VolkswagenStiftung

MARTIN-LUTHER-UNIVERSITÄT HALLE-WITTENBERG

MUHAS

UFZ

Workshop

Drug lifecycle control in Subsaharan Africa

From production to responsible safe disposal and elimination in wastewater treatment plants

(Med4Africa)

UFZ HELMHOLTZ Centre for Environmental Research

Drug Lifecycle Control in Subsaharan Africa:

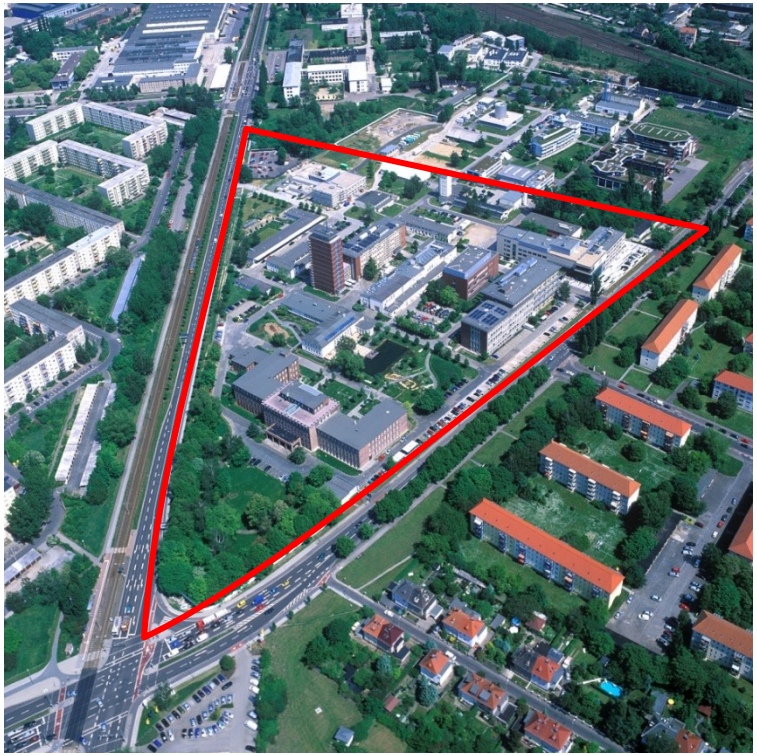
From production to responsible safe disposal and elimination in wastewater treatment plants wastewater

Perspectives of decentralized waste water treatment systems for transient and developing countries

Roland A. Müller, Nadine Sossalla and Manfred van Afferden

September 01, 2022

Where we are from: The UFZ as a part of the *Science Park Leipzig*



Picture: PUNCTUM

- Established in 199; 37 departments in 7 thematic divisions

Personnel / ca. 1,190 employees in total

- ca. 650 scientists
- ca. 300 postgraduates incl. guest postgraduates
- ca. 670 guests and assistants
- 42 joint appointments with German Universities
- 59 trainees in 9 disciplines

- Funding: BMBF 90%, Saxony 5% and Saxony-Anhalt 5%; approx. Systemic, interdisciplinary environmental research, solutions for managing complex environmental systems

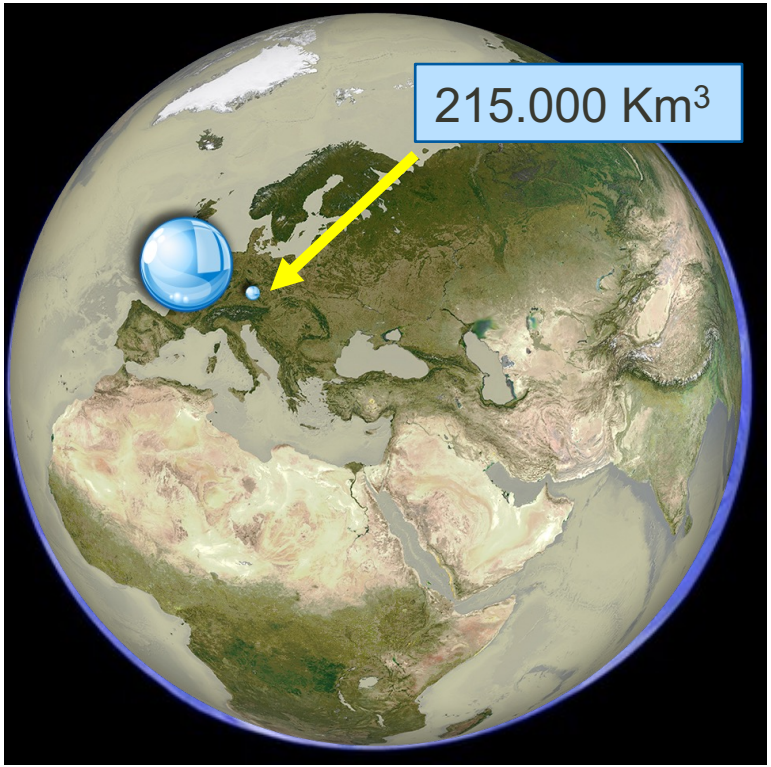
Neads for Wastewater Management with progressive Civilization

Sanitary services are the most important

London.-Clean water and wastewater treatment represent the most important advance in medicine since 1840. This was the result of an Internet survey conducted by the British Medical Journal (BMU). This renowned journal listed 15 advances in medicine and asked its readers to select the most important o. Around 11,000 readers from around the world participated in the survey in the last two weeks. Behind public hygiene in first place, antibiotics came second and anaesthetics came third.

(bva)

Tages Anzeiger, 24.1.2007

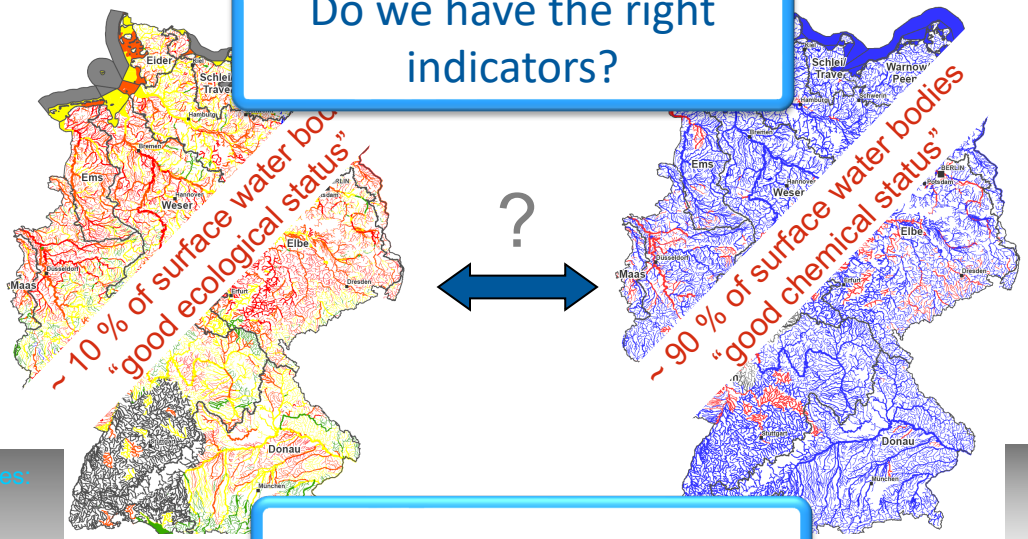


Surface Water Quality in Germany and Indicators

Ecological tatus of surface water (biological indicators)

Chemical status of surface water (33 pollutants)

Do we have the right indicators?



Status classes:
- Very good
- Good
- Moderate
- Poor
- Bad
- Not classified

Do we have the right management strategies

Status classes:
- Good
- Bad
- Not classified

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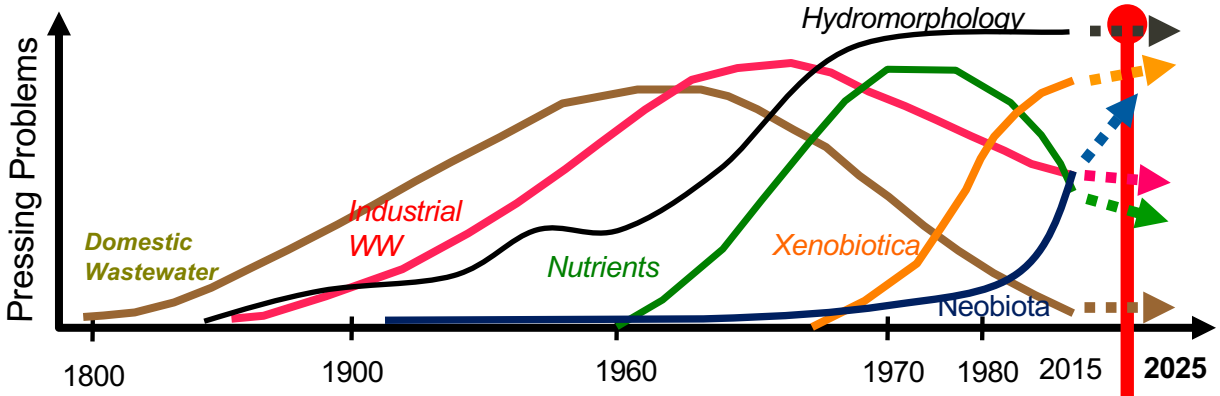
EARCH – UFZ

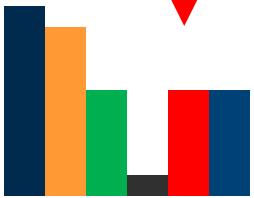
Neads for Wastewater Management with progressive Civilization



…and Climatic Change?…

India (Ganges)

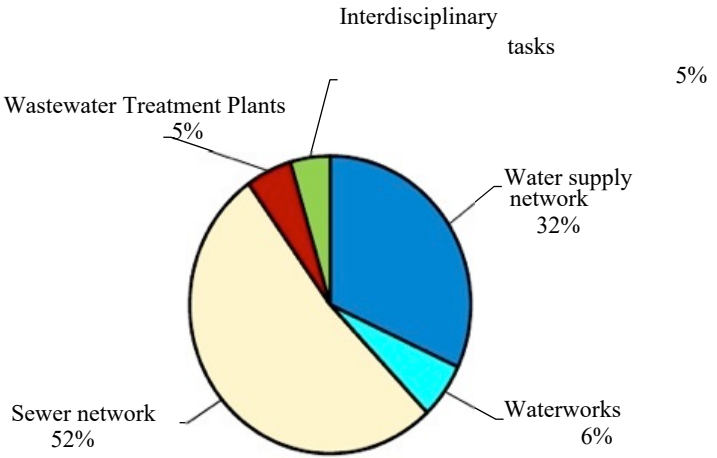
Different treatment priorities on local level



Europe (Rhein)

Challenges in Wastewater Management

Long-term water infrastructure focal points of investment in Leipzig



Distribution of investment requirements of KWL
(From KWL's long-term planning 2013-2032)

Investment focus:

- Sewer network refurbishment
- Applies for the next 20 years

Investment backlog:

- 1/3 of the sewer network is over 75 years old

No CLIMATE CHANGE Scenarios: > 800.000.000 € included (till 2045)

Operation & Maintenance Costs

- Public sewer network: Length of approx. 575,600 km
- Repair: 113 €/m
- Refurbishment: 411 €/m
- Replacement: 1584 €/m
- Development: 909 €/m

Zustand der Kanalisation in Deutschland; DWA Umfrage in Deutschland, 2015

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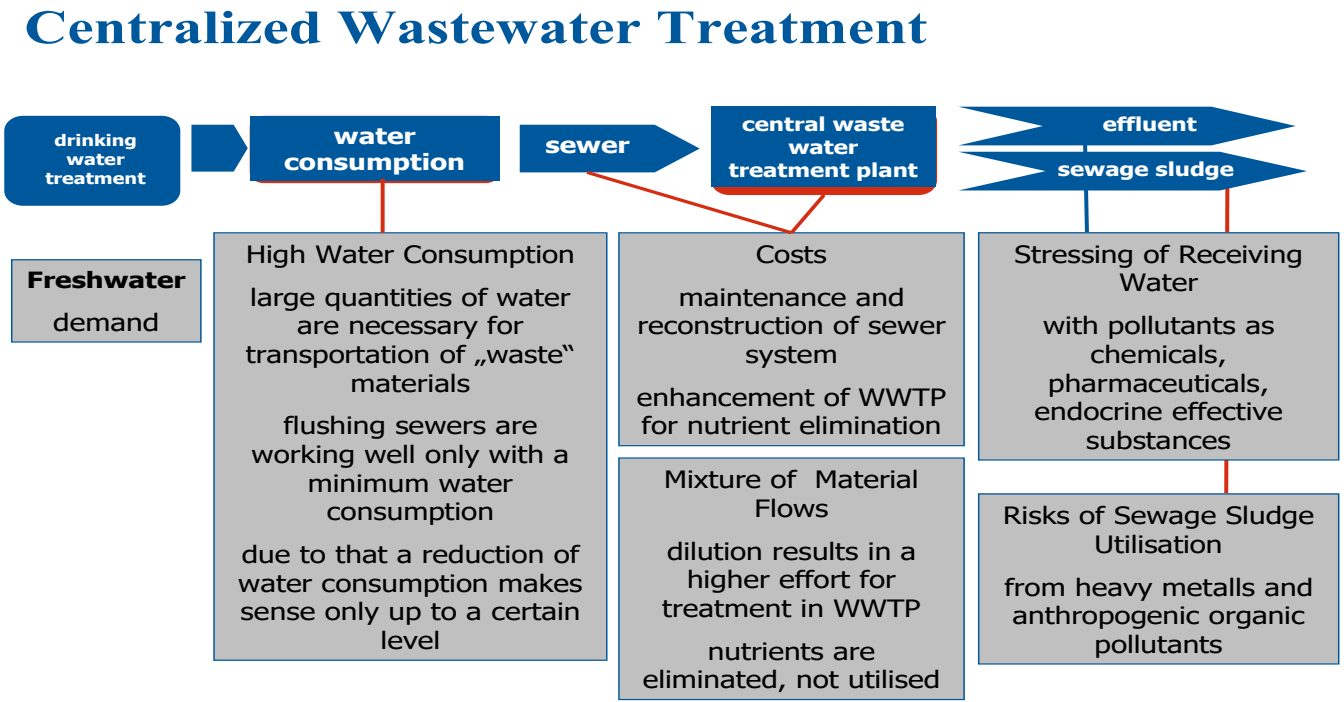
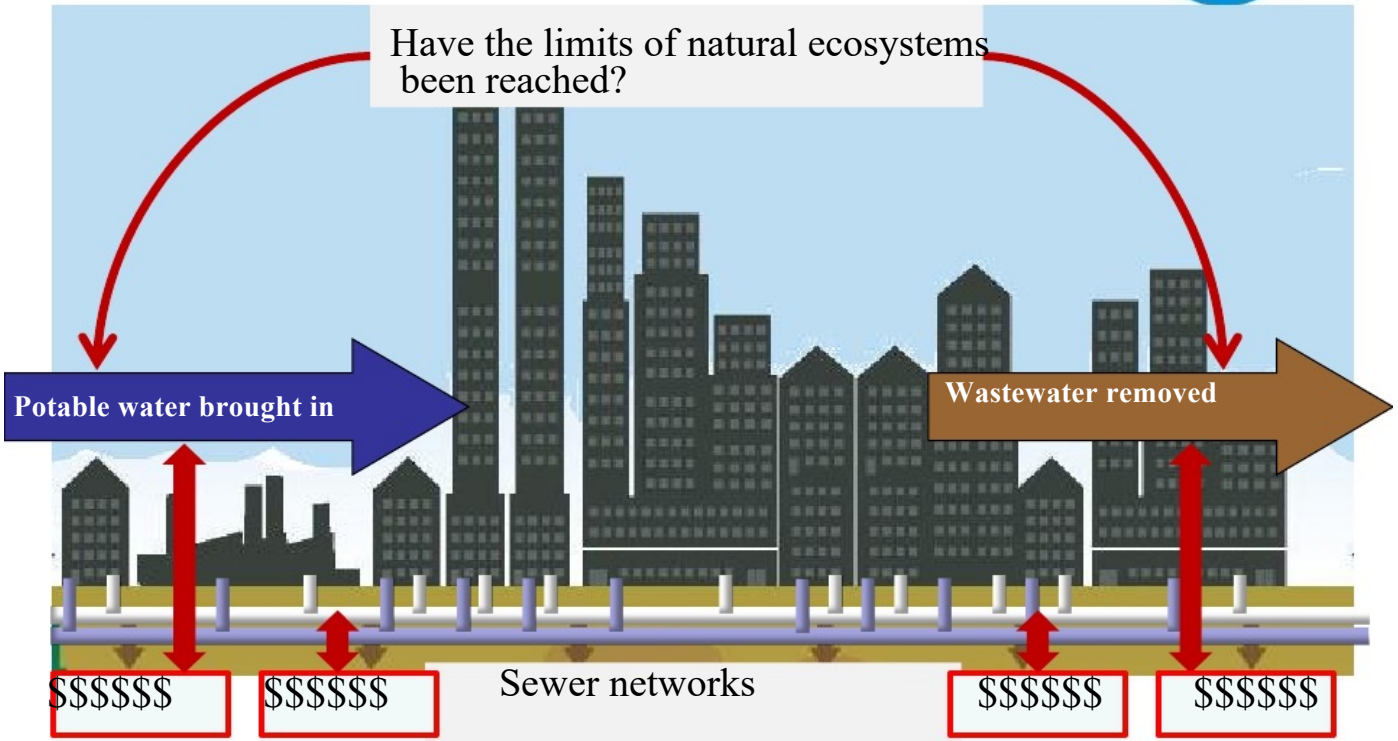
Facts on centralized wastewater infrastructures

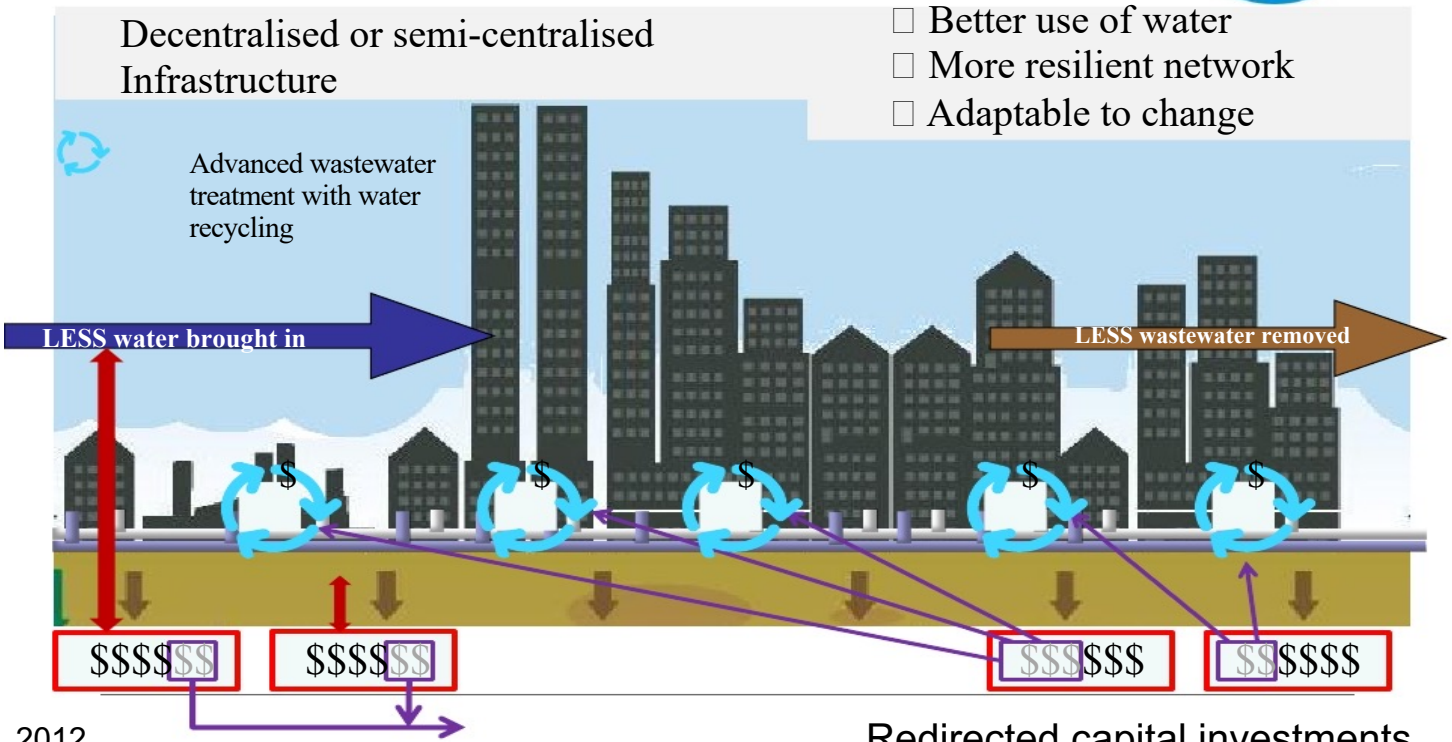


Current situation: Today's city Water Management



Source: Meeten et. al. 2012

Towards Tomorrow's city?



Meeten et. al. 2012

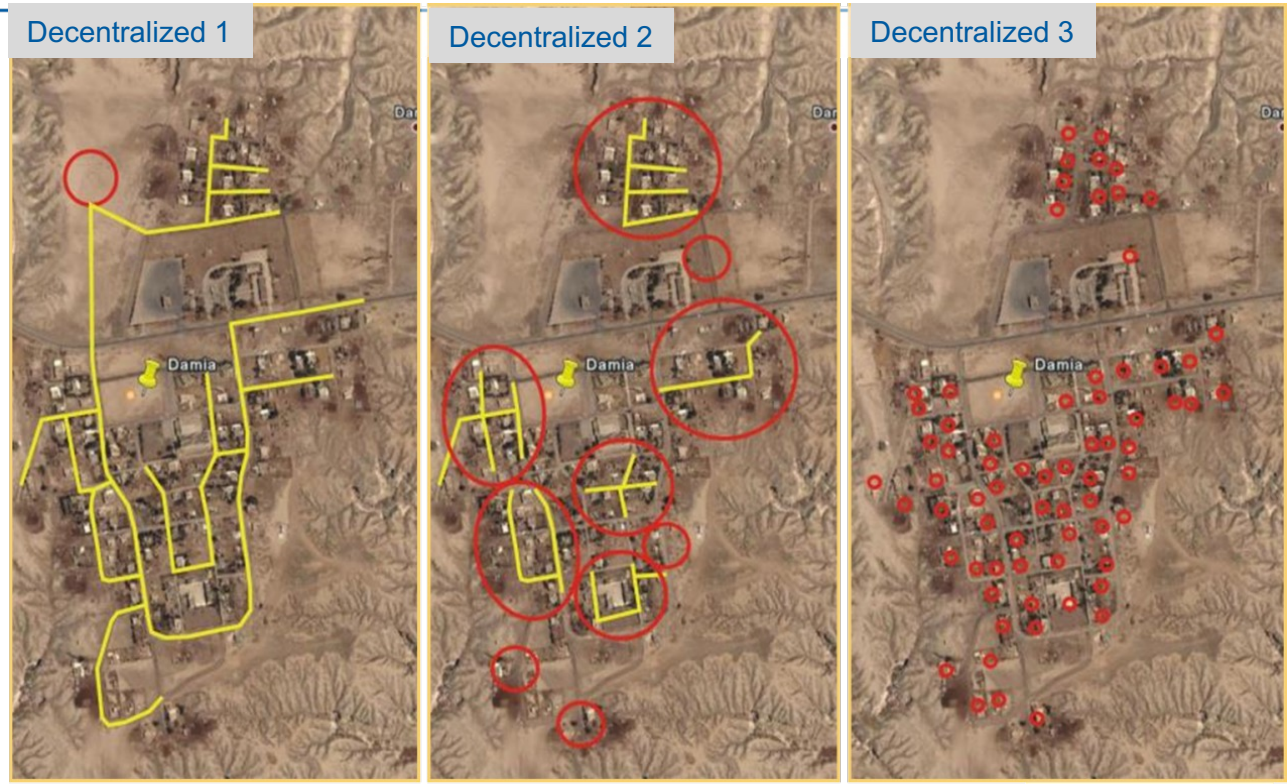
Redirected capital investments

Definition: Decentralised wastewater treatment

"Decentralised wastewater systems

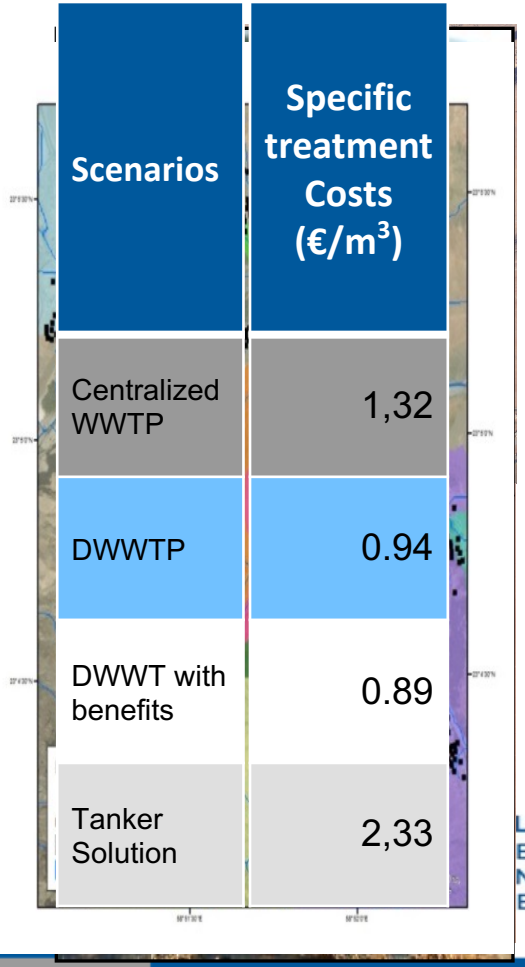
collect, treat and reuse or dispose wastewater

at or near its point of generation.



Potentials of Decentralized Wastewater Infrastructures

- Reuse of treated wastewater provide the communities with additional water resources in the *local scale*
- DWWT is a flexible tool for infrastructural planning: Helps to cope with the dynamics of demographic/climatic change *(suburban scale)*
- DWWT in rural settlements help to support groundwater protection in a *regional scale*
- Reduction of Investments and O&M costs on national Level



Scenarios	Specific treatment Costs (€/m³)
Centralized WWTP	1,32
DWWTP	0.94
DWWT with benefits	0.89
Tanker Solution	2,33

Wastewater “System-Architecture”

Centralized Systems have

High efficiencies for

- Sufficient availability of water
- Concentrated settlement
- Stable planning horizon
- Slow population development
- Availability of public funds

Resilient Sanitation Infrastructures

Low efficiencies for

- Water scarcity
- Dispersed settlement
- Lack of planning security
- Dynamic population development
- Low availability of public funds

Advantages of decentralized systems

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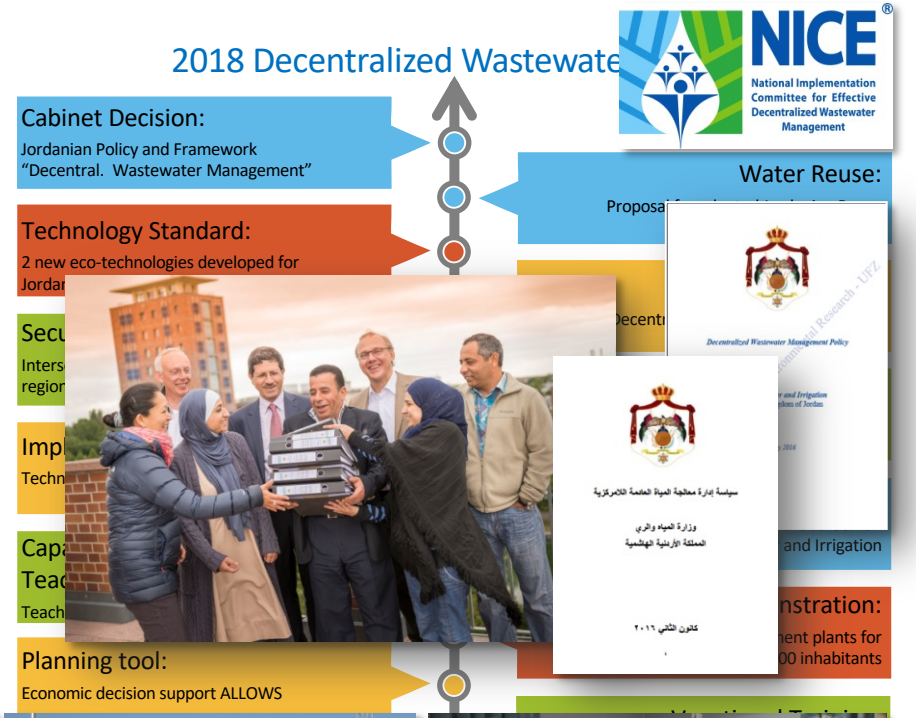
Science and Implementation

- Office in the Jordanian Ministry of Water and Irrigation
- **Framework Arabic & English 12/2015**
- **Submission of Framework to the Jordanian Cabinet in January 2016**
- **Adoption of the framework and policy February 2016**



National Implementation Committee for Effective Decentralized WW Management in Jordan" - NICE

- **Ministry of Water & Irrigation**
  - Secretary Generall
  - Secretary General Assistant Strategies & Policies
- **Water Authority of Jordan**
  - Secretary General Assistant Wastewater
  - Secretary General Assistant Laboratories & Water Quality
- **Jordan Valley Authority**
  - Secretary General Assistant for the North and Middle Jordan Valley
- **Ministry of Environment**
  - Director of Inspection and Control
- **Jordanian Standards and Metrology Organization**
  - Director of Inspection and Control
- **Helmholtz Center for Environmental Research – UFZ**
  - Head of Department 'Center of Environmental Biotechnology'
- **University of Jordan**
  - Water, Energy and Environment Center
- **German Jordanian University**
  - School of Natural Resources Engineering and Management
- **Housing and Urban Development Corporation**
  - Manager of Studies, Design and Tenders
- **Ministry of Health**
  - Director of Environmental Health
- **Ministry of Municipal Affairs**
  - Director of Projects
- **Ministry of Agriculture**
  - Director of Irrigation and Land Use
- **Ministry of Planning & International Cooperation**
  - Head of Water and Agriculture Division
- **Al-Balqa Applied University**
  - Dean of Scientific Research
- **Royal Scientific Society**
  - Head of Water Studies Division

Observers: GIZ, BMZ, KfW, ACWUA, IUCN

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Pioneer Work – Blue Print for other Regions?

German Environmental Prize; 2018

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Perspectives on Drug Control with Water Mangement Technologies

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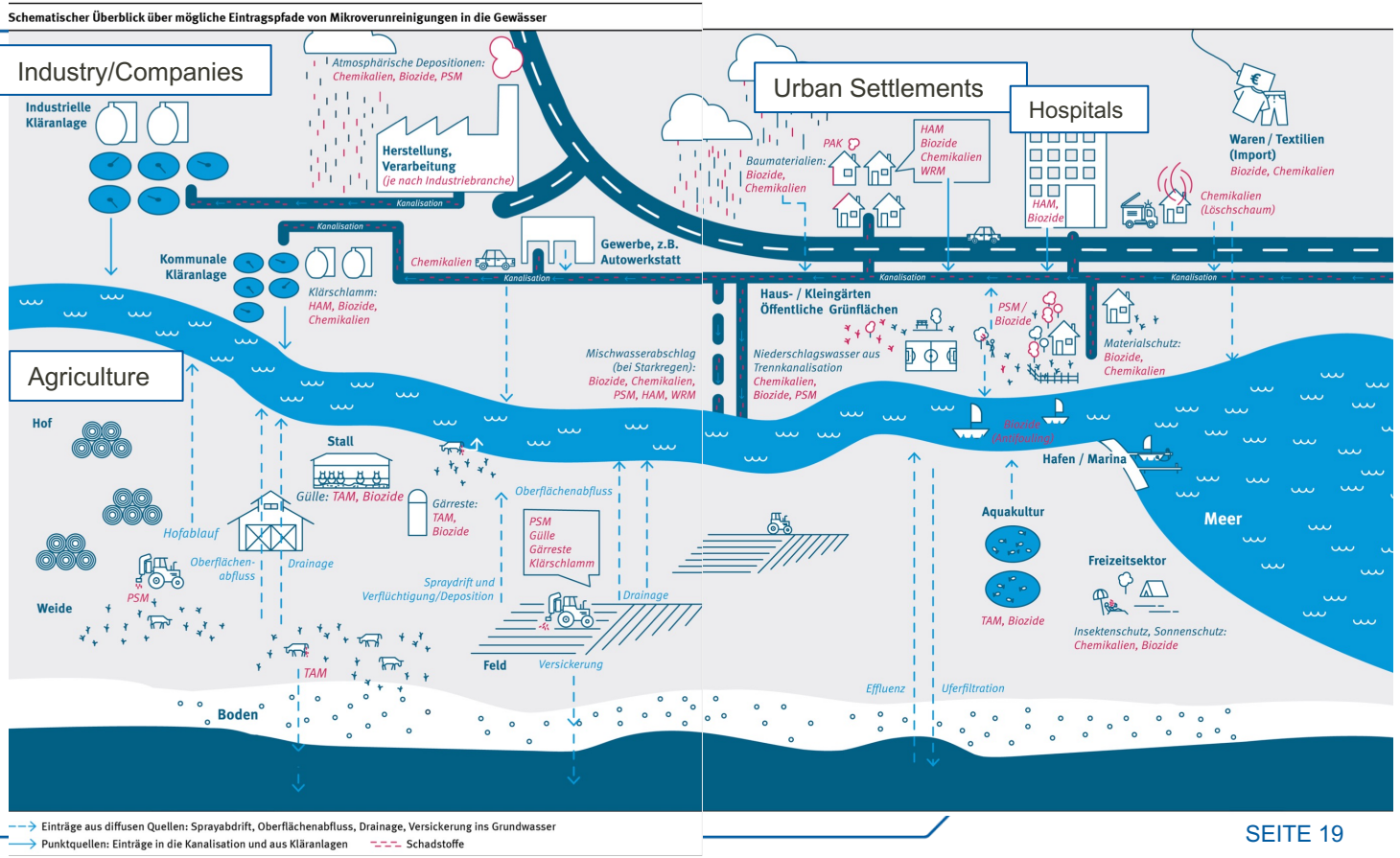
Overview of possible entry paths of micropollutants into water bodies

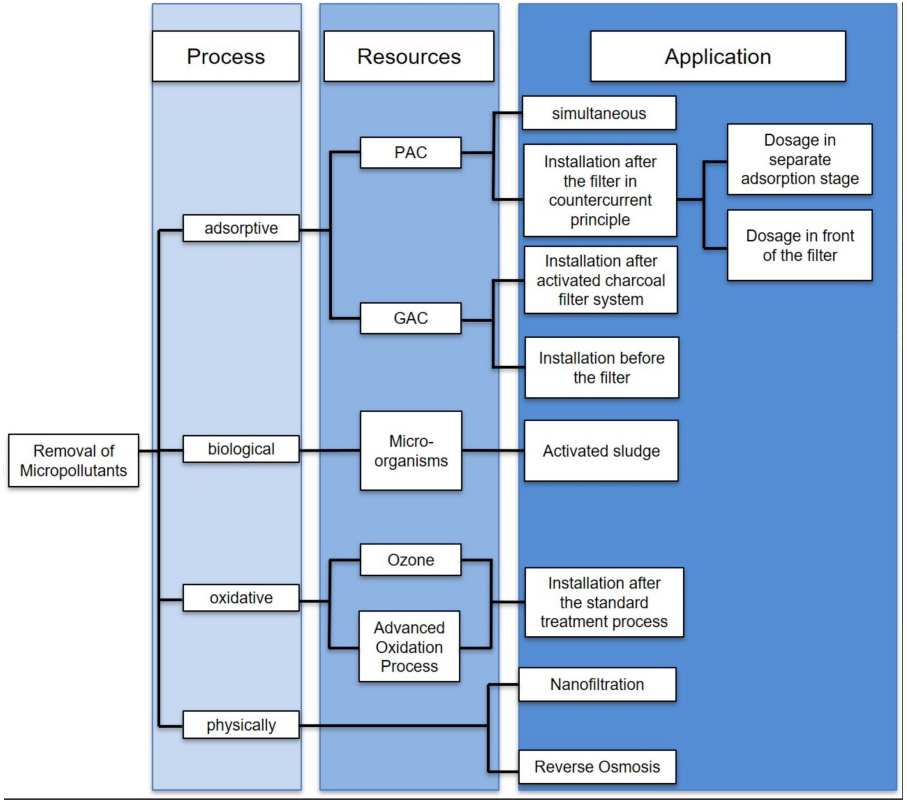
Diffus entry

Point sources



From: Empfehlungen zur Reduzierung von Mikroverunreinigungen in den Gewässern (2018); UBA 2018

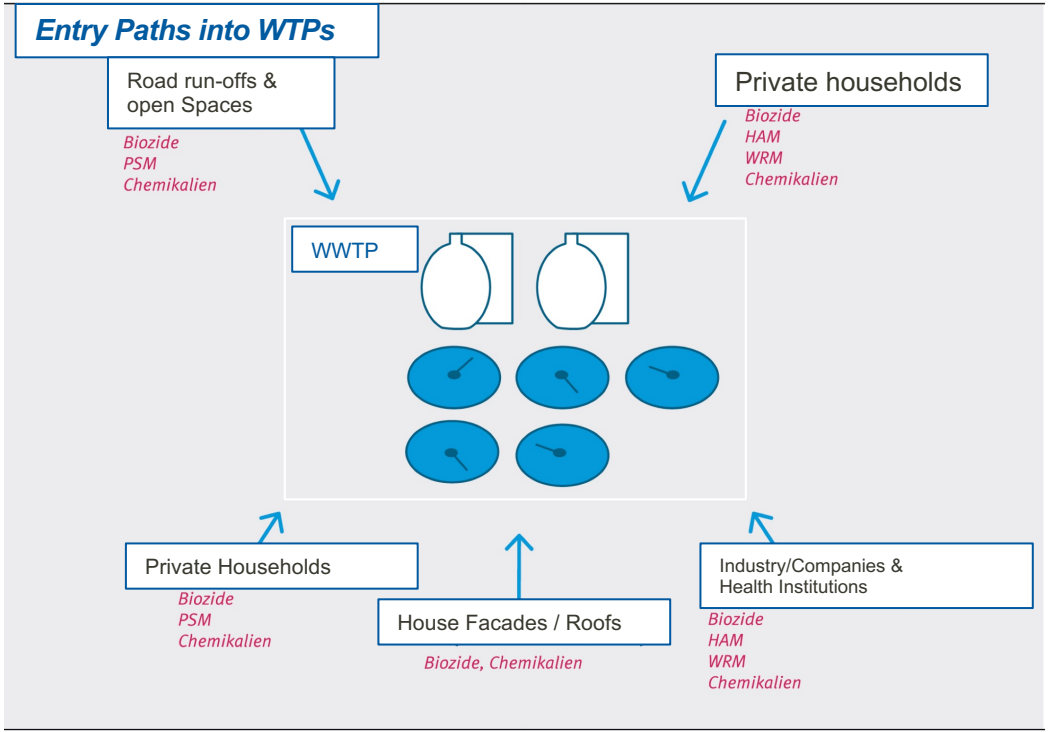
Micropollutants and the fourth purification stage in municipal wastewater treatment plants



Procedural limits:

- Established 1-3th treatment steps
- the uncertainty about by-products in oxidative processes
- slip and desorption of powder activated carbon
- high consumption of chemical auxiliaries
- high maintenance costs,personnel and / or spatial capacity.

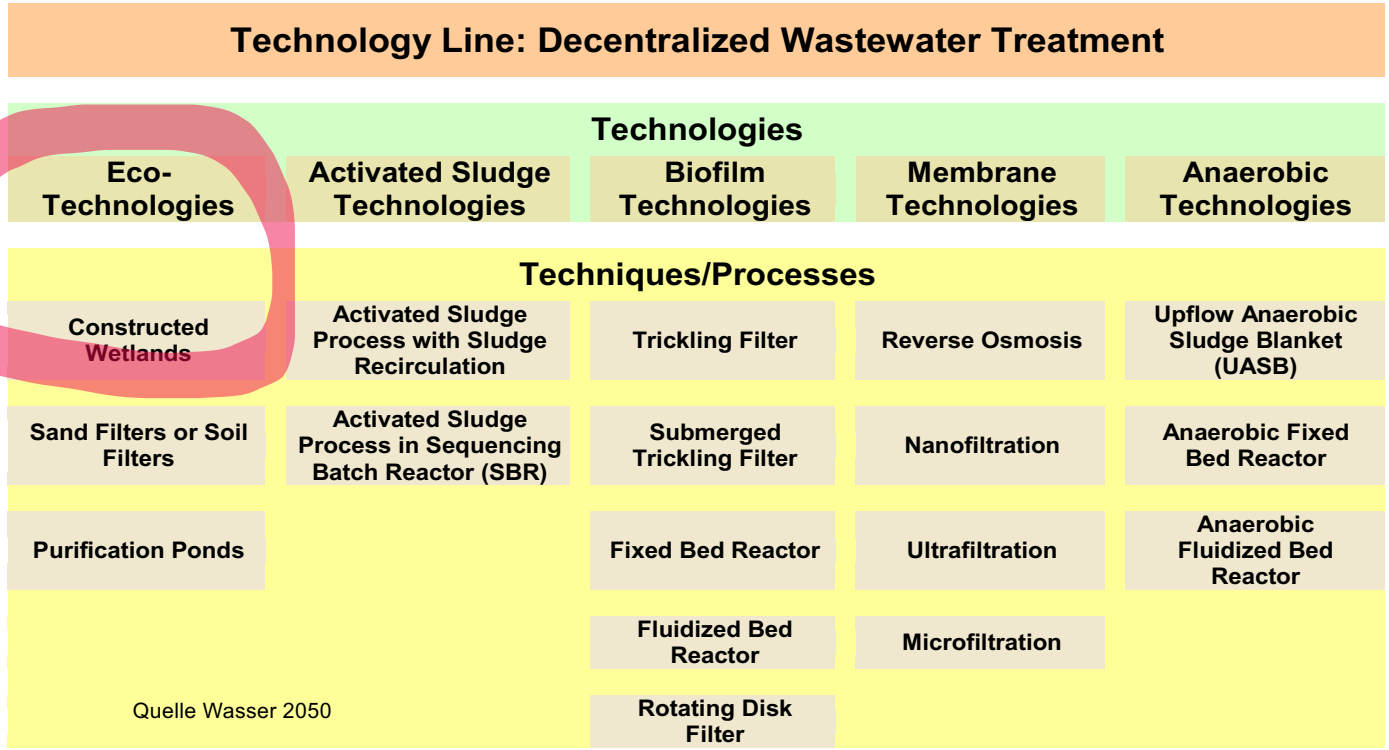
Overview of possible Entry Paths of Micropollutants into Central Wastewater Treatment Plants



End of Pipe Treatment

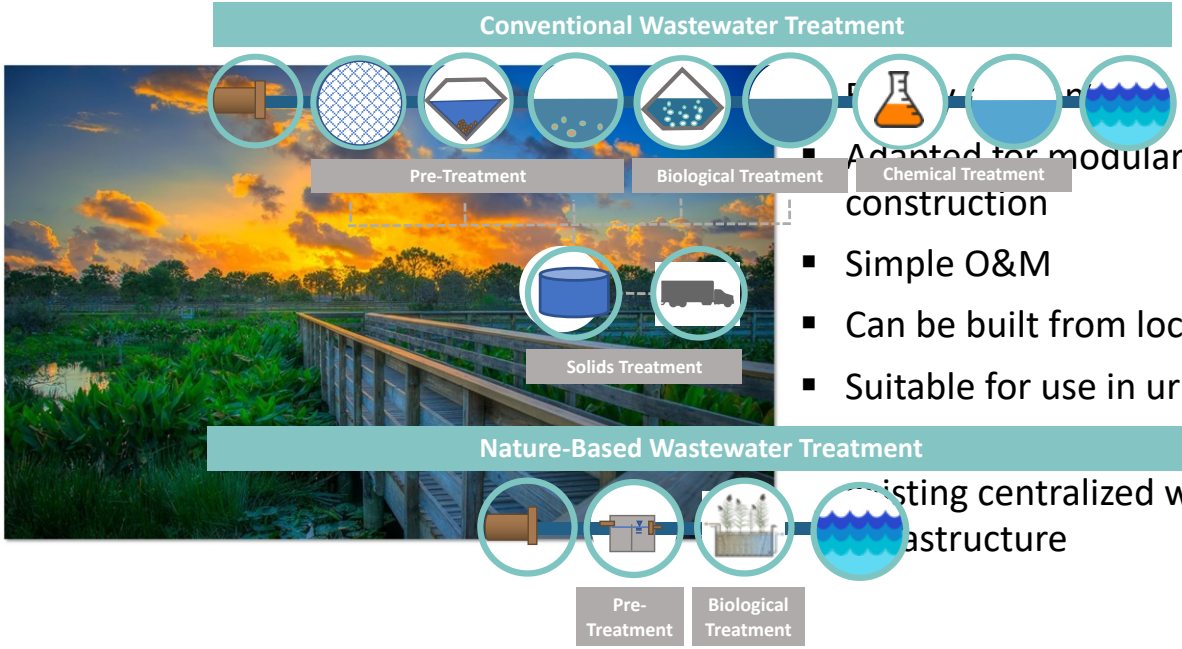
Point Sources

Decentralized Technologies: Flexible in Treatment performance



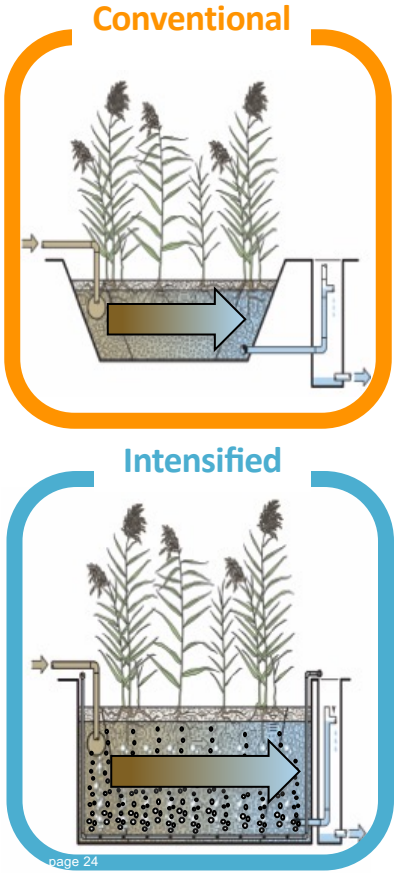
Example: Decentralized Eco-Technologies

Why Nature-Based Solutions?



- Adapted for modular construction
- Simple O&M
- Can be built from local materials
- Suitable for use in urban settings
- ated into isting centralized wastewater astructure

New Designs: Nature-Based Technologies for Wastewater Treatment



- Complete $CBOD_5$ removal
- Stable nitrification despite winter water temperatures as low as 1° C
- 4.0 log unit removal of *E. coli* in one treatment step

Boog et al. (2014) STOTEN
Boog et al. (2018) Wat. Res.
Headley et al. (2013) Ecol. Eng.
Kahl et al. (2017) ES&T
Nivala et al. (2013a,b) Ecol. Eng.
Nivala et al. *in prep*, Wat. Res.

Nature-Based Solutions: Technology Development

Langenreichenbach, Germany

New National Design Standard

- **UFZ** served as task group member and co-author
- **Six new technologies** (two from UFZ)
- First national guideline in the EU that is **officially translated and published in English**
- **Go-to design standard** in countries where no such document exists

Nivala et al. (2018) WST 78(11):2414-2426

Perspectives on Drug Control with Water Mangement Technologies

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Micropollutant degradation in Ecotechnologies:

Characterization, resilience, and optimization of micropollutant and biological effect removal by treatment wetlands treating municipal wastewater

Nadine Angela Sossalla

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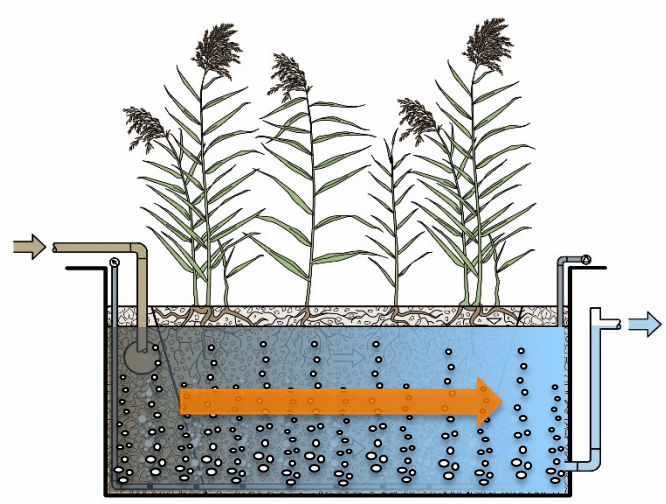
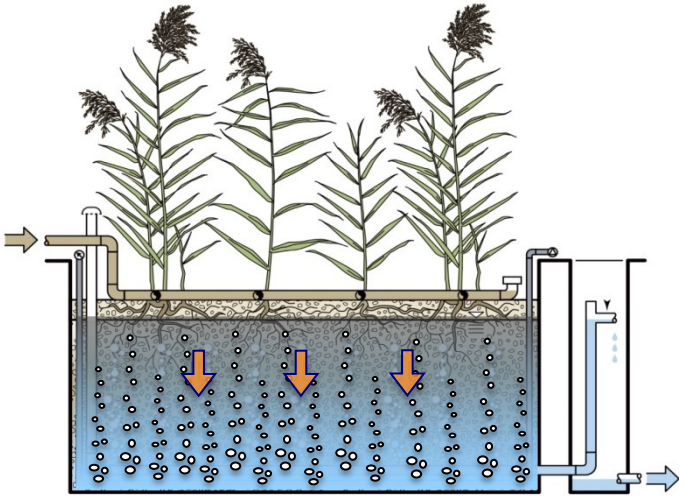
Basic technology – treatment wetlands

Horizontal flow system



Vertical flow system



Knowledge gaps

- Analysing micropollutants means to analyse known compounds
- **impossible** to quantify **every individual compound** present in a water sample
  - High **number of methods** needed to quantify all compounds
  - **un-/known transformation products**
  - **interaction** between pollutants and/or transformation products
- **Sum environmental effect** of pollutant mixtures **not known**

How can we account for all of the pollutants in a given water sample?

Research questions of the doctoral thesis

- Do treatment wetlands effectively remove specific relevant biological effects?
- **To which extent** does treatment wetlands remove biological effects?
- Is there a **correlation** between removal of **micropollutants** and removal of **biological effects**?
- Which are the **most efficient design aspects** for the removal of biological effects?
- How **resilient** is a treatment wetland in terms of removal of micropollutants and biological effects?

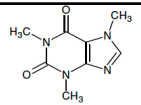
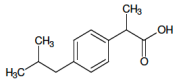
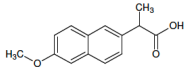
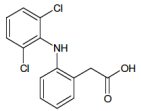
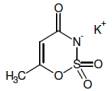
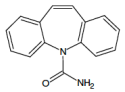
Treatment wetlands

- Langenreichenbach, Leipzig – Germany
  - Secondary treatment steps of municipal wastewater
  - Seven treatment wetlands and a municipal wastewater treatment plant

Municipal Wastewater treatment plant

WWTP

Model Compounds in Wastewaters

Compound	Chemical Structure	Application [a]	Biodegradability
Caffeine (CAF)		Stimulant	High (aerobic)[1] Medium to high (anaerobic)[1,2]
Ibuprofen (IBU)		NSAID	High (aerobic)[3,4,5,6] Low (anoxic, anaerobic)[2,6]
Naproxen (NPX)		NSAID	Medium to high (aerobic)[3,4,5,7] Medium to high (anaerobic, anoxic)[2,7]
Benzotriazole (BTZ)		Corrosion inhibitor, antifreeze agent	Low to medium (aerobic)[8,9,10] Low (anaerobic)[8,9,10]
Diclofenac (DCL)		NSAID	Low to high (aerobic)[3,4,5,6,7,9,11] Low (anoxic, anaerobic)[2,4,6,7,9]
Acesulfame (ACE)		Artificial sweetener	Low [b] (aerobic, anoxic, anaerobic)[11]
Carbamazepine (CBZ)		Anticonvulsant	Low (aerobic)[4,5,9,10] Low to medium (anoxic, anaerobic)[2,4,9,10,11,12]

BMBF funding measure

NaWaM RiSKWa

Risk Management of Emerging Compounds and Pathogens in the Water Cycle

Handbook of good practice

SPONSORED BY THE

Federal Ministry of Education and Research

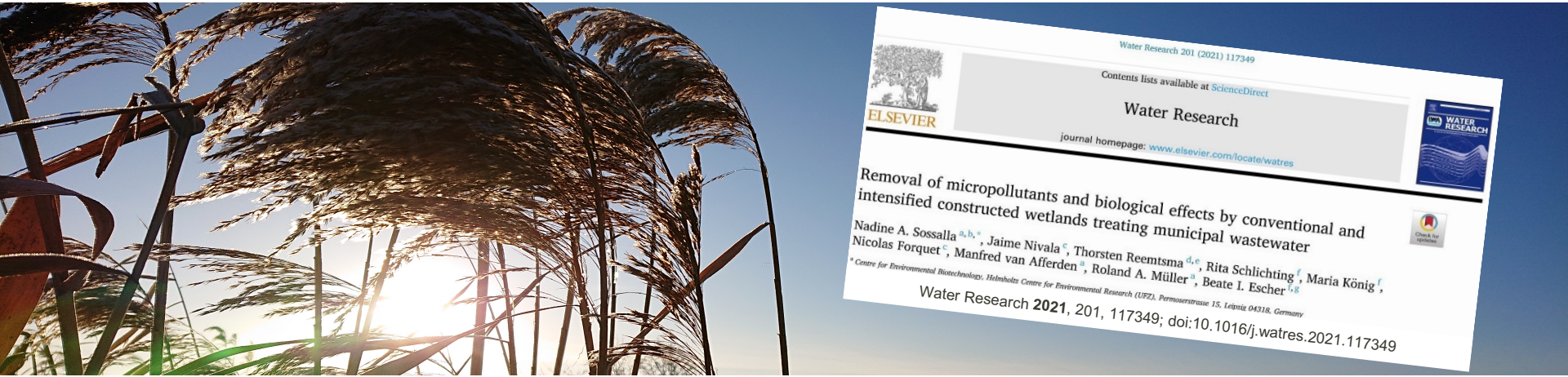
https://riskwa.de/Downloads/_/RISKWA_Handbook_of_good_practice.pdf

Micropollutants

- **Seven indicator chemicals** identified and a simple method developed (HPLC-MS/MS; direct injection) to analyse micropollutants

  → Micropollutants selected according to **different level of biodegradation** under aerobic conditions

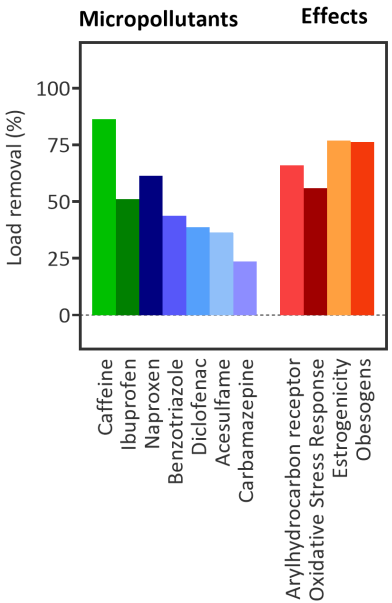
Identification



- Seven treatment wetlands and a municipal wastewater treatment plant
- Weekly influent and effluent sampling over the course of one year

Increasing Removal Efficacy

Non-Aerated Horizontal Flow Treatment Wetland

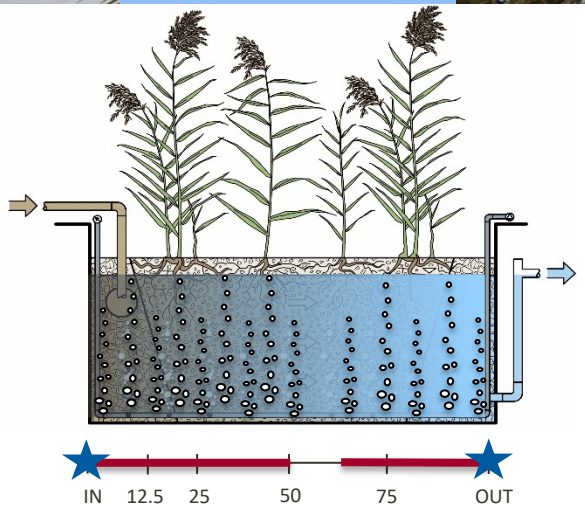


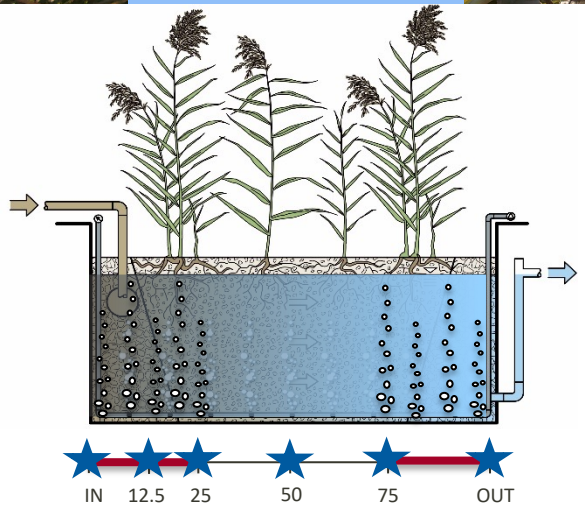
Influence of the redox milieu on the removal of micropollutants and biological effects in aerated horizontal flow treatment wetlands

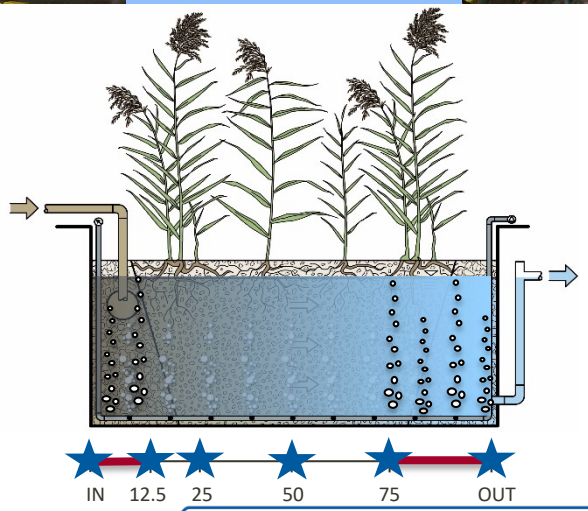
85% aerated
One year

50% aerated
5 months

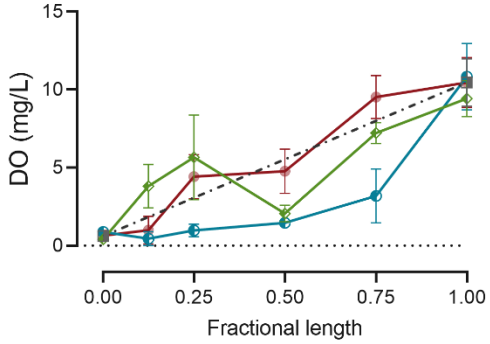
35% aerated
6 months

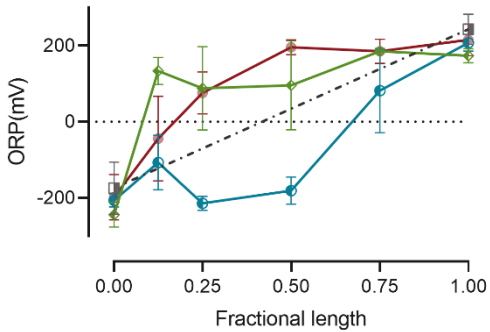


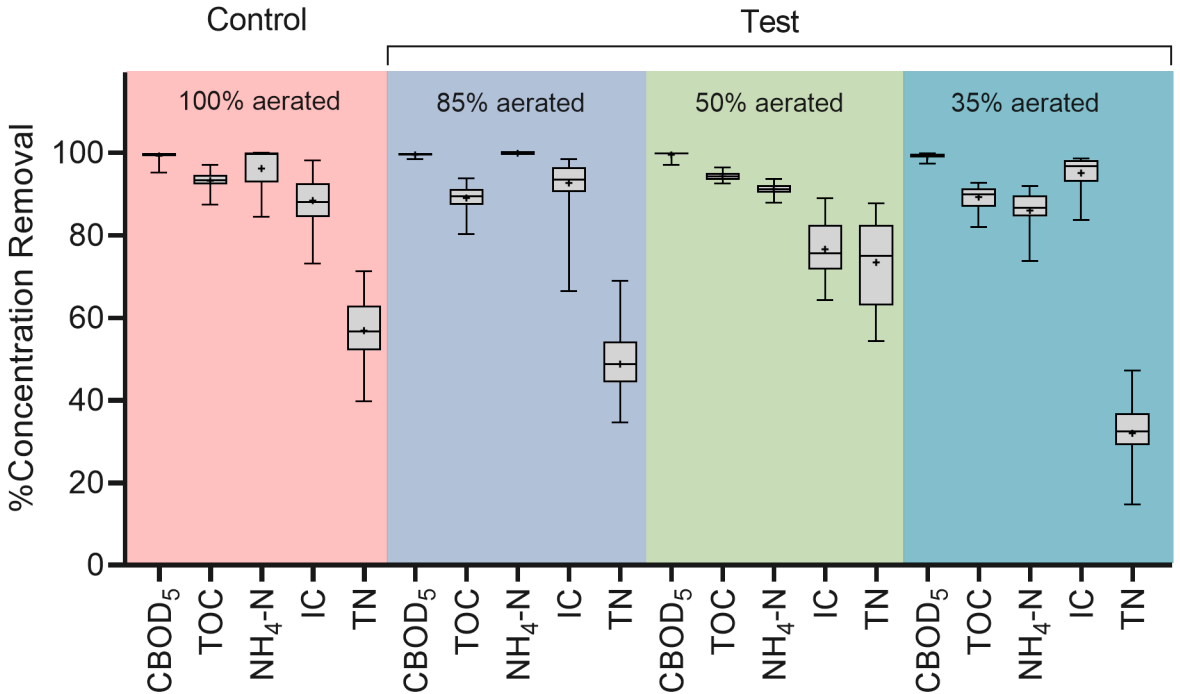




Conventional Wastewater Parameter

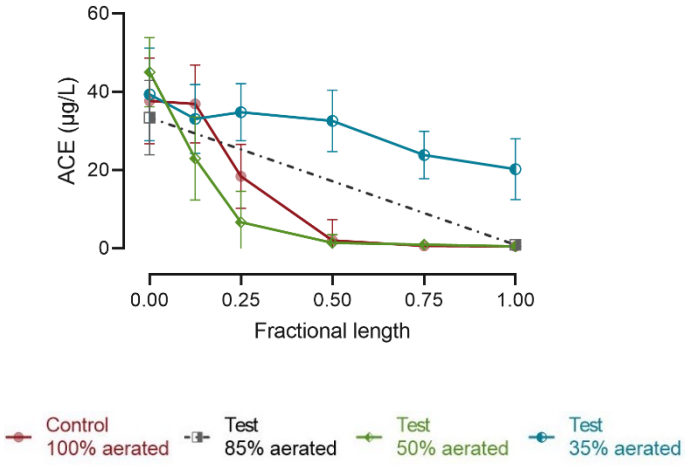


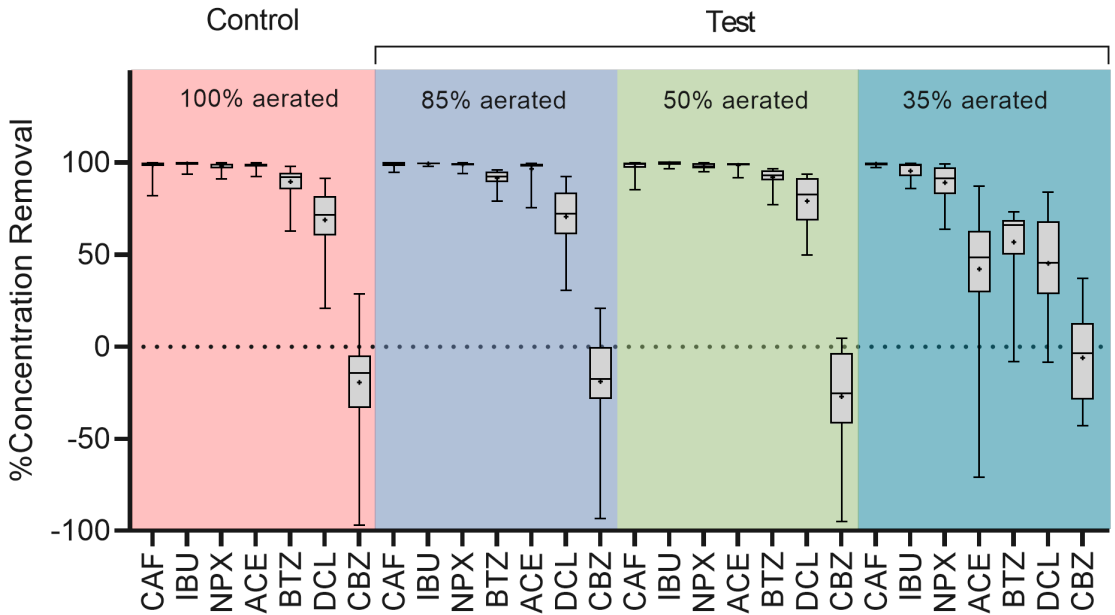




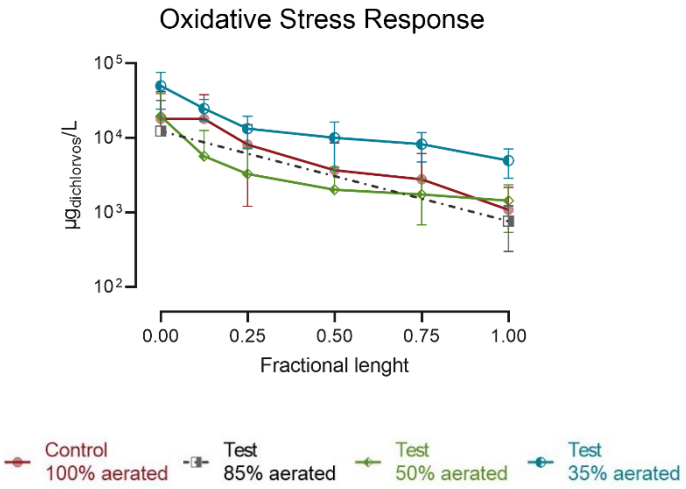
Control 100% aerated | Test 85% aerated | Test 50% aerated | Test 35% aerated

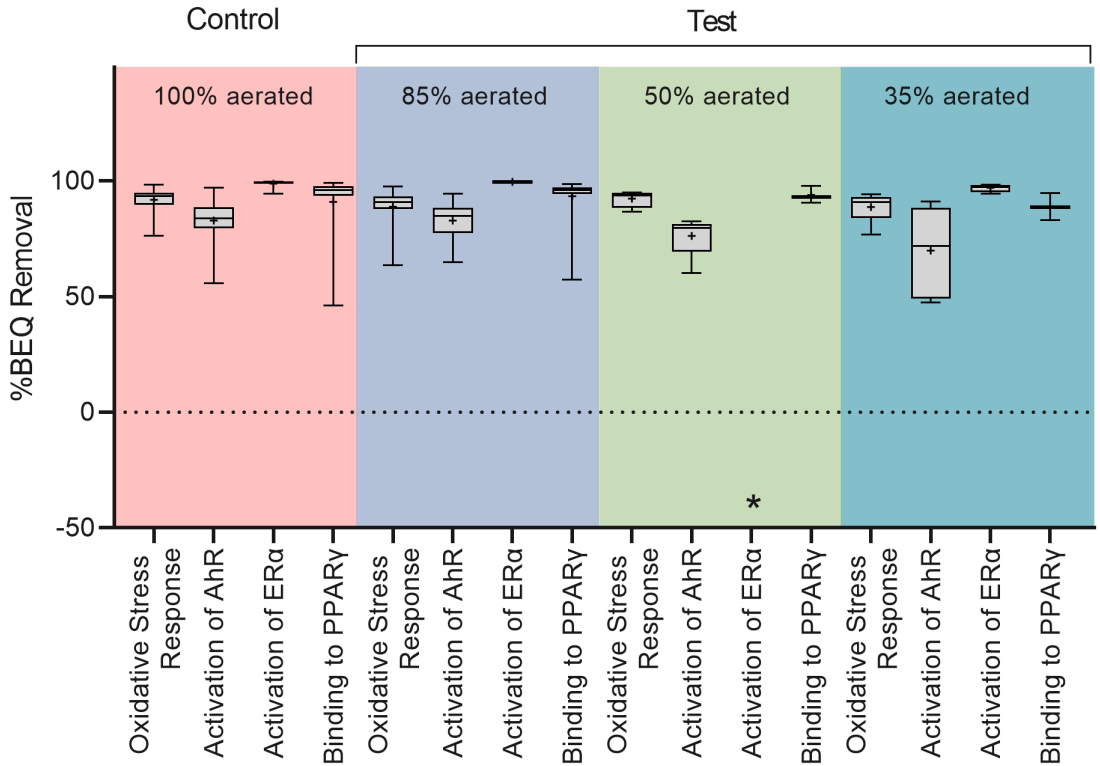
Micropollutant removal





Removal of biological effects





Conclusion – Influence of the redox potential

- **Different redox conditions** could be **achieved** by different aeration modifications
- An aeration reduction up to **50%**
  - lead to a **smaller influence** for the removal of **wastewater parameters** and **micropollutants**
  - removal of **biological effects** are **impacted**
- **No increased removal efficiency** for **poorly degradable compounds** such as CBZ could be achieved
- The horizontal flow treatment wetland should be **aerated** over **at least 50%** of the **fractional length** of the system

Resilience test of an aerated horizontal flow treatment wetland

water

Article

MDPI

Resilience of Micropollutant and Biological Effect Removal in an Aerated Horizontal Flow Treatment Wetland

Nadine A. Sossalla [1,2,*], Jaime Nivala [3], Beate I. Escher [4,5], Thorsten Reemtsma [6,7], Rita Schlichting [4], Manfred van Afferden [1] and Roland A. Müller [1]

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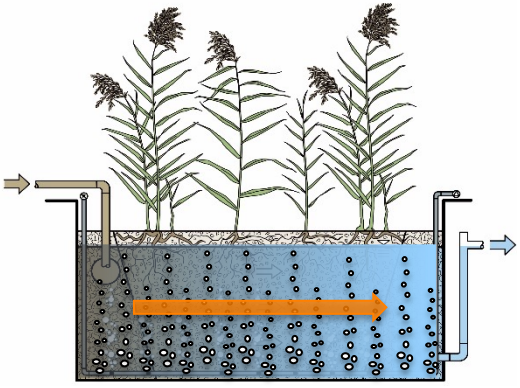
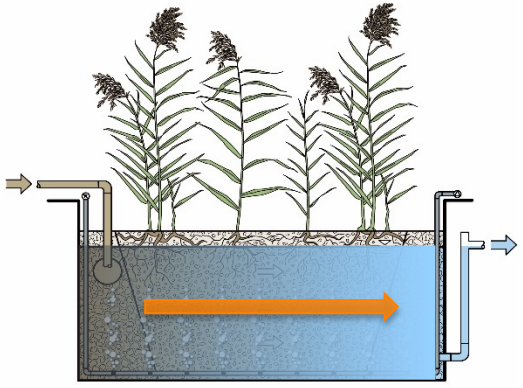
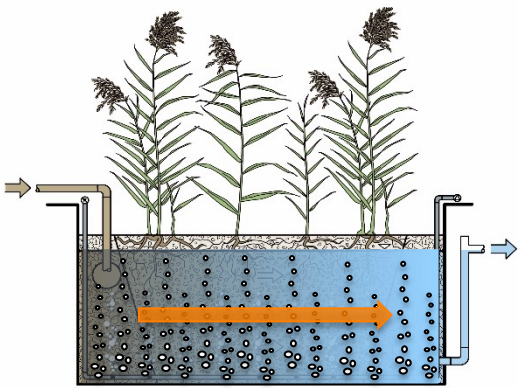
Water 2020, 12, 3050; doi:10.3390/w12113050



3 weeks aerated

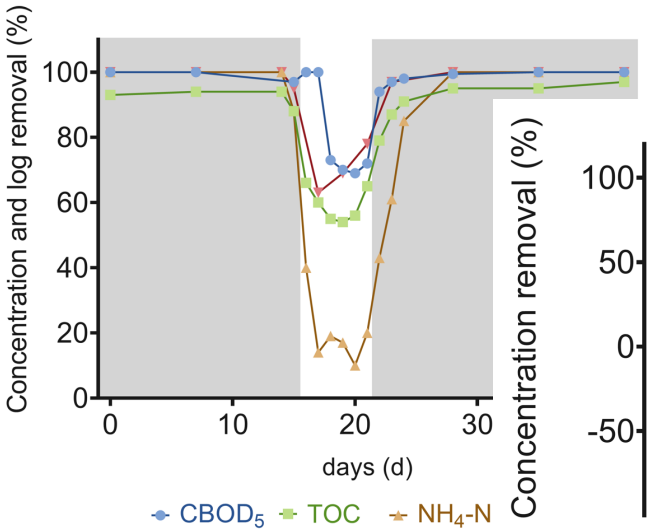


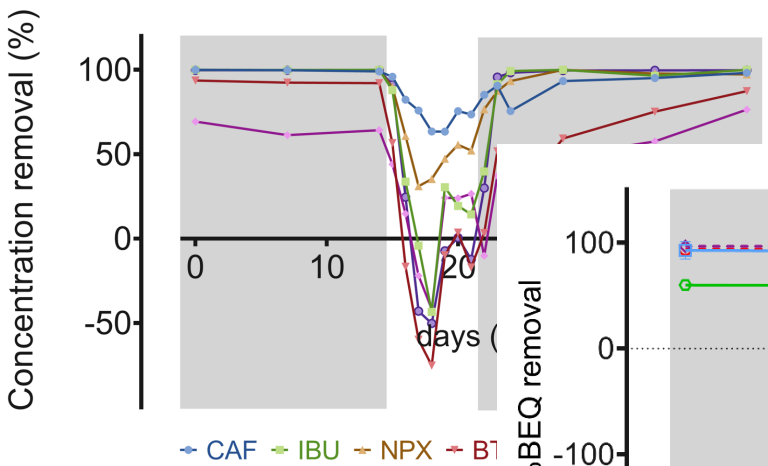
6 days not aerated

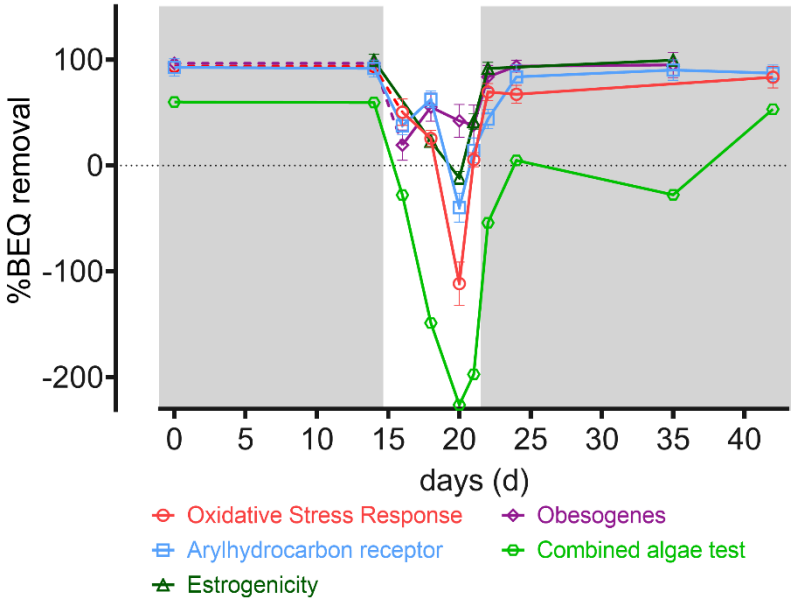


3 weeks aerated

Results of the resilience test



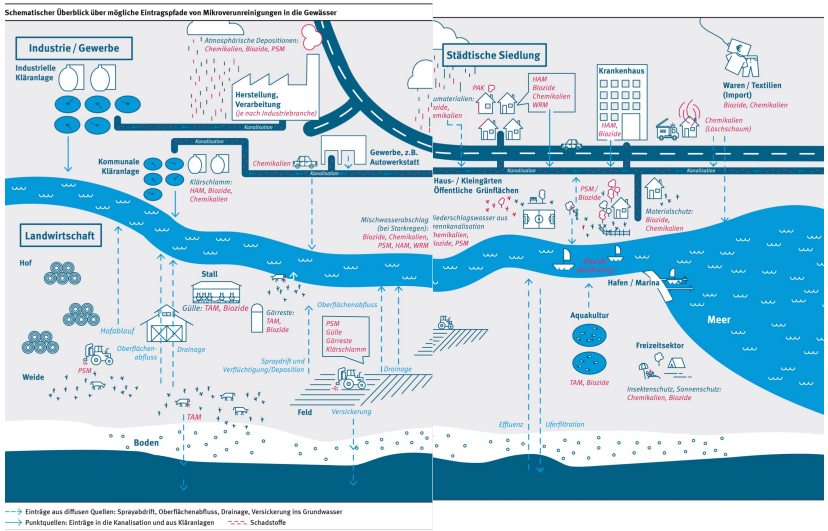




Outlook

- **Expanding** chemical analysis
  - To include **transformation** products and **degradations** products
  - improve and **maximize** the capacity of **treatment wetlands to remove** micropollutants and biological effects
  - Identifying and linking micropollutants **cause observed effects** in *in vitro* bioassays
- Developing approach dependent treatment wetlands, e.g. the implementation in urban water cycles (BlueGreenInfrastructure)
- Development of an **easy-to-use** and **simple to evaluate bioassay test batterie**
- Risk assessment

Next Steps-Recommendations



- System Wastewater architecture in a synergistic centr./dectr. Approach – Cost Reduction
- (Model) River Basin Approach (legal Frame)
- Adapted Monitoring Systems (Routine/extended)
- 3D GIS Szenarios – recommendations for decision making - priorities of action
- Political Interest: Multi Barriere System

Thank you for your attention!

Roland Müller

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