WETPOL 2023

Bruges Meeting & Convention Centre, Belgium

## 10th International Symposium on Wetland Pollutant Dynamics and Control

# Conference Proceedings

10–14 September 2023 Bruges, Belgium

**Organized By:** Ghent University · University of Applied Sciences · KU Leuven · Rietland · Aquafin

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**10th International Symposium on Wetland Pollutant Dynamics and Control**

## Conference Proceedings

**Ghent University**

**Sint-Pietersnieuwstraat 25**

**Ghent, Belgium**


**Edited by: Huma Ilyas; Diederik Rousseau; Flor Louage**

**Ghent University, Belgium**



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# Welcome to 10th International Symposium on Wetland Pollutant Dynamics and Control

## Welcome to 10th International Symposium on Wetland Pollutant Dynamics and Control

Dear wetland colleagues,

Welcome to the 10th edition of the International Symposium on Wetland Pollutant Dynamics and Control, WETPOL 2023, jointly organized by Ghent University, KU Leuven, Aquafin and Rietland (Belgium) and with HZ University of Applied Sciences (The Netherlands).

We have chosen to organize this festive anniversary edition back where it all started in 2005, in Belgium, be it this time in the beautiful and historical city of Bruges. In medieval times, Bruges was still connected to the North Sea and gained international importance with trade as one of the famous Hansa cities. With large parts of that medieval heritage still preserved, the entire city center of Bruges was declared a World Heritage Site by UNESCO. Do enjoy the view on the skyline of Bruges from the 4th floor of the BMCC conference venue, take your time to stroll along the canals of this 'Venice of the North', and enjoy our famous burgundy lifestyle with good food, even better beers, and delicious Belgian chocolate.

While travelling through the country, it is probably hard to imagine, but Belgium is one of the 25 countries on our globe with an extremely high water stress (World Resources Institute, 2023), meaning that more than 80% of the available water resources are consumed by the dense population, intensive agriculture and wide-spread industry. Yet, more than 15% of the territory of Flanders (northern, Dutch-speaking part of Belgium) has a sealed surface, hence precious water resources are quickly drained to the sea instead of being captured in the soil for later use. Just across the border, in the Dutch province of Zeeland, the brackish and saline waters of the Scheldt estuary add another level to this complex problem. This makes the entire region vulnerable to climate change, as we have already witnessed the past couple of summers, with restrictions on among others potable water use, irrigation, and river navigation.

But problems are also a trigger for action and innovation. Flanders for instance recently launched the Blue Deal, an ambitious program to tackle water scarcity and drought not only with infrastructure, but also through legislation, research, monitoring, communication, and awareness raising. Likewise, in the Netherlands, the government took several initiatives to promote fresh water conservation and storage, and prioritizing the integral water system (water and soil) in future spatial planning. Nature-based solutions play an important role in all these initiatives as their extended ecosystem services contribute to water storage, water treatment and reclamation, habitat provision, microclimate regulation and so on. Several projects from the region will be presented during the plenary and parallel sessions, and concrete realizations will be on display during one of the fieldtrips. But first and foremost, we are also looking forward to share experience and exchange ideas with you, the international experts from academia, companies and governments that join WETPOL 2023!

This book of abstracts contains the contributions of 7 keynote speakers, 123 oral presentations and 29 poster presentations.

A big thank you to all the collaborators from Ghent University for the practical organization aspects, and to all our sponsors (mentioned on the next pages) without whom it would have been impossible to organize WETPOL 2023.

We do hope you enjoy the conference, and your stay in Bruges.

WETPOL Organizing Committee

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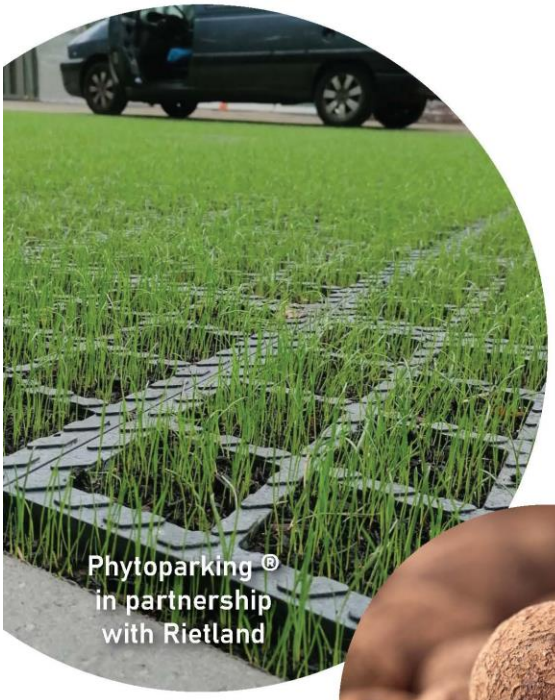

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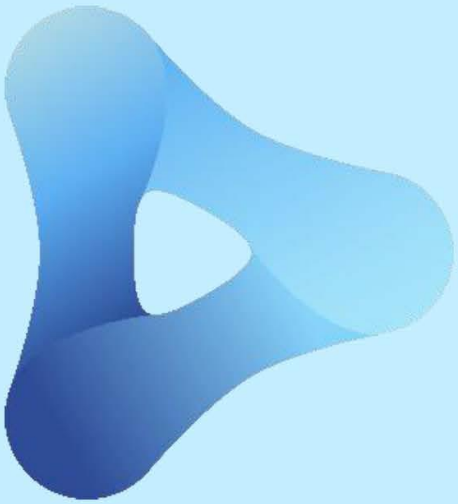

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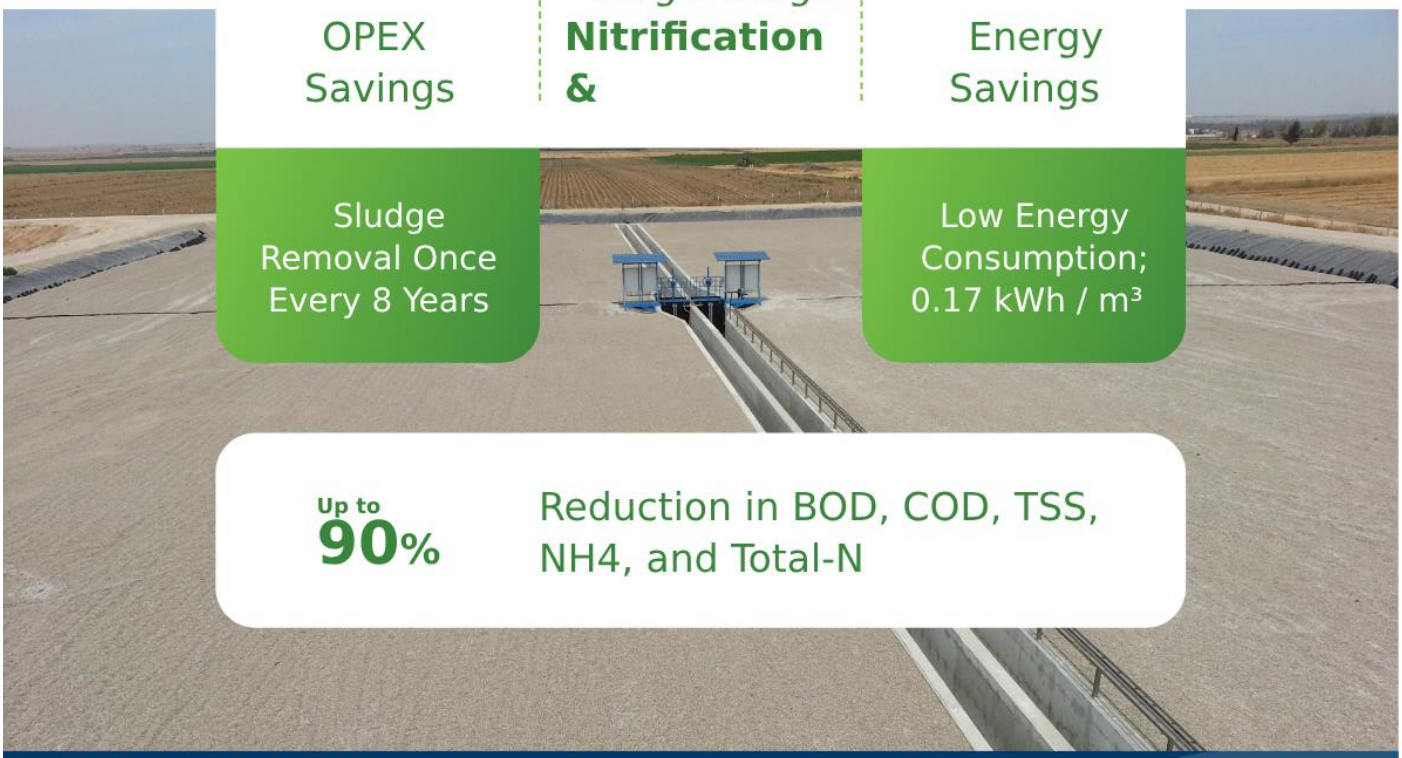

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# AQUATUUR

## TOWARDS A HIGHER CLIMATE ROBUSTNESS USING NATURE-BASED SOLUTIONS


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Aquatuur is an Interreg VI Vlaanderen – Nederland project that runs from 22.05.2023 to 21.05.2026. The project aims at increasing the climate robustness of the region around the mouth of the river Scheldt by focusing on water storage and improving water quality. To this end, nature-based green-blue solutions are used and solutions will be proposed to overcome potential non-technological barriers.

WETPOL is hosting the Aquatuur start conference on Monday 11 September 2023.

# Conference Topics

# Conference Topics

| | |
|---|---|
| Topic 1 | Biogeochemical cycling of carbon and nutrients |
| Topic 2 | Carbon sequestration and greenhouse gas emissions |
| Topic 3 | The role of wetlands in pollutant management at the catchment scale |
| Topic 4 | Increase process understanding for treatment wetland types, e.g., sludge treatment wetlands, intensified wetlands, microbial electrochemical wetlands resources recovery from wetlands |
| Topic 5 | Wetland plants ecophysiology and invasiveness |
| Topic 6 | Impact of climate change on wetland systems |
| Topic 7 | Attenuation of diffuse pollution in wetlands |
| Topic 8 | Behavior of priority and emerging pollutants |
| Topic 9 | Molecular and microbial advances related to pollutant fate, disposal, and removal in wetlands |
| Topic 10 | Role and functioning of wetlands and other nature-based solutions in urban settings |
| Topic 11 | Advances in modelling for process understanding and design |

# Keynote Speakers

# Keynote Speakers

**Birgit De Bock –** R&D Engineer at Aquafin (Belgium)

Birgit De Bock graduated as an environmental engineer in 2009 from the university of Gent, and is working as a researcher at Aquafin. She studies reuse and infiltration of stormwater, sustainable urban drainage and helped found the website www.blauwgroenvlaanderen.be.

# Wetlands: a promising solution in a changing framework

*De Bock Birgit* [1,*], *Veulemans Paulien* [1]
[1] Aquafin Nv, Dijkstraat 8-2620 Aartselaar, Belgium
* Birgit.debock@aquafin.be

**Perspectives from Aquafin, the regional wastewater treatment company of Flanders**

Aquafin was established by the Flemish Region in 1990, for the purpose of expanding, operating, and pre-financing the wastewater treatment infrastructure in Flanders. Aquafin collects household wastewater from the municipal sewers in collector sewers and transports it to wastewater treatment plants, where it is treated in accordance with European and Flemish standards.
When Aquafin was established in 1990, just 30% of domestic waste water was treated. The Flemish Region gave Aquafin the task of closing this large gap compared with neighboring countries rapidly. Aquafin currently treats about 86% of domestic waste water before it reaches a stream or river.
Healthy aquatic plants, colorful kingfishers, even an otter here and there and more and more species of fish returning to our streams and rivers.

Aquafin operates about 40 constructed wetland systems to treat municipal wastewater. 5 of them consist only of a wetland with a settling tank as first step before the wetland. The other 35 small wastewater treatment facilities use constructed wetlands as a secondary treatment step after a submerged aerated filter (SAF) or a biorotor. All these smaller systems were built in the 90's. The constructed wetland systems without SAF or biorotor however generate a lot of operation issues. If they start to fail, correcting the system is very difficult. A large surface space of 3-5m²/ PE is also a disadvantage in densely populated Flanders. The nutrient removal of these systems is limited to 30% N and 10% P.

Maintenance costs are estimated to be around €14000/year and include sludge removal, personnel costs and electricity. This amounts to €30-60/PE/year (based on 5 small scale treatment systems).
As the large wastewater treatment plants remove about 80% of all nutrients at a lower OPEX, we can say that these systems are preferred at Aquafin.

But it is not all a story of failures. As the ecosystem benefits of wetlands are becoming more important, Aquafin is currently looking into wetlands as a solution to integrate water treatment in our landscapes.
The R&D department is looking at wetlands as an NBS for treatment of CSO and stormwater flows. At R&D we believe that wetlands and other filter based low tech, low energy treatment systems will be used more in the future. Maybe not for the classic municipal wastewater treatment but rather in the storm and combined overflow treatment business. We are looking forward to see a bright future for NBS in this field of research.

# Keynote Speakers

**Simon De Paepe –** Water Innovator at VITO-Vlakwa (Belgium)

Simon De Paepe first achieved a BA in Chemistry-Environment and acquired considerable expertise working for a soil consultancy firm. After eight years of field research, he switched to working as a project engineer while simultaneously obtaining a master's degree in environmental sciences at the Open University in the Netherlands. In 2021 he started at VITO-Vlakwa (Flemish Institute for Technological Research-Flemish Knowledge Center Water) as a Water Innovator. He is setting up and coordinating partnerships which focus on nature-based solutions and rural open space combined with an integrated systemic view.

He is also member of the transition arena water H2O50, a free space where fresh thinkers reflect on futureproof water. It is also a network where a systemic long-term vision on water in Flanders is mapped out.

Simon De Paepe born and raised in the Province of West-Flanders, 30 minutes away from his favorite city in Belgium: Bruges. When he is not wrapped up in one of his projects, you will find him running or hiking in nature, spending time on MTB-trails or alongside the water, one of his favorite elements in nature.

# Aquatuur: towards a higher climate robustness by using nature-based solutions

*Simon De Paepe* [1,*]
[1] VITO – Vlakwa, Kortrijk, Belgium
* sdp@vlakwa.be

**An Interreg Vlaanderen – Nederland Project (May 2023 – May 2026)**
Within the Aquatuur project we will demonstrate various nature-based green-blue solutions (NBSs) so as to increase freshwater availability for human consumption and nature over a three-year period. Aquatuur will be carried out by a consortium composed of nine proactive partners (VITO-Vlakwa, HZ University of Applied Sciences, Inagro, the province of Zeeland, Ghent University, the Flemish Land Agency, the Flemish Environment Agency, and the municipalities Noord-Beveland and Schouwen-Duiveland), all of which are instrumental to realizing the project goals.

The intended NBSs are aimed at tackling the climate-change-related challenges in the Scheldt mouth region (provinces West & East Flanders (Belgium), and Zeeland (the Netherlands)). Of particular interest for this project are drought and the many waterbodies which are not meeting the standards set in the Water Framework Directive (WFD). More particularly, drought in the region leads to salinization and more concentrated surface waters. In addition, after large periods of drought and subsequent intense rains, the surface water suffers from high concentrations of pollutants such as nutrients. It is clear that one of the driving causes is climate change, but the area under investigation is also characterized by high pressure on land use causing higher emissions (e.g., nutrients), and a decreased self-cleaning capacity of surface water.

Within Aquatuur we aim to improve said surface water quality through various NBSs which are integrated within the landscape. Furthermore, these solutions will contribute to higher volumes of water storage. Freshwater storage will be achieved by means of creek ridge infiltration, with an additional focus on how nature can be a facilitator in water buffering. In addition, we aim to verify how large-scale buffer systems can be integrated in the landscape, and how double functions can be stimulated such as energy production and increased biodiversity. Considering water quality, 6 CWs in 3 locations will be demonstrated testing for pollutants spanning heavy metals, polycyclic aromatic hydrocarbons, pesticides, PFAS, nutrients, mineral oil, and microplastics.

We strongly believe in a complete narrative where the understanding of non-technical barriers such as mental models, thought patterns, and institutional rules is crucial for successfully implementing and replicating innovative solutions. Therefore, an actor analysis will be carried out so as to identify responsibilities, interests and roles during the implementation phase. Moreover, water availability and ecosystem services will be valued systemically in order to achieve a sustainable value model. The goal of this replicability-focused work package is twofold: its insights with regard to non-technical issues (i) will support the test cases focused on water quality and water storage, and (ii) lead to a publication on best practices and lessons learned.

Overall, Aquatuur exemplifies a forward-looking initiative based on interdisciplinary collaboration, innovative implementation of NBSs, and a commitment to enhancing water management and environmental sustainability within the Scheldt mouth region.

# Keynote Speakers

**John & Catherine Day –** Professor of Oceanography & Coastal Sciences, Wetlands & Aquatic Biogeochemistry Laboratory, Louisiana State University (USA)

Dr. John R. White is the Catherine and John Day Professor of Oceanography & Coastal Sciences at Louisiana State University, Baton Rouge, LA. He also serves as the Associate Dean of Research for the College of the Coast & Environment. Dr. White's research areas are broadly on the biogeochemical transformations of nutrients and contaminants in wetlands and aquatic systems He has contributed research informing management and restoration of two of the largest restoration projects in North America, the 10 billion dollar Comprehensive Everglades Restoration Plan and the 50 billion dollar Mississippi River Delta Restoration Program. Current research is focused on changes in biogeochemical cycling of C, N and P resulting from sea-level driven coastal erosion as well as trajectory of wetland ecosystem services under a range of coastal wetland restoration activities including marsh creation, thin layer dredge placement and river reconnection. Dr. White has supervised a total of 38 graduate students and has published over 120 peer reviewed journal articles. Dr. White has served on the Governors Steering Committee for the state of Louisiana Coastal Master Plan and currently serves on the Board of Scientific Counselors for the US Environmental Protection Agency.

# The impact of high relative sea level rise on nutrient biogeochemistry of coastal wetlands: "a harbinger of change for the world's stable coastlines

*John R. White [1,*], Lisa G. Chambers [2]*

[1] Oceanography & Coastal Sciences Department, Louisiana State University, Baton Rouge, LA USA

[2] Biology Department, University of Central Florida, Orlando, FL, USA

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**Abstract**

Coastal Wetlands provide a wide range of valuable ecosystem services. During the past 18,000 years, global sea level has been rising after emergence from the previous glaciation maximum. Rates of sea level rise began to slow significantly 7-8 thousand years ago, leading to emergence of the world's coastal deltas. While subsidence is common in deltaic regions, springtime overbank normally provides a sediment subsidy to make up for the lost elevation. Recently, the Mississippi River Delta has, as have other deltas around the world, undergone significant changes due to human activities, including construction of levees to protect human settlements which diminishes the hydrologic connectivity of the river with the adjacent coastal basins. Consequently, the state of Louisiana, USA contains 40% of the coastal wetlands in the continental US but is experiencing 80% of the coastal wetland losses. Deltas around the globe, like the Mississippi River delta, are experiencing a high relative sea level. The Mississippi River delta experiences the effects of global eustatic sea level (~3.6 mm/yr) combined with regional subsidence (~10 mm/yr). This relative sea level rise rate is the rate that most of the world's stable coastlines are predicted to experience in the next 50-70 years. Therefore, this coastline serves as a living, future model on the effects of projected sea level rise for the majority of coastlines, happening today. The coastal land loss by edge erosion has implications for the global C cycle as lost wetland area equates to lost C sequestration into the future. In addition, erosive forces also exhume up to 1000 yrs of previously stored C in the anerobic soils, releasing it into the shallow, aerobic estuarine water column where it is quickly converted to $CO_2$ multiplying the impact on C cycling. Additionally, erosion of vegetated, organic-rich wetland soils leads to the potential loss of water quality improvement by denitrification, as submerged bay sediments provide about 1/3 of the denitrification capacity as the vegetated marsh. A 50-billion US dollar coastal restoration plan for the Mississippi River delta will build conveyance structures in the levee permitting 75,000 $ft^3\ s^{-1}$ of river water and associated nutrients and sediment to be discharged into the adjacent coastal basin. This restoration plan has implications for the marsh vegetative communities and water quality, including salinity and nutrients responses. The addition of mineral sediments to the primarily organic soils of Barataria Basin has implications for both nitrogen and phosphorus cycling. Mineral sediment overlying organic rich wetland soil will decrease denitrification by 2.5 times. The mineral sediment will also release Fe-bound P through reduction which has consequences for algal blooms and in particular, some harmful algal species. The proliferation of HABs can have a negative economic impact to the region's fisheries. The coastal basins of the northern Gulf of Mexico are home to economically important fisheries with recreational fisheries alone combining for an economic impact of over 10 billion dollars per year for the 5 Gulf coast states.

# Keynote Speakers

**Dr. Karin Tonderski –** Senior associate professor at Linköping University (Sweden)

Professor Karin Tonderski, researcher and teacher in Environmental science at IEI, div. Environmental Technology and Management, Linköping University, Sweden. My research focuses on various aspect of nutrient flows, where field studies and mass balance analyses of wetlands created as filters in agricultural landscapes have been a long-term interest. A particularly intriguing issue is the challenges involved in understanding the impact of rapid load variations on physical, chemical, and microbiological processes in wetlands intended for water quality improvement. Apart from in agricultural landscapes, this is also highly relevant questions for improved sanitation in informal urban settlements in developing countries. I am currently also very involved in systems analyses of nutrient cycling and recycling in society at large, e.g., linked to biogas solutions, and using the results to contribute to a bioeconomy and to secure future food production. One example of this is urban agriculture as part of blue-green infrastructures in cities, where also stormwater wetlands are important components

# Mitigating nutrient losses from agriculture – the role of created wetlands

*Karin Tonderski* [1,*]

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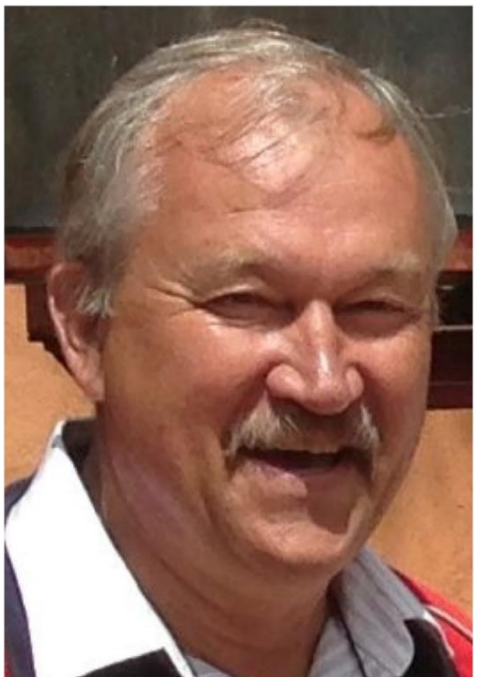
## Abstract

Mitigating nutrient losses from farming is a challenge that is addressed in both EU legislation and national strategies. Focus is on farm and field nutrient management, but edge-of-field measures such as constructed (CW) and restored (RW) wetlands are increasingly used to capture phosphorus (TP) and transform nitrogen (TN). This presentation discusses landscape factors that influence wetland removal performance, challenges with understanding event-driven wetland nutrient removal and cost-effectiveness of wetlands as a mitigation measure.

Assessments have suggested that optimized CWs may be more cost-effective than measures such as riparian buffer strips and delayed soil tillage; though there is still relatively few studies that present high-resolution field data on IN-OUT nutrient balances for wetlands receiving agricultural runoff. Such studies are faced with considerable measurement difficulties, particularly in colder climates. Published results show that the removal rates of both TN and TP are highly variable, *e.g*. a TN median removal efficiency of 36% (25-46% C.I.) and 44% (31-54%) for TP. There is general agreement that wetlands remove TN, with an efficiency (%) that drops with increasing mass N load, but the TP removal rates are more difficult to predict. Wetlands created to remove nutrients generally remove TP, but they may temporarily act as both sinks and sources of P. RWs on agricultural land demonstrate a legacy effect that may last for several years, but there is also seasonal wetland performance variations. This is linked both to variations in the dominant source of TP in catchments, leading to variations in inlet concentrations and $PO_4^{3-}$/TP, and to flow variations and temperature affecting the internal biogeochemistry of P.

Since cost-efficiency is evaluated as cost per removed kg TN and TP, a high nutrient load is desirable, as supported by data from the wetland creation program in Sweden. However, this leads to more nutrient rich wetlands, poorer outlet water quality and may contradict other goals with wetland creation. Desirable multiple functions should receive early attention when creating wetlands to mitigate agricultural TN and TP losses, as this has implications on both design and location.

# Keynote Speakers



**Dr. Ülo Mander –** Professor of Physical Geography and Landscape Ecology at the University of Tartu, (Estonia)

Main research interest of Ülo Mander (Ph.D. in biology/ecology 1983 at the University of Tartu (UT), Estonia): biogeosciences (carbon and nutrient cycling in wetlands and forests), landscape ecology (landscape structure and related material fluxes) and ecological engineering (constructed wetlands and riparian buffers zones). Was supervisor of 40 PhD theses and 4 postdocs, currently supervising 9 PhD students.

Been involved in 19 EU 5th, 6th, 7th FP, Horizon 2020 and Horizon Europe projects. Was visiting professor at research centers in Germany, Sweden, Norway, Japan, China, USA and France. Editor/member of editorial board of 9 international peer reviewed journals.

# Are wetlands a source or a sink of greenhouse gases?

*Ülo Mander* [1,*]
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**Abstract**
Wetlands have long been drained for human use, thereby strongly affecting greenhouse gas fluxes, flood control, nutrient cycling, and biodiversity (Zedler & Kercher 2005 *ARER*). The deliberate drainage of wetlands—plus impacts from climate change, rising sea levels, fires, and groundwater extraction—have taken wetlands among the most threatened ecosystems in the world (Fluet-Chouinard et al 2023 *Nature*). All wetlands are capable of sequestering and storing carbon (C) through photosynthesis and accumulation of organic matter in soils, sediments, and plant biomass. Wetlands hold between 20 and 30% of the estimated 1,500 Pg of global soil C (Lal 2008 *BioScience*) despite occupying only 5–8% of the Earth's terrestrial surface (Mitsch & Gosselink 2007). Nitrogen (N) storage in global wetlands is largely unknown, due to intensity of the N cycle and variety of N forms. On the other hand, wetlands are sources or sinks of carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$) – important anthropogenic greenhouse gases (GHG). Most likely, wetlands are the largest natural source of $CH_4$ (Bridgham et al 2013 *GCB*). $CH_4$ emissions from natural wetlands and C release from permafrost thaw feeds back positively on tropospheric temperature (Comyn-Platt et al 2018 *Nat Geosci*), however, their full role in climate warming remains unclear. Forested wetlands, which are the dominant type of wetland in the tropics (Pangala et al 2018 *Nature*) and cover about 30% of temperate and boreal wetlands, provide challenges to estimate GHG fluxes. Although their $CO_2$ capture is high, the role of trees and their canopy in $CH_4$ and $N_2O$ budgets is largely unknown (Mander et al 2021 *npj Clim Atm Sci*; Mander et al 2022 *STOTEN*).
Peatlands as typical wetlands occupy about 3% (Gorham 1991 *Ecol Appl*) of land surface; due to high C density they are a globally important C and N store, holding about 21% of the global soil organic C stock of ~3000 Pg (Leifeld & Menichetti 2017 *Nat Comm*), and up to 26 Pg N (Yin et al 2022). Undisturbed peatlands are a C sink (~0.1 Pg C $y^{-1}$), a moderate source of $CH_4$ (~0.03 Pg $CH_4$ $y^{-1}$), and a very weak source of $N_2O$ (~0.00002 Pg $N_2O$ $y^{-1}$) (Frolking et al 2011 *Envir Rev*). Anthropogenic disturbance, primarily agriculture and forestry drainage (up to 20% of global peatlands) produce net $CO_2$ emissions (~0.1 Pg C $y^{-1}$), reduce $CH_4$ emissions (10% below natural conditions), and increase $N_2O$ emissions (>20 times above natural peatlands; Pärn et al 2018 *Nat Comm*). This changes the global peatland GHG balance to a $CO_2$ source, a small $CH_4$ source, and a larger (but still small) $N_2O$ source (Frolking et al 2011 *Envir Rev*).
Constructed wetlands (CW) for water treatment make up a very small portion of global wetlands, however, their GHG flux potential can be high (Mander et al 2014 *Ecol Eng*). In free water surface (FWS) CWs $CO_2$ emission is normally lower than in horizontal subsurface flow (HSSF) and in vertical subsurface flow (VSSF) CWs, whereas $CO_2$ assimilation in plants and rapid C sequestration in sediments can keep these CWs as climate coolers (Mander et al 2008 *STOTEN*). $CH_4$ emission can be high in FWS and HSSF CWs whereas optimized biomass harvesting can mitigate emissions (Kasak et al 2021 *STOTEN*). Intermittent loading in VSSF CWs may significantly intensify $N_2O$ emission (Filali et al 2017 *Ecol Eng*).
Restoring old and creating new wetlands is the most effective way to facilitate C storage and minimize $N_2O$ emissions (Leifeld & Menichetti 2017 *Nat Comm*). During the first 30–40 years after rewetting/establishment, $CO_2$ capture and C sequestering in sediments is offset by the global warming effect of $CH_4$ emission, however, in a 100-year perspective most wetlands will turn to net climate coolers (Mitsch et al 2013 *Landscape Ecol*). We need to develop better linkages between time horizons of restored and created wetlands and the potential for C sequestration by wetland type, as well as to understand how we can sustain C storage in wetlands while continuing of human development.

# Keynote Speakers

**Dr. Jaime Nivala –** Director of Research at INRAE (Lyon, France)

Jaime Nivala is a senior scientist at INRAE (French National Institute for Agriculture, Food and Environment), in Lyon, France in the research unit REVERSAAL. Her main research interests include 1) wastewater pollutant removal processes; 2) treatment wetland technology development and optimization, 3) of treatment wetlands for water reuse. She has a BS in Civil Engineering (University of Minnesota, USA), an MS in Environmental Engineering (University of Iowa, USA), and PhD in Biosciences (Aarhus University, Denmark). She is coordinator of the EU project MULTISOURCE (www.multisource.eu), and co-chair of the IWA Specialist Group on Wetland Systems for Water Pollution Control.

## TW3: Treatment wetlands, third edition

*Scott Wallace[1], Jaime Nivala[2,*], Guenter Langergraber[3], Pascal Molle[2], Marcos von Sperling[4], Kela Weber[5]*

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**Abstract**

The field of treatment wetlands has increased exponentially in the past 15 years (e.g., since the publication of Kadlec and Wallace in 2008). The two authors of Treatment Wetlands, Second Edition amicably agreed in 2016 that the field has expanded to the point where treatment wetland technology can no longer be entirely addressed in a single textbook. As a result, Robert Kadlec published a new book entitled Treatment Marshes for Runoff and Polishing, in 2019 which expanded upon the fundamentals, application, and design and implementation of what was formerly referred to as Free Water Surface (FWS) treatment wetlands. Although some of the fundamentals from Treatment Wetlands, Second Edition was incorporated into this new textbook, it also contains new information on hydraulics, vegetation and biomass cycling, nutrient cycling, ecological perspectives, as well as design and implementation of treatment marshes.

The fundamentals, application, design, and implementation of subsurface flow treatment wetland technologies are the focus of Treatment Wetlands, Third Edition (Subsurface Flow Wetlands, Processes, Design, and Implementation). Scott Wallace and Jaime Nivala started with the conceptualization of this new textbook WETPOL (Montana, USA) in 2017, meaning that it has been a work in progress for the past seven years. The diversification of subsurface flow treatment wetland technology and its global application has revealed a range of technologies and depth of knowledge over the past 15 years that exceeds the scope of what any single individual can write about. To capture the diversification and worldwide application of subsurface flow treatment wetland technology, the establishment of global team of treatment wetland experts was necessary. Pascal Molle, Kela Weber, Marcos von Sperling, and Guenter Langergraber have been invited as co-authors to Treatment Wetlands, Third Edition (which is lovingly referred to as “TW3” between friends and colleagues). Each co-author brings unique, in-depth, and practical expertise to this new textbook, which, despite the “reduced” scope (e.g., no treatment marshes), is estimated to exceed 1,000 pages.

TW3 is structured into four main parts, including I) Fundamentals, II) Pollutant Removal, III) Data Analysis, and IV) Design, Implementation, and Management of a wide range of subsurface flow treatment wetland types. Technologies covered in TW3 include Horizontal Flow (HF) wetlands, Vertical Flow (VF) wetlands, aerated wetlands (both HF and VF), French VF wetlands, fill-and-drain wetlands, Combined Sewer Overflow (CSO) wetlands, and sludge treatment wetlands.

The chapters on subsurface flow treatment wetland fundamentals have been expanded to include new information on vegetation and biomass cycling, microbiology, and solids accumulation. Chapters on pollutant removal include recent data (both published and unpublished) on carbon and nitrogen removal in a wide range of subsurface flow treatment wetland technologies, as well as brand new chapters on micropollutant and pathogen removal.

The backbone of TW3 contains three extensive, completely new chapters on the fundamental concepts of design, deriving design parameters, and conducting statistical interpretation of wetland data. This new information aims at providing students, academics, and practitioners with the most recent and comprehensive approaches for conducting research and reporting data on subsurface flow treatment wetlands, analyzing pollutant removal, and how to approach upscaling from pilot to full-scale designs. TW3 also provides a guideline for reporting treatment wetland data in reports and peer-reviewed publications, so that the data produced by the research in our field can be used, compared, and understood worldwide.

The last section of the book is dedicated to the design, implementation, and management, operations, and maintenance of the various subsurface flow treatment wetland technologies. The chapters on individual treatment technologies are preceded by a comprehensive, all-new chapter on the general basis for selection and design of subsurface flow treatment wetlands. An extensive synthesis of primary pollutants of concern and their inclusion in water quality and treatment objectives is presented, along with a thorough comparison between subsurface flow treatment wetlands and other wastewater treatment processes (e.g., facultative ponds, upflow anaerobic sludge blanket reactors, trickling filters, activated sludge, and activated sludge with biological nutrient removal). The main types of subsurface flow treatment wetlands and their pollutant removal performance are compared, both qualitatively and quantitatively in easy-to-read summary tables. This information is followed by the proposal of unified design approaches, one based on influent pollutant and hydraulic loading rates, and another based on process models.

The provisional publication date for TW3 is mid-2024 and this abstract doesn't cover all of the good news, so please come numerous to this keynote session on the final day of WETPOL 2023!

References:
Kadlec R.H. (2019) Treatment Marshes for Runoff and Polishing. CRC Press. Boca Raton, Florida, USA. 1056 pp.

Kadlec R.H. and Wallace S.D. (2008) Treatment Wetlands, Second Edition. CRC Press. Boca Raton, Florida, USA. 1016 pp.

# Keynote Speakers

**France Guertin –** Senior Technology Manager of Engineered Natural Technology – DOW (USA)

France holds a bachelor's degree in Chemical Engineering, a Masters in Environmental Studies and a professional certificate in Biomimicry. She is Senior Technology Manager of Engineered Natural Technologies as part of the Global Environmental Technology Center (EnvTC) creating this new pillar of technology for DOW.

In this role, France is accountable to deliver fit for purpose nature-based solutions lowering Dow's overall cost of operations while producing environmental and societal benefits.

France also serves as technical lead for Dow's Valuing Nature Goal working with manufacturing sites and businesses to implement projects and tools that plan, manage, and invest in smarter, more productive ways that fit seamlessly within Nature. Since 2015, this goal has recognized greater than $756 million in net present value in projects that are better for nature's pillar of clean water, clean air, healthy soil, and healthy ecosystems.

## Making the business case for nature-based solutions

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**Abstract**
Nature-based solutions, which combine natural and engineered ecosystems, are becoming an increasingly important means of addressing environmental and business challenges in a cost-effective manner. The adoption of this engineered natural technology within a company or organization, however, can be difficult as it requires tweaking, often long-standing, engineering, finance, and business practices. In this keynote, I will present the evolution of the nature goal methodology that was developed and implemented to help drive the adoption of nature-based solutions within our company through our collaboration with The Nature Conservancy. This methodology was introduced to provide information on a project's environmental components and performance to complement traditional financial metrics, such as return on investment. Responding to continued improvements and learning in this field, one of the supporting tools, the Ecosystem Services Identification and Inventory tool, devised to assess the level of ecosystem services of a land use project has evolved to include additional services such as biodiversity. Going forward, robust scientifically grounded information and metrics, like those provided from the Nature Goal Methodology, will be critical for driving the continual adoption and integration of nature-based solutions in business decisions. Ultimately, the methodology presented here is just one example; future iterations will need to be informed by on-the-ground use, new relevant science and data while aligning with emerging reporting requirements such as the Task Force on nature-related Financial Disclosures (TNFD) and The Science Based Targets for Nature (SBTN).

# Oral Presentations

# Oral Presentations

# Poster Presentations

# Poster Presentations

# Fieldtrips

# Fieldtrips – Tour 1

## Total Value Wall – Kamp C, Westerlo

Kamp C is an autonomous company of the Province of Antwerp in Belgium. The mission is to accelerate the transition of a more durable and circular urban environment in Belgium and beyond, by giving independent advice to all stakeholders.
In 2022, Kamp C opened the first 'fully circular office building' in Belgium. The building sets an example for the future of the building sector. One aspect of the circular building is the incorporation of a total value wall. This is a green wall where grey water gets treated and is reused as an alternative water source.
A time-lapse was made during the construction of the building (Dutch)
More info (Dutch): Total value wall, Circular office building

## Horticulture drainage water treatment – Rietland, Lochristi

Drain water of horticulture typically contains high concentrations of nitrogen and phosphorus, but low CODncentrations. Rietland designed a nature-based solution for meeting the local discharge limits. The system is a hybrid between aerated and free surface flow constructed wetlands.
Occasional carbon dosing for optimal denitrification is controlled by a water temperature sensor.
More info: System overview, Article Aquarama (Dutch)

## Municipal wastewater treatment – Aquafin, De Pinte

The municipal wastewater treatment plant at De Pinte – Zevergem is a classical secondary hybrid constructed wetland consisting of a vertical subsurface flow unit followed by a horizontal subsurface flow unit. The system was designed for 750 PE and has been in operation since 2000.
More info: Long-term results

# Fieldtrips – Tour 2

## De Blankaart – Diksmuide

'De Blankaart' is an almost 1000 hectare nature reserve in the Province of West-Flanders. The reserve is situated around 'De Blankaart' pond which is an artifact of peat extraction during the Middle Ages.
Nowadays, the domain is an important staging area for migratory birds. The reserve is part of the Ramsar 'De Ijzerbroeken te Diksmuide en Lo-Reninge' and Natura 2000 'Ijzervallei'.
More info: Ramsar, Natura 2000

## Aquaduin - Koksijde

The intermunicipal water company of 'Veurne-Ambacht' (IWVA) is located on the eastern part of the Belgian coast. Drinking water is locally produced from ground water, resulting in a lowered ground water table and some small scale desertification.
To counter these negative effects, effluent of the municipal wastewater treatment plant is being infiltrated in the sand dunes. The infiltration area and surroundings are part of a nature reserve called 'De Doornpanne', which is part of the bigger Natura 2000 'Duingebieden inclusief IJzermonding en Zwin'
More info: Natura 2000

# Fieldtrips – Tour 3

## Het Zwin – Knokke-Heist

Het Zwin was a tidal channel of the North Sea created by the storm surge of 1134. The newly formed channel reached up to 15 km inland where it connected the city of Brugge to the North Sea. It was now possible for small ships to reach Brugge by the sea, leading to the economic flourishing of the city. By the late 13$^{th}$ century, the channel was silted up and the port of Brugge was no longer reachable by sea.

Nowadays the area is a natural brackish water wetland and is RAMSAR (link) and Natura 2000 (link) classified.

More info: Het Zwin website, Ramsar, Natura 2000

## Aerated constructed wetlands – DOW Chemicals and Evides, Terneuzen (Netherlands)

The industrial site of DOW Chemicals at Terneuzen (Netherlands) is a 440 hectare industrial complex for the production of hydrocarbons and polymers.

Demineralized water is needed in large quantities and it is produced on-site by Evides. The main sources are local fresh surface waters, such as the 'Maas Rivier' and the 'Brielse Meer'. The extensive use of water from these areas puts pressure on the local environment. Therefore, Evides and DOW Chemicals are investigating whether effluent from municipal wastewater treatment plants can be used.

The chemical composition of this effluent water is of course different than water from a fresh water body. A pilot project is underway to assess the feasibility of using aerated constructed wetlands as pretreatment for the demineralization plant.

Publications from the pilot project: Khan et. al. (2022a), Khan et. al. (2022b)

# Oral Presentations

# HCH and PFAS removal

# Wetland+® technology for treatment of HCH-contaminated water

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**Abstract**
The Wetland+® technology was installed in the frame of LIFEPOPWAT European project focuses on innovative technology based on constructed wetlands for the treatment of pesticide-contaminated waters (LIFE18 ENV/CZ/000374). The first prototype of Wetland+® technology was installed at the Hajek repository (the Czech Republic), where between 3,000-5,000 tonnes of the ballast HCH isomers and waste chlorobenzenes were historically deposited. The remediation system is based on four steps. The drainage water from the Hajek repository enters *the sedimentation tank,* where dissolved Fe (in concentration over 20 mg/L) should precipitate and sediment. The first reactive stage is *a permeable reactive barrier* filled with Fe chips, where water is deoxygenated and converted to a reduced state. Subsequently, HCHs are partially dechlorinated, and chlorobenzenes (ClB) are formed. The second reactive step is the *biosorption unit*, where HCH compounds are sorbed and subsequently degraded by present microorganisms. This unit is filled with a mixture of peat, crashed stones, loamy soil and wooden chips. The last step is the *aerobic wetland*, where the plant root system purifies the water, and the concentration of HCHs and their daughter products decrease below specified limits.

In September 2021, the full-size Wetland+® system was commissioned at Hajek on an area of 130 x 70 m. Since then, it has been running in test mode, where the efficiency of each stage is gradually improving. The wetland plants are growing and the contribution of the wetland remediation step to the overall contaminant removal is increasing. The input to the system is drainage water with a flow of 1-3 L/s, and HCH and ClB concentrations of 50-260 µg/L and 100-1300 µg/L, respectively. During the first 14 months of operation, due to the system's tunning, the contaminant removal efficiency gradually increased to almost 100% for ClB and 97 % for HCH. Nowadays, the operation of the Wetland+® led to a significant decrease in HCH mass discharge to the Ostrovsky Creek from an initial 24 g/day to 0.8 – 0.9 g/day.

BIO of Presenter:
**Miroslav Černík** worked in AQUATEST (Czech R.) in the field of remediation of environmental liabilities. In 2014, he was appointed a professor of applied sciences at TUL. In 2021 he became the director of CXI TUL. He is the author of over 250 scientific publications, his H-index is 32.

# Assessment of intensified constructed wetland for removing persistent, mobile and toxic (PMT) compounds from groundwater and wastewater

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**Introduction**

The occurrence of compounds such as per- and polyfluoroalkylated substances (PFAS) or benzotriazoles (BTri) in surface and groundwater (GW) bodies is a matter of concern due to their persistence, mobility, and toxicity (PMT). Consequently, different advanced treatment methods such as advanced oxidation or membrane-based technologies have successfully been assessed. Nevertheless, they have the disadvantage of high energy consumption and maintenance costs.

In this sense, the use nature-based solutions such as intensified constructed wetlands (CWs) can solve all these issues at the same time of providing a good removal of PMTs, but there is low information available of how the use of intensified CWs based on different materials such as coke can be used for removing PMTs from both wastewater (WW) and GW. In this study we will assess the effectiveness of using coke and vegetation in intensified CWs based on coke for removing 10 PMT compounds from GW and WW.

**Materials and methods**

The study was conducted in laboratory-scale biofilters under water-saturated conditions during more than 200 operational days for the removal of PMTs. Twelve methacrylate columns (43.5mm int. Ø, x 320mm height) were designed and constructed. Each column was filled with 25mm of gravel followed by 300 mm of coke of different granulometric sizes (3 columns with particle size of 2-5 mm and 3 columns with 0.5-2 mm) or washed sand (2 mm Ø). 9 of the 12 columns were planted with *Cyperus alternifolius*. All columns were fed with either GW or secondary treated WW at an HLR of 70 and 40 mm/d. Plants were acclimatized for 8 weeks and the system started to operate with spiked GW at 5 µg/L (BTr, MBTr and TFA) and 10 µg/L (TFMS, PFBS and PFPeA) for 8 additional weeks. After that, columns were fed with real secondary treated WW spiked with more PMTs according to the occurrence of the area (Diclofenac, Carbamazepine, Bisphenol A and Sucralose at 5 µg/L) and the performance of the technology was monitored for 2 additional months. Every week inlet and outlet water samples from each column were collected and analysed for physico-chemical properties (pH, redox, dissolved oxygen) and general quality parameters (chemical oxygen demand, ammonium, nitrates, phosphates, and sulphates).

**Results and discussion**

Preliminary results show that CWs based on sand can remove PMTs by 44%, on average, whereas the use of coke materials increases that removal up to 61%, on average. The intensified CW with the greatest coke granovolumetric size resulted in a higher removal efficiency of pollutants (73%, in comparison to 50% for the coke of 0.5-2 mm, on average). The use of WW did not increase the attenuation of PMTs (61% vs 63%, on average), but vegetation increased the attenuation of PMTs from 32% to 73%. We also monitored the biofilm development in the columns, current results indicate that it is greater in columns fed with WW. The full 16S characterization of biofilm communities will be presented in the congress.

**Conclusions**

In conclusion, results indicate that both the presence of vegetation and coke impacted positively the attenuation of PMTs, achieving removal efficiencies of 73%, on average.

BIO of Presenter:

**Alicia Cano** is a PhD student from IDAEA-CSIC in Barcelona, Spain. My thesis aims to evaluate different remediation strategies from chemical oxidation and Natural-Based-Solutions (NBS) to remove persistent, mobile and toxic (PMT) compounds from wastewater and groundwater.

# Behavior and impact of per- and polyfluoroakyl substances within treatment wetland mesocosms

*Isaac Timoffee-Maberly [1,*], Kevin G. Mumford[2], and Kela Weber[1]*
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**Abstract**
Per- and polyfluoroalkyl substances (PFAS) represent a class of anthropogenic chemicals that have been used extensively in both consumer and industrial applications. Due to the characteristic carbon-fluorine bonds in their structure, PFAS like perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) are extremely resilient to breaking down in the environment from physical, biological, or chemical means. With both oleophobic and hydrophobic properties, along with high surface activity, PFAS have ideal physiochemical properties for many industrial uses, a prime example of which is their application in aqueous film forming foam (AFFF) used to fight high intensity fires. Many AFFF formulations are composed of fluorotelomers, a subcategory of PFAS, and PFAS precursors that can break down into shorter chain, more stable PFAS when discharged into the environment. A commonly detected fluorotelomer that has been found in AFFF formulations is 6:2 fluorotelomer sulfonate (6:2 FTS). The wide-reaching use of PFAS and AFFF has resulted in significant contamination of surface and groundwaters, especially in locations that have been directly impacted by the production of PFAS or with the use of AFFF in the area. Treatment wetlands (TWs) are engineered systems that take advantage of the wastewater treatment capacity of wetland environments, providing an alternative solution for water treatment. Determining how PFOA, PFOS, and 6:2 FTS affect and behave in TW mesocosms is the objective of this project. Under a triplicated 22 factorial design, 12 mesocosms with established *Phragmites australis* will be used to investigate the effects of aeration and PFAS amendment on mesocosm biological, hydrological, and water treatment parameters. Each mesocosm is filled with pea gravel, has a total volume of 30 litres, and a pore volume of ~10 litres. The mesocosms have already undergone 12 weeks of characterization, utilizing a suite of four categories (water chemistry, hydrology, microbial characteristics, and plant health). The systems are currently being fed PFAS and simulated wastewater for a total of 4 months. During this second phase, PFAS concentrations and effects are being tracked. At the end of the current phase, the mesocosms will be deconstructed. Mass balance on the PFAS will be calculated to determine, the vertical distribution, removal, sorption, and transformations within the mesocosms. Particular focus will be on the potential influences of the rhizosphere in the TW mesocosms on the fate of PFAS. Improving the understanding of removal mechanisms and transport of PFAS within TW mesocosms will contribute to the advancement of TW designs and our ability to better assess PFAS contamination in wastewater treatment.

BIO of Presenter:
**Isaac Timoffee-Maberly** is a civilian graduate student at the Royal Military College of Canada, in the Environmental Sciences Group, currently working on their master's degree in Chemistry and Chemical Engineering. Isaac is primarily interested in toxicology, risk assessment, and emergent contaminants like PFAS.

# Insight into the constructed wetland-microbial fuel cell technology: electrode materials, plant cultivation, and PFAS exposure

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**Abstract**
Constructed wetland-microbial fuel cell (CW-MFC) shows the potential as a sustainable approach to alleviate the growing energy gap while also treating wastewater effectively and affordably. However, there are still many uncertainties that need to be studied and solved in CW-MFC technology in terms of system design, performance optimization, energy recovery efficiency, and the removal of emerging contaminants. Here, we studied the removal performance of per- and polyfluoroalkyl substances (PFASs) in the optimized system by optimizing the electrode design and plant culture model of the CW-MFC system (Fig. 1).

**1. Exploring the performance of GAC as air-cathode materials in CW-MFC system**
We found that the performance of bioelectricity generation by using granular activated carbon (GAC) with ring-shape structure as air-cathode is associated with better electron transportation, fast charge transfer, enhanced ORR kinetics and the suitable environment for microorganisms. The highest voltage of 420.77 mV, MPD of 13.71 $mWm^{-2}$, CE of 0.493%, and NER of 9.06 Wh/Kg COD, respectively, was obtained in GAC as electrode material in CW-MFC system.

**2. Roles of plant and interrelation between macrophytes roots and cathode in CW-MFC system**
The macrophyte roots directly laid on the air-cathode layer could allow to establishing a "plant root-assisted bio- & air-cathode". This is a key issue to obtaining a better cathode working pattern, thus achieving a quick and stable voltage output (550-600 mV) and excellent performance in wastewater treatment (removal rates over 90% for COD, over 85% for TN and TP).

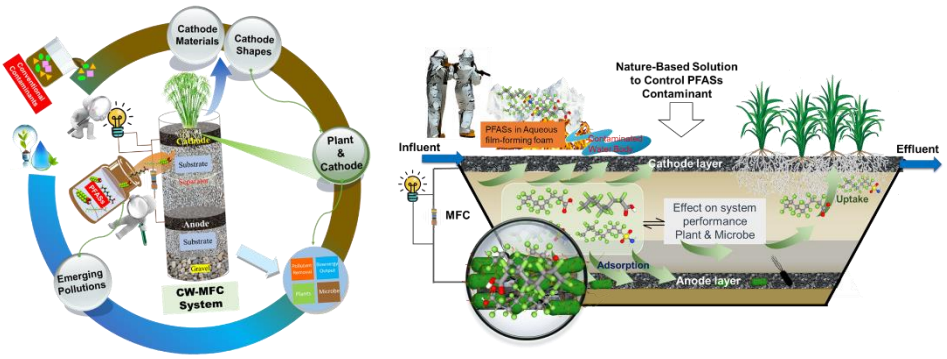


Fig. 1 The effect of electrode materials, plant cultivation, and PFASs exposure in CW-MFC system

**3. Curbing PFASs: First investigation in a CW-MFC system**
This study in both closed-circuit and open-circuit operation of the CW-MFC systems demonstrated over 96% removal of the influent containing PFOA and PFOS through adsorption by electrode materials and uptake by plants plus the MFC enhancement. PFASs not only directly changed the microbial community structure, but also indirectly inhibited microbial enzyme activities. Collectively, CW-MFC systems open an alternative way for the removal of PFASs from the aquatic environment, which can alleviate some barriers to the full application of physical and chemical techniques, but further investigation is highly desirable.

BIO of Presenter:
**Yaqian Zhao** is a Fellow member of IWA and Distinguished Professor in the Department of Municipal and Environmental Engineering, Xi'an University of Technology, China, since Jan. 2019 while he was an academic staff in University College Dublin, Ireland, from 2004 to 2018. He has published > 400 research papers and is a highly cited researcher (Elsevier).

# Microplastics I

# Impact of microplastics in urban constructed wetlands

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**Abstract**
Plastics and microplastics (plastic particles <5 mm in diameter) are ubiquitous and a growing planetary threat. Wastewater is an important source of microplastics. As constructed wetlands are nature-based solutions or green infrastructures for treating wastewater, the subsequent impact of wastewater-rich microplastics on the performance of such constructed wetlands needs to assess. Here we explore wastewater nutrient attenuation at different constructed wetlands under polystyrene microplastics (control or 0, 1, 10, 20 and 50 mg/L doses). We observed significant changes in macrophytes' (*C. indica*) chlorophyll, net photosynthesis, SOD activity, POD activity, CAT activity, antioxidant enzyme activities, and secondary metabolites in constructed wetlands under higher microplastics doses. Ammonium and total nitrogen removal efficiencies of constructed wetlands reduced significantly after 45 days of polystyrene microplastic exposure. Besides, we observed distinct nitrification and denitrification signature in constructed wetlands under microplastic exposure compared to wetlands without any microplastic doses.

**Acknowledgement**
I acknowledge the support from the CASS Foundation travel grant.

BIO of Presenter:
**Tanveer Adyel** is a Lecturer of water Engineering at the University of South Australia. His research interest includes urban stormwater management using nature-based solution and microplastic problem in aquatic systems.

# Observations on microplastic from wastewater in treatment wetlands of the surface flow type – removal variability and atmospheric deposition as potential explanation

*Lina Büngener[1,*], Heini Postila[1], Martin Löder[2], Christian Laforsch[2], Anna-Kaisa Ronkanen[1,3], Elisangela Heiderscheidt[1]*

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**Abstract**

Microplastic (MP) is an anthropogenic pollutant of emerging concern prominent in both raw and treated municipal wastewater as well as urban and agricultural run-off. There is a critical need for mitigation of both point- and diffuse sources, and treatment wetlands could be a nature-based option. So far, excellent retention of MP has been reported for horizontal and vertical subsurface flow systems. Wetlands of the widely-used surface flow type (SF), on the other hand, have shown great variations among studies, ranging from almost complete- to negative retention. Potential explanations and factors responsible for this inter-study variation remain undiscussed, also because there is still only a low number of studies available.

In the present study, we investigated if a full-scale reed-based SF wetland operating in Northern Finland is capable of additional MP removal from pre-treated secondary municipal wastewater. We were particularly interested in investigating the role of atmospheric deposition (AD) on MP concentration in the wetland water, hypothesizing that this might lead to negative net MP removal in SF wetlands, and possibly explain variable removal efficiencies observed in literature. MP sampling and sample treatment procedure were compiled and developed to be suitable for treatment wetland water matrix, which is typically high in plant and insect residues as well as other suspended solids that would interfere with MP analysis. MP particles were identified in the size range 1 mm to 25 µm (polymer type and size) from in- and outflow water as well as collected atmospheric deposition (AD) by FPA µFT-IR spectral imaging in combination with automated result interpretation by Bayreuth Microplastic Finder software.

We found concentrations of 104 MP $m^{-3}$ and 56 MP $m^{-3}$ in the wetland inflow (=secondary pre-treated wastewater). The SF passage then increased the water MP concentration by 92% during a rain intense- and by 43% during a rather dry hydraulic retention period, respectively. We measured an atmospheric deposition of 590 MP $m^{-2}$ $7d^{-1}$ during the rain intense period. Our findings point towards AD as an important factor in the fate of MP in open SFs.

It is becoming evident that more research is needed on the different types of treatment wetlands and the mechanisms therein influencing MP fate, before making choices on treatment wetland applications targeting the enhanced removal of MP from wastewater.

BIO of Presenter:

**Lina Büngener** graduated in Environmental Sciences M.Sc. (focus: hydro(geo)logy, atmosphere) at TU Braunschweig, Germany, and is working on her doctoral research project at University Oulu, Finland since 2019. Her research interest has been microplastic in the aquatic environment for the last 6 years, which extended to sustainable sanitation during PhD.

# Lab-scale study on the fate and removal of microplastics in horizontal subsurface flow constructed wetlands

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## Introduction

Microplastics (MPs) have been a global problem since it was reported that they are a potential threat to human and animals' health. Constructed wetlands (CWs) as a nature-based solution for wastewater treatment received little attention regarding MPs. This study investigated the influence of vegetation and hydraulic loading rate on the fate and removal of MPs in lab-scale subsurface horizontal flow CWs.

## Material and methods

Polystyrene (PS) particles (75-425 µm), high-density polyethylene (HDPE) particles (75-425 µm), polypropylene (PP) particles (75-425 µm), and PE microbeads (45-53 µm) were used in this study. Lab-scale horizontal subsurface flow constructed wetlands (HSSF CWs) with a length, width, and height of 75 cm, 14 cm, and 13 cm, respectively, were filled with gravel (3-8 cm) and constructed in a thermostatic room at 22 ± 1 °C. To investigate the influence of vegetation and hydraulic loading rate (HLR) on the removal and fate of microplastics (MPs), the CWs were divided into three different sets (A, B and C) based on different operating conditions, including different HLR, with and without vegetation. All the CWs were fed with synthetic wastewater and MPs, and the operation lasted for 160 days. At the end of the experiment, the distribution of MPs in the CWs was analyzed by sections from the inlet to the outlet, and MP abundances were presented as percentages of the overall amount.

## Results and conclusions

In set A, where the CWs were unplanted and run at a low HLR, most MPs were retained in 5-15 cm section, the average abundance of the four kinds of MPs was 34.4%. MPs abundance decreased towards the end of CWs, and PS particles showed 5% abundance near the outlet (65-75 cm). In set B, the CWs were planted with Typha and run at a low HLR. The MPs abundance in 0-5 and 5-15 cm section was much higher than in the unplanted CWs of set A, i.e., 36.2% and 45.3% respectively. Moreover, MPs abundance in the later stages was much lower than in unplanted CWs. The average abundances were 0.2%, 0.2% and 0.1% in the last 3 sections of set B. Interestingly, both the PP particles and PE microbeads were absent in the last 3 sections, which suggested that the transport of MPs in CWs could be hindered in the presence of vegetation, which in turn could be related to adsorption and filtration by plant roots. In set C, the CWs were planted with Typha and run at a high HLR. The MPs distribution results showed a large difference from the CWs which were also planted but run at a low HLR. Most MPs were retained in 5-15 cm stage, and the average abundance was 37.2%. In the last 3 sections, MPs abundance was 2.1%, 2.1% and 2.2%, respectively, which was significantly higher than the results from set B ($p < 0.05$). This indicated that the high flow rate accelerated the transport of MPs in planted CWs.

BIO of Presenter:

**Qintong Wang** is a PhD student in the Laboratory for Industrial Water and Ecotechnology (LIWET), Ghent University. He is studying on the fate and removal of microplastics in Constructed wetlands.

# CSO treatment

# New German code of practice on special applications of treatment wetlands for CSO and stormwater

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**Abstract**
Treatment wetlands for combined sewer overflows, stormwater from separate sewer systems and road runoff are a standard application in Germany at critical discharge points. The increasing number of installations especially built in the early 2000s allowed for a revision of design and operation practices. In consequence, the national code of practice published in 2005 by the German Association for Water, Wastewater and Waste was replaced with the national guideline DWA A-178 in 2019, focusing on the standard application (improved removal of particles, BOD, and ammonia).
However, numerous pilot- and field-scale plants with modified design and operation respond to complex treatment tasks. These include the improved removal of phosphorus, micropollutants and pathogens at sensitive discharge points, but also runoff from surfaces highly contaminated with organic substances (especially in agriculture, but also from deicing on airports). Another field of application not covered by the standard design is decentral treatment of road runoff, similar to bioretention filters.
To make the experience gained from the existing systems and design recommendations accessible to planners and involved stakeholders such as communities and local authorities, the specialist group on these types of treatment wetlands within the DWA is currently finishing a new code of practice (DWA M-187). It will be made publicly available in the coming months.
The different types of special applications and the design recommendations derived from the practical application will be presented.

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DWA M-187 Retentionsbodenfilteranlagen – Sonderanwendungen, Hinweise und Beispiele. (Retention soil filter sites – Special applications, advice and examples.) German Water Association (ed.). Under preparation.

BIO of Presenter:
**Katharina Tondera** was recently appointed professor at the research group ENTPE-IAPHY, France, where she will continue her work on treatment mechanisms in NBS for stormwater. She is active member of several working groups, including the IWA Working Group on Nature-based Solutions for Water and Sanitation.

# First monitoring results of aerated wetland for combined sewer overflow upstream the WWTP of Merone (IT)

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**Abstract**
Since combined sewer overflows (CSOs) constitute nowadays a major environmental concern, this study presents the results obtained from a monitoring campaign involving the constructed wetland (CW) system of Merone, located in Como province (Italy) and managed by the public water management company COMO ACQUA Srl. The treatment is one of pilots of the enhanced natural treatment solutions (ENTS) included in Multisource (ModULar Tools for Integrating enhanced natural treatment SOlutions in URban water CyclEs), an EU-funded project on planning of nature-based solutions for urban water treatment, storage, and reuse. The project started officially on June 2021, and it will end in June 2025.
The CW was designed to treat the CSOs upstream the centralized WWTP (120,000 PE), which occur frequently with an average overflow volume of approximately 1,400,000 $m^3y^{-1}$, spread over about 100 events. It represents, to the best of our knowledge, one of the first monitoring of a full-scale aerated CSO-CW upstream of the WWTP. The studied treatment is a forced aeration system fed by the CSO upstream the centralized WWTP, characterized by a treated volume equal to 5000-9000 $m^3d^{-1}$ per rainfall event and a Q max of 900 $m^3h^{-1}$. The system is a multistage CW: the 1$^{st}$ stage comprises four parallel subsurface flow aerated beds, with a total area of 4000 $m^2$; the 2$^{nd}$ stage is a free water surface (FWS) CW of 1500 $m^2$. The CSO-CW is equipped to provide a pre-treatment by an automatic screen and an aerated grit removal. The samples analyzed show large fluctuations in COD (120 – 800 mg $L^{-1}$ with an average concentration of 343 $mg_{COD}$ $L^{-1}$), and a more constant ammoniacal nitrogen (average value of 12 $mg_{NH4}$ $L^{-1}$). Based on the overflow data from 2005 to 2013 for the system design, the overflow of the Merone WWTP is characterized by two different types of overflow events: Event A, with a short duration after dry period (no more than 2 days) and event B, characterized by a longer duration due to diffuse rainfalls in the catchment area. As expected, the results of the wastewater quality characterization (based on the analysis of 23 samples taken between 2012 and 2013) confirms the higher pollutants load of event A.
The observed removal rates of the first aerated stage during the monitoring campaign on A events (mean values equal to 84%, 79%, 84% and 63% for $BOD_5$, COD, TSS and $N\text{-}NH_4^+$ respectively) demonstrated the satisfactory treatment efficiency of CW system for all the investigated parameters, consistent with literature data for CSO-CWs in line with the sewerage network, despite its different scale and hydraulic characteristics. Furthermore, the system also provides additional ecosystem services such as flood mitigation, enhancement of biodiversity and a low operational and maintenance cost.
Finally, data withdrawn from the PLC of the WWTP will be also presented, for instance the water level fluctuation within each one of the four aerated bed, the discharge rate, and the cumulative treated CSO volume, important for the investigation of the hydraulic and organic loading rates experienced by the pilot during the monitoring period.

**Acknowledgement**
This work was supported by the Horizon 2020 research and innovation action program MULTISOURCE (grant agreement No 101003527).

BIO of Presenter:
**Riccardo Bresciani** is partner of IRIDRA Srl, since 2005. He is MSc in Environmental Engineer. He has more than 20 years of experience in sustainable water management and nature-based solutions for wastewater treatment.

# Forced aeration in a vertical flow wetland to treat combined sewer overflow

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## Introduction

Forced aeration in CSO treatment wetlands (CSO-TWs) is a promising approach for increasing the removal of ammonia-nitrogen, biological oxygen demand (BOD), micropollutants, and pathogens. In a conventional CSO-TWs, the resting time between the wet and dry periods is necessary to mineralize and nitrify the substances (Dittmer and Schmitt, 2011). Using forced aeration is expected to increase the oxidation rate and reach higher removal efficiencies of pollutants during the rain event. Latest results from intensified TWs treating domestic sewage showed a more efficient total nitrogen removal, reduced clogging, and resilience to unforeseen charges or aeration interruption (Nivala et al. 2020). Therefore, under the framework of the H2020 NICE project, a CSO -TW with forced aeration is studied to improve pollutant removal and resilience when receiving high hydraulics loads.

## Methods

The newly installed 20 m² pilot was designed with a top layer of 20 cm of gravel (2/4 mm) and a permanently saturated layer of 95 cm of coarse gravel (10/20 mm). 13 m/m² of driplines (40 mm) are installed at the bottom of the filter for the aeration distribution. The outlet flow is controlled in 0.03 $L.s^{-1}.m^{-2}$, to maintain the water retention time, when the filter reaches its maximum storage capacity of 1 m of water above the surface. To control aeration system, online redox and pH probes are installed inside the filter to track aerobic and anaerobic microbial responses. Composite samples are analyzed for COD, total suspended solids, $NH_4^+$-N, $NO_3$-N, $NO_2$-N, microorganism indicator, micropollutants, and heavy metals. The hydraulic behavior has been verified with tracer tests in December 2022 before starting the feeding with CSO (with and without aeration, with and without ponding on the top).

The filter is being fed with pre-conditioned CSO (mixture of real rainwater and wastewater 4:1). To optimize treatment efficiency, different intermittent aeration strategies are being tested. Hydraulic charges of 0.5, 1.0, and 1.5 m per event are applied with cycles of short (2 days) and long (6 days) rest periods between feedings. The annual hydraulic load is of 70 $m.yr^{-1}$.

## Results

Results from tracer tests showed that when aerated, the CSO-TW behaves as a continuous stirred tank reactor. The tanks in series (TIS) equation resulted in N equal to 1.1 and volumetric efficiency above 80%. Overall, results from tracer tests showed a high degree of mixing in the aerated filter, which is favorable for pollutant removal (Kadlec and Wallace 2009). The oral presentation will focus on the different removal performances according to aeration strategies and loads, as well as how online sensors can be used to control aeration.

## References

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BIO of Presenter:

**Daniella Portela** is a civil engineer with a master's degree in chemical engineering, working with research to treat polluted water. Currently, I am a Ph.D. student working on pollution control of runoff and combined sewer overflow using vertical flow wetlands with forced aeration.

# Limestone for re-carbonation of treatment wetlands for combined sewer overflows

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## Introduction

Treatment wetlands for combined sewer overflows (CSO-TWs) are nature-based solutions and an effective method for reducing emissions from untreated stormwater (Rizzo et al., 2020). To maintain the treatment performance of CSO-TWs, the buffering capacity of the filter material is essential. The protons produced during nitrification are neutralized by the carbonates in the filter material, which is thus protected against acidification. The pH stabilization also contributes to an immobilization of heavy metals in the filter material (Grotehusmann et al., 2015). A survey on the condition of CSO-TWs in North Rhine-Westphalia (NRW) found that the filter materials are subject to progressive acidification in the absence or at low levels of carbonates. As a result, nitrification will no longer be possible and heavy metals are washed out into deeper filter layers, leading to their breakthrough (Grotehusmann et al., 2016). Therefore, it is important to develop a suitable re-carbonation strategy for carbonate depleted CSO-TWs in order to sustainably increase their buffering capacity.

## Methods

Requirements for a re-carbonation agent were defined based on experience from agriculture and forestry. Liming materials containing their alkaline component in the form of oxides or hydroxides were identified as unsuitable re-carbonation agents due to their strong alkaline effect. Eighteen lime products with high carbonate content and with different grain sizes (0–8 mm) were evaluated as suitable re-carbonation agents and compared with each other based on quality criteria for fertilizers. Lab-scale monolith column tests with carbonate-depleted filter material were performed. Six lime products, two at a time, were applied to the filter surface. In addition, two blank columns without lime (non-meliorated) were also investigated. A real operating time of 40 months was represented with a hydraulic filter load of 50 m in total. Before and after the experiments, soil samples were taken in different filter layers.

## Results

Liming materials with grain fractions < 2 mm clogged the CSO-TW resulting in an insufficient nitrification. When calcitic and dolomitic liming materials were applied on the filter surface, first positive effects of re-carbonation could be observed after an operating time of 40 months. A progressive heavy metal mobilization into the lowest filter layer (45–75 cm) was found only for the non-meliorated filter columns, while heavy metal immobilization in the filter layer (30–45 cm) was found in the meliorated filter columns. Thus, the buffering capacity of the filter material has been increased in the long term and the effective purification performance of a CSO-TW can be preserved. In a further investigation, these results will be validated in semi-technical column tests.

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BIO of Presenter:

**Julia Storath** Studied environmental engineering at RWTH Aachen University. Working at the Institute of Environmental Engineering (ISA) as research assistant. Previous studies: Behavior of microplastics in wastewater treatment plants, toxicological and ecotoxicological effects of fragrances in the aquatic environment.

# Vertical flow wetlands I

# Red ceramic, autoclaved aerated concrete and chemically activated aerated concrete as novel materials for vertical sub-superficial constructed wetlands treating synthetic effluent

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**Abstract**

Based on the strategy of promoting recycling and reuse of construction materials to contribute to SDG 11 - Sustainable cities and communities, the use of construction waste with high sorption capacity in the environment could enhance pollutant removal and promote the development of diverse microbial communities, favoring the remediation of contaminated waters through constructed wetlands (CW). The objective of this research is to evaluate the use of red ceramic waste (bricks, RC), autoclaved aerated concrete (AC), and the composite generated from AC chemically activated with white cement (WAC) as filter media in vertical subsuperficial constructed wetland systems (VSSF-CW) for the removal of carbonaceous, nitrogenous, and phosphorous matter. Three CW, in microcosm scale, were assembled in 0.2 $m^2$ polypropylene containers, filled with a layer of 0.20 m of each material overlaid by a 0.05 m saturated bottom layer, vegetated with *Eichhornia crassipes* macrophyte (25 plants $m^{-2}$) in the treatment of synthetic effluent. The operation was carried out in sequencing-batch mode for 180 days, with feeding cycles of 48-48-72 h, treating a synthetic effluent simulating sanitary sewage with a low concentration of carbonaceous matter (< 339 mg $L^{-1}$), totalizing 84 feeding days. The systems were evaluated in Stage I with cycle time of 24 h and Stage II with cycle time of 48 h (after feeding) to investigate the influence of the cycle time on their performance and removal efficiency. Except for the removal efficiencies of COD, TKN, and TP, which did not show a significant difference between Stages I and II for CW-RC (p-value ≤ 0.05), the cycle time influenced the removal efficiency of all parameters for CW-AC and CW-WAC. Higher removal efficiencies were obtained with the cycle time of 48 h in Stage II for CW-AC with removal efficiencies of 84%, 70%, 70, 45%, 89%, and 98% for COD, TKN, TAN, $NO_2^-$-N, $NO_3^-$-N, and TP, respectively; and for CW-WAC with 78%, 66%, 62%, 78%, 37%, and 82% for the same parameters, respectively. For CW-RC, the higher removal efficiencies for COD (71%), TKN (33%), TP (85%), $NO_2^-$-N (60%), and $NO_3^-$-N (88%) were achieved in Stage I and for TAN (10%) in Stage II. By analyzing the microbial community structure of the systems, the most abundant phyla were *Firmicutes*, *Proteobacteria*, and *Planctomycetes*. In addition, Anammox bacteria were identified, such as *Candidatus brocadia* and *Candidatus Jettenia*, and some microorganisms capable of degrading endocrine disruptors, such as *Pseudomonas*, *Citrobacter*, and *Comamonas*. The results indicate that AC and WAC increased phosphorus removal in the systems, providing favorable conditions for the growth and development of bacteria responsible for nitrogen removal at low DO concentrations, integrating nitrification and ANAMMOX. These novel materials could be considered alternatives to promote microbial community diversity and remove carbon and nitrogen in CW, besides reusing these wastes, thus minimizing their disposal in landfills.

BIO of Presenter:

**Karina de Carvalho** graduated in Civil Engineering at State University of Maringá, Maringá, Brazil. MSc. and Ph.D. in Engineering at School of Engineering of São Carlos, University of São Paulo, Brazil. Ph.D. Professor at Civil Construction Academic Department at Federal University of Technology – Paraná, Curitiba, Brazil, at Environmental Science and Technology Graduate Program (PPGCTA), and Civil Engineering Graduate Program (PPGEC).

# Integrating circular economy and biodiversity in upgrading constructed wetlands (LIFE RENATURWAT)

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**Abstract**

Water scarcity is a chronic problem in southern Europe, which is extending to northern regions. The production of reclaimed water can help to adapt regions to the new climatic conditions. It is needed not only for agriculture but also for environmental uses, such as the maintenance of wetlands or other water bodies. This reclamation can be achieved by means of environmental and economic sustainable solutions, such as constructed wetlands (CWs). LIFE Renaturwat project is combining different kind of CWs to reclaim wastewater from a holistic point of view, looking at physicochemical and microbiological properties but also at biodiversity. Additionally, the project seeks for integrating circular economy in the urban water cycle, through the industrial symbiosis between drinking and wastewater treatment plants (DWTPs, WWTPs). Specifically, a waste produced in DWTPs, the alum sludge, is being valorized as reactive media for CWs, to upgrade treated wastewater in WWTPs.

To this end, three vertical flow CWs (VFCWs) have been built for upgrading treated wastewater in two WWTPs (Carrícola -CWWTP-, and Monasterios -MWWTP-, Valencia, Spain), to remove phosphorus (P) and other contaminants. These VFCWs have been filled with alum sludge coming from a near DWTP. In MWWTP a single VFCW of 60 $m^2$ was built and in CWWTP two VFCW in series (20 $m^2$ each). In addition, two free water surface flow wetlands (FWSCWs, 50 $m^2$ each) have been created to enhance microbiological quality and biodiversity. One of the FWSCWs receives the effluent from the VFCW (FWSCW1) and the other one is fed with the effluent of the secondary treatment (FWSCW2), thus receiving a higher load of P and other contaminants.

During the first six months the operation conditions were as follows. Hydraulic loading rate (HLR): 0.9 and 1.0 $m^3/m^2/d$ in VFCW of CWWTP (first cell, the second one is not yet working), and MWWTP respectively. Hydraulic retention time (HRT) of 7 hours in both VFCW. HLR in FWSCWs is 0.3 $m^3/m^2/d$ and HRT 1.5 days. First results indicate a high efficiency for total P removal, around 75%, reducing the concentration from 7.0 to 1.6 mg/l (CWWTP) and from 3.2 to 0.8 mg/l (MWWTP). *Escherichia coli* was significantly reduced in VFCWs from 5639 to 835 MPN/100 ml (MWWTP) and from $1.8 \cdot 10^5$ to $5.9 \cdot 10^4$ MPN/100 ml, as well as in FWSCWs, from 835 to 183 MPN/100 ml in the FWSCW1 from 5639 to 683 MPN/100 ml in the FWSCW2. Chlorophyll *a* in FWSCW1 (20 μg/l) is significantly lower than in FWSCW2 (39 μg/l).

Regarding biodiversity, in the FWSCW1, colonization of species absent in the FWSCW2 has been observed, with the presence of larvae of the dragonfly *Brachythemis impartita*, as well as various mayflies indicators of good water quality. A protected species of amphibian (Iberian ribbed newt, *Pleurodeles waltl*) has been introduced to recover its presence in the area, where it disappeared due to the drying up of endorheic lagoons. It feeds on mosquito larvae, so it will help control their population.

The LIFE RENATURWAT project has received funding from the LIFE Programme of the European Union.

BIO of Presenter:

**Carmen Hernández-Crespo** is senior researcher with broad experience in CWs, especially in big systems directed to restore ecosystems, and sustainable urban drainage systems for stormwater management.

**Nuria Oliver** is senior researcher with a PhD based on the use of CWs for restoring ecosystems and currently responsible for the research line focused on the use of CWs for wastewaters valorizing in a big company.

# Performance evaluation of operational changes in modified vertical flow treatment wetlands with ornamental plants under arid conditions

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**Abstract**

Currently, there is a need of data related to performance, when treatment wetlands (TWs) are employed in arid climates; specially, if modifications in design and operational variables are introduced. In this way, this technology can be improved and adjusted to this particular environment. Thus, the aim of this work was to analyze the performance of modified (in bed depth and medium) vertical flow (VF) TWs located in an arid environment, when operational changes are introduced for wastewater treatment. Three experimental units of VF-TWs systems were implemented (ø, 0.2 m) with an effective bed depth of 0.7 m, at the Coastal Atacama Desert (Iquique, Chile). The VF-TWs were filled with 0.1 m gravel layer at both the top and bottom. The main support media was divided into two layers, a 0.25 m sand layer followed by a 0.25 m zeolite layer. Ornamental species, *Zantedeschia aethiopica* was used as the experimental plant. The VF-TWs were operated in three phases (5 months each) with two hydraulic loading rates (HLR): a) phase I, HLR of 120 mm/d, and b) phase II and phase III, HLR of 160 mm/d. The daily loading frequency was 12 pulses/d. Two feeding and resting period (F/R) were employed: a) phase I and II, 5-day loading period and 10-day resting period, and b) phase III, 3.5-day loading period and 3.5-day resting period. During phase III, bottom saturation of the zeolite layer was introduced. Wastewater for feeding the treatment systems was collected from a full-scale wastewater treatment plant and diluted 30% to simulate the removal expected from a septic tank as primary treatment. The physical-chemical parameters of pH, temperature (T), oxidation reduction potential (ORP), Electrical Conductivity (EC), total suspended solids (TSS), chemical oxygen demand (COD), ammonium ($NH_4^+$-N), nitrate ($NO_3^-$-N), total nitrogen (TN) and phosphate ($PO_4^{-3}$-P) were measured in influents and effluents every three weeks.

The results showed that average T (21 - 23°C), pH (7.0 - 8.2), ORP (+30 - +60 mV) and CE (2,800 to 3,100 µS/cm), were not affected by changes in HLR, F/R and partial saturation. TSS and COD removal were stable during the three phases with average removal efficiencies between 80-90% and 65-85%, respectively. Thus, TSS and COD removal was not affected by HLR increasing, F/R modification, and partial saturation. For nitrogen forms, ammonium removal was around 98% and transformed into $NO_3^-$-N (around 13 mg/L) during the three phases. Lastly, TN removal was stable during the three phases: between 45% to 60%, with a positive effect by partial saturation of zeolite layer, increasing removal efficiency up to 72%. The average phosphate removal was around 40%. Therefore, the results achieved in this work suggest that for VF-TWs modified in bed depth and medium, the effluent quality was not affected by changes in the operation related to HLR increases and F/R. Furthermore, partial saturation suggests a positive influence on TN removal. Finally, the proposed modifications in the design and operation variables could be introduced in arid conditions for VF-TWs, not affecting performance, and thus, confirming the adaptation of the technology to this particular environment.

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BIO of Presenter:

**Ismael Vera-Puerto** has 19 years of experience dedicated to wetlands use for water quality improvement. He has experience with specials support mediums, nutrients removal, effluent reuse, aeration, plants, and resource recovery.

# Decentralised wastewater treatment and water reuse for regions with seasonal drought stress

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## Introduction

In the DeWaResT project (BMBF: 02WQ1596B; Aug. 2021 - Jan. 2024), a novel Constructed Wetland (CW) is being developed. The vertical multi-layer design is intended to achieve a significant reduction in surface area (approx. 1m²/EGW). The system will be tested at a campsite with seasonal operation. The following concentrations apply as internal purification targets: COD < 90 mg/L, BOD < 20 mg/L, $NH_4$ - N < 10 mg/L, $N_{anorg}$ < 18 mg/L, $P_{tot}$ < 2 mg/L. Two identical vertical CWs each with an area of 12 m² are operated at the test site. This corresponds to a design capacity for up to 30 PE with alternating and seasonal operation. By optimising the process conditions (e.g. recirculation ratio, aeration, intermittent feeding, expansion of the plant through additional denitrification capacity), the efficiency of nitrogen removal has to be increased. An additional chemical precipitation serves to reduce the phosphate content in order to ensure an effluent concentration of below 2 mg/L $P_{tot}$. A downstream slow sand filtration (SSF) and a filter with granular activated carbon (GAC) ensure further disinfection and additional removal of trace substances, so that the treated wastewater also meets high requirements for water reuse.

## Results

The mean influent concentrations in the first experimental period (June 2022 - Oct. 2022) were 2143 mg/L COD, 575 mg/L TSS, 190 mg/L TN, 106 mg/L $NH_4$ -N and 27 mg/L TP. The high concentrations are due to the low specific water consumption (< 40 L/PE *d) at the experimental site. Due to the high influent concentrations, the specific feed was limited to 1 m³/d. From the first day on, a very good COD and TSS elimination of approx. 97% was achieved in the CWs. By optimising the aeration, the nitrification performance could also be increased. In relation to the $NH_4$ -N influent concentration (106 mg/L), a reduction of 97% (3.4 mg/L) could be achieved. However, an insufficient carbon/nitrogen ratio in the denitrification stage resulted in reduced $NO_3$ -N reduction. Thus, only an insufficient reduction of $N_{anorg}$ = 66% could be achieved. By increasing the air flow rate, it was possible to reduce the aeration time per day and specifically shift it to the night hours when no wastewater was applied. This temporal decoupling improved the denitrification performance in the biofilm. Towards the end of the 2022 operating season, a nitrogen concentration of 24 mg/L $N_{anorg}$ was achieved for the first time with an approximately reduced filter load by half. This corresponds to a reduction of 87% in relation to 190 mg/L TN in the influent. In the second test period (April 23 - Oct. 23), one filter is operated with a filter load by half. The second filter is equipped with a bypass denitrification system. Furthermore, the overall system (CW + SSF + GAC) will be evaluated with regard to the elimination of trace substances and the reduction of coliforms.

BIO of Presenter:

**Jan Schuetz** has been a researcher at the Kompetenzzentrum Wasser Berlin for six years. His work focuses on classical and advanced wastewater treatment processes and their optimisation. His favourite topics are decentralised wastewater treatment and water reuse. He also enjoys plumbing and construction work in general.

# Microplastics II

# Fate of microplastics in a free-water surface constructed wetland - removal, microbial colonization and antimicrobial resistance (AMR)

*Jannis Wenk[1,*], Daniel Ifayemi[1], Gordon Webster[2], Andrew J. Weighman[2], Ruth Barden[3], Barbara Kasprzyk—Hordern[1], Franciszek Bydalek[1]*

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**Abstract**

The issue of microplastic (MP) pollution in freshwater ecosystems and wastewater is a growing concern. Wastewater treatment plants (WWTP) have been identified as one of the primary sources of MPs in freshwater systems. MPs discharged with treated wastewater can act as vectors for pathogen and AMR spread in downstream environments. Little is known about the fate of MPs in constructed wetlands (CWs), particularly free-water surface CWs. This study aimed to quantitatively analyze MPs' abundance throughout a CW to assess the effectiveness of MP removal in free-water surface CWs. The research also employed a colonization experiment to monitor changes in microbial communities and the occurrence of pathogens and AMR genes in MP-associated biofilm during MPs' passage through the CW.

The study was conducted at a full-scale free water surface constructed wetland (CW) operating as a polishing step for a 2100 population equivalent WWTP in Southwest England. To quantify MPs, water samples were collected at four different points across the CW, including inflow and effluent points. MPs were characterized based on their size, type, and polymer composition. The biofilm associated with MPs was assessed through a colonization experiment where MPs inoculated in the upstream WWTP were deployed at the CW to undergo four-day and twenty-day colonization. For qualitative bacterial community analysis of the MP-associated biofilm, bacterial 16S rRNA gene sequencing was carried out. Additionally, quantitative analysis of antimicrobial resistance (AMR) genes (sul1, ermB, tetW, intiI1) in the biofilm was performed using qPCR. Comparative analysis between the MP-associated biofilm and planktonic community in CW was carried out to assess whether MPs were actively supporting pathogen and AMR spread in the CW.

The CW received an average of 6 MPs per liter, equating to $5 \cdot 10^6$ MPs per day. Most of the MPs were synthetic fibers and fragments sized between 100-1000 µm. The CW retained 95% of the MPs, resulting in 0.30 ± 0.09 MPs/L in the CW effluent. Most MPs (97%) were trapped in the opening 20% of the CW, which comprised of a settling pond and a shallow vegetated wetland zone. Upon transfer into the CW, the MPs-biofilm community diversity increased. However, even after a long incubation period, the MP-biofilm composition carried a significant taxonomic footprint of the upstream WWTP, indicating the high adaptability of WWTP-associated biofilm in the CW environment. The MP biofilm population of human pathogenic genera, particularly Pseudomonas and Aeromonas, was reduced on MPs when transferred into the CW environment. The AMR relative abundance in the biofilm was comparable to or higher than that among the planktonic community, while AMR removal in the planktonic community was significantly higher than that among MP-associated biofilm. This indicates that MPs might be an AMR reservoir in the CW. MPs' retention time had little to no effect on AMR removal effectiveness.

BIO of Presenter:

**Jannis Wenk** is an Associate Professor in Water Science and Engineering at University of Bath, UK. He is trained as an environmental engineer (Dipl.-Ing.) at TU Berlin (2008) and holds a PhD in environmental sciences (2013) from ETH Zurich. His research interests include nature-based solutions for water treatment.

# Microplastics occurrence, characterization, and removal in full-scale combined sewer overflow-constructed wetland systems upstream centralized wastewater treatment plants

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**Abstract**
Combined sewer overflows (CSOs) represent a major source of untreated pollution to receiving water bodies, releasing significant amounts of conventional pollutants, pathogens, heavy metals and emerging microcontaminants, such as microplastics (MPs), which are a key environmental concern due to their potential impact on aquatic ecosystems. Although there is no single effective solution, one of the most promising strategies to reduce the environmental pressure of CSOs can be found in Constructed Wetlands (CWs).
In this context, the present study aims to quantify and characterize the MPs detected in inlet and outlet water samples and to investigate the effectiveness of MPs removal from wastewater by two CSO-CW systems upstream the centralized wastewater treatment plants (WWTPs) located in Merone and Carimate (Como province, Italy) respectively. The systems under investigation are two different multistage CWs: Merone CSO-CW consists of a 1$^{st}$ stage constituted by four parallel aerated beds (4000 m$^2$) and a 2$^{nd}$ free water surface (FWS) stage (1500 m$^2$), while Carimate CSO-CW is composed by a 1$^{st}$ stage comprising two vertical subsurface flow (VF) CW beds (8500 m$^2$) and a 2$^{nd}$ FWS stage (4500 m$^2$).
A semi-quantitative analysis of the MPs in the water samples was carried out using a stereo microscope, followed by a chemical characterization performed by a Fourier transform infrared spectrometer (FTIR), coupled to an optical microscope, with an FPA detector in reflection mode.
The data obtained highlighted two main macro-categories of MPs, fibres and fragments, with a clear prevalence of the former, representing over 70% of the total in the samples from both the CSO-CW systems. The MPs determined were characterized by almost similar colours and shapes, with a general predominance of black and blue fibres. Additionally, a size classification demonstrated a higher percentage of particles in the 100 to 500 μm range. The main plastic polymers identified in these samples were polyethylene terephthalate (PET) and polyacrylonitrile (PAN). Interesting to notice the high percentage (approximately 86%) of cellulosic fibre, a natural polymer widely used in various human activities (especially textiles). Cellulose may not be an environmental hazard in itself, but the dyes or additives associated with it could be potentially harmful to aquatic ecosystems and therefore its widespread presence should not be underestimated. Experimental data show that more than 60% and 67% of the total microparticles detected in the inlet water samples were removed during the 1$^{st}$ treatment stage, i.e. Merone aerated beds and Carimate VF beds respectively.
This research represents, to the best of our knowledge, the first monitoring of emerging microcontaminants, such as MPs, in full-scale CSO-CW systems upstream centralized WWTPs.

BIO of Presenter:
**Chiara Sarti** has a MSc in Environmental Chemistry and experience as research fellow in the framework of a LIFE project. She is currently a PhD student in Chemical Sciences at the University of Florence, in collaboration with IRIDRA Srl and Cranfield University.

# Do microplastics impact the treatment efficiency of pollutants in constructed wetlands?

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**Abstract**
Constructed wetlands (CWs) are sustainable and low-cost wastewater treatment technology gaining widespread popularity as a decentralized treatment option. Microplastics (MPs) generated from widespread plastic use find their way to CWs through wastewater channels. CWs can treat these MPs by physical mechanisms, but MPs effect on CW's normal functioning is still unclear. In this study, we compared the effects of MPs on the treatment performance of vertical flow CWs systems equipped with three different filter materials, *i.e.*, gravel, graphite, and biochar. These CW systems were assessed in the presence and absence of MPs. Synthetic wastewater with and without MPs was fed in continuous up-flow mode in the systems, and COD, $NH_4^+$, $NO_2^-$, $NO_3^-$, TN, and $SO_4^{2-}$ were analysed. The studied MPs were polyethylene terephthalate (PET) and high-density polyethylene (HDPE). The presence of MPs enhanced COD removal in all the VFCWs. An opposite trend was observed for TN, $NH_4^+$-N, and $SO_4^{2-}$ removal, where removal was reduced in the presence of MPs addition in CW systems. In the case of $NO_3^-$ , no significant difference was observed in MPs presence. Our early results indicated that the presence of MPs in wastewater affected nitrogen removal negatively in CW systems. We are performing further experiments for more conclusive results.

BIO of Presenter:
**Saurabh Dwivedi** is a PhD scholar at AcSIR and CSIR-Institute of Minerals and Materials Technology, India, and he is interested in microplastic removal in constructed wetlands systems.

# Microbial ecology

# Grey water an issue in urban slums – microbial community

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**Abstract**
Greywater in shanty townships in much of the developing world, including e.g. cities in South Africa, is usually discarded untreated to the streets. In South Africa, many settlements have access to potable water taps, as well as chemical toilets provided by municipalities, but the unplanned nature of a shanty town prevents the provision of a sewer system. Therefore, greywater disposal poses a sanitation problem that needs to be addressed.
In the framework of the EU JPI project URBWAT, a demonstration constructed wetland greywater treatment unit was built in s'Swetla, a shanty area north of Alexandra Township, Johannesburg. In parallel, three 1m long lab-scale wetland systems (2 with nutshell-building rubble, and one control with gravel) were set up in a greenhouse at UFZ Leipzig to study the effect of variable greywater loading regimes. The effect was measured as removal of DOC, ammonia, and phosphate over the entire wetland, and at defined points along the flow path. Adding to the water quality studies, samples were collected at the same points to study the effect on changes in the microbial community structure. Here, we present those results for the experimental phase with greywater concentrations equal to 25 % of the concentrations observed in greywater in-situ in s´Swetla. Bui et al., (this conference) show that the main water quality improvements took place in the first quarter of the system, and that sulfate reduction was an important pathway, given high sulfate concentrations in the greywater.
This was also indicated by the results of monitoring the demonstration unit in s'Swetla, particularly in periods with higher loads. In line with the measured reduction of sulfate, and detectable amounts of sulfide, the ongoing data analysis of microbial data demonstrated a strong expression of members of the sulfate reducing community. In the sequence data analysis, the existence of the order *Desulfobacteriales*, *Desulfovibrionales*, *Desulfovibrionales* as δ-subgroup of Proteobacteria indicated their active involvement in the anaerobic microbial transformation of organic matter in the wetland. Surprisingly, sequences of *Nitrospirales* and *Nitrosomonadales* were detected, suggesting also aerobic transformation, i.e., nitrification of ammonia. A direct link between taxonomic information derived from DNA sequencing and activity measurements could not be established. However, the measured transformation products, sulfide, and nitrate, supports that anaerobic respiration processes were the dominant pathways for the drop in DOC concentrations along the wetland, and that nitrification was a contributing process to ammonia removal.

BIO of Presenter:
**Uwe Kappelmeyer** holds a PhD in Environmental Microbiology from Technical University of Dresden and a M.Sc. (former Diploma Engineer) in Biotech- and Chemical Engineering from Technical University of Magdeburg. Currently, he is working at the Helmholtz Institute Centre for Environmental Research (UFZ) under the Environmental Biotechnology department in Leipzig, Germany.

# Novel lightweight substrate in constructed wetland for domestic wastewater treatment: preparation, performance, and microorganism community

*Ting Wei[1,2,*], Yaqian Zhao[1], Jia Guo[1], Minwei Zhou[3], Abraham Esteve-Núñez[2]*

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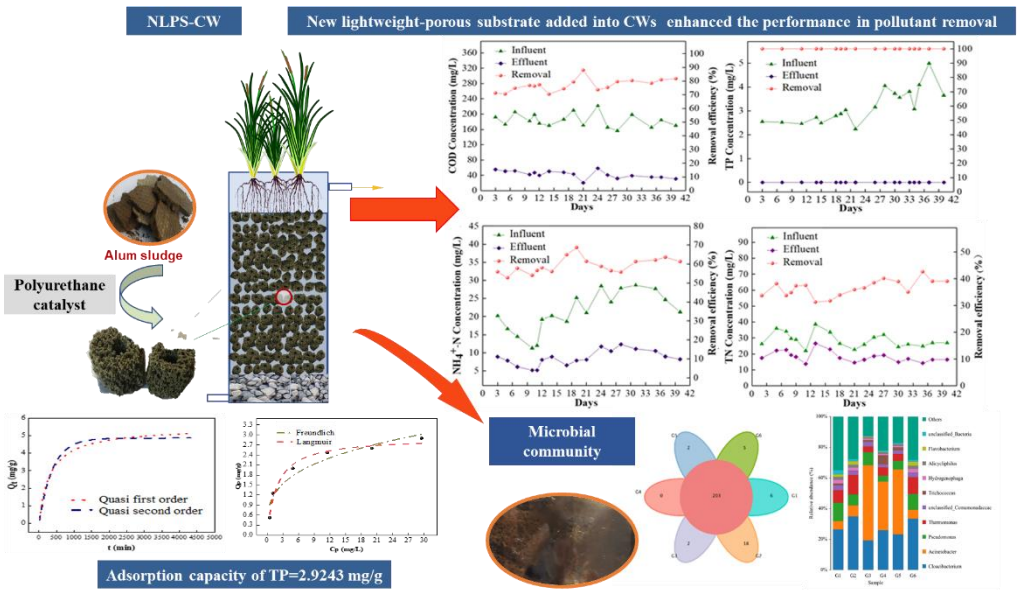
**Abstract**

The cost-effective and environmentally friendly substrates play an important role in the function of constructed wetlands (CWs). However, the traditional substrates have been limited by the relatively low treatment efficiency, heavy mass quantity, clogging problem etc. Therefore, many alternative substrates have been studied and applied to enhance pollutant removal and practicability, especially in the long-term operation of CWs. This study firstly composes drinking water treatment sludge (DWTS) and polyurethane under the action of catalyst to prepare a new type of lightweight-porous substrate (NLPS) used in CWs for wastewater treatment. It was founded that the total porosity of NLPS was obviously improved by around 50%. The static adsorption experiments showed that the adsorption behavior of NLPS to phosphorus conforms to a quasi-second-order kinetic model and the adsorption process can be simulated using Langmuir and Freundlich models. The maximum adsorption capacity of phosphorus by NLPS was calculated as 2.92 mg/g, while the phosphorus adsorption was a spontaneous exothermic process. Using the NLPS as wetland substrate to treat real domestic wastewater has favorable removal efficiencies of COD (77.04%), TP (80%), $NH_4^+$-N (59.12%), and TN (45.35%). Moreover, high-throughput sequencing analysis revealed that the abundance of key functional bacteria was higher in longer retention time stage of CWs (HRT=2 days). These results indicated that NLPS could be used as a new alternative substrate in CWs technology.




BIO of Presenter:

**Ting Wei** is a research assistant at Xi'an University of Technology and a Ph.D student in Hydrology and Water Resources Management at the University of Alcalá, Spain, focusing on new constructed wetland substrates, modular constructed wetland technology and microbial electrochemical wastewater treatment.

# Microbial community dynamics in a cold climate treatment wetland

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**Abstract**
Microbial processes drive secondary treatment of wastewater constituents in treatment wetlands (TW). This study investigated the composition and dynamics of the microbial communities in a TW treating wastewater at the Bridger Bowl ski resort during the months of December 2020 – April 2021. The Bridger pilot TW system is a two-stage process where the second, nitrifying stage effluent is recycled back to the first stage, where chemical oxygen demand (COD) removal and denitrification of recycled nitrate occurs. The first stage of the system is mostly saturated to facilitate anoxic conditions required for denitrification, while the second stage is unsaturated to facilitate oxygen transfer required for nitrification. The system begins treating wastewater every December upon the opening of the ski resort until its close in April and remains saturated with freshwater during the summer to facilitate plant growth. It has demonstrated effective removal of COD and total nitrogen since 2013 while operating only in the winter months and with average 3-4°C water temperature.

We hypothesized that the Bridger system would contain distinct microbial communities between three zones: 1) the unsaturated zone of the first stage, containing high COD and ammonia from the influent and likely aerobic 2) the denitrifying saturated zone of the first stage containing likely anoxic conditions and high concentrations of COD, and nitrate via recycle 3) the unsaturated second stage containing low COD, high ammonia and oxic conditions for nitrification. Wetland media samples consisting of gravel or sand from each zone were collected in December, February, and April, allowing for assessment of spatiotemporal microbial community dynamics over an operational season. DNA was extracted and 16S rDNA sequenced via Illumina Miseq, and the QIIME 2.0 pipeline was used for data analysis.

Analysis of the microbial community composition of the zones indicated that in December, microbial signatures of the three zones were mixed, but developed into distinct communities later in the season. In February and April, the second stage cultivated a nitrifying community dominated by *Nitrospira* and *Nitrosospira*. The microbial communities in the unsaturated and saturated zones of the first stage did exhibit significant differences that shifted over the course of the season. Microbial communities in the first stage included facultative bacteria known to denitrify at low temperatures, such as *Polaromonas, Pseudomonas* and *Dechloromonas* species. Samples of plant roots collected from the TW were found to have potentially distinct microbial communities from the sand or gravel samples collected from the same zone.

The study documents shifts in the microbial communities in a TW undergoing transition to treating high-strength wastewater in winter. The results verify that communities adapt over the several months of operation and are dominated by redox conditions in each zone. Ongoing work will investigate shifts in microbial communities in the summer months while no wastewater is fed to the TW. The results will provide insight into the role of microbial community shifts during start up and changes to TW system operations.

BIO of Presenter:
**Stephanie Ayotte** is a third year PhD student in Environmental Engineering at Montana State University. She is a fellow of the Thermal Biology Institute's Extreme Biofilms National Research Traineeship program. Her research interests in treatment wetlands include greenhouse gas emissions and mitigation, and understanding nitrogen-associated microbial community dynamics.

# Antibiotics removal & antimicrobial resistance

# The UK's efforts to understand and tackle antimicrobial resistance (AMR): the role of nature-based solutions

*Tao Lyu[1,*], Lucie Krejcova[1], Pablo Campo Moreno[1], Gabriela Dotro[1], Bruce Jefferson[1]*
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**Abstract**
Antimicrobial resistance (AMR) is present in people, animals, plants, and the environment, which has been identified by the World Health Organization as one of the top 10 global public threats. The extensive use of antimicrobials, including antibiotics, antivirals, and antifungals, for human consumption and agricultural activities, has led to a significant accumulation of residues in the water environment, providing ideal conditions for the occurrence and proliferation of AMR. Through microorganism mutations and horizontal gene transfer processes, AMR can spread in water bodies even when antimicrobials are not present. Conventional Wastewater treatment plants (WWTPs) are not designed to remove such emerging contaminants and are considered a key source and hotspot of antibiotics and AMR. The UK national effort, through the Chemical Investigation Programme (CIP), has monitored 10 WWTPs across England and Wales over several years, and the results shown that appropriate tertiary treatments are essential for enhancing the remediation of AMR up to 99% from wastewater.

Nature-based solutions (NbS), in particular constructed wetlands (CWs), have been widely used as low-cost, ecological, and aesthetically pleasing solutions for wastewater treatment. UK water utilities are at the forefront of implementing NbS in their existing sewage works as part of their strategical plans. However, the current UK CIP efforts have not included CWs in their investigated sewage works' flowsheet. This study is sponsored by the UK research council and water utility to evaluate the use of CWs as NbS for the removal of AMR. The aim is to understand the removal capabilities and mechanisms of CWs and propose potential optimisation strategies for the enhancement of AMR removal. The first step of the project was to conduct a systematic literature review to summarise existing evidence and identify knowledge gaps by collecting and analysing datasets from academic literature databases and grey literature.

The results of the current research indicated that vertical flow CWs performed better in AMR removal compared with horizontal flow and surface flow CWs. Moreover, the use of highly porous substrate and polyculture conditions could facilitate AMR removal. Lower hydraulic loading rates and higher retention times could lead to more efficient removal of resistance genes. However, the majority of the studies were conducted in small-scale systems with artificial wastewater influent, leaving a significant knowledge gap that needs to be filled by the studies in implemented large-scale CWs. Further details will be presented during the presentation. With the results of this study, this study can contribute to the optimisation of NbS for the mitigation of global AMR risks and supporting the public and ecosystem health.

BIO of Presenter:
**Tao Lyu** is a Lecturer in Green Technologies and the Environmental Engineering MSc course director at Cranfield University. He received his PhD from Aarhus University in 2016, and his research focuses on the innovation and implementation of Nature-based Solutions (NbS), specifically Constructed Wetlands (CWs), for treating diverse wastewater types.

# Antibiotics and microbial community dynamics in estuarine ecosystems and wetlands (saltmarshes) role in pollutants removal

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**Abstract**

Nature Based Solutions (NBS) have been used for several years to improve water quality. Estuarine saltmarshes can be used as NBS to improve the water quality of estuarine areas and ecosystems function. Saltmarshes are natural wetlands where biotic and abiotic functions simultaneously occur contributing to the elimination of several types of compounds. Recently, concerns are increasing about the occurrence of contaminants of emerging concern (CECs), namely antibiotics, in aquatic ecosystems. However, there is still little information about the utility of using NBS to reduce their impact on water quality. In the frame of the project NATURE, which aims to explore NBS to reduce antibiotics, pathogens and antimicrobial resistance in aquatic ecosystems, the current study aims to assess the potential of an estuarine saltmarsh for reducing the prevalence of antibiotics, and other contaminants, in aquatic ecosystems from inland to coastal areas. This aim is complemented with the assessment of the microbial community dynamics in estuarine water to evaluate their role in saltmarshes potential for pollutants removal, namely antibiotic resistance phenomena.

An estuarine area with a saltmarsh (ca. 267 ha) located in the Lima River Estuary (NW Portugal) was selected as a case study. This area receives diffuse pollution from several sources including from the cities upstream and in its margins. *Juncus maritimus* is the predominant plant species, but *Spartina maritima* and *Phragmites australis* are also found in the saltmarsh area. Water was collected at low tide in different locations upstream, within and downstream of the salt marsh area, as well as in some potential sources of pollutants into the estuary over a one-year monitoring seasonal campaign: winter (February 2022), spring (May 2022), summer (August 2022) and autumn (November 2022).

Antibiotics and other organic micropollutants relevant in the context of water quality were determined using an analytical methodology based on offline solid-phase extraction and liquid chromatography coupled to mass spectrometry (SPE-LC-MS/MS). Microbial characterization was carried out by 16S rRNA gene amplicon sequencing and quantitative PCR (qPCR) of marker genes for antimicrobial resistance.

Of the 14 antibiotics selected, only two, clarithromycin and trimethoprim were detected, mostly in the summer sampling campaign. Although clarithromycin was detected in estuarine water, trimethoprim was only detected in freshwater stream, a possible pollutant source to the estuarine area. Amplicon sequencing and qPCR analysis indicated a substantial replacement of the microbial communities from the sources with microbes better adapted to the salt marsh environment. Data is still being analyzed and integrated to evaluate the potential of saltmarshes to remove pollutants from estuarine waters.

These results will contribute to highlight the potential role of estuarine salt marshes as NBS that can contribute to enhance water quality and ecosystems preservation.

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BIO of Presenter:

**Marisa Almeida** is a senior researcher. With a PhD in Chemistry her main research area is bio and phytoremediation, participating actively in studies that aim to potentiate the use of these biotechnological tools as nature-based solutions to improve and recover aquatic environments contaminated with different pollutants.

# Removal of enrofloxacin using *Eichhornia crassipes* in wetlands at microcosm scale

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[5] Programa de Investigación y Análisis de Residuos y Contaminantes Químicos, Facultad de Ingeniería Química, Universidad Nacional del Litoral, Santa Fe, Argentina
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**Abstract**

The consumption of antibiotics worldwide entails the possibility of their occurrence in the environment. The use of nature-based solutions (NBS) is an innovative and environmentally friendly alternative. In this work, we assessed the efficiency of microcosm scale free-water surface wetlands (FWSWs) using *Eichhornia crassipes* in enrofloxacin (ENR) removal. The studied system(S) and controls (C) were: S1: water + ENR + sediment; S2: water + ENR + sediment + plants; S3: water + ENR + plants; C1: water + ENR; C2: water + sediment + plants; C3: water + plants. While it is known that antibiotics can be accumulated in the sediment, further studies should assess the bioaccumulation in the vegetation to understand the complete cycle of these contaminants in CWs. The behavior of enrofloxacin in the system, its accumulation and distribution in plant tissues, the detoxification mechanisms, and the possible effects on plant growth were also studied.

Enrofloxacin was first taken up by *E. crassipes* in the first 100 h and then it was accumulated in the sediment. Removal rates higher than 94 % were obtained in systems with sediment and sediment + *E. crassipes*. Enrofloxacin was found in leaves, petiole, and root (8.8-23.6 µg, 11-78.3 µg and 10.2-70.7 µg, respectively). Enrofloxacin and degradation products were quantified in tissues and the presence of chlorosis in plants was observed on days 5 and 9. Finally, the degradation products of enrofloxacin were analyzed in the samples, and four possible metabolic pathways of enrofloxacin in *E. crassipes* were described.

BIO of Presenter:

**María Maine** is a senior scientist with more than 25 years of experience in the study of contaminant dynamics in natural and treatment wetlands. She was the President of the Pan-American Wetland Network (HUPANAM). She has published more than 90 journal articles and book chapters, and more than 200 presentations in scientific meetings.

# A review on antibiotics removal: combining grey processes with green process/ constructed wetland

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**Abstract**

Antibiotics pose serious risks to both human health and the environment, making them a major concern worldwide. This review examines the effectiveness of secondary wastewater treatment processes (known as the grey process) and constructed wetlands (CWs) (also known as the green process) in eliminating antibiotics and antibiotic resistance genes (ARG). The study found that while the grey process primarily removes antibiotics, it is less effective in removing ARG and may even lead to their enrichment in some cases. In contrast, CWs proved to be more effective in overall treatment, particularly in regards to ARG. VFCWs were found to be more efficient in removing antibiotics, whereas HFCWs were more effective in ARG removal. The combination of the grey and green processes proved to be the most effective approach, with the grey process serving as the primary treatment and CWs acting as the polishing stage. The most advantage of the combination lies in realizing complementary advantages. This hybrid system demonstrated significantly higher efficiency than either treatment process used individually. It must be clear that the removal in CW mainly depends on the substrate and the microorganisms growing on it. In fact, anaerobic and anoxic treatments (AD and HFCWs) or "oxygen-free" treatment systems are more successful in removing ARG than aerobic treatments (ASP and VFCWs). But the overall mechanisms are still unclear. The question of whether the biological processes lead to ARG transmission and proliferation or gave rise to their degradation is still remaining, and future research should focus on it.

BIO of Presenter:

**Peiying Kang** is a PhD candidate of Xi'an University of Technology. Research direction: wastewater ecological treatment by constructed wetland.

# Intensification

# Nitrification and denitrification in Taya, a fill and drain constructed wetland

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**Abstract**
Rapid population growth, climate changes, and failed management of water resources are some of the reasons for the exacerbating water shortage in many countries. To overcome this problem, an integrated approach, which includes the prevention of surface and ground water pollution, as well as the creation of new water sources, must be adopted. Since currently more than 70% of the world's freshwater is used for agriculture, reusing treated wastewater in irrigation, provides a significant factor in alleviating water scarcity.

Wastewater reuse which began in Israel in the mid-1980s, reduced 50% of freshwater withdrawals by 2018. Effluent qualities have been defined for different irrigation purposes. Among other parameters, Total nitrogen and ammonia standards were set.

TAYA, a fill and drain constructed wetland was developed specifically to answer the needs for decentralized agricultural villages who wished to treat wastewater locally and reuse it for irrigation.

The technology is based on the transfer of wastewater between a pair of basins filled with gravel as a biofilm carrier in fill and drain cycles. The filling phase allows the supply of organic matter and nutrients to the biofilm, while the draining phase provides passive aeration and saturates the biofilm with oxygen.

In addition to the organic and hydraulic loading, the cycles frequency, duration, and time allocated to each of the cycle components, determines the system treatment ability.

This recurrent sequence of filling and draining creates different redox conditions, enabling the growth of diverse biofilm and allows nitrification and denitrification processes at the same basin.

In the nitrification process, Ammonia ($NH_4^+$) is oxidized to nitrite ($NO_2^-$), which is then further oxidized to nitrate ($NO_3^-$) under aerobic conditions. During the denitrification process, mineralization of organic matter is conducted, using nitrate as the electron acceptor to produce $N_2$ gas under anoxic conditions.

In different conventional treatment technologies, nitrification and denitrification processes are usually separated into different basins and wastewater flows between them. It poses operational challenges such as oxygen concentration control, recirculation rate for C:N ratio etc., and involve additional treatment costs.

In the TAYA technology, the two processes take places at the same basin but at a different cycle phase. During the fill phase, ammonia cations and organic matter are adsorbed to the negatively charged biofilm while in the drain phase biofilm is saturate with atmospheric oxygen and ammonia cations are oxidized to nitrate ions. During the next fill phase, the nitrate ions diffuse from the biofilm into the bulk water and organic matter is metabolized reducing the nitrate to gaseous nitrogen. All is accomplished with a low energy consumption of 0.17 kwh/$m^3$ treated, thanks to special patented hydraulic design and operation.

Another important feature of TAYA, is that nitrification is not hindered by the presence of COD, since $O_2$ in the biofilm is not a limiting factor, nitrification and COD removal, occurs simultaneously.

TAYA performance data of 3 projects will be presented, showing TN influent average of 70, 65 and 48 mg/l and effluent average of 16,9 and 9 mg/l respectively and more than 90% ammonia removal.

BIO of Presenter:
**Keren Aizenberg** is a biotechnology engineer with 25 years of experience in wastewater treatment technologies. Keren established and is leading Triple-T's R&D department. She is involved with the development, design and operation of the company's wastewater treatment plants and a key part of the TAYA development team.

# RHIZOSPH'AIR – a single stage "FRENCH" treatment wetlands for nitrogen removal. 2-years monitoring of industrial-scale pilots

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**Abstract**

Rhizosph'Air® system consists of an intensified single-stage treatment wetland (TW) for domestic wastewater that combines in a single stage classical French wetlands with forced bed aeration. Two semi-industrial scale Rhizosph'Air® pilots (100-125 PE) were assessed in the frame of LIFE INTEXT project in two different locations in Spain with different climate conditions: Talavera de la Reina (Continental Climate, Toledo) and Carrión de los Céspedes (Mediterranean Climate, Seville). The pilots have been commissioned in Spring 2022 and treat raw domestic wastewater.

The Rhizosph'Air® system combines the advantages of classical French treatment wetlands (robustness, integrated sludge management) and of forced bed aeration (compacity, removal efficiency). The Rhizosph'Air® implements vertical and horizontal flows within a unique stage, thus improving the overall residence time with a limited footprint (~ 1m²/PE). Moreover, this innovative configuration offers high removal efficiencies with limited energy consumption while offering a strong resilience to the variations in organic and hydraulic loads encountered by most of small communities (<5000 PE) equipped with combined sewers.

The monitoring within LIFE INTEXT includes (1) weekly analysis of 24-hour composite and spot samples at the inlet and outlet of the system using standard HACH test kits. Also, samples taken from piezometers inside the Rhizosph'Air® were analysed on a weekly basis; (2) Online monitoring of dissolved O2, redox at the outlet of the system and pressure of blowers; (3) Pathogen monitoring; (4) Gas emission measurements.

Preliminary results run at nominal load show high removal efficiencies of the major pollutants (97% BOD5, 91% COD, 97% SS) and full nitrification with almost full denitrification (TN removal of 79%). Further optimization of operational parameters is currently being assessed to improve TN removal. Moreover, a comprehensive process validation has started in April 23', aiming at assessing system response to stress tests, namely temporary organic and hydraulic overloading that are classical in the small-communities sanitation context. The main overcomes of this study will be presented at the conference.

BIO of Presenter:

**Alain Petitjean** is research engineer at Syntea since 2016. He holds a Ph.D degree from Strasbourg University and spent 3 years as post-doc at INRAE. Alain is specialized in domestic wastewater treatment wetlands and works on the optimization and intensification of French systems.

# Practical examples of aerated treatment wetlands in the Czech Republic

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## Introduction

Thanks to their advantages, aerated treatment wetlands are gaining popularity in our field, and their use is also expanding in the Czech Republic. We have been designing and implementing treatment wetlands with forced aeration since the turn of 2018/19, mainly as domestic systems, where they are gradually replacing vertical flow constructed wetlands. We have implemented a few dozen small domestic systems, but larger treatment plants take considerably longer to design and permit. In the past year, we have completed two of the largest aerated root systems in the country so far, designed for 50 and 70 PE, respectively. In this presentation, we would like to present their design, price calculation, and initial results from the trial operation.

## Treatment wetland Držovice

The first wetland is designed for facilities with highly seasonal usage, with an expected capacity of more than 100 guests in the high season, with the possibility of accommodating up to 30 people on site and only a site manager in the low season. The treatment wetland was originally designed with a capacity for 50 PEs, with a bed area of 50 $m^2$. But the local water authority insisted on greater safety, so the size is now 68 $m^2$.
Pre-treatment is provided by a 16 $m^3$ septic tank consisting of two concrete sumps of 10 and 6 m3. The second sump is equipped with an effluent filter. The pre-treated water is pumped to the wetland. The wetland bed is divided into two equally sized parts. Both parts are aerated by one blower with a capacity of 200 l air/$m^2$. Both the blower and the pump are connected to a simple alarm system that sends an SMS in case of failure of these devices.

## Treatment wetland Hamráček

This wetland is designed with a capacity of 50 PE and a surface area of 50 $m^2$ and works for a restaurant building with planned accommodation in caravans or camping houses. In this case, the pre-treatment is provided by a series of 4 tanks, the first being an existing concrete sump of approximately 6 $m^3$, supplemented by 3 identical plastic tanks of 5 $m^3$. The outflow from the septic tank is again fitted with an effluent filter and pumped on the wetland bed. The main difference from the previous system is that water recirculation can be used to achieve better treatment results. The standard recirculation ratio is 1:1 but can be adjusted as required (e.g., completely interrupted). The air is again blown in by a blower with a capacity of approx. 200 l/m2. The treated water is then discharged into the infiltration object but can be used for garden irrigation and is planned for toilet flushing in the future.

## Summary and results

A major advantage of the actively aerated wetland is its low investment costs. Both treatment plants were built with investors, who mainly provided earthworks and gravel. The total construction costs of these plants were below 400 euros/PE. A sampling campaign will be carried out this year as part of a trial run, and the results for a substantial part of this year will be presented at the conference.

BIO of Presenter:
**Vit Rous** is an environmental engineer focusing on nature-based solutions in water management.

# Intext platform: innovative hybrid intensive – extensive technologies for wastewater treatment in small communities

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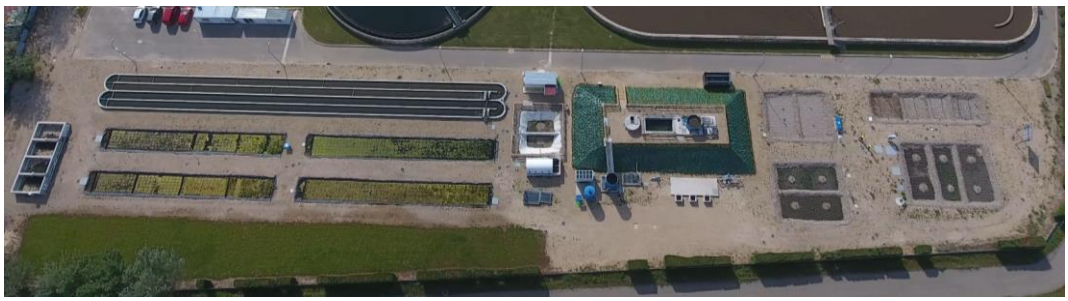
**LIFE INTEXT**

The LIFE INTEXT project, led by Aqualia, proposes the footprint reduction of constructed wetlands (CW) through the INTensification of EXTensive wastewater treatment systems into innovative INTEXT technologies. This communication provides information on the INTEXT platform at Talavera de la Reina (Spain) which includes up to 16 different INTEXT technologies, including several CWs designed in collaboration with the project partners SYNTEA/EcoBIRD, PROJAR and AIMEN:

- **French system** – A 2 stage vertical flow constructed wetland (200 $m^2$, 19 $m^3$/day, 125 PE) treating raw wastewater built to allow comparison between a well proved and robust type of constructed wetland with other INTEXT technologies.
- **Rhizosph´air®** - Single stage constructed wetland (120 $m^2$, 19 $m^3$/day, 125 PE) treating raw wastewater is intensified with forced aeration for improved treatment and footprint reduction.
- **Aerated Horizontal Flow CWs** – Two forced aeration CWs (72 $m^2$, 12 $m^3$/day, 80 PE) designed to treat either primary effluent from the first stage of a French system or effluent from an anaerobic UASB pretreatment.
- **Vertical Flow CW** – Designed to treat anaerobic UASB pretreatment effluent (50 $m^2$, 9 $m^3$/day, 60 PE).
- **Sludge Drying Reed Beds** – Designed to treat and accumulate activated sludge from Talavera WWTP oxidation ditches and anaerobic sludge from the anaerobic UASB pretreatment (60 $m^2$, 6,5 kgDS/day), or to polish suspended solids from the secondary effluent of a high-rate algae pond and a trickling system as a substitute to conventional settlement tanks (25 $m^2$, 12 $m^3$/day, 80 PE).
- **Floating CW** - (500 $m^2$, 76 $m^3$/day, 500 PE). Floating CW systems intensified with blowers and pumps for internal recirculation.



Comparison of these systems under similar environmental conditions will start in April 2023. A comprehensive process validation will allow assessing system response to organic load and hydraulic stress tests which are representative of small-communities sanitation. Explanation of the INTEXT platform and main results of the different technologies will be provided at the conference.

BIO of Presenter:

**Rubén Hervas** is a project manager at Aqualia´s Department of Innovation and Technology since 2022. He holds a PhD in treatment wetlands and has several years of experience implementing NBS in the water industry. He is currently managing the LIFE INTEXT and H2020 NICE projects in Aqualia to promote NBS in the Spanish water industry.

# Hybrid constructed wetlands for the treatment of floriculture drainage water

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## Introduction

A floriculture company in the province of East Flanders, Belgium was granted a new environmental permit in 2021. Discharge limits to surface water were imposed, where 15 mg N $L^{-1}$ for TN and 2 mg P $L^{-1}$ for TP were most noteworthy. The company reuses approximately 80% of its process water. The remaining 20%, which corresponds with 15 $m^3$ $d^{-1}$, needs to be treated and discharged. The company was in favor of treating the discharge water with a nature-based solution. The main design constraint was the removal of TN, as the COD:N ratio was 1:2. The average influent composition of TN was 65% $NO_3^-$-N, 25% organic N and 10% $NH_4^+$-N.

## Design treatment system

The wastewater is first passed through a Forced Bed Aeration (FBA®), enhancing the oxidation of the organic N and $NH_4^+$-N. Low BOD concentrations are also removed here, limiting further denitrification. Subsequently, the water is passed through a series of three surface flow CWs, planted with different species. Plant detritus is the main electron donor for denitrification. However, during periods of low detritus production and colder seasons, an additional electron donor is required for denitrification. After the surface flow CWs, the water is collected in a pumping well, where an additional carbon source can be dosed for further denitrification. The carbon dosing is water temperature controlled, with higher dosing at lower temperatures. Next, a second FBA® removes remaining BOD. As a last step before discharge to surface water, the wastewater is passed through a tobermorite filter, acting as a phosphate adsorbent.

In the period of 2021-2023, 17 influent and effluent grab samples were taken and analyzed.

## Results

During a difficult start-up phase, multiple adjustments were made to the carbon dosing system: (1) technical issues with the dosing pump were resolved; (2) mixing of the carbon source in the pumping well was improved; (3) viscosity of the carbon source was lowered through dilution with water and (4) more carbon was dosed at given temperatures. Since the beginning of 2023, TN discharge limits were met with on average 7.4 ± 2.4 mg N $L^{-1}$.

Effluent TP was 0.56 ± 0.63 mg P $L^{-1}$, with one sample above the discharge limit, probably due to a measurement error. The tobermorite filter raised the effluent pH above the limit of 9. The piping was rerouted, so only half of the original tobermorite filter was operated. No changes in effluent TP were observed, but effluent pH decreased to 8.72 ± 0.12, reaching discharge limits.

BOD and COD concentrations always met discharge limits, as the second FBA® efficiently removed residual concentrations.

BIO of Presenter:
**Flor Louage** is a PhD student and teaching assistant at Ghent University, Campus Kortrijk. He is involved in topics around nature-based solutions for wastewater treatment. He did his master thesis in Ecuador on the treatment of shrimp pond effluent with local available macroalgae.

# Non-point source pollution I

# Favourability maps for planning nature-based solutions for agricultural water management in Europe

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**Abstract**
Water management is essential to agriculture: crops require sufficient water of appropriate quality to balance their evapotranspiration, and agricultural activities may be a significant source of pollution for surface and groundwater. Water management requires adequate infrastructure, including treatment plants and storage volumes. These can be designed in order to exploit natural processes, using biological and geological materials, so that they provide the service required while they contribute to improve the agricultural landscape and to support biodiversity. In this case, we speak about “nature-based solutions” (NBS). We consider the following types of NBS:

1) Treatment wetlands for the removal of excess nutrients originating from manure and sewage sludge;
2) Landscape elements, such as buffer strips, ponds and vegetated ditches, for the mitigation of diffuse nutrient pollution;
3) Ponds for the storage of runoff, or its infiltration in aquifers (managed aquifer recharge), in order to support irrigation.

This work documents the criteria proposed to map the favourability to investments in NBS for agricultural water management, the costs and effectiveness of various types of NBS. We identify areas where the selected typologies of NBS can be implemented, taking into account various landscape suitability constraints, such as slope, elevation, flood hazard, or water table depth. We introduce indicators representing the intensity of "demand" for NBS, i.e. presence of diffuse pollution, excess manure and sewage sludge, soil erosion and pesticide, summer deficit of precipitation with respect to potential evapotranspiration, lack of biodiversity at the landscape scale, and intensity of extreme precipitation requiring flood buffering. We developed a simplified methodology for estimating NBS investment and operational and maintenance costs, differentiated among different type of NBS and scalable among different European countries based on a limited number of parametric costs (e.g. excavation, filling media, personnel).
We propose an approach based on this information to build scenarios of implementation of NBS, which can be applied for the appraisal of programmes of measures at the regional and European scale. Indeed, we can use the information on demand to select priority sub-basins for implementation. A sub-basin could be selected because of its high primary demand, or because of a combination of multiple significant demands for primary and secondary services. Once priority sub-basins are selected, we can calculate the required extent of a given type of NBS as the demand divided by the performance of the unit area of NBS. Once we have estimated the extent of NBS required to meet the demand, we can compare the latter with the available land, in terms of suitability and as a percentage of the total agricultural land, and carry on with the minimum between demand and availability of land for NBS. On the basis of the costs per $m^2$ of NBS, we can estimate the overall cost of investment and compare it with the expected effect (cost-effectiveness analysis).

BIO of Presenter:

**Fabio Masi** is R&D Manager and Technical Director of IRIDRA Srl, since 1998 and Vice-President of Global Wetland Technology since 2012. He is PhD in Environmental Sciences and MSc in Environmental Chemistry (1991). He has more than 30 years of experience in sustainable water management and nature-based solutions for wastewater treatment.

# Using small riparian wetlands for surface water purification: effect on water nutrient concentration and biofilm function

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**Abstract**
Nutrients (i.e., inorganic nitrogen and phosphorus) are major diffusive pollutants originating from agriculture and wastewater treatment plants. Excess nutrient availability in steams and downstream lakes and coastal areas can led to massive ecosystem disruptions, such as eutrophication and hypoxia. To mitigate the negative effects of high nutrient concentration in aquatic ecosystems receiving agricultural and urban runoff, we propose to install small riparian constructed wetlands for nutrient transformation and removal.
The objective of our study was therefore to examine the purification efficiency of mesocosms constructed riparian wetlands using unsaturated vertical flow, followed by saturated horizontal flow bed in five different locations along a catchment, receiving different proportion of agricultural and urban runoff. The constructed wetlands receive water from the adjacent stream (<30% of discharge) and the effluent water from the constructed wetland is discharged back to the stream. To examine purification efficiency of the constructed wetlands, we measured the typical water quality parameters to evaluate organic matter and nutrients as well as in situ parameters including dissolved $O_2$, ORP, Electric conductivity and temperature at the river and the inlet and outlet water from the constructed wetland. In addition, we measured biological effects of water purification using biofilm. Assay biofilms were incubated twice in spring for four weeks in the inlet and outlet water from the riparian wetlands, and benthic biofilm structure (e.g., biomass and chlorophyll-a) and function (e.g., metabolism) was quantified (Figure 1).

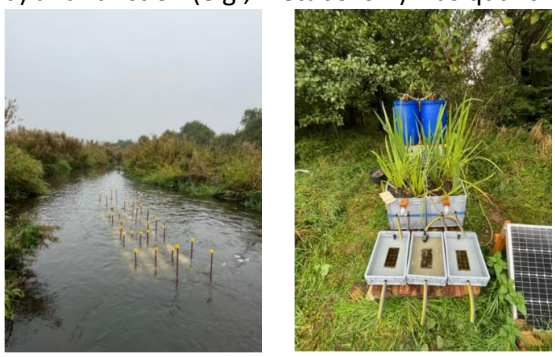

**Figure 1.** Placement of assays along the river and after the constructed wetland mesocosms

Preliminary results show that the constructed riparian wetlands receiving agricultural and urban runoff, efficiently removed organic matter, retained dissolved nitrogen but not phosphorus, and that biofilm biomass was lower, but primary production higher per surface area in the outlet when compared to the inlet water of the small constructed wetlands. This preliminary result also suggest that constructed riparian wetlands may be a useful mean to reduce adverse effects of high nutrient concentrations in downstream aquatic ecosystems.

**Acknowledgement**
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.101003765.

BIO of Presenter:
**Anne-Kirstine Dybdahl**, MSc in biology from Aarhus University where she is currently working as a research assistant with focus on nature restoration, gas emission from both natural wetlands, and nature-based solutions for polluted water treatment.

# Addressing nutrient removal from agricultural runoff and subsurface drainage using two pilot nature-based solutions, Austria

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**Abstract**
This research work falls within the conference topic: the role of nature-based solutions in pollutant management at the catchment scale of agricultural fields.
This work is part of WATERAGRI, an H2020 research and innovation project (G.A. 858375) aiming to re-introduce and enhance water retention and nutrient cycling solutions to enable sustainable agriculture and cope with climate change challenges. The project aims to re-introduce nature-based solutions, such as constructed wetlands and bio-inspired drainage systems in the agricultural landscape, leading to better water retention and nutrient retention. This research will present two types of systems, one addressing agricultural runoff (Mistelbach), and the other addressing subsurface drainage water (Gleisdorf). In the first pilot, we implemented three vertical-flow bio-inspired multi-layer filter systems in IBC tanks for better collection and measurement, on agricultural land in Mistelbach, Austria. The purpose was to retain water and nutrients from agricultural landover runoff from a 30 $m^2$ catchment area. The filter systems received surface runoff through a three-way distributor, every time there was enough precipitation to produce agricultural runoff. Investigation period: April-September 2022. The agricultural runoff of a 10x3m confined area was collected with a pipe 30 m long, so the water flows per gravity on top of the filter systems. The filter systems operated in parallel, and they differed in terms of substrate used in the main layer and presence or not of vegetation: 1) Biochar filter (not vegetated), 2) DrainGarden$^{(R)}$ filter (vegetated), 3) Soil filter (vegetated). The physicochemical parameters monitored in the effluent of the three filter systems were: ammonia, nitrate, orthophosphate, pH, and EC, while temperature and soil moisture sensors were installed in two depths of the filter system (17 and 30 cm). Tracer experiments using 50 L of 25 mS/cm NaCl were also carried out to have insight into filter hydraulic efficiency.
In the second pilot site, Gleisdorf, we developed a patron filter structure that was inserted in the agricultural drainage pipe of organic farmland. The filter structure was filled with zeolite 4-8 mm in the first stage and $Mg(OH)_2$ coated biochar 0-4mm in the second stage and water passed through it horizontally. Nutrients, pH, EC were monitored for the period 2022 and 2023. The results from both systems will be presented.

BIO of Presenter:
**Eriona Canga** is a researcher and project manager at alchemia-nova, Vienna. Her expertise is in the hydrogeochemistry properties of filter substrates to retain nutrients and pollutants from various sources (agricultural and municipal wastewater). She has 13 years of experience focused on constructed wetland technologies, nature-based solutions, and academia (lecturer).

# Are riparian buffer strips effective for nutrient retention under cold frozen conditions?

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**Abstract**

Riparian buffer strips, as nature-based solutions, are widely used to decrease the transport of soil nutrient from cultivated lands to streams, but effective nutrient retention in freezing cold conditions remains a challenge because herbaceous vegetation wilt in the winter by snow and ice and is not actively absorbing pollutants, while soils are frozen and infiltration is extremely limited or nonexistent. This study aimed to assess the impacts of riparian buffer strips on decreasing nutrients levels in agricultural runoff in northern China. Four field experimental plots with herbaceous were established adjacent to the agricultural edge from 2019 to 2023 under both cold and warm temperatures. Surface runoff samples were sampled by setting up paired weirs at 50 cm and at 600 cm into the riparian buffer strips along the expected runoff flow passage. Furthermore, nutrient concentrations were estimated in riparian buffer strip soil samples taken within and outside of the runoff flow passage to obtain additional understanding into nutrient dynamics within various riparian buffer strips. Overall, it was observed that riparian buffer strips possessed little or insignificant influence on decreasing the levels of nutrients in surface runoff in the most of circumstances, leading to decreased runoff losses of nitrogen and phosphorus levels in 15 and 8% of the circumstances. Furthermore, 30% of soil nutrient concentrations in the studied riparian buffer strips were significantly different from field soils and buffers (e.g., within the flow passage). This study also found that vegetation does release nutrients after undergoing freeze-thaw cycles, thus buffers can become a source of nutrients. The ineffective nutrients removal by buffers in this freezing cold area is likely connected to the fact that the most of the runoff flow is concentrated (rather than uniform sheet flow) through small parts of buffers and took place during snowmelt when biogeochemical processes responsible for nutrient removal in buffer zones are restricted. Further studies are required to establish develop alternative management measures that improve nutrient removal during concentrated snowmelt runoff periods in such cold-climate areas.

**Keywords**: Nutrient; Riparian buffer strips; Warm and cold climates; Nutrient retention by buffer zones; watershed management, freeze- thaw cycles

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BIO of Presenter:

**Mathieu Kumwimba** is a postdoc fellow, his research interests lie in the field of ecological control of NPS pollution and treatment of rural and urban wastewater in particularly by using vegetated buffer strips, vegetated ditches, and wetlands. He has earned a recognized scientific experience, with >30 scientific publications in SCI peer- reviewed journals. Dr. Mathieu has won various national and regional research grants as principal investigator. Passionate with environment safety and human wellbeing, he is looking forward to building a strong scientific career and interdisciplinary network.

# Improving the risk assessment of phosphorus loss from rewetted riparian wetlands in Denmark

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**Abstract**

It is well accepted that riparian wetlands under undisturbed conditions fulfil an important sink function for phosphorus (P). However, over the years, the important function of these ecotones as P sinks has been significantly altered due to human intervention in many parts of the world. Today, in the face of rising global challenges like eutrophication of water bodies associated with the decline of biodiversity, increasing greenhouse gas fluxes and other societal challenges, rewetting of wetlands is proposed as a valid cost-efficient nature-based mitigation solution. The challenge is, however, that the long-term drainage and intensive agricultural use of wetlands have created significant changes in both physical and chemical soil characteristics such as significantly increased dry bulk densities and mobile P content in connection with soil carbon mineralization and land use. During the last decades, we have gained a comprehensive understanding of the processes and driving factors controlling the cycling of nutrients in wetlands. Both the hydrology and the quality of the discharging water are important determinants of the physico-chemical conditions of an individual wetland, and they control a broad range of biogeochemical processes driving the P removal and thus the P export to downstream systems. This paper summarizes the recent improvement of a simple Danish P risk model applied before of rewetting riparian wetland systems including groundwater charged peatlands and floodplains. Further it will be shown how the challenge of complex wetland hydrology will be tackled currently to improve our assessment of P export from rewetted wetland soils to downstream systems.

BIO of Presenter:

**Dominik Zak** has 23 years' experience in freshwater and wetland-related environmental research, land use change, conservation, restoration. My research is strongly dedicated to interdisciplinary research integrating biology, ecology, microbiology, and hydrochemistry across aquatic and terrestrial systems.

# Resource recovery & pathogen removal

# Assessing the effectiveness of constructed wetland-derived sludge as biofertilizer

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**Abstract**

Sludge Treatment Constructed Wetlands (STCW) are an alternative to conventionally used technologies for sludge treatment, with the advantage that they reduce operating and maintenance costs, and are environmentally friendly. In addition, a dry, stable, and mineralized by-product known as a biosolid can be obtained. Thus, the large annual production of sludge generated in Wastewater Treatment Plants (WWTP) could be treated using this STCW technology and then biosolids produced can be reused, avoiding production of unmanage waste. Therefore, these biosolids can be reused as biofertilizers with the aim of replace mineral fertilize that affect physical, chemical, and biologically the quality of the soil. In this context, the present study had two main objectives: to characterize the sludge treated in STCW during the rest time (without sludge feeding) and to evaluate the quality of the biosolids in agronomic essay. Samples were collected from the WWTP Sentfore-La Guixa (1000 PE) and the WWTP Santa Eulàlia de Riuprimer (2000 PE) in Vic (Barcelona, Spain). Sampling campaigns (4 in total) were carried out every three months, beginning a week after STCWs received the last feeding (June 2022). In each facility, a representative bed was selected and divided into four sections; then, one sample was collected from each section and carefully mixed to obtain a composite sample of the bed. Standard techniques were employed to analyse the samples in triplicate; pH, total solids (TS), volatile solids (VS), nutrients, and metals were analysed conforming to the Standard Methods. To evaluate the agronomic potential of the biosolid, an experiment was conducted at the Tona WWTP in Barcelona. Three fertilizer treatment were tested to meet the nutritional requirements of the wheat crop: 3 Tn·ha of biosolids from STCW, 3 Tn·ha of crushed biosolid from STCW and 2 Tn·ha of mineral fertilizer. Three smallholdings (3x8 $m^2$) for each treatment were studied. 200 Kg·ha of wheat seed (KWS ultim) was sown, and samples of plants and soil were taken over a six-month period to assess the biomass and yield of the crop. The sludge with pH values were close to neutrality from 4,75 to 6,38 for both CW studied, so they could be safe for use as fertilizer. As expected, the TS values increase from 36% to 51% for the two STCW studied, showing the dewatering effect of the treatment after 6 months without feeding. On the other hand, VS were reduced after 6 months without feeding from 38-46% VS/TS to 37-50% VS/TS for La Guixa and St. Eulàlia, respectively, demonstrating progressive sludge stabilization and mineralization. Regarding nutrients, 2,4 % N, 8,95% $P_2O_5$ and 0,97% $K_2O$ were found for La Guixa and 2,8% N, 7,49% $P_2O_5$ and 1,09% $K_2O$ for St. Eulàlia, indicating the potential use of the biosolids as biofertilizer. The concentration of heavy metals did not exceed the limits established by the directives for the two STCW studied. Finally, crop trials are currently taking place, and it is expected that the biosolids will favour the wheat crop performance due to its nutrient content and its low content of heavy metals thanks to the stabilization process carried out in the STCW.

BIO of Presenter:

**Ana Cano** is a second-year PhD student at the Universitat Politècnica de Catalunya (UPC). She holds a Bachelor's degree in Industrial Microbiology (Universidad de Santander, Colombia) and a Master in Natural Resources Engineering (UPC). Her scientific interests are: sludge treatment, constructed wetlands, and biosolids as biofertilizers in a circular economy approach.

# Application of constructed wetland-derived compost: assessment of the circularity potential

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**Abstract**

Nature-Based Solutions (**NBS**s) have been widely investigated for substituting conventional treatment plants with eco-sustainable alternatives dedicated to resource saving and recovery. In such context, constructed wetlands (**CW**s) have been studied as cheap and environmentally-friendly solutions for the wastewater treatment and for carbon sequestration, in the perspective of circular agriculture and green economy. More specifically, the composting of the crop biomass produced in **CWs**, either alone or combined with agricultural waste such as plant debris or anaerobic digestates, can represent a partial solution for carbon sequestration, waste valorisation and nutrients recycling.

In such framework, this study investigated a full-scale CW (3700 $m^2$) located in Budrio, Italy, mainly cultivated with *Phragmites australis* (Reed), species selected for the low input requirements and the high phytoremediation potential. This **CW** has performed efficient agricultural drainage water treatment for 23 years and can be regarded as a semi-natural system. In such framework, harvested Reed was used to produce either pure compost (***RC***), or mixed with 75 % (wet wt.) potato cuttings (***PC***) or with 37 % (wet wt.) liquid anaerobic digestate (***DC***), to promote both circularity and carbon sequestration by revalorising the harvested biomass and the nutrients-rich agricultural wastes that are generally discarded.

The produced composts were tested in pot over 60 days on lettuce, in a full organic (100 % N from compost) and a mixed organic-chemical fertilization paths (50 % N from compost + 50 % N from chemical fertiliser), along with a reference green waste compost (***GWC***), a chemical N-P-K reference (***Chem***) and an unfertilized control (***Ctrl***). The tissues were analysed for total nitrogen (N) and the soil for the total organic carbon (TOC).

Amongst the compared composts, ***PC*** at 100 % yielded the best dry biomass weight (2.8 g $pot^{-1}$), higher than ***DC*** and ***RC*** (1.6 and 0.9 g $pot^{-1}$). Similar pattern was detected at 50 %: ***PC*** (2.4) > **DC** (2.0) > **RC** (1.8) g $pot^{-1}$. ***GWC*** was intermediate at both 100 and 50 % (2.3 and 1.6 g $pot^{-1}$), while ***Chem*** performed the best (3.1 g $pot^{-1}$). The ratio $N_{uptk}/N_{applied}$ *vs.* ***Chem*** $N_{uptk}/N_{applied}$ (relative agronomic efficiency, N-RAE %) can give a better insight to the N utilization from the different composts and application levels. At 100 % compost application, N-RAE (%) was the best in ***PC*** (60) > ***DC*** (21) > ***RC*** (10). At 50 %, a similar N-RAE (%) pattern was detected, to a different extent: ***PC*** (76) ***DC*** (53) > ***RC*** (52). ***GWC*** resulted intermediate, attaining 57 and 52 N-RAE (%) at 100 and 50 % application level, respectively.

The different composts yielded different lettuce dry biomass: at 100 %, ***PC*** performed the best, being in the same range of ***Chem***, and thus managing to substitute chemical fertilization almost completely. The use of the combined organic-chemical fertilization strongly reduced the variation between treatments, generally promoting higher N-RAE, which resulted 37 and 58 % at, respectively, 100 and 50 % compost application level. Soil analysis showed that compost at 100 % attained the best TOC, reaching about 20000 mg $kg^{-1}$ on average. At 50 % application level, a TOC of about 16500 mg $kg^{-1}$ was attained. However, both compost application levels performed better than ***Ctrl*** and ***Chem*** (≈15000 mg $kg^{-1}$, on average).

These results indicated that the biomass harvested from the **CW**s can represent an interesting material for composting, combining carbon sequestration and nutrients recycling potential of these system, in addition to their wastewater treatment capacity.

BIO of Presenter:

**Francesco Chioggia** is bachelor in pure chemistry and Master in environmental sciences and technologies, M.Sc. Francesco Chioggia is Ph.D. student at the Department of Agricultural and Food Sciences (DiSTAl) of the University of Bologna. His main studies contemplate the application of NBS for wastewater remediation and the reuse of their various outputs.

# Effect of granulometry and loading rate in vertical sand bed filter for pathogen removal of municipal wastewater

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**Abstract**

Outbreaks of waterborne diseases are of great concern, particularly in some developing countries or when water reuse is considered and in countries lacking of widespread wastewater treatment. Across the water spectrum, enumeration of bacterial contaminants i.e., Total Coliform, Fecal Coliform (hereinafter denoted as T.Coli, F.Coli, respectively), and *Escherichia coli* was oftentimes conducted, to evaluate the performance of a particular treatment method for pathogen removal. Former investigations verified the merits of sand bed filters dealing with pathogen removal as well as their relevant practice for nature-based solutions. In fact, grain size and loading rate reportedly mattered administering their performance. This study was set up to observe the mode of T.Coli, F.Coli, and *E.coli* removal from real municipal wastewater via sand bed filter implementing different grain sizes as well as loading rate adjustment. Additionally, some standard water parameters were likewise analyzed and associated.

The experiment was carried out at Aarhus University Påskehøjgård greenhouse facility, Denmark from November 2022 to February 2023. Twelve PVC columns (Ø160 mm, h: 505 mm) were set up having four different types of grain sizes i.e., sand grain A (0–2 mm), B (0.4–0.8 mm), C (0–4 mm), and D (mixed sand) and were configured in vertical flow. The sand categories are typically used for water filtration (except for sand grain C, commonly used for construction purposes). Sand grain D was the mixture of grain C and another sand having the same granulometry of 0–4 mm (ratio 1:5). The base part of each column (underneath the sand bed) was filled with gravel. The height of sand bed and gravel section was 390 and 55 mm, respectively. There were five sampling batches in which the loading rate was fortnightly increased (5.7, 10.5, 17.25, 23.9, and 33.4 $cm.d^{-1}$). T.Coli, F.Coli, and *E.coli* were quantified in MPN unit using IDEXX Colilert-18/Quanti-Tray® method.

The granulometry test showed that the employed sand was confirmed as a uniformly graded cluster having a uniformity coefficient range of 2.25–2.52. This range fulfilled the recommended value for the projection of vertical flow system Constructed Wetlands. In the overall system, the highest average removal was 2.6 $log_{10}$ for T.Coli, and 3.38 $log_{10}$ for both F.Coli, and *E.Coli.* Sand grain size and loading rate had each significant effect on T.Coli and *E.coli* removal ($p<0.05$). Both sand grain A and D showed equal performance on T.Coli and *E.coli* removal ($p>0.05$), hence, the type D was thereby put into preference, as the $D_{60}$ of the sand type A was observably the lowest as compared to the other counterparts (0.36). The increase of loading rate of more than 17.2 $cm.d^{-1}$ led to the decrease in Total Coliform and *E.coli* removal. Removal of F.Coli was insignificant in terms of different sand grain sizes effect ($p>0.05$), but was significant in response to loading rate adjustment ($p<0.05$). The Fecal coliform removal decreased along with the loading rate increase, however, such was not the case for the sand grain A and D at the loading rate of 33.4 $cm.d^{-1}$. Besides, our result indicated that T.Coli and *E.coli* were positively associated upon each other, and their removal was likewise positively correlated mainly with the COD removal.

**Acknowledgement**

The present study is funded by the EU Horizon 2020 under grant agreement No.101003765.

BIO of Presenter:

**Mayang Perdana** is a PhD student at the Department of Applied Ecology, CULS Prague. Her current study focuses on the use of commercial reactive materials for micropollutants removal from greywater via nature-based solutions.

# Nutrients recovery and pathogen removal for wastewater reuse combining microalgae and constructed wetland systems

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## Demonstration plant

A 3,000 $m^2$ microalgae High Rate Algae Pond reactor (HRAP), followed by a dissolved air flotation unit (DAFAST) as harvesting system and 5x50 $m^2$ vertical constructed wetlands as polishing step, were commissioned in El Toyo WWTP (Almería, Spain) in the frame of H2020 Incover and LIFE Biosol projects (Fig 1).The efficiency and reutilization capacity of the wastewater treatment process is assessed under the favorable solar radiation conditions for photosynthetic microorganisms of South Spain (more than 6.5 kWh $m^{-2}$ of solar radiation in Summer).

**Figure 1.** Panoramic view of the demonstration plant at El Toyo WWTP (Almería).

## Results and discussion

El Toyo demonstration plant has been operated under real conditions treating urban raw wastewater from 2,000 population equivalent (PE). The treatment process can produce an effluent with low pathogen detections after the polishing treatment based on vertical wetlands and solar disinfection, that can be reused for irrigation purposes (European Regulation 2020/741).

The periodic analyses of the plant show favorable removal efficiencies with the combination of the three different technologies. During the summer, an overall COD removal of 97% was achieved; TN and TP removal reached 77% and 90%, respectively; and TSS removal came to a value of 99% during the whole period.

Data collected after the constructed wetlands indicate that an operation with no significant seasonal variations was recorded, leading to quite a constant effluent quality. These results also confirm that the wetlands effluent meets the legal limits for its use for agricultural, industrial, or environmental purposes (EU 2020/741), with a reduction of up to log 6 of E. Coli with respect to the raw wastewater and with very low TSS (<0.3 mg $L^{-1}$), turbidity (<0.5 NTU) and pathogen content (E. Coli < 100 CFU/100 mL). This, in combination with their scarce maintenance and operational problems, make this system robust and ideal as a polishing step after the main wastewater biological system.

Furthermore, characterization of microalgae biomass after harvesting in the flotation unit have shown interesting biofertilizer, biopesticide and biostimulants properties for its use in agriculture, providing an added value to the biosolids obtained from wastewater and promoting nutrients recovery in WWTPs.

BIO of Presenter:

**Enrique Lara** is a Process Manager of the R&D department of Aqualia, and a former Technical Director of Aqualia Industrial, a company that designs and installs full scale wastewater plants in municipalities and industry. He has 33 years of experience in municipal and industrial wastewater treatment and handling difficult substrates, with 9 patents and more than 40 papers and conferences in the sector. He is specialized in the whole Innovation and commercialization pathway, scaling up from laboratory to full-scale plants and final market product development and commercialization.

# Electrochemical disinfection systems for water reclamation from constructed wetland effluents

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**Abstract**

Constructed wetlands (CWs) can treat wastewater efficiently at low energy costs and with non-specialized maintenance. However, enteric pathogens removal is only sometimes guaranteed to meet water reuse standards. Coupling CWs with disinfection technologies is currently being investigated to safeguard non-potable water reuse in remote locations. Electrochemical disinfection (ECD) via in situ oxidant production has recently attracted interest as it allows inactivation of pathogens and residual action to rule out pathogen regrowth. This coupling of CWs with ECD (CW+ECD) has been proven efficient for water reclamation at lab-scale. However, very few studies have shown experiments under actual field conditions and during long-term operation.

In this study, we test the CW+ECD coupling to continuously treat for 21 weeks the wastewater from an educational building in Kortrijk, Belgium. A two-staged aerated CWs (pore volume of 0.7 $m^3$) was continuously fed with septage water. The CW was coupled to an electrochemical cell consisting of an anodic and a cathodic compartment (dimensions 5 × 20 × 2 cm) divided by either a 100 $cm^2$ cation exchange membrane (CEM) or an anion exchange membrane (AEM). During the experiments, a power supply was used to set a fixed current (50 A $m^{-2}$). The anode was a 5 × 20 cm Ti/$IrO_2RuO_2$ electrode (MMO Magneto, Netherlands), and the cathode was stainless-steel mesh (AISI 316L mesh size 495 µm, Solana, Belgium). The system ran continuously using peristaltic pumps. Water samples were collected weekly for examining (in)organic removal and disinfection effectiveness.

Effective COD removal (averaging 84.2 ± 5.9 %) and complete nitrification were observed with the aerated pilot CW for 25 weeks, after the 3.5 weeks of maturation period. As expected, the fecal coliforms were removed below < 1.9 logs, unacceptable for water reuse. CW effluents were then treated with different ECD configurations, obtaining water free of total coliforms. A configuration allowed the passage of the CW effluent from the anodic compartment to a contactor (0.2 L) and finally through the cathodic compartment to assure that the treated water recovered a circumneutral pH. Despite disinfection being achieved, the system failed when the cell voltage reached the power supply limit (31V), in less than 1 week. The CW effluent was calcium-rich (130.5 ± 41.7 mg $L^{-1}$), which provoked salt precipitation at the cathode and the ion-exchange membrane. Another configuration used (calcium-free) rainwater in the cathodic compartment for producing an alkaline stream to remove calcium from the CW effluent via precipitation before being pumped to the anolyte. The latter ECD configuration was able to run for at least 21 weeks, and disinfection was proved with 4 indicators: *Escherichia coli*, Total Coliforms, Heterotrophic plate counting, and *Enterococcus.* This work illustrates the feasibility of the coupling (CW+ECD) for water reuse and highlights strategies to deal with the impact of scaling in ECD.

BIO of Presenter:

**Suanny Mosquera-Romero** is a researcher and lecturer at the Escuela Superior Politécnica del Litoral (ESPOL)-Ecuador. She pursued a Master in environmental sanitation at UGent. She is ending her PhD in bilateral cooperation between UGent and ESPOL focusing on constructed wetlands coupled to electrochemical systems for water treatment and resource recovery.

# Antibiotics & pharmaceuticals removal

# Nature-based solutions to reduce antibiotics and antimicrobial resistance in aquatic ecosystems

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**Abstract**

Antibiotics (ABs) have been found in 2/3 of the world's rivers and experts expect a 65% increase of drug concentration in water by 2050. Once in the environment, ABs can promote antimicrobial resistance (AMR) which creates resistant microbial strains posing a risk to ecosystems and human health. AMR is already responsible for an estimated 33,000 deaths per year in the EU and costs €1.5 billion per year in healthcare costs and productivity losses. The NATURE project (https://www.natureproject.eu/) aims to explore the use of nature-based solutions (NBS), especially wetlands, as management option for reducing the presence of ABs and AMR at the river catchment scale, from wastewater treatment to estuarine areas in four countries (Denmark, Spain, Portugal, and Mali).

The results show the presence of several classes of ABs (fluoroquinolones, lincosamides, macrolides, sulfonamides, and rifamycin) and AMRs in wastewater samples, but their concentration and abundance were highly variable (ranging from 4 to 760 ng/L), at least in small decentralized wastewater treatment NBS monitored in Denmark (10 to 100 PE). Trimethoprim was the most abundant AB in the pre-settled wastewater from Denmark, whereas in the case of the Spanish site, clindamycin and azithromycin were the most abundant compounds in secondary treated wastewater effluents. The main results achieved so far demonstrate that the use of NBS as secondary or tertiary wastewater treatments results in a greater removal of ABs and AMR than conventional wastewater treatment solutions. For example, average removal of identified ABs and AMR (intI1 and sul1) in conventional tertiary wastewater treatment was of 40% and 1.5 log units, whereas these removals increased up to 70-80% and 2-3 log units by using NBS, respectively. Similarly, the renaturalization of river streams has been observed to enhance the attenuation of antibiotics by 30-40%. Several micropollutants have been detected in water of a Portuguese river estuary, all at low amounts (concentrations lower than 5 ng/L except for trimethoprim, which was detected up to 100 ng/L). However, the most abundant compounds were anti-inflammatory and analgesic compounds (up to 2,700 ng/L for acetaminophen). The potential of the estuarine saltmarsh to remove these pollutants is being evaluated. Results from Mali indicate that hospital wastewater effluents discharging into the Niger river are a very important source of ABs, reaching concentration levels greater than 30,000 ng/L (ciprofloxacin and acetyl-sulfamethoxazole). Therefore, we expect that the implementation of NBS at these sites would aid to reduce the impact of ABs and AMR into the Niger river. Overall, the results demonstrate that the implementation of NBS at different river catchment levels (wastewater treatment, river stream or estuarine area) can improve the attenuation of ABs and AMR.

BIO of Presenter:

**Victor Matamoros** is currently research scientist at the Institute of Environmental Assessment and Water Research (IDAEA). His field of expertise lies on the understanding of the attenuation mechanisms of emerging and priority pollutants in nature-based solutions (constructed wetlands, microalgae systems, biofilters, and natural wetlands).

# Innovative hybrid intensive – extensive resource recovery from wastewater in small communities

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**Abstract**

LIFE INTEXT project aims to develop innovative solutions based on a combination of INTensive and EXTensive technologies for dealing with urban wastewater treatment in small communities. Two demo sites have been constructed in Talavera de La Reina (TALAVERA, ES) and Carrión de los Céspedes (AMAYA, ES), with a combination of traditional technologies and nature-based solutions such as floating, clarifying, aerated and sludge treatment wetlands. Emerging pollutants (EP) are a growing concern since most of them represent potential risks to human health and aquatic ecosystems. The study of the removal of these contaminants with hybrid combinations of technologies at demo scale is still uncertain. The objective of this work is to assess the removal of emerging pollutants using novel and different combinations of traditional technologies and nature-based solutions in both technological platforms developed in LIFE INTEXT. Initial screening campaign was carried out to select the EP under study in the project. A total of 22 compounds of 3 groups of EP: *pharmaceutical*, *hormone* and *biocides* were studied. All the sampling process was developed under the recommendations of Robles-Molina et al. (2012)[1]. A total of 8 EP were detected in each demo site and they will be monitored along the project according to i) their presence in the raw wastewater; ii) inclusion in the Watch List 1&2[2]; iii) their potential hazard to aquatic environment (Reg EC 1272/2008).

The first campaign results (January 2023) have preliminarily demonstrated the capacities of the technologies to abate these compounds. According to the results, in TALAVERA *Azithromycin* and *Acetaminophen* stand out with a higher inlet presence (7.47µg/L and 14.42 µg/L, respectively). Nevertheless, these EP have reached the highest removal capacity in all the technologies. On the other hand, *Sulfamethoxazole* is present in the wastewater in a low concentration (< 2.5 ug/L) but it is the most difficult to remove for the technologies studied. Likewise, in AMAYA the *Acetaminophen* stands out with a high presence, ranging between 19 - 29 µg/L, with significant removal for the technologies analysed. Besides, *Imidacloprid* is the compound in lower concentration in the inlet wastewater and, the removal performance achieved for the technologies is the lowest.

The results of the first campaign are promising but further sampling campaigns are needed to compare the results between novel combinations of technologies.

BIO of Presenter:

**Cristina Ávila** is senior researcher at the Environmental Tech Unit of AIMEN since 2018. She holds 15 years of experience in R&D on wastewater (WW) treatment through constructed wetlands and other NBS, focusing on nutrient and emerging contaminant removal. She has participated in more than 15 regional, national and international projects and is currently PI of the projects LIFE GREEN ADAPT for treatment of landfill leachate and LIFE INTEXT for decentralized WW treatment in small communities.

LIFE INTEXT is a project co-funded by the European Union under the LIFE Programme Grant Agreement nº. LIFE18 ENV/ES/000233

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# Treatment wetlands for controlling wastewater-born antibiotic emissions

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**Abstract**
Treatment wetlands are among the most competent and frequently applied nature-based solutions (NBS) for wastewater treatment. Treatment wetlands, namely horizonal flow (HF) and vertical flow (VF) systems, have been demonstrated to provide attenuation of organic micropollutants as secondary and/or tertiary wastewater treatment. In the last years, novel concepts such has the hybridization of bioelectrochemical systems and treatment wetlands have emerged, but their efficiency to remove organic micropollutants, including antibiotics, is yet unknown. The present work, developed within project NATURE, aims at comparing the efficiency of three different full-scale systems (and configurations) for controlling the emission of antibiotics.
The similar size (approx. 30 – 200 PE) study sites started to be monitored in May 2022 and will complete a 1-year monitoring cycle in May 2023. The bioelectrochemical treatment wetland (200 PE) has two beds 45 $m^2$ each, the vertical flow treatment wetland (60 PE) has two beds 96 $m^2$ each, while the aerated treatment wetland (30 PE) has a single 30 $m^2$ bed. All sites are located in Denmark and have a sedimentation tank as pre-treatment. The monitoring work includes monthly characterisation of water quality parameters (e.g. pH) and regulated pollutants (e.g. NH4-N), as well as quantification of antibiotics and antimicrobial compounds - 12 antibiotics; 5 antimicrobials (e.g., quaternary ammonium chlorides), 3 antifungal agents (e.g., miconazole), and 22 other domestic wastewater-relevant micropollutants.
Results, so far, show a sparse occurrence of antibiotics in the monitored decentralized wastewater systems (< 200 PE). In the bioelectrochemical system 3 antibiotics were measured (sulfadiazine, sulfamethizole and trimethoprim with 3/8, 3/8 and 3/8 occurrences), in the aerated system 2 antibiotics were measured (sulfamethizole and trimethoprim with 1/8 and 8/8 occurrences), while in the vertical flow system 2 antibiotics were measured (azithromycin and sulfamethizole with 2/8 and 6/8 occurrences). Antibiotics tended to be measured in the cold seasons (Autumn and Winter). Maximum concentrations measured were 2.8 µg/L for azithromycin, 0.36 µg/L for sulfadiazine, 5.5 µg/L for sulfamethizole, and 3.7 µg/L for trimethoprim. The compound occurrence in these decentralized systems is lower than for large urban wastewater treatment plant (WWTP). Moreover, the inlet concentration in the decentralized systems tends to be larger than for large WWTP. In terms of removal performance, the bioelectrochemical system showed removal in the range 47 – 72%, but was antibiotic specific and for sulfamethizole removal varied from no removal to 72% removal. The aerated system showed on average 94 % removal of trimethoprim. For the vertical flow system azithromycin was well removed (96%) while sulfamethizole removal ranged from 35 to 87% removal. At WETPOL2023 we will present these and other highlights of the 1-year monitoring results of the three NATURE Danish study sites providing secondary wastewater treatment.

**Acknowledgement**
NATURE project financed by the AquaticPollutants ERA-NET Cofund (GA no. 869178)

BIO of Presenter:
**Pedro Carvalho** is Associate Professor in environmental chemistry with an extensive research activity in water treatment technology. He has more than 15 years of experience working with organic micropollutants in the environment and more than 10 years dedicated to micropollutants occurrence in wastewater and their fate in treatment wetlands.

# Biochar

# Biochar from recovered cellulose as new substrate for micropollutant removal in a circular economy perspective

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**Abstract**

Average person uses around 85 rolls of toilet paper per year, meaning that a thousands of tons of paper ends up in the wastewater treatment plants (WWTPs) through the sewage. In this context the Interreg North-West Europe project WOW! - Wider business Opportunities for raw materials from Wastewater- aims to recover that cellulose as raw material for the production of activated biochar that can be applied as admixture in constructed wetlands (CWs) for micropollutants removal. Cellulose was recovered by CirTec B.V (The Netherlands) from the inflow of Ede WWTP (The Netherlands) and Klimafarmer GmbH (Germany) processed it obtaining three different mixed pellets: 100% cellulose, 50% cellulose-50% straw and 50% cellulose-50% wood. Those three products were carbonized at 750°C for 210 minutes to obtain highly aromatic and non-polarized biochar. After that, they were biologically activated by fermentation and sent to the University of Luxembourg to assess their capability in micropollutants elimination.

Fig. 1. From left to right: raw cellulose, mixed pellets, carbonized pellets and biologically activated biochar.

The three types of biochar were characterized physically and chemically before and after the activation. Removal of 5 micropollutants was evaluated: benzotriazole, carbamazepine, clarithromycin, DEET and diclofenac. Adsorption was tested in batch mode via bottles in a shaking table and in continuous mode with rapid small-scale columns. As happens with other adsorbents, such as granular activated carbon, diclofenac was the most recalcitrant one, so it was used as a reference to compare the different biochars. 100% cellulose and the mix with straw showed a high adsorption capacity in batch (82% and 72% respectively in 4 days) and in continuous mode when comes to the non-activated variation. Contrary to our expectation, the removal via adsorption was significantly lower for the activated biochar: 25% and 14% for 100% cellulose and the mix with straw respectively in 4 days, which suggests that during fermentation the material has undergone a disadvantageous physical-chemical change. Physical surface characterization performed by 3P instruments confirmed this behavior. $CO_2$-BET surface area ($m^2/g$) for 100% cellulose, the mix with straw and the mix with wood was 211, 243 and 280 respectively for the non-activated biochar but it was not possible to determine it for the activated one due to the instability of the isotherms. This shows the importance of microorganisms in biologically activated materials, not only due to the changes induced in the material, but also for the role that they play as pollutant-purifier (namely bioremediation), which is one of the main depurative mechanisms involved in CWs performance. For this reason, microbiological activity analysis will be included also in this study to select the most suitable option to be implemented and tested at pilot scale at Bliesen WWTP (Germany).

BIO of Presenter:

**Joachim Hansen** is Professor for Urban Water Management at University of Luxembourg. Civil Engineer from his background, he has more than 30 years experiences in wastewater treatment with specific focus on micropollutant elimination, energy efficiency and development and application of sustainable technologies in the Urban Water cycle.

WETPOL 2023
Bruges Meeting & Convention Centre, Belgium

# Assessment of aging biochar properties in constructed wetlands

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**Abstract**
Biochar is recognized worldwide for environmental remediation and is therefore increasingly used in constructed wetlands (CWs) as an alternative substrate. While most studies have focused on the positive contributions of biochar to pollutant removal in CWs, less is known about the aging and longevity of the embedded biochar. In this study, litter bags containing biochar were inserted in two aerated horizontal subsurface flow CWs (350 m² each) which were post-treating the effluents of both a municipal and an industrial wastewater treatment plant. The bags were retrieved on several dates (8 to 775 days after burial) and assessed for weight loss/gain and changes in the biochar characteristics. Besides, a 525-day laboratory incubation test was also conducted to analyze the biochar mineralization.
Overall, no biochar weight loss was observed over time in the CWs. On the contrary, a slight increase (2.3-3.0%) in weight was observed, presumably due to mineral sorption from the wastewater. Biochar pH relatively remained stable (7.5-8.0) except for a sudden drop at the start (8.6 to 8.1). In contrast, biochar electrical conductivities continued to increase (96 to 256 µS. $cm^{-1}$) throughout the experiment. The sorption capacity of the aged biochar for methylene blue was significantly increased (1.0 to 1.7 $mg.g^{-1}$). FTIR analysis revealed that some additional oxygen-containing functional groups were formed on the biochar surface thereby improving the adsorption capacity. Furthermore, a change in the biochar's elemental composition was also noted, as the O-content increased by 13-61% whereas the C content decreased by 4-7% indicating some oxidation taking place as the biochar aged in the CW. Nevertheless, the biochar was deemed to remain stable according to the European Biochar Foundation and International Biochar Initiative criteria. The incubation test also indicated a negligible biochar mass loss (< 0.02%), validating it as well-stable biochar. This study is beneficial to understand the evolution of biochar characteristics in CWs.

**Keywords:** Aerated constructed wetlands, biochar aging and stability, tertiary treatment

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BIO of Presenter:
**Hafiz Khan** is a Ph.D. student at Ghent University, Department of Green Chemistry and Technology, Kortrijk, Belgium, and working on intensified constructed wetlands. His entire Ph.D. work was on the two pilot scale intensified constructed wetlands at Dow Industries (Terneuzen, the Netherlands).
https://kenniscentrumtoerisme.nl/images/0/00/WetlandsHybridDesalinationDowTerneuzen.pdf

# Immobilization of chromium enhanced by arbuscular mycorrhizal fungi in semi-aquatic habitats with biochar addition

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**Abstract**

Arbuscular mycorrhizal fungi (AMF) exhibit great potential in heavy-metal immobilization in semi-aquatic habitats. Under high heavy-metal stress, however, the role of AMF is limited, and the detoxification mechanism of AMF in heavy metals' stabilization remains unclear. This study investigated the effects of AMF on a wetland plant (*Iris pseudacorus*) and chromium (Cr) immobilization at different water depths in semi-aquatic habitats with biochar addition. Results showed that AMF increased the physiological and photosynthetic functions in I. pseudacorus under Cr exposures. Besides, AMF alleviated the accumulation of reactive oxygen species and lipid peroxidation by enhancing the antioxidant enzyme activities. AMF and biochar significantly decreased Cr concentrations in outlet water and increased Cr accumulation in I. pseudacorus. Besides, biochar also vastly improved Cr accumulation in the substrate under the fluctuating water depth. AMF reduced Cr bioavailability in the substrate, with Cr (Ⅵ) concentrations and acid-soluble forms of Cr decreased by 0.3–64.5% and 19.0–40.8%, respectively. Micro-proton-induced X-ray emission was used to determine element localization and revealed that AMF improved the nutrients uptake by wetland plants and inhibited Cr translocation from roots to shoots.

BIO of Presenter:
**Zhongbing Chen**, associate professor at the Czech University of Life Sciences Prague, mainly focus on the fate of heavy metals and organic micropollutants in constructed wetlands.

# Removal mechanisms of persistent organic pollutants by biochar and its potential application in constructed wetlands

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**Abstract**

Persistent organic pollutants (POPs), including some pharmaceuticals, personal care products, and pesticides, have emerged as a major environmental issue in recent years due to their long-term hazardous impact on human health and aquatic life. Despite the number of POPs specified by the Stockholm Convention has increased from the initial 12 to the current 26, new organic pollutants are still being identified as potential candidates. POPs are widely distributed throughout the environment due to human activities and natural transportation. Their diverse physical and chemical properties cause them to behave differently in the environment, making them challenging to control. Hence, it is imperative to develop sustainable and versatile technologies for their removal.

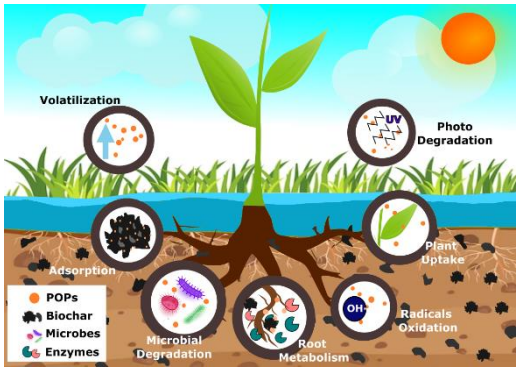


*Fig. 1. Removal mechanisms of POPs by biochar in CWs*

Constructed wetlands (CW) have been regarded as an environmentally friendly technology for remediating pollutants. However, their efficacy in eliminating POPs is limited. Biochar has been introduced as an innovative substrate for enhancing the performance of CWs, given its superior adsorptive and catalytic properties. Numerous studies have demonstrated that, in addition to physically retaining the pollutants, biochar also participates actively in a variety of biochemical processes in the rhizosphere zone by facilitating the transfer of electrons between chemicals and microbes. This participation potentially catalyzes metabolic processes and speeds up the rate of degradation. Contradictory findings however, indicate that biochar may decrease the bioavailability of POPs and increase their persistence by firmly bonding with them. Although previous studies reported different mechanisms based on specific types of biochar and compounds, the underlying mechanisms and factors governing the remediation processes have rarely been explored. Moreover, factors such as biochar properties, POPs characteristics, and environmental conditions may influence the effectiveness of biochar in POPs remediation.

This review aims to summarize previous studies systematically and highlights the mechanisms of biochar participation in remediation processes. Specifically, this review will discuss 1) the biochar application potential in CWs 2) the removal patterns based on different physicochemical properties of biochar and POPs, 3), the role of biochar in the adsorption, microbial degradation, and plants metabolism in remediation processes, and 4) possible approaches to enhance the remediation performance. Overall, this work will contribute to a better understanding of the mechanism of POPs removal by biochar in nature-based remediation systems and help guide practical applications.

BIO of Presenter:

**Jingyu Wang**, a Ph.D. student, is researching new approaches to intensify the remediation of pesticides within wetlands. Dr. Shubiao Wu, an Associate Professor, has dedicated himself to investigating efficient natural-based solutions for water treatment and understanding the biogeochemical interactions that occur within wetland systems.

# Non-point source pollution II

# VERTECO® - vertical green wall system demonstration for domestic wastewater treatment and on-site water and nutrient reuse

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**Abstract**

The vertECO® vertical green wall constructed wetland (CW) system has been developed by alchemia-nova as part of earlier research projects and was successfully demonstrated for treatment of greywater and on-site reuse for toilet flushing and irrigation (e.g., demEAUmed project GA N° 619116). At one of the four demo sites of the EU funded HOUSEFUL project, the vertECO® was implemented for the first time for the treatment of domestic wastewater, i.e., including the blackwater (see Figure 1). The wastewater of an Austrian eco-community with 70 person equivalent was diverted from the existing sewer and pre-treated in a 4-chamber septic tank, whereas the second chamber is aerated. From there 0.5 $m^3$ - in the future up to 1.5 $m^3$ - are treated in four parallel vertECO® modules within a greenhouse (each module with 4 stages of 2.5 m long aerated subsurface horizontal flow constructed treatment wetland basins planted with a variety of plants). For the measured influent COD of 275 mg/l the organic loading rate (OLR) results in 8.6 g COD/$m^2$·d (based on the surface area of 16 $m^2$) or 202.2 g COD/$m^2$·d (based on 0.68 $m^2$ cross-sectional surface area). After the vertECO®, the purified water is stored in integrated tanks underneath the vertical system and is ozonated (IDROPAN, Italy) three times per day for halve an hour while being recirculated in the treated water tanks, aiming at water and nutrient reuse in the local agriculture. The system was installed in April 2022 and wastewater feeding started in May 2022. A variety of relevant microbial and physico-chemical parameters are sampled and analyzed bi-weekly by the BOKU University, Vienna, Institute of Sanitary Engineering and Water Pollution Control (SIG) starting from November 2022.

**Figure 1.** Cambium vertECO®

**Table 1.** vertECO® results of the latest sampling

| Parameter | Influent | Effluent | After $O_3$ |
|---|---|---|---|
| $NH_4^+$-N [mg/l] | 50.5 | 0.4 | 0.1 |
| $NO_3^-$-N diss. [mg/l] | < 0.01 | <0.01 | 1.5 |
| P diss. [mg/l] | 6.5 | 5.9 | 5.2 |
| *E. coli* [CFU/100ml] | $1.47 \cdot 10^6$ | 218 | **26.0** |
| *Legionella* [in 100 ml] | 0.0 | 0.0 | **0.0** |
| TSS [mg/l] | 120.0 | 24.0 | **5.0** |
| $BOD_5$ [mg/l $O_2$] | 49.0 | 11.0 | < 3.0 |
| COD [mg/l $O_2$] | 275.0 | 51.0 | 27.0 |
| Turbidity [NTU] | 168.0 | 9.4 | **5.2** |

In regards to the EU water reuse regulation (EU) 2020/74, results in Table 1 show that the targeted reuse class B (spray irrigation of certain edible plants possible) is reached with the current results after ozonation. For most parameters, class B could already be achieved after the vertECO®, i.e., without ozonation, with $BOD_5 \leq 25$ mg/l, TSS ≤ 35 mg/l and Legionella < 1,000 CFU/l. The *E.* coli result of 218 CFU / 100 ml makes the vertECO® effluent still suitable for class C (drip irrigation only). Water storage and ozonation recirculation are still being improved over time so the authors are confident to further reduce *E.coli* after the vertECO® and ozonation to ensure a safe long-term reuse for all irrigation methods with at least class B and potentially even class A on the eco-community's agricultural area.

**Funding acknowledgement:** EU Horizon 2020 RIA (HOUSEFUL project, GA N° 776708).

BIO of Presenter:

**Marco Hartl** is project manager and technical coordinator at alchemia-nova, Vienna. His work focuses on nature-based solutions for wastewater purification and reuse, especially using constructed wetlands and green wall systems. Before that, in mid-2020, he obtained his PhD at UPC Barcelona and Ghent University on CWs combined with bio-electrochemical systems.

# Pilot scale optimisation of floating treatment wetland design for cleaning of the water channels of Ho Chi Minh city

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**Abstract**
Floating treatment wetlands (FTW) are nature-based solutions for the purification of open systems such as rivers, ponds, and lakes polluted by diffuse sources as untreated or partially treated domestic wastewater and agricultural run-off. Compared with other physicochemical and biological technologies, FTW is a technology with low-cost, simple configuration, easy to operate, relatively high efficiency, energy-saving, and aesthetic. This work investigated the treatment capacity of FTW to treat the real channel water from Ho Chi Minh city at pilot scale. The effect of rack design, plant species and aeration on the pollutant (COD, ammonium, nitrate and phosphorous) treatment performance of FTW was monitored over 90 days. Special attention was given to the fate of heavy metals (iron and zinc) and pathogens (faecal and total coliforms) in these systems. The role of the biofilm that developed on the roots of the floating plants was elucidated by mass balances and microscopy. The pathogen removal by the floating plants was studied in pot experiments with a single plant. The potential benefits and economics as well as limitations and solutions for improvement of FTW are also discussed, including new designs including photovoltaics to provide aeration to the FTW and integration of bioelectrical systems for disinfection and sediment clean-up.

BIO of Presenter:
**Piet Lens** is established professor at National University Ireland Galway. His research focusses on biorefineries, green mining and green water processes, including nature-based solutions. Besides innovative research, he is also a leader in education and capacity-building, organizing numerous study-days, conferences, summer schools and short courses.

WETPOL 2023
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# East fork wetland: lessons learned from 14 years operation of a 745-HA treatment marsh

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**Abstract**
The East Fork Wetland is an award-winning water supply project operated by the North Texas Municipal Water District (District). Water from the East Fork Trinity River, which is dominated by treated effluent, is diverted from the river and polished in a 745-ha treatment marsh to remove suspended solids and nutrients. The wetland-treated water is then pumped 70 km to Lavon Lake where it is blended and stored with other inflows until it is sent to the Wylie Water Treatment Plant for treatment as drinking water. From there, it is distributed to customers across the District's ten-county service area. The project began operation in late-2009 and has matured as a wetland system. Since then, several observations have been made with respect to maximizing water supply and optimizing treatment performance.
Water availability studies conducted in 2004 established an average design inflow rate of 4.69 m3/s for the wetland based on river flows projected for the year 2015. However, due to a prolonged drought and implementation of water conservation measures within the service area, the anticipated volume of effluent available in the river did not materialize, resulting in an actual average inflow rate of 1.48 m3/s. Furthermore, the system does not operate on a continuous-flow basis but has had significant periods where water could not be diverted into the system due to insufficient water in the river or by having adequate supply in the lake and the District electing to not pump wetland-treated water, thereby reducing energy costs. Operational protocols have been developed to address the highly variable inflow rates. During periods of peak evapotranspiration and/or minimal inflow, water losses have been reduced by removing wetland cells from operation. In spite of these operational challenges, the project has provided more than 5.37x108 m3 of additional water supply for the District.
The treatment performance of the system has been monitored throughout the entire operational period. While several constituents are monitored, the primary focus has been on total suspended solids (TSS), total nitrogen (TN), and total phosphorus (TP). Mass removal rates of 54%, 75%, and 57% have been observed for TSS, TN, and TP, respectively, with an average hydraulic loading rate of 1.70 cm/day during the operational period. First-order rate coefficients (k20) were 6.2 m/yr, 8.7 m/yr, and 4.7 m/yr for TSS, TN, and TP respectively. Higher rate coefficients between 10.8 to 13.1 m/yr for TP were observed during operational years 1 through 3 due to P-saturation of the native calcareous clay soils and establishment of wetland vegetation. Long-term P removal has been hampered by invasive carp (which forage on P-laden floc and discharge P back into the water column from their digestive system) and water lotus (which outcompetes move favorable vegetation and contributes little to the formation of soils through bio-accretion).
In addition to water lotus and carp, the system has been invaded by substantial populations of nutria and feral hogs which cause damage to vegetation and wetland embankments. The most successful approaches for controlling nutria and feral hogs have been hunting and trapping, while carp have been controlled through dewatering wetland cells. Control methods for water lotus have focused on early spring plantings of competing emergent vegetation (e.g., giant bulrush) to provide a long-term solution.

BIO of Presenter:
**Tim Noack** is a professional engineer and principal with Plummer Associates, Inc. (Fort Worth, Texas). He leads the Natural Systems Practice and has over 25 years of experience. He has worked on treatment wetland projects ranging from 0.7 to 970 hectares in size for a wide variety of applications.

# Constructed wetlands for the remediation of cyanotoxins: a story of bacteria, fungi, and transformation products

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**Abstract**

Drought events and higher temperature will occur more often in our environment. This, along with the increased use of fertilizer in agriculture, is leading to the eutrophication and shortage of freshwater reservoirs. Irrigation-water quality standards suffer from a lack of regulation worldwide. When episodes of water scarcity occur, vulnerable populations may be forced to irrigate their crops with cyanotoxin-polluted water (from the occurrence of harmful cyanobacteria blooms). Consequently, indirect, or direct human consumption of cyanotoxins happens, which may lead to several cytotoxic pathologies.

Initial studies have suggested that constructed wetlands are promising for cyanotoxin bioremediation, despite its unknown microbial mechanisms. Therefore, it is essential to clarify what are the best operational designs, as well as system management that can optimize the degradation efficiency.

Hence, we tested two hypotheses: 1) CW systems can efficiently remove cyanotoxins while recycling the nutrients for crop irrigation. 2) The indigenous CW microbiota (bacteria and fungi) are cornerstones of the cyanotoxin removal and the cyanotoxins act as microbial community evolutionary drivers.

Due to the lack of scientific studies, mesocosms studies can be applied to explore the system variables prior to pilot and scale up implementation.

Therefore, 12-L mesocosms systems were set up using different reed species (*Phragmites australis* vs. *Juncus effusus* vs. unplanted*)* and porous media (gravel vs. sand) operated in saturated mode. Control and spiked systems were fed using synthetic eutrophic lake water. The latter was maintained using a 10 µg/L of two cyanotoxins, microcystin-LR and Cylindrospermopsin, mimicking a cyanobacterial bloom. Removal percentages, metabarcoding of bacterial and fungal communities and screening of transformation products were carried out intending to disclose removal mechanisms taking a holistic approach.

Removal rates showed stabilization of the systems along time and effective removal of the toxins, even indicating possibilities to meet the threshold values for drinking water proposed by WHO (1 µg/L) in most of the scenarios. The plant species is the design variable with higher effect in the removal of both toxins, followed by porous media type. Bacterial and fungal community showed a response to the toxins, having a higher effect on beta-diversity than any other variable.

To conclude, the CWs potential, at mesocosms scale, to remove cyanotoxins in surface waters was confirmed. Strong evidence suggests that the microbial community was affected by the cyanotoxins. Next steps are to use different hydraulic configurations to disclose the variables effect and to point towards an optimal design.

BIO of Presenter:
**Alba Martínez** is a PhD student at the Department of Environmental Science at Aarhus University. Her background education is environmental biotechnology. Her interests are combining environmental chemistry and microbiology to analyze nature-based solutions for bioremediation purposes.

# Other wetland applications

# Optimizing sewage sludge dewatering using constructed wetlands: a large experimental study in Greece

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**Abstract**

In Greece, over 50% of the sewage sludge produced in wastewater treatment plants (WWTPs) ends up in landfills, with limited reuse. In most small and medium-sized WWTPs, linear management is carried out, i.e., thickening and dewatering with mechanical and chemical methods (e.g., calcification, addition of polyelectrolytes, filter presses, centrifuges) and daily transport and disposal in landfills. This strategy is usually economically unsustainable due to the high associated costs and leads to environmental problems, such as the risk of surface and groundwater pollution, the high consumption of energy and chemicals, insufficient drying and stabilization of sludge, and high environmental footprint due to the energy required and transportation. Furthermore, landfilling is at the base of the sustainability pyramid as sludge's useful components are not utilized. The adoption of circular economy implies the promotion of appropriate practices for the utilization of a useful and nutrient-rich material and the adoption of new treatment technologies which themselves will minimize the environmental footprint of the drying process sludge.

In this framework, a new research project is running since January 2023 at the Technical University of Crete, funded by the Green Fund, that investigates green and sustainable solutions for circular management of sewage sludge. Among other methods, Sludge Treatment Wetlands or Sludge Treatment Reed Beds are tested in pilot experiments. For this, 16 pilot scale Sludge Treatment Wetlands units of 1m² surface area are installed at the WWTP of Chania in Crete. Different construction and operation parameters are tested such as sludge loading rates, different plant species, different substrate materials, presence/absence of earthworms, unit external insulation, greenhouse/outdoor units etc. The project will run for three years. This work will present the first results of this experiment after the first 5 months of operation.

This research is part of the project entitled "Management and Valorization of Sewage Sludge in Circular Economy using Green technologies" and is funded by the Green Fund – Ministry of Environment and Energy of Greece. The coordinator is the Laboratory of Environmental Engineering and Technology, School of Chemical and Environmental Engineering, Technical University of Crete and the Principal Investigator is Assistant Professor Alexandros Stefanakis. Partners of the project are the Municipal Company for Water and Sewage Management of Chania (DEYACh) and the Inter-municipal Enterprise for Solid Waste Management (DEDISA).

BIO of Presenter:

**Alexandros Stefanakis** is Assistant Professor at the School of Chemical and Environmental Engineering, Technical University of Crete in Greece. He is President of the International Ecological Engineering Society, Editor-in-Chief of the Springer journal 'Circular Economy and Sustainability'. He is also an active professional Engineer and Researcher with more than 15 years of experience in the design, operation and implementation of NBS and constructed wetlands projects internationally.

# Assessment of basic processes and bacterial community in reed bed systems for beach wrack treatment

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**Abstract**
Beach wrack (BW) is a naturally occurring phenomenon on beaches all over the world. The waves, wind and tides wash the material ashore where it quickly decomposes, release nutrients. The same factors sometimes take material back to the sea which in the case of highly trophic reservoirs contributes to the deepening of the eutrophication process. Beach wrack contains of a lot of organic matter which is easily degradable and consumes a lot of oxygen, so that a bad smell very often is associated with their natural often anoxic decomposition. Thus, the beach wrack phenomena, cause a lot of issue with their disposal specially in the touristic regions. Aim of the work was to tested NBS like reed bed system for dewatering and stabilization of beach wrack and produce the" fertiwrack" material for dunes creation.
To treat beach wrack from beach in Rzucewo (Poland) on a pilot scale, a reed bed system (RBS) was built. Pilot facility consists of 8 quarters (A-H) in two cube deposits with dimensions of 1 x 1 x 1 m, where the possibilities of RBS used for beach wrack were tested.
Each quarter was loaded with a different pollutant load. Not only the algae biomass- BW was examined, but also a mixture of BW and compost was supplied to different quarters of the pilot to evaluate the system's respond.
The research has been conducted in two years, every month the fresh BW and treated BW and substrate material have been tested for various parameters. The vertical profile of substrate material has been tested for Illumina 16S rRNA gene sequencing as a process treatment identification.
Obtained results indicated that the dry matter content in BW in analyzed quarters varies in range from 18,8% to 90,8%. The organic matter was from 0,4% to 55,6% in treated material and from 0,3% to 55,6% in filter layer. In case of nutrients, it was found that the concentration of nitrogen was from 0,68 to 1,96 % d.m. in treated material and in substrate - from 0,01 to 0,17% d.m. The concentration of phosphorus achieved in BW in quarters was from 0,15 to 2,31% d.m. For the filter layer- substrate- the phosphorus concentration was from 0,03 to 0,10% d.m.
An assessment was also made of the microbial community. The composition of the samples differed between quarters and depended on the pollutant load, the origin of the sample (surface-BW/substrate) and the addition of compost. Three bacterial types dominated in samples: Firmicutes, Proteobacteria, Actinobacteria, the average share of which in the samples was about 25%. The Firmicutes which are mainly responsible for decomposition of organic matter, dominated in quarters with the addition of compost, most heavily loaded with organic compounds. The representatives of Proteobacteria dominated at low and medium loads parts of deposit. The other numerous bacterial types, whose average share was in the range of 2 to 5%, were representatives of Bacteroidota, Chloroflexi, Planctomycetota and Verrucomicrobiota.
The obtained research allows to assess the processes occurring in the treated materials and show their relationship with microorganisms.

BIO of Presenter:
**Alicja Kupczyk** is a doctoral student of environmental engineering, mining, and energy at the Gdańsk University of Technology. The idea for a doctoral dissertation which is based on testing the possibility of using sewage sludge reed bed systems to processing sea organic waste, was inspired by participation in the "CONTRA" project.

# Assessment of water balances in re-designed zero discharge willow evapotranspiration systems for treating domestic wastewater in areas with low permeability soils

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**Abstract**
Between 2010 and 2014, fourteen full-scale Willow Evapotranspiration (ET) systems were constructed and trialed as potential zero discharge nature-based solutions (NbS) to treat domestic wastewater effluent from single house dwellings at various sites across Ireland. The sites were located in areas with low permeability (i.e., clayey) subsoils, in which soil percolation was not feasible for wastewater effluent in line with national regulations. The ET systems were constructed in a sealed basin, made from an impermeable membrane. The area and depth of the systems were based upon a modeled water balance between the expected wastewater production, local rainfall, and estimated evapotranspiration from the basins. Effluent flow into the systems, water level, rainfall and potential evapotranspiration were continuously monitored over a ten-year period to determine the water budget and crop coefficients at each site. The addition of effluent into the systems was shown to have had a positive effect on willow tree development. Pollutant uptake/removal was found to be very high on the systems with well-established willow trees. However, ET results varied greatly between sites, as some sites exhibited excellent willow tree establishment and correspondingly high ET rates, while other sites showed much poorer performance.

The trials concluded that no Willow ET system managed to achieve zero discharge in any year, with water balances remaining at maximum levels for much of the winter months, indicating some loss of water by lateral exfiltration at the system surface. Sampling and analysis of the surface overflow quality from the systems showed that it was similar to rainfall runoff in the adjacent fields. A significant problem identified with the ET systems was the usable void ratio in the basins that had been refilled with the excavated low permeability subsoil was much lower than expected thereby leaving little room for effluent storage over the winter periods. Furthermore, the ET rates in an Irish setting were lower when compared to other countries, which was attributed mainly to the predominantly high relative humidity of the local climate.

With the above in mind, the performance results of the exiting systems were used to remodel theoretical water balances for new Willow ET systems in an Irish climate. Revised designs were formulated incorporating a mounded surface profile partially covered in an impermeable membrane to divert approximately 70% of incident rainfall away from the basins, which, based on predictive modeling, should achieve zero discharge performance throughout the year. New full-scale systems were constructed during Spring 2023 in areas of low permeability soils according to this design, with monitoring commencing immediately thereafter. Subsequent monitoring included the effects on water balances, and associated surface water run-off as a result of the partially covered mounded surface profile.

BIO of Presenter:
**Laurence Gill** is a Professor in Environmental Engineering in the School of Engineering, Trinity College Dublin. His research interests involve studying the fate and transport of both air and water-borne pollutants in the natural and built environment, the development of passive treatment processes, the ecohydrology of wetlands and the characterisation of karst hydrological catchments.

# First experiences with natural treatment based on willows for concentrate of reverse osmosis

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**Abstract**

Aquaduin started reusing wastewater effluent for infiltration, cf managed aquifer recharge (MAR), in its dune water catchment St-André in 2002. The treatment train at the Water Production Centre (WPC) Torreele is based on multiple barrier approach with submerged ultrafiltration prior to reverse osmosis (RO).

The project not only resulted in enhanced ecological values of the dunes but during the recent longer periods of droughts, the combination of reuse/MAR proved to be a robust and safe way to ensure drinking-water production and thus is a solution to mitigate the impact of climate change (Van Houtte et al., 2021).

Concentrate disposal is an issue when using RO. As Aquaduin operates in a coastal area, it could be managed. The concentrate was discharged in a canal that drained to the sea. To mitigate the impact of this discharge, since 2007 tests were performed using willows for the treatment of the concentrate of RO. From 2011 until 2015 a pilot test field (3 m wide, 9.5 m long and 70 cm deep, 4 rows in line with 70 cuttings in total, 9 species randomly planted) was used, part of it in the DEMOWARE project. The main objective of the test was to investigate the potential to remove nutrients from the concentrate. As the results were promising, about 30 to 35% of both phosphorous and nitrogen were removed, Aquaduin entered a new project, FRESH4Cs (Interreg 2Seas Mers Zeeen Progamme), which funded the construction and demonstration of the full-scale willow marsh.

The construction started in 2021; beginning 2022 the willow marsh of 7.500 m² became operational. The concept is a horizontally constructed wetland combined with short rotation coppice using willows. The results of the first 18 months confirmed those obtained in the DEMOWARE project and will be presented.

**Keywords:** water reuse, membranes, concentrate disposal, natural treatment, MAR, climate change

**Bibliography**

Emmanuel Van Houtte & Johan Verbauwhede (2021): *Environmental benefits from water reuse combined with managed aquifer recharge in the Flemish dunes (Belgium)*, International Journal of Water Resources Development, DOI: 10.1080/07900627.2020.1858035

BIO of Presenter:

**Thomas Rogier** is a biologist. Since 2020 he works at Aquaduin where he is responsible for ecological management.

# Natural wetlands, restoration & maintenance

# Tidal marsh restoration on Sapelo island: a legacy of R.J. Reynolds, Jr., Eugene Odum and the University of Georgia Marine Institute

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**Abstract**
Restoration of tidal marshes throughout the 20th century have attempted to bring back important functions of natural tidal systems. In this study, vertical accretion, organic carbon (C) sequestration, and nitrogen burial were compared between a natural, never diked tidal salt marsh and a hydrologically restored tidal salt marsh on Sapelo Island, Georgia to examine the impacts of restoration years later. 64 years after hydrologic restoration in 1956, the restored marsh studied had higher rates of accretion based on $^{137}$Cs and $^{210}$Pb (4.8-5.1 mm/yr), C sequestration (118-125 g C/m$^2$/yr) and N burial (8.3-8.8.g N/m$^2$/yr) than the never diked marsh (2.9-3.4 mm/yr, 75-85 g C/m$^2$/yr, 4.8-5.6 g N/m$^2$/yr).

Since maximum $^{137}$Cs deposition in 1964, approximately 30 cm of accretion has occurred in the restored marsh while the never diked marsh had approximately 10-30 cm of new soil deposited. The accumulated soil in the restored marsh was comparable to the natural marsh soil in terms of bulk density, percent C and N. However, below this depth, legacy effects from diking could be found through the higher soil bulk density and lower percent organic C and N relative to soils of the natural marsh.

Vertical accretion in the natural marsh appears to be keeping pace with the current rate of sea level rise (SLR) (3.4 mm/yr) while accretion in the restored marsh exceeds SLR as the marsh compensates for subsidence that occurred when it was diked. Under current SLR and accretion rates, ecosystem functions of continual sequestration of C and burial of N will be supported. However, as SLR accelerates, the ability of both marshes to sequester C and bury N will depend on their ability to keep pace. If not, the marshes will eventually convert to mudflats or open water with a concurrent loss of these and other ecosystem services.

Bio of Presenter:
**Christopher Craft** is the Janet Duey Professor of Rural Land Policy in the O'Neill School of Public and Environmental Affairs. He has engaged in research of the wetlands, marshes and forests, around Sapelo Island since 1998.

# Tracking coastal wetland area change integrating remote sensing with field-based measurements

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**Abstract**

Remote Sensing is a powerful tool for assessing land changes, especially over large spatial scales. Remote sensing for wetland area change can be problematic as surface water levels respond to seasonal and interannual changes, leading to apparent land loss when land is covered by surface water. Coastal systems around the globe are being re-integrated with adjacent river systems to restore the natural hydrologic connection to riparian wetlands. The Mississippi River sediment diversions or river reconnections are one such tool to combat high rates of wetland loss in coastal, deltaic Louisiana, USA by providing freshwater, sediment, and nutrient inputs. We examined the impact of river reconnection on wetland change for a previously rain fed wetland system, after a decade+ of river reconnection. In addition, our remote sensing analysis was integrated with a spatial model developed from data of over 140 soil samples collected and analyzed in 2007 and again in 2018, to separate the wetland into three distinct areas: area receiving 1) sediment and nutrients, 2) nutrients only and 3) no sediments or nutrients. Remote sensing tied to these specific areas detected significant wetland area increase in the sediment and nutrient zone, a small increase in land area in the nutrient only zone, and no statistical wetland area change in the area receiving no sediment and nutrients over the 11 years. In addition, soil C content was found to increase in the nutrient only area over the 11 years, with no change in the sediment and nutrient area. One would have to assume the entire wetland area was equally affected by the river reconnection without the spatial modeling derived from the soils data, muting our mechanistic understanding of wetland response on riparian reconnection. Therefore, this study underscores the need for spatial and temporal soil sampling data to be utilized in concert with remote sensing data to detect hydrologic impacts on wetland soil development.

BIO of Presenter:

**John White** is the lead of the Wetland & Aquatic Biogeochemistry Lab at Louisiana State University and over the past two decades, has been conducting research on biogeochemical cycling of C, N and P related to sea level rise and coastal restoration.

# Environmental conditions mediating decomposition and nutrient release in forested peatlands

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**Abstract**

Peatlands provide important ecosystem services, including nutrient and carbon storage. Therefore, they are intrinsically linked to the quality of surface waters downstream. However, drainage of peatlands to increase forest production exposes peat to oxidizing conditions potentializing the release of nutrients from decomposition. This may be mediated by the level of forest management, which interferes with the water table level. Furthermore, these processes may be affected by local environmental conditions such as peat properties and climate. Therefore, it is important to understand such dynamics so that suitable measures can be devised to protect surface waters in forested peatland catchments.

We hypothesize that (i) forest management, peat properties and climate affect decomposition and nutrient leaching in forested peatlands, and (ii) this subsequently influences the groundwater quality.

The study includes experimental data from Ireland, Sweden, Finland and Estonia, where different forest management practices were identified across a range of sites including different tree species, harvesting techniques and drainage intensity. Here the Tea Bag Index approach—which uses green and rooibos teas differing in decomposability and incubated for ca. 90 days—was used to measure litter decomposition. This allowed standardization of the method across all countries and sites, as well as the determination of decomposition rates and stabilization factors. The teabags were buried just below the surface and at the standard depth (8-10 cm). Piezometers were placed alongside for measurements of water table level and collection of pore water, which was analyzed for dissolved carbon, nitrogen, phosphorus, and potassium concentrations. Transects of teabags relative to the nearby ditch and consideration of slopes commonly occurred. The overall experimental period was from 2019 to 2021. The local environmental conditions were assessed. This included determination of soil composition, e.g., carbon, nitrogen, phosphorus, and potassium concentrations; and climate, i.e., precipitation and temperature measurements.

Preliminary results show significant differences ($p < 0.05$) for decomposition rate and stabilization factor between different forest managements for some countries. This suggests that forest management may accelerate decomposition processes and nutrient leaching as a result of changes in biogeochemical and hydrological conditions. However, further analyses are necessary to attest the current observations and properly assess our hypotheses. These analyses will take into account a full environmental dataset, which is currently being assembled, thus allowing investigation of detailed relationships of decomposition with local conditions. The effect of such relationships on groundwater quality will then be examined. The study is expected to shed light on the potential for nutrient export under local environmental conditions, and improve management in drained peatland forests.

BIO of Presenter:

**Lipe Mendes** has experience with drainage filters, water treatment and biogeochemical processes in peatland and agricultural catchments. Research work includes constructed wetlands, woodchip bioreactors and filter materials focusing on performance, driving factors and removal mechanisms. He is interested in studying nutrient export and mitigation measures to protect surface waters downstream.

# Maintenance of oxidation ponds for wastewater treatment in Kenya - can it be made easier by use of amphibian tractors?

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## Introduction

In Kenya oxidation ponds, also called wastewater stabilization ponds, are the most successful application for wastewater treatment, not only relatively cheap in construction, but also as most natural systems with a very low energy need. Initially oxidation ponds were constructed relatively simple, however most new ones do have concrete walls. And, like all constructed wetland systems, supervision, control, and maintenance is needed.

## Maintenance

During visits in 2023 to the Nyalende ponds (Kisumu), the Thika ponds, Ruiru ponds and the Dandora ponds (Nairobi) it was asked how do you maintain the oxidation ponds and what are the problems?
Daily maintenance as removing of floating scum, plastics is done largely manual from the banks; tough and dirty work, with high health concerns, not very effective. Above that; the ponds are large. Dandora ponds covers more than 250 ha, on 1000 ha land.
During time the anaerobic ponds fill up with sludge, and when the ponds are not desludged on timely the facultative ponds will fill up, and eventually even the aerobic ponds. For cleaning, desludging, the ponds have to be emptied in order to remove sludge.

## New methods for maintenance?

In Sweden Truxor Wetland Equipment developed very light aquatic tractors, with an array of light-weight hydraulic tools.
*A Truxor in the Anaerobic ponds:*

- equipped with a miller can break the scum layer, and pump the thinner layer away;
- a sediment pump can remove sludge on a daily basis to a sludge thickening basin or a digester, reducing the release of methane gas evading from the ponds;
- a digger can remove sand deposits, making sand and grit traps redundant;
- a rake can remove plastic and other floating material.

*A Truxor in the Facultative and Aerobic ponds:*

- can also remove the floating material;
- remove floating plants like Lemna and Waterhyacinth;
- cut submerged water plants;
- maintain earth dikes (concrete dikes will not be needed in at least the aerobic ponds).

The Truxtor amphibian tractors will become shortly be available on the Kenyan market.

Bio of Presenter:
**Ruud Kampf** is Wetland specialist and quartermaker new markets for Truxor Wetland Equipment, Dorotea Sweden.

# Post-treatment

# Long-term monitoring of two full-scale wetlands polishing urban wastewater treatment plant effluents

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## Introduction

Climate change is irreversibly impacting water resources. Most regulators and policy makers are aware of the urgent need to protect the quality of freshwater, applying stricter regulations and standards. However, the enhanced wastewater treatment is often unsustainable due to high costs, usually connected to the high energy requirements. In this context, wetlands are being increasingly used due to their capacity to polish effluents from wastewater facilities. Furthermore, they are low-cost systems with fewer operational and maintenance requirements and offer an environmental-friendly approach.

## Objective of the research

The research involved a multi-year (about 6 years) monitoring activity in two full-scale wetlands in Northern Italy (Fig. 1), and it was aimed at evaluating the removal of different wastewater contaminants (e.g., *E. coli*, $BOD_5$, TN, TP and TSS), which in residual concentrations were found in the effluents from two different wastewater treatment plants. The treatment capacity of the two WWTPs were 5,500 PE for S. Matteo della Decima and 75,000 PE for Imola, respectively. The S. Matteo della Decima and Imola semi-natural wetlands had a total area of 1.2 ha and 7.4 ha, and a total volume capacity of 12.8 x $10^3$ $m^3$ and 311.1 $10^3$ $m^3$, respectively.


*Fig. 1 - a) S. Matteo della Decima and b) Imola semi-natural wetlands.*

## Main results of the research

The outcomes of this research showed that the fate for the investigated contaminants was the same (Table 1). In particular, both semi-natural systems were capable to remove pathogens (e.g., *E. coli*) and nutrients from wastewater. No reduction for $BOD_5$ concentration was observed, probably due to relatively high background concentration. The TSS concentration was higher in the wetland effluents compared to influent, possibly due to the death of microbes, fragmentation, detritus from plants, and formation of chemical precipitates, but effluent values can anyway be considered low.

*Table 1 - Mean value (period of about 6 years) of inlet/outlet concentrations of the monitored parameters.*

| Semi-natural wetlands | *E.coli* (Log CFU 100 $mL^{-1}$) | | $BOD_5$ (mg $L^{-1}$) | | TSS (mg $L^{-1}$) | | TN (mg $L^{-1}$) | | TP (mg $L^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *inlet* | *outlet* | *inlet* | *outlet* | *inlet* | *outlet* | *inlet* | *outlet* | *inlet* | *outlet* |
| a) San Matteo della Decima | 13,944 | 62 | 9 | 11 | 10 | 22 | 10 | 5 | 2 | 2 |
| b) Imola | - | 137 | - | 11 | 16 | 40 | 14 | 7 | 1 | 0 |

BIO of Presenter:
**Giuseppe Mancuso** is an assistant professor (*junior*) at Alma Mater Studiorum – University of Bologna. His current research focuses on sustainable agricultural water management, wastewater treatment and reuse, nature-based solutions, irrigation and drainage systems.

# Nature-based hybrid solutions to remove nitrogen from municipal wastewater in arctic regions

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**Abstract**

In Finland, many anthropogenic processes, including mining, municipal wastewater treatment, urban runoff, agriculture, forestry, etc., lead to nitrogen (N) loading to recipient water bodies. Nitrogen removal from wastewater in small-scale treatment systems that are normally used in remote Arctic regions is challenging due to the harsh climatic conditions and strong variation in the yield of wastewater obtained from households. A combination of active and passive treatment units could be a cost-efficient alternative for small-scale municipal wastewater treatment plants to improve nitrogen removal.

In a village-scale (300 PE) wastewater treatment plant (WWTP) in Kallo (Kittilä), Northern Finland, pilot-scale active and passive treatment systems were tested in combination to enhance the nitrogen removal achieved by the conventional treatment unit operating in the WWTP. The outflow of the WWTP discharged to a serpentine ditch-type wetland area and subsequently to the recipient river. The pilot systems were constructed at the beginning of the summer of 2019. Prior to their implementation, nitrogen in the outflow of the WWTP was mainly present as ammonium, thus nitrification was needed before denitrification could be introduced. Therefore, a moving-bed nitrifying bioreactor (active unit, treating only part of wastewater) was installed indoors within the WWTP facilities. Subsequently, settling ponds were implemented in the ditch area just outside the indoor facilities and these were followed by a moss treatment (*Warnstorfia fluitans*) unit, a mushroom-woodchip unit and two woodchip bioreactors which discharged still within the inflow area of the serpentine ditch-type wetland.

The combined removal of total nitrogen by all implemented units ranged between 10 to 25 mg/L. This represents a significant improvement, as prior to the implementation of the units, no nitrogen removal in WWTP was achieved and even nitrogen leaching from the WWTP was observed. While the moss unit had no clear effect on nitrogen retention, the mushroom-woodchip unit removed about 1 mg/L of total nitrogen. In the starting phase, problems with the nitrifying moving-bed bioreactor affected the treatment. Issues have been mostly resolved and a maximum increase of 5 mg $NO_2$+$NO_3$-N/L in outflow concentration has been achieved. The denitrifying woodchip bioreactors removed nearly all $NO_2$+$NO_3$-N contained in the water. The serpentine ditch-type wetland at the end of the pilot structure also presented some nitrogen removal. The system has worked year-round, even in extremely low (-30°C) temperatures. Overall, the combination of moving bed-bioreactor, settling ponds and woodchip bioreactor was found to be the most effective hybrid solution for the removal of nitrogen from sewage even in arctic conditions.

BIO of Presenter:

**Heini Postila** has 17 years' experience from studies related of treatment wetlands purification efficiency, hydrology, and hydraulics in the Nordic climate conditions and over 10 years' experience other NBS/passive hybrid purification systems. NBS has treated runoff from peat extraction, urban and mining area and municipal wastewater treatment plant in polishing phase.

WETPOL 2023
Bruges Meeting & Convention Centre, Belgium

# Constructed wetlands for removal of micropollutants from wastewater treatment plant effluent: an exploratory study

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**Abstract**

Micropollutants are discharged through wastewater treatment plants (WWTPs), which are not designed to remove these recalcitrant contaminants, and adversely affect ecosystems and contaminate drinking water resources. Compared to existing micropollutant removal technologies, such as ozonation or activated carbon adsorption, constructed wetlands (CWs) offer a promising sustainable solution to remove micropollutants from wastewater. However, it is not clear whether CWs can obtain comparable removal efficiencies as existing technologies. Therefore, this study was commissioned by STOWA, the Dutch Foundation for Applied Water Research, as part of a program focused on decreasing emissions of micropollutants through accelerating implementation of post-treatment technologies at Dutch WWTPs.

Micropollutant removal from wastewater by CWs has been increasingly studied over the past years. Only few of these studies specifically focus on micropollutant removal from WWTP effluent, which has a significantly different composition compared to raw wastewater. Therefore, this study explored the potential of CWs as post-treatment to remove micropollutants from WWTP effluent, focusing on 11 Dutch indicator micropollutants. Different types of CWs were reviewed to identify important removal mechanisms (e.g., adsorption and biodegradation) and derive optimal CW design and operational parameters to improve micropollutant removal from WWTP effluent. Data was gathered through a scientific literature review and from Dutch pilot- and full-scale CWs. In addition, the most promising systems were further evaluated for implementation at a 100,000 p.e. reference WWTP, focusing on removal efficiency, $CO_2$-footprint and costs. Integrating innovative techniques into the CW, such as ozonation, white-rot fungi or advanced adsorption substrates, was studied as well.

This study showed that CWs are able to remove micropollutants from WWTP effluent through different mechanisms. CWs to which organic enhanced adsorption substrate is added show the highest average micropollutant removal efficiency (80%) due to adsorption. However, it is unknown whether or when the adsorption substrate will saturate and how this will affect enhanced micropollutant adsorption. Aerated CWs and vertical flow CWs reach 45-85% and 60-80% removal on average, respectively, with aerobic biodegradation as dominant mechanism. Ponds and surface flow CWs exhibit average removal efficiency of 40-60%. In these types of CWs, photodegradation is a relevant mechanism to remove specific indicator micropollutants.

This study presents the current available knowledge on behavior of micropollutants in CWs and the role of wetlands in removing micropollutants from WWTP effluent. Based on the identified knowledge gaps, further research suggestions were defined to enable wide application of CWs as post-treatment step to prevent micropollutant discharge to the environment and improve water quality.

BIO of Presenter:

**Joost van den Bulk** is consultant at TAUW in the field of wastewater treatment and works for Dutch Waterboards and private companies. He graduated in MSc Environmental Sciences, Wageningen University. Joost has over 12 years of professional experience and is an expert in design of natural treatment systems for nutrient and micropollutant removal.

# The role of treatment wetlands in potable water reuse

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**Abstract**

Treatment wetlands in the United States have historically been used to polish effluent from wastewater facilities to protect the quality of receiving water bodies. The main goal of most wastewater treatment wetlands has been to reduce nutrient to reverse or avoid eutrophication. While the need to protect the trophic state of receiving water bodies continues, the fate of wastewater effluent is being reconsidered as water shortages are growing in many parts of the country, and wastewater effluent is being considered as a source of water supply. Treatment wetlands are becoming an important tool in the implementation of potable water reuse projects for their ability to remove trace organics and provide consistent water quality; provide storage, detention, and treatment barriers; and serve as an important tool for public engagement, education, and acceptance.

Treatment wetlands improve water quality naturally by providing a multitude of biological, chemical, and physical processes that work together to remove a myriad of water quality parameters, including micro-constituents and trace organics. Processes such as photolysis, soil sorption, oxidation, reduction, and plant uptake coupled with long detention times provide more robust treatment of these parameters than most conventional wastewater facilities, making wetlands technology well suited for potable reuse applications. Many utilities are using and considering treatment wetlands as a part of the treatment train to achieve potable reuse due to their ability to reduce organic compounds. Examples of treatment wetlands such as the Huie Wetlands in Clayton County, GA, USA are being used for potable reuse. Performance data will be summarized in this presentation.

Storage, detention, and treatment barriers are an important component of potable reuse projects. These provide natural buffering to enhance public health protection, manage seasonality in water supply availability, and increase public acceptance. Reservoirs and aquifers are often used for storage and detention of reuse water. Treatment wetlands provide both storage and detention while also providing additional treatment barriers that work to further protect public health. Long detention times through wetland communities provide robust supplies of raw water ready for treatment to potable standards.

Ecological parks implemented at wastewater treatment wetlands are popular destinations for residents and visitors. Examples such as the Wakodahatchee Wetlands in Palm Beach County, FL, USA welcomes over one million visitors per year for passive recreation, birding, and sightseeing. These wetland parks are very popular and serve an important role in educating the public about ecology and water resource management. Furthermore, it supports the communication and engagement with public stakeholders to remove fears and concerns associated with potable water reuse. Wetlands provide the “kiss of nature” that many stakeholders require to accept reuse water as a source of water supply. This presentation will showcase examples of wetland parks used as tools in public outreach for potable water reuse planning.

Wetlands are being considered throughout the United States as a part of potable water reuse projects for their ability to provide improve water quality, storage, detention, and serve as educational tools needed for public engagement and acceptance. This presentation will provide example treatment wetlands being used for potable reuse, available data associated with water quality performance from full-scale systems, and examples of wastewater wetlands designed as popular ecological parks as a tool for public outreach.

BIO of Presenter:

**Rafael Vazquez-Burney** is a Professional Engineer and Principal Technologist with Jacobs Engineering specializing treatment wetlands and water reuse. He has led large innovative and award-winning wastewater wetland projects and supports a myriad of clients with water reuse planning around the world.

# Removal of nitrogen and emergent pollutants from municipal wastewater with woodchip bioreactors

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**Abstract**

Nitrogen removal from sewage water in small-scale treatment systems, which are typically used in remote Arctic regions, is challenging due to the harsh climatic conditions and strong variation in wastewater yield from households. Passive systems, like woodchip bioreactors, present a potential cost-efficient option for small-scale treatment facilities to remove nitrate-nitrogen in combination with other conventional treatment units. Woodchip bioreactor have been found capable of removing a wide range of organic micropollutants from different water sources. However, further research is needed on using representative scale systems for evaluation of the effect of different design and operational parameters on the bioreactor's performance and lifespan.

In this study, two woodchip bioreactors were designed and built in parallel (May-June, 2019) within the facilities of the small-scale (300 PE) wastewater treatment plant operating in Kallo (Kittilä) in Northern Finland. One of the bioreactors contained birch woodchips (particle size 3 x 1.4 x 0.3 cm) and the other was filled with birch woodchips mixed with waste potato peels which serve as an extra carbon source. The bioreactors were insulated with 12 cm thick Finnfoam, which allowed these units to operate yearround, even in extremely low (-30°C) temperatures. The bioreactors were roughly equal in size (4.2m x 1.5m x 0.35m and 4.3m x 1.6m x 0.31m) and fitted with two material sampling points at approximately 1/3 and 2/3 of the way through the reactors lengthwise. The water level within the reactors was controlled via a v-notch weir which also served as the outflow sampling point. The bioreactors were part of a multiunit pilot scale system consisting of a moving-bed bioreactor followed by a settling pond, a moss treatment (Warnstorfia fluitans) unit, a mushroom-woodchip unit and lastly the woodchip bioreactor. The denitrifying woodchip bioreactors removed nearly all incoming NO2+NO3-N via denitrification. Samples have also been taken and analyzed for stable nitrogen isotopes to better understand the processes occurring within the bioreactor. The bioreactors showed phosphate leaching shortly after startup, which reduced over time. The bioreactors also lowered the aluminum concentration of water by 78-85%. Several samplings were done to screen for selected emergent pollutants and to determine the removal efficiency of the woodchip bioreactors for these compounds. Initial results show good removal of specific antibiotics (64-90% removal) and some removal of blood pressure medications (15-38% removal).

BIO of Presenter:

**Matthew Hopkins** is in the second year of his PhD studies at the University of Oulu with a background in Civil-Environmental engineering and experience in environmental monitoring and remediation. His research deals with the development of bioreactors as nature-based solutions for water treatment with a focus on nitrogen and microplastics removal.

# Non-point source pollution III

# Carbon and nutrient sequestration in natural wetlands fed by agricultural runoff and drainage

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## Introduction

Wetlands may naturally occur on the bottom part of agricultural fields which are situated in a sloping terrain. During the rainy periods the water runs down along the field surface and usually creates conditions suitable for wetland macrophytes which may create extensive stands if the wet conditions remain for a longer period of time. These wetlands may act as efficient filters for nutrients and in addition, the sequester high amounts of carbon due to vigorous growth of macrophytes. However, the area overgrown by macrophytes is often considered as agricultural land and farmers are getting subsidies to farm such areas. Unfortunately, this situation often results in ploughing of stands of wetland macrophytes, thus eliminating of both carbon sequestration and nutrient removal. The objective of this study was to evaluate the amount of carbon, nitrogen, and phosphorus in soil of wetlands naturally occurring on agricultural land and compare these values with the soil from nearby agricultural land.

## Methods

During the summer of 2018, a total of 55 wetlands on agricultural land were evaluated. The locations were spread all over the Czech Republic. For the experiment, only monoculture wetlands were selected and the size of the wetland should be at least about 400 $m^2$ in order to include wetlands which have developed for longer period of time. Five macrophyte species, which represent the most frequently occurring species in these wetlands, were included in the study – *Phragmites australis* (common reed), *Phalaris arundinacea* (reed canarygrass), *Scirpus sylvaticus* (wood club-rush*), Filipendula ulmaria* (meadowsweet) and *Carex nigra* (smooth black sedge). For each plant species, at least ten wetlands were taken into consideration. At each site, three soil samples were taken within the wetland and three samples from the agricultural field, about 50 m apart from the wetland. The soil samples were split into sections 0-10 cm and 10-20 cm, dried at 40°C to a constant weight and ground. Total nitrogen and organic carbon were analyzed directly by using Skalar Primacs SNC Analyzer (Breda, the Netherlands). Total phosphorus was determined by a colorimetric analysis after digestion in nitric-perchloric acids. To colorize phosphorus, molybdate-blue method and spectrophotometer Agilent Technologies Cary60 UV-Vis were used. In separate samples, the bulk density was evaluated in triplicate.

## Results

The results of this study revealed that the bulk density was the highest in the agriculture soil (field) - 1.36 $g/cm^3$ while the lowest value was found in *Filipendula* stands (0.73 $g/cm^3$). The highest TOC carbon content was found for *Carex* (8.89 %) and Phragmites (7.62%) stands while the average field content was only (2.00%). The average nitrogen content of field soils was 0.23% while the N concentration in wetland stands varied between 0.43% and 0.69% and plant species. Phosphorus concentrations were 404 mg/kg in field soils and between 544 and 749 mg/kg in the wetlands. The amount of TOC in upper 10 cm soil layer varied between 2.73 $kg/m^2$ and 6.21 $kg/m^2$ for the fields and *Carex* wetlands, respectively. The results of this study clearly indicated the positive role of spontaneous wetlands on agricultural land in relation to filtering nutrients from the runoff and sequestration of carbon in the soil.

BIO of Presenter:
**Jan Vymazal** has been dealing with natural and constructed wetlands since the late 1980s. In natural wetlands, Jan´s focus is the sequestration of carbon and nutrients in the soil and vegetation.

# A saturated buffer zone as cost-effective nature-based solution to mitigate the agricultural nutrient pollution of streams in Denmark

*Dominik Zak[1,*], Astrid L Maagaard[2], Carl C Hoffmann[1], Brian Kronvang[1], Mette V Carstensen[1], Joachim Audet[1], Majken M Deichmann[3], Charlotte Kjærgaard[4], Sophie B Lyngaa[5], Rasmus J Petersen[1]*

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**Abstract**

According to the EU Water Framework Directive 2000/60/EC (WFD), all waters including surface and ground waters must achieve at least good ecological status by 2027. However, it can be challenging as the compliance with the WFD can result in costly investments and set limits for agricultural and industrial production. Agriculture is reported by the European Environmental Agency as one of the key drivers for failure in realizing good ecological status in EU water bodies. Thus, intensively farmed agricultural land can have significant losses of nutrients through drainage, soil leaching, ditches, and surface runoff. According to the Danish political agreement "Agreement on green conversion of Danish agriculture" published 4th of October 2021, it is planned to achieve around 1,500 t of total nitrogen reduction using collective methods, such as afforestation as well as use of restored natural and constructed wetlands. The saturated buffer zone (SBZ) is a new drainage mitigation measure and was not tested in a Northern European context yet. The simple principle is that drain water from the field becomes reconnected to the non-cropped riparian zone. Specifically, drainage water and riparian buffer soil are reconnected by a buried, lateral perforated distribution pipe running parallel to the stream (0.5-1 m below soil surface), which redirect the drainage water into the riparian zone. In this paper, we present the performance of the first pilot-scale SBZ established in Denmark in 2018. Based on comprehensive field-testing the efficiency of the newly established SBZ for removing nutrients from agricultural tile-drain water was proven during three subsequent drain seasons from 2019 to 2022. Specifically, we investigated: 1) the site hydrology, i.e., water inflow and spatial differences of soil water fluxes, hydraulic conductivity, and ground water table changes, 2) effects on water quality and nutrient removal such as total dissolved nitrogen, nitrate, ammonium, and phosphate and 3) assessment of long-term performance regarding P sorption and cost efficiency. The SBZ investigated showed an overall N removal and P retention of 77% and 72%, respectively. Additionally, biomass analysis from the pilot site shows that the plant uptake could explain 30% of the N removal and all the P removal. This underlines SBZs as promising mitigation measure for agricultural drainage water, however specific site factors need to be considered before of successful implementation.

BIO of Presenter:

**Dominik Zak** has 23 years' experience in freshwater and wetland-related environmental research, land use change, conservation, restoration. My research is strongly dedicated to interdisciplinary research integrating biology, ecology, microbiology, and hydrochemistry across aquatic and terrestrial systems.

# Enhanced denitrification in a constructed wetland by reshaping sediment / water column interface: challenges with upscaling

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**Abstract**

Constructed wetlands are engineered systems designed for wastewater treatment, including removing nitrogen from polluted water flowing from agricultural fields. Denitrification is the process of nitrate reduction by microbes present mostly in wetland sediment, using nitrate as an electron acceptor and mostly organic matter as an electron donor. One limitation is that the electron donors are more present in sediment and nitrates are present in water. In this study, we investigated the influence of the water/sediment interface, key access of electron donors, on the nitrate reduction rate. Tubes design was considered to increase this interface on the same global wetland surface.

We first tested this assumption at a laboratory scale through several experiments considering the shapes and fabrics (geosynthetic) to hold the sediment tubes in place and allow perfect sediment – water column eschanges. Secondly, two series of 12 and 30 tubes from 160 and 100 mm of diameter filled with local sediment were set up in 1m$^2$ "In-situ" mesocosm. This way, the surface ratio increased 2.4 times compared to the control without tubes. Each mesocosm was built directly within the constructed wetland of Rampillon (Parisian Basin), exposed to natural climatic conditions. Once a week for 53 days (spring 2022), we added about 100 mg.L$^{-1}$ nitrate to all mesocosms. Nitrogen concentration ($NO_3$, $NH_4$, $NO_2$), total organic carbon, dissolved oxygen, temperature, and electrical conductivity were continuously monitored. The microbiological composition of sediments was analysed using quantitative polymerase chain reaction (qPCR) at the beginning, middle, and end of the experiment.

We found that in laboratory, the first-order nitrate reduction rate constant can be increased 3.5 times with 10 times increased interface (from 2 to 10 surface ratio), regardless the origin and composition of the sediment. At field scale, whereas the initial experiment showed an increase of nitrate removal efficiency from a factor 2, congruent with the lab experiment, the following experiments did not. After 53 days, the mesocosms with tubes and controls did not exhibit any removal difference.

Analysis have shown significant decreases in the abundances of denitrification (*nirK*, *nirS*, *nosZI* and *nosZII*), bacterial nitrification (bacterial *amoA*) and nitrogen fixation (*nifH*) genes in the middle of the experiment, although the abundances of *nirK*, *nirS* and bacterial *amoA* recovered to some extent at the end of the experiment, suggesting higher rates of the $N_2O$ emission as the *nosZ* gene abundances decreased further. Dissimilatory nitrate reduction to ammonium (DNRA, *nrfA* genes) process potential increased throughout the experiment, and the abundance of archaeal nitrification genes (archaeal *amoA*) increased in the middle of the experiment. It seems that nitrate reduction to ammonium was always happening, and nitrogen was circulated in the system because of the DNRA and archaeal nitrification processes.

If the initial assumption of increasing water / sediment interface is validated by both lab and field experiments, the natural conditions showed a time adaptation of microbial functions leading to a failure of the upscaling.

BIO of Presenter:

**Julien Tournebize** is a senior scientist at INRAE, Antony, France. He develops research on non-point source control and water preservation in agricultural catchment. He tested design and performance of constructed wetlands and riparian zones to mitigate nitrate and pesticides in subsurface drained areas.

# Assessment of nutrient accumulation and translocation in plant biomass in a mature free-water surface treatment wetland mitigating diffuse agricultural pollution

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**Introduction**

Treatment wetlands (TWs) are effective measures to reduce agricultural diffuse pollution, however, there is still lack of information about the long-term role of macrophytes in nutrients uptake. Furthermore, it is unclear what is the amount of N and P that is removed from TWs by harvesting aboveground biomass during winter periods above ice cover and how much nutrients are translocated by macrophytes at the end of the growing season from aerial parts to roots and rhizomes.

**Objectives**

The main objectives of this study were to: a) determine the N and P uptake by typical TW macrophyte *Typha Latifolia* (common cattail) in free-water surface treatment wetland for agricultural diffuse pollution control in Estonia; b) determine the distribution and accumulation of N and P between the aboveground and belowground biomass during winter harvesting; c) determine the relationship of nutrient uptake with plant location in the TW system, with water depth and with vegetation cover of wetland.

**Materials and methods**

Macrophyte harvesting was carried out for 5 winter periods (on years 2018, 2019, 2021, 2022 and 2023) on Vända TW system (58.2826412, 26.722779). Macrophytes were harvested on both subsequent TWs on 6 locations per TW. Above ice biomass (stems, leaves, flowers) was harvested from 0.25 $m^2$ area per location and below ice biomass (roots and rhizomes) with 20 cm diameter metal pipe. Dry weight of above ice biomass per sampling location was measured for all years and additionally from roots and rhizomes in 2022 and 2023. From all biomass samples C, N and, P content were analyzed.

**Results and discussion**

Preliminary data analyses show that on average the total biomass weight from the two TWS is not significantly different in different sampling locations, i.e., TW1 vs TW2 (e.g., above ice biomass 0.7 and 0.6 kg/$m^2$, respectively) and inlet vs outlet areas. As expected, during winter harvesting periods, the most of N and P are stored in plant rhizomes (i.e., on average 20 g N/kg and 3-4 g P/kg in rhizomes vs 11-13 g N/kg and 1 g P/kg in above ice biomass). Interestingly, based on N and P uptake (mg/$m^2$) in winter 2022 it seems that in end of vegetation period nutrient translocation from aboveground to belowground biomass is higher in densely vegetated areas compared to locations with lower vegetation density. Further analyses of 2023 samples will probably show us if this pattern is persistent and if water depth is also playing important role in nutrient uptake and translocation. Above ice cover macrophyte harvesting does not guarantee high nutrients removal capacity from TW systems as nutrients are already mostly translocated to belowground in the end of each growing season. When the main aim of harvesting is removal of stored nutrients then plant harvesting could be performed during the peak of growing season. However, summer harvesting is causing much more disturbance in the TWs compared with above ice harvesting.

BIO of Presenter:

**Margit Kõiv-Vainik** is an Associate Professor in environmental technology in University of Tartu. She is conducting process-based research with aim to enhance the efficiency of green infrastructures like treatment wetlands and SuDS in removal of contaminants from urban stormwater, agricultural diffuse runoff, landfill leachate, municipal and industrial wastewater.

# Hydrogen and oxygen isotopes along the hydraulic flow gradients and plant-bed/ditch system in four constructed root channel wetlands

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**Abstract**
The stable isotope technology and mathematical statistics were used to analyze the distribution of $\delta$D and $\delta^{18}$O in four constructed root-channel wetlands in Jiaxing, south China, and to reveal the influence of plant-bed/ditch system on water stable isotopes. The main results were as follows: ① The spatiotemporal variations of water isotopes in the stream networks were largely affected by different water supply and evaporation enrichment effects. The slope and intercept of wetlands water line in Jiaxing were both significantly lower than the regional precipitation line of the adjacent Changshu Station (CHNIP). This showed that the wetlands area appeared hydrogen and oxygen isotope enrichment. The $\delta$D values in Shijiuyang wetland water ranged from −52.2 ‰ to −49.4 ‰ and $\delta^{18}$O ranged from −7.6 ‰ to −6.9 ‰. As for Guanjinggang wetland water, $\delta$D ranged from −48.1 ‰ to −45.1 ‰ and $\delta^{18}$O ranged from −6.8 ‰ to −5.8 ‰. Isotopic composition of Changshuitang wetland water ranged from −49.8 ‰ to −48.4 ‰ in $\delta$D and −7.2 ‰ to −6.6 ‰ in $\delta^{18}$O. The $\delta$D values in Taishangang wetland water ranged from −55.3 ‰ to −51.6 ‰ and $\delta^{18}$O ranged from −7.8 ‰ to −7.2 ‰. ② Water hydrogen and oxygen isotope abundance and composition showed complex nonlinear changes in the vertical and horizontal dimensions at different scales. In the regional scale, water level elevation in the vertical dimension had a greater impact on water isotope distribution than hydraulic flow pathway length in the horizontal dimension. Water isotopes tended to be enriched in low-lying areas with low water level. At the local scale, the influence of hydraulic process driving often played a greater role in determining the water isotope distribution. The spatial variations of water isotopes were comprehensively determined by the evaporation of regional water and the meandering hydraulic processes inside the wetland. ③ Compared with other functional areas of wetlands, the central constructed root-channel area (middle treatment zone) was more enriched in water isotopes. ④ The underground macropore network formed by plants with developed rhizomes or roots (e.g., *Phragmites communis* Trin., *Typha orientalis* Presl, etc.), mineral-rich substrate soil and aquatic plants in the plant bed had certain influence on the abundance of hydrogen and oxygen isotopes in the plant-bed/ditch system. Therefore, when water passed through the plant-bed/ditch system, the values of $\delta$D and $\delta^{18}$O in lower ditch (outlet) were lighter than those in higher ditch (inlet). ⑤ The abrupt change of isotopic contents in the plant-bed/ditch system might be the inflection point of water quality purification. ⑥ The deuterium excess (*d*-excess) in subsurface water of plant-bed/ditch system was significantly higher than that in ditch water, and the coefficient of variation in subsurface water was much greater than that in ditch water. The *d*-excess in wetlands root-channel ecological purification zone showed significant temporal difference being negative in hot and humid summer, the rainy season, while positive in dry and cold season in winter, which reflected the seasonal difference of water vapor sources and spatial difference of isotope fractionation behavior in wetland. The research results would provide some reference for understanding the water isotopic distribution characteristics in constructed wetlands and strengthening the operation and management of constructed wetlands. This study also provides some thought about probing into new water quality improvement technology. Meanwhile, this study shows that water isotope technology has reliable great potential in analyzing wetland hydrology.

BIO of Presenter:
**Weidong Wang** is Professor at Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China; Interests: land/water ecotones; wetlands science and technology; restoration ecology; ecological engineering.

# Vertical flow wetlands II

WETPOL 2023
Bruges Meeting & Convention Centre, Belgium

# Influence of media size and plant species on nitrification in unsaturated vertical flow wetlands

*Mohammad H. Mozaffari[1], Christopher R. Allen[1,*], Ellen G. Lauchnor[1], Alexandros Stefanakis[2], Otto R. Stein[1]*

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**Abstract**

The unsaturated second stage of a two-stage vertical flow (VF) treatment wetland is commonly used to enhance nitrification of domestic wastewater after most organic carbon (BOD, COD) is removed in the first stage. Effective nitrification rates vary based on wetland design, loading rate, and temperature. This study aims to characterize the effects of media size, and plant presence on nitrification rates as temperatures vary between 0.5˚C and 24˚C. In addition, better characterization of the effect of media size and plant species on hydraulic characteristics such as percolation time (PT), hydraulic residence time (HRT) and specific retention will enhance modeling of unsaturated vertical flow wetlands. An experiment beginning in July 2022 includes 24 experimental vertical flow mesocosms in 20 cm diameter, 50 cm deep PVC columns, with a factorial design including two types of media and three plant treatments. The media include a washed sand ($d_{50}$ ~ 0.4 mm) and a crushed-rock gravel ($d_{50}$ ~ 5 mm) while the plant treatments include *Phragmites australis*, *Carex utriculata* and unplanted microcosms.

Since October 2022 the mesocosms have been dosed 12 times per day with approximately 500 ml of an ammonium rich (109-115 mg/l $NH_4^+$-N) solution that is devoid of organic carbon, idealizing flow to a second stage VF (HLR= 0.19 m/d; N load rate= 21 g N/$m^2$·d). Temperature will be cycled on an annual basis in steps between 4-24°C (4, 8, 16, 24°C and back). Sampling at 0.5°C in an illuminated cold-room is also planned. Initial results at 4°C indicate that the sand microcosms discharged 45-50% of the incoming ammonium as nitrate while the gravel columns converted only 16-22% of the influent ammonium. Differences between plant treatments within a particular media were minimal, with only a slight increase in the presence of plants. Sampling campaigns are continuing for the next 18 months and data for temperatures up to 24°C will be available for presentation.

Prior to planting and wastewater feeding, hydraulic characteristics of the media were assessed. Volumetric porosity was 34% for sand and 48% for gravel. The specific retention (volume of water retained after freely draining/total volume) averaged 19% for sand and 9% for gravel. Percolation Time (PT) is typically used for defining the HRT of unsaturated media. To calculate PT, the change in the cumulative volume of water exiting the microcosms with time over a dose cycle was measured. Values for $t_{50}$ and $t_{90}$ (time when 50 and 90 percent of the influent dose exits) averaged 35 min and 82 min for sand and 12 min and 52 min for gravel respectively. The influence of plant growth on PT and porosity will be assessed throughout the project. Water quality results will ultimately be assessed using the measured media and hydraulic parameters to better inform kinetic models of nitrification in TW.

BIO of Presenter:

**Christopher Allen** is an Assistant Teaching and Research Professor in the Dept of Civil Engineering at Montana State University (MSU) and a Senior Scientist with the WGM Group. His research centers around nutrient cycling in wetlands and the application of treatment wetlands in cold climates.

# The use of vertical flow constructed wetlands to phosphorus and nitrogen removal from domestic wastewater

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**Abstract**
Urban wastewater contains organic matter and nutrients, among other chemical compounds. The major source of these pollutants are residences, schools, hospitals, and commercial buildings. Some environmental problems that may arise from the urban wastewater deposition, such as water bodies eutrophication and baby blue syndrome, are caused by the presence of nitrogen and phosphorus. The aim of this study was to evaluate the efficiency of a Vertical Flow Constructed Wetland (VFCW: 0,4 x 0,6 x 0,70 m) to remove, from an urban wastewater, organic matter (COD: 450±5 mg $L^{-1}$), ammonium (NH4+-N: 21±1 mg $L^{-1}$), total nitrogen (TN: 32±1 mg $L^{-1}$), nitrate ($NO3^-$-N: 40±1 mg $L^{-1}$) and phosphorus ($PO4^{3-}$-P: 22±2 mg $L^{-1}$); and also to assess the tolerance of *Vetiveria zizaniodes* plants for this type of effluent. The work was carried out in a VFCW in continuous mode with hydraulic loading rates (HL) that varied from 61±3 to 367±7 L $m^{-2}$ $d^{-1}$. Wastewater samples were collected every day, in influent and effluent, for the determination of dissolved oxygen (DO), pH, redox potential (Eh), COD, $NH4^+$-N, $NO3^-$-N, $NO2^-$-N, TN, and $PO4^{3-}$-P contents. Calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), phosphorus (P) contents were measured in the aboveground biomass at the beginning and end of the experiment. The results revealed that organic load applied increased from 27±1 to 165±3 g $m^{-2}$ $d^{-1}$ due to the raise of the HL. The COD mass removed increased according to a first order kinetics, ranging from 89±2% to 63±4%. The $NH4^+$-N removal occurred in all the tests, and the ammonium nitrogen removal efficiencies obtained varied from 80±1 to 33±3. The ammonium nitrogen mass removed was always higher than nitrate and nitrite in the effluent. So, the nitrification followed by denitrification were the probable responsible processes for the ammonium removal. Total nitrogen mass applied varied from 3±0.5 to 15±1 g $m^{-2}$ $d^{-1}$ and the removal efficiency obtained varied from 52±3 to 30±1%. $PO4^{3-}$-P mass applied varied from 1.5±0.5 to 8±1 g $m^{-2}$ $d^{-1}$ and the removal efficiency varied from 66±4 to 37±2%. Significant correlation between the $PO4^{3-}$-P mass applied and removed was observed only in the first three trials (HL of the 61±3; 100±8; 190±6 L $m^{-2}$ $d^{-1}$). However, $PO4^{3-}$-P mass removed decreased when the HL increased, probably due to short contact time between plants, microorganisms and phosphorus, given that these are some of the most important factors for the phosphorus removal. During the trials all the wetland plants grew well without visual toxicity symptoms, such as chlorosis, leaf curl, early senescence stages, and deficit of nutrients. The Na and Mg contents in the plants leaves remained constant ($p > 0.05$); whereas, Ca and K contents increased during the assay ($p < 0.05$). Despite the high removal efficiencies obtained for all parameters, the remaining concentration of nitrogen and phosphorus in the effluent was always higher than the acceptable by the Portuguese legislation (15 mg $L^{-1}$ N; 2 mg $L^{-1}$ P).

BIO of Presenter:
**Adelaide Almeida** is Coordinator Professor at Polytechnic University of Beja. Completed his PhD in Environmental Engineering at Instituto Superior Técnico - University of Lisbon and since 2013 is director of Water Quality Control Laboratory in IPBeja. Her main research areas are phytoremediation, nutrients removal and pharmaceutical compounds.

# Partial siphon operational strategy strengthens the nitrogen removal performance through intensified oxygen supply and carbon utilization ability in partially saturated vertical flow wetland

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**Abstract**
The out of carbon-oxygen balance had always been problematic in constructed wetland (CW), which putting pressures on the stable and efficient nitrogen removal. In this study, a novel partial siphon operational strategy was developed to further optimize the carbon and oxygen distribution of traditional partially saturated vertical flow (SVF) CW to enhance the performance of nitrogen removal. The removal performances of partial siphon SVFCWs were monitored and compared with that of traditional SVFCW under three different operational conditions (partial siphon depths: 15 cm, 25 cm and 35 cm) in both warm and cold seasons. The results showed that partial siphon operating strategy could significantly facilitate the chemical oxygen demand ($COD_{Cr}$), ammonium nitrogen ($NH_4^+$-N) and total nitrogen (TN) removal efficiencies in both warm and cold seasons. The highest TN removal percentage was achieved when the partial siphon depth was 25 cm (71% in warm season and 56% in cold season, respectively). The oxidation-reduction potential (ORP) results indicated that periodic aerobic, anoxic and anaerobic environments were created through partial siphon operation in SVFCWs, which were available for both aerobic and anaerobic biodegradations. Microbial analysis showed that higher nitrification and denitrification potentials were observed in the unsaturated zone with enriched functional genes (e.g. amo_AOA, amo_AOB, nxrA and nirK), which related nitrification and denitrification processes. Meanwhile, the denitrification bacteria were enriched in partial siphon SVFCWs, indicating its higher carbon utilization ability. Furthermore, the cyclic nitrogen profile analysis illustrated that nitrogen removal was improved due to the enhanced simultaneous nitrification and denitrification processes with intensified oxygen supply and carbon utilization ability in the unsaturated zone. Therefore, we not only provided a new indirect modification method to improve the nitrogen removal performance at cold temperature, but also gave a practical and economical modification method to further improve the nitrogen removal performance of traditional SVFCWs, especially for the established practical CWs.

BIO of Presenter:
**Shangwu Zuo** is currently working toward the Ph.D. degree in environmental engineering with Tongji university, Shanghai, China. His research interests focused on water ecological treatment.

# Adapting vertical-flow constructed wetlands for on-demand nutrient removal from greywater

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## Abstract

This work presents the development of flexible and compact vertical-flow constructed wetlands (VFCWs) for on-demand removal of nitrogen and/or phosphorus from light greywater. The greywater was sourced from showers and hand wash basins at a student accommodation facility and contained small amounts of kitchen wastewater. The VFCWs were designed and operated to effectively treat this type of wastewater and provide a sustainable solution for nutrient removal.

Over the course of about 18 months, this study investigated the operation of six small-scale VFCW columns. These VFCWs, each with a diameter of 29 cm, were packed with either Rhine sand (0 – 2 mm) or lava sand (0 – 4 mm) as filter layers. The filter layer depth varied between 40 – 60 cm. Various design strategies, including substrate selection, embedment of adsorbent materials, and operation modifications, such as impoundment of the drainage layer, recirculation of nitrate-rich effluent, and increased loading rates, were investigated to achieve flexible effluent qualities based on reuse quality requirements, for instance for irrigation, infiltration, or toilet flushing.

The results showed that screening (1.3 mm) and untargeted settling in the storage tank were effective as a pretreatment step. Partial nitrogen removal ranged from 25-50% TNb, through drainage impoundment, up to 50-70% TNb, through both drainage impoundment and time-delayed recirculation of nitrate-rich effluent to the surface. Additionally, significant phosphorus removal was achieved by embedding a 10 cm-thick anthracite coal layer (grain size 2-4 mm) in the drainage layer (gravel 2-8 mm) and operating the drainage layer under water-saturated conditions. During operation, the anthracite coal was successfully regenerated using NaCl/NaOH as a desorbing agent. The time required for regeneration can be combined with the downtime/resting period usually recommend for wetland operation (see e. g. DWA A-262, 2017). Significant improvement in the service life of adapted VFCWs can be achieved through extensive phosphorus removal followed by regeneration. Furthermore, all lava sand VFCWs investigated in this study exhibited high phosphorus retention throughout the investigations.

The study found that the area required for the adapted VFCWs to treat light greywater amounted to only 0.3-0.4 m2/PE, which is significantly lower than the recommended 2 m2/PE for total greywater in Germany, as specified in DWA A-262 (2017). The authors suggest that VFCWs for on-demand nutrient removal could play an important role in resource-oriented sanitation schemes, contributing to the sustainable use of water. Overall, this study demonstrates the effectiveness and potential of adapted VFCWs for removing nitrogen and/or phosphorus from light greywater, with important implications for sustainable water management.

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BIO of Presenter:

**Carlo Morandi** currently works at the Department for Resource-Efficient Wastewater Technology at the RPTU in Kaiserslautern, Germany. Carlo has a master's degree in Environmental Engineering by the University of Stuttgart. One of his phd work's main topics consisted of the on-demand greywater treatment by adapted vertical-flow constructed wetlands.

# Optimizing denitrification in a cold weather two-stage vertical flow treatment wetland using operational controls

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**Abstract**
An experimental, two-stage vertical flow treatment wetland has treated clarified high-strength wastewater at the Bridger Bowl Ski Resort near Bozeman, Montana, USA since 2012. This wetland is operational from December to April when influent water temperature ranges from 3 to 4°C. The system employs a partially saturated first stage and unsaturated second stage with effluent recycle to enhance total nitrogen removal, which has ranged between 60% and 75%. With near complete nitrification in the second stage (>99%), total nitrogen removal has been limited by denitrification capability, which occurs predominately in the saturated zone of the first stage (see Figure 1). Previous research optimized the carbon to nitrogen ratio in this saturated zone via recirculation ratio and saturation level.

Current research focuses on the effect of respective recirculation and septic dose volumes on denitrification in the first stage. Water quality data from the 2021-22 and 2022-23 ski seasons indicates that, for a constant hydraulic load rate, recycle ratio and saturation level, larger, less frequent, septic doses enhance denitrification when compared to smaller, more frequent doses, without compromising COD removal or nitrification of the system, likely a result of increased carbon availability in the saturated zone. When operating at 3.8 $m^3$/day, doubling the septic dose from 4 cm (6 doses per day) to 8 cm (3 doses per day) increased total nitrogen from 70% to 77%. Similar results were observed when operating at 5.7 $m^3$/day. Continued refinement of operating controls for a subsurface vertical flow treatment wetland allows for far greater denitrification than previously expected during cold weather operations.

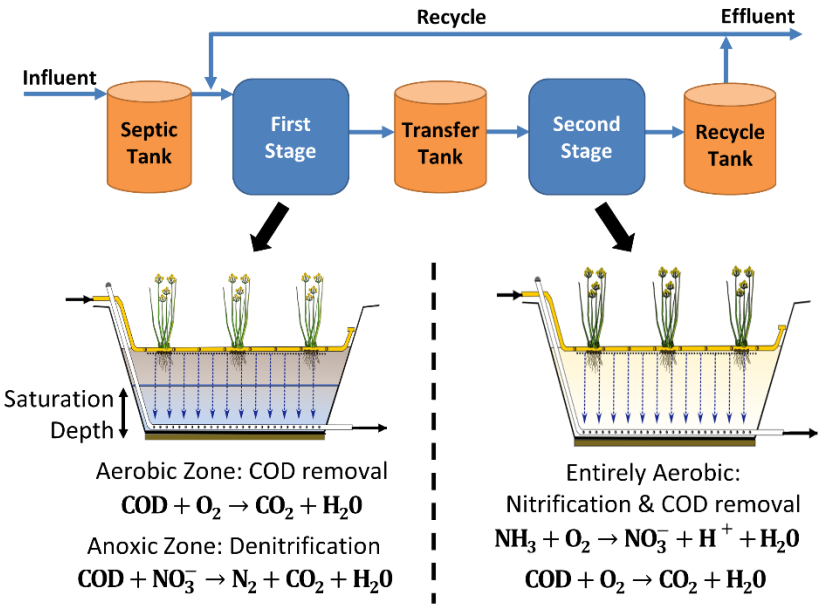


***Figure 1**: Process flow diagram of Bridger Bowl vertical flow treatment wetlands. The first stage has an aerobic zone for COD removal and an anoxic zone for denitrification. The second stage is completely aerobic for nitrification and any remaining COD removal.*

BIO of Presenter:
**Otto Stein** is Professor of Civil Engineering, member of the Management Committee for the IWA Constructed Wetland Specialist Group and was Chairman of the 2017 WETPOL Conference held in Big Sky, Montana.

# PPCP removal

# Constructed wetlands to reduce first flush ammonium peaks in wastewater treatment plant effluent: an exploratory study

*Joost van den Bulk [1,*], Fleur Rempe[1], Mirit Hoek[1]*
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**Abstract**
The aim of the EU Water Framework Directive (WFD) is to achieve a "good" chemical and ecological status for all waters by 2027. Currently, waterboards in the Netherlands are finalizing their plans for the third implementation cycle of the WFD, amongst others to improve the quality of wastewater treatment plant (WWTP) effluent to comply with the WFD water quality standards. In the east of the Netherlands, a WWTP that discharges to a sensitive surface water body will implement a technical post-treatment step to meet year-round WFD effluent quality standards regarding nutrients and remove micropollutants. However, ammonium peak concentrations during rain weather conditions (first flush) will not be reduced sufficiently with this technical post-treatment step.
Therefore, the goal of this study was to explore the potential of different types of constructed wetlands (CWs) to reduce ammonium peaks in WWTP effluent during rain weather conditions. Current knowledge on and experience with ammonium removal from WWTP effluent was analyzed for ponds and vertical flow-, horizontal flow-, aerated horizontal flow- and hybrid CWs based on literature review and data gathered in pilot- and full-scale systems in the Netherlands and Sweden. We specifically focused on the capability of these CWs to reduce ammonium peaks during rain events. Three promising types of CWs were selected to evaluate performance (effluent quality), required surface area, costs, and improvement of the effluent oxygen dynamics when designed for the Dutch WWTP studied.
This study showed that aerated CWs effectively reduce ammonium concentrations during rain weather conditions by adjusting oxygen supply to enhance nitrification. Active aeration in this type of CW reduces required surface area, but is accompanied by a larger $CO_2$-footprint and higher costs compared to the other CWs. Vertical flow CWs effectively reduce ammonium peaks due to aerobic conditions, though oxygen supply cannot be regulated to enhance nitrification, in contrast to aerated CWs. Ponds reduce ammonium peaks by biological degradation (nitrification) and dilution with WWTP effluent already present. Compared to the other CWs, ponds are relatively cheap, robust and have a more natural appearance; though they require a relatively large surface area. Due to anaerobic conditions, ammonium peaks are not removed in horizontal flow CW. A hybrid system consisting of a pond followed by a batch-fed vertical flow CW exhibits good reduction of ammonium peaks. In all CWs, removal efficiencies depend on season (biological activity and plant-uptake), hydraulic retention time and oxygen concentrations (nitrification). In addition to decreasing ammonium peak concentrations, CWs contribute to restoring oxygen dynamics in the effluent.
The results of this study show that CWs are a promising solution to reduce ammonium concentrations, both during dry and rain weather conditions, when applied as post-treatment step at WWTPs. Not only is this interesting for the WWTP studied, but also for many WWTPs within and outside the Netherlands that discharge effluent into (sensitive) surface water bodies. Applying CWs as post-treatment step has potential to contribute to meeting effluent quality standards set in the WFD to improve European surface water quality by 2027.

BIO of Presenter:
**Joost van den Bulk** is consultant at TAUW in the field of wastewater treatment and works for Dutch Waterboards and private companies. He graduated in MSc Environmental Sciences, Wageningen University. Joost has over 12 years of professional experience and is an expert in design of natural treatment systems for nutrient and micropollutant removal.

# Assessing and monitoring wetland efficiency with miniaturised bioassays- does the sorption of lipophilic substances to plastic microtiter plates confound results ?

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**Abstract**

Both natural and constructed wetlands have been shown to play a role in reducing chemical pollution, including contaminants of emerging concern persisting in discharged wastewater, many of which are highly hydrophobic (logKow > 4). Assessing the efficiency of such green solutions and monitoring related aquatic ecosystems is vital and relies on accurate toxicity testing to evaluate risk reduction. However, substances with a high hydrophobicity are difficult to test. The type of vials or test vessels employed are a main reason for this. Usually, *in vitro* tests with cell cultures and, increasingly, tests with organisms such as microalgae (S. vacuolatus), daphnids (*D. magna*) and/or fish embryos (*D. rerio*), are carried out with test vessels made of polystyrene (PS). Use of PS material can potentially cause a loss of bioavailability due to sorption of test substances to the well plates. An underestimation of toxicity might be the result. A workaround would be the application of advanced methods, *e.g.,* passive dosing, pre-incubation of the titer plates, or regular exchange of the test solutions. Another critical challenge is that aqueous environmental samples from wastewater or agricultural-influenced creeks are mixtures of a large number of substances causing toxic interactive effects in the test organisms. A "loss of toxicity" through sorption that may alter such interactions cannot be excluded but may be crucial, leading to underestimation of toxicity and the environmental risk.

This work thus investigated the influence of the titer plate material on the toxicity of environmental samples and analytical data from two monitoring projects running in Germany and Europe (https://www.ufz.de/kgm/index.php?en=44480, *https://www.natureproject.eu/*) using micro algae and daphnid assays. Replicate samples were tested in PS and glass titer plates. In the german samples a clear difference in toxicity was observed in the daphnid assay. In portuguese samples from a wetland under evaluation in the NATURE project, analytical data is in use to: model toxicity loss and test an artificial mixture of the main toxicity drivers in these samples with the same tests. Overall, the work points the need to account for the test material to increase the informative value and robustness of (eco-)toxicological investigations of both individual substances and complex mixtures to assess the efficiency of waste-water treatments and wetland function in pollution control.

BIO of Presenter:

**Eberhard Küster** did Master in Biology, since 2000 work in different groundwater and surface water monitoring projects using a variant of organismic bioassays to assess toxicity reduction evaluation in environmental samples. Specialized in the analysis of volatile and lipophilic substances and mixtures.

# Organic micropollutants on multisource pilots: results from a non-target screening analysis

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**Abstract**

The growing demand for water treatment, storage and reuse in urban areas can be addressed by Nature-Based Solutions (NBS). We operated seven pilots using different NBS (green roofs, green walls, raingardens, and different treatment wetlands). The removal efficiency of each pilot for priority substances and contaminants of emerging concern was assessed.

The operator of each pilot regularly samples the influent, mid-flow (where relevant) and effluent waters, analyses multiple basic water quality parameters and provides samples to specialized laboratories for performance of e.g., micropollutant analyses. The analytical work includes target analysis by GC-MS and LC-MS/MS. Moreover, non-target and suspect-screening approaches using high-resolution mass spectrometry (GC-orbitrap and UHPLC-QTOF) have been employed together with semi-quantitation tools.

In general, the target methods reveal high removal of micropollutants in the pilots, e.g., over 96% removal of pharmaceutical venlafaxine, broad-application antiseptic didecyl-dimethylammonium chloride and insecticide DEET. The suspect screening results retrieved over 3700 features by GC-Orbitrap and up to 4000 features by UHPLC -QTOF analysis, which after software supported filtration and deduction of features in blank samples resulted in a combined list of 181 compounds matching with potential micropollutants in mass spectrometric libraries. From these compounds, 27 are already included in the target methods and 10 compounds were part of the MULTISOURCE suspect list, while the rest were retrieved from the other databases. Out of the identified compounds, 147 compounds were found up to 4 times in different samples, while 34 compounds were found frequently (≥ 5 times). The compounds which occurred in more than one sample were semi-quantified and this data is being used by a MULTISOURCE partner Norwegian Institute for Water Research (NIVA) for a second-tier risk assessment -based prioritization. Chemical standards can be very costly, thus, the objective is also to assess the environmental relevancy of newly identified compounds before starting the laboratory work to include them in the target methods.

The compound-specific and pilot-specific micropollutant results and perspectives will be more broadly presented at the conference.

**Acknowledgement**

The MULTISOURCE project has received funding from the European Union's Horizon H2020 innovation action program under grant agreement 101003527.

BIO of Presenter:

**Vaidotas Kisielius** is a postdoc working on several projects concerning Nature-Based solutions at Aarhus University. He holds a PhD in Environmental Chemistry and Toxicology from University of Copenhagen (2020).

# Degradation and transformation of E2-3S in horizontal flow constructed wetland

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**Abstract**

Conjugated estrogens (CEs) are a type of natural estrogen that can be hydrolyzed into free forms (Free estrogens, FEs), which have strong endocrine-disrupting effects on the environment, and thus pose potential environmental risks. The sewage treatment system's ability to degrade and transform CEs with complex structures is not well understood, and this is crucial to accurately assess estrogen removal. This study adopted a methodology of simultaneous analysis and detection of 15 kinds of FEs and CEs, to study the degradation behaviour of 17β-estradiol-3-sulfate (E2-3S) in planted and unplanted horizontal flow constructed wetlands (HFCWs) and also the transformation relationship between various estrogens. The findings indicate that E2-3S can be efficiently removed by HFCWs, with a removal efficiency of 98% at a substrate depth of 15 cm and a hydraulic residence time of 1.5 days. E2-3S can be transformed into other estrogens, primarily FEs, which account for over 70% of the total. Plants in HFCWs can enhance DO concentration and decrease FE residual concentration, resulting in a higher total estrogen removal efficiency in planted CWs (84%) compared to unplanted CWs (56%). The primary transformation pathway of E2-3S in HFCWs involves breaking the thioester bond to form E2, which is then oxidized to E1, followed by direct oxidation to E1-3S and hydrolysis to E1. A minor pathway involves hydroxylation to form E3-3S, which is then hydrolyzed to E3. Additionally, trace amounts of D-CEs (< 5% of total estrogen) can be produced by E2-3S, but the residual quantity is lower in planted CWs.

BIO of Presenter:
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# Modelling

# Automatically optimizing the sizing of a wastewater treatment wetland Chain: case study of the French system

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**Abstract**
Wastewater treatment solutions using nature-based solutions (NBS) are numerous and diverse. Finding the most appropriate solution for a given context is challenging when developing such technologies in new territories. Based on this issue, the CARIBSAN project was created to promote the use of treatment wetlands in the Caribbean region.

One of the goals is to develop a methodology that can automatically combine and size different treatment wetlands (first stage French system, classical vertical filter, vertical unsaturated/saturated filter, horizontal filter, forced aeration filter…) to achieve specific treatment objectives. The resulting combination of treatment steps is called a treatment chain. The ability to implement recirculation loops must also be included in the methodology.

In order to select the most appropriate treatment chain, we use a multi-criteria analysis (technical, economic, social and environmental criteria). Among the different components of this analysis, the technical component is of importance and will be discussed in this presentation for the case of the two stage French vertical flow treatment wetland. The challenge is to evaluate if the treatment system is able to achieve the desired level of treatment on the available surface and for which sizing. To this end, pollutants have been fractionated into their solute and particulate fractions. Each treatment stages was modeled independently, and the removal efficiencies were estimated using a data-driven approach that includes both the surface area of the treatment step and the depth of the filter material.

Finally, these independent models were combined and optimized simultaneously. The code, written in Python, allows to define the best sizing in terms of surface and material depth of each treatment step, thanks to a cost function, so that the total material volume of the treatment chain is minimal. The process is constrained by physical bounds, which are the minimum and maximum hydraulic and organic loads, as well as by the constraint of achieving targeted treatment objectives.

The choice of minimizing the filter volume was made because it determines the construction cost. To provide the user with not only an estimate of the surfaces, but also a range of validity of the design, a Markov Chain Monte Carlo approach was implemented to propagate uncertainty through the model. The model was tested against a large database of removal efficiencies of French vertical flow treatment wetlands. The results are in agreement with the observed values.

BIO of Presenter:
**Zoé Legeai** is a junior research engineer at INRAE.

# Using numerical experiments to determine the influence of design parameters on the performance of vertical flow wetlands

*Canet-Martí Alba[1], Forquet Nicolas[2], Langergraber Günter[1], Pucher Bernhard[1,*]*

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**Abstract**

Vertical flow (VF) wetlands are commonly used for the treatment of domestic wastewater. The actual treatment performance is thereby influenced by the design and operational parameters including the geometry, granular size of the filter media, hydraulic and organic loading rates, the distribution system and the loading intervals. The variability of those parameter could lead to different designs, however, actual guidelines are based on a rule of thumb approach, providing the needed area per person. While the guideless also includes clear operational parameters, the daily variability in wastewater production can influence the feeding interval and loading rates and influence the effluent concentrations.

In order to investigate the influence of the design, process-based modelling tools such as the HYDRUS Wetland module can be applied to carry out numerical experiments and thus can give a detailed insight for the variability in the performance.

This study aims to investigate the relationship between design and operational parameters at different water temperatures and the VF wetland treatment performance. For this purpose, a calibrated and validated model is used to simulate a single stage VF wetland based on the Austrian guidelines with different substrate depths (20, 50 and 80 cm), organic loading rates (20, 40 and 80 $gCOD.m^{-2}.d^{-1}$), granular sizes of the filter material (0.06-4, 1-4 and 4-8 mm), loading intervals (1, 6 and 12 hours), density of distribution openings (0.5, 1 and 2 openings per $m^2$) and water temperature (5, 10, 15 and 20 °C). The available combinations resulted in 1728 individual simulations.

The results show that all parameters included in the study give key insights into the VF wetland performance and thus indicate the possibility of a more individual design approach. Based on the available dataset of the numerical experiments derived regression functions can describe the effect of the operation and design parameters on the treatment performance of COD, $NH_4$-N and $NO_3$-N. These functions will serve as design support for new VF wetlands as well as to investigate the adaption existing systems.

BIO of Presenter:

**Bernhard Pucher** is a senior scientist at the Institute of Sanitary Engineering and Water Pollution Control (BOKU, Vienna). His field of research includes the investigation of nature-based solutions for water pollution control and urban water management

# Hydraulic characterization in a hybrid aerated vertical flow-horizontal flow treatment wetland

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## Abstract

Pollutant removal in treatment wetlands (TW) can be affected by hydraulic characteristics, such as hydraulic retention time (HRT), dead zones, or short-circuiting (Headley & Kadlec, 2007). In the case of aerated TW, the air supplied influences the hydraulic behavior of the system. Previous research on aerated TWs has shown that aeration improves the mixing and provides conditions similar to a continuously stirred tank reactor (CSTR) for aerated vertical flow (VF) wetlands (Boog et al., 2014) and 4.5 tanks-in-series (TIS) in horizontal flow (HF) wetlands (Nivala et al., 2020). The studies published so far about aerated TWs have investigated systems that only have one flow direction (horizontal or vertical). The hydraulic behavior of a hybrid aerated wetland would presumably exhibit a different tracer response. This study reports the hydraulic characterization of a Rhizosph'air® system, which is a hybrid aerated wetland (vertical flow + horizontal flow). The system is dosed with raw wastewater on alternating halves of the system. To treat the solids and organic matter present in the raw wastewater, this hybrid design consists of a thin unsaturated layer gravel, followed by a saturated zone where the flow is a mix between vertical and horizontal flow, and a second saturated zone where the flow is predominantly horizontal. The aeration in each of the saturated zones can be modified independently, greatly complicating the hydraulics within the system. To better describe the impact of aeration on hydraulic behavior in this system, this study utilizes two complementary approaches: systematic, using a tracer test with an injection of amino-G acid, and local, using an Electrical Resistivity Tomography (ERT). The combination of these methods allows hydraulic characterization the complex system (HRT, NTIS, presence and location of dead zones, effective volume used). It also enables the characterization of aeration on mixing in the system. Six different aeration modes (varying aeration duration, aeration between primary/secondary filter) were conducted. The study was conducted in an experimental platform located in France, on a pilot with 20$m_2$ (2.5 m x 8 m).

This oral presentation will highlight how aeration affects hydrodynamics. The results include a NTIS value for each of the six aeration modes, with approximately 80% mass recovery and showing between 10-30% of dead zone volume in the system. The 3D-images from ERT indicate preferential pathways at the center of the wetland cells, and dead zones closer to the borders. Further analysis will be done to characterize the tracer plume development through space and time, as well as and its dispersion using moment-spatial calculations.

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BIO of Presenter:

**Caroline Miyazaki** is an Environmental Engineer and I am currently doing my PhD, which my main goal is to optimize and control nitrogen removal performance using online sensors (pH, redox potential, $NH_4$-N, and $NO_3$-N) in a new kind of TW (Rhizosph'air®), which has been specifically designed for achieving effluent quality suitable for water reuse.

# Modelling of arsenic removal, fate and distribution in subsurface flow constructed wetlands: preliminary results using a process-based tool

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**Abstract**

The removal of contaminants from water in constructed wetlands have been modelled with different purposes, from predicting the performance of a given system to comprehend the complexity of the physical, chemical and biological phenomena that take place in these systems. Among contaminants that can be found in water, arsenic is a metalloid of worldwide concern due to its toxicity and effects on human health. In the last two decades, several studies in the constructed wetlands area have proposed different types of models based on their purposes, and they can be categorized in two groups: (1) process-based mechanistic models that make effort to represent all the complex interactions between the contaminant and the components of the constructed wetland; and (2) simple approach models that use black-box terms, statistical regressions or simple kinetics law components. The second group is usually a useful tool for specific design purposes with known characteristics of the inflow and required water quality, but they are not capable to predict results for different environmental and operation conditions.

Among the currently available models in the literature, BIO_PORE is a useful tool that supports the understanding of the functioning of constructed wetlands for organic matter removal and bacterial growth and decay. Also, this model can be used as a basis for the development of models for other contaminants, despite being unrelated to organic matter. Another model that has been proposed for the removal of contaminants in constructed wetlands is RetrasoCodeBright (RCB) code. RCB code formulates the flow components through a multiphase approach that simulates hydraulics and hydrodynamics, as well as the main biodegradation and transformation processes in saturated media.

RCB-ARSENIC model is an implementation of RCB code for the arsenic removal processes in a constructed wetland. Despite being one of the most powerful tools currently available for this contaminant, still lacks mechanistic components that are not properly modelled yet. For example, sorption processes on the granular media are modelled using Monod-type kinetics, and parameters adjustment was performed using data from an unplanted wetland cell. This means that arsenic is considered to behave as biomass; however, arsenic sorption depends on the type of media. Also, this tool includes empirical correlations for kinetic laws associated to the arsenic uptaken by plants and to the sorption processes in plant roots. The associated parameters were adjusted using experimental data obtained from a pot system, having *Eleocharys macrostachya* as vegetation and tested under different arsenic concentrations. As such, this experiment poorly represents the process of arsenic uptake by plants occurring in a wetland system.

In this work, a first version of a BIO_PORE model adaptation to arsenic, based on RCB-ARSENIC code, will be implemented using experimental data from different studies. This adaptation will modify previous formulations of RCB-ARSENIC for sorption processes in the granular media and plant roots, and plant uptake, reformulating kinetic laws using a process-based approach. These studies tested different types of synthetic contaminated water, including synthetic acidic water prepared using tap water and chemicals to represent the Azufre River in Northern Chile; and synthetic water prepared using well water from Mexico and sodium arsenite. The predictive capacity of this model will be tested via parameter settings. This test and its parameter goodness-of-fit and statistical significance will verify the robustness of the mechanistic model, its applicability and extension. Preliminary results of the adapted model will be presented at the conference.

BIO of Presenter:

**Diego Bravo-Riquelme** is a chemical engineer and a Ph.D. candidate at University of Chile, under the supervision of Prof. Katherine Lizama-Allende. His research work is focused on the modelling of arsenic removal in constructed wetlands. Diego also teaches chemical and civil engineering subjects, focused on water quality and treatment systems.

# Bio-electrochemical systems

# Boosting electric voltage and powering an UV lamp for effluent disinfection in a electro-wetland system

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**Abstract**

In recent years, bioelectrochemical process in terms of microbial fuel cell (MFC) technology has been emerged with constructed wetlands (CWs) to form electro-wetlands (EWs) for wastewater treatment while electricity production. It has been demonstrated that the EW can enhance wastewater treatment performance while it faces practical barriers since it produces low electric energy, making it gloomy in terms of energy reuse.

This study is a contribution to developing integrated EWs and the use of generated electricity to power an UV lamp for effluent disinfection. A series of tiny EWs were integrated while an operational amplifier with a power management system was utilized to power supply an UV lamp. It then allows the generated electricity for used as treated wastewater (effluent) disinfection via the UV lamp radiation. Although it is the first try and the trial is in small scale (Fig. 1), the low voltage output obtained from the EW, was substantially increased by the amplifier prior to polarization. The amplified voltage was thus sufficiently enough and in consequence, utilized to feed a light. The low output voltage 0.45±0.22 V was simply harvested, successfully boosted up to approximately 3.5 V and effectively harnessed as a power supply. Disinfection efficiency of 94% can be achieved after 120 s UV radiation. This novel application is very interesting to utilize the green and natural bioenergy contained in wastewater to supply small electronic devices for disinfection purpose. This opens a novel way among the attempts of the reuse of generated electricity.

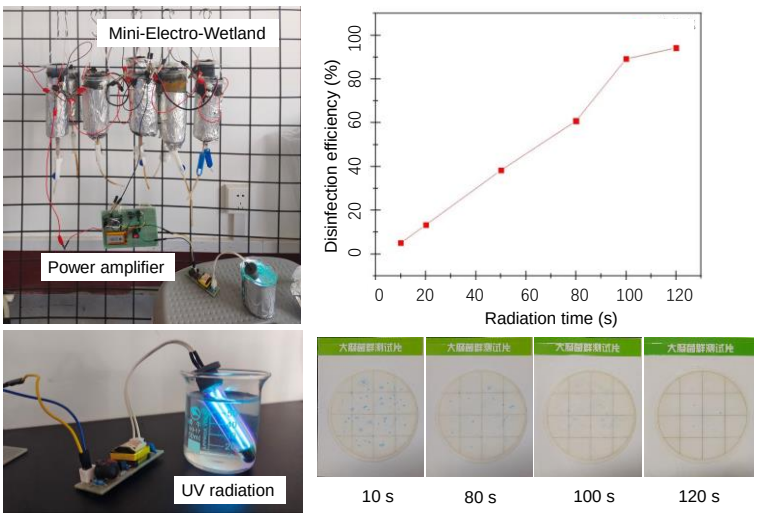


Fig. 1 EWs-UV system and disinfection results

BIO of Presenter:

**Yaqian Zhao** is a Fellow member of IWA and Distinguished Professor in the Department of Municipal and Environmental Engineering, Xi'an University of Technology, China, since Jan. 2019 while he was an academic staff in University College Dublin, Ireland, from 2004 to 2018. He has published > 400 research papers and is a highly cited researcher (Elsevier).

# Evaluating the impact of seasonal changes in temperature on secondary METland treatment performance

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**Abstract**
Constructed wetlands (CWs) have been widely utilized as a nature-based solution in treating various types of wastewaters due to their advantages such as low-cost and easy-operation, however, with stringent effluent concentration discharge by regulating bodies coupled with emerging pollutants globally numerous strategies to intensify pollutant removal/degradation processes have continue to emerge. The Microbial Electrochemical Technology Intensified treatment wetland (METland) is one of the emerging intensification strategies. The concept of METland involves substituting the traditional wetland media, such as gravel and sand, with an electroconductive (EC) media. This EC media creates conditions that promote electron exchange among naturally occurring electroactive bacteria (EABs) within the bed. These EABs are capable of transferring electrons from electron donors, such as carbon, to specific areas within the METland where these electrons are needed to complete microbial-mediated remediation processes, such as denitrification).
Research in this area has shown that, under similar operational conditions, the METland can achieve better treatment performance as a vertical flow system than conventional CWs, increasing COD removal from 73% up to 97% (Prado et al. 2020, Aguirre-Sierra et al., 2016, Aguirre-Sierra et al., 2020), while resulting in lower environmental impact (up to 75%) compared with other grey treatment technologies like activated sludge (Peñacoba-Antona et al., 2021).However, the impact of influencing factors such as changes in temperature at different seasons and age remains unknown. The aim of the study therefore was to evaluate the impact of seasonality on the treatment performance of the secondary METland system as it ages. The pilot scale secondary METland was operated as an unsaturated downward vertical subsurface low mode with a 6.25m$^2$ surface area and a flow rate of 1.01m/d. The average effluent temperature, DO and pH in Winter, Spring, Summer, and Autumn ranged from 7.8°C to 12.2 °C, 1.1 to 2.0 mg/L and 6.9 to 7.0 respectively.
**Key findings on impact of seasons and age on treatment performance**
Overall, there was no significant difference in the effluent concentrations of COD, $BOD_5$, TSS and ammonia which ranged from 52 ± 16 to 70 ± 27 mg/L, 17 ± 8 to 29 ± 12 mg/L, 22 ± 2 to 32 ± 6 mg/L and 4 ± 1 to 9 ± 2 mg/L respectively across all seasons despite changes in temperature. This observation is contrary to previous studies that argued that there is a decrease in carbon and nitrogen removal efficiency with decrease in temperature in particular winter due to poor oxygen transfer and subsequent microbial growth rate. The steady pollutant removal observed in the METland despite changes in temperature could be attributed to the enhanced electron exchange occurring within the METland, which supports electron availability and encourage microbial growth in cold season. Furthermore, it was observed that the effluent concentration of COD, $BOD_5$, TSS and ammonia were not significantly different between the 1$^{st}$ and 2$^{nd}$ year of operation despite increase in the influent concentrations in the 2$^{nd}$ year compared with the 1$^{st}$ year of operation. The findings so far show the METland systems can maintain a robust treatment performance at different seasons and as it ages. As an ongoing study, the microbial community evolution within the METland will be further assessed to give an insight on the electron exchange pathways occurring within the METland.

BIO of Presenter:

**Gabriela Dotro** main area of work is on understanding the biogeochemical transformation of phosphorus, iron and nitrate in engineered ecosystems, and translating research outputs for implementation by industry. This abstract is part of Gareth's PhD project for a water utility that is now building a full-scale demonstration treatment plant in Scotland.

# Microbial electrochemical technology constructed wetland for municipal wastewater treatment

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**Abstract**

Microbial electrochemical-based constructed wetlands (CW) are engineered systems (referred to as METlands) that use microbial fuel cell (MFC) principles aiming at improving treatment efficiency. In METlands, electroconductive materials are used as wetland media instead of e.g., gravel. The media acts as the connection between anoxic zones (anode, lower oxidation-reduction potential (ORP)) and oxic zones (cathode, higher ORP). By using electroconductive media, the CW becomes a short-circuited (no resistors between electrodes) MFC. Published reports advocate that these systems can enhance organics biodegradation rates and reduce clogging issues of conventional CW. However, despite studies so far reporting that METlands have the potential to outperform conventional CW, further research is still needed for the development and uptake of the technology.

In our study, pilot-scale experiments were used to (1) test the suitability of different electroconductive media materials and the efficiency of METland in the treatment of sewage water compared to conventional CW; (2) to measure and compare the GHG emission potential of METlands with CW; (3) to identify microbial-driven processes involved in organic matter oxidation and nitrogen cycling. Triplicates of vertical up-flow columns (D= 10 cm and H= 60 cm) were implemented to test three electroconductive biochars (olive pit, woodchip and wood pellet), coke and gravel (reference) as media. Systems were fitted with ORP sensors as well as pore water, inflow and outflow sampling ports. Real primary treated municipal wastewater was fed to the systems (ca 0,75 L/d) by displacement pumps. Gas collection chambers were specially designed to fit the systems and gas ($CO_2$, $CH_4$ and $N_2O$) flux measurements were conducted on two separate occasions. Inflow and outflow water samples were analyzed for: COD, total-P, $PO_4$-P, total-N, $NO_3$-N, $NH_4$-N, turbidity, etc. Materials were characterized via e.g., SEM, XRD, and cell voltammetry analysis. Biofilm will be investigated using DNA isolation, 16S rRNA gene amplicon and metagenomic sequencing.

Results of 6 months of pilot operations will be presented including systems efficiency and GHG emissions. Preliminary results show that the average (n = 13) COD removal was 75,9% in the gravel, 84,6% in the coke, 85,3% in the wood pellet biochar, 86,4% in the woodchip biochar and 85,7% in the olive pit biochar columns. Thus, being about 10% higher in columns filled with electroconductive material. Overall, systems filled with electroconductive biochars presented about 20% higher total N removal. The average (n = 9) removal of total N was 19,6%, 23,2%, 39,6%, 39,2% and 37,5% in the gravel, coke, wood pellet biochar, woodchip biochar and olive pit biochar columns consecutively.

BIO of Presenter:

**Elisangela Heiderscheidt** is a docent in wastewater engineering with over 20 years of experience working with wastewater treatment systems and processes including nature-based solutions. She works as a senior researcher at the University of Oulu (Finland) where she manages several projects and supervises 6 doctoral candidates.

# A decade of electroactive constructed wetlands- achievements and the way forward

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**Abstract**

Constructed wetlands (CWs) can efficiently treat wastewater without the use of energy, chemicals, or mechanical equipment. However, the slow treatment rate caused by the presence of inferior or insufficient electron acceptors in the anaerobic bed of the CWs limits their large-level implementation. The CW bed has a small aerobic surface layer and a huge deeper anaerobic layer where aerobic and anaerobic wastewater treatment processes occur, respectively. On the other hand, Microbial fuel cells (MFCs) are intriguing bioelectrochemical technologies that oxidize organic substances found in the waste/wastewater to produce electricity through the catalytic activity of living microorganisms. In the MFC, pollutants degrading oxidation (and reduction) reactions occur with the assistance of externally provided conductive material-based electrodes. However, much more research is required before the MFC technique can be practically applied in the real world. Despite having immense promise, each of the CW and MFC technologies has its own drawbacks.

CWs face significant challenges due to their slow treatment rate, which results in a large land use footprint. Various experiments were done to intensify the pollutant removal capacities of the CWs. A decade ago, another technology, i.e., Microbial Fuel Cells (MFCs) were merged with CWs (jointly named as CW-MFCs or electroactive constructed wetlands) to improve the treatment performance and to add on new features in CWs like electricity generation, nutrient recovery, pollutants sensing, etc. It got notable attention among constructed wetlands scientists. Nearly 150 plus research articles are published in scientific journals. A few focused sessions on CW-MFC were also held at the IWA and the WETPOL conferences.

The CW-MFC technology is at its early stage. Many researchers/groups are working and contributing in this domain for a decade. As technology is new and progressive in nature, it lacks many essential information, direction, and knowledge. For instance, design aspects are not fully optimized, cost of the material and how to reduce the cost are still not discussed with proper focus. The surface area of the electrodes is vital but largely ignored in most of the studies, which limits the benefit to a smaller level, and the mechanical strength of the conductive material are not discussed. Besides, there is a need for unified techniques, terminology, and methodology for further development. A frank assessment of problems associated with CW-MFC should also be discussed. Thus, this presentation at this conference will discuss the overall development, potential applications, and definite future direction for CW-MFC technology.

BIO of Presenter:

**Asheesh Yadav** is working as a scientist at CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, India. He is leading a research group with a focus on electroactive constructed wetlands development.

# Vertical flow wetlands III

# Modified plasterboard sheet waste from the civil construction industry as substrate in vertical-flow constructed wetland

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**Abstract**

. Constructed wetlands (CW) represent an economically viable alternative for decentralized wastewater treatment focusing on removing nutrients that could interfere with the balance of more sensitive receiving environments, leading to eutrophication. Recent research has explored emergent materials as substrates to improve the removal of pollutants in CW systems. Some exhibit a high affinity for phosphorus due to Al, Si, Ca, Fe, and Mg on their surface. Among these low-cost materials, plasterboard sheets (PS) stand out as construction waste because they are constantly consumed in this industry, and there are still few alternatives for its reuse. One significant advantage of using this waste is its low acquisition cost, as it has no value to the industry and instead incurs landfill expenses. Thus, fragments of modified plasterboard sheet waste (MPS) were applied as substrate in a vertical-flow constructed wetland (VFCW) of 28 L of the working volume and 0.18 $m^2$ of surface area to evaluate the removal of carbonaceous and phosphorous matter from synthetic wastewater. The system, named CW-MP, was planted with *Eichhornia crassipes* onto fragments of MPS (9.34 kg; 35% porosity) and operated in sequencing-batch mode for 308 days. To remove the layers of paper covering the gypsum panel, the fragments of PS were immersed in tap water for 4 days, and dried at 100 °C for 3 h in an oven for further application in the CW. The operation was divided into Phase I, with cycles of 24 hours, and Phase II, with cycles of 48 hours, counted after feeding. MPS was characterized using SEM, SED, and XRF analyses, and the bacterial community in the biofilm was evaluated in the system. SEM photomicrographs indicated that the internal surface of MPS exhibited smaller particles with heterogeneous shapes. Voids were detected, probably resulting from the presence of united and intertwined crystals, characteristic of the microstructure of dihydrate gypsum. Conversely, the external surface was smooth, with slight roughness and low porosity. After treatment in CW, no voids were detected, indicating a homogeneous distribution of aggregates. The chemical composition showed high O, Ca, S, and C values, besides presenting exchangeable ions on its surface, which increases its capacity for sorption, ion exchange, and precipitation. A decrease in S levels was associated with sulfur-oxidizing denitrifying bacteria, which actively participate in sulfur cycles. CW-MP showed COD removal efficiencies of 65% in Phase I and 70% in Phase II for the influent concentration range of 117 to 207 mg $L^{-1}$. Regarding total phosphorus, the system achieved removal efficiencies of 62% in Phase I and 54% in Phase II for the influent concentration range of 11 to 13 mg $L^{-1}$. No significant differences (p-value < 0.05) between the cycle times of 24 and 48 h were noted on the removal of COD and TP. The physical-chemical properties of MPS influenced the removal of phosphorus, probably related to the adsorption and precipitation of the formed aggregates. Therefore, microbial activity, adsorption, precipitation, and plant uptake were the most probable mechanisms to remove these pollutants in this CW.

BIO of Presenter:
**Karina de Carvalho** is graduated in Civil Engineering at State University of Maringá, Maringá, Brazil. MSc. and Ph.D. in Engineering at School of Engineering of São Carlos, University of São Paulo, Brazil. Ph.D. Professor at Civil Construction Academic Department at Federal University of Technology – Paraná, Curitiba, Brazil, at Environmental Science and Technology Graduate Program (PPGCTA), and Civil Engineering Graduate Program (PPGEC).

# Functions of the successive stages of vertical flow treatment wetlands based on biotic and abiotic solid/liquid interactions

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**Abstract**
With about 5000 units in operation, Vertical Flow Treatment Wetlands (VFCTWs) have become in France the system of domestic wastewater treatment most widely used in small communities below 4000 population equivalents (PEs). Most VFTW units in France have two successive filter stages and receive unsettled wastewater influents. A layer of organic sludge deposits therefore accumulates at the surface of the first stage at a rate of about 2 to 3 cm per year. The treatment of the Influent wastewater therefore proceeds by successive percolations through different porous media and the liquid/solid (L/S) interactions are therefore controlling the performance of treatment.

This presentation considers the nature of L/S interactions from the input to the output of the system in an attempt to describe how they are related to the characteristics of the circulation of wastewater through the media. The different porous media the wastewater successively flows through from input to output of the treatment line exhibit different characteristics. Three major parameters may be considered. The particle size distribution (texture) conditions the inter-particle porosity and thereby the permeability of the medium and the velocity of the flow. The organic content, nature of the mineral phases and specific surface area influence the sorption (and therefore residence time) of contaminants, substrates and nutrients and the attachment and development of microbial biofilms. Finally, the water saturation rate and depth control oxygenation and redox potential.

Based on these considerations, the functionalities of the successive stages of the treatment line are discussed. Data from the monitoring of pilot-scale and full-scale treatment units are used to verify how the theoretical functions fit to reality. The operating conditions are then considered (hydraulic and organic load, feed and rest alternance rate, etc.) to provide general strategies to steer the process according to the objectives of the treatment.

BIO of Presenter:
**Mathieu Gautier** is an Associate Professor at National Institute of Applied Sciences (INSA) of Lyon since 2009. He is working in DEEP laboratory (Wastes Water Environment Materials). His major field of research deals with the fate of contaminants in solid matrices. Since 2011 he is involved in research dealing with constructed wetlands.

# Full scale constructed wetland with novel post-treatment step and continuous monitoring, as alternative for sewerage in rural Flanders

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Conventional municipal wastewater treatment plants have been around for 100 years and are essential for safeguarding human and environmental health. However, still a lot of households in Flanders (Belgium) are not connected to a proper well-functioning wastewater system, as it is difficult and not cost efficient to connect everyone to the sewage system. This results in the emission of wastewater into the environment by around 400.000 houses, as one of the key origins of water quality problems. The European Water Framework Directive requires EU Member States to achieve good status in all bodies of surface water and groundwater by 2027. However, improvements in water quality in Flanders are achieved very slowly, partly due to sewer construction projects taking too long to accomplish in rural area's. Therefore the thought of using decentralized treatment is not new. But because of the lower removal efficiency (mainly nutrients) and limited monitoring compared to conventional wastewater treatment, alternative solutions were hardly deployed in Flanders.

Nowadays, solutions for the previous mentioned limitations with local treatment plants are available. In this case study, a rural residential area consisting of 14 houses in Ledegem (West-Flanders, Belgium) has been treating the domestic wastewater with a full-scale nature-based treatment plant. The main treatment step consists of a 140 m² constructed wetland (CW), with modular prefab elements. This makes the setup scalable, in case future houses are added or removed in the residential area. The pre-treatment step consists of solid-settlers, while a novel post-treatment step captures phosphates out of the CW effluent. This last step reuses a granular iron-based rest-product out of the potable water production process, to capture phosphate by low-cost and without energy consumption means. In the first 8 months of treatment, a total of 2100 m³ water was purified at a total energy use of 360 kWh, with the following average concentrations: <3 ± 0,3 mgBOD/L; 16 ± 8 mgCOD/L; <1 ± 0,3 mgTSS/L; 0,3 ± 0,2 mgTP/L; 22 ± 10 mg$NO_3$-N/L. The treatment is guaranteed by the continuous monitoring implemented inside and outside the system. Hereby, water quality sensors measure influent and effluent, as well as monitoring of the pressure pump (waterflow, pump times and energy consumption) and weather conditions by a weather station. All the collected data is presented in a clear dashboard, visible for the municipality and Flemish government. This complete and smart implemented decentralized domestic treatment is a pioneer case in Flanders. The company HelloWater has the ambition to optimize the CW's with the results of the continuous monitoring, as well as implementing this tailored solutions across Belgium and neighboring countries, as a faster implemented, lower environmental footprint and more cost-effective alternative for sewerage and conventional municipal wastewater treatment plants.

I would like to present an oral presentation at WETPOL 2023, where I will share the collected results and conclusions after one year of excessive monitoring of this project. As well as briefly explaining the challenges that become visible during these practical cases.

BIO of Presenter:
**Jente Lezy** After graduating as an Environmental Ind. Eng., I started working as a water researcher for UGent on the EU Interreg project I-Qua. Here my interest for decentralized wastewater treatment grew and led me to HelloWater, where we provide tailored nature-based solutions, with a focus on innovation.

# 5 years of performance of a novel design involving vertical and horizontal flow constructed wetlands for sewage treatment in India

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**Abstract**

Within the EU-India Water Cooperation Programme, one of the major R&D collaborative projects was SWINGS (Safeguarding Water Resources in India with Green and Sustainable Technologies) that focused on the deployment and development of low-cost sustainable technologies for wastewater treatment in India. This project was supported by the European Union FP7 Framework and the Department of Science and Technology of the Government of India (DST). Out of the six prototypes in real field conditions under this project, one is located in Aligarh, India (27.9185N and 78.0784E). The treatment system comprises an anaerobic digestor (UASB), a combination of a new type of design involving vertical and horizontal flow-constructed wetlands and solar power-driven disinfection techniques for treating domestic wastewater and reusing the treated effluent for non-potable purposes. To ensure high removal efficiencies, the latest models available in the scientific literature (i.e., the PkC* model) were used to calculate the sizes and operational conditions. The system was calculated to serve 2000 PE initially and to remove at least 95 % of the $BOD_5$, complete nitrification and removal of TN higher than 50%. One of the novelties in the design was underdrainage PVC perforated 110mm Ø pipes, spaced at 1 m in both directions and natural air ducts. These manifolds were engulfed in gravel and connected to perpendicular pipes of the same diameter, reaching the surface of the bed to allow the diffusion of atmospheric air to the bottom of the bed. The beds were planted with locally available *Phragmites australis* and *Phragmites Karka* at a density of 4 Plants/m2. The subsurface horizontal flow wetland has 2 parallel beds of 460 m2 each, but with different depths; one bed with 60 cm effective depth, while the other bed with 40 cm, resulting in a difference of 50% in the HRT, if loaded at the same rate. The media selected was a mixture of coarse sand and gravel, a 1:1 mixture of 2-4 mm and 4-8 mm washed media. The beds were planted with native *Iris, Canna indica* and *Sagittaria sagittifolia*. Based on the regular sampling, and monitoring in the last five years of its operations, the wetlands installed and the overall treatment facility have been treating sewage very effectively, reaching much below the maximum discharge standards as per the Indian norms. The treated effluent is being used for non-potable purposes like fish rearing, gardening, and toilet flushing. SWINGS has successfully demonstrated the use of treatment wetlands and also added value to this technology that has further triggered its application PAN India.

BIO of Presenter:

**Nadeem Khalil**, PhD from IIT Delhi is one of the experts of UASB and Treatment Wetlands based in India. Presently, working as a full-time Professor of Environmental Engineering in the Department of Civil Engg AMU Aligarh. Currently, he is holding a major collaborative research project "PAVITR" within HORIZON2020 Framework with research partners from 6 countries of Europe and 8 from India.

# SUDS I

# Multistage constructed wetland for water protection against urban drainage pollution

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**Introduction**
Progressive urban development affects the environmental balance and disrupts the hydrological cycle in which rainfall plays a significant role. Since stormwater is considered a valuable resource of the environment, many technical solutions are implemented that enable effective stormwater management. However, stormwater runoff from urban areas contains numerous (also toxic) substances and therefore should be properly treated. The study aimed to test the hybrid constructed wetland as a technology for the protection of Gdańsk Bay against urban derange discharge.

**Methods**
In this study, a multistage constructed wetland (MCW) pilot installation was used to remove selected groups of priority substances and emerging pollutants from a drainage collector in Gdańsk, Poland.
Collector water is a mixture of the former stream (closed in the underground pipe now), drainage water, and stormwater from the urban district of Gdańsk. The investigation has been carried out over two years period in an outdoor technical pilot installation consisting of 5 stages of treatment. The MCW was discharged by various hydraulic loads to mimic storm events. The flow in the MCW varied from 212 to 710 l/d.

**Results**
Obtained results showed that collector water was characterized by variable concentrations of heavy metals (Zn, Cd, Cu, Ni, Pb, Hg), polycyclic aromatic hydrocarbons (PAHs) like benzo(a)pyrene, benzo(b)fluoranthene, phenanthrene, fluoranthene, and pyrene and microplastics. The efficiency of total suspended solids (TSS) was very high and varied from 94% to 100% and surprisingly was higher for higher hydraulic loads.
Depending on the hydraulic load of the first bed (SS VF), the reduction efficiency for heavy metals ranged from 26.19 to 100%, for microplastics from 77.16 to 100%, whereas for PAHs was consistently high and equal to 100%.

**Conclusions**
Carried out investigation revile high and stable efficiency of both basic and emerging pollutants removal from urban drain water in MCW and thus proven usefulness of such solution for water protection. Based on the calculated MRR (mass removal rate) will be possible to upscale the system for Gdańsk Bay protection.

BIO of Presenter:
**Magdalena Gajewska** is a full Professor at Gdańsk University of Technology, and coordinator of EcoTech Center one of four excellence Center at GUT. Her background is environmental engineering and her work focus on NBS. She is co-author of 85 JCR papers, 5 international projects in the last 4 years, ORCID 0000-0002-6806-9771

WETPOL 2023
Bruges Meeting & Convention Centre, Belgium

# Where treatment wetland knowledge meets sustainable drainage system? An overview on design links and future research trends

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**Abstract**

There is an increasing demand by city planners to implement Nature-based Solutions (NBS) for stormwater management, with a particular attention to hydraulic climate change adaptation issues, mainly pluvial flooding. However, the hydraulic needs of infiltrating the stormwater (Water Quantity) must be coupled with the environmental needs of protecting the groundwater from the pollutants collected on paved urban surfaces (Water quality). If not properly addresses, the willingness to protect groundwater could become a barrier for the future implementation of Sustainable Drainage Systems (SuDS). On this regard, SuDS manuals and guidelines reports bioretention systems (or rain garden) among the best NBS solutions to deliver both stormwater infiltration and an effective pollution control. One of the most recent and recognized book for SuDS design, the SuDS Manual of CIRIA (Woods Ballard et al., 2015), suggests sand mixed with compost and/or soil as filling medium for bioretention systems, for an effective infiltration, first flush treatment, as well as plant sustainment. Interestingly, the sand proposed by the SuDS Manual is practically the same (diameter 0.2 – 2 mm) used in vertical subsurface flow constructed wetlands (Dotro et al., 2017). Essentially, SuDS Manual 2015 is, indirectly, bringing subsurface flow wetland in cities for stormwater treatment and infiltration. If on one side the effectiveness of bioretention systems for stormwater treatment have been extensively studied by the SuDS community of experts (e.g. Vijayaraghavan et al., 2021), on the other side the experience of the wetland community in designing NBS for water pollution control could bring a higher attention, and effectiveness, on water quality aspects of future SuDS design, looking for a better integration and collaboration with other professionals that usually plans and design SuDS in cities, i.e. architects, urbanism, landscapers, and hydraulic engineering.

This match, between knowledge of wetland community and different design needs coming from the SuDS sector, is raising new design and research challenges, as well as prospecting future innovative design of wetlands in multipurpose SuDS interventions. The presentation will give some insights on this trend, reporting experiences coming from the recent Italian experiences, where SuDS have been recently wide spreading, raising local doubts and uncertainties that, especially from the perspective of the water pollution control, can be successfully better addressed by wetland experts. Moreover, clarifying and highlighting the links between wetland and SuDS aim suggesting better design practices and future research trends.

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BIO of Presenter:

**Anacleto Rizzo** is partner of IRIDRA Srl since 2018. He M.Sc. in Civil Engineering, PhD in Engineering for Natural and Built Environment in 2013. He has 10 years of experience in sustainable water management, treatment wetlands, green-blue infrastructure, and nature-based solutions.

# Pollutant removal in bioswales

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**Abstract**
Pollutants such as nutrients, heavy metals, polycyclic aromatic hydrocarbons (PAHs) and micro plastic are transported with runoff during precipitation events. If these pollutants end up in the aquatic environment, they can have detrimental effects on the biota but also on human health. Currently, urban runoff is often collected in combined sewers where it is mixed with wastewater and then treated at the wastewater treatment plant (WWTP) before being discharged to the aquatic environment. Treatment at the WWTP reduces the load of pollutants discharged to the aquatic environment.
Precipitation events are expected to increase in intensity and frequency due to climate change. This will result in increased events with combined sewer overflow, as the sewers hydraulic capacity can be exceeded during these events. During combined sewer overflow, a mixture of runoff and wastewater is discharged directly to the aquatic environment without treatment, which constitute a serious threat to the aquatic environment. To prevent sewer overflow, several countries have started to separate their sewer systems. Separation of combined sewers could increase the amount of pollutants transported with runoff to the aquatic environment, because in separated sewers, wastewater is transported in one piping system while runoff is transported in another. In the second piping system, runoff is transported to a retention or detention pond before being discharged to the recipient without treatment at the WWTP. Removal in retention and detention ponds are mainly due to sedimentation, but this is not able to reduce the concentration of pollutants to levels below the discharge standards.
An alternative to ponds are bioswales. Bioswales are a constructed depression or trench in the landscape where runoff is collected by gravity and then infiltrated through a soil matrix. During infiltration, pollutants are mainly removed by sorption to the soil matrix. However, knowledge on removal rates in bioswales are limited and calls for an assessment. To assess removal rates, water quality is monitored in two bioswales located in the city of Aarhus, Denmark. Water quality is monitored in the in- and outlet of the bioswale combined with samples from two suction lysimeters at different depths in the soil matrix. Removal rates in the bioswales will be compared with removal rates in two retention ponds. We predict that the bioswales will show higher removal rates than the ponds due to sorption in the bioswales compared to sedimentation in the ponds.

**Acknowledgement**
The present study is funded by the EU Horizon 2021 under grant agreement No. 101060922.

BIO of Presenter:
**Emil Jespersen** has a PhD in biology from Aarhus University where he is currently working as a researcher with focus on nature-based solutions for water purification, resource recovery from wastewater and gas emission from nature-based solutions and natural systems.

# Qualitative and quantitative assessment of nature-based solutions to tackle urban stormwater

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## Introduction

Considering the global change (climate change combined with increasing urbanization) sustainable water management become one of major issue in urban area. On the Ostwaldergraben site (Strasbourg, France), a stormwater constructed wetland (SCW) (combining sedimentation pond and horizontal flow constructed wetland) was set up 10 years to explore the impact of nature-based solution on water (quality and volume) management. The aim of the study was to understand how SCW can mitigate the impact of water flow (impact on geomorphology) of water chemistry (releases of pollutants or change of the rivers physico-chemical parameters).

## Material & Methods

To investigate the impact of this SCW, the approach used in this study combined hydrology, hydraulics and physic-chemical analysis. First the catchment area with 33 % of impervious area was characterized. This data help to obtain the potential of runoff feeding the SCW based on Montana coefficient. Then the study site was instrumented by a weather station monitoring temperature, precipitation, relative humidity, radiation, atmospheric pressure, velocity and direction of the wind. The parameters combined with the hydraulics study (measurement of water flow using ultrasonic probes) and calculated parameters such evaporation (Rohwer), evapotranspiration (Penman-Monteith), infiltration (Darcy) help to determine the water budget. Finally, YSI probes were set up in the SCW to monitor physico-chemical parameters (pH, temperature, oxygen, conductivity,redox) combined with sampling campaigns to measure heavy metals.

## Results & Discussions

201 rainfalls were detected between May 2021 and June 2022. These rainfalls could be clustered in 4 main classes. After statistical analysis, the only hydrological parameter used to distinguish the clusters is the dry weather period. Only 54% of rainfall has reached the SCW, showing the importance of evaporation, evapotranspiration, and infiltration in the catchment area. However, during intense rainfall, 76% of peak flows are skimmed (and 65% are related to the pond activity), suggesting the key role of the pond in peak flow clipping.

Concerning the physico-chemical parameters, season and different rainfall will not impact the water quality observed in the systems, as no significant difference can be observed. This lack of difference is even more obvious in the second part of the SCW (filter) suggesting its buffer role of the bed filter. This bed filter is the key component of the system involved into the treatment. Indeed, the filter have a high removal rate for nutrient (70% for phosphorus) or heavy metal (such as 89% for Zn or Pb). This result could be explained by altering the oxygen conditions (aerobic, anoxic and anaerobic conditions) in the horizontal filter.

## Perspectives

The system seems to work with the current objective concerning stormwater quality but further studies should be conducted to model the potential impact of global changes.

BIO of Presenter:

**Loïc Maurer** is Assistant Professor at ENGEES. His main research activity is focused on Nature based solutions and their impact on water quality and their key role in the sustainable management of water. His research combined chemical analysis, hydraulics and hydrology.

# Green roofs & walls & greywater treatment

# Guidelines for designing green roofs and green walls for greywater treatment and reuse

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**Abstract**
Green walls are vertical systems that provide vegetation cover to the external – and possibly internal – walls of buildings. Green roofs are vegetated surfaces built on building roofs, composed of a medium layer where vegetation grows, a waterproof membrane and a vegetation layer. The implementation of these nature-based solutions (NBS) must take into account their water requirements, and the use of greywater has been proposed as an alternative water source to mitigate the water footprint of green walls and green roofs. Moreover, green walls can also be adapted to become greywater treatment systems, becoming NBS that generate reclaimed water resources for non-potable reuse. The interest in this particular application, i.e., green walls and roofs for greywater treatment and reuse, is rapidly growing in the last years, together with the interest of planners and designers. To this aim, NICE EU-funded project (Innovative and enhanced nature-based solutions for sustainable urban water cycle) will develop updated guidelines for designing green walls and green roofs based on the following information:

- literature review based on: (i) peer-reviewed literature, starting from the articles on living walls that were selected in cooperation with the Green Wall Cluster of the Circular City COST Action (https://circular-city.eu/); (ii) grey literature, including IRIDRA's recent experiences in designing and implementing innovative green walls within the NAWAMED project.
- Data from the laboratory stress tests developed within the NICE Project at the Politecnico di Torino, aimed to verify the stressful conditions that green walls for greywater treatment and reuse can face in real life: (i) hydraulic stresses, i.e. rapidly increases, decreases and stops of functioning; (ii) chemical stresses, i.e. increased dosage of aggressive cleaning products mixed with the standard greywater.
- Monitoring of the urban real labs demos of the NICE project dealing with greywater.

Based on the collected data, a dataset was systematized collecting performance (e.g. TSS, $BOD_5$, COD, nutrients) and design values. Particular attention has been paid on collecting data in line with design parameters typical of treatment wetland technology (e.g. area, weight, HLR – Hydraulic Loading Rate, OLR – Organic Loading Rate, OTR – Oxygen Transfer Rate). When not directly reported in the papers, the parameters have been calculated from information given in the paper or from literature values (e.g., weight of the filling media). The guidelines will also include a comparison of design variables with design values from most updated manuals and guidelines of treatment wetlands (e.g., Dotro et. 2017; DWA 2017), in order to identify sufficiently conservative design indications, merging the current knowledge on innovative NBS (green walls and roofs) with well-known NBS (treatment wetlands). Finally, the guideline will also pay a particular attention in listing the materials used for filter medium, including their main properties, benefits, and frequency of use.

**Acknowledgement**
This work was supported by the Horizon 2020 research and innovation program NICE (grant agreement No 101003765).

BIO of Presenter:
**Fabio Masi** is R&D Manager and Technical Director of IRIDRA Srl, since 1998 and Vice-President of Global Wetland Technology since 2012. He is PhD in Environmental Sciences and MSc in Environmental Chemistry (1991). He has more than 30 years of experience in sustainable water management and nature-based solutions for wastewater treatment.

# Vertical greening systems as multifunctional systems for urban water treatment reuse and circularity

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**Abstract**

Vertical greening systems (VGS) represent nature-based solutions (NBS) implemented within the building envelope to address challenges such as the urban heat island effect, air pollution, building energy consumption and decrease of biodiversity. To provide the needed functions and address these challenges water is a key resource. Up to now the main used water source for irrigation of VGS is drinking water. This practice eliminates the attribute of sustainability and contributes to the increase in urban water depletion. Therefore, with the application of circular economy principles for the operation of VGS, the use and reuse of wastewater and greywater is of high interest. Thus, the application of VGS as building integrated treatment wetlands (TW) has become a new research area in the recent years.

Due to the multifunctionality and interdisciplinarity in the design and operation of VGS for wastewater and greywater treatment various different designs and operational approaches are applied. In contrast to TW, VGS have a multifunctional purpose and are used by different professions, hence a more open research design investigating multiple approaches of application and their effect on the functionality is called for.

**Figure 1:Full-scale experimental system**

In this study, the multifunctionality of a pot-based VGS operated for over two years using a low-tech irrigation design is evaluated (**Error! Reference source not found.**). A main objective was the investigation of different irrigation schemas in terms of volume, time, and water quality, including irrigation with tap water and untreated greywater as well as greywater treatment. The data collection included, air and substrate temperature, precipitation and wind, substrate water content, water flow, plant biomass and vitality as well as water quality parameters (COD, $NH_4$-N, $NO_3$-N, TN, pH, EC, Turbidity). In addition, the comparability to other designs for greywater treatment is investigated to provide more insights for further development and application.

Based on the results recommendations on operational strategies to maximize the multifunctionality are established. This includes soil physical parameters of the substrates and applicability of multiple ornamental plants for greywater treatment, sizing, and irrigation practices.

BIO of Presenter:

**Bernhard Pucher** is a senior scientist at the Institute of Sanitary Engineering and Water Pollution Control (BOKU, Vienna). His field of research includes the investigation of nature-based solutions for water pollution control and urban water management.

# vertECO® raft – Lab-scale and prototype testing and development of a floating wetland system to mitigate eutrophication in the Baltic Sea

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**Abstract**
The Baltic Sea is the most polluted sea in the world and suffers from severe eutrophication due to internal phosphorus release from the polluted sediment under anoxic conditions. The goal of the lab-scale and prototype "vertECO® raft" systems are the investigation of Baltic sea water purification, nutrient retention and reuse, and release of treated sea water to the Baltic Sea.
**Lab-scale**; Initial tests used cut open plastic pipes (saturated pore space 4.5 L) filled with a substrate mix (zeolite, pumice, and biochar). Brackish water adapted plants *Schoenoplectus tabernaemontani* (ST) and *Bolboschoenus maritimus* (BM) were planted in six systems (triplicates) with one unplanted control (only substrate mix) (Figure 1). During establishment, systems were fed 25 days with artificial Baltic Sea water. After that real Baltic Sea water was fed with 7 L per system and day (HRT of ca. 15 h) in a horizontal subsurface flow. Four sets of inlet and outlet samples were taken every 2 days over a period of 9 days.

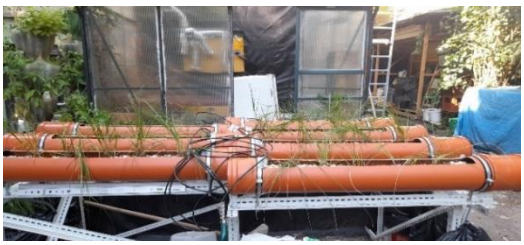

**Figure 1.** Lab-scale outdoor test setup

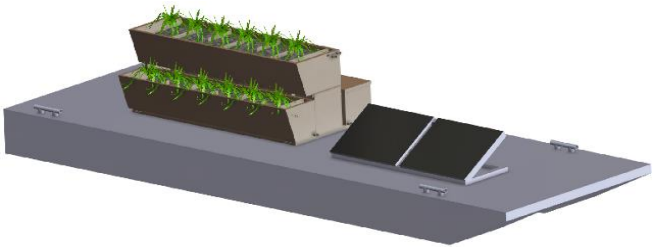

**Figure 2.** vertECO® raft prototype 3D model

BM systems showed higher average $PO_4^{3-}$ and $NH_4^+$-N reduction of 59% and 98% compared to ST with 38% and 90% and control with 37% and 91%, respectively. The comparatively high removal rates in the control systems indicated that the majority of removal was due to substrate (especially in the case of P adsorption) and microbial effects (especially in the case of N conversion processes). Nitrate levels were generally low (below 0.05 mg/L) and pH increased on average from 8.1 to 8.6 in the control and 8.9 in the two planted triplicates. Interestingly, EC was reduced by 5, 10 and 7% in control, ST and BM, respectively.
**Prototype vertECO® raft system**; In the next step, a prototype system was developed to be placed in-situ into the Baltic Sea in a bay at Utö island, Sweden. The system consists of a raft equipped with two vertECO® basins stacked step-wise above each other, with subsurface horizontal flow over a length of 2 m with ca. 100 and 80 L pore volume and artificial aeration (Figure 2). After that, a chamber with magnesium hydroxide coated biochar cartridges adsorbs remaining nutrients - especially P - with a pore volume of ca. 80 L. A pump feeds Baltic Sea water from the surrounding waters into the upper vertECO® stage, with ca. 500 L/d resulting in an overall HRT of ca. 12.5 hours. All equipment, i.e., pump and air compressor, is powered with solar panels. Selected plants are BM, ST as well as a mix of further salt tolerant plants. The system will be set up in April 2023 and sampling and analysis performed from May to August 2023.
**Funding:** *Lab-scale*; a short-term scientific mission of Ece Kendir Cakmak (EU Cost Action CA17133), (TUBITAK, 2219-Grant Agreement No:1059B192000320) *Prototype*; The Nordic Council of the Ministers Program "Nature Based Solutions in the Nordic Region".

BIO of Presenter:
**Marco Hartl** is project manager and technical coordinator at alchemia-nova, Vienna. His work focuses on nature-based solutions for wastewater purification and reuse, especially using constructed wetlands and green wall systems. Before that, in mid-2020, he obtained his PhD at UPC Barcelona and Ghent University on CWs combined with bio-electrochemical systems.

# Nature-based solutions for greywater reuse to reduce the consumption of drinking water: the potential for public buildings in Luxembourg

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**Abstract**

Water stress indicators have been widely used in the last twenty years to assess the vulnerability of our ecosystem when it comes to water availability. A growing population and economy in fact result in a more intensive consumption of freshwater to meet the demands of agriculture, industry and households. Additionally, the impact of climate change negatively influences the replenishment of groundwater storage hampering the achievement of a good quantitative status as a pillar of the Water Frame Directive (2000/60/EC). This cross-cutting nature of the water stress issue has forced the Member States to adopt measures among the different policy areas.

Despite water has been considered abundant in Luxembourg, limits on consumptive use were precautionarily adopted already since 2008 (The Water Act). Groundwater provides today 57% of the annual use of water in Luxembourg (45 million m3 in 2022) while the remaining 43% is supplied to public utilities from the Esch-sur-Sûre reservoir, located in the north of the country. According to a recent forecast, withdrawals are projected to equal freshwater replenishment by 2035, calling for action towards its responsible use. With 140 litres per day per capita, Luxembourgish households represent most of the abstracted water (60%), followed by industry (23%) and agriculture (less than 7%). While the total share of industrial water consumption in Luxembourg is lower than in other Member States due to the decline of the steel industry, agricultural consumption is expected to increase with the increasing rule of locally produced food. Household consumption has finally increased by 1.35% per year over the last 15 years reflecting the specific situation of Luxembourg, with its demographic growth (1.5% per year) and steady increase in cross-border workers.

The project GreyReuse is funded by the Luxembourgish water agency (Administration de la gestion de l'eau) and particularly aims to save potable water anticipating the challenge of 2035. It is based on the principle that light greywater (from showers and bathtubs) can be separated, treated on-site, and reused for non-drinking purposes, such as toilet flushing. A few challenges including lack of minimum legal requirements, affordability, public acceptability, and liability have been the main barriers towards its implementation in the construction sector.

To this end, a vertical flow constructed wetland will be tested in Clerveux at the international school Edward Steichen (circa 741 students in 2021-2022) for the treatment of light grey water from showers. The nature-based solution will be supported by an innovative substrate whose efficiency is enhanced with the use of admixtures produced in a circular economy perspective (i.e., biochar from plants biologically activated). The substrate is selected on the base of a preliminary study conducted at a laboratory scale under controlled conditions. General macropollutants such as Chemical Oxygen Demand (COD) and Total Nitrogen (TN) will be monitored together with common pathogens (total coliforms, Escherichia coli and Pseudomonas aeruginosa). Stress conditions such as the high release of detergents will be tested together with the need for disinfection options and online monitoring strategies. The proposed solution is expected to be simultaneously resilient, with a low footprint and reduced maintenance which will encompass its challenges providing additional biodiversity benefits.

BIO of Presenter:

**Silvia Venditti** is a Research Associate at the University of Luxembourg since 2017. She has 14 years of experience in the treatment of emerging contaminants from wastewater effluents. Her interests are in the circular economy, collaborative projects and translating science into policy for a better environment.

# Micropollutants removal

# Performance of artificial wetland to reduce pesticide flows: a review of 10 years of monitoring coupling mesocosm and field results

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**Abstract**
The use of pesticides in large-scale farming results in the dissemination of residues in all environmental compartments. In the specific case of agricultural drainage, even if the fluxes in drained waters rarely exceed 0.1% of the applied quantity, the concentrations in surface waters can exceed the predictable no-effect concentration (PNEC) and generate an impact for aquatic organisms.
In addition to actions based on the reduction of pesticide use, intercepting drained flows is an option that has been tested for more than 10 years on an experimental watershed in Paris suburb (France). The concept of buffer zone implies a role of natural interface between agricultural production areas and aquatic environments. In the case of agricultural drainage, artificial wetland buffer zones (AWBZ) are the most suitable to store drainage water and promote biogeochemical processes of pesticide retention.
We propose to present a multi-year analysis of the retention efficiency of a hundred pesticide molecules applied at the scale of a 400ha watershed. These full-scale experimental results are compared to the results of in situ mesocosm experiments (semi-controlled conditions) exploring the retention potential by playing on different factors.
The Rampillon experimental ZTHA was constructed in 2010 on a 0.5ha land area. The AWBZ intercepts the drainage water of a 400ha fully drained upstream watershed. The type of agriculture is representative of the large cereal crops of the Paris basin with 56% wheat, 18% beet, 14% corn and 15% other crops. The performance monitoring started in 2012.
Monitoring of inflow and outflow based on flow-sensitive composite sampling shows variability in retention for all pesticides monitored. Herbicides are on average retained at -18% [-5 to -40%], fungicides at -24% [+2 to -67%], insecticides at -12% [0 to -100%] and metabolites at -13% [+13 to -43%].
In parallel, fate tests of 11 pesticides applied at environmental doses (between 1 and 10µg/L) were performed on so-called in situ mesocosms (1m²) as they were directly deployed in the center of the AWBZ. Four replicates were monitored for 28 days in May 2022. The results show that the AWBZ concept has a real retention potential for the 11 molecules tested, since 50% of the quantity initially added is dissipated in 10 days on average. The half-life times calculated from the temporal monitoring are shorter than those available in the databases (e.g., PPDB). If the kinetics of the parent molecules are encouraging, the metabolites seem in most cases to be very stable, which raises questions about their impacting fate in aquatic environments.
Comparing the two experiments, the performance of the AWBZ is consistent with the mesocosm monitoring, considering a mean annual residence time of 3 days (-16%). The water residence time is a key factor in the efficiency, in addition to the properties of the molecules. The design of the experimental AWBZ, resulting from a process of co-construction with the stakeholders, led to a surface and volume ratio of 0.15% and 7m3/ha drained. To ensure an annual average time of 10 days, the sizing should have been ten times bigger.
These results from 10 years of monitoring show that the ZTHA solution has a real potential to retain pesticides from agricultural drainage and that performance is highly dependent on sizing with a recommended ratio of 70m3/ha drained.

BIO of Presenter:
**Julien Tournebize** is a senior scientist at INRAE, Antony, France. He develops research on non-point source control and water preservation in agricultural catchment. He tested design and performance of constructed wetlands and riparian zones to mitigate nitrate and pesticides in subsurface drained areas.

# Performance of constructed wetlands for the removal of personal care products[3]

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**Abstract**

This research investigates the performance of four types of constructed wetlands (CWs): free water surface flow CW (FWSCW), horizontal subsurface flow CW (HFCW), vertical subsurface flow CW (VFCW), and hybrid CW (HCW) for the removal of 20 personal care products (PCPs), based on secondary data compiled for 137 CWs reported in 39 peer reviewed journal papers. Despite considerable variation in the removal efficiency of PCPs, CWs prove to be a promising treatment technology. The average removal efficiency of 15 widely studied PCPs ranged from 9.0% to 84%. Although CWs effectively reduced the environmental risks caused by many PCPs, triclosan was still classified under high-risk category based on effluent concentration. Five other PCPs were classified under medium risk category (triclocarban > methylparaben > galaxolide > oxybenzone > methyl dihydrojasmonate). In most of the examined PCPs, adsorption and/or sorption is the most common removal mechanism followed by biodegradation and plant uptake. The comparatively better performance of HCW followed by VFCW, HFCW, and FWSCW was attributed to the co-existence of aerobic and anaerobic conditions, and longer hydraulic retention time (HRT) enhancing the removal of PCPs (e.g., triclosan, methyl dihydrojasmonate, galaxolide, tonalide, and oxybenzone), which are removed under both conditions and by adsorption/sorption processes.

This research also examines the correlation analysis of selected design and operational factors (depth, area, hydraulic and organic loading rate, and HRT), and physicochemical parameters (pH, temperature, and dissolved oxygen) of CWs with the removal efficiency of PCPs. The results demonstrated that the removal efficiencies of the studied PCPs exhibit a significant correlation with two or more of these factors. The role of plants in the removal of PCPs is demonstrated by the higher performance of planted compared with unplanted CWs due to direct uptake of PCPs and their aerobic biodegradation. The enhanced removal of PCPs was achieved with the use of substrate material of high adsorption capacity and with high surface area in CWs. The removal efficiency of almost all the studied PCPs revealed seasonal differences, but significant difference was established in the case of galaxolide and methyl dihydrojasmonate. Based on the above findings, the efficient removal of PCPs demands the integrated design of CWs ensuring suitable environment for the occurrence of required processes along with the optimal values of design and operational factors, and physicochemical parameters.

BIO of Presenter:

**Huma Ilyas** is a postdoctoral assistant at LIWET – Laboratory of Industrial Water and Ecotechnology, Department of Green Chemistry and Technology, Ghent University Campus Kortrijk, Belgium. Her research focus is to develop novel models of constructed wetlands for simulation of emerging organic contaminants using process-based and data driven modelling approaches.

[3] This presentation is based on following publications:

**Ilyas, H.,** van Hullebusch, E.D., 2020. Performance comparison of different constructed wetlands designs for the removal of personal care products. *International Journal of Environmental Research and Public Health*. 17 (9), 3091, 1-26. DOI: https://doi.org/10.3390/ijerph17093091

**Ilyas, H.,** van Hullebusch, E.D., 2020. The influence of design and operational factors on the removal of personal care products by constructed wetlands. *Water*. 12 (5), 1367, 1-20. DOI: https://doi.org/10.3390/w12051367

# PESTIPOND project: fate and behavior of pesticides in ponds and at the catchment scale

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**Abstract**

Ponds in agricultural areas are ubiquitous water retention systems acting as reactive biogeochemical hotspots controlling pesticide dissipation and transfer at the catchment scale. Several issues need to be addressed in order to understand, follow-up and predict the role of ponds in limiting pesticide transfer at the catchment scale. Using well-referred field survey data, a cutting-edge hydro-biogeochemical approach combined with integrative modelling at different scales, the ANR project PESTIPOND aims to address the major bottleneck faced by agricultural wetland and ponds scientists and practitioners today. New laws, governance and concepts to implement pond impact in interlocked scales from the head-water to river catchment will only become accessible through evaluation of key processes sustained by pond compartments involved in pesticide cycling, storage and transformation and relating them with pesticide transfers at the catchment scale.

Here we present the main results of PESTIPOND and keys messages on the potential of ponds systems to mitigate pesticide pollution will be addressed following the three interconnected experimental tasks of the project:

- Biogeochemistry of pesticide behavior under field conditions depending of pond characteristics (lifespan, efficiency, processes, fluxes), and hydro-climatic conditions in different agricultural contexts. This has been explored through the monitoring of three contrasted pond systems: Rouffach in Alsace in vineyard context, Rampillon in Ile de France in subsurface drained cereal crops, Aurade in Occitany in surface runoff cereal crops;
- Pesticide dissipation pathways in ponds and involved compartments: in situ and in laboratory experiments, including evaluation and prediction of the distribution, persistence and degradation characteristics of pesticides at the water-sediment-organisms interface of ponds in laboratory microcosms and outdoor mesocosms, and develop technic based on isotope pesticides and passive samplers POCIS;
- Impact of ponds on pesticide transfer to surface waters based on simulation of pesticide dissipation from the pond scale to the landscape with cumulative effects of ponds at catchment scale to generate pond management scenarios and relationships with land use and agricultural practices on the slopes of watersheds upstream of the ponds. Here a genuine modeling approach has been developed to integrate the role of ponds at the catchment scale, and to improve the spatial prediction of pesticide transfer and risk assessment across the catchment-ponds-river continuum to facilitate management rules and operations.

Overall, the innovative concept of the agricultural pond-centered PESTIPOND workflow is to constrain in situ processes of pesticide transformation in pond compartments to feed into an integrative modelling framework of risk and spatial predictions of pesticide transfer at the catchment scale, including the cumulative role of inter-connected ponds.

BIO of Presenter:

**Julien Tournebize** is a senior scientist at INRAE, Antony, France. He develops research on non-point source control and water preservation in agricultural catchment. He tested design and performance of constructed wetlands and riparian zones to mitigate nitrate and pesticides in subsurface drained areas.

# Emerging contaminant behaviour within a full-scale free water surface constructed wetland

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**Abstract**

Constructed wetlands offer a nature-based treatment option to tackle the widespread discharge of pharmaceuticals and other chemicals of emerging concern to the freshwater environment via domestic wastewater. This research investigates emerging contaminant behaviour within a full-scale free water surface constructed wetland in South-West England, which receives effluent from a rural wastewater treatment plant (2,000 population equivalent). This research was carried out in collaboration with Wessex Water, a regional water utility company, to better understand the value of constructed wetlands as a tertiary step in wastewater treatment in the UK.

Water, sediment, and wetland plant samples were collected in the summer of 2021, to assess the behaviour and distribution of 139 chemical targets within the wetland. These include pharmaceuticals and their metabolites, personal care products and illicit drugs. Water samples were prepared by solid phase extraction, and sediment and plants by the QuEChERS method, prior to analysis by ultra-high performance liquid chromatography coupled with tandem mass spectrometry (UPLC-MS/MS). Of 139 targets, > 80 were quantified in wetland water samples in the ng $L^{-1}$ – µg $L^{-1}$ range. Overall, the wetland reduces cumulative influent loads of these targets by 40-45%. Removal efficiency is compound dependent with ≥90% removal of some compounds, notably quinolone antibiotics and tetracycline, and >50% removal of carbamazepine and diclofenac (known to be recalcitrant in the environment). 45 targets are quantified in sediment samples, with concentrations typically below 100 ng $g^{-1}$. This evidences partitioning to the sediment phase for certain compounds, however it is considered to be a minor mechanism of pharmaceutical removal from the aqueous phase. Analysis of plant tissues shows evidence of uptake and translocation of chemical targets within plants.

Concentrations of some compounds exceeded literature predicted no effect concentrations in wetland effluent, notably fexofenadine and diclofenac. However, the wetland acts to significantly reduce dissemination of chemicals of emerging concern from treated wastewater into the wider environment. Detailed assessment of removal mechanisms and the system mass balance may be used to determine optimal operational parameters for similar systems installed in the UK in future.

BIO of Presenter:

**Emma Vaughan** is a PhD candidate at the University of Bath, supported by GW4 NERC Centre for Doctoral Training in Freshwater Biosciences & Sustainability. Her research interests are in freshwater environmental chemistry and water treatment. Her current research investigates emerging contaminant behaviour in constructed wetlands, in collaboration with Wessex Water.

# Special wastewaters

# Set-up and performance of a constructed wetland system to improve landfill leachate management containing PFAAS in a conventional wastewater treatment plant

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**Abstract**
Constructed wetlands (CWs) treating landfill leachates have shown relatively good removal efficiencies so far. However, the disposal of difficult-to-process matrices such as perfluoroalkyl acids (PFAAs) in landfills raises questions about the role CWs can actually play within a treatment plant, as well as the treatment performance.
Here, our aim was to show how a CW can effectively integrate a conventional wastewater treatment plant that also handles landfill leachates containing PFAAs and improve the wastewater management. A pilot hybrid plant was set up in March 2023 at the "Acque del Chiampo Spa" sewage treatment plant in Arzignano (Vicenza province, NE Italy) consisting of two in-series vertical subsurface flow CW followed by one subsurface horizontal flow CW. The innovation of the system lies in the use of readily available and transportable tank modules, giving the designed CW the characteristic of transportability, disposal, or use where most required. This aspect is of primary importance given the quali-quantitative heterogeneous characteristics of the produced leachates, which often come from different landfills –operating or closed– that are managed by the same company.
The CW covered an area of about 20 $m^2$, was filled with gravel and planted with common reed (*Phragmites australis* (Cav.) Trin. Ex Steud), and has been managed with a hydraulic load of about 20 mm $d^{-1}$. The system was fed with a landfill leachate containing high concentrations of ammonium (>150 mg $L^{-1}$), chloride (> 200 mg $L^{-1}$), COD (>600 mg $L^{-1}$), EC (>3000 µS $cm^{-1}$) and total PFAAs (>70 mg $L^{-1}$), and managed according to wastewater recirculation, i) to improve contaminants removal efficiency, and ii) to reduce effluent discharge before its transfer to the sewage treatment plant. Whether required, e.g., in drought periods with low leachate production, the CW can be fed with wastewater or water outputs from the sewage treatment plant. The monitoring of CW performance efficiency, as well as the water and contaminants balance between input and output (including 11 perfluoroalkyl carboxylic acids and 3 perfluorosulfonic acids with different perfluorinated C-chain length), was planned to start from April 2023. First results are encouraging: the created modular CW system showed its suitability for handling different leachate volumes, which suggests its ability of improving the physicochemical leachate parameters. Furthermore, it promises to improve the management of the entire wastewater and landfill leachate treatment plant.

BIO of Presenter:
**Nicola Celadon** is a recent graduate in 'Sciences and Technologies for the Environment and Territory' at the University of Padua. He is currently a research fellow studying PFAAS accumulation in plants through a collaboration between the Department of DAFNAE of the University of Padua and the company "Acque del Chiampo Spa".

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# Implementation of landfill leachate treatment with nature-based solutions: LIFE GREEN ADAPT project

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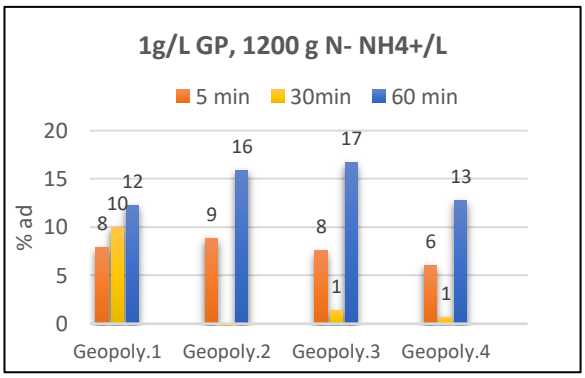
**Abstract**

Landfill facilities have been dealing with leachate treatment in the last decades. In recent years, the use of nature-based solutions (NBS) has been identified as treatments that are comparatively inexpensive, easy to operate, and environmentally sustainable in comparison with conventional ones[4]. The NBS also support the necessity of the landfills to work in the 2030 Agenda and the UN sustainable development goals due to the numerous benefits provided to human health, food, and energy security[5].

One of the goals of the LIFE GREENADAPT project is to treat in a demo plant the leachate and the water runoff generated in XILOGA Landfill (As Somozas, Galicia, NW Spain). This wastewater has a high content of nitrogen compounds, (N-$NH_4^+$ 500 mg/L – 900 mg/L) and organic matter (COD: 907 mg/L – 1364 mg/L; BOD: up to 113,8 mg/L). These effluent needs to be treated prior to discharge. Thus, the treatment selected is a combination of three constructed wetlands:

- **Floating treatment** as a preliminary phase to install directly in one of the ponds which receive the wastewater. The challenge of this unit is to deal with the high content of ammonium trying to reduce the organic matter content before pumping the wastewater to the next systems.
- In parallel it will be studied the capacity of:
  - **Aerated vertical wetland with Geopolymer** (GP): The aerated treatment wetland is updated with a GP unit formulated to enhance the reduction of ammonium. Preliminary results in the laboratory of different formulae have provided satisfactory results for treating high ammonium concentrations at different times.
  - An **electroactive constructed wetland** with a bed formed by recycled conductive material which will be studied to face the different pollutants and generate treated water with high quality standards to ensure the reuse in the landfill facilities.




The pilot plant construction is near complete, and the preliminary operations results will provide information for the capacities of plant to deal with landfill leachate treatment challegues. This info will be employed to optimize the wastewater treatment minimizing the impact of these effluent on the landfill and providing a source of alternative water for reuse in the facilities the climate change.

BIO of Presenter:

**Luz Herrero** (MSc Environmental Chemistry) is the Head of the Environmental Tech. Unit in AIMEN and coordinator of LIFE GREENADAPT project. She has been working on national and international R&D projects for more than 20 years, focusing on the use of NBS for water treatment, waste valorization and circular economy.

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The project **LIFE GREEN ADAPT** has received funding from the LIFE programme of the European Union under the Grant Agreement no LIFE20 CCA/ES/001795.

# Carbamazepine and diclofenac removal from real industrial wastewater using hybrid constructed wetland: pilot study

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**Abstract**
A pilot study of constructed wetlands (CWs) was designed and operated to remove Carbamazepine (CBZ) and diclofenac (DCF) from pharmaceutical wastewater discharged at factory in Jordan. This pilot is installed after secondary activated sludge system where the CBZ and DCF are hardly removed by this treatment system. Jordanian zeolitic tuff (RZT) and its modification (MRZ) were used as a wetland media in all CWs. A tidal flow CW (TFCW) filled with MRZ was used for the first stage treatment followed by a horizontal subsurface flow CW (HSSF CW) filled with RZT as the second stage treatment. The CWs systems was continuously operated under the hydraulic loading rate 0.32-0.64 m/day for 75 days. The average influent concentrations of CBZ and DCF 284 and 935 µg/L respectively. Removal efficiencies up to 84% and 77% were achieved for CBZ and DCF, respectively in the CWs pilot. The removal efficiencies of CBZ and DCF gradually decreased from 84% to 34% and 77% to 8%, respectively after 34 days operation. The removal rates of CBZ & DCF by MRZ is higher than those by RZT. The pilot results demonstrated a promising performance for innovate nature-based solutions for pharmaceuticals removal. Moreover, the pilot system is continued monitored and the results will be present during the conference.

BIO of Presenter:
**Tao Lyu** is a Lecturer in Green Technologies and the Environmental Engineering MSc course director at Cranfield University. He received his PhD from Aarhus University in 2016, and his research focuses on the innovation and implementation of Nature-based Solutions (NbS), specifically Constructed Wetlands (CWs), for treating diverse wastewater types.

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# Impact of design aspects on iron removal from coal mine drainage in full-scale lagoons

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**Abstract**
In response to the potential deterioration and significant ecological problems caused by coal mine drainage, passive Mine Water Treatment Schemes (MWTS), consisting of settlement lagoons and aerobic wetlands, were developed to remove iron and other contaminants prior to discharge into the environment. Existing research, which has examined individual design aspects separately, has suggested the influence of lagoons' and wetlands' design on treatment performance. Long-term research is however lacking in design aspect combination of full-scale mine drainage treatment systems that will ensure consistent iron removal and optimal treatment of the mine drainage. This study analyzed the design aspects of lagoons in five (5) full scale passive MWTS, alongside monthly iron concentrations spanning over a period of twelve (12) years to evaluate the treatment performance based on different design aspects. Correlation and regression analysis were conducted to offer a better understanding of the potential relationships between iron removal efficiencies and the design aspects of the lagoons.

Results showed that the mean iron removal efficiencies of the lagoons ranged from 25.12% to 92.85% and were impacted by the different designs of the lagoons. The correlation and multiple regression analysis results suggest that Water Level, Surface Area, Aspect Ratio, layout and ratio of inlets and outlets as well as Shape of the lagoons affected iron removal ($R^2$ 0.78, p-value <0.05). Lagoons with higher aspect ratio were observed to have performed better at removing iron. The presence of multiple inlets and outlets, which if properly configured, also allows for an even inflow distribution across the width of the lagoon, resulting in better iron removal. A reduction in water level was also observed to lead to increased iron removal, and as water level changes with season, seasonal variation also influences iron removal. Furthermore, the result of the data analysis demonstrated that the age of the lagoon affects its treatment performance. It is known that the older the lagoon, the more the deposition of sludge and other organic materials which negatively impacts the lagoon's treatment performance, especially if the sludge is not regularly removed from the lagoon. Overall, lagoons with mid-mid configuration, multiple inlets and outlets and aspect ratio of 4 allows for better flow and contaminant spread within the system, ensuring better adsorption and optimal removal of iron, although subject to regular ochre removal.

**Keywords**: iron removal, coal mine, full-scale, design aspects, mine water discharge, treatment performance

BIO of Presenter:
**Oluwanisola Okeleji** is a PhD student in the School of Engineering and the Built Environment at Birmingham City University. Her research focuses on the performance of full-scale water treatment systems. With a passion for environmental sustainability, Sola hopes to contribute to the development of safe and cost-effective water treatment solutions.

# SUDS II

# Treatment capacity of enhanced rain garden – case study in Gdańsk

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## Introduction

Today, nature-based solutions (NBSs) are developing an innovative multifunctional structure to maximize urban ecosystem services such as stormwater preservation, reduction of runoff and flood protection, groundwater pollution prevention, biodiversity enhancement, and microclimate control. However, a very big problem in collecting rainwater in the city is its quality, which is variable over time and depends on many factors occurring in the micro-catchment. The work aims to evaluate different solutions both technical and non-technical which could be applied in rain gardens to enhance the treatment of stormwater. In the last 4 years, rain gardens have become more and more popular and it is estimated that they now provide a retention capacity of c.a 200.000 $m^3$, which is also a huge potential for the reuse of retained water, but the water needs to be clean and bacteriologically safe. The work presents various technical considerations and their impact on the effectiveness of rainwater treatment, and ecosystem functions provided by rain gardens operating in different technologies and surroundings will be evaluated. Among such tools, an oil separator or setter can be included to absorb the initial, most polluted runoff. During winter, the most undesirable for biodiversity and plants may be a large amount of sodium chloride, which is usually used to prevent black ice.

## Case study description

Moreover, in the NICE project an enhanced rain garden consisted of 3 stages of treatment: 1- sedimentation part, 2- filtration part through 3 different sorption materials, and 3 – main part with different plant spices that will be evaluated and compeer with solutions already existing in Gdańsk. Three separate filtering segments will be filled with (1) gravel with a grain size of 2-8 mm, (2) sorption material - heated carbonate-silica rock with a grain size of 2-8 mm, and (3) biochar with a grain size of 2-8 mm, thus the sorption capacity of different material will be easily comparable.

## Results

Analyzed runoff samples were collected during rain and snow events. Achieved results have shown a significant variation in runoff measurements in enhance rain garden location. A considerable difference was observed in TSS concentration, where the TSS lowest value was equal to 16 mg/L and the highest 452 mg/L. Whilst, TSS values in typical rain gardens implemented in Gdańsk vary from 220 to 2920 mg/L in the inflow and from 62 to 148 mg/L in the outflow, depending on the micro catchment type.

**Acknowledgement**
The investigation was carried out in the NICE project – "Innovative and Enhanced Nature-Based Solutions for Sustainable Urban Water Cycle" HORIZON 2020 project, grant agreement ID: 101003765.

BIO of Presenter:
**Magdalena Gajewska** is a full Professor at Gdańsk University of Technology, and coordinator of EcoTech Center one of four excellence Center at GUT. Her background is environmental engineering and her work focus on NBS. She is co-author of 85 JCR papers, 5 international projects in the last 4 years, ORCID 0000-0002-6806-9771

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# Preferential flow in partially saturated treatment wetland and its impact on pollutant residence time

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**Abstract**

Preferential flow is common phenomenon in porous media, and treatment wetlands are no exception to this rule. Therefore, it is important to clearly identify the mechanisms that can cause them and to quantify their effects. The Bugeaud stormwater treatment wetland built as part of the Life ADSORB project and located in the Bois de Boulogne park (Paris, France), consists of two 600 $m^2$ treatment wetlands and was designed to treat runoff water from a heavy traffic highway and, in particular, selected metallic and organic micropollutants. The latter are supposed to be retained in treatment wetlands by adsorption. The two treatment wetlands are similar in terms of configuration (100 m long, 1 m deep) and operated with equal feeding period (alternation every month). To enhance the adsorption capacity, one the two wetlands has been filled up with a specifically designed adsorbent material called Rainclean®. It is therefore necessary to ensure that no short circuits could reduce the contact time with it. There is only one feeding point per TW, at one extremity of each and the treated water outlet is located at the opposite end. The Bugeaud stormwater treatment wetland continuously receives water (not only during storm events) and during rain events the maximum water level is set to 1.05 m above the bottom of the treatment wetlands. A throttle outflow located 30 cm above the bottom of each treatment wetland maintains a saturated layer and controls the water level and the outlet flow rate to not exceed 20 L/s when the treatment wetland is fully saturated (storm events). A previous study has clearly shown the strong correlation between drainage network sizing and preferential flow where undersizing can lead to the development of a dead zone in the porous medium.

A numerical model of the treatment wetlands was developed to attempt to quantify the extent of this dead zone and its effect on the contaminant residence time under different flow regimes. The resulting model, developed in COMSOL, includes original features such as (i) a coupling with an analog drainage model written in MATLAB that accounts for hydraulic head losses in the drainage network, and (ii) surface flow to describe the progressive flooding of the treatment wetland surface during its operation. It has been calibrated using data collected during two tracer tests, including water level measurements obtained from piezometers and water contents obtained from TDR probes distributed along the treatment wetland and continuously monitored. The results confirm the existence of a dead zone at the bottom near the inlet end of the treatment wetland, the extent of which depends on the operating conditions. The numerical model also allows estimation of the contaminant residence time for a suitably sized drainage network.

BIO of Presenter:

**Ania Morvannou** is a senior scientist at EcoBIRD who has been active in the field of treatment wetland modeling for the last 14 years. She owned a PhD degree from the UCL Louvain-la-Neuve, Belgium, and has previously been working at INRAE on several projects related to treatment wetlands.

# The role of nature-based solutions for the water flow management in a Mediterranean urban area

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**Abstract**

Water balance, fluxes and management are increasingly affected by global warming, rapid land use changes, population growth and the ensuing intensification of the water cycle. In last decades, central Mediterranean Regions are often subjected to extreme hydro-meteorological events with ever-greater flow rates and runoff volumes in critical urban and sub-urban areas. Conventional engineering solutions, known as grey infrastructures, are showing their failure to manage rainwater increasing the potential damages for the risk receptors (i.e., human health and life, environment, cultural heritage, economic activities, and infrastructures). Within the concept of green urban infrastructures (GUIs), Nature-Based Solutions (NBSs) are strategies increasingly used in the urban storm water management to minimize water quantity and to improve water quality. These measures are implemented in the urban environment with grey infrastructures to retain, decelerate, infiltrate, and slowly release rainwater.

The aim of this study is to evaluate the effectiveness of small-scale NBSs (i.e., green roofs, rain gardens, porous pavements, and rain barrel), in a Sicilian hydrological river basin (Toscano catchment), for urban storm water management in terms of flood peak reduction and delay, and runoff volumes reduction. To identify the flood risk areas in which locate NBSs, a hydraulic model (HEC-RAS) is used. After, the NBSs mitigation effects into the identified risk areas are evaluated at sub-catchment (0.38 $km_2$) and urban block scale (0.03 $km_2$) through EPA SWMM model. Model simulations are performed with the return periods (T) of 10, 50, 200 years and by considering an area of 0.01 $km_2$ of NBSs (in EPA SWMM model) that means 30% of the urban block area.

Preliminary results show that the estimated peak flow ($m_3/s$) obtained from the simulations performed at catchment scale for each T in the current scenario (without NBSs) using HEC-RAS (27.91 $m_3/s$, 50.27 $m_3/s$, 61.37 $m_3/s$, respectively, for T 10, 50, 200 years) and EPA SWMM models are very close to each other (even if the last one overestimates peak flow of 14.78%, 2.82%, 11.43%, respectively, for T 10, 50, 200 years). In addition, the model EPA SWMM shows its sensibility to NBSs implementation at urban block scale with a peak flow reduction up to about 16% and a runoff volume reduction up to about 24%. These reductions are lower significant at the outlet of the sub-catchment. NBSs mitigation effects are higher for the lower return periods.

The results highlighted that the integration of NBSs in urban areas could have hydrological and hydraulic positive effects, particularly in terms of peak flow and runoff volume reduction. Furthermore, the results suggest that small-scale NBSs have a potential to be effective to smaller rainfall events, but a combination with large-scale NBSs is necessary to cope with extreme events. The proposed approach could provide a tool to support decision makers, planners, and stakeholders to evaluate NBSs performance and potential for urban storm water management in Mediterranean Regions.

**Acknowledgement**

This research was funded by the Project – "Green Infrastructures to mitigate Flood risks in Urban and sub-urban areas and to Improve the quality of rainwater Discharges - GIFLUID" - INTERREG V-A Italia-Malta 2014-2020 and the PhD Course in Agricultural, Food and Environmental Science (Di3A, University of Catania).

BIO of Presenter:

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# Circular urban water solutions with nature-based solutions: urban real labs in Spain

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**H2020 NICE**

The H2020 NICE project seeks to promote the integration of Nature-based Solutions (NbS) such as green walls and constructed wetlands in the urban environment to support circular urban water management solutions. This communication provides details on 3 of the case study pilots to be built in Spain by AQUALIA, co-designed in collaboration with the project partners EcoBIRD and IRIDRA. Design of the pilots and progress in the commissioning of the pilots and first results will be presented at the conference.

**Parking lot building (Vigo)**

Stormwater (SW) will be harvested in the large impervious area of the top floor of a Parking lot building of the Balaidos Industrial Park in Vigo (NW Spain). Water will be treated in a 30 $m^2$ vegetated filter to simulate a sustainable urban drainage system for runoff mitigation. Greywater (GW) from the reception offices will also be collected for treatment in the vegetated filter. The treated water will be stored and reused to reduce the water demand required to irrigate 50 $m^2$ section of an existing green wall.

**Boardwalk (Algeciras)**

The Bay of Algeciras (South Spain) experiences pollution events associated to runoff during storm events. An innovative 85 $m^2$ constructed wetland (CW) pilot has been designed and is under construction to treat SW and demonstrate the potential of NBS in preventing such events. With a challenging dry weather with warm temperatures in the period May-September, the effect of water stress on the CW during this period will be addressed by collecting GW from a nearby building and selecting plants adapted to water stress.

**Office building (Madrid)**

A pilot in the AQUALIA Corporative Offices in Madrid will demonstrate NBS technologies for large EU cities. GW will be segregated in the building toilets, allowing a regular GW supply that will be collected and pumped to a CW integrated in the building surroundings for its treatment. Treated water will be reclaimed and used for watering of green areas and reduce the water demand in the building.

Locations of the parking lot building at Vigo (left), Plot in boardwalk in Algeciras (centre), and plot at the street level in the Aqualia Corporative Offices in Madrid (right)

BIO of Presenter:

**Rubén Hervás** is a researcher at Aqualia´s Department of Innovation and Technology since 2022. He is a Chemical Engineer specialized in water treatment and now focused on water treatment with nature-based technologies. He is currently working on LIFE INTEXT and H2020 NICE projects in Aqualia to promote and implement NBS in the Spanish water industry.

# LCA & sustainability

# A wholelife cost and carbon perspective of alternatives to septic tanks utilising aerobic wetlands

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**Abstract**
Septic tank systems are still widely used around the world for small wastewater treatment works, ranging from single houses to a few hundred population equivalents. Whilst upgrading these systems with grey infrastructure like package treatment plants (eg, submerged aerated filters, SAFs) was the norm until recently, the UK water industry is now looking for lower carbon, whole life cost and wider benefits options. This study calculated the whole life financial and carbon benefits of a flowsheet consisting of an enhanced septic tank (EST) followed by either a vertical flow (VF) or an aerated horizontal flow (AHF) wetland benchmarked against a standard septic tank and a SAF upgrade. The whole life cost of the flowsheets and scope 2 cradle to grave lifetime carbon emissions (LCE) were assessed at 15 population sizes between 5 and 1000 PE using a net present value analysis with a discount rate of 3.5% and OpenLCA 1.11.0 (GreenDelta) with the Ecoinvent v3.8 database for LCE, considering a retrofit and a greenfield scenario. Results showed SAFs have the highest WLC per PE at all population sizes, with economies of scale reducing the difference at the higher end. For example, at 10 PE WLC was £3650/PE and £1700/PE for SAF vs aerobic wetlands, whereas at 1000 PE the SAF had a WLC of £758/PE against £675/PE and £370/PE for the VF and AHF wetlands, respectively. Analysis of the cost breakdown reveals that the operating costs dominated the WLC at smaller scales but became a lesser component as scale increases, reaching approximate parity with capital investment at a scale of 30 PE, 75 and 1000 PE for the SAF, EST-VF and EST-AHF, respectively. All upgrades reduced LCE compared to the standard septic tank, but the adoption of the EST-wetlands options reduced the LCE by between 56 and 90% and 60 - 86% for the EST-AHF and the EST-VF flowsheet, respectively, compared to 26 - 71% for the SAF. In terms of the wetland options, the VF flowsheet had a lower LCE at small scales and reaches parity with AHF option at a scale of 100 PE. Beyond that, the EST-AHF provides the lowest LCE as the capital components decreased more significantly with scale than that of the EST-VF. The work provides quantified evidence on the whole life carbon and costs benefits for upgrading existing infrastructure with an EST-wetland flowsheet rather than the traditional high energy, low benefit grey alternatives.

BIO of Presenter:
**Gabriela Dotro** main area of work is on understanding the biogeochemical transformation of phosphorus, iron and nitrate in engineered ecosystems, and translating research outputs for implementation by industry. This abstract is part of Gareth's PhD project for a water utility that is now building a full-scale demonstration treatment plant in Scotland.

# Rapid assessment for sustainable suitability of constructed wetlands

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**Abstract**
Sustainability intends to simultaneously take into account and provide for the need of "striving for the maintenance of economic well-being, protection of the environment and prudent use of natural resources, and equitable social progress which recognises the just needs of all individuals, communities, and the environment" (Waas et al. 2011). Achieving sustainability is often referred to as accomplishing the 'triple bottom line' or serving 'People, Prosperity, and Planet'. Sustainable Development intends "[…] to ensure that it [development] meets the needs of the present without compromising the ability of the future generations to meet their own needs" (WCED 1987; UN 1987).
In general, sustainability assessments intend to guide decision-making towards sustainable solution options by applying evaluation techniques (J. Pope et al. 2017; Jenny Pope, Annandale, and Morrison-Saunders 2004; Hacking and Guthrie 2008). Hacking and Guthrie (2008) broadly define Sustainability Assessments as "means of directing planning and decision-making towards sustainable development".
In the H2020 project WATERAGRI (www.wateragri.eu), several water and nutrient retention measures are being implemented in 10 case study sites distributed across three climatic zones, namely Boreal, Continental and Pannonian. Their sustainability was analyzed through various sustainability assessments such as Cost-Benefit-Analysis, Life Cycle Assessment and Water Footprint Assessments.
Before diving deeply into the various sustainability assessments of solutions and sites, a rapid assessment of which solutions might be considered sustainably 'suitable' for which site was performed. For this purpose, several criteria for the three dimensions of sustainability, namely environmental, economic, and social, were identified by the research team at OULU and vetted by the project's solution and case study owners for general soundness. Then, the research team at OULU screened the literature and the project documentation for the respective solution and case study information for each criterion and asked solution providers and case study owners to double-check and correct the data if needed. In this process, several solutions were removed as the evidence-base was not considered to be strong enough for a sufficiently sound judgement. The assessments were therefore only done for four WATERAGRI solutions that have seen implementation on sites, namely: Farm Constructed Wetlands, Precision Irrigation System, Biochar and Drainage Systems.
Finally, the 'fit' of the solutions for the respective sites was carried out by matching the information of the criteria through a traffic light system (highly matching, medium, not at all) for each of the dimensions of sustainability. Not matching at all meant that the solution was considered to be 'Not Suitable' in any of the three dimensions, whereas for a solution to be fully suitable for a site it had to be suitable in all dimensions. All other (mixed) scenarios were considered as moderately suitable. As such, across all sustainability dimensions Farm Constructed Wetlands and Precision Irrigation Systems were deemed suitable solutions for all cases except Finland. Biochar and Drainage systems were considered moderately to highly suitable solutions in some cases.

BIO of Presenter:
**Tamara Avellan** is passionate about making the change happen towards sustainable lifestyles by managing scientific and development aid projects that bridge the gap between global politics and local realities. She worked for the United Nations for almost a decade. Currently, she is a docent at the University of Oulu.

# Survey on socio-economic impact of the Wetland+® technology for treatment of HCH-contaminated water

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**Abstract**
Sustainable remediation is the practice of demonstrating, that the benefit of undertaking remediation is greater than its impact and that the optimum remediation solution is selected through the use of a balanced decision-making process. Assessing sustainable remediation is site and project specific, and is strongly multifactorial across a wide range of categories, which may or may not be readily quantifiable. The applied socio-economic survey framework is based on the 2020 SuRF-UK guidance (CL:AIRE 2020 A & B). The assessment was carried out in three steps. An initial sustainability assessment being developed by a small core tea, an interim assessment by the project of all beneficiaries, and a final assessment by a broad range of external stakeholders, representatives of local or regional authorities, environmental authorities, watershed authorities and local NGOs. The 15 broad categories of indicators, which revolves around three main elements of sustainability (environment, society, and economy), were established. In the initial assessment, out of a total of 73 criteria, 45 relevant was selected, namely 15 from the Environment category, 19 from Economic and 11 from Social, and the assessments compared Wetland+® with the conventional WWTP and no-intervention scenario. Wetland+® outranked the use of WWTP, and both performed significantly better than the no-intervention scenario. In the third step, there was no change in the question set but in some cases the proposed gradings. Finally, Wetland+® outranked the use of conventional WWTP for most of the 15 general categories, and where it did not outrank, the ranking was very similar.

BIO of Presenter:
**Pavla Svermova** works at the Technical University of Liberec, Czech Republic. She is the Head of the Information Support and Analysis Department at the Institute for Nanomaterials, Advanced Technologies and Innovation. Her teaching activities include lectures on the Management of Innovation and Corporate Social Responsibility. Her research activities are represented by around 70 papers focused mainly on the field of business economics, sustainability, and regional development. She is a member of the research project teams.

# Life cycle assessment of enhanced constructed wetlands for micropollutant removal from municipal effluent

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**Abstract**

Constructed wetlands (CWs) act as a form of nature-based solution (NBS), and their use as a post-treatment step in wastewater treatment has received limited attention. Full-scale applications have yet to be implemented, therefore the primary focus of this study is to compare the life cycle performance of experimental results for laboratory and pilot plant scale CWs. The CWs have been enhanced using an admixture of activated biochar to treat municipal effluent in small-to-medium sized wastewater treatment plants (WWTPs) in Luxembourg. A life cycle assessment (LCA) of this technology has been carried out to evaluate the embodied and operational environmental impacts of these systems. Furthermore, the study aimed to quantify the avoided environmental impacts of CWs through their capacity to remove micropollutants (MPs) that would otherwise be released into local water bodies. Finally, an examination of the scaling-up effect of such a system (from laboratory to pilot plant) is evaluated to determine the burdens of implementing these systems in real-world settings.

The CWs unit incorporated a 15% admixture of activated biochar within the sand-based substrate, with the study accounting for the impacts of biochar production. A set of environmental impact categories were selected based on their relevance to MP removal through these enhanced CWs, namely: freshwater ecotoxicity, climate change, human toxicity, water use, and non-renewable energy resources. In addition, the results accounted for any avoided ecotoxicological impacts through the enhanced CW's, namely atenolol, carbamazepine, ciprofloxacin, and diclofenac.

A comparison of the installations highlighted higher embodied environmental burdens in the laboratory scale across all impact categories. This is demonstrated by Fig. 1 for an example of the Water Use needed for production of the components for each installation.

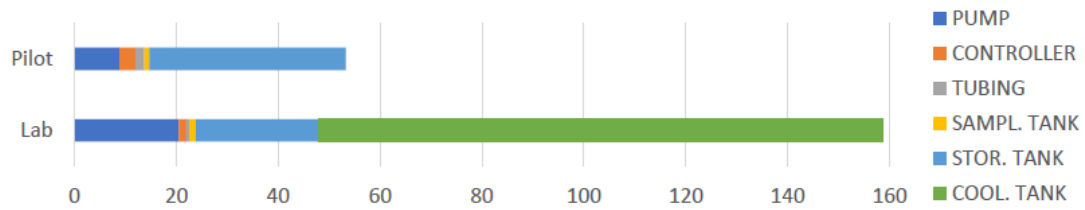


Fig: 1: Comparison of the generated environmental impacts for WU (in m3 of world eq. deprived water) for a) lab, and b) pilot scale installations.

The study demonstrates that the scaling-up effect decreases the associated embodied environmental impacts of this system (considered without the used substrates), in addition to reducing the environmental impacts of MPs being released into the natural environment (given by the better performance of the lab scale under constant conditions). Application of CWs for treatment of municipal effluent results in the avoided environmental impacts of the eliminated micropollutants varying from 50% up to 99%.

BIO of Presenter:

**Hana Brunhoferova** completed her PhD in 2022 at the University of Luxembourg on the topic of CWs for MPs elimination. She continues her research career in the field, working as a Research Fellow at Trinity College Dublin in Ireland, where her primary focus is LCA of NBS technologies used for wastewater treatment.

# Role of plants & hydraulics

# Native Canadian plants to phytoremediate triclosan in constructed wetlands

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**Abstract**
The objective of the proposed work is to establish the triclosan removal potential of three plants native to Canada: *Eutrochium maculatum* (syn. Eupatorium maculatum), *Phragmites australis* subsp. *americanus* and *Sporobolus michauxianus* used in monoculture or composite plantings within constructed wetlands. Two main issues are addressed here: the management of triclosan-contaminated water and the effects of the contaminant on the communities established in the resulting ecosystem. General water quality parameters, triclosan removal, bacterial diversity and resistance, and effects on algae will be discussed to determine the extent to which constructed wetlands are an appropriate green technology for mitigating and resolving the major issues involved.

**Key Words:** *Phytoremediation, Triclosan, Water quality, Biodiversity, Indigeneity*

BIO of Presenter:
**Laurianne Bédard** graduated from a transdisciplinary bachelor (chemistry, ecological sciences). I am now master student at the University of Montreal and supported by the Quebec Society of Phytotechnology (scholarship 2022) and the Institut de recherche en biologie végétale (Mitacs fellowship 2022-2023). I work on the phytoremediation potential of native flora of Quebec.

# Benefits of the presence of plants in Wetland+ system, treating HCH polluted sites

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**Abstract**

Hexachlorocyclohexane (HCH) is an insecticide banned around the world, but it is still a worldwide problem since there are many legacy sites that are leaching polluted waters to the environment. The most common solution to limit the leaching has been confining the site to retain the pollutant, but the solution does not treat the source and no actual treatment results from the procedure. Pilot plant studies have shown the capacity of treatment wetlands to remove HCH, and as result a LIFE EU project, LIFEPOPWAT has financed the establishment of two sites, one in the Czech Republic and one in Poland as well as the performance of parallel studies to assess the capacity of planted system to treat the pollutant.

The LIFEPOPWAT project has developed a wetland treatment system (Wetland$^{+}$), where the combination of planted anaerobic and anaerobic environments speed up the removal of HCHs. To evaluate the roll of plants A total of 60 experimental units were set up for each selected treatment for δ-HCH and t HCH. These 60 pots were divided into five groups - four planted groups and one unplanted group set up in one-liter pots containing 800 ml of a mixed substrate. Simultaneously, the unplanted pots containing the same amount of substrate were established. The substrate was composited from three different materials - sand, peat and vermiculite in the volume ratio 40%: 30%: 30%. Every group consisted of 12 pots split into four triplicates. The individual triplicates will be exposed to three different pesticide concentrations (20, 200, 1000 µg.l-1) with one control triplicate (not planted). The plant species tested included *Juncus effusus, Typha latifolia Phragmites australis (PA), and Alnus glutinosa* and kept in growth chamber under controlled light cycles, humidity and temperature. All the plant parts were measured and grouped. The samples were subjected to extraction procedures to determine HCH and ClB and analysed by LC/HRMS.

**Conclusions**

Plants in treatment are a main component of the system and enhances the removal performance of HCH compounds through their functions that include Growth and biomass production, photosynthesis, nutrient uptake, water uptake, oxygen transport, metabolism, $CO_2$ sequestration, food chain support and integration to the landscape. Despite the high variability of data and artificial growth chamber conditions, our study provides important conclusions towards species dependent HCH phytoextraction differences. Even though *Alnus glutinosa* does not belong to a commonly used species for treatment wetlands due to the highly developed root system, It seems to be the most effective species for HCH elimination in our experiment. The capacity for removal being *Alnus > Juncus > Typha > Phragmites*. We suggest the installation of alder shrubs/coppice culture with regularly disturbed rooting can be the best option for HCH contaminated water treatment. Juncus seedlings performed also well, especially at low and medium HCH loads. At high HCH loads, Typha showed similar performance to Juncus. Phragmites only showed results comparable to Typha at small and medium loads. Il species shown better phytoexctractability toward δ-HCH isomer (max. 50-70 %) than to t-HCH of the same load (40-50 %). 1,3-DiCB was found as HCH transformation product in most of the plants.

**Acknowledgement**

This transnational cooperation project is funded by the European UnionLIFE Programme under grant agreement n° LIFE18 ENV/CZ/000374.

BIO of Presenter:

**Carlos Arias** is an experienced Senior Researcher with a demonstrated history of working in the research industry. Skilled in Waste, Sustainable Development, Environmental Issues, Environmental Compliance, and Water Treatment. Strong research professional with a PhD. focused in Environmental Science from Aarhus University.

# Efficiency of horizontal macrophytic ponds with phragmites australis and its influence on the pollutants assimilation by the plants

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**Abstract**

Worldwide, in developed countries, the water quality from different water sources as rivers, lakes, and ultimately the ocean, depends on how wastewater produced from anthropogenic activities in all inhabited regions, especially those that are densely populated, is processed and disposed. Domestic and municipal wastewater annual production is estimated to be around 360 km3, of which 52.8 % is treated in wastewater treatment plants (WWTP) being the remaining volume released directly into the environment. Although the main objective of WWTP is to reduce the load of pollutants reaching any of the three environmental compartments (air, soil, and water) they typically focus on the removal of organic matter and other substances (macro and emerging pollutants). This study aimed to evaluate the efficiency removal of nitrogen, phosphorus, and potassium by macrophytes lagoons planted with Phragmites australis (horizontal load flow), through phytoextraction and rizodegradation processes, in two different wastewater treatment plants in Portugal. The WWTP1, with an area of 3000 m2, was designed to a population of 400 inhabitants receiving an average flow of 69 m3/d. The WWTP2, with an area of 5963 m2, was designed to a population of 600 inhabitants receiving an average flow of 107 m3/d. The assimilation of nitrogen, phosphorus, and potassium by the plants roots, stem and leaves was also evaluated.

Wastewater from lagoons (in and out) and P. australis tissues samples were collected over the month of June. The pH, redox potential, BOD5 and COD, Kjeldahl and ammonia nitrogen, phosphorus, and potassium were determined in wastewater samples. Plants dry matter, Kjeldahl nitrogen, phosphorus, potassium and photosynthetic pigments (chlorophyll a, b and carotenoids) contents, were also assessed in the plant tissues. The main results showed an efficiency removal in lagoons of 62% and 70% to WWTP1, 77% and 78 % to WWTP2 for Kjeldahl and ammonia nitrogen, respectively. The phosphorus efficiency removal ranged between 76 to 78% in both WWTP. Although the organic loading rate was, on average, five times higher in WWTP1 (BOD5: 29.9 g/m2·d and COD: 56.9 g/m2·d) in relation to WWTP2, both presented efficiency removals, for both parameters, above 95%. The analysis of the plants biomass (roots, stems and leaves) showed an increase of nitrogen whereas potassium content decreased, when compared with the control plants. The WWTP1 exhibited a higher amount of nitrogen removed (Kjeldahl: 1.4 g/m2·d; ammonium: 0.8 g/m2·d) being the concentration of this nutrient in the roots of 16.8±0.01 mg/g dry biomass and in the leaves 53.5±6.2 mg/g dry biomass. It was observed, in both treatments, a direct relation between the nitrogen assimilated by P. australis and the chlorophyll a, b and carotenoids contents.

BIO of Presenter:

**Renata Ferreira** is an Adjunct Professor at Polytechnic Institute of Beja. She completed her PhD in Environmental Engineering in 2014 at Instituto Superior Técnico, University of Lisbon. Her research work addresses the study of phytoremediation of contaminated water and soils, focusing on the plant's role (oxidative stress response and detoxification mechanisms).

WETPOL 2023
Bruges Meeting & Convention Centre, Belgium

# Simulation of the hydraulic behaviour of a treatment wetland in the Mediterranean area using HYDRUS

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**Abstract**

In the last decades, Nature-Based Solutions (NBS) such as treatment wetlands (TWs) have been proven to be a convenient solution for the decentralized treatment of wastewater of various origin and for their high landscape integration and low maintenance costs. During the last few years, several numerical models with different complexities have been developed as tools to get a better understanding of the processes in TWs. The aim of this study was to simulate by the software HYDRUS Wetland Module the water flow and the reactive transport (using the biokinetic model CWM1) in a horizontal flow (HF) wetland. In particular the first stage of the of the 8-years old hybrid-TW of the IKEA® store, located in Catania, Sicily (Italy), was analysed. The Mediterranean region is one of the most vulnerable areas to climate change. This area is affected by severe water scarcity, which is expected to prevail by the upcoming years. The use of reclaimed water in agriculture is a way to reduce water scarcity, alleviate pressures on groundwater and other freshwater resources and improve irrigated crop productivity and environmental sustainability. In the case study simulated water flow and COD and NH4-N concentrations were compared with observed data (2020-2023) in order to test the model robustness to simulate the recovering from peak loads. To characterize the hydraulic behaviour of the HF wetland, a tracer test experiment with NaCl was carried out. After a calibration of the hydraulic conductivity (Ks) at saturation, a good simulation of NaCl values was achieved. The model was able to simulate COD and NH4-N concentrations at the outlet of the HF wetland in both the standard and the peak load conditions. Preliminary results also indicated that the higher the COD concentration at the inlet of the system is, the longer the quasi steady state condition at the outlet takes to be reached.

In general, we concluded that (i) for the calibration of the water flow model of the HF wetland an adjustment of the Ks was required; (ii) a good match between simulated and measured COD and NH4-N effluent concentrations for standard and peak load conditions could be obtained after the water flow calibration; (iii) the time to recover from peak loads simulated by the model is well represented by the actual hydraulic retention time (HRT) observed in the HF wetland.

**Acknowledgement**

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BIO of Presenter:

**Feliciana Licciardello** is an Associate Professor in the topic Agricultural hydraulics and watershed protection at University of Catania - Department of Agriculture, Food and Environment (Italy) Associate Editor of the International Soil and Water Conservation Research journal since February 2008 Author/co-author of more than 70 papers (33 indexed by SCOPUS, h-index 15, citations 692)

# Greenhouse gases & sequestration

# Greenhouse gas emissions from a cold-climate treatment wetland

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**Abstract**

Treatment wetlands (TW) remediate wastewater by harnessing microbial metabolisms to biotically degrade nutrients. However, these microbial processes additionally generate nitrous oxide ($N_2O$), methane ($CH_4$) and carbon dioxide ($CO_2$), which may result in high global warming potential (GWP) of TW. Greenhouse gas (GHG) emissions from TW remain poorly quantified and influencing factors loosely defined, especially in cold-climate systems. This study investigates the GHG emissions from a two-stage cold climate vertical flow TW treating ski area wastewater at a water temperature of 3-4°C. The system is designed to optimize total nitrogen removal. The first stage is partially saturated to establish anoxic conditions for denitrification with a course gravel media. The second stage is unsaturated for aerobic conditions for nitrification with a fine sand media. Nitrified effluent is recycled periodically to the first stage in alternating doses with pre-settled raw influent. The TW has demonstrated effective total nitrogen and COD removal in high-strength wastewater over its ten years of winter operation.

We hypothesized that separate, intermittent hydraulic loading of COD-rich raw influent and nitrate-rich recycled effluent would result in distinct patterns of GHG flux from the TW as nutrient loading and the carbon to nitrogen ratio changed. We additionally hypothesized that due to non-ideal environmental conditions, such as low temperatures, inefficiencies of both nitrification and denitrification may result in similar rates of $N_2O$ flux from the first (denitrification) and second (nitrification) stages. Gas flux was measured over two sampling campaigns in March and April of 2022, using the Picarro G2508.

Following two closed-loop, intensive GHG winter sampling campaigns at the TW, the magnitude of $N_2O$ flux was found to be 2.3 times higher for denitrification processes than nitrification processes despite low average temperatures and intermittent dosing. Median fluxes of $N_2O$, $CH_4$ and $CO_2$ were 752.3 µg $N_2O$-N $m^{-2}$ $h^{-1}$, 0.96 mg-$CH_4$-C $m^{-2}$ $h^{-1}$, and 251.1 mg $CO_2$-C $m^{-2}$ $h^{-1}$ from the first stage, and 330.0 µg $N_2O$-N $m^{-2}$ $h^{-1}$, 0.20 mg-$CH_4$-C $m^{-2}$ $h^{-1}$, and 605.8 mg $CO_2$-C $m^{-2}$ $h^{-1}$ from the second stage. Temporal variation of methane and $N_2O$ emissions were strongly correlated with hydraulic dosing schedule of wastewater, whereas $CO_2$ was more heavily linked to surface temperature. Emissions were related to not only microbial activity but also outgassing of dissolved species during wastewater dosing, thus the time of sampling relative to dosing strongly influenced observed fluxes. Emission factors of 0.21% for $N_2O$ (kg $N_2O$-N/kg $TN_{in}$) and 0.05% for $CH_4$ (kg $CH_4$-C/kg $COD_{in}$) were observed, with a seasonal GWP of 629.4 kg of $CO_2$ equivalent GHG. This suggests that efforts to mitigate GHG from TW should be further investigated to reduce their contributions to global climate change. Further, these results suggest that GHG flux from intermittently dosed wetlands should be continuous over several dosing cycles to capture the effects of mass transfer and the mechanism of wastewater application.

BIO of Presenter:

**Stephanie Ayotte** is a third year PhD student in Environmental Engineering at Montana State University. She is a fellow of the Thermal Biology Institute's Extreme Biofilms National Research Traineeship program. Her research interests in treatment wetlands include greenhouse gas emissions and mitigation, and understanding nitrogen-associated microbial community dynamics.

# Comparing analysis of carbon sinks effects between constructed wetlands and natural wetlands

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**Abstract**
Natural wetland systems exist a variety of ecological service functions, such as water purification and carbon sink effect. Some types of constructed wetlands (CWs) are thus designed for wastewater or sewage treatments, while such treatment types of CWs can also sequestrate and store carbon showing carbon sink effects during the wastewater treatment processes. However, three main greenhouse gases, $CO_2$, $CH_4$ and $N_2O$, are produced simultaneously during treatment processes, which may let the CWs change from carbon sink to carbon source. In addition, it was reported that coastal salty wetlands (mangrove swamp, salt marsh, and seagrass bed) exhibited better carbon sink effects, which are known as coastal blue carbon, than inland freshwater wetlands due to high salinity and sulphate contents in seawater depressing methane fermentation and showing competition of sulphate ($SO_4^{2-}$) reducing process against denitrification causing decreasing emission of $CH_4$ and $N_2O$, respectively. Thus, in this study, a saline CW (Datang CW, DCW), a coastal wetland park (Yuanchungkan Wetland Park, YWP) and a natural salt marsh wetland (Kaomei Saltmarsh Wetland, KSW) were selected for investigating and comparing these four wetland systems to learn if they presented as either carbon sink, or carbon source through analyzing and calculating their balance of carbon budgets. Finally, the issues of how to decrease the emissions of GHGs to intensify the carbon sink effects for CWs or polluted natural wetlands were discussed. The analytical results showed that the net carbon fluxes in DCW and YWP were calculated equal to -676 and +185 g $CO_2$ eq $m^{-2}$ $yr^{-1}$, presenting carbon source and carbon sink effects, respectively, while for KSW, the net carbon flux was calculated equal to +815 g $CO_2$ eq $m^{-2}$ $yr^{-1}$ exhibiting blue carbon sink function. DCW was mainly functioned as a treatment wetland treating mariculture wastewater, while the influent discharged into YWP was partly from the lightly polluted Dianbao River and partly from the nearby Nantzi Sewage Treatment Plant effluent, both of which were measured some amounts of $N_2O$ released through incomplete denitrification, which greenhouse effect is 265 times higher than $CO_2$ resulting in increasing GHG release flux values in the wetlands to depress the carbon sink effects of wetlands and even to let wetlands present carbon source effect. Although the natural type of KSW performed better than the two artificial wetlands on carbon sink effects, the values of carbon budget calculated in KSW was still lower comparing to other natural coastal wetlands. The reason may be due to the influent discharged into the wetland containing agriculture tail water and sewage, which might contaminate the wetland resulting in more emissions of GHGs to depress the carbon sink effect. Therefore, it is recommended that no matter for natural or constructed wetland systems, either nitrogen nutrients in the influents should be strictly limited discharged into the wetlands, or let the wetland systems achieve complete denitrification to the final product of $N_2$, in order to enhance the blue carbon sink function of wetlands. It was reported that the efficient way to complete denitrification in CW systems is to provide sufficient organic carbon sources for heterotrophic denitrifying bacteria.

BIO of Presenter:
**Lei Yang** received a Ph.D. degree on environmental engineering in the School of Civil Engineering, Purdue University, U.S.A. in 1990, and then has served as a full-time professor in the Department of Marine Environment and Engineering, and has been the Director of the Water Resources Research Center since 2004 at National Sun Yat-sen University, Kaohsiung, Taiwan. Professor Yang is one of the pioneers to introduce and promote constructed wetlands in Taiwan.

# Micropollutant removal and microbial community dynamics of a 3-year old constructed wetland with adsorption substrate

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**Introduction - The influence of a 50% reduced hydraulic retention time**

In previous work, we have shown that adding an enhanced adsorption substrate for micropollutants (a mixture of tree bark and biochar) to a tidal-flow operated constructed wetland resulted in an increased micropollutant removal from the effluent of a wastewater treatment plant compared to a system with only sand as substrate (presented at IWA Wetlands for Pollution Control in Lyon 2022 and published: https://doi.org/10.1016/j.watres.2022.119494). For that study, we constructed 3 pilot-scale outdoors constructed wetlands of 12 $m^2$ (one with sand, 2 with sand + bark/biochar), fed these with the effluent of a wastewater treatment plant spiked with 5 µg/L of 12 micropollutants and monitored the removal of the micropollutants in 2021 (metoprolol, benzotriazole, carbamazepine, propranolol, sulfamethoxazole, furosemide, diclofenac, sum of 4- and 5-methylbenzotriazole, clarithromycin and hydrochlorothiazide). Since then, this experiment was continued without additional spiking of micropollutants and the constructed wetlands are now treating the effluent of the wastewater treatment plant for more than 2 years. In addition, the hydraulic retention time of 1 of the 2 bark/biochar constructed wetlands was reduced by 50% from 8h to 4h in 2023 to determine the effect of this reduction on the micropollutant removal efficiency. In this **oral presentation**, we will update the audience about this ongoing research and discuss 3 main topics:

- *The micropollutant removal of both the systems with sandy substrate and sand + bark/biochar after >2 years of operation.* The difference in micropollutant removal between the sand and sand + bark/biochar constructed wetlands became smaller in the 2nd and 3rd year of operation compared to year 1, mainly as a result of increasing micropollutant removal in the system with sandy substrate. In addition, a lower removal efficiency of the bark/biochar constructed wetland was observed in the 2nd and 3 year compared to the 1st year for some micropollutants, such as the hardly biodegradable carbamazepine. A point of discussion is whether this is due to saturation of the bark/biochar or as a result of stopping with actively spiking micropollutants, resulting in changing sorption equilibria. Furthermore, a stronger effect of low temperatures was observed in the systems with sand only compared to the systems with sand + bark/biochar.
- *The influence of a 50 % reduction of the hydraulic retention time of one of the systems with bark/biochar on the micropollutant removal.* A 50% reduction of the hydraulic retention time resulted in a < 25% reduction of the micropollutant removal efficiency for some micropollutants, while other micropollutant removal efficiencies were not affected.
- *A first analysis of the microbial community over the depth of the systems with sand and bark/biochar before and after reducing the hydraulic retention time.* To do so, we made use of the new UNLOCK infrastructure for microbial community research, which is a collaboration between Wageningen University and TU/Delft, which can also be used by other constructed wetland scientists: www.m-unlock.nl. This infrastructure allowed us to determine and compare the composition and functional profile of the microbial community in different parts of the 3 different constructed wetlands.

BIO of Presenter:

**Thomas Wagner** coordinates the constructed wetland research at the Department of Environmental Technology of Wageningen University. His current research focusses on enhancing the removal of micropollutants from treated wastewater by developing innovative constructed wetlands designs and improving our understanding of micropollutant removal mechanisms.

# Performance of floating treatment wetlands in ponds with high eutrophic level during different seasons of the year

*Eugenia J. Olguín[1,*], Gloria Sánchez-Galván[1], Francisco J. Melo[1] and Susana Alvarado Barrientos[2]*
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**Abstract**
Ten years ago, our research group installed two Floating Treatment Wetlands (FTWs), to reduce the eutrophication level of a recreational urban pond (pond 1) in a system of four interconnected ponds, in the city of Xalapa, Veracruz, México. The FTWs have a low-cost and novel design including *Cyperus papyrus* and *Pontederia sagittata* as vegetation. The FTWs capacity to remove nutrients and organic matter was evaluated during two years (Olguín *et al.*, 2017) and it was demonstrated that they were quite efficient at removing these pollutants. Subsequently, other two FTWs were established in pond 4, which is located about 0.8 km further away from pond 1, but remains interconnected and receives water from pond 3. The contribution *C. papyrus* and *P. sagittata* to carbon storage in these FTWs has been also investigated (Sánchez-Galván *et al.*, 2022). The aim of the present work was to provide further evidence of the performance of the FTWs operating in the two ponds, 1 and 4, which are under different eutrophication level, monitoring during the dry season (D.S, April and December), transitional season (T.S., May) and raining season (R.S., July and August) of 2021.
Results showed that during all seasons, FTWs in pond 1, were promoting a higher Oxygen Dissolved (O.D). level (in the range of 39-100% during the D.S. to 17-90 % during the R.S.) nearby the second FTW. In contrast, in pond 4, lower levels of O.D. were observed (9-19 % during D.S. and 6 % during R.S). On the other hand, the level of organic matter measured as COD and BOD at the entrance of each pond was varying along the year. In pond 1, during April and May, COD levels were high (125 mg $L^{-1}$) and decreased significantly during the rest of the monitoring periods (20, 5 and 31 mg $L^{-1}$, during July, August and December). The FTWs showed medium removal percentage (R.P.) of COD and BOD during April and May (38 and 34 %, respectively) and no removal was observed during the rest of the monitoring periods. A similar behavior was observed in pond 4, in which a high R.P. (78.3 and 78.6 %) was observed when the inlet COD was in the range of 128 and 149 mg $L^{-1}$, during August and December. Thus apparently, they perform better when a relatively high concentration of organic matter is present, regardless of the season of the year. A similar behavior was observed in relation to the removal of Chlorophyll (indicating microalgae concentration), the higher the level at the entrance of the pond, the higher the removal capacity of the FTWs. In conclusion, the type of FTWs utilized in this study, perform better under high eutrophic levels.

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BIO of Presenter:
**Eugenia Olguín** is a professor with more than 43 years of experience in environmental biotechnology, developing and evaluating technologies for wastewater treatment, utilizing plants (phytoremediation) or microalgae (phycoremediation), at lab and field scale. She has led 43 projects and founded the Latin American Society of Environmental and Algal Biotechnology.

# Poster Presentations

# Testing local agro-waste materials as substrate candidates for constructed wetlands treating cyanotoxin contaminated water

*Guna Bavithra [1,2,*], Alexandre Campos[1], Joana Azevedo[1], Pedro Carvalho[3,4], Marisa Almeida[1,2]*

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**Abstract**

Toxic cyanobacterial blooms are a growing environmental problem across the world. The most prevalent cyanotoxins that are of great concern in irrigation waters, are cylindrospermopsin (CYN) and microcystin-LR (MC-LR) found in eutrophic freshwaters. Its high chemical stability and broad biological activity pose an array of risks to human and animal health. Thus, adequate treatment technology is needed. Constructed wetlands (CWs) have been considered promising for such applications.

Substrates are considered the medium of constructed wetlands (CWs) and are a crucial component in the system. The role of substrates includes sorption of the contaminants, regulation of the hydraulic activity, plant growth, as well as the microbial community and biofilm formation in the CW systems. The characteristics of the substrates determine the overall performance of CWs, but the selection of substrates usually also depend on factors like cost and availability.

Hence, this study tested the adsorption capacities of various waste materials locally found in Portugal, for the removal of cyanotoxins cylindrospermopsin (CYN) and microcystin-LR (MC-LR). The materials tested were rice husk (RH), dried pumice of olive pulp (OP), cork granules (CO), biochar (BC) made from mixed pine-woodchips, and light expanded clay aggregates (LECA) and local sand. All these materials were separated to a uniform particle size (2-4 mm) and rinsed in deionized water.

Preliminary studies were done with a fixed concentration of MC-LR (0.1mg/L) and CYN (0.3mg/L), at 24 h and 48 h contact periods. The substrate-to-water ratio was retained at 2:3. Studies were carried out in 100 mL beakers on an automatic shaker, and after the contact period, the water was vacuum filtered for cyanotoxin analysis by LC-MS/MS. Afterwards, the two materials that displayed the most removal potency were further tested for effect contact period (1, 2, 4, 8, 16, 24, and 48 h) and different initial concentrations (0.1, 1, and 10 mg/L) of MC-LR and CYN.

BC and LECA showed the highest sorption capacity. CYN removal of 98% (BC) and 68% (LECA) at 24h, and 99% (BC) and 80% (LECA) at 48h, was observed. MC-LR removal of 69% and 85% was observed at 24h and 48h, respectively, for LECA, whereas there was up to 99% removal by BC at 24h and 48h. The sorption equilibrium was quickly reached by BC than LECA for both tested toxins. BC reached 99% removal already in 8 hours. The analysis of the study on effect of initial concentration is being processed. With that, more information on the sorption mechanisms will be provided during the conference.

This work indicates that agro-wastes can be good sorbents of cyanotoxins and therefore have the potential as substrate candidates in CWs for surface water treatment. However, more research is needed on their long-term effects on CW performance, with regards to hydraulics, and effect on plant growth and microbial community.

**Acknowledgement**

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BIO of Presenter:

**Guna Bavithra** is a PhD student at CIIMAR- Faculty of Sciences, University of Porto, Portugal. Her research area is on developing eco-technologies for the treatment and reuse of wastewaters, with focus on constructed wetlands for the remediation of surface waters contaminated with cyanotoxins.

# Auxin and gibberelin ammendment for fluoride phytoremediation: a screening study

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**Abstract**
Adjusting fluoride concentration in water as recommended by the World Health Organization (≤ 1.5 mg $L^{-1}$) is a serious concern and it need to be done through inexpensive, yet efficient techniques like phytoremediation. New approaches have been made to improve this treatment strategy, such as the use of plant hormones. The main goal of this research was to perform a screening study to evaluate the effect of exogenous auxin (0-10 µM) and gibberellin (0-50 µM) on *Eichhornia crassipes* performance for fluoride phytoremediation, as well as the effect of pH (5-9) and initial fluoride (5-15 mg $L^{-1}$) and phosphorus concentration (2.14-6.42 mg L-1). After a 10-day hydroponic assay, higher initial concentrations of fluoride reflected on greater fluoride removals, though in relative terms efficiencies were quite similar for all treatments (~60%). Auxin contributed to greater fluoride removals per mass of plant and it may be used to enhance defluoridation. Phosphorus helped in a nutrition matter as well as it may have influenced some fluoride precipitation.

BIO of Presenter:
**Alisson Borges** is Associate Professor at Federal University of Viçosa (Brazil). He does research on treatment wetlands and phytoremediation in the Agricultural and Environmental Engineering Graduate Program (PPGEA/UFV). Link: www.researchgate.net/profile/Alisson-Borges-2

# Constructed wetlands for water defluoridation

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**Abstract**
High concentrations of fluoride in water bodies have endangered public health worldwide. Constructed wetlands (CW) have been explored as an alternative method for a variety of contaminants, but when it comes to fluoride not much was reported. The goal of this research was to evaluate the performance of constructed wetlands on the removal of fluoride from water, as well as the effect of the addition of exogenous auxin on *Eichhornia crassipes* plants. Three CW with hydraulic retention time of 2 days were monitored throughout 70 days as they received fluoride-contaminated water at a concentration of 15 mg $L^{-1}$. CW1 and CW2 were planted with *Eichhornia crassipes* while CW3 was non-planted. CW2 was also amended with the phytohormone auxin at a concentration of 2.5 µM. Fluoride concentrations in effluent water and plant tissues were determined via ion selective electrode. Overall fluoride removal percentages were higher for planted cells in comparison to the non-planted one. Among planted units, CW2 showed greater removals of fluoride than CW1, 42% and 27% on average, respectively. It seems that the addition of exogenous auxin contributed to better performances. Fluoride contents in plant tissues went up to 0.82 mg $g^{-1}$ and were mostly observed in aerial parts of the plants, so translocation factors were greater than 1. Constructed wetlands demonstrated to be efficient for water defluoridation and *E. crassipes* seemed tolerant to fluoride. The species may act as an accumulator. The addition of auxin enhanced the performances of planted CW as they showed higher fluoride removal rates.

BIO of Presenter:
**Alisson Borges** is Associate Professor at Federal University of Viçosa (Brazil). He does research on treatment wetlands and phytoremediation in the Agricultural and Environmental Engineering Graduate Program (PPGEA/UFV). Link: www.researchgate.net/profile/Alisson-Borges-2

# The effects of lead/zinc mine wastewater on macrophyte stress

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**Abstract**
Lead/zinc mines and the wastewater that they produce can cause serious risks to the environment and current clean-up methods are labour intensive, financially costly and require harmful chemicals. Constructed wetlands (CW) have been utilised as an environmentally friendly solution to treat the wastewater. One area of CW study that has not been extensively researched is the longevity and health of macrophytes in these systems.

The research presented here aims to get a better understanding of what happens to macrophytes while under stressful levels of heavy metals. *Phragmites australis*, a common wetland macrophyte, was grown from seedling under hydroponic conditions in solution treated with varying concentrations of zinc (0.5-14 mg/L). Following 5 weeks, growth parameters of each plant were measured and compared. Further, macrophyte stress in wetland plants was analysed using chlorophyll content and photosynthetic yield measurements. Novel technologies including the chlorophyll content meter and PAM fluorometer were chosen for their quick, portable and accurate measurements, useful both in the lab and for future work in the field.

Results from the growth parameters showed a trend of reduced plant growth as Zn concentrations increased. This result shows us that high levels of zinc in the wastewater may impact macrophyte establishment and growth in constructed wetlands. Macrophyte stress measurements did not show a conclusive trend. This has been attributed to the variable condition that initial seedlings were grown from. Future studies would benefit from growing macrophytes from seeds to reduce variability in seedling morphology. Future studies include repeating this research with lead to compare the two highest concentration pollutants in lead/zinc mine wastewater.

BIO of Presenter:
**Nathan Bourke** is a first year PhD student studying the optimization of constructed wetlands for treating metal contaminated water. I completed my undergraduate degree at University College Dublin studying Zoology and Plant Biology and worked as a Teaching Assistant with the Department of Biological Sciences, UL before my PhD.

# Scenario analysis of microplastics flow in constructed wetland

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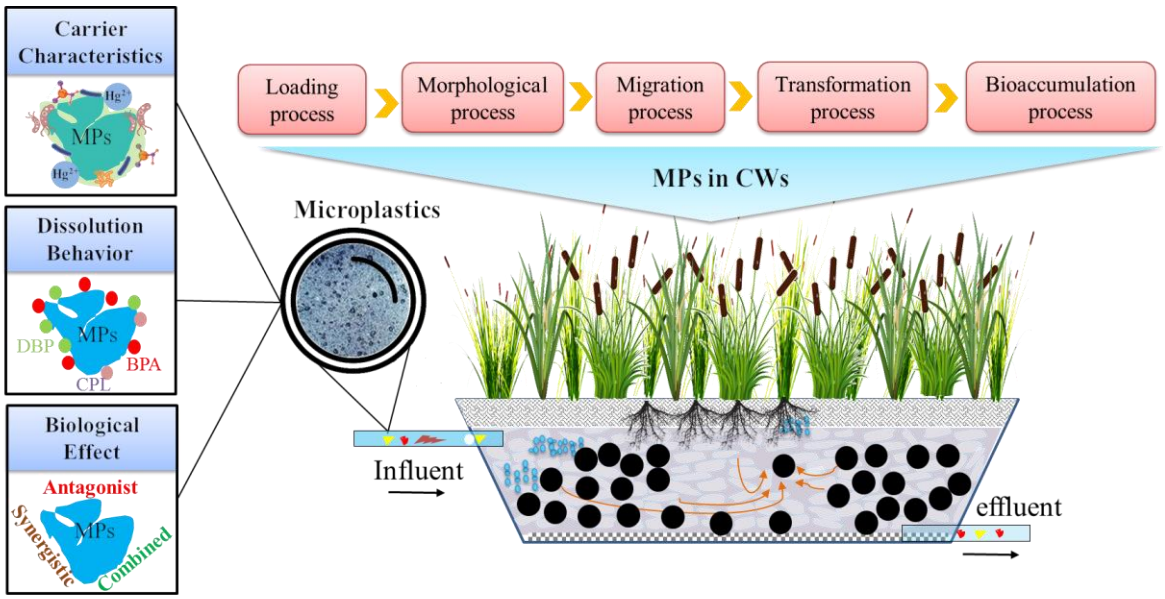
**Abstract**

Microplastics (MPs) are a novel type of contaminants that persist and prevalent in aquatic environments. Studies have shown that MPs hinder the microbial community structure and thus affect the efficacy of sewage treatment. As a nature-based solution, constructed wetlands (CWs) are a promising treatment method that owns a good removal effect on both conventional pollutants and emerging contaminants like MPs. However, current studies on the ecological effects and migration and transformation characteristics of MPs in CWs is relatively limited. In view of the carrier characteristics, dissolution behavior and biological effects of MPs, it is necessary to integrate information on the migration and transformation behavior of MPs to identify and evaluate the potential ecological risks of MPs to CW systems. This review summarizes previous relevant studies, focusing on the environmental behavior and fate mode of MPs in CW systems. This review analyzed the "loading process - morphological process – migration process – transformation process – bioaccumulation process" of MPs in different scenarios of CWs. It also explored the factors that might affect MPs' removal, distribution, and persistence, as well as the potential for transformation or degradation. The potential environmental and ecological impact of MPs on CWs is clarified. It is highly expected that the review can offer a scientific theoretical basis for the complex mechanism of MPs pollution removal by CWs.




BIO of Presenter:

**Yamei Cai** is now a Ph.D. student of Xi'an University of Technology. She is currently participating in the doctoral joint training program of the China Scholarship Council at Universidad Rey Juan Carlos in Spain. Her main research direction is ecological treatment of constructed wetlands.

WETPOL 2023
Bruges Meeting & Convention Centre, Belgium

# The impact of biofilter media additive and irrigation method on the removal performance for micropollutants from light greywater

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**Abstract**

The study focused on the role of design aspects of biofilters such as irrigation method and filter media additive for understanding the effect on the removal efficiency of micropollutants from light greywater. The biofilters were filled from bottom to top with gravel (4 cm) and filter media (44 cm). The filter media was chosen only sand as control group, and compositions of sand-biochar (1:1), and sand-manganese (1:1). The irrigation methods were decided as free-down flow, aerated flow, and dripping flow. Free-down flow was the imitation of an unregulated biofilter system worked with batch-feeding mode. The aerated flow was the same batch-feeding mode with including aeration system and dripping flow was imitation of an intermittent-feeding mode. The biofilters were set up in 2-litre column (5 replicates each 45 in total) and filled with weekly prepared synthetic light greywater (SGW). The SGW recipe included $N\text{-}NH_4$ (25 mg/l), $PO_4^{3-}$ (5 mg/l), glycerin (5 mg/l), boron (1 mg/l), metals such as copper, nickel and zinc (0.2 mg/l) and 16 different compounds (each in 50 µg/l concentration) such as pharmaceuticals (Ibuprofen and Acetaminophen), non-steroidal anti-inflammatory drugs (Diclofenac and Ketoprofen), corrosion inhibitor (Bisphenol S and Benzotriazole), insect repeller (DEET), anti-fungal (Climbazole), stimulant (Caffeine) and artificial sweetener (Saccharin). The duration of the experiment was 143 days. The collected samples were analyzed twice a week for basic water quality parameters and biweekly for metals and micropollutants. The initial results for micropollutants indicated that filter media with biochar has the most efficient removal results in comparison with the filter media with manganese and control group. Most likely that the absorption capacity of biochar helped the removal of micropollutants since no removal of bisphenol S, benzotriazole, DEET, and saccharin was observed in manganese included biofilters and control group while biochar included biofilters had more than 80% removal efficiency. These results did not show any significant change according to the irrigation method of the biofilters. Ibuprofen removal was enhanced by the additives (biochar+sand and manganese+sand) with >97% removal efficiency in comparison to control group (77.5%). Furthermore, comparing the irrigation method effect on the removal of ibuprofen for control group, the dripping method had the highest with 85%, followed by the free-downflow method with 79%, and the aeration method with 69%. Caffeine and climbazole removal did not show any change according to both filter media and irrigation method which were higher 95% which might be due to their high biodegradability. Overall, these results indicate that biochar included biofilters have high efficiency for removing the compounds that have low biodegradability like benzotriazole and bisphenol S. However, further research is needed for the regeneration of used biochar since the absorbed compounds can start leaking to environment after a time and cause ecotoxicological effect.

BIO of Presenter:

**Öykü Çömez** is a second year PhD student at the CZU Prague. She had master's degree on the role of different filter media additives for the removal of greywater pollutants. Main research topic includes sustainable urban water, greywater reuse through nature-based systems, and challenges for the implementation into urban areas.

# Constructed wetlands hydrodynamic modelling for enzymatic activity analysis

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**Abstract**
The processes involved in pollutant removal in constructed wetlands (CW) are physical, chemical, and biological. The bacterial community degrades organic matter by releasing enzymes to decompose it. The evaluation of treatment performances of CWs usually consists of a comparison between concentrations of inlet and outlet water samples. This method does not perturb the system and it is the most appropriate in real operating conditions. However, to better understand the specific contribution of the microbial community, conventional samplings are performed, perturbing the system or even destroying it in the case of mesocosm systems. Unfortunately, with these methods is impossible to see the evolution over time or to analyse the system in normal operating conditions. In this context, a new imaging method was proposed to obtain 2D spatial information on enzymatic activity using fluorescent reactive tracers. This approach has demonstrated that the enzymatic activity varies considerably within a CW, but the factors that control this variability are not fully understood.

This contribution analyses some potential controls of enzymatic activity in laboratory CWs. Starting from a dataset of enzymatic maps related to horizontal sub-surface flow (HSSF) CWs, this work aims to evaluate the impact of water flow and oxygen transportation on the spatial distribution of enzymatic activity. The Comsol Multiphysics software was used to build 2D and 3D models of the flow field with a conservative tracer, integrating Darcy's law with convective-diffusive mechanisms for solute transport. An unplanted model and two plant species with different root systems (*Phragmites australis* and *Phalaris Arundinacea*) have been compared. The root density was assumed to modify the permeability of the porous medium, which led to the development of spatially heterogeneous models. Then, these models were used to assess the potential controlling role of oxygen release from the rhizosphere which could constrain the biofilm consumption rates. The model employed a first-order kinetics and considered different combinations of characteristic consumption time (1h and 24 h) and multiple areal rates of oxygen release from roots (0.5, 2.5 and 5 g $m^{-2}$ $day^{-1}$). The results of the numerical model have been compared with the enzymatic activity maps looking for a correlation between oxygen concentration and fluorescence concentration.

The 2D model, compared with the 3D model, adequately describes the tracer transportation mechanisms, with limited (6%) variations in the hydraulic retention time $t_{50}$ for the unplanted homogenous model. This result indicates that a 2D model is a good approximation of the full 3D flow field, and supported the use of a 2D approximation for the following analyses. However, no clear correlation was found between the spatial distribution of enzymatic activity and the water flow field. On the other hand, the simulated oxygen concentrations were mildly correlated to the enzymatic activity in some plant species. The model thus suggests that the oxygen release by roots can contribute to control the spatial variations of enzymatic activity, even though additional factors are required to fully explain this variability.

BIO of Presenter:
**Elisa Costamagna** is a post-doc researcher. She is involved in NICE project, working on green walls for greywater treatment. She is interested in sustainable water management and water treatment mechanisms. During her PhD she developed an automatized method for image analysis, to implement a photographic method for enzymatic activity mapping.

# Performance of canna indica floating treatment wetlands in the removal of Cr species

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**Abstract**

Chromium contamination of water is caused by a variety of anthropogenic activities. Cr could enter aquatic ecosystems mainly in two oxidation states: Cr(III) and Cr(VI), exhibiting distinct chemical and physical properties, as well as different influences on living organisms. Floating Treatment Wetlands (FTWs) are a promising and cost-effective ecological engineering tool for the restoration of water bodies polluted with metals, among other contaminants.

In this study, the efficiency of FTWs populated with *Canna indica* in the removal of Cr(III) and Cr(VI) was assessed. Also, metal distribution in the system water-plant-sediment was evaluated.

The experiment was carried out in plastic reactors (70L capacity, containing 4 Kg of sediment and 38 L of water) placed outdoors under a semi-transparent plastic roof. FTWs were constructed so that only the roots and rhizomes were in contact with the water column. Four *C. indica* plants were placed in each FTW. The treatments were 5 and 10 ppm Cr(III) and 5 and 10 ppm Cr(VI), in both cases with presence/absence of FTW. A Biological Control was included (with FTW, without Cr addition). All treatments were arranged in triplicate.

The results showed an efficient removal of both Cr species in treatments with presence of FTWs, with removals greater than 80% after 35 days. Also, Cr removal was faster in treatments with FTW than in treatments without FTW.

At the end of the experiment, Cr concentration increased in the sediment of all treatments. In Cr(III) treatments, the sediment from the reactors without FTW accumulated significantly more metal than the sediments with FTW, while the opposite occurred in the Cr(VI) treatments.

Regardless of the presence or absence of FTW or the Cr species added, chromium accumulated in the sediment mainly bound to organic matter. However, in the sediment of the treatments without FTW, there was a significantly higher accumulation of Cr in the Fe-Mn oxides fraction compared to the treatments with FTW.

*C. indica* accumulated Cr in their tissues regardless of whether it was added as Cr(III) or Cr(VI). In all treatments, the highest Cr concentration was determined in the roots of *C. indica*, while the lowest concentration was measured in leaves.

FTWs populated with *C. indica* were efficient in the remediation of Cr-contaminated water, adding an aesthetic value to the treatment as it is an ornamental plant.

BIO of Presenter:

**Gisela Di Luca** is a researcher at the Institute of Applied Chemistry of Litoral, National Council of Technical and Scientifical Research (IQAL, CONICET-UNL, Argentina). My research is focused on contaminant accumulation and distribution in different compartments in natural wetlands and in constructed wetlands for the treatment of effluents.

# SWOT analysis for the implementation of constructed wetlands treating coffee processing wastewater in Ecuador

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**Introduction**

High-quality coffee production in Ecuador is nationally and internationally recognized. To keep standards, small coffee producers must cultivate and harvest beans with unique flavor profiles, and prevent negative impacts on surrounding environments, such as water courses. Coffee processing wastewater is generally characterized by its acidic pH, high concentration of organic matter, nutrients, total solids, etc. In Ecuador, no assessment is given to this type of wastewater. Thus, this study examines the effectiveness of a lab-scale constructed wetland in removing organic matter and nutrients from simulated wastewater. Additionally, a SWOT analysis was conducted based on literature, agricultural practices, and living conditions of small coffee producers, to assess the potential for implementing CWs in Ecuador.

**Methodology**

The hybrid flow system considered recirculation, gravel, and sand as substrates and had no vegetation. After two months of system stabilization, three sampling campaigns, with a duration of ten days each, were carried out. Water samples were taken daily at the outlet of the system, every 4 hours. The control parameters were pH, turbidity, electrical conductivity (EC), dissolved oxygen (DO), total (TS) and dissolved solids (TDS), chemical oxygen demand (COD), total nitrogen (TN), and total phosphorus (TP). The study examined the effect of time on the concentration of the control parameters. Additionally, the influence of pH and DO on the removal of COD, TN, and TP was evaluated.

**Results and Discussion**

The ANOVA statistical analysis revealed that significant changes occurred every 24 hours with a p-value of less than 0.05. Removals of 78.7% for COD, 69.2% for TN, 93% for TP, and 87.7% for TS were achieved by the system. Though, EC, TDS, and turbidity concentrations increased over time in each sampling campaign. These phenomena could be caused by the presence of bacteria such as *Clostridium,* found in environments with low oxygen levels and acidic conditions, like the system being studied, and which play an important role in the breakdown of organic matter.

Regarding the SWOT analysis for the implementation of CWs, there are strengths and opportunities to highlight, i) Ecuador's diverse range of ecosystems, allows the effective operation of constructed wetlands, ii) collaboration with rural communities and stakeholders can increase awareness and support for implementing a sustainable farming practice in areas less than 9 $m^2$. Among the weaknesses and threats, iii) the lack of technical knowledge and training, iv) insufficient income and infrastructure technology for post-harvest processes, and environmental factors, can become opportunities to implement CWs, increase productivity and reduce waste while preserving the environment.

**Conclusions**

Small coffee producers in Ecuador strive to remain competitive and sustain their livelihoods. Sustainable development of coffee farming in rural areas does not necessarily require large investments, but cooperation between farmers and researchers is crucial. CWs offer various benefits including wastewater treatment, stormwater management, irrigation water, and enhancement of soil fertility through nutrient cycling.

BIO of Presenter:

**Natalia Donoso** is an environmental engineer with extensive experience in the design and implementation of constructed wetlands. She has worked on some projects in Belgium and Ecuador, on wastewater treatment systems, and environmental assessment. Her expertise in constructed wetlands has been focused on developing sustainable solutions for water management and conservation.

# Water requirements and sap flow speed in poplar plantation under different agronomic managements

*Vittoria Giannini[1,2,*], Alberto Barco [1], Carmelo Maucieri[1], Maurizio Borin[1]*

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**Abstract**

Poplar-vegetated constructed wetlands have been proposed as an eco-sustainable method to treat low-quality wastewaters, mainly derived from urban sector. In this framework, the proper design of the wetlands and their management needs to be defined on the effective poplar water requirements. For this reason, our research focused on the comparison among different strategies for a six-years-old poplar stand (clone I-214) that maximize poplars evapotranspiration, crop coefficient (Kc) and xylem sap flow. The studied strategies were the following: i) C: control without irrigation and bio-stimulant application, ii) W: drip irrigation, 60 mm week$^{-1}$, iii) B: 3 kg ha$^{-1}$ foliar bio-stimulant application, iii) WB: drip irrigation, 60 mm week$^{-1}$ + 3 kg ha$^{-1}$ foliar bio-stimulant application. The highest cumulative poplar evapotranspiration rates were recorded in the WB and W treatments (on average 2029 mm) whereas the lowest one was showed in the C thesis (754 mm). Also, Kc maintained the same treatment-trend, the average seasonal values ranged from 0.8±0.5 to 1.9±0.9. Irrigation alone did not significantly affect xylem sap flow speed, whereas a single application of foliar algae biostimulant significantly increased the xylem sap flow speed both in WB and B thesis immediately after the treatment and then during the entire growing season.

BIO of Presenter:

**Vittoria Giannini** is a tenure-track assistant Professor at the Department of Agronomy, Food, Natural resources, Animals and Environment at University of Padua. Her research topics are phyto-treatment, paludiculture, nature-based solutions, organic agriculture, multi-cropping.

# Root morphometrical response in plants growing in a wetland constructed for the treatment of a metallurgical effluent

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**Abstract**

Treatment wetlands are used all over the world due to the wide range of effluents that they can treat. In the case of effluents containing metals, they are applied as secondary or tertiary treatments. In this work we studied a free-water surface wetland that treat the effluent containing Cr from a metallurgical factory. However, during the monitoring occurred an unintentional dumping of effluent without the primary treatment and showing a high Cr concentration during 30 days. This work is aimed to assess the plant response after an accidental dumping of high Cr concentration in an effluent without the primary treatment in a treatment wetland. The studied system is a free-water surface wetland located in Santo Tomé city, Santa Fe province, Argentina (31º39'45" S, 60º48'58" W). It is 20 m long, 7 m wide, and 0.3–0.7 m deep, and is waterproofed with a geomembrane. Mean wastewater discharge is approximately 10 $m^3$ $d^{-1}$ and water residence time is 7–10 days. The wetland was planted with *Typha domingensis*. Samples were taken shortly after the unintentional dumping of effluent. Water, plants (aerial and submerged parts of leaves, roots, and rhizomes), and sediment were sampled at the inlet and outlet. All samples were collected in triplicate. Cr bioconcentration (BCF) and translocation factors (TF) were calculated. Besides, plant anatomical measurements and Scanning Electron Microscopy (SEM) X-ray micro-analysis were carried out. The wetland showed a high Cr percent removal from water indicating that the system was able to remediate the accidental dumping of this metal. After the accidental dumping, plant tissues from the inlet showed Cr concentrations significantly higher than those measured during the normal operation period. Death leaves also act as Cr accumulation compartment. Regarding sediment, Cr concentrations after the accidental dumping were significantly higher than those obtained during the normal operation period. Cr measured in water was not proportional to the Cr measured in tissues and sediment. This indicates that once the Cr is discharged into the wetland, it precipitates accumulating on the plant tissues and bottom sediment. In the mapping obtained under SEM-EDX, Cr accumulation was observed in the root epidermis. BCFs were higher than 1 in all cases, being the values obtained after the accidental dumping an order of magnitude larger, indicating that Cr was accumulated in the bottom sediment and then taken by the roots and accumulated in this organ. During the normal operation period, Cr was translocated from roots to rhizomes. However, after the accidental dumping, this metal does not translocate, indicating that faced to high Cr availability, this metal is not transported to the aerial parts being accumulated in roots as a defense mechanism. After the dumping, the inlet values of root cross-sectional areas (CSA) were significantly higher than that of the outlet. This indicates that one of the plant responses faced to Cr exposure in the TW was to increase the size of roots to tolerate this metal. Cr tolerance was determined by significantly higher parameters of the root morphometry in comparison with those of the plants studied in a natural wetland. Faced with an accidental Cr dumping, the studied treatment wetland was capable of recovering its performance, demonstrating its robustness. *T. domingensis* demonstrated tolerance to the high Cr concentrations detected during the accidental dumping and accumulate this metal in its tissues demonstrating its potential for rhizofiltration and phytostabilization in the studied wetland.

BIO of Presenter:

**Hernán Hadad** studies the effect of pollutants on the growth and diversity of macrophytes in wetlands constructed for effluent treatment and in natural wetlands, the efficiency of these systems in purifying pollutants, and the retention capacity of pollutants in macrophyte tissues.

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# DIVAGRI - multifunctional constructed wetlands with a focus on productive plants for further valorisation in seven African pilot sites

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**Abstract**
Further development of known co-benefits of Constructed Wetlands (CW) might offer new opportunities and incentives for stakeholders, such as smallholder farmers in rural Africa, to adopt and implement this well-established nature-based solution (NBS). The Multifunctional Constructed Wetland (MfCW) system co-developed, in the EU-funded project DIVAGRI, with local stakeholders aims at wastewater purification and local water and nutrient reuse, as well as promoting and trialling productive plants within the MfCW's filter-beds. The purpose is to provide an additional income and/or nutrient supply for the owners and/or their livestock in four sub-Saharan countries, namely Botswana (BW), Namibia (NA), South Africa (ZA), and Ghana (GH). Most pilot sites are two-staged MfCW with horizontal subsurface flow (HSSF) receiving greywater (GW). However, some sites receive different wastewater sources. Also, pilot site 5 has floating wetlands as first stage and pilot site 4 has vertical subsurface flow (VSSF) as second stage, as unsaturated conditions were favoured due planting of herbs for use in the hotel school kitchen (see Table 1).

**Table 1.** Pilot site characteristics and plant selection in 1st treatment stage and 2nd productive stage

| Pilot site | Source | Inflow (L/d) | Basic Design | Plants 1st Treatment Stage | Plants 2nd Productive Stage |
|---|---|---|---|---|---|
| **1** Experimental farm (BW) | dairy farm wash water | 500 | ground-based, 2-stage HSSF | *Phragmites spp.*, *Typha spp.*, *Cyperus papyrus*, *Cyperus laevigatus,* Ornamental: *Iris pseudacorus* (yellow iris) *Heliconia spp.* (lobster-claw) and *Zantedeschia spp.* (Calla Lily) | *Amaranthus* (Amaranth), *Andropogon gayanus* (Gamba grass), *Cenchrus clandestinus* (Kikuyu grass), *Colocasia esculenta* (Taro), *Cajanus cajan* (Pigeon pea), *Musa sp.* (banana), *Pennisetum spp.* (Napier grass), *Oryza sativa* (Upland rice), *Tetrapleura tetraptera* (Prekese), Vetiveria nigritana (black vetivergrass), *Zea mays* (Maize), and various herbs such as *Menta aquatica* (water mint) |
| **2** Research St. (BW) | domestic wastewater | 300 | ground-based, 2-stage HSSF | | |
| **3** Mammanaka Farm (BW) | domestic wastewater | 300 | ground-based, 2-stage HSSF | | |
| **4** Hotel School (NA) | GW from kitchen | 150 | tank-based, 2-stage HSSF-VSSF | | |
| **5** Uni campus (ZA) | polluted river water | <3600 | tank-based, 2-stage floating-HSSF | | |
| **6** Experimental farm (ZA) | GW from showers | 600 | ground-based, 2-stage HSSF | | |
| **7** Kumasi (GH) | GW | 450 | ground-based, 2-stage HSSF | | |

The productive wetland plants include species that can be used for one or several purposes such as plant biomass, non-food crops for weaving (e.g., fibres, weaving, thatching, insulation), energy crops, ornamental plants (the before stated could also be planted in the first stage), animal fodder, various herbs and potentially even food crops for human consumption. Two key challenges are ensuring safety in terms of potential contamination and finding plant species that are suitable for the conditions within the MfCWs. The DIVAGRI project delivers theoretical and practical experiences and insights into these matters by implementing and monitoring these seven pilot-scale MfCWs. Of course, the plants should also be known by the locals and be part of their eating habits. In this regard, rice and banana seem to be ideal candidates, as they are able to grow in wetland conditions and are virtually eaten in every region of the world.

**Acknowledgement:** This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101000348.

BIO of Presenter:

**Marco Hartl** is project manager and technical coordinator at alchemia-nova, Vienna. His work focuses on NBS for wastewater purification and reuse, especially using constructed wetland and green wall systems.

# Benchmarking and the integration of nature-based solutions and engineered technologies for enhanced pesticide removal

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**Abstract**

Pesticides are widely used in agriculture to increase crop quantity and quality; however, their application imposes a significant threat to both aquatic and terrestrial life due to non-targeted contamination of atmosphere, soils, and water bodies. Effluents of agro-food industries (such as the vegetable and potato processing facilities) are considered as important sources of pesticide release into the environment, despite not yet being investigated in depth. Water treatment technologies currently applied are either unable to effectively remove pesticides or have considerable disadvantages, such as high operational costs. Moreover, case-specific constraints (*e.g.,* limited space availability) can limit the application of certain treatment technologies in agro-food industries. Therefore, the general objective of this PhD project is to develop a **decision tool**, enabling the identification of the most suitable treatment technology for a case-specific pesticide contamination in (waste)water of vegetable and potato processing companies.

As various classes and types of pesticides exist, the first specific objective of this PhD is to select **relevant pesticides** that need to be tackled in the project. For this, multiple aspects will be considered, such as the presence of pesticides in relevant water types (being surface water, groundwater, tap water, and process water) and chemical properties (e.g. octanol-water partitioning coefficient, toxicity to aquatic organisms, half-life time in water). Input from industry will also be used to identify bottlenecks in a specific context such as water-reuse or bio-label certification. Results of this pesticide screening, along with an overview of the project and most important findings of literature study, will be presented in the poster.

The second specific objective is to test, improve and compare **constructed wetlands** and **membrane technologies** as single treatment technologies. In addition, the optimization of the overall removal efficiency may require a smart coupling of unit processes (integrated solutions) or hybrid treatment solutions (e.g., adsorbers in wetlands). This work is the central part of this project and will be carried out via lab scale and on pilot scale tests related to demo cases in Flanders. Finally, benchmarking of treatment technologies will be carried out with a value chain view, using criteria such as spatial requirements, energy use, operational expenditures, capital expenditures.

BIO of the presenter:

**Perry Hoendervangers**, after obtaining his master's degree in Bioscience Engineering (specialization environmental technology) in 2021, followed postgraduate courses on Energy&Climate and Entrepreneurship to further broaden his knowledge. Apparently, this was merely a sidestep as he started PhD in water treatment technology in December 2022.

# Microbial community and sediment quality of a constructed wetland treating alkaline leachate after 5.5 years operation

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**Abstract**
Constructed wetlands (CWs) have been demonstrated to be a cost-effective treatment method for the treatment of mine waters and refinery wastes. Although the use of CWs for alkaline leachates has been demonstrated, little data on their long-term performance (>5 years) is available; with little to no knowledge available on the microbial communities present within the wetland substrate. Within these CWs, microbial communities have been attributed with the aiding of pH neutralization as a result of carbonation.

A pilot scale (4m x 11m) CW treating alkaline bauxite residue disposal area (BRDA) leachate had been operating since May 2015, with the primary objective of reducing pH from ca 11.2 to pH<9. Across the length of the wetland, supernatant and sediment samples were collected at 1.5 m intervals in October 2020 and analysed for pH, EC, trace element content and metal fractionation. Implications on the microbial community were described by determining microbial biomass, community composition (phospholipid fatty acid analysis-PLFA) and functional (respiration) catabolic profiles.

Analysis revealed supernatant pH and trace element concentrations decreased from 11.5 to 7.8, with sediment concentrations of soluble, exchangeable and carbonate bound Al, As, V and Na elevated in the first 5 m of the cell. Microbial biomass was greatest in the first 5 m of the wetland. Microbial respiration using endemic *Phragmites australis* foliage as a substrate demonstrated an ability to cycle recalcitrant carbon within the CW system, with greatest respiration rates from sediments in the first 3.5 m of the wetland. PLFA population biomarkers significantly changed across the wetland for gram-positive and gram-negative bacteria ($p$<0.05): with gram-negative decreasing and gram-positive biomarkers increasing from inlet to outlet. No significant changes were detected for biomarkers of total bacteria, ectomycorrhizal fungi or bacteria:fungal ratio.

Investigations into the microbial community reveal the biomass, respiration and gram-negative biomarkers were greatest in the first 5 m of the cell. Further investigations are needed to determine the species present to compare with those found in BRDAs. Additionally, investigations of the organic matter content of the substrate may determine whether the elevated biomass is due to the increased solubility of organic matter with higher salinity in the first few metres, whether organic matter reflects the vegetation present, or whether the population may have shifted to comprise a community tolerant of the conditions. This study demonstrates that a CW operating for 5.5 years can effectively treat BRDA leachate by reducing the pH<9 as intended, with the microbial community demonstrating the ability to cycle recalcitrant plant material endemic to the site, providing a carbon source for respiration and subsequent carbonation of leachate, implying the ability to replenish their adsorptive and treatment capacity.

BIO of Presenter:
**Ashlene Hudson** is currently a PhD student at the Department of Biological Sciences at the University of Limerick. Her current research project focuses on the optimisation of constructed wetland design for the treatment of alkaline bauxite residue leachate.

# The occurrence and toxicity of emerging contaminants and their removal using constructed wetlands: a review

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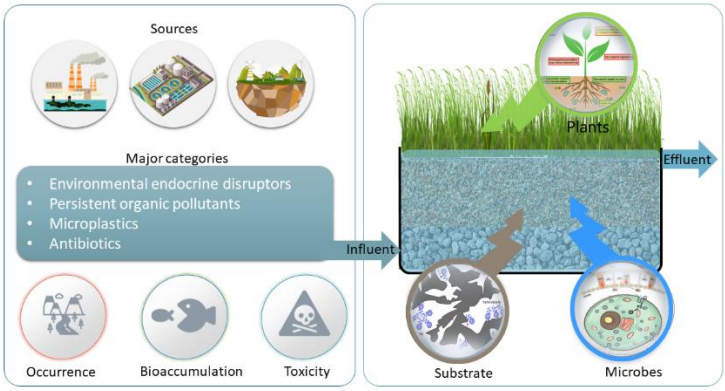
**Abstract**

As new chemical compounds are generated while scientific knowledge of present and historical contaminants continues to advance, emerging contaminants (ECs) have attracted global attention. The occurrence of these ECs in the environment and organisms is surprisingly wide while various toxic effects for living organisms, such as neurotoxicity, reproductive toxicity, immunotoxicity, etc. have been reported. Although the list of ECs remains moving, this paper focuses on the fate of major categories, including persistent organic pollutants, environmental endocrine disruptors, microplastics, and antibiotics, and their removal behavior in constructed wetlands (CWs). In recent years, there is an increase in research into the removal methods of ECs from water. As an effective, economic, and environmental-friendly wastewater treatment technology, CWs have a positive effect on the removal of ECs. The removal effectiveness of CWs on ECs is influenced by a variety of elements, such as the physical and chemical properties of ECs, the types of plants and substrates, and the design and operation parameters of CWs, etc. It is well recognized that the plant, substrate, and microbes cooperate to remove contaminants from wastewater in CWs. Unlike common contaminants, ECs are usually difficult to biodegrade. Hence, substrate adsorption may be the primary removal approach of most ECs in CWs. However, the adsorption behavior is reversible and may result in contaminant leakage due to adsorption saturation. Furthermore, some studies made effort to improve the removal efficiency of ECs by the intensive CWs, such as the application of CWs with microbial fuel cells, multi-stage CWs system, and tide-flow CWs. The review is helpful to identify and clarity the fate and removal mechanisms of ECs in CWs, which need more attention.




BIO of Presenter:

**Peiying Kang** is a Ph.D. student at Xi'an University of Technology, China, focusing on constructed wetlands and emerging contaminants especially microplstics and PFASs. She is currently participating in the doctoral joint training program of the China Scholarship Council at Trinity College Dublin, Ireland. She has published 8 research papers.

# Acid rock drainage remediation with constructed wetlands in Ancash highlands - Perú

*Vladimir León[1,*], Edson Palacios[1], Noemi Herrera[1], Kiara Aguirre[1], Bryan Picón[1], Mariza Brito[1], Vidal Roldan[1], Rosario Pastor[3]*

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**Abstract**

Acid rock drainages (ARD) are serious problem in Peru, generated by deglaciation process polluting water sources in basin heads. In addition, they are toxic and detrimental to health and environment. Likewise, the last 50 years more than 50% of glaciers in Peru (the most important tropical glaciers in the world) have been lost. Consequently, the previously covered rocks (containing metal sulfides) are now exposed and form ARD by contact with water and oxygen, presenting high concentrations of heavy metals, acidic pH, and sulphates. This problem has manifested itself in Canrey Chico, a population that uses river water for the purpose of irrigating vegetables and drinking animals. For this situation, a constructed wetland to treat ARD was implemented.

The first results were: At Canrey chico wetland the ARD affluent conditions had pH <3, Fe 8 ppm, As 0.150 ppm, Cd 0.074 ppm and Pb 0.31 ppm. The recovered effluent had pH 6.5, Fe <1 ppm, As 0.05 ppm, Cd 0.028 ppm and Pb 0.143 ppm.

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BIO of Presenter:

**Vladimir León** is a Peruvian scientist working at the Universidad Nacional Santiago Antúnez de Mayolo with experience in constructed wetlands to treat acid rock and acid mine drainage in peruvian highlands. He has been involved in international and local cooperation projects.

# Constructed wetlands for final polishing of slaughterhouse effluent

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**Abstract**

The slaughterhouse industry represents an important economic sector in Argentina. Cattle slaughter generates significant volumes of effluents that require treatment before final disposal. Constructed wetlands (CWs) constitute a consolidated technology for the treatment of sewage and have been used successfully for different industrial wastewater depuration. However, slaughterhouse wastewater is complex and has a high organic strength. The aim of this study was to evaluate the feasibility of using constructed wetlands for the final treatment of this effluent.

The performance of free water surface (FWS) and horizontal subsurface flow (HSSF) wetlands were compared in greenhouse experiences. CWs were planted with *Typha domingensis* and *Canna Indica*. The raw effluent receives a primary treatment through a separation chamber, followed by a system of anaerobic, facultative and aerobic ponds. In the latter pond, COD and BOD tend to increase when temperatures rise and algae develop. To evaluate the feasibility of replacing the aerobic pond with a CW, the inlet wastewater of this pond was used in the study.

Plants tolerated the effluent. Both CWs were efficient in the final effluent treatment. N-$NH4^+$ and TKN mean removal were 99.1 and 89.5%, respectively, not presenting significant differences between FWS and HSSF wetlands. TN removals did not present significant differences between CWs (78.1- 80.8%), while in controls (without macrophytes) they were 23.6% (FWS control) and 51.3% (HSSF control). Regarding nitrate, there were not significant differences between initial and final concentrations in both wetlands. Comparing the FWS and HSSF controls, it was observed that nitrate increased in both controls, indicating the plant role in these systems. Nitrate concentration was higher in FWS controls, probably because its conditions did not favor denitrification, which implies less NT removal in controls.

The mean removal of COD, BOD and TP were 71.2; 80.7 and 68.3, respectively for FWS *with T. domingensis*. In HSSFs, COD and BOD removal did not present significant differences between the two species (65.2 and 66.4, respectively) while TP removal was higher in HSSF planted with *C. glauca* (75.2%) than those planted *with T. domingensis* (54.7%) The highest removal efficiencies were achieved in FWS wetlands. *T. dominguensis and C. glauca* were tolerant and efficient species in the effluent treatment. FWS wetlands are the best option for this case, taking into account not only the efficiency in effluent treatment, but also the lower cost of construction and operation.

BIO of Presenter:

**Maria Maine** is a senior scientist with more than 25 years of experience in the study of contaminant dynamics in natural and treatment wetlands. She was the President of the Pan-American Wetland Network (HUPANAM). She has published more than 90 journal articles and book chapters, and more than 200 presentations in scientific meetings.

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# Assessment of surface flow artificial wetlands in the control of pollution from urban runoff in l'Albufera de Valencia natural park

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**Abstract**

Discharges from unitary sewerage systems (USS) are a major environmental problem in the receiving environment where they are discharged. The continuous increase in impervious surfaces means that these overflows from unitary systems are becoming significant in terms of both quantity and quality. During heavy rainfall events, it is possible that flows that exceed urban wastewater treatment plants capacity were generated, resulting in a mixed discharge of stormwater and urban wastewater into the receiving medium. The impact on the receiving environment is greatest when the sewerage system is separative, and decreases as the precipitation event progresses. However, whether it is a unitary or separative system, the concentrations of pollutants during this initial flushing can be elevated.

The project aims to evaluate the effectiveness of large surface artificial wetlands as a buffer for pollutants from runoff, including urban and agricultural types. The experimental study is being carried out in Tancat de la Pipa (TPCW), a former rice field that was transformed into a 40-ha wetland area in 2009. The site is located on the northern shore of the lake of l'Albufera de Valencia and bordered by the irrigation channel of the Port of Catarroja (PC) and the mouth of the Poyo streambed (BP), which collect water for treatment inside the TPCW. Both watercourses receive runoff from part of the metropolitan area of l'Horta Sud de Valencia, since the sewerage system of that area, the West Collector, regularly overflows during rainfall events. The overflow points of the collectors are located about 5.5 km from the TPCW.

A total of six sampling points have been selected, including two water inlets to the wetland, two intermediate points, and two outlets. For the two inlets, 24 bottle autosamplers have been installed and programmed to take samples every hour. At the other four points, spot samples will be taken every twelve hours during the event and up to one week after the end of the event. The variables to be measured will include organic matter (Chemical Oxygen Demand), forms of nitrogen (total, ammonium, nitrites, and nitrates), total phosphorus and phosphates, dissolved oxygen, turbidity, and conductivity. Measurements will also be taken for various pesticides and emerging pollutants during rice growing seasons.

The investigation results indicate an increase in the average concentration of total nitrogen and total phosphorus in the inlet waters. Specifically, in the PC inlet, the average concentration of total nitrogen significantly increased from 8.8 mg N/L to a maximum of 13.1 mg N/L, and the average concentration of total phosphorus increased from 0.69 mg P/L to 1.1 mg P/L. Similarly, in the BP inlet, there was an observed raise in phosphorus concentration from 0.39 mg P/L to 0.7 mg P/L and in nitrogen concentration from 5 mg N/L to 10.5 mg N/L. Regarding removal efficiencies, the results indicated an increase in total nitrogen removal from 76% to 81% in PC and from 96% to 98% in BP. Additionally, there was not only an increase in total phosphorus removal from 94% to 96% in PC but also from 93% to 96% in BP. Notably, the removal efficiencies were similar before and during rainfall in BP, although slightly higher.

BIO of Presenter:

**Adrian Martínez-Biosca**, PhD student and mid-level technician at the Polytechnic University of Valencia. He is currently working as an intermediate technician in a research project on the role of Surface Flow Artificial Wetlands in the control of pollution from urban runoff.

# Recovery of water quality from drained forested peatlands with biochar

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**Abstract**

Ireland has 21% of its territory consisting of peatlands of which more than a third has been afforested. Irish bogs are naturally treeless, therefore afforestation and reforestation require drainage of the peat causing substantial changes in the biogeochemical and hydrological conditions. This includes release of nutrients and increased runoff ultimately disturbing aquatic ecosystems downstream. Thereby, measures that recover the water quality of these effluents are warranted. Biochar has sorption properties representing a potential solution as supported by previous studies. However, application in this context needs verification.

We hypothesize that (i) biochar significantly reduces the concentration of nutrients in peatland forest drains and (ii) flow dynamics regulate treatment performance.

The experiment takes place in two forested Irish blanket bogs named Lake Atorick (53°01'50.4"N 8°31'40.7"W) and Annalaka (53°03'44.5"N 6°24'24.9"W). Previous water quality analyses in the drainage ditches revealed pH generally between 4 and 5, and carbon, nitrogen and phosphorus concentrations generally below 40, 1 and 0.10 mg/L, respectively. We installed a pile of biochar bags (1.5-2.0 m long) in a drain in such a way as to allow permeation of the flow. Grab samplings were conducted once a week before and after the bags for 8-9 weeks (Aug-Nov/21 in Lake Atorick and Oct-Dec/22 in Annalaka). The samples have been analyzed for carbon, nitrogen and phosphorus compounds as well as pH and electrical conductivity. A V-notch weir was installed downstream the bags to allow flow measurements. Here a Raspberry Pi ultrasonic sensor HC-SR04 preceding the weir is allowing automatic measurements of water level variation every 30 min (Nov-Dec/22 to date), which will be converted into flow data. Rainfall data were obtained from regional meteorological stations on dates close to the grab samplings.

Data analysis performed to date reveals no significant difference ($p > 0.05$) in water quality before and after the biochar bags. However, trends are graphically visible: pH rises while dissolved nitrogen concentration and carbon aromaticity decrease. The results suggest that successful application of biochar probably depends on favorable conditions for sorption, e.g., high concentrations of incoming nutrients, near neutral pH and/or good flow distribution. This highlights the need for design optimization.

BIO of Presenter:

**Lipe Mendes** has experience with drainage filters, water treatment and biogeochemical processes in peatland and agricultural catchments. Research work includes constructed wetlands, woodchip bioreactors and filter materials focusing on performance, driving factors and removal mechanisms. He is interested in studying nutrient export and mitigation measures to protect surface waters downstream.

# Root morphometry and tolerance of canna indica in floating treatment wetlands for Cr(III) and Cr(VI) removal

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**Abstract**

Floating treatment wetlands (FTWs) consist of a buoyant artificial medium, which facilitates root development of plants in the water column. Macrophytes are an essential component of FTWs. Plants possesses mechanisms to modulate their element acquisition in response to their environment availability and demand during their life cycle It is of vital importance to know in depth about their tolerance and adaptability to survive in an environment different from their natural habitat. The aims of this work were to evaluate the changes in root morphometry and tolerance of *Canna indica* plants and the implication in the removal efficiency of Cr(III) and Cr(VI) in a FTW.

Plants were collected from an unpolluted pond near Santa Fe city, Argentina. The plants were pruned for their transport to the greenhouse. Plastic reactors (70 L) containing 4 Kg of sediment and 38 L of tap water were installed outdoors under a semi-transparent plastic roof. FTWs consist of a plastic net and had a surface area of 0.10 $m^2$. Buoyancy was provided by a PVC frame. Each raft had a total of 4 plants. The rafts were designed to allow roots (hanging in the water column) and rhizomes to remain in the water while aerial parts emerge. After plant acclimatization (about 30 days), fifteen reactors were treated with Cr(III) or Cr(VI) solutions and three were used as biological controls (CB: with FTW, without the addition of experimental solution). Treatments were 5 and 10 mg $L^{-1}$ of Cr(III), and 5 and 10 mg $L^{-1}$ of Cr(VI). Also, a biological control (BC) with FTW without Cr addition was used. Water was sampled periodically. The experiment lasted 35 days. Cr concentrations in leaves, roots, rhizomes, and sediment were determined at the end of the experiment. Chlorophyll *a* concentration was determined at the beginning and the end of the experiment. For the study of the internal morphology of roots; segments close to the base of the roots were extracted. The cross-sectional areas of roots, steel, and metaxylematic vessels were measured, and the number of vessels was counted.

Both Cr species were efficiently removed from water in all treatments. The roots were the main accumulator organ of this metal and there was translocation to the aerial parts of the plants, being significantly higher in the case of Cr(VI) 10 ppm. A decrease in biomass and chlorophyll concentration was determined in Cr(VI) 10 ppm due to the translocation of this metal. In the Cr(VI) 5 and 10 ppm treatments, the plants showed symptoms of chlorosis. In the histological sections analyzed in the different treatments, significant changes were observed in the morphology of the roots with respect to the BC. The cross-sectional areas of roots were significantly higher in 5 and 10 mg $L^{-1}$ Cr(III) treatments. Cr(VI) treatments presented the largest vessel area and the lowest vessel number. Plasticity morphology is an important mechanism for the plant to tolerate harmful conditions. Root modifications allowed *C. indica* to tolerate the conditions to which it was exposed, without affecting the removal efficiency of the two added Cr species. The obtained results demonstrated that the use of FTWs populated with *C. indica* is a promising tool to remediate water bodies contaminated with Cr.

BIO of Presenter:

**Mercedes Mufarrege** is a researcher at the Institute of Applied Chemistry of Litoral, National Council of Technical and Scientifical Research (IQAL, CONICET-UNL, Argentina). My research is focused on the morphological responses of macrophytes to pollutants in natural wetlands and in constructed wetlands for the treatment of effluents.

# Personal care products removal from greywater using nature-based solutions for water reuse in sustainable buildings: the "ReCare" project approach

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**Abstract**
The on-site greywater treatment is an interesting alternative for the load decrease of micropollutants, such as personal care products (PCPs), due to their removal at the source. Moreover, the treated greywater, following the required quality standard, could be reused for different purposes, such as toilet flushing or irrigation of gardens and green areas. By doing so, besides contributing to the preservation of water bodies quality and aquatic ecosystem, potable water could be saved, and green spaces could be integrated in urban environment.
The use of vertical-flow constructed wetlands (VFCWs) as selected nature-based solution to remove PCPs from wastewater and greywater has been already demonstrated to be a sustainable solution for this. However, the PCPs removal mechanisms within VFCWs, such as phytoremediation, adsorption on soil and biodegradation, as well as the targeted design and dimensioning of VFCWs for this purpose need to be investigated in depth for the up-scale integration to a city's water services.
In this context, the ReCare project, funded by the FNR (Fonds National de la Recherche Luxembourg), within a 4-year PhD study aims to test the viability of VFCWs for the removal of PCPs from greywater, using different admixture substrates: conventional zeolite and activated biochar produced in a circular economy perspective I) biochar from plants, and II) biochar from cellulose-sewage. The bacterial community involved on the removal will be characterized, and finally, a VFCW treatment technology "fit for purpose" will be designed based on quality standards for water reuse in sustainable buildings.
The lab scale investigation will be carried out with 6 lysimeters (L), with a total volume of about 71 L each, filled with different substrates L1: 85% sand + 15% zeolite, L2: 95% sand + 5% zeolite, L3: 85% sand + 15% activated biochar-I, L4: 95% sand + 5% activated biochar-I, L5: 85% sand + 15% activated biochar-II, and L6: 95% sand + 5% activated biochar-II. The lysimeters will be fed simultaneously and intermittently with three types of synthetic greywater (light: only from bathrooms, medium: bathrooms + laundry, and dark: bathrooms + laundry + kitchen) in a vertical-flow mode at a frequency of three times per day. Different hydraulic loading rates will be tested.
The project will be composed of three phases: during the first phase, all lysimeters will be planted with a mix of *Phragmites australis* and *Iris pseudacorus* to then select the best substrate(s) as the main objective. With the selected substrate(s), other plants will be tested in the second phase, which will lead to the third phase, where the identified microorganisms from the two phases can be fostered, e.g., via inoculation, to enhance the PCPs removal in VFCWs. Because bioremediation is expected to be the driving mechanism in the PCPs removal, a characterization of the most abundant genera will be performed using 16S rRNA sequencing from different layers of the lysimeters, varying substrate and load rate to identify bacterial specialists contributing to the removal of PCPs. Wastewater quality and microbial biomass, as well as the pollutants removal efficiency and the residual amount in the soil/ plants will be monitored at all phases.
The knowledge gained from these lab scale studies will be then used to design and dimension a suitable greywater treatment for sustainable buildings, based on effluent quality standards for water reuse.

BIO of Presenter:
**Fernanda Muniz Sacco** is a Doctoral Researcher at the University of Luxembourg. She is an Agronomist Engineer with a Master in sustainable development, with more than 10 years of experience in sustainable agriculture. Since 2021, she has been developing her career in circular economy applied to the urban wastewater management.

# Comparison of hybrid wetland arrangements for dairy wastewater treatment

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**Abstract**

The aim of this work was to compare the performance of two pilot-scale hybrid wetland systems to assess the best arrangement for the treatment of dairy wastewater. The hybrid wetland 1 (HW1) was composed of a first stage of three parallel vertical flow (VF) wetland units followed by a second stage of a horizontal subsurface flow (HSSF) wetland unit. The hybrid wetland 2 (HW2) was composed of a first stage of three parallel VF wetland units followed by a second stage of a free water surface (FWS) wetland unit. Coarse sand, river stones, and sediments were the substrates used in VF, HSSF, and FWS, respectively. *Typha domingensis* was planted in all wetland units. The HW1 and HW2 received 0.170 $m^3$ $d^{-1}$ of dairy wastewater which was previously treated by a dissolved air diffusion and an aerobic pound. Wastewater, plants, and sediments samples were taken from each wetland unit. COD, BOD, TKN, $NO_2^-$, $NO_3^-$, and TP were determined in all wastewater samples. TN was estimated as TN = TKN + $NO_2^-$-N + $NO_3^-$-N. TKN and TP concentrations also were determined in plant and sediment samples. The removal percentages of main pollutants in each wetland unit were calculated. Mean chemical composition of the inlet wastewater was: COD = 1211.9 mg $O_2$ $L^{-1}$, BOD = 238.9 mg $O_2$ $L^{-1}$, TN =96.4 mg N $L^{-1}$, and TP =32.1 mg P $L^{-1}$. Figure 1 shows COD, BOD, TN, and TP removal percentages in stage 1, stage 2, and full system for HW1 and HW2. COD, TN, and TP removals did not show significant differences between HW1 and HW2. However, COD and TP removals from the VF stage of HW1 were significantly higher than HW2. BOD removal showed significant differences between HW1 and HW2, due to BOD removal in FWS was lower compared to HSSF. N and P concentrations in plant tissues increased during the treatment in HSSF and FWS wetlands while in VF stage of HW2 TN and TP removals in were correlated to low concentrations of nutrients in plant tissues, indicating a significant plant uptake. Nutrient concentrations in the sediment from FWS wetland did not show a significant increase. Both the HW1 and HW2 were efficient for the treatment of dairy wastewater. The obtained results suggest that uptake by plants could be a key process for N and P removal from the wastewater.

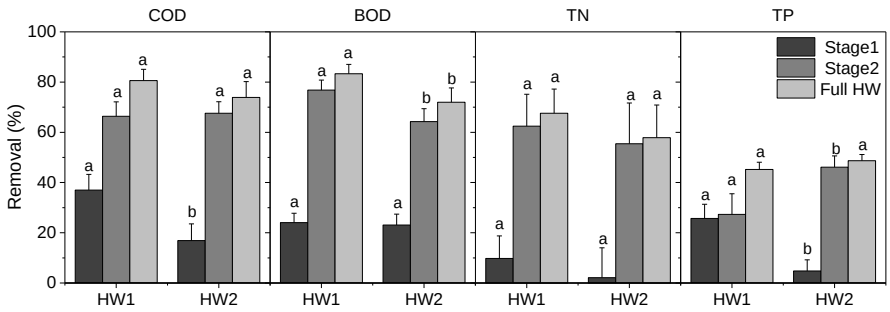


Figure1: COD, BOD, TN, and TP removal in stage 1, stage 2 and full HW for HW1 and HW2. Different letters represent statistically significant differences between HW1 and HW2 for each stage.

BIO of Presenter:

**Emanuel Nocetti** is specialized in constructed wetlands for industrial wastewater treatment. His research topic is the application of hybrid wetland systems for the treatment of dairy effluents focused on nitrogen compounds removal.

# Floating treatment wetlands, composed of *Pontederia sagittata* and *Cyperus papyrus*, for the removal of microplastics in two urban ponds

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**Abstract**

The "Paseo de Los Lagos" is a famous park in the city of Xalapa, Veracruz, México, which has four artificial lakes. In 2013, the Environmental Biotechnology Group of INECOL installed two lines of Floating Treatment Wetlands (FTWs) composed of *Cyperus papyrus* and *Pontederia sagittata* in the pond at the main entrance (pond 1) to reduce water pollution caused by various nutrients, coliforms and microcystins. Due to its high removal efficiency, in 2016, two FTWs were installed in the pond located at the final area of the park (pond 4).

It has been observed that plastics that are dumped into these two ponds are trapped in the wetland lines, where they become fragmented into smaller fractions, considered as microplastics. A methodology was implemented to quantify microplastics in water, sediments and roots, which demonstrated that the FTWs in both ponds are efficient in the removal of these pollutants. In the water column, values of 6.3 to 0.9 mg $L^{-1}$ were found in pond 1 and from 5.1 to 2.4 mg $L^{-1}$ in pond 4, with removals of 85.4 % and 52.7 % respectively. Sediments were shown to have the ability to accumulate the highest concentration of microplastics. The highest removal percentages were obtained in sediments with 94 % in pond 1 (from 33.6 to 3.3 mg $g^{-1}$) and with 97 % in pond 4 (from 9.6 to 0.28 mg $g^{-1}$). The roots of *C. papyrus* and *P. sagittata* were also able to strongly trap microplastics; in pond 1, a decrease in microplastics in the roots from 16 to 5.3 mg $g^{-1}$ with a 67 % removal was observed, while in pond 4 this concentration decreased in the first line of plants (from 3.1 to 1.7 mg $g^{-1}$ with a removal of 45 %), but it increased after the second line of plants (5 mg $g^{-1}$) due probably to the fact that visitors throw plastic containers into the pond and that they become accumulated nearby this area. This study is one of the first reports in México on the ability of FTWs to remove microplastics in urban water bodies.

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BIO of Presenter:

**Eugenia Olguín** is a Professor with more than 43 years of experience in environmental biotechnology, developing and evaluating technologies for wastewater treatment, utilizing plants (phytoremediation) or microalgae (phycoremediation), at lab and field scale. She has led 43 projects and founded the Latin American Society of Environmental and Algal Biotechnology.

# Wastewater treatment and greenhouse gas emissions: herbaceous vs woody horizontal constructed wetlands

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**Abstract**
Projections estimate that 2.8 billion people will lack safely managed sanitation in 2030 [1], and constructed wetlands (CWs) will be instrumental as they provide nature-based, low-cost, decentralised solutions to wastewater treatment [2]. Horizontal subsurface (HSSF) CWs have been used across Europe since the 1980s and are predominantly planted with *Phragmites australis* (*P. australis*) [3]. Recent research has shown that woody species (especially *Salix*) could improve the longevity of CWs [4] and be coppiced for biofuel [5], which could provide added income in rural areas. However, limited literature compares *P. australis* and *Salix* species for the removal of conventional pollutants. To address this gap, eight mesocosm experiments have been set up at an outdoor laboratory facility on the University of Birmingham campus (UK) to mimic a tertiary stage HSSF CW serving a population of less than 2000. The climate is classified as temperate with no dry season and a warm summer. Treatment efficiency and greenhouse gas emissions of herbaceous and woody HSSF CWs under different modes of active aeration are being compared. Four mesocosms are planted with *Salix alba vitellina* (golden willow), three with *P. australis*, and one has been left unplanted to act as the control. Active aeration is applied following Table 1 and is either continuous, intermittent (aerated for 1 hour 4 times a day), seasonal (continuous aeration applied during the coldest six months), or not aerated. Synthetic secondary treated municipal effluent is continually applied to the wetlands and recirculated, where the results of pollutant concentration are plotted with time. The results are expected to inform regional water authorities regarding the applicability of woody CWs in small treatment works and potential emissions trade-offs.

*Table 1: Aeration-plant matrix*

| | Continuous | Intermittent | Seasonal | No aeration |
|---|---|---|---|---|
| *P. australis* | X | X | | X |
| *Salix alba vitellina* | X | X | X | X |
| Unplanted | X | | | |

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BIO of Presenter:
**Dee Phillips** studied Civil Engineering at the University of Birmingham in Birmingham (UK), where she stayed. She is currently completing her PhD on horizontal constructed wetlands for wastewater treatment with industry involvement. Her focus is comparing Phragmites australis and Salix species regarding seasonal treatment efficiency and greenhouse gas emissions.

# The role of *Sparganium erectum*, substrates and microorganisms in constructed wetlands treating anaerobic digestion effluents

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**Abstract**

Constructed wetlands are a green, low-maintenance and cost-effective technology that are widely used for wastewater treatment and nutrient recovery. Anaerobic digestion liquid effluents are a complex matrix rich in organic matter and nutrients than can accumulate many pollutants such as trace metals and antibiotics. Constructed wetlands are an effective solution to remove the pollutants before being discharged in the environment, but the impact of metals and antibiotics in the systems are still not fully understood.

Hence, the aim of this study was to understand the role of plants, substrates, and microorganisms in the removal of metals and antibiotics from the liquid digestate. Four different digestates (liquid digestate spiked with oxytetracycline, sulfadiazine, ofloxacin at a final concentration (100 µg/L) and negative control were treated in vertical subsurface flow constructed wetlands at microcosm scale. The wetlands configuration was gravel, light expanded clay aggregate and sand with *Sparganium erectum*.

Removal efficiencies of Fe, Mn, Zn, Cu, Pb and Cr reached over 82 %. At the end of the experiment, most of Fe, Cu, Pb and Ni were present in the plant's roots, Mn was mobilized in the plant shoot, and Zn, and Cr were captured in the clay layer.

The characterization of the microbial community revealed a differentiation between the communities in sand along time, with a relative increase in richness after two-month treatment in wetlands. In addition, the sand was dominated by the phylum Proteobacteria, whereas after three-month treatment this dominance decreased and other phyla gained abundance (e.g., Planctomycetota, Bacteroidota, Acidobacteriota). Furthermore, comparing the different conditions, it was not possible to observe a clear effect of the antibiotics on the microbial community structure of the below-ground microbial communities.

Data on the characterization of the microbial community associated with the plant roots, under processing, will allow a deeper insight into the contribution of different compartments to the removal processes occurring during treatment of the digestate liquid fraction in CWs.

**Keywords:** Antibiotics, constructed wetlands, liquid digestate, metals, microbial communities, Sparganium erectum

**Acknowledgement**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 861088

BIO of Presenter:

**Pau Porras Socias** is enrolled in a doctoral program in the framework of M2ex-H2020-MSCA-ITN aiming to exploit metal-microbe applications to expand the circular economy. His research conducted at the University of Porto and the University of Galway focuses on the performance of constructed wetlands to remove metals and pharmaceuticals from the digestate.

# Partially-saturated constructed wetlands as performance all-rounders for the removal of household micropollutants

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**Abstract**

The degradability of specific organic micropollutants in constructed wetlands (CWs) may differ depending on the prevalence of oxic (as in unsaturated CWs) or anoxic conditions (saturated CWs). This study investigated the removal of three environmentally-relevant organic micropollutants: plasticizer bisphenol S (BPS), household-use insecticide fipronil (FPN) and non-steroidal anti-inflammatory drug ketoprofen (KTP) in the model CWs set up in an outdoor column system. BPS and KTP, in contrast to FPN, exhibit higher biodegradability potential under oxic conditions. The experimental CWs were operated under various saturation conditions: unsaturated, partially saturated and saturated, and mimicked the conditions occurring in unsaturated, partially-saturated intermittent vertical-flow CWs and in horizontal-flow CWs, respectively. The CWs were fed with synthetic household wastewater with the concentration of the micropollutants at the level of 30–45 µg/L. BPS and KTP exhibited contrasting behaviour against FPN in the CWs in the present experiment. Namely, BPS and KTP were almost completely removed in the unsaturated CWs without a considerable effect of plants, but their removal in saturated CWs was moderate (approx. 50%). The removal of FPN (approx. 90%) was the highest in the saturated and partially-saturated CWs, with moderate removal (66.7%) in unsaturated systems. Noteworthy, partially-saturated CWs provided high or very high removal of all three studied substances despite their contrasting degradability. Namely, their removal efficiencies in planted CWs were 95.9%, 94.5% and 81.6%, for BPS, KTP and FPN, respectively. The removal of the micropollutants in partially-saturated CWs indicated that they could be considered as performance all-rounders for compounds with contrasting biodegradability properties [1].

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**Acknowledgement**

This work was financially supported by project IGA (University-wide Internal Grant Agency Project, No. 2020B0026) of the Czech University of Life Sciences Prague, Czech Republic.

BIO of Presenter:

**Tongxin Ren** is a PhD student in Environmental Sciences at the Czech University of Life Sciences. Her research includes the effects of different aeration conditions on micropollutants removal, nitrogen removal and pathogen removal in constructed wetlands. She has already published an article in the journal of *Chemosphere.*

# Vertical flow constructed wetlands for anaerobic digestate safe reuse: microplastics, metals and pathogens removal, fate and persistence

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**Abstract**

Constructed wetlands (CWs) have been widely applied for wastewater treatment as they have demonstrated to effectively remove pollutants such as organic matter, nutrients, metals and antibiotics. Anaerobic digestate is a by-product of wastewater treatment with potential to be used in agriculture due to its high nutrient content, however, it may contain pathogens, metals and microplastics, which pose significant risks to human health and the environment when reused. Numerous studies reported variable pathogens removal efficiencies, in some cases not achieving the quality required by regulations for water reuse. On the other hand, up to now, only few studies have reported microplastics removal in CWs and their effect on CWs biota has not been understood.

The objective of this study is to investigate the potential of vertical flow CWs at a microcosm scale for treatment of anaerobic digestate to be further reused. Special attention is given to evaluate CWs capacity to remove pathogens, metals and microplastics, and retain nutrients.

Four vertical subsurface flow CWs microcosms, each with dimensions of 0.4 m x 0.3 m x 0.3 m, were assembled and filled with three layers of substrates, including gravel, lightweight expanded clay aggregate, and sand. Six individuals of *Sparganium erectum* collected from a stream in Matosinhos, Portugal, were planted in each system. The CWs are being fed with anaerobic digestate collected from a wastewater treatment plant in Porto, Portugal. Aliquots of CWs influent and effluent will be analyzed to determine removal yields of organic matter, nutrients, metals, pathogens and microplastics.

The outcomes of this study will contribute to the optimization of CWs as nature-based solutions designed for water treatment and reuse, namely in agriculture, promoting waste valorization and identifying opportunities for the recovery of valuable resources from wastewater.

BIO of Presenter:

**Ailén Soto** is an environmental engineer and early stage researcher with a MSc. in wastewater treatment and environmental biotechnologies. She is currently a 3rd year MSCA PhD candidate working on applying bioprocesses for waste valorization and water reuse. Her research interests are constructed wetlands, anaerobic digestion and bioresource recovery.

# Removal of organics and nutrients in floating treatment wetlands combined with microbial fuel cells under different organic loading rates

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**Abstract**
Floating Treatment Wetlands (FTW) are a type of CW in which emerging vegetation grows on buoyant frame on surface waters. A recent development in the field of wastewater treatment in FTW is their integration with Microbial Fuel Cell (MFC), which can boost remediation effects while also recovering bioelectricity (Colares et al.,2021). However, studies regarding integration of FTW and MFC are relatively scarce and little is known about performance under different loading rates and with different species of macrophytes. The objective of this preliminary study is to investigate the impact of a) Organic Loading Rate (OLR) and b) plant species: *Phragmites australis, Iris pseudacorus*, and mix of both species on organics and nutrients removal, as well as bioenergy generation. The investigations will be performed in 6 mesoscale reactors (0.8 m height, 0.4 m diameter) made of polyethylene. Three reactors are FTW (planted with *P.australis, I. pseudacorus* and mix), and other 3 are FTW equipped with MFC and planted with the same species (Fig 1). FTW reactors without electrodes will serve as a control in terms of microbiome composition development and nutrient removal rates Anode and cathode are composed of graphite, and located at 0.6 m distance from each other. Synthetic wastewater will be fed to the reactors. We plan to use OLR between 40 and 90 g COD/$m^3$·d and HRT between 4 and 7 days.

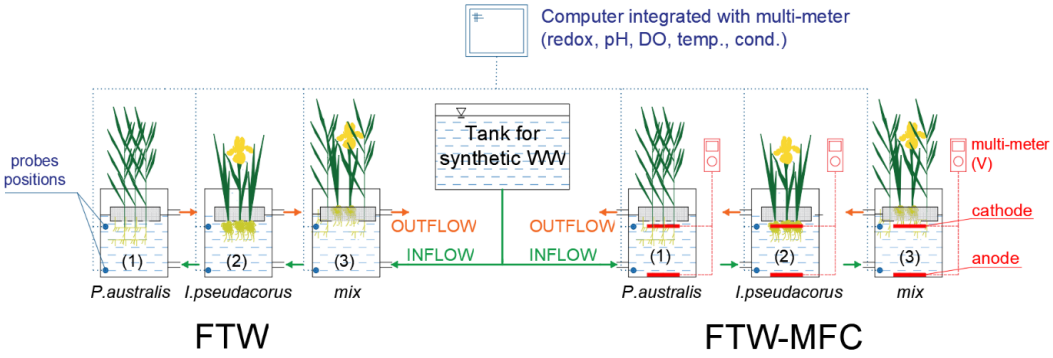


Fig. 1 Scheme of experimental reactors

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BIO of Presenter:
**Joanna Strycharz** is a Ph.D candidate at Gdansk University of Technology. Main research interests are wastewater treatment, natural based solutions and constructed wetlands. Currently working in a project: „Integrated approach 3M (Macrophytes-Microbiome-Modelling) to elucidate mechanisms of bioenergy production and micropollutants transformation in Floating Treatment Wetlands combined with Microbial Fuel Cells"

# Straw and wood biochar application to marginal soil for *Miscanthus giganteus* energy biomass production: a pot scale study

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**Abstract**

Eutrophication due to nutrient supply continues to be a major problem in the Baltic Sea. Agriculture and municipal sewage are the most prominent sources of biogenic substances. While nutrient inputs to virtually all Baltic Sea sub-basins have considerably decreased, introducing of more effective mitigation measures in the agriculture sector remains critical. Application of carbon-based materials, such as biochar, to poor-quality soils has shown numerous positive impacts, i.e. increase of water retention, elevation of pH and prevention of leaching of nutrients supplemented with mineral fertilizers. At the same time, thermal conversion of organic wastes to produce biochar, which can be reused for improvement of crop yield and mitigation of nutrient leaching, is in agreement with SDGs and European Green Deal policy.

The feasibility of producing energy biomass from *Miscanthus giganteus* grown on marginal soils treated with biochars while lowering nutrient leaching from crop production is investigated in the eBIOCOOL project entitled "Energy BIOmass CULtivation on marginal soils enhanced with biochar amendments fertilized with by-product in order to reduce nutrients leaching".

The first phase of experiment assumes to verify the optimum doses of straw and wood biochars to support growth of *Miscanthus giganteus* on marginal soils (Fig.1). The basic soil parameters employed are as follows [%]: C=0.5, H=0.5, N=0.5, P=0.05, Mg=1.17, Ca=0.62, K=0.81. The NPK ratio is 10:1:16. The experiment is set up in 3L pots with 5 replications of each, and the biochar amendments investigated are [%, v/v]: 0, 1, 2.5, 5, 10, 15. Potential stress response based on growth metrics, photosynthesis analysis, gas exchange, and anatomical analyses will be validated after 2 months of experiment. According to the preliminary results, the doses of 10 and 15% of biochars are the least favorable, while the addition of 1% and 2.5% appears to be the most optimal.

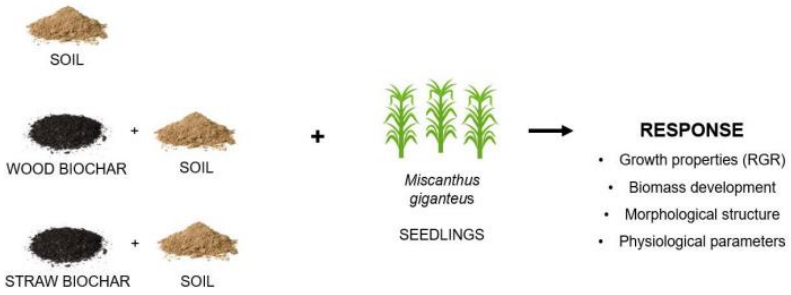


**Fig.1** The idea for stress response analyses of *M×g* seedlings on biochar amendments

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