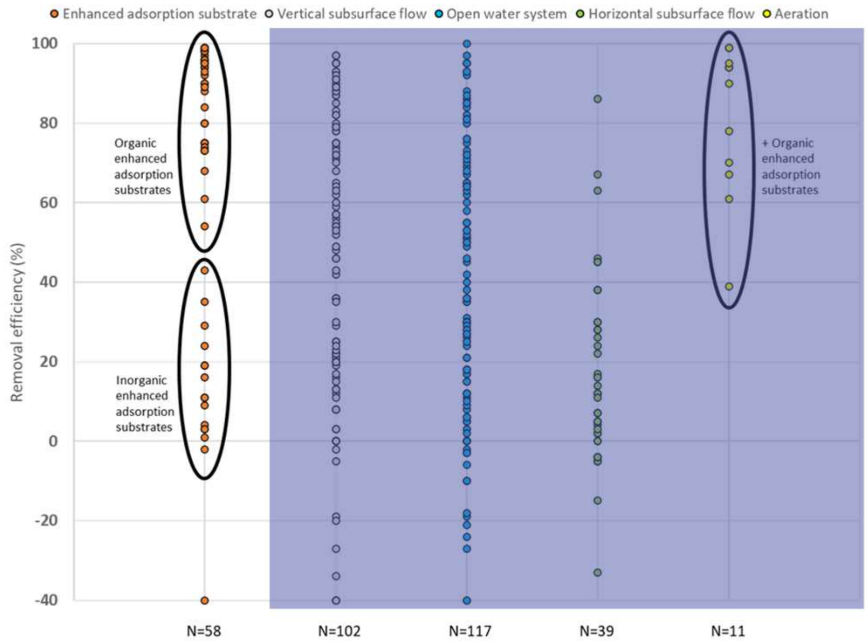
Organic enhanced adsorption substrate

- Most efficient CW system
- Main removal mechanism: Adsorption

  ✓ All micropollutants

Long-term performance:

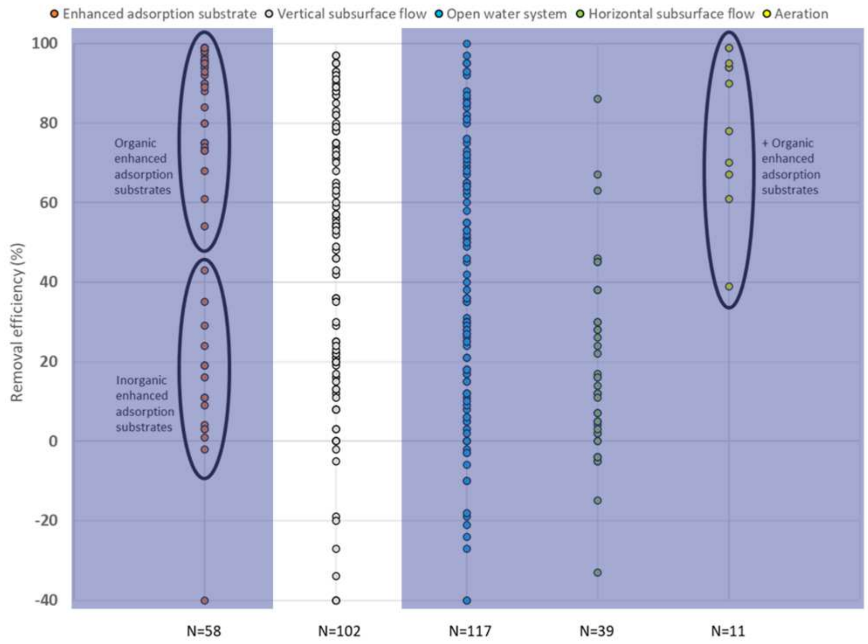
Saturation vs. biological regeneration



Constructed wetlands can remove micropollutants from WWTP effluent

Vertical subsurface flow CWs

- Most datapoints >75% removal
- Main removal mechanism: Aerobic biodegradation
  - ✓ 10/16 micropollutants

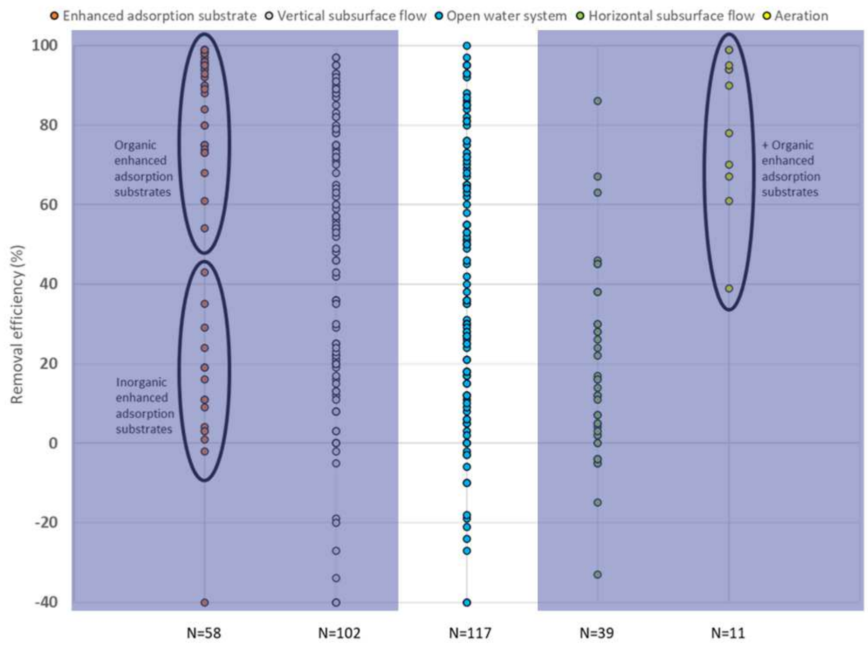


- Wide range in removal
  - Biodegradability
  - Seasonality
  - Age
  - Feeding strategy: redox conditions

Constructed wetlands can remove micropollutants from WWTP effluent

Open water systems

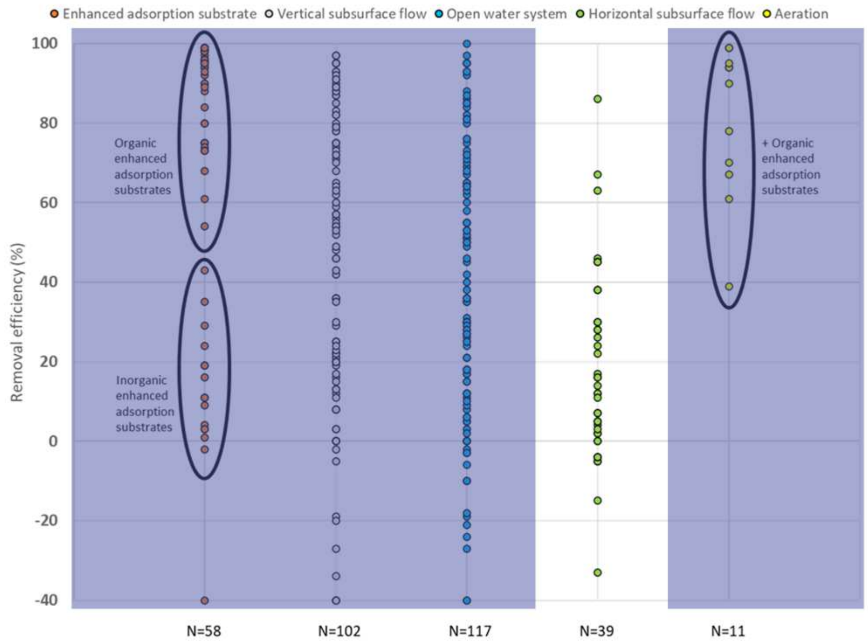
- Wide range in removal
- Main removal mechanism: Photodegradation
  - ✓ Micropollutants which are hard to biodegrade
- Wide range in removal
  - Susceptibility to photodegradation
  - Seasonality
  - Shallow vs. deep
  - Hydraulic loading rate ($m^3.m^{-2}.d^{-1}$)



Constructed wetlands can remove micropollutants from WWTP effluent

Horizontal subsurface flow CWs

- Low removal: <30%
- Main removal mechanism: Anaerobic biodegradation
- Not suitable as WWTP post-treatment



Constructed wetlands can remove micropollutants from WWTP effluent

Active aeration

- High removal
- Main removal mechanisms: Aerobic biodegradation and adsorption

Effect of active aeration