OPENING THE BLACK BOX: FLUORESCENCE-BASED IMAGING OF SPATIAL PATTERNS OF MICROBIAL ENZYMATIC ACTIVITY IN A VEGETATED WALL FOR DOMESTIC GRAYWATER

WETPOL 2019

AARHUS UNIVERSITY - DENMARK

SOLIDUM PETIT IN PROFUNDIS · UNIVERSITAS ARHUSIENSIS ·

BOOK OF ABSTRACTS

8th International Symposium

on Wetland Pollutant Dynamics and Control

17 – 21 June, 2019

Aarhus University, Denmark

SOCIETY of WETLAND SCIENTISTS
Europe Chapter

Edited by: Carlos A. Arias, Carlos A. Ramírez-Vargas, Lorena Peñacoba-Antona, and Hans Brix

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INTRODUCTION

On behalf of the WETPOL 2019 organizing committee, we would like to welcome you to Aarhus University for the 8TH International Symposium on Wetland Pollutant Dynamics and Control.

After 16 years, the WETPOL symposium has evolved to become an important meeting for scientists, practitioners, engineers, biologists, environmental authorities and students as a platform for knowledge exchange dealing with natural wetlands, as well as wetlands for the treatment of pollutants and residues. WETPOL 2019 brings 300 attendees from all the continents, along with the 7 most eminent scientists invited as keynote speakers, plus 14 special sessions chaired by experts in their field, 218 oral presentations, 78 posters and 6 technical tours that will guarantee the success of WETPOL 2019. Without a doubt, the success of the meeting is due your participation and willingness to share your experiences so that the wetland community can profit from your research, and the new knowledge acquired through the investment of resources and investigation.

We would like to thank Aarhus University for the unlimited support given through the two years of preparation of the symposium. We also thank the Municipality of Aarhus, as well as the multiple sponsors that generously have contributed to the realization of WETPOL 2019. Their support has been invaluable and encouraging to make sure we put our best efforts to the success of WETPOL 2019.

Additional thanks to the Bioscience secretarial staff and all the volunteers that have joined us in the planning, preparation and arranging of WETPOL 2019. This group has worked hard to make sure all the activities planned are successful and for sure have been a strong support and have made our work easier; it has been great to rely on their expertise.

Finally, we are pleased to present the book of abstracts, summarizing all the oral presentations and posters in WETPOL2019.

Welcome to Aarhus University and we hope that you enjoy your stay and profit from WETPOL 2019.

Hans Brix

Carlos A. Arias

Aarhus, June 2019

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TABLE OF CONTENTS

POSTERS

KEYNOTE SESSIONS

Hans Brix

Carlos A. Arias

KEYNOTE SPEAKERS

Dr. **Curtis J. Richardson** is Professor of Resource Ecology and founding Director of the Duke University Wetland Center in the Nicholas School of the Environment, Duke University, North Carolina, USA.

Dr. Richardson was elected President of the Society of Wetland Scientists in 1987-88. His research interests in applied ecology focus on long-term ecosystem response to large-scale perturbations such as climate change, toxic materials, trace metals, flooding, or nutrient additions. He has specific interests in phosphorus nutrient dynamics in wetlands and the effects of environmental stress on plant communities and ecosystem functions and services. The objectives of his research are to utilize ecological principles to develop new approaches to environmental problem solving. The goal of his research is to provide predictive models and approaches to aid in the management of ecosystems.

Dr. **Jennifer Tank** is the Galla Professor of Biological Sciences at the University of Notre Dame, Indiana, USA, and Director of the Notre Dame Environmental Change Initiative.

Dr. Tank studies the cycling of nutrients in stream and rivers with a focus on the restoration of ecosystem function in impacted systems. Dr. Tank currently leads a multidisciplinary group of researchers examining the effect of agricultural land use on freshwater. Since 2006, her research has explored innovative conservation strategies to improve the health and nutrient removal efficiency of streams draining cropland in the agricultural Midwest by restoring floodplains in formerly channelized ditches. Her federally-funded research programme includes grants from the U.S. Department of Agriculture, National Science Foundation, and the Environmental Protection Agency. She is also the current President of the Society for Freshwater Science.

Prof. Dr. Dr. h.c. **Hans Joosten** is a Professor of Peatland Studies and Palaeoecology at the Institute of Botany and Landscape Ecology of Greifswald University, Germany.

As the director of the Department of Peatland Studies and Palaeoecology of Greifswald University, Dr. Joosten studies peatlands in an integrative way at the crossroads between palaeo-ecology, ecology, landscape ecology, nature conservation and wise use. A key research topic is paludiculture, i.e. wet agriculture on peatlands on which he edited the first handbook in 2016. Hans Joosten has produced several books on mires and peatlands, including ‘Wise use of mires and peatlands’ (2002) and ‘Mires and peatlands of Europe’ (2017). Hans Joosten has been intensively involved in UNFCCC negotiations and IPCC guidance development, especially with respect to accounting for emissions from organic soils, and in FAO in advancing climate-responsible peatland management.

Dr. **K. Ramesh Reddy** is a Graduate Research Professor and Chair of the Soil and Water Sciences Department, University of Florida’s Institute of Food and Agricultural Science, Gainesville, USA.

For over 40 years, Dr. Reddy has led ground-breaking research on the biogeochemical cycling of nutrients in natural and managed wetland and aquatic ecosystems, particularly in the Florida Everglades. He is a renowned biogeochemist, mentor, and leader in wetland science. He promoted an integrated approach to wetland science that included biogeochemistry in research and education, he co-authored a textbook entitled Biogeochemistry of Wetlands: Science and Applications, and has produced more than 350 peer-reviewed papers. He served on the National Research Council Committee of the National Academy of Sciences for an independent review of the Everglades Restoration Plan and currently serves on the U.S. EPA Science Advisory Board’s Ecological Processes and Effects Committee.

Dr. **Tom Headley** is an independent consultant, offering expertise and services internationally via Wetland & Ecological Treatment Systems (WETSystems), Newcastle, Australia.

Dr. Headley holds a PhD from Southern Cross University and has over 20 years' experience in the research, design, construction and operation of ecological technologies for wastewater treatment. Dr. Headley has worked in New Zealand, Fiji, Denmark, Germany, the USA and throughout the Middle East applying the full spectrum of wetland technologies across a broad range of applications, including treatment of sewage, sludge, oilfield production water, landfill leachate, industrial effluents and agricultural runoff. Dr. Headley has been involved with the design, construction and operation of the world's largest industrial constructed wetland system, with >700 ha of surface flow wetlands and ponds for managing 115 ML/d of oilfield wastewater in the desert of Oman. He is currently engaged to expand this project by 60 ML/d with > 400 ha wetlands/ponds.

Dr. **Karin M. Kettenring** is an Associate Professor of Wetland Ecology at the Department of Watershed Sciences and the Ecology Center at Utah State University, USA.

Dr. Kettenring received her B.A. in Biology from Oberlin College. She received her PhD in Applied Plant Sciences from the University of Minnesota where she did research on restoration of sedges (*Carex* species) in prairie pothole wetlands. She was a Postdoctoral Fellow at the Smithsonian Environmental Research Center, where she studied the invasion of *Phragmites australis* in Chesapeake Bay tidal wetlands. She has been a faculty member at Utah State University since 2008 and teaches courses on wetland and restoration ecology. Her research efforts focus on (1) the ecology, genetics, and management of wetland invaders, (2) seed ecology of native wetlands plants with implications for wetland revegetation, (3) restoration genetics for sustainable, functioning wetlands, and (4) drought effects on wetlands with potential policy and management solutions.

Dr. **Bill Mitsch** is Eminent Scholar and Director of the Everglades Wetland Research Park and Juliet C. Sproul Chair for Southwest Florida Habitat Restoration at Florida Gulf Coast University in Naples Florida, USA.

Bill Mitsch has been a university professor specializing in wetland and aquatic biogeochemistry and ecological engineering for 44 years at 4 universities in the USA. His over 700 publications include 5 editions of the textbook/reference book 'Wetlands' and two ecological engineering books. He founded in 1992 and served for 25 years as editor-in-chief of the international journal 'Ecological Engineering'. He is Past President of the Society of Wetland Scientists and American Ecological Engineering Society, the latter which he founded. Dr. Mitsch has received several prestigious awards such as the Stockholm Water Prize, the first Odum Award for Excellence in Ecological Engineering, and the Ramsar Award for Merit.

A PARADOX FOR WETLAND ECOSYSTEM SERVICES: HIGHLY VALUED BUT UNDER APPRECIATED

***Curtis J. Richardson*[1]**

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The term "ecosystem services" rarely appeared in the scientific literature before 1980, but by 2018 citations reached 16,000, nearly 60% of all wetland citations. The broad definition of ecosystem services used today follows the 2005 Millennium Ecosystem Assessment that "ecosystem services are the benefits people obtain from ecosystems". Thus, it follows that what nature contributes usually as a variety of "goods and services" are normally classified as (1) Goods: water, harvested resources like timber, wildlife or plants etc. (2) Services: ecological regulatory and habitat functions such as water purification, climate regulation, flood protection, erosion control, recreation and tourism benefits and (3) Cultural: heritage values, and spiritual beliefs. Unfortunately, while the term "ecosystem services" has saturated the environmental literature "wetland ecosystem services", while highly valued at the landscape level still receive low global recognition. In this review and analysis, I will briefly address how recent studies have tried to better quantify the relationships between wetland ecological functions and economic values. Representative examples of wetland ecosystem services drawn from both the literature and my 40 years of research covering water quality improvement, flood abatement, carbon management and climate change will be used to assess key wetland services and how we might better enhance their value to society.

BIO: Dr. Curtis Richardson is Director of the Duke University Wetland Center and the John O. Blackburn Distinguished University Professor of Resource Ecology at Duke's Nicholas School of the Environment. He directs research on wetland biogeochemistry, climate change and ecosystem restoration. He is a Fellow of the Society of Wetland Scientists, the Soil Science Society of America, and the American Association for the Advancement of Science.

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THE INFLUENCE OF FLOODPLAIN RESTORATION ON WATER QUALITY IN AGRICULTURAL STREAMS

Jennifer L. Tank
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The Midwestern US has undergone extensive land use change as forest, wetlands, and prairies have been converted to agroecosystems. Excess fertilizer nutrients now enter adjacent waterways, degrading both local and downstream water quality. We have quantified changes in water quality after floodplain restoration (via a two-stage ditch) over 10yrs in a small agricultural watershed. Floodplains increased nitrate-N removal via denitrification and reduced sediment export during high flows (e.g., spring snowmelt and storms), but impacts on nutrient concentrations were negligible due to high catchment loading relative to the length of floodplain restoration. In contrast, modeling efforts using the Soil and Water Assessment Tool (SWAT) suggested that longer two-stage reaches could achieve significant reductions in nutrient and sediment export from agricultural watersheds, showing promise for improved water quality at larger spatial scales. This project has provided insights into how floodplains influence nutrient export, while also highlighting water quality improvements achieved through a regional demonstration project.

PALUDICULTURE - THE PEATLAND PATHWAY TO 2050

Hans Joosten
Greifswald University
Greifswald Mire Centre

The Paris Agreement has made the world simple. We have one common goal: to limit global temperature rise to clearly below 2°. The physical consequence is, that we have to reduce global net CO_2 emissions by 2050 to 0 (zero). Furthermore, the goal has to be reached "…in the context of sustainable development and efforts to eradicate poverty". The challenges are thus enormous, also for peatlands, as drainage based land use is currently responsible for 5% of global anthropogenic CO_2 emissions.

The peatland pathway to 2050 implies the complete fading out of drained peatland use. This is not only necessary from the perspective of climate change mitigation but also urgently for climate change adaptation, including the stopping of coastal land subsidence, the cooling of the regional climate and the buffering against more unstable weather conditions. As the growing demand for biomass implies that the 500,000 km^2 of drained peatlands worldwide must largely maintain their production function, peatland agriculture and forestry must rapidly advance the development of wet alternatives, i.e. of paludicultures. This keynote gives an overview of the principles of paludiculture, presents examples of pilot projects worldwide, identifies the challenges to overcome and clarifies the perspectives of this novel land use practise.

PHOSPHORUS BIOGEOCHEMISTRY IN WETLANDS: INSIDE THE BLACK BOX

K. R. Reddy
Wetland Biogeochemistry Laboratory
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Wetlands serve both as a sink and a source of phosphorus (P). Wetlands have the ability to store large amounts of particulate matter in soils through settling and deposition. They are also known to generate dissolved constituents which can be potentially transported downstream. Mobility and reactivity of P in wetlands are controlled by the chemical composition of P in soil and water, relative sizes of various P pools in the soil, interactions of soluble fractions with solid phases, and decomposition of organic substrates including soil organic matter. As a result, processes controlling retention of one element (such as P) in wetlands are also linked or closely coupled with other macro-elements (carbon, nitrogen and sulfur) which affect vegetation growth, microbial activity, and other associated biogeochemical processes. In this presentation I will review both biotic and abiotic processes regulating the inter-relationships between and within carbon, nitrogen, and phosphorus cycles as related to surface water quality.

HOW DO YOU TURN 200,000 M3/DAY OF OILY WASTEWATER IN THE MIDDLE OF THE DESERT INTO A 480HA TREATMENT WETLAND OASIS?

Tom R. Headley

Wetland & Ecological Treatment Systems, East Maitland, NSW, Australia

This is the story of the Nimr Water Treatment Plant in Oman, which has recently been augmented by an additional 130ha of surface flow wetlands with a capacity to treat up to 80,000 m^3/d of extra wastewater. This brings the total area of treatment wetlands to 481 ha, providing a total capacity to treat up to 200,000 m^3/d of oilfield wastewater ("produced water"), all with gravity flow and the power of nature. This makes it one of the biggest "constructed" wetland systems in the world and an iconic demonstration of the potential that wetland and ecological technologies offer the industrial sector in their endeavors to improve the sustainability of their water management operations.

The produced water management facility has been developed by BAUER Nimr LLC (an Omani subsidiary of the German BAUER company) under a design, build, own and operate project delivery model, which means they will continue to own and operate the facility for the next 25 years. In 2017, BAUER Nimr were awarded the contract to expand the original 351 ha wetland system and engaged me to lead the wetland design, construction and commissioning aspects of the project. This presentation will summarise the experiences of that 2 year journey, including a review of the lessons learned from 8 years of operation of the existing wetland system, design innovations adopted to improve the efficiency and operability of the system, how to overcome hydraulic constraints, and the challenge of propagating and planting-out wetland vegetation for 130 ha of new wetlands in the middle of the desert.

Figure 1: Areal view of the newly planted 130ha wetland system (centre) and the existing 351 ha wetlands (background left).

BIO: Dr. Tom Headley is a constructed wetland specialist with over 20 years' international experience in the research, design, construction and management of eco-technologies for treatment of a broad range of wastewater types. After spending many years as a research scientist in academia, Tom then went on to establish and lead the wetland department of the BAUER company which specialises in implementation of large-scale treatment wetlands. Tom returned home to Australia in 2015 and now leads the specialized wetland consulting firm: WET Systems.

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MECHANISMS, IMPACTS, AND MANAGEMENT OF WETLAND PLANT INVASIONS

Karin M. Kettenring, *Carrie Reinhardt Adams, Stephen Hovick and Neil O. Anderson.*

Wetlands are highly invasion prone due to their position in the landscape downstream of anthropogenic activities and their natural propensity for disturbances. Invasions of non-native plants are also the bane of wetland managers. Over recent decades, our understanding of invasion mechanisms and impacts has advanced considerably and our approaches to invader management have improved markedly, but we still have a lot to learn. In this talk, I will explore invasion mechanisms related to various genetic, ecological, and evolutionary factors conferring plant success. I will also evaluate how aspects of wetland environments—increasing anthropogenic environmental modifications, resource availability, and global change—further contribute to wetland invasions. Regarding invader impacts, I will consider population, community, and ecosystem-scale impacts following plant invasions as well as changes (both positive and negative) to ecosystem services. Finally regarding invader management, I will address how we can develop invasive plant management strategies that are transferable and translatable across species and contexts. And I will discuss how native wetland plant communities might be established that best resist invasions. Ultimately my goal in addressing these topics is to improve the management of some of our most intractable plant invaders.

FUTURE CHALLENGES AND OPPORTUNITIES FOR WETLAND CREATION AND RESTORATION IN RELATION TO CLIMATE AND LANDSCAPE CHANGES

William J. Mitsch
Everglades Wetland Research Park, Florida Gulf Coast University, Naples, Florida, USA

Humans have caused both landscape change and climate change, leading to ecological calamities around the world in freshwater and coastal waters. Harmful algal blooms (HABs), more common and wicked because of excessive and non-stop fertilization and runoff from farms and urban areas, are accelerated by increased water temperatures. These HABs include hypoxia, dead zones, and red tide due to excessive nitrogen and phosphorus. We have also changed our landscapes by draining wetlands that could help with nutrient retention and carbon sequestration. The world has lost 87% of its wetlands, with half of that loss occurring in the 20th century alone. A sizeable increase in the wetland resources around the world is needed, especially for the strategic purpose of mitigating excess nutrients in regions with harmful algal blooms. Examples include: 1. minimizing phosphorus inflows to the oligotrophic Florida Everglades with 40,000 ha of new treatment wetlands added to an existing 24,000 ha of treatment wetlands, and 2. reducing nutrient inflows to Lake Erie in the Laurentian Great Lakes by restoring 40,000 ha, or 10 %, of the completely drained Great Black Swamp. A nutrient recycling approach applicable to landscapes around the world called "wetlaculture" (wetlands + agriculture) could help solve downstream nutrient pollution problems while decreasing the amount of fertilizers added to landscapes. We have established field *physical models*, two in temperate Ohio and one in subtropical Florida, for estimating the amount of time needed for wetlands to accumulate nutrients before flipping the land to agriculture. In addition, our early *business model* suggests that farmers could make profits comparable to crop by receiving payment for ecosystem services (PES) coupled with public Environmental Impact Bonds sold to investors.

SPECIAL SESSION 1

CONSTRUCTED WETLANDS FOR TREATMENT OF AGRICULTURE DRAINAGE AND RUNOFF

Jan Vymazal

SURFACE FLOW CONSTRUCTED WETLAND REDUCES NONPOINT-SOURCE NITRATE POLLUTION UNDER HIGH LOAD EPISODIC EVENTS

Nicola Dal Ferro *[1],Carmelo Maucieri[1], Carlo Camarotto[1] and Maurizio Borin[1]*
[1]Department of Agronomy, Food, Natural resources, Animals and Environment, University of Padova, Italy

In the agroecosystems, surface flow constructed wetlands (SFCW) are cost-effective nature-based solutions that reduce nonpoint-source nutrients pollution. Nowadays researchers and professionals has gained expertise on SFCW management in steady state conditions of nutrient loads and water flow. In contrast, event-driven treatment performances are still poorly understood due to strong site-specific dependence on internal water movement and its interaction with vegetation and microbial activity.
This study aimed to monitor nitrate (NO_3–N) dynamics in a SFCW where episodic event-driven nitrate loads due to intensive rainfall and leaching were simulated, and to evaluate the SFCW treatment performance.
The experiment was set up in a 365-ha wide farm (Tenuta Civrana) in the low-lying Venetian plain (northeastern Italy) which is characterized by a shallow water table. A SFCW, composed of five basins, was constructed in 2014 in a swampy area of the farm to treat agricultural runoff and drainage. After basins excavation, a gradual revegetation was improved with rhizome burial and plantation of clumps with some developed autochthonous plants, mainly *Phragmites australis* Cav. (Trin.), *Typha latifolia* (L.) and *Carex* spp. A basin called "B4", 60 m long × 30 m wide and with a constant water depth of 0.6±0.1 m (apart for an emerged area of 80 m^2 in the center that splits the water flow), was used for load tests in three consecutive years (2016, 2017 and 2018) with event-driven water pumping at hydraulic loadings rates of 150-1200 mm d^{-1}, depending on the experimental test, and NO_3-N concentration (solution of $Ca(NO_3)_2$, N = 15%) in the range of 40-60 mg/L. Continuous monitoring of NO_3–N and electrochemical parameters (T, EC, pH etc.) was done up to 30 sampling points across B4 to evaluate internal water movement and N reduction dynamics.
Results showed that water movement was affected by basin morphology and vegetation, in turn modifying locally both hydraulic and NO_3-N residence time. However, the SFCW was able to reduce nitrate concentration of outlet water, suggesting its buffering capacity also in the case of episodic events of high nutrients load.

BIO: Dr. Dal Ferro research activity focuses on soil and water management in the agroecosystems which aim at sustainable agriculture, with particular emphasis on nutrient cycling and carbon dynamics.

Contact Information: Nicola Dal Ferro, Department of Agronomy, Food, Natural resources, Animals and Environment, University of Padova, Italy, Viale dell'Università 16, 35020 Legnaro (PD), Italy, Phone: 0039 (0)49 827 2818, Email: nicola.dalferro@unipd.it

WETLAND MITIGATION OF PESTICIDES IN INTENSIVELY CULTIVATED WATERSHEDS OF THE SOUTHEASTERN UNITED STATES: PAST SUCCESS AND FUTURE POSSIBILITIES

Matthew T. Moore[1] *and Martin A. Locke*[1]
[1]United States Department of Agriculture, Agricultural Research Service, National Sedimentation Laboratory, Oxford, MS USA

With a growing global population, changes in climate patterns, and limited production acreage, agriculture faces significant challenges in providing sufficient food and fiber for the world. To help offset some of these challenges, farmers rely on pesticides to reduce weed and insect pressures affecting crops. Even judicial use of pesticides may still result in non-point source runoff when significant precipitation events occur during the growing season. To help counteract negative effects of pesticide runoff, various management practices such as constructed wetlands are used at the edge-of-field setting.

Beasley Lake (Sunflower County, Mississippi, USA) is a 25 ha oxbow lake surrounded by 850 ha of intensively cultivated farmland in the Mississippi Delta, USA. To help reduce water quality impairments to Beasley Lake, a constructed wetland system comprised of a sediment retention pond and two individual wetland cells was established adjacent to the lake. Simulated storm runoff events containing pesticides were applied to the wetland system to determine mitigation efficiency of the organophosphate insecticide diazinon, in addition to two pyrethroid insecticides, lambda-cyhalothrin and cyfluthrin. Water, sediment, and plant samples were collected for 55 days to measure fate and transport of pesticides within the wetland system.

Approximately 43% of the measured diazinon mass (during the 55 day experiment) was associated with plant material, while lambda-cyhalothrin and cyfluthrin plant material associated masses were 49% and 75%, respectively. Measured pesticide masses in sediment were 23%, 47%, and 7% for diazinon, lambda-cyhalothrin, and cyfluthrin, respectively. Of the measured diazinon mass, 34% was associated in water, while 6% and 18% of lambda-cyhalothrin and cyfluthrin masses were found in the water column. Using basic regression analyses on maximum observed pesticide water concentration data at individual sampling locations, wetland lengths of 306 m, 217 m, and 210 m would be needed to decrease diazinon, lambda-cyhalothrin, and cyfluthrin concentrations to acceptable levels for aquatic ecosystems, based on conservative toxicity endpoints and available USEPA aquatic life criteria.

BIO: Dr. Moore is a research ecologist and lead scientist in the Water Quality and Ecology Research Unit of the USDA Agricultural Research Service's National Sedimentation Laboratory, with over 20 years of experience in fate and transport of pesticides and nutrients in constructed wetlands and agricultural drainage ditches.

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CONSTRUCTED WETLANDS FILLED WITH A MIXTURE OF GRAVEL AND WOODCHIPS FOR TILE DRAINAGE TREATMENT

Jan Vymazal[1]*, Petr Fučík*[2]*, Tereza Hnátková*[3]*, Michal Šereš*[3]*, Adam Sochacki*[1] *and Zhongbing Chen*[1]
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In 2018, three constructed wetlands were built at the discharge of a tile drainage at Velký Rybník, about 130 km southeast of Prague. This site was selected as it had already been monitored for ten years and during this period, the drainage flow never stopped. The surface area of each wetland is 90 m^2. Two wetlands (nos. 1 and 2) were filled with a mixture of gravel (4-8 mm) and birch woodchips with 10:1 volume ratio, the third wetland (no. 3) was filled with gravel (4-8 mm) and topped with 20 cm of birch woodchips. All wetlands are run as subsurface horizontal flow units but in the first wetland the water level is about 15 cm above the surface. Birch woodchips were selected as they leached out the lowest amount of organics out of seven various tree woodchips. All wetlands were planted with parallel bands of *Phalaris arundinacea* (reed canarygrass) and *Glyceria maxina* (sweet mannagrass) in a density of 6 plants /m^2. The inflow and outflows from all three wetlands are equipped with automatic samplers. The system has been monitored since the beginning of August 2018 and so far 33 samplings for nutrients and 5 samplings for pesticides have been carried out. Within pesticides, a total of 94 pesticides and their metabolites were monitored but only metabolites (oxanilic acid – OA, and ethanesulfonic acid – ESA) of several chloracetanilides (alachlor, acetochlor, metolachlor, metazachlor and dimethachlor) were detected. However, this is a very common situation in the Czech Republic.

The first results revealed a very steady inflow concentration of nitrate (53.4±2,0 mg/l) and variable removal efficiency of three wetlands. The mean removal for four months period was similar in the first (98.6%) and third (99.2%) wetlands while the second one achieved only 86.8%. The removal was very steady in the first and third wetland but in the second one, the removal decreased and amounted to only 70% during the last two months. On the other hand, the mean inflow TOC concentration of 3.7 mg/l increased to 57 mg/l, 12 mg/l and 55 mg/l in wetlands 1, 2 and 3, respectively. The outflow TOC concentrations are highly variable but tend to decrease over time of operation. Despite the fact that alachlor and acetochlor were banned in EU in 2007 and 2013, respectively, the ESA metabolite of both pesticides was still detected. The removal of these compounds was low (19-30%) and comparable in wetlands 1 and 3, while wetland 3 exhibited nearly zero removal. Metolachlor ESA and OA were removed best in wetland 1 (63% and 8%) followed by wetland 3 (51% and 23%) while wetland 3 exhibited no removal. Metazachlor ESA was found at the highest inflow concentration (1188 ng/l) and was removed by 36%, 11% and 0% in wetlands 1, 3 and 2, respectively. Similar removal efficiencies were found for Metazachlor OA but mean inflow concentration was much lower (41.4 ng/l). Dimethachlor was removed on average by 23% in wetland 1 while wetlands 2 and 3 were inefficient.

So far, the configuration of wetland 1 seems to provide best results but two more years of monitoring will give us better idea about the best treatment option.

BIO: Prof. Vymazal is a head of Department of Applied Ecology at CULS. He has been working with constructed wetlands since the late 1980s focusing on removal of organics including micropollutants, nutrients, heavy metals and compartmentalization of these pollutants in the plants.

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ESTIMATING ATTENUATION OF AGRICULTURAL NITROGEN LOADS BY A HEADWATER WETLAND RECEIVING SUBSTANTIAL GROUNDWATER INFLOWS

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Headwaters commonly generate a substantial proportion of diffuse contaminant loads from agricultural catchments. Wetlands are one of the key edge-of-field options available for managing diffuse pollution from agricultural land-use. We assessed the nitrogen removal performance of a small natural headwater wetland in a pastoral agricultural catchment in Waikato, New Zealand over two-year period (2011–2013). The ~0.15 ha wetland occupies 2.8% of its surface catchment and is enclosed in a ~1.9 ha paddock rotationally grazed by dairy cows. Flow and water quality samples were collected at the top and bottom of the wetland, and in piezometers installed at strategic points inside and outside the wetland. This information was incorporated into a simple 5 tanks-in-series dynamic model operating on an hourly time step to estimate wetland nitrogen inputs and removal performance. Measurements of inflow, outflow, rainfall, and Penman evapotranspiration estimates were used to calculate a dynamic water balance for the wetland. N concentrations measured at the inflow, outflow and within piezometers were used as input data for the model. A dynamic nitrate-N mass balance was calculated by coupling influent concentrations to the dynamic water balance and applying a first order areal removal coefficient (k_{20}) adjusted to the ambient temperature. The model showed nitrate (NO_x-N) and organic (TON) forms dominated the N load entering the wetland (~50% and 45% of in-load, respectively). Despite large episodic inputs of highly contaminated surface run-off during heavy rainfall, shallow groundwater was the dominant source of flow and N load, accounting for over 90% of the nitrate and ammonium-N loads to the wetland and more than 40% of the organic-N loads. The concentrations of nitrate-N, dissolved inorganic nitrogen and Total-N were always lower at the outlet of the wetland regardless of flow conditions or seasonality, even during winter storms. The modelled water quality measurements showed high seasonal variability of pollutant loads with wetland N removal efficiency best during low flow, and poorest during high flow events and low temperatures. Overall, we estimate the wetlands attenuated headwater nitrate-N loads by ~70% and TN loads by ~40%.

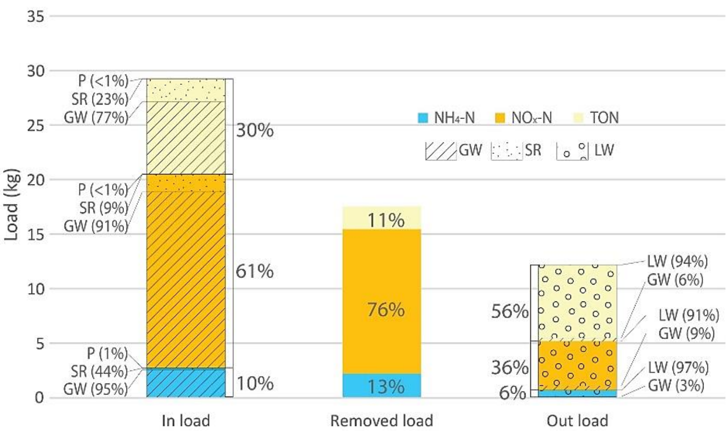

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Figure 1: Estimated proportion of TN components entering, leaving and removed by the headwater wetland. P precipitation; SR = surface runoff; GW groundwater; LW = Lower weir or wetland outlet

BIO: Dr Chris Tanner is a Principal Scientist at NIWA in New Zealand, and Director of the Te Waiora Joint Institute for Freshwater Management (with University of Waikato). He has over 35 years of research and consultancy experience on natural and constructed wetlands, and other ecotechnologies for treatment of point and diffuse source pollution.

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LONG TIME PERFORMANCE OF WOODCHIPS BASED SUBSURFACE FLOW CONSTRUCTED WETLANDS.

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Two subsurface flow constructed wetlands (CW) with horizontal flow and with a matrix consisting of willow woodchips and crushed mussel shells used for treating agricultural drainage water have been in operation since November 2012. During the first three years the CW's performed very well with an annual removal of total nitrogen (TN) amounting to 0.7 – 0.8 kg N m^{-2} $year^{-1}$ or 54-55 % of the load, which was around 1.5 kg N m^{-2} y^{-1}. In contrast to nitrogen, a high net release of phosphate-P (6-8 g PO_4-P m^{-2} $year^{-1}$) was seen in the first year of the monitoring period. Except for CW1 in 2013, both CW's retained total phosphorus (TP) in the range 1 – 16 g TP m^{-2} $year^{-1}$ during all the years and this was mainly due to retention of particulate P.

During the first two summer periods when the hydraulic loading was low the nitrate (NO_3-N) removal was 100 %, and the reduction sequence continued with sulfate reduction and formation of H_2S followed by methane production. Also, emission of nitrous oxide was occasionally high during summer. Thus in order to reduce the negative side effects it was decided to decrease water residence time during summer from approximately 80 hours to 10 hours by increasing the hydraulic load (i.e. four other CW's connected to the same drainage system were closed down). The aim of this step was to keep a higher redox potential mainly allowing nitrate reduction.

The results so far revealed that lowering the water residence time in summer decreased sulfate reduction to 1-2%, and lowered methane and nitrous oxide emissions considerably, but this was on the expense of TN and nitrate reduction, which decreased from 100 to around 30%. Although percentage TN and nitrate removal decreased the annual mass balances for nitrate and TN remained at the same level, exhibiting removal rates in the range 0.6 – 0.8 kg NO_3-N m^{-2} $year^{-1}$ and 0.7 – 0.9 kg TN m^{-2} $year^{-1}$, respectively.
During the first six years in operation, there has been a gradual change in the structure of the matrix. The grain size of the willow woodchips (8-60 mm) and mussel shells (2-4 mm) have changes to much smaller particle size, and the matrix in the two CW's have subsided with approximately 50 cm due to changes in porosity and consumption of carbon by the denitrifiers. In addition, concurrent laboratory tests with woodchips of different ages revealed that the nitrate removal capability of woodchips declined over the years. In May 2018, both CW's were refilled with 0.5 m willow woodchips on top of the old matrix layer.

BIO: Dr. Carl Christian Hoffmann is a senior scientist with more than 30 years of experience in wetland research and wetland restoration. At present CCH works with constructed wetlands/bioreactors treating agricultural drainage water.

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SPECIAL SESSION 2

PALUDICULTURE: CROP CULTIVATION ON REWETTED PEATLAND

Wendelin Wichtmann

CAN WE ENHANCE NUTRIENT REMOVAL IN WETLAND BUFFER ZONES BY BIOMASS HARVESTING? A COMPARISON OF RESTORED (DANISH) AND NAURAL (POLISH) SITES

Wiktor Kotowski[1], *Annette Baattrup-Pedersen*[2], *Marta Baumane*[2], *Carl Christian Hoffmann*[2], *Ewa Jabłońska*[1], *Craig Walton*[3] *and Dominik Zak*[2]

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For wetland buffer zones (WBZ) to effectively remove nutrients from through-flowing water, nutrient sink mechanisms (sedimentation, peat accumulation and plant uptake) should be complemented with nutrient export mechanisms. The latter incorporate biological processes, such as nitrification, denitrification and export through terrestrial food-chains, which can be supplemented by biomass harvesting and removal by man. However, while the effectiveness of microbial processes has been well documented and quantified from a number of localities throughout the world, the amount of nutrients that can be removed from wetland buffer zones by harvesting above-ground biomass is site-specific and may depend on a number of ecological and human-related factors, so a local calibration is needed to assess importance of plant uptake and harvesting in regional scenarios of WBZ development. Another important question is how much of the nutrients are built into more stable (structural) compounds, and what part may become easily leached from (dead) plant biomass in contact with groundwater. Finally, in the context of riparian restoration projects, it is interesting to compare effectiveness of nutrient capture by vegetation in restored and undisturbed (reference) wetlands. We address these questions by comparing productivity, nutrient concentrations and their solubility in vegetation of (1) relatively undisturbed riverine wetlands in the Narew catchment in Poland and (2) Danish riverine wetlands in the catchment of Odense A, which were restored 15-20 years ago after several decades of arable farming.

Aboveground biomass was cut from quadrats of 0,14 m2 localised in all typical vegetation types and distributed across the stream valleys. Around each sampling plot, vegetation composition was described in a 2x2 m quadrate. The harvested biomass was oven-dried, weighted and analysed for the total content of nitrogen (N), phosphorous (P) and carbon (C). Another subsamples were used for a nutrient leaching experiment, in which dried plant litter was cut in 5 cm pieces and incubated for 24h in dark bottles with a 0.02%-solution of NaCl placed on shaking tables in dark climatic chambers at 25°C. Afterwards the leaching solution was filtered and analysed for dissolved N, PO4-P and organic C. While biomass production and nutrient contents varied a lot depending on the ecological type of WBZ and plant community, there was surprisingly little difference between restored and undisturbed sites. However, the leaching experiment showed a much higher fraction of easily soluble nitrogen in vegetation samples from restored Danish sites as compared to undisturbed Polish sites. We attribute these differences mainly to (a) higher concentration of plant-available nitrogen in the intensively-fertilised Danish landscape and (b) different plant composition in restored (dominance of grasses) and undisturbed (dominance by sedges or reed) sites. We conclude, that biomass harvesting can be an important mechanism of nutrient removal in WBZ, but its effectiveness is significantly affected by dominant plant species.

BIO: W. Kotowski is a professor at the University of Warsaw, specializing in wetland ecology, vegetation science and fen restoration.

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THE IMPORTANCE OF WATER QUALITY IN SPHAGNUM FARMING ON REWETTED PEATLANDS

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Peat moss cultivation (Sphagnum farming) is paludiculture on rewetted degraded peatlands. Harvested *Sphagnum* biomass can be used as a renewable raw material for horticultural substrates, substituting fossil peat. Sphagnum farming allows the sustainable use of abandoned cut-over bogs and degraded bog grasslands, with benefits for climate change mitigation and biodiversity.

Sphagnum mosses require adequate water quantity, water quality and nutrient stoichiometry to proliferate. In this study, we investigate nutrient dynamics and *Sphagnum* performance in the peatland Hankhauser Moor (NW-Germany). The site was developed on a former bog grassland in 2011 (4 ha) and expanded in 2016 (additional 10 ha). It comprises *Sphagnum* production fields surrounded by narrow ditches and bunds used as causeways. To convert the bog grassland into a *Sphagnum* farm, the sod was removed and *Sphagnum* fragments were spread on the peat surface. The site has been rewetted and the water table is regulated with an automatic irrigation system connected to an adjacent stream.

Our results show that these ditches successfully irrigate the *Sphagnum* lawn over the entire production field of 10 m width, and thus directly affect biomass production via water quantity and quality. *Sphagnum* covers the lawn homogeneously throughout the fields and is able to alter the pH of its environment regardless of slightly alkaline ditch water. The infiltrating irrigation water is a substantial source of potassium and in particular of phosphorous. While large amounts of nitrogen are supplied by atmospheric deposition (ca. 22 kg N ha^{-1} a^{-1}), mainly from agricultural surroundings, its concentration is low in pore water in the lawns and in the ditch water. An ammonium legacy persists in deeper peat layers of the 2016 site, but concentrations have lowered substantially within a year. Despite high N deposition we observed a high *Sphagnum* biomass productivity probably as a result of a balanced nutrient stoichiometry.

Our study over six years shows that successful Sphagnum farming can be persistently accomplished on former agricultural peatlands using a surface water-fed irrigation system under nutrient-rich conditions.

BIO: Ms. Vroom is a PhD student focusing on nutrient and greenhouse gas dynamics in rewetted peatlands. In field and laboratory studies, she investigates the effect of different potential paludiculture crops on peatland functioning and underlying processes, in order to aid effective management and decision-making for the preservation of peatlands globally.

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EXPERIENCES FROM PALUDICULTURE DEMONSTRATION SITES AND EXPERIMENTS IN THE NETHERLANDS: WHICH FACTORS INFLUENCE C FIXATION AND CH4 EMISSION?

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[3]University of Jinan, Jinan, China

Paludiculture is sustainable and climate-friendly biomass production on rewetted peat soils. This innovative agricultural approach can provide significant yields and simultaneously restore several important ecosystem functions. These include peat preservation, CO2 reduction, water retention, water purification, and biodiversity. In the Netherlands, a lot of work has been done with regard to rewetting for climate adaptation and nature development, but also with regard to harvesting of biomass under wet conditions.

In several pilot sites and experiments different paludiculture crops are currently investigated: cattail, reed, peat moss and willow. These pilot projects were or will be started in co-operation with provinces, water authorities, land users, and nature management organizations. Regional economic collaborations between farmers and companies are developing.

The main objective of our research is to extend the scientific base for paludiculture by identifying the optimal (a)biotic conditions for paludiculture crops and by quantifying the different ecosystem services in different experimental settings in the greenhouse and in the field. We will present some results about the factors that influence C fixation in biomass and CH4 emissions from paludiculture sites, such as water level management, top soil removal, nutrient and carbon input, specific plant characteristics, and harvest, including the life cycle of the specific biomass application. We will conclude with management options to lower CH4 emissions and increase C fixation in paludiculture.

BIO: Dr. Geurts is a post-doc researcher with 20 years of experience in biogeochemistry, water quality improvement, wetland restoration, paludiculture, and greenhouse gas emissions.

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PEATLAND RESTORATION BY PALUDICULTURE IN DEGRADED PEATLANDS IN INDONESIA: GHG EMISSIONS AND ECONOMIC PERSPECTIVES

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Two-third of the total of 15 million ha (Mha) Indonesian peatland have been affected by drainage and used either for large scale oil palm (*Elaeis guineensis*) and *Acacia crassicarpa* plantations and small-scale annual and perennial crop agriculture, or covered by shrub and remain unused following forest concession. Both land cover types (agricultural and shrub) are the sources of greenhouse gases (GHG), especially CO_2 emission, and are prone to peat fire during long dry season. To avoid peat fires and to reduce GHG emissions, the Indonesian Government is targeting to restore 2.5 Mha peatland by 2020 for which paludiculture is one of the approaches believed to solve the environmental problems, where drained peatland is restored by building up canal blockings to raise water tables.

Tree species selection for paludiculture varies among sites in Indonesia, depending on various factors, such as peat typology and available market. Species such as *Dyera polyphylla* and *Metroxylon sago* are adaptable for non-drained system on peat, and aquaculture is also a promising system. These species are suitable for small-scale systems, since, unlike oil palm and *Acacia*, the market scale is expected to be easily saturated if the mass production takes place. Land use right from the government, and subsidies such as from the Green Climate Fund will be necessary for initial investment. The abandoned shrub peatland is likely the main area where these systems could be implemented. Abandoned shrub peatland is usually dominated by ferns (*Stenochlaena palustris*) and *Melastoma malabathricum*. In the meantime conventional agriculture will likely continue and the best approach for minimizing GHG emission and peat fire risks in these areas is by rising water tables to the level that will not negatively affect crop production.

Keywords: Aquaculture, Oil palm, Acacia, GHG Emissions, shrub

BIO: Dr. Tata is a senior researcher with more than 20 years of research experience in tropical lowland ecosystem and has been working on peatland research since 10 years ago, particularly on ecology, peatland restoration and local community engagement.

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PHOTOSYNTHETIC AND PRODUCTIVITY RESPONSES HIGHLIGHT THE SUITABILITY OF *TYPHA* SPP AS PALUDICROPS

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By reflooding peatlands that have been drained for agriculture, paludiculture aims to halt and reverse peat oxidation, add carbon to soils, and remove excess nutrients previously applied during fertilization. For successful paludiculture in heavily fertilized landscapes, it is important to use plant species that respond strongly to nutrients, and accumulate nutrients effectively in the above-ground biomass that will be harvested.

Although European paludiculture research and practice has previously focused primarily on common reed (*Phragmites australis*), due largely to its use in thatching, *Typha* spp. are emerging as particularly beneficial crop species. As part of our contribution to the ERA-net Plus project CINDERELLA*, we have compared photosynthetic carbon acquisition and productivity of several candidate paludicrops. We have compared their photosynthesis-leaf nitrogen responses to establish preferences over the range of nutrient availability found in drained agricultural peat. For maximum nutrient removal, *Typha* species have superior responses to N, with a photosynthesis-N slope of 10.4 $\mu molCO_2\ g^{-1}N\ s^{-1}$ in *Typha latifolia,* vs. 6.5 $\mu molCO_2\ g^{-1}N\ s^{-1}$ in the standard bioenergy crop *Arundo donax*. The suitability of *Typha* spp. for eutrophicated agricultural peatland extends to other *Typha* spp. such as the Australasian *Typha orientalis*, with an even higher photosynthesis-N slope of 12.1 $\mu molCO_2\ g^{-1}N\ s^{-1}$. *Typha* also accumulates much higher concentrations of N and P in aboveground biomass (> 50 mgN g^{-1} dry wt. leaf tissue and > 2 mgN g^{-1}dry wt. leaf tissue) than other candidate paludicrops. When combined with the high productivity of these species, these data demonstrate much greater potential nutrient removal during harvesting for *Typha* spp. than alternative paludicrops.

Our experiments have revealed several other benefits of *Typha* biomass. For example, *Typha* leaves have lower S, higher Ca content, and higher Ca:K ratios than other wetland plants tested, making *Typha* more suitable as a biofuel as these elemental properties assist in reducing ash and slagging. *Typha* was also able to maintain a consistent above-ground:below-ground ratio across a wide range of nutrient availability, suggesting that it has benefits for adding carbon to soils and maintaining production in later seasons, as well providing high above-ground yield for biocrop purposes. Overall, our research supports the increasing interest in *Typha* as a wetland crop, and the economic as well as ecological benefits of its application in wetland restoration.

***Funding:** European Union ERA-NET Plus on Climate Smart Agriculture project CINDERELLA (Comparative analysis, INtegration anD ExemplaRy implEmentation of cLimate smart LAnd use practices on organic soils: Progressing paludiculture after centuries of peatland destruction and neglect).

BIO: Dr. Sorrell is an Associate Professor with more than 30 years' research and management experience in wetland ecology, conservation and restoration. His research has focused on photosynthesis, ecophysiology and productivity in wetlands, with more than 100 papers in peer-reviewed journals.

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SPECIAL SESSION 3

MULTIFUNCTIONAL WETLAND BUFFERS: ASSESING SYNERGIES AND CONSTRAINS BETWEEN DIFFERENT ECOSYSTEMS

Wiktor Kotowski

ECOLOGICAL TYPES OF WETLAND BUFFER ZONES – HOW LANDSCAPE DEFINES FUNCTIONALITY

***Ewa Jabłońska**[1], Wiktor Kotowski[1] and Mateusz Grygoruk[2]*
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River ecosystems, along with riparian landscapes, are essential for maintaining and regulating natural cycles of water and nutrients between terrestrial and aquatic ecosystems. The key role is played in this respect by riverine wetlands, which can be regarded as hubs of biodiversity and ecosystem services. Yet, due to the large-scale modification of European rivers and wetlands and intensification of agricultural productions, these functions are seriously impaired. CLEARANCE project stresses the necessity of their protection and restoration, indicating wetland buffer zones (WBZ) as the solution.

Although WBZs are commonly formed as strips of land adjacent to rivers, other shapes and locations can sometimes be more operational. These include specific groundwater discharge zones (e.g. fens) and floodplains. Moreover, when considering the role of in-stream nutrient removal processes, also whole section of a water stream can be regarded as a WBZ in reference to the lower reaches of the river or higher-order rivers. The role of WBZ in purifying water is strongly linked to eco-hydrological conditions and vary over time. In addition, the role of WBZ for nutrient removal by harvesting (and further recycling) will depend on the potential to promote high productivity and good access for agricultural machinery.

CLEARANCE takes an operational approach to WBZ that stems from geomorphology, hydrology and landscape functioning. Spatial delineation of WBZs and the level of intervention necessary to optimise their ecosystem services depends on local natural conditions, specific nutrient loads and socio-economic constraints and opportunities. CLEARANCE proposes a hierarchical approach to WBZ classification, where the first level distinguishes between (i) WBZs as linear structures (i.e. section of the water course with its banks/shores) and (ii) WBZs as polygons (wide part of the water course valley). In practice, both types should preferably be combined to optimise nutrient removal and other functions of WBZs. However, the effectiveness of these two categories may vary a lot depending on regional physical circumstances (e.g. organic vs. mineral soils). Within each of these categories, CLEARANCE distinguishes sub-categories that differ with respect to physical constraints on possible WBZ introduction under different landscape circumstances. The considered WBZ types are: wetland banks/shores, two stage channel, meandering channel, undrained fen, rewetted fen, floodplain with organic soil, floodplain with mineral soil, oxbow.

Additionally, we discuss some aspects of social landscape's impact on establishment and maintenance of WBZs, pointing at the role of already performed and planned large-scale hydro-technical projects in rivers.

BIO: Dr. Jabłońska is a scientist with more than 10 years of experience in mire ecology, vegetation ecology and nature conservation of wetlands.

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CONTRARY RESULTS OF PHOSPHORUS, NITROGEN AND CARBON RETENTION - A TRANSIENT SIDE EFFECT IN REWETTED PEATLANDS

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Over the last 30 years, rewetting has occurred on several million hectares of peatland in Europe, Asia and other parts of the world. Rewetting was proposed as a valid strategy to restore the unique biodiversity of peatlands. In recent years, the focus has increasingly been on the re-creation of carbon and nutrient sink functions, in order to decrease the climate impact and mitigate the eutrophication of water bodies respectively. However, as a result of historical land use and soil subsidence, there is a tendency for eutrophic shallow lakes to form after rewetting (water depth mostly < 1m), potentially elevating nutrient mobilization and greenhouse gas emissions, plus hindering the development of target vegetation. Over the last decades, comprehensive laboratory and field research has improved the understanding of the processes controlling the formation of these “novel ecosystems” and the development and change of these physico-chemical processes over time can effect restoration targets and goals. For example, nitrogen removal can be very successful in the short-term, however this paper suggests that extended rewetting periods up to several decades may be necessary in severely degraded fens before other ecological functions and ecosystem services are fully restored. It is expected that observed phosphorus, dissolved organic matter and greenhouse gas pulses to the external environment could still continue for decades after initial rewetting. In this light, soil analysis and other investigations prior to rewetting can afford insight into matter fluxes, vegetation development or microbial changes that may occur throughout restoration. An improved knowledge and understanding of the process of matter turnover, both under differing environmental settings and temporally, allows for a better assessment of different ecological and societal consequences of rewetting severely degraded peatlands.

BIO: Dr. Zak has over 15 years’ experience in freshwater and wetland-related environmental research, land use change, conservation, restoration and worked on several freshwater-related projects. His work is dedicated to interdisciplinary research integrating biology, ecology, microbiology and biogeochemistry across aquatic and terrestrial systems.

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WET AGRICULTURE IN WETLAND BUFFER ZONES: SYNERGIES AND CONSTRAINTS BETWEEN NUTRIENT REMOVAL AND BIOMASS UTILIZATION

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Natural wetlands play a key role in nutrient retention. As “kidneys of the landscape”, they are able to reduce eutrophication in adjacent water bodies. Due to intensive drainage for agriculture and forestry a large number of wetlands have been destructed in Europe – by this we are facing a dramatic reduction of water quality and eutrophication in rivers and seas. Implementing water buffer zones along rivers are a common practice in Denmark to recreate river systems, but not yet in other European Countries. In the Clearance project, we aim to combine the beneficial functions of water buffer zones, e.g. nutrient retention, water storage and flood protection, with the cultivation of wetland plants in a wet agriculture approach. This means that farmers can continue with biomass production on these areas after rewetting and create added value. The concept has already been developed for organic soils - Paludiculture, with a wide range of possible use options, that can also partly be transferred to mineral soils. The main aim of Paludiculture is to reduce greenhouse gas emissions from drained peatlands, which contribute approximately 5% to the global anthropogenic GHG emissions.

Importantly, we highlight the substantial synergies that exist between the functions of nutrient capture and plant biomass utilisation. Suitable plant species are flood tolerant, productive wetland species like Common Reed, Sedges, Cattail, Reed Canary Grass as well as wet meadow communities. In the current study we analysed their nutrient removal potential by biomass harvesting. It is influenced by the date of harvest, that also effects biomass characteristics that are required for specific use options, e.g. energetic or material utilization. Therefore, we reviewed research results about biomass characteristics of wetland plant species in terms of solid biofuel, biogas, bio-refinery, construction material and raw material for other products. The study shows that summer and autumn harvest systems are more preferable for water buffer zone management, because of higher nutrient removal rates. Promising utilization options for this systems are biogas, solid biofuels, fodder, as well as bio-refinery.

Sustainable biomass from wetland buffer zones has a great potential for various utilizations in a bio-based economy approach and contributes to the local supply of resources and therewith to regional added value. But large scale implementation of wet agriculture needs still further research e.g. on long-term perspectives of cultivation methods, harvest concepts and subsequent processing of biomass.

BIO: Claudia Oehmke (Landscape Ecologist) has been working on Paludiculture since 2010 at the Institute of Botany (University of Greifswald). In the CLEARANCE project (2017-2020) she focuses on management and biomass quality of productive wetland plant species for energetic and material use. Claudia is an active member of the Greifswald Mire Centre.

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DO PEOPLE PREFER DITCHES OVER BROOKS AND CREEKS? AN EVIDENCE FROM DCE VALUATION EXERCISE OF SMALL RIVERS APPEARANCE AND ECOSYSTEM SERVICES

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The overwhelming majority of small rivers in the rural landscapes of lowland Europe have been transformed to some extent. Due to the straight shape, some people do not recognise them as rivers anymore but instead regard them as drainage canals and ditches. Thus, there are about 100 thousand km of such rivers in Poland only. Besides the very matter of aesthetics, such characteristics of small rivers as degree of their tortuosity and type of riverine vegetation are known to affect important ecosystem services, e.g. water quality for people's domestic and recreational use, supporting wildlife refuge and migration corridors for biota, or nutrients cycling. Some of those ecosystem services are potentially noticeable on the local and regional levels, whereas the others apply on the national and international levels, like the water quality in the Baltic and North Seas being dependent on the nutrient cycling in their basins. Therefore, restoring natural features of small rivers like their meandering and adjacent wetland buffer zones is often contemplated by natural scientists as a tool for improved provision of various ecosystem services. However, the question whether those recommendations are consistent with people's preferences and supported by people's Willingness-To-Pay (WTP) is far from trivial and requires empirical testing.

With this purpose we conducted a Discrete Choice Experiment (DCE) aimed at learning preferences of representative samples of the Polish, German and Danish adult citizens residing in lowland parts of their countries towards the principle characteristics of the small rivers. With this purpose, the questionnaire has been designed, explaining the basic facts and regularities of small-rivers management and their likely outcomes for certain ecosystem services both locally and nationally, followed by the DCE valuation exercise itself. The respondents were asked to choose between the status quo option or either of two programme alternatives, decomposed into the attributes of both global importance (degree of eutrophication of the Baltic or North Sea, and overall water purity of the country's small rivers) and local importance (riverbed shape and riverine vegetation type of the small river being the closest to the respondent's place of residence), plus programme costs.

The questionnaire was administered to (1) representative national samples of Poland, Germany and Denmark lowland parts' adult population, and (2) additional subsamples of adult rural population residing in the case-catchments of the rivers Narew in Poland, Ryck in Germany, and Odense in Denmark. The data subsequently underwent econometric analysis following the Random Utility Modelling (RUM) methodology, which allowed us to estimate people's WTP for small rivers management and provided some insights into how people shape their preferences towards the small rivers' appearance and related ecosystem services.

BIO: Dr. Marek Giergiczny is an adjunct and senior researcher at the Faculty of Economic Sciences of the University of Warsaw. His scientific interests embrace environmental and resource economics, economic aspects of biodiversity conservation as well as non-market valuation methodology.

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SUMMARISING AND UPSCALING DIFFERENT BENEFITS AND COSTS OF WETLAND BUFFER ZONES ON THE CATCHMENT SCALE

***Marta Wiśniewska*[1]** *and Ewa Jabłońska*[1]
[1]University of Warsaw, Poland

Wetland buffer zones (WBZs), as areas between agricultural land and a water body, support wetland ecosystems and protect surface water from non-point source pollution, in addition providing other ecosystem services. "CircuLar Economy Approach to River pollution by Agricultural Nutrients with use of Carbon-storing Ecosystems" project (CLEARANCE) addresses the global environmental challenges - limited access to good quality water coupled with climate change, resulting in profound adverse social and economic effects. It seeks wetland solutions for clean water provision and restoration of vanishing riverine nature.

We propose ecological types of WBZs along water courses in selected case catchments in Poland (five tributaries of Narew river), Germany (Ryck river) and Denmark (Odense river), spatially delineate the WBZs and analyse benefits and costs of their potential implementation.

Assessments of benefits accompanying WBZs development is conducted for several scenarios of WBZ development differing with scale of their application. Such an approach allows to evaluate benefits of synergistic functions of WBZs, in terms of economic gains and reduction of pollutants (circular economy & resource efficiency perspective). CLEARANCE focuses mainly on benefits coming from nutrient capture potential (which effectiveness differs depending on WBZ type) and wet agriculture. The project copes with valuation of other ecosystem services i.e. reducing the risk of floods and droughts, sustaining and increasing biodiversity, regulation of local climate and mitigation of the global climate change.

For selected scenarios, costs of WBZs development are also calculated. Each type of WBZ is linked to intervention elements needed for its establishment e.g. excavations, land purchase, etc. For each element, total costs are estimated based on standardized cost per unit length or area, actual size of the feature and type of WBZ. These costs are then summarized for all WBZs in a sub-catchment, including intervention phase and maintenance phase. We present this approach using: 1) benefits versus costs for different scenarios of WBZs development in CLEARANCE case catchments, 2) upscaled project results for the whole catchment of Lower Narew (Poland).

BIO: Dr. Wiśniewska is an environmental engineer, experienced in water management. In CLEARANCE project, she is responsible for cost calculation, valuating benefits coming from wetland ecosystem services and upscaling project results.

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SPECIAL SESSION 4

SWS SYMPOSIUM ON WETLANDS AND ECOSYSTEMS SERVICES: WATER QUALITY IMPROVEMENT, CLIMATE REGULATION AND FLOOD CONTROL

Jos Verhoeven

A NEW METHOD TO QUANTIFY THE IMPACT SUB-SURFACE DRAINAGE IN WETLANDS

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Wetlands are known by their specific biodiversity and their ecosystem services such as the contribution in flood control, groundwater recharge and wastewater treatment. During the last decades, numbers of natural wetlands have been drained and most of them converted into agricultural areas. The agricultural drainage in wetlands modify the hydrological behavior, the exosystemic services and ecological functions. The French water law, in application of the European water framework directive aims at protecting the natural wetlands and proposes policies to regulate the implementation of agricultural drainage systems in wetlands. The policy is based on thresholds of wetland impacted area by the implementation of the drainage system.

The aim of this study is to develop a new method for assessing the real extension of a drainage system in wetlands. To reach this objective, we assume that the relatively complex transitory phenomena of water table fluctuations can be simplified to an equivalent steady state representation. The main parameters of this equivalent regime are the groundwater recharge, the most frequent water table depth and the amplitude of water table fluctuations. The amplitude of the water table fluctuations is determined from the cumulative frequency curve of the water table depth. It represent the difference between the presence rate of 20% and 80%. These parameters are defined based on groundwater measurement in 170 piezometers installed in different wetland types in France. In the first step, a frequency analyses and PCA analysis have been applied to define the functional relationships between the different types of wetlands and the indicators of water table fluctuations. This analysis showed that the amplitude of water table fluctuations allow a functional classification of wetland depending on the type of groundwater table supplying the wetland. In the second step, a numerical simulations using HYDRUS-2D model used to determine the representative water table depth in the steady state equivalent behavior. The simulation results, in the steady state regime, showed that the mean precipitation in winter period could represent an annual presence rate of water table between 20 to 30%.

BIO: Dr. Henine has been a researcher with Irstea since 2011. The main researcher activities at Irstea are mainly base on field experiments and modeling. He assesses the impact of agricultural activities on subsurface flow and pollutant transfer processes, and on the natural wetlands.

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OUTLINE OF A GLOBAL MODEL FOR WETLANDS ECOSYSTEM SERVICES

Jan H. Janse[1]*, Jeroen J.M. de Klein*[2]*, Anne A. van Dam*[3]*, Edwin M.A. Hes*[3] *and Jos T.A. Verhoeven*[4]

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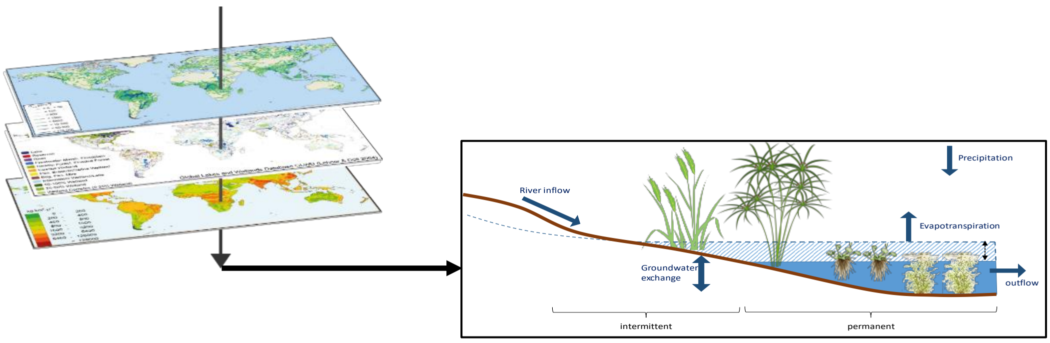
[3]IHE Institute for Water Education, Delft, and Deltares, Delft, The Netherlands

[4]Utrecht University, Utrecht, The Netherlands

Natural wetlands play an important role in the provision of key ecosystem services like the provision of clean water to the world, adaptation to climate change, and support for biodiversity; although they are in some cases also associated with adverse climate effects. Despite their value, wetlands are disappearing at an alarming rate, and the remaining wetlands are threatened by hydrological changes, eutrophication, pollution and climate change. Policy makers at the global level need to know to what extent, on the global scale, these ecosystem services are impaired, how this links to global land-use and climate change, and how wetlands functioning can be improved to optimize these services. A global model of wetland functioning could sustain this decision making. Wetlands are, however, currently grossly under-represented in global environmental models.

Here we present the outlines of a generic model describing the effects of climate and land-use changes on the functioning of freshwater wetlands world-wide, expressed in terms of area and water resources, biomass production, carbon emissions, water quality and threats to biodiversity. Core variables are water level, nutrients, carbon and vegetation. The main processes linking these are described in a generic way, building on existing elements, accounting for climate zones and main wetland types (rain-/groundwater fed and floodplain wetlands) as minimally necessary for a global picture. The model is embedded in, and receives input from, existing global hydrological, climate and land-use models. In this way it may project the impacts of climate change, land-use changes and water use on wetlands functioning, and the contribution of wetlands to important ecosystem services. The model has been preliminarily tested with typical input from various climate regions and is now apt for parameterization and validation with datasets from varying types of wetlands, for which we seek cooperation with colleagues from different parts of the world.



Ref.: Janse, J.H., van Dam, A.A., Hes, E.M.A., de Klein, J.J.M., Finlayson, C.M., Janssen, A.B.G., van Wijk, D., Mooij, W.M., Verhoeven, J.T.A., 2019. Towards a global model for wetlands ecosystem services. Current Opinion in Environmental Sustainability 36, 11-19.

BIO: Dr. Janse is a senior aquatic ecologist at PBL and guest scientist at the Neth. Inst. of Ecology in Wageningen, with extensive experience in ecological modelling of standing waters (e.g. *PCLake*) and now working on global biodiversity modelling in integrated assessment projects.

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RESTORATION OF SPECIES-RICH FEN LANDSCAPES IN THE NETHERLANDS

Jos T.A. Verhoeven[1]
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In fen landscapes, the assemblages of plant communities associated with the succession from open water to terrestrialized fen have become increasingly rare, because many peatland areas have been modified strongly and lost their natural dynamics. On the other hand, peat dredging in the fen meadow areas in the Western Netherlands, starting in the 18th century, has resulted in landscapes with rectilinear, narrow and shallow fen ponds. These fen pond complexes in so-called 'turbaries' now show a remarkable botanical richness with plant communities characteristic for the succession from open water to fen carr forest.

However, even these ponds have terrestrialized and since several decades, there is a risk of losing biodiversity by losing successional stages. In addition, there are also risks which are related to some major environmental disturbances, such as poor water quality and atmospheric N and S deposition. Nature conservation agencies in The Netherlands have identified four major targets in the conservation and restoration of species-rich fen communities: (1) restore open-water habitats and ensure that the initial succession stages of submerged vegetation and floating-mat forming species become established again; (2) improve the water quality in the fen landscapes to avoid eutrophication and internal loading of phosphorus through sulfate reduction; (3) reduce or mitigate atmospheric N deposition to prevent rapid acidification and N enrichment and (4) strive for a more natural hydroperiod by allowing more water level fluctuations in fen landscapes. In the period 2007-2017, a consortium of government agencies, nature conservation organizations, water authorities and knowledge institutions has designed, executed and evaluated a collaborative restoration program under the umbrella of the national network for nature quality OBN (Kennisnetwerk Ontwikkeling en Beheer Natuurkwaliteit). The results achieved in this program have been reported recently.

The OBN program has further enhanced the knowledge needed for effective management of hydrology and local vegetation to achieve successful restoration and the conservation of the entire range of plant communities characteristic for the succession from open water to fen carr. The main new aspects of the approach have been (1) the consideration of regional hydrology at a large scale to ensure that water quality and quantity at the local scale in the reserves are matching the needs of the plant and animal communities; (2) a stronger focus on the effects of grazing of shore communities by geese and exotic herbivores (muskrat and American crayfish); (3) design of local measures to better cope with grazing effects and with early acidification of the species-rich mid and late succession communities; and (4) institutionalized contacts between water managers, nature managers and scientists to keep improving the situation in the future.

BIO: Dr. Verhoeven is Professor emeritus at Utrecht University and has 50 years of experience in Wetland ecology, restoration and management. He has participated in many national and international projects and has published 170+ peer-reviewed papers. He is a Board member of INTECOL and Past President of the SWS Europe Chapter.

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EFFECTS OF MULTIPLE ENVIRONMENTAL FACTORS ON THE PLANT-SOIL-MICROBE SYSTEM IN WET GRASSLANDS: A MESOCOSM STUDY

***Keith R. Edwards*[1]**, *Jiří Bárta*[1], *Eva Kaštovská*[1] *and Tomáš Picek*[1]
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An Electroactive Biofilm-based Constructed Wetland (EABB-CW) is a wastewater treatment system that relies on the presence of electroactive bacteria (EAB) to enhance the degradation of pollutants. Compared to other microbial electrochemical setups, EABB-CW is designed in short-circuit mode (dispensing of external circuits) and uses an electro-conductive substrate acting as a single-piece electrode. A major challenge of this type of system is to correlate the EAB metabolism with the electrical current generation and hence with the removal of pollutants. In environments with the presence of EAB, electric fields are created by anodic and cathodic reactions, therefore generating ionic/electron currents that can be quantified. That quantification can be done by measuring electric potentials (EP), with the aid of sensors insensible to redox active compounds, but able to collect low current signals in highly conductive matrixes.

As with any ecological system, wetlands are influenced by numerous factors that may change simultaneously and thus interact in affecting ecosystem processes and functions. Unfortunately, most past studies have focused on one factor at a time, although there is growing evidence that the effect of these multiple factors may not be additive. It is also known that plants affect soil microbial community structure as well as belowground processes. Since plant growth and development are affected by multiple environmental factors, changes to the factors should also influence belowground structure and functions. We studied the effect of soil type (mineral vs peat), and water and nutrient levels on the plant-soil-microbe system in wet grasslands, using a mesocosm approach. The study plant species, Carex acuta, was subjected to two possible water level treatments, either saturated, at which the water level was maintained at the soil surface , or drier conditions (water level maintained at 15 cm below the soil surface). In addition, nutrient treatments consisted of no added nutrients or the addition of 300 kg NPK * ha-1 * yr-1. Treatments were maintained for five years.

Plant growth and production were directly affected by nutrient additions while soil type and water levels more directly influenced soil microbial community composition and processes. Nutrient levels indirectly affected microbial community composition and its activities acting through the effects on plant root exudation and litter decomposition.
Overall, the presence of plants in our study organized belowground structure and activities. Therefore, changing conditions resulting from changed management regimes or climate change can cascade upwards to affect ecosystem functioning. Since the response of numerous parameters, including plant production and greenhouse gas emissions, were similar in the mesocosm as in our wet grassland field sites, the mesocosm results likely provide a good approximation of field conditions. Such studies can indicate how simultaneous changes in multiple factors can affect the ability of wet grasslands to provide important ecosystem services.

BIO: Keith Edwards is an associate professor at the University of South Bohemia. His main emphasis is on wetland ecosystem functioning, including wetland restoration, plant-soil interactions in wetlands and plant eco-physiology.

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WHERE HAVE ALL THE COWS GONE? THE PUBLIC PERCEPTION OF CREATING AND RESTORING COASTAL WETLANDS

Robert J. McInnes [1], *Hiromi Yamashita* [2], *Naoyuki Mikami* [3] *and Mark Everard* [4]

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Managed realignment, or managed retreat, is a widely practiced ecosystem-based approach to coastal flood risk management. Often driven by rising sea levels, habitat creation targets or the economics of maintaining flood management infrastructure, the removal and setting back of coastal defences is being actively implemented in Europe and beyond.

Whilst often championed by the conservation community and government agencies alike, the changes to the coastal landscape arising form managed realignment have the potential to impact on the very communities that live and work within these landscapes. Sometimes replacing verdant pastures populated by the benign ambling of lowing cows with mudflats fluttering with jittery flocks of wading birds may be seen as a negative. Understanding the local perceptions of changes in the management of coastal wetlands is essential in order to improve social uptake and design sustainable solutions that are inclusive and beneficial to all.

This presentation reports on a survey conducted in the summer of 2018 of the public perception of the UK's largest ever coastal realignment scheme covering some 250 hectares at the Steart Peninsula in Somerset, England. The survey identifies both negative and positive perceptions of the restoration of saltmarsh and mudflat habitats and how the local community perceives changes to their landscape some four years after the completion of the project. As part of a wider study, comparisons are drawn with similar surveys conducted at tidal flat restoration schemes in Japan and Malaysia. Key policy messages have been distilled which demonstrate the need for nuanced messaging and the essential need to understand the socio-cultural aspect of restoring coastal wetlands for flood risk management. The implications of these outcomes will also be considered in the light of wider wetland creation and restoration activities including for improving water quality and providing habitats for species of conservation concern.

BIO: Based in a wooden shed in rural Oxfordshire, UK, Rob McInnes is an independent wetland advisor. He works globally on a range of wetland-related issues ranging from supporting international Conventions, advising governments and NGOs, to assisting civil society with restoring degraded and undervalued wetlands.

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SPECIAL SESSION 5

RECENT ADVANCES IN THE DESIGN, APPLICATION AND OPERATIONS AND MAINTENANCE OF AERATED TREATMENT WETLANDS

Jaime Nivala

HYDRAULIC CHARACTERIZATION AND METALS REMOVAL IN AN AERATED HORIZONTAL SUBSURFACE FLOW "RACETRACK" WETLAND

Mohammad-Hosein Mozaffari [1], Ehsan Shafiepour [2], Seyed Ahmad Mirbagheri [2], Gholamreza Rakhshandehroo [1] and ***Scott Wallace [3]***

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[3] Naturally Wallace Consulting LLC, Stillwater, Minnesota, United States

Four pilot-scale horizontal subsurface flow (HSSF) wetland studies were conducted (with/without plants, and with/without aeration) at two different flow rates to evaluate the removal of metals, phenol, ammonia (NH_4-N), and nitrate (NO_3-N) from oil refinery wastewater. Tracer tests were conducted at two flow rates of 0.67 and 0.2 ml/s, where the resulting hydraulic parameters were a hydraulic residence time (HRT) of 1.37 and 3.16 days, respectively, and associated number of tanks-in-series (*N*TIS) of 6.4 and 12.32. Treatment performance was summarized using first-order *k*-rate coefficients:

Parameter	First-order rate coefficient (*k*)	Comments
Iron (Fe)	219–290 m/yr 82-107 m/yr	1.37 d HRT 3.16 d HRT
Manganese (Mn)	169 m/yr 71-88 m/yr	1.37 d HRT with aeration 1.37 d HRT without aeration
Copper (Cu)	54-97 m/yr 23-39 m/yr	1.37 d HRT 3.16 d HRT
Nickel (Ni)	81-82 m/yr 29-42 m/yr	1.37 d HRT 3.16 d HRT
Lead (Pb)	219-284 m/yr 95-121 m/yr	1.37 d HRT 3.16 d HRT
Chromium (Cr)	52-57 m/yr 148-168 m/yr 34-46 m/yr 59-66 m/yr	1.37 d HRT, no vegetation 1.37 d HRT, vegetation 3.16 d HRT, no vegetation 3.16 d HRT, vegetation
Zinc (Zn)	360-450 m/yr 118-146 m/yr	1.37 d HRT 3.16 d HRT
Phenol	96-165 m/yr 152-201 m/yr	1.37 d HRT 3.16 d HRT
Ammonia (NH_4-N)	233-237 m/yr 13.8 m/yr 24.4 m/yr	vegetation + aeration 1.37 d HRT, no vegetation, no aeration 3.16 d HRT, no vegetation, no aeration
Nitrate (NO_3-N)	0.9-2.0 m/yr 51-73 m/yr 6.0-9.3 m/yr 16-19 m/yr	1.37 d HRT, no vegetation 1.37 d HRT, vegetation 3.16 d HRT, no vegetation 3.16 d HRT, vegetation

BIO: Scott Wallace is a technology expert with more than 25 years of experience designing, constructing and operating wetland treatment systems. He is the co-author of *Treatment Wetlands, Second Edition*, widely considered the definitive textbook on wetland design, and is a pioneer in the development of intensified wetlands.

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AERATED WETLANDS TREATING HIGH FLOW / LOW CONCENTRATION WASTE WATERS

***Dion van Oirschot*[1,3]**, *Patrick Hawes*[2,3] *and Scott Wallace*[3,4]

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[2]ARM Group Ltd, Rugeley, Staffordshire, UK
[3]Naturally Wallace Consulting, Stillwater, Minnesota, USA
[4]Global Wetland Technology – www.globalwettech.com

Forced Bed AerationTM (FBA), was introduced by Naturally Wallace Consulting in 1997 and has been implemented in a variety of wetland projects in Europe and in North America, treating domestic wastewater, wastewaters from petroleum industries, agrofood industry and airport runoff containing deicing products.

FBA systems rely on the very uniform injection of small quantities of air at low pressure, in saturated subsurface flow wetland systems, to increase oxygen transfer. This precise control over air flow rates is necessary since aeration-induced hydrodynamic mixing in gravel bed reactors (such as subsurface flow wetlands) is much less than in open-tank systems such as activated sludge

Most publications and research on aerated wetlands have focused on systems that receive a relatively high organic load. Systems receiving relatively low concentration waste water streams and high hydraulic loading rates have received less attention.

Aerated wetlands fed with medium to high strength waste waters are in general designed based on the total oxygen consumption of the organic load, taking the clogging limit into account. High-flow aerated wetlands, however, show a relatively low hydraulic retention time (HRT) and dimensioning of the systems occurs based on k-values.

Several high-flow, low-concentration systems will be presented, fed with various types of waste water: two CSO systems (Cowdenbeath and Kunshan, China) and two systems in Belgium and the Netherlands processing low concentrion waste water from agricultural origin. Dimensioning of the systems, operation and some limited data series will be presented.

BIO: Dion van Oirschot is the director of Rietland bvba, a Belgian company that has been active in waste water treatment with treatment wetlands since 1994. Several hundreds of systems have been designed and implemented, mainly in the Netherlands and Belgium, but also in Jordan, UAE and China. Dion van Oirschot was one of the founding members of Global Wetland Technology and has been specializing in aerated wetlands since 2012.

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FORCED AERATION AND TN REMOVAL IN SINGLE STAGE VERTICAL FLOW TREATMENT WETLANDS FED BY RAW WASTEWATER

Pascal Molle[1], *Stéphanie Prost-Boucle*[1], *Stéphane Troesch*[2] *and Ania Morvannou*[1]

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When targeting TN removal by treatment wetlands, the use of multi stage wetland systems leads to use large footprint per p.e. and, consequently, larger investment and operation costs. TW may be not competitive compared to conventional systems for instance for large treatment capacities. Forced aeration may offer a real competitive solution. To maintain the easy sludge management stakeholder can observe with French system, some companies developed forced aeration wetlands systems fed with raw wastewater. They implement a top unsaturated media layer, like in classical French system, above a saturated layer in which forced aeration is used. Reaching low values of TN at the outlet requires fixing different design and operational parameters like design loads, media granulometry and depth, retention time in the saturated layer, aeration frequency and air flow. One of the difficulties is to balance nitrification and denitrification periods long enough to transform nitrogen form while keeping carbon source for denitrification. Knowledge on gas transfers and nitrification/denitrification kinetics is fundamental. This presentation will focus on those processes at different scales.
The experiments are conducted in 3 different phases:

- At column scale (0.1m²) the impact on air flow and media granulometry on gas transfers is studied in clean water.
- At pilot scale (20m²), and in controlled loading conditions, a Rhizosph'air® (Syntea company) process is monitored in term of oxygen and nitrogen forms in continue to precise aeration strategy to be implemented to reach low outlet TN concentrations.
- At full scale (1,400 p.e.) Rhizosph'air process is monitored to confirm observations done at pilot scale and assess its ability to face load variations.

The presentation will present this different experiments focusing on the gas transfer and aeration strategy to reach TN removal.

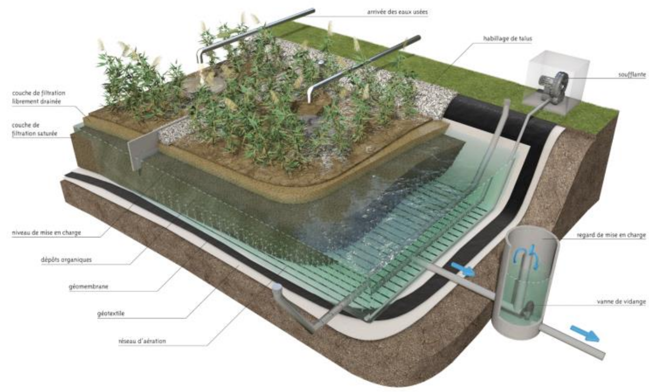

Figure 2. Rhizosph'air process, patented by Syntea/Naturally Wallace and Rietland companies.

BIO: Pascal Molle is a Research Director at Irstea. He develops researches on treatment wetlands for wastewater, sludge and storm water since more than 20 years.

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OPERATIONAL CHALLENGES OF AERATED WETLANDS

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Artificially aerated wetlands have been used across the globe for around twenty years, with more than 90 systems in the UK and >300 globally. Initially used for the treatment of high strength or complex industrial effluents such as landfill leachates, groundwater contaminated with hydrocarbons and deicer treatment from airport run-off, the use of aerated wetlands for the treatment of sewage has increased over the last ten years. In addition to new treatment systems, aeration has been retrofitted into existing wetlands to increase their treatment capacity within the same footprint, thereby increasing their asset life. Twenty years of experience has given designers some insight into the operational challenges associated with aerated wetlands with a view to optimizing design and identifying areas for further research to overcome these challenges.

A number of challenges will be discussed in the specialist session on aerated wetlands, including:

- Aeration has had an observable effect on *Phragmites australis* growth, in terms of reduced coverage across the bed, initial stunted growth, and altered root growth, particularly in systems operated with water above the gravel surface.
- The type of blower used to provide the aeration has provided a series of challenges associated with airflow delivery and its capacity to deal with fluctuating water levels and solids accumulated within the media.
- Challenges observed with efficient air delivery through a network of aeration pipe and associated emitters to provide equal distribution across the whole bed. Reduction in bubble pattern a sign of emitters being blocked and associated maintenance
- Understanding clogging mechanisms within aerated wetlands.
- Understanding the resilience of aerated wetland systems.

BIO: Clodagh Murphy works for ARM Ltd and has more than 13 years of experience in researching treatment wetlands. Working closely with water companies, industrial companies and academia, she specializes in design implications on the performance of passive and aerated wetland treatment systems and in wetlands treating glycol contaminated runoff from airports.

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E. COLI REMOVAL IN AERATED SUBSURFACE FLOW WETLANDS

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Escherichia coli is a pathogen indicator organism that is commonly used to assess the presence of fecal contamination in water samples and is often used to assess pathogen removal in treatment wetland systems. Although most subsurface flow wetlands providing secondary treatment of domestic or municipal wastewater are not explicitly designed for pathogen removal, some level of *E. coli* reduction has been observed in traditional horizontal flow (HF) and vertical flow (VF) wetland designs. The removal of *E. coli* in aerated wetlands has been reported a few times in the literature, but only for short-term datasets on the order of one year. This study compares over eight years of *E. coli* removal for three pilot-scale treatment wetland systems in Langenreichenbach, Germany: a traditional HF wetland (H50p), an aerated HF wetland (HAp), and an aerated VF wetland (VAp). Details of each system are provided in Table 1. All systems were planted with *P. australis* and have been in steady-state operation since August 2010. The systems treat municipal wastewater which has received primary treatment in a septic tank with an approximate hydraulic retention time of two days. Samples were generally collected and analyzed on a weekly basis over the eight-year period, providing a robust and long-term dataset for the three wetland systems (Figure 1). Detailed treatment efficacy and first-order removal rate coefficients (*k*-rates) will be presented and discussed.

Table 1. Characteristics of the three pilot-scale systems.

System Abbreviation[a]	System Type	Saturated depth (cm)	Main Filter Media	Surface Area (m^2)	Design Flow (m^3/d)
H50p	HF	50	8 – 16 mm gravel	5.6	0.20
VAp[b]	VF + Aeration	85	8 – 16 mm gravel	6.2	0.60
HAp[b]	HF + Aeration	100	8 – 16 mm gravel	5.6	0.75

[a] Systems were aerated continuously (24 h/d)

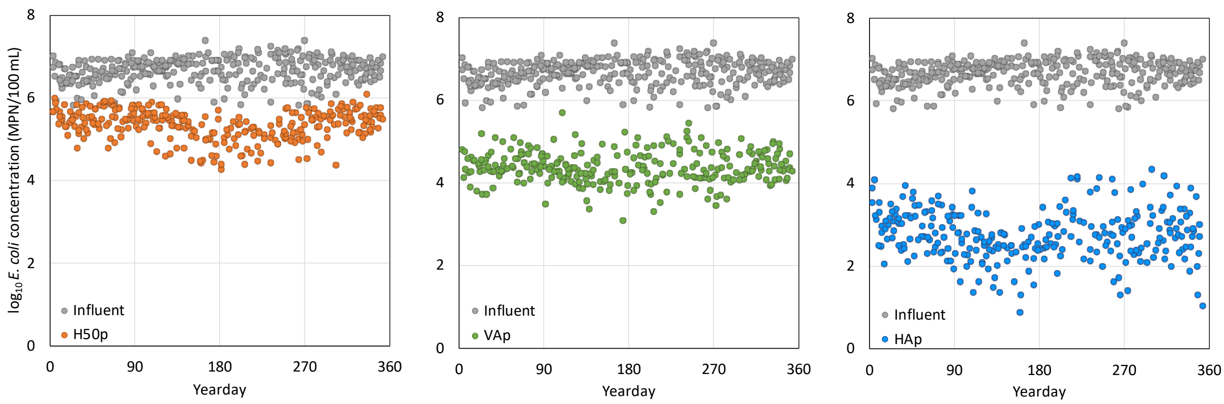

Figure 1. Influent and effluent *E. coli* concentrations for the three pilot-scale systems.

BIO: Jaime Nivala is a senior scientist at the UFZ with 20 years of experience in research and development of aerated subsurface flow treatment wetland technology. She is co-author of the forthcoming textbook *Subsurface Flow Treatment Wetlands*, which will be released in 2020.

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SPECIAL SESSION 6

WETLANDS, CLIMATE CHANGE AND CARBON CYCLING: FROM FIELD MANIPULATIONS TO HEMISPHERIC SURVEYS

Chris Craft

HERBIVOROUS WATERFOWL AND THE ROLE OF WETLAND PLANTS IN MEDIATING METHANE EMISSIONS

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Wetland methane studies indicate that aerenchymous herbaceous wetland vegetation cover tends to increase net efflux of this potent greenhouse gas by supplying carbon substrate for methanogens and by facilitating emissions via stem-flux. This paradigm relies on evidence from two types of studies: 1) cross-site comparisons (meta-analysis) of methane and vegetation cover, and 2) clipping experiments, in which stems are cut and sealed to prevent stem-flux. The evidence from comparative studies is generally weak because vegetation zonation covaries with many biotic and abiotic variables that are also related to methane production and emission, most importantly hydrology and net ecosystem productivity. The clipping experiments are effective at documenting the magnitude of stem-flux relative to diffusive and ebullitive fluxes, but may not give an accurate impression of the overall role of vegetation. The effect of radial oxygen loss from plant roots and an oxidized rhizosphere is also known to be quite important for facilitating methane oxidation, which prevents a substantial percentage of potential methane emissions from occurring. Based on incubation experiments, the effects of lost oxygen transport to rooting zone soils should be expected to lag days or months behind an experimental clipping event depending upon the amount of poise provided by alternative electron acceptors, such as iron oxides. In order to better understand the relative importance of radial oxygen loss versus stem-flux, we conducted a two-year field experiment utilizing waterfowl as a natural source of vegetation removal. Contrary to expectations, we found that waterfowl grazing greatly increased methane emissions by 230% compared to paired exclosure control plots. Porewater concentrations of dissolved methane in grazed plots were also significant higher than in control plots indicating that a lack of oxygen delivery to soils limited the capacity for grazed plot soils to oxidize accumulated methane. This interpretation was further supported by differences in the availability of extractable nitrate and nitrous oxide emissions, indicating that grazed plots soils lacked the capacity to nitrify. These results provide a unique counter-example to the dominant paradigm surrounding the role of aerenchymous plants as generally enhancing the emission of CH_4. We found that intensive grazing on dormant plant roots during the winter prevented plants from emerging quickly during the early growing season, which prevented the development of an oxidized rhizosphere, leading to the changes we observed in methane and other biogeochemical parameters. This finding suggests that there is ample room for further research on the role of plants in wetland methane emissions and provides experimental evidence that herbivores may play an unrecognized role in the regulation of wetland biogeochemistry.

BIO: Dr. R. Scott Winton is a postdoctoral researcher at the Institute for Biogeochemistry and Pollutant Dynamics at ETH Zurich. He has diverse wetland research interests spanning ecology, biogeochemistry, water quality and biodiversity, and he is particularly fond of wetland birds.

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FATE OF COASTAL WETLAND SOIL CARBON UNDER HIGH RELATIVE SEA LEVEL RISE: IMPLICATIONS FOR FUTURE GLOBAL CARBON BUDGETS

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Eustatic sea level rise combined with coastal subsidence in the Mississippi River Delta presents one of the highest rates of relative sea level rise in the world. Coastal wetland land loss rates are consequently among the highest in North America. The mechanism of land loss is primarily through marsh edge erosion with shoreline recession rates ranging from 49 to 324 cm per year. Coincident with land loss, is the vertical loss of up to 1.5 meters of peat, which is released into the shallow, aerobic waters of the bay. Data of erosion rates from 33 transects spread over 6 islands were not well correlated with wind speed, but strongly related to wind duration, which drives wave formation in the bay. The vertical loss of wetland soil carbon represents millennium scale (~ 900 years) carbon sequestration exhumed over decadal time scales. Bathymetric profiles and spectroscopic analyses support the assertion that the eroding wetland carbon is not being reburied in the bay.

The coastal wetland soil carbon deposits world-wide, represent a significant pool of C. With projections for sea level rate increases, there is the potential for other wetland-dominated coasts to experience the relative sea level rise rate found in coastal Louisiana within 50-75 years. These results can therefore be used to inform the world's stable coastlines on the relative vulnerability of their coastal marshes and associated soil C in the very near future The impact of the release of this older, stable C to the atmospheric C budget could overwhelm any societal plans for reducing C emission through reduction in fossil fuels unless plans for conservation of the soil C are created and realized.

<u>BIO</u>: Dr. White is the John and Catherine Day Professor of Oceanography and Coastal Science with over 25 years of experience researching wetland and aquatic biogeochemistry in freshwater, estuarine and salt marsh systems. He has supervised 30 graduate students and managed 30 grants and contracts on C, N and P cycling.

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SEA LEVEL RISE AND SALTWATER INTRUSION REDUCE CARBON ASSIMILATION AND STORAGE IN TIDAL FRESHWATER MARSHES

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Accelerated sea level rise driven by global warming is expected to squeeze many coastal wetlands. Tidal freshwater wetlands, marshes, and forests are expected to migrate upstream, convert to other vegetated habitats, or become submerged, leading to dramatic and widespread changes in biological productivity and carbon (C) and nutrient cycling. We experimentally dosed tidal freshwater marsh plots in-situ with brackish water to simulate the effects of increased inundation and saltwater intrusion on plant productivity, decomposition, soil C, and elevation gain/loss.

Of the four dominant plant species, brackish water intrusion led to eradication of *Ludwigia* (primrose) and significant reduction in biomass of *Polygonum* (smartweed) and *Zizaniopsis* (giant cutgrass), the dominant keystone species. Saltwater intrusion reduced plant productivity as total aboveground biomass in the brackish water plots was only 8% (53 g/m^2) of control plots while belowground biomass was 56% (1630 g/m^2) of controls. There was no effect of increased inundation on plant biomass and productivity. During the four-year experiment, brackish water plots lost about 3 cm of elevation whereas control and inundation plots gained 3 cm. The loss of soil elevation in brackish water plots was attributed to reduced belowground biomass and root C inputs (10% relative to control plots) since there was no effect of brackish water additions on root decomposition. Based on this 6 cm difference in soil surface elevation, soil C stocks are reduced by 1320 g/m^2.

Of greater concern is the loss of 6 cm elevation “capital” that is needed to maintain marsh elevation as sea level rises. Without this, tidal freshwater marshes are likely to convert to brackish marsh or open water as the climate warms and sea level rise accelerates, leading to loss of essential ecosystem services including high levels of biological productivity, denitrification, and C sequestration.

BIO: Christopher Craft is Janet Duey Professor of Rural (Wet)-Land Policy in the School of Public and Environmental Affairs, Indiana University Bloomington. He has 35 years of experience working in freshwater and estuarine wetlands. Professor Craft is author of *Creating and Restoring Wetlands* (Elsevier) and co-editor of *Wetland Soils* (CRC Press).

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ARE TROPICAL PEATLANDS MORE RESISTANT TO CLIMATE CHANGE THAN BOREAL PEATLANDS?

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The primary mechanisms responsible for peatland formation in boreal regions are typically attributed to cool temperatures and uniformly wet soil conditions that limit microbial respiration. However, outside of boreal regions peatlands are widespread and continue to accrete carbon despite higher temperature, seasonal drying of root-zone soil strata and recurring patterns of wildfire. This implies additional regulatory mechanisms constrain rates of OM decomposition and carbon accretion in subtropical and tropical peatlands. We propose that a "chemical latch mechanism" reduces decomposition rates in subtropical and tropical peatlands by: (1) higher production of polyphenol and aromatic compounds in the plants of low-latitude shrub/tree communities than found in northern Sphagnum/Carex dominated communities and (2) the selective removal of labile carbon and buildup of recalcitrant pyogenic OM produced by frequent low-intensity wildfires in the native-fire-adapted communities. Wildfire season in southern peatlands often occurs when vegetation is desiccated but peat soils still have high moisture content. Notably, the surface soil layers are typically subjected to flash-heating with a rapid loss of soil moisture but little loss of soil organic matter (SOM). Key findings to-date include 1) a latitudinal gradient of carbohydrates and aromatic/phenolic compounds were found with low-latitude peat having fewer carbohydrates and greater aromaticity, which indicate that southern peat is more recalcitrant than boreal peat; 2) a chronosequence of low-intensity prescribed burns and laboratory fire simulations provided a lower H/C ratio, lower sugar+carbohydrate and lower klason lignin at burned sites; 3) Incubation of burned and unburned peat replicates over more than six months exhibited an initial pulse of CO_2, CH_4 and NO_2 emissions, but within four weeks emissions from the burned replicates dropped significantly below those from unburned replicates. After accounting for small initial losses of organic matter (<10 %) during the fire simulations, thermal alteration of peat resulted in a net long-term reduction in carbon loss; 4) High phenolics in shrub peatlands have overarching control on the diversity and abundance of fungi—the predominant peat decomposer, thus directly decreasing carbon decomposition, but also shifting fungal composition from fast-growing to slow-growing species. These factors decrease climatic decomposition sensitivity and stabilizes stored carbon, thus improving tropical peatland sustainability under climate change.

<u>BIO:</u> Dr. Curtis Richardson is Director of the Duke University Wetland Center and the John O. Blackburn Distinguished Professor of Resource Ecology at Duke's Nicholas School of the Environment. He directs research on wetland biogeochemistry and ecosystem restoration. He is a Fellow of the Society of Wetland Scientists, the Soil Science Society of America, and the American Association for the Advancement of Science.

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EFFECTS OF CHRONIC AND ACUTE SEAWATER INTRUSION ON TIDAL FRESHWATER MARSH CARBON CYCLING

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[2] Department of Biological Sciences, University of Cincinnati, Cincinnati, OH

[3] School of Public and Environmental Affairs, Indiana University, Bloomington, IN

Tidal freshwater ecosystems experience acute seawater intrusion associated with periodic droughts and will become chronically salinized as sea level rises. To better understand the effects of chronic and acute seawater intrusion on tidal freshwater marsh carbon cycling, we performed an experimental manipulation in a tidal freshwater Zizaniopsis miliacea marsh on the Altamaha River, GA. We added diluted seawater to replicate marsh plots on either a press (constant) or pulse (2 months per year) basis. We measured changes in porewater chemistry (SO42−, Cl−, organic C, inorganic nitrogen and phosphorus), and ecosystem CO2 and CH4 exchange. We found that press (chronic) seawater additions increased porewater chloride, sulfate, ammonium and phosphate. Chronic increases in salinity also decreased net ecosystem exchange, resulting in reduced CO2 and CH4 emissions from press plots. Our pulse treatment temporarily increased porewater ammonium concentrations but had few lasting effects on porewater chemistry or ecosystem carbon balance.

BIO: Dr. Schubauer-Berigan is an ecologist with expertise in wetland biogeochemistry. His work includes studying the effect of sea level rise on coastal ecosystems; quantifying wetland ecological services; and evaluating the effectiveness of management practices for mitigating pollution. Dr. Schubauer-Berigan currently resides in Lyon, France.

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SPECIAL SESSION 7

WETLANDS AND BUFFER ZONES MITIGATING WATER POLLUTION AND CLIMATE CHANGE

Ülo Mander

ANNUAL CO_2, CH_4 AND N_2O BALANCES OF A RIPARIAN GREY ALDER FOREST

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Riparian buffer zones, as the interface between terrestrial and aquatic components of the landscape, are important ecotechnological measures to control water quality in agricultural catchments and provide other ecosystem services. The water purification effect of riparian ecosystems has been thoroughly studied, yet their role as greenhouse gas (GHG) sources needs to be better understood. Water purification efficiency may be less favorable in riparian zones, which can emit GHGs with high global warming potential (GWP).

Riparian forests are known as carbon dioxide (CO_2) sequestering ecosystems. Little is known about methane (CH_4) and nitrous oxide (N_2O) balance in forests. Recent studies demonstrate that trees themselves can emit CH_4 and the forest vegetation can be a significant CH_4 source. Few studies show that drained N-rich organic soils in deciduous forests can be significant N_2O sources whereas a significant part of such emissions appears in winter. Nevertheless, no studies on ecosystem-level N_2O budget (fluxes from soil, tree stems and shoots + above canopy flux measurements) could be found. Grey alder (*Alnus incana*) is a fast-growing tree species with a great potential for short-rotation forestry in the Nordic and Baltic countries. In this region, grey alder stands are typically found in riparian zones, they are considered as carbon (C) accumulating ecosystems. The symbiotic dinitrogen (N_2) fixation ability makes alders important for the regulation of nitrogen (N) cycle in forested areas.

During the period August 2017 to September 2018 we measured budgets of CO_2, CH_4 and N_2O of a 40-yrs old riparian grey alder forest stand on former agricultural land in Estonia considering fluxes from the soil surface (12 automated chambers; Picarro 2508), tree stems (60 manual sampling campaigns from 12 model trees with chambers at 0.1, 0.8 and 1.7 m; gas chromatographic analysis in lab) and whole ecosystem (eddy covariance (EC) technique: Li-7200 for CO_2, QCL for N_2O and CH_4). Simultaneously, soil water level, temperature and moisture were measured automatically and composite soil samples were taken for physico-chemical analysis.

In the wet periods, stem flux of CH_4 was the main source for ecosystem exchange, whereas in the dry periods, unpredictably, ecosystem flux was significantly higher than fluxes from soil and tree stems. Most likely, canopy was the main CH_4 emitter. N_2O fluxes from the soil and stems were low during the dry periods and peaked during the wet periods and the freezing-thawing. The forest was a net annual source of both CH_4 and N_2O (6.33±0.29 kg CH_4 ha^{-1} and 3.42±0.12 kg N_2O ha^{-1}, mean±SE) and a net annual sink of CO_2 (-21025±158 kg CO_2 ha^{-1}). Estimated average annual losses of total organic C and total N in groundwater flow were 7.5 kg C ha^{-1} and 1.8 kg N ha^{-1}, thus the forest was a net annual C sink (-5224 kg C ha^{-1}).

For better understanding of C and nutrient budgets of riparian forests, we need long-term, high-frequency measurements of soil and tree CO_2, CH_4 and N_2O fluxes in combination with ecosystem-level EC measurements. The identification of microorganisms and biogeochemical pathways associated with GHG production and consumption is also a challenge.

BIO: Dr. Mander is Professor of Physical Geography and Landscape Ecology at the University of Tartu, having more than 30 years experience in research and teaching of nutrient cycling of ecosystems and landscapes, in particular in design and performance of constructed wetlands and riparian zones in various countries of the world.

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PRINCIPLES FOR CONSTRUCTED WETLANDS AND RIPARIAN BUFFER ZONES IN AGRICULTURAL CATCHMENTS

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[2] University of Tartu, Tartu, Estonia

Constructed wetlands (CWs; artificial or man-made wetlands) and riparian buffer zones (RBZs) are widely used ecological engineering measures to control water quality in agricultural catchments. However, quite often the water quality improvement has contradictory results. In most cases this is due to underestimating or even ignoring the role of hydrological factors of water quality improvement. This has resulted in biased efficiency estimates of buffering systems at catchment scale and, consequently, has caused planning and establishment failures, mistakes and inconsistencies in legislative acts and finally, it has influenced stakeholder's willingness to support these eco-technological measures. In the following we highlight the most important aspects to be considered when planning, establishing and managing these systems.

For CWs these are: (1) hydrological diagnosis of the catchment (quantity and seasonality of water flow and transport of substances); (2) the hydroperiod length governed by inflow, outflow and storage capacity, strong linkage to precipitation, runoff and tile-drainage regime; (3) average (not peak) flow and variability in removal efficiency as the basis for the design; (4) optimal location down-stream from sources of pollution in the landscape; (5) suitable interception strategy (in-stream or off-stream or a combination thereof); (6) avoidance of hydrologically isolated CWs; (7) preference of historical locations for new CWs; (8) integrated CWs treating polluted agricultural runoff and farm wastewater; (9) harvesting biomass on a regular basis for bioenergy or fodder.

In terms of PBZs different aspects can be highlighted for according to width. For wider buffer zones: (1) preference towards three-zone RBZs: from field to stream − grass strips, younger forest/brush, and older forest stands; (2) regular grass mowing and brushwood harvesting for bioenergy production; (3) protection of floodplains by using buffer zones/strips at field edges;(4) enhancing regulating services (e.g., biodiversity support) to connect the network of RBZs with wider floodplains and river corridors. For narrow buffer strips: (1) establishing RBZs on thalwegs and at the edge of sloping fields; (2) avoidance of water flow bypasses; (3) redirection of flow from tile drainage; (4) horseshoe wetlands and/or bioswales on the widened ditch bottoms to enhance denitrification; (5) establishing denitrifying bioreactors with P-sorbing filter media; (6) contouring of soil surface in RBZ to tranquilise concentrated storm flows and (7) periodical sediment removal.

Further on, cooperation with farmers and other stakeholders is imperative, the transfer of the most recent know-how about the best practices for managing buffer strips is necessary for their success. Likewise, preference of the principle of multifunctionality is important, even if services for regulating water quality are less favorable in a particular location. Never should CWs and RBZs be considered as an excuse to increase loading in upstream fields. Hydrologically connected CWs with effective buffer zones along the streams support water quality in river basins.

BIO: Dr. Tournebize is a senior scientist at the IRSTEA, Antony, France. He is an internationally renowned expert in catchment hydrology, particularly in design and performance of constructed wetlands and riparian zones in various countries of Europe and the US.

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NUTRIENT RETENTION BY FLOODPLAIN MESOCOSM WETLANDS OVER TWO YEARS IN A HYDROLOGIC EXPERIMENT ADJACENT TO A EUTROPHIC LAKE IN THE OHIO RIVER BASIN

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Significant expansion of agricultural land use has been widely recognized as leading to global and regional negative environmental impacts, especially reduced soil fertility and increased eutrophication of surface water systems for the last few decades. Few quantitative studies have been developed on agricultural land that was initially wetland in central Ohio on the potential of restoring the land to wetlands. The importance of regional seasonality and hydrologic conditions on agricultural runoff treatment wetlands is still in need of more investigation. Mesocosm compounds consisting of twenty-eight 379 L Rubbermaid tubs, were constructed in 2016 and planted in October 2016 with the sedge Schoenoplectus tabernaemontani. Started in April 2017, inflow and outflow water samples are collected and analysis for soluble reactive phosphorus (SRP), total phosphorus (TP), nitrate+nitrite (NO3+NO2-N), total Kjeldahl nitrogen (TKN), and total nitrogen (TN) every two other weeks during sampling hydroperiods. River water containing agricultural runoff is pumped weekly into the elevated water feed tank systems, with sampling hydroperiods from April to November. The mesocosms were randomly assigned to a 7x2x2 hydrologic experiment involving 2 water depth and 2 hydraulic loading rates (HLR). Early data in 2017 and 2018 suggest the mesocosms have already become nutrient sinks with a positive removal rate of total phosphorus (33 ± 4% (n = 248) and total nitrogen (40 ± 2% (n = 322)) concentrations. By comparing different water levels, hydraulic loading rates, and soil accumulation in an agricultural runoff treatment wetland system, this research will provide a valuable understanding of wetland mechanisms and dynamics. Moreover, dynamic and spatial mathematical models basing on wetland mesocosm investigations will be discussed and developed to predict the behavior of landscape-scale wetlands. A sustainable wetland-agriculture integration system (we call it “wetlaculture”) will be developed with these restored wetland to reduce fertilizer usage significantly, and eventually benefit farmers with maximizing the value by applying the eco-functions of wetland in the Ohio River basin.

NUTRIENT REDUCTION IN CONSTRUCTED WETLANDS RECEIVING TREATED WASTEWATER

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Constructed Wetlands receiving treated wastewater (CWtw) are systems downstream of Wastewater Treatment Plants (WWTPs) before the receiving water bodies. They have recently become attractive in France under the perception that they increase water quality of the WWTP effluent. In order to assess the efficiency of these systems, a 6-years project has been conducted on 3 sites (full and pilot scales).

From 1 m² of land-take to 10 000 m², the 3 experimental sites present different shapes. They receive treated wastewater of different qualities. For example, depending on the site, KN may vary from 1 to 40 $mg.L^{-1}$ and Pt from 0.1 to 10 $mg.L^{-1}$.

The three compartments: i) free water and the deposits of organic matter, ii) emerged and floating plants and iii) the soil were analyzed in details in terms of quantity and quality. Thus, all the related instrumentation of the sites makes possible to assess daily water balance. Plant samplings allow to quantify the exportable biomass, and the volume of the deposits is estimated. To the pilot-scale, the masses of requested soil were determined. Moreover, a monitoring of free and pore water, plants, deposits and soil is carried out to understand the fate of conventional pollutants (C, N, P).

For the CWtw systems, various treatment mechanisms allowing nutrient removal can take place simultaneously since they can occur in the three compartments. Among them, can be assumed the sedimentation of suspended solids, nutrient absorption by plants, phosphate adsorption in the soil, denitrification, etc. These mechanisms do not have the same impacts according to nutrients forms (dissolved or particular) and the nutrients degree of oxidation. Moreover, the age of the site is of importance, including potential malfunctions from the WWTP upstream the CWtw.

The results underlines the impact of the sedimentation of the particulate fractions, which seems first positive, then negative over time, subjected to low flow velocities. It also underlines the adsorption of phosphates in the soil and, to a lesser extent, ammonium retention, if maintaining a long-term infiltration. Furthermore, as expected, the plants uptake is a small contribution to nutrients reduction even with long residence times. Thus, if optimizing the CWtw design by emphasizing the predominant mechanisms, it is possible to predict its efficiency according to nutrients that are present in the influent.

BIO: Catherine BOUTIN is a senior scientist with more than 20 years of wetlands construction projects. She has contributed to elaborate the French line CW used for raw sewage. She currently manages this French research project about the use of CWtw.

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THE DANISH CONCEPT TO MITIGATE NUTRIENTS IN DRAINAGE DISCHARGE: FOUR NEW OPTIONS

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Pollution of surface waters and shallow groundwater with nitrogen (N) and phosphorus (P) is an urgent problem in most regions of Europe and in many other parts of the world. A significant pollution source is the nutrient runoff from intensively farmed agricultural land either via tile drainage, ditches, soil leaching and/or surface runoff. For the improvement of water quality both the restoration of wetlands but also the establishment of constructed wetlands are two important strategies. In Denmark, a new era of targeted agro-environmental nutrient regulation has been accepted as part of the Agricultural Package adopted by the Danish Parliament in 2016. Thereafter farmers were allowed to increase their fertilization to the economic optimum in exchange of implementing collective and targeted measures mitigating nutrient losses from fields. In areas where groundwater or estuaries are threatened by excess N and where natural N removal in groundwater is presumable low have targeted adoption of supplementary catch crops been implemented as open calls for farmers. The collective measures include large schemes for wetland restoration, surface flow constructed wetlands targeting drainage losses, afforestation and taking organic soils out of production. To this end a new national program with catchment officers have been established with the aim to bridge farmers, municipalities and national agencies. Finally, an improved sub-catchment based targeted nutrient regulation will be adapted from 2019 and include new mitigation measures such as integrated buffer zones (IBZ), subsurface flow constructed wetlands with biofilters (SSCW), saturated buffer zones (SBZ) and controlled drainage (CD) which are all currently being tested in several larger innovation and research projects (BIOWATER, BUFFERTECH, MMM, InnoDrain). For these research efforts it is essential to know the processes that control the local N and P removal efficiencies of the measures , the performance over time, the need for management and the cost-efficiency. The paper will provide basic information on four new mitigation strategies (IBZ, SSCW, SBZ and CD) and compiles important aspects on their implementation in the landscape.

BIO: Dr. Zak has over 15 years' experience in freshwater and wetland-related environmental research, land use change, conservation, restoration and worked on several freshwater-related projects. His work is dedicated to interdisciplinary research integrating biology, ecology, microbiology and biogeochemistry across aquatic and terrestrial systems.

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S.S. 8

SPECIAL SESSION 8

SWS SYMPOSIUM

Matthew T. Moore

EXPLORING THE ROLE OF WETLAND VEGETATION IN ENHANCING NUTRIENT REMOVAL WITHIN AGRICULTUAL DITCHES

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There is a keen interest in enhancing nutrient mitigation within agricultural ditch networks to reduce nitrogen (N) and phosphorus (P) loading impacts. Using rice cutgrass (Leersia oryzoides), we summarize several experiments exploring the role of vegetated ditches in enhancing nutrient removal in ditch environments. Early experiments demonstrated that ditch mesocosms vegetated with rice cutgrass had significantly higher nutrient retention during simulated runoff events and rapid removal compared to unvegetated systems while holding enriched water.

Overall nutrient mitigation potential of vegetated ditch environments depends on factors that control breakdown of senescent plant material and release of nutrients back into ditch environments during winter months. In a study investigating nutrient retention in the summer as well as export during 14 winter rain events in ditch mesocosms planted with rice cutgrass across treatments representing a P enrichment gradient, we found that winter P export was similar to summer retention under background P conditions but did not increase with increasing enrichment. Nitrogen export during the winter was also minimal compared to retention in the summer. This suggests that vegetated ditches have potential to store or remove excess N and P on annual timescales.

Vegetated ditches may serve as a permanent sink for excess N via denitrification. Two experiments demonstrated that denitrification was significantly enhanced by rice cutgrass and could account for as much as 56% of NO3--N removal over a 48-hour period but rates were concentration and temperature dependent. Current work is focused on scaling up these results by measuring whole system diel N2 fluxes between control and vegetated ditches. Results reveal complex patterns that suggest fluxes may be controlled by the balance of both N2 production via denitrification and consumption driven by physical or biological processes. However, improved diel N2 flux models that account for these additional constraints demonstrate that rice cutgrass can enhance nitrate removal via denitrification at the whole ditch scale. Taken together, our results demonstrate that wetland vegetation has potential for enhancing nutrient mitigation capacity in agricultural ditch networks, but more research is needed to evaluate additional physical and biological constraints.

<u>BIO:</u> Dr. Taylor is a research ecologist with more than 15 years of experience with freshwater conservation planning and conducting research related to bioassessment, community ecology, and biogeochemistry in aquatic ecosystems. His current research focuses on the role of denitrification in nitrogen cycling in aquatic agroecosystems.

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AN OUNCE OF PREVENTION IS WORTH A POUND OF CURE: MANAGING MACROPHYTES FOR NITRATE MITIGATION IN IRRIGATED AGRICULTURAL WATERSHEDS

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Although ubiquitous elements of human-impacted watersheds, the interest on ditches and canals as effective filters to buffer NO_3^- pollution has been raised only recently. Open questions concern how management practices of the drainage networks may affect their N removal capacity and how this may, in turn, affect broader-scale N dynamics in agricultural catchments.

Here, we summarize recent findings about N dissipation via denitrification in the capillary ditch network of the Po River lowland (Northern Italy), a worldwide hotspot of eutrophication and NO_3^- contamination. Several experimental approaches (i.e. incubations targeting benthic N metabolism, N_2 open-channel method, upstream-downstream budgets of N species, upscale models) at multiple spatial scales (mesocosm, whole-reach, watershed) were applied to parameterize N removal in relation to biotic (e.g. presence of macrophytes and biofilms) and abiotic drivers (e.g. NO_3^- availability, water velocity, temperature). GIS-based upscaling procedures allowed to evaluate the importance of in-ditch denitrification supported by macrophytes at the entire drainage network scale and in the context of agricultural N excess. Several scenarios of variable extent of aquatic vegetation maintenance were simulated, along with the current situation where mechanical mowing, a management practice performed routinely by water management authorities to preserve hydraulic performance, has led to the almost complete disappearance of macrophytes.

Outcomes demonstrate the pivotal role of emergent vegetation in sustaining ditch network depuration capacity. Storage in plant biomass represents only a small fraction of the total N amount removed by vegetated sediments, while the most part of it is due to the complex synergistic action of macrophytes and bacterial communities, mostly via denitrification. Vegetated ditches express the highest denitrification rates in summer when elevated water temperature enhances microbial activity and when vegetation acts as an *ecosystem engineer* by favoring the development of denitrification hotspots (e.g. biofilms on submerged portions, oxic-anoxic interfaces in the rhizosphere). Denitrification performed by biofilms on senescent stems proceeds also beyond the vegetative season throughout the cold period and maintains the depuration potential when high NO_3^- loads may be leached from agricultural fields. Also hydrodynamic transport conditions (i.e. water velocity) play a key role in regulating N dissipation in slow-flow vegetated waterways, by affecting the supply of NO_3^- from the water column to the bioactive surfaces where denitrification occurs.

Restoration of aquatic vegetation could be an effective low-cost tool to mitigate the widespread NO_3^- contamination in surface waters, with potentially improved water quality at the watershed level and in the coastal zones. The management of agricultural ditches should thus turn to conservative practices of in-stream vegetation which, though guaranteeing the hydraulic efficiency, might at the same time maximize the ecosystem function of denitrification.

BIO: Dr. Soana defended her PhD in Ecology in 2013 (University of Parma, Italy) working on the rhizosphere-microbial community interactions in freshwater ecosystems undergoing eutrophication. Main research topics: nitrogen cycling in shallow aquatic environments (e.g. ditches, wetlands), genesis and transformation of nutrient loads in agricultural watersheds via mass balance approach.

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CONSTRUCTED WETLANDS MULTIPHYSICS SIMULATION DESIGN TOOL FOR PHOSPHORUS POLLUTION PREVENTION IN THE EVERGLADES, FLORIDA

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Eutrophication is a widespread global scale pollution problem. Agricultural areas are generally the main contributors to eutrophication, whereas sewage and industrial discharges, which usually receive some treatment prior to discharge, are a secondary source. This is mostly the case of the Everglades, because their natural water sources are enriched with nutrients from agricultural runoff. These agricultural polluted waters could even have significant amounts of pesticides. Agricultural runoff is a type of non-point pollution characterized by high and fluctuating flows in space and time, and relatively low concentrations of pollutants (in comparison to other wastes and wastewaters). Especially for these intrinsic properties, remediation of these agricultural waters cannot be conducted with the usual environmental engineering solutions, and in this context ecological engineering approaches such as constructed wetlands are much more suitable. Constructed wetlands provide large hydraulic retention times, and a number of differentiated compartments giving place to multiple microenvironments, where multitude of processes can interact among them for the benefit of water quality improvement. However, their hydraulic design and functioning is not trivial and, in many cases reported in literature, the systems perform in suboptimal conditions reducing their predicted capacities.

In recent years a number of rigorously scientific studies carried out in the Everglades area have demonstrated the capacity of mesocosm wetlands to remediate agricultural runoff, and in particular to reduce significantly phosphorus concentrations. Also extensive monitoring studies on field-scale constructed wetlands (named storm treatment areas STA), which are already in operation in the area, have demonstrated the potential of the technology. However, these mesocosms and field scale studies have also shown the difficulties to achieve the 10 P ppb limit in the long term which have been stablished by authorities to protect the Everglades. The objective of this on-going research is therefore to analyze how constructed wetland hydraulic design can be improved to increase their removal efficiencies to reach the 10 P ppb limit by means advanced dynamic modeling. For this purpose we are using extensive data from 2.5 years in 6 x 1 x 0.4 m mesocosms studies to calibrate and validate a mechanistic model written into the COMSOL Multiphysics software. Preliminary results show that mesocosms performed under strongly laminar conditions and much of water volume (>50%) is never in contact with the bottom of the wetlands, where many of the key phosphorus retention processes occur. This has led to suboptimal removal efficiency of the mesocosms. In the next steps of the project we are going to study different hydraulic configurations of the mesocosms to improve their hydraulic performance and evaluate subsequent improvements in P removal. Finally, the model will be extrapolated to the currently functioning storm treatment areas to evaluate how changes in their design can improve their removal efficiencies. All these results will be presented during the conference.

BIO: Dr. Joan Garcia is Professor of environmental engineering at Technical University of Catalonia in Barcelona and visiting Fulbright scholar at FGCU's Everglades Wetland Research Park in Naples. He has > 20 years of experience on the use of natural treatments such as microalgae systems and constructed wetlands for wastewater engineering.

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IMPROVING WATER QUALITY AND BIODIVERSITY: THEN YEARS OF EXPERIENCE IN CONSTRUCTED WETLAND *TANCAT DE LA PIPA*, ALBUFERA DE VALENCIA NATURAL PARK, SPAIN

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In April 2009, the water began to flow in *Tancat de la Pipa Constructed Wetlands (TPCWs)*, a free water surface constructed wetland created from a former rice paddy aiming to improve water quality and biodiversity in Albufera de València Natural Park. After ten years of operation, it is the unique example of constructed wetland focused on treatment of eutrophicated waters in Spain. In ten years, 20 Hm^3, approximately, of water from eutrophicated channels connected to l'Albufera Lake, have been introduced. The chlorophyll *a* concentration in these inflows ranged between 6.3 and 487 $\mu g\ l^{-1}$, with a mean value of 64 $\mu g\ l^{-1}$ (n=139). One of the main challenges is the vegetation maintenance because one of the main pressure for wildlife conservation in the Natural Park is the reduced availability of suitable and well-conserved marshland habitats. Thus, the initially restored habitats in 2009 suffered overexploitation by vegetarian birds as the Purple Gallinule (*Porphyrio porphyrio*), whose flocks have almost consumed the original cattails (*Typha domingensis*) patches, being cattails formations scarce in the Natural Park. In some periods, the vegetation cover was less than 15% of wetlands surface, resulting in a loss of efficiency. A big effort on vegetation restoration in 2014 and 2015 with reeds, bulrush and lilies made it possible to achieve a 70% of vegetation coverage.The aging of *TPCWs* can be seen in the less and less organic matter removal and in the increase of phosphorous fluxes from sediments in anoxic conditions, for example. Nevertheless, the removal efficiencies of total nitrogen and phosphorus, in its various forms, is still positive (37% TN and 31% TP between March 2017 and December 2018, n= 33) and the decrease of phytoplankton biomass remains. Moreover, it has been found that the constructed wetlands reduces dramatically the peaks of nutrient loads to Lake from runoff of impervious urbans zones and combined sewers overflows surrounding the natural park, acting as a buffer system. For example, from peaks about 1.5 mg $N\text{-}NH_4^+\ l^{-1}$, the outflow is less than 0.2, from 1.0 mg $P\text{-}PO_4^{3-}\ l^{-1}$ to 0.2 and, in spring, from 93 µg Chl*a* l^{-1} to 10. Regarding biodiversity, it can be stated that CWTP is a "hatchery" of zooplankton that is exported to the Lake. Because of water quality improvement, changes in phytoplankton composition towards a more diverse, and edible, community are produced; the increase of zooplankton biomass is a natural consequence of all these changes. The *TPCWs* have triggered some relevant changes in the Natural Park. Waterfowl dependent on habitats with good quality of water breed regularly in the constructed wetland with a significant population, i.e. more than 50 % of the breeding pairs of Red-crested Pochard (*Netta rufina*) and Common Coot (*Fulica atra*) of the whole Natural Park. Other species with national relevant conservation concern have established in *TPCWs* for the first time in the Natural Park as Garganey (*Anas querquedula*) and Eurasian Bittern (*Botaurus stellaris*), or feeding grounds for new breeding species as Great Egret (*Egretta alba*), also reflecting the recovery of other aquatic fauna and flora. Nowadays, the *Tancat* is just as natural that is has been chosen as reintroduction site to protect endangered species. The constructed wetlands like *TPCWs* have been considered as one of the programme of measures in the Júcar River Basin Management Plan to achieve the water quality objectives of l'Albufera Lake. Finally, *Tancat de la Pipa* is not just a water quality treatment/biodiversity system. Its success in these ten years has been possible thanks to a participative way to do the management based on land stewardship agreements. Agreements between public administrations as landowners and the managers of the TPCWs has given as a result the involvement and raising environmental awareness of society. Many environmental volunteer projects, scholar and private visits, courses, Master Thesis, Ph.D. Thesis, etc. have been developed in last years, showing to people the benefits of habitats recovery.

BIO: Dr. Martin is Associate Professor at UPV with more than 25 years of experience in water quality modelling and monitoring, both natural waters and water treatment systems. He has experience with constructed wetlands in natural environments and sewage treatment. He is interested now in Natural Based Solutions for urban environments. Contact Information: Prof. Miguel Martin, IIAMA-Universitat Politècnica de València, Cno. De Vera/sn, Valencia, Spain, Phone: +34 963 877 617, Email: mmartin@hma.upv.es

FUNGICIDE RISK MITIGATION IN AGRICULTURAL LANDSCAPES - THE ROLE OF VEGETATED TREATMENT SYSTEMS

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Large amounts of fungicides are commonly applied to agricultural fields, particularly vineyards. Following their application, fungicides may accidentally be introduced into agricultural surface waters posing a potential risk for the integrity of aquatic ecosystems. In this context, the present study characterized the aquatic fungicide exposure at base flow and during rainfall-related runoff events in viticulture in Southern Palatinate (SW-Germany) over three years. The mitigation performance of three vegetated ditches (VD) and five vegetated detention ponds (DP) was assessed. The measurements uncovered the presence of four to eleven different fungicide compounds in each of the 81 samples. During runoff events, the ecotoxicological potential – expressed as the sum of toxic units calculated based on the acute toxicity towards algae, *Daphnia* and fish – of some of the mixtures detected at the inlet of the VD or DP exceeded the Uniform Principle threshold set by the European Union. Both the VD and the DP systems reduced the median fungicide concentrations and thus their associated ecotoxicological potential by 56% and 38%, respectively. This fungicide mitigation efficiency was mainly explained by the plant density and size-related properties of the vegetated systems. Although VP and DP are promising tools to mitigate fungicide exposure, a better mechanistic understanding of the factors triggering the remediation potential finally feeding back into policy decision making is required.

BIO: Dr. Bundschuh is Junior-Professor in Functional Aquatic Ecotoxicology with more than a decade of experience his field. In the last years he also developed a research line related to the use of wetland in agricultural landscape as well as self-cleaning capacity of streams.

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SPECIAL SESSION 9

MICROBIAL PROCESSES IN WETLANDS FOR WATER POLLUTION CONTROL

Kela Weber

MACROSCALE SEMI-QUANTITATIVE IMAGING OF THE NITRIFICATION PROCESS IN SUB-SURFACE FLOW CONSTRUCTED WETLANDS USING FLUORESCENT BACTERIA

Vincent Gagnon[1] *and* ***Kela Weber***[1]

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Constructed wetlands are engineered ecosystems where microbial processes play an important role in the removal of pollutants from wastewater. Much of the treatment occurs when pollutants flow through the plant rhizosphere where it encounters a complex array of micro-scale environments populated with a diverse microbial community which breakdown pollutants. Nitrogen is one of the major pollutants in wastewater which can be treated by the sequential action of multiple bacterial consortia. A central aspect of the overall nitrogen removal process is nitrification, which occur in two steps: nitritation oxidizes ammonium (NH_4) into nitrite (NO_2), and nitratation which further oxidizes NO_2 to nitrate (NO_3). Even though nitrification plays a crucial part in overall nitrogen transformation and removal, little is known about nitrifying bacteria spatial distribution and temporal activities. Thus the objective of this study is to develop a new non-destructive analytical method to spatially map nitrifying bacteria in subsurface flow constructed wetlands.

The experimental setup consists of a transparent horizontal subsurface flow constructed wetland mesocosm (23 x 27 x 40 cm) filled first with 30 cm of transparent gravel (5-15 mm), and second with 5 cm of gray gravel (5-20 mm) at the surface to prevent algae development. The exterior of the CW is covered with a removable black corrugated plastic to prevent algae development. The CWs were batch feed once a week with synthetic wastewater. The macro scale mapping of nitrifying bacteria within the CW was done using genetically modified nitrifying bacteria which produce fluorescent proteins when nitrification processes occur. Each step of the nitrification process produces its own fluorescent colour, where *Nitrosomonas europaea* produce green fluorescence proteins (GFP) during the nitritation process and *Nitrobacter winogradskyi* produce red fluorescence protein (tdTomato) during the nitratation process. Fluorescence is measured photometrical using a Nikon D3100 camera fitted with a long pass optical filters (>510 nm) for GFP and a band pass optical filters (570-645 nm) for tdTomato fluorescence. The light source is filtered with band pass optical filters (400-500 nm) for GFP and band pass optical filters (510-655 nm) for tdTomato fluorescence. Bacterial density of active nitrifying bacteria is inferred according to a standard curve correlating the fluorescence intensity to the bacteria density. The resulting data set will serve to construct a 2D map of nitrifying bacteria within the CW. This new method could serve to test the influence of plant species or intensification process such as artificial aeration on nitrifier communities and assess the toxicity of emerging contaminants on key microbial processes of CWs.

BIO: Dr. Gagnon is a post doctoral researcher with Dr. Kela Weber at the Environmental Sciences Group. He is interested in the fundamental biological process of CWs and how it can be applied to improve ecological engineering. He is also known for helping organized the last three WETPOL symposiums.

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MICROBIAL TOLUENE DEGRADATION IN THE COMPLEX ROOT-ZONE OF AN IDEALIZED LAB-SCALE WETLAND REACTOR: ANALYSIS OF THE MICROBIOME AND PROTEOME

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In the field of green water technology constructed wetlands are widely used and represent one accepted treatment technology. Design criteria for constructed wetlands often based in practice on the "rule of the thumb" – condensed to be a specific area per capita which is to apply to reach an acceptable treatment result. This engineering approach may be suitable for many municipal waste water treatment installations using constructed wetlands under defined range of climate conditions and a narrow composition of the waste water. However, this black box approach may fail for additional waste water types like industrial waste water, acid mine drainage or for different climate conditions. It is widely accepted that ideal and reproducible flow condition are one of the key issues for transferable experimental results towards generalized design criteria and system understanding. A laboratory-based wetland reactor (PFR – Planted fixed bed) where used to perform tracer experiments applying stable isotope methods to understand the microbial transformation processes involved in complex roots zones systems. ^{13}C labelled toluene was applied in a short-term pulse. The total mass balance of added toluene of the whole systems also involves the emission over root zone border, such as phytovolatization of the volatile toluene via leaves and surface of the phyto-reactor. It shows low emissions via the phyllosphere of about 2 % of the inflow toluene. This finding suggests, together with the no detectable amount of toluene in the outflow, a degradation in the PFR. It is widely accepted that organic pollutants mainly degraded via microbial transformations in constructed wetlands. Elucidation of the involved organisms and pathway, respectively, in combination with the knowledge of the given transformation kinetics under the local given micro-scale conditions is shedding light on the black box design and will improve the modeling approaches.

Phylogenetic analyses show that the PFRs harbour a longer time stabile broad phylogenetic diversity with high abundance of P*roteobacteria*, which represented more than 80% of the phyla in the reactors. More in detail the families *Comamonadaceae* and *Xanthomonadaceae* comprised more than 50% of the total population. The analysis of functional genes shows the existence of phenol hydroxylase group together with toluene 2-monooxygenase and dioxygenases as key enzymes of the aerobic. This finding of the dominance – proven by meta-proteom analysis – of aerobic toluene transformation processes are in contrast with the anaerobic status of the PFR.
A clear experimental strategy derived from scale up process known in biotechnology and sophisticated analytical tools are necessary to reach this goal of a deeper process understanding. The analysis of the well described microbial toluene degradation in the complex root-zone of an idealized lab-scale wetland reactor is demonstrating the successful strategy.

BIO: Uwe Kappelmeyer is a research engineer at the Helmholtz Centre for Environmental Research in the Ecological Water Treatment Technology group. Dr. Kappelmeyer research focuses on studying the fate and removal of contaminants from water and the involved microbial processes and the microbial diversity involved in root processes.

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DISSIPATION OF ATRAZINE AT THE SEDIMENT-WATER INTERFACE OF A WETLAND AND A BIORETENTION CELL

***Elodie Passeport**[1,2], Boris Droz[3], Leandra Rhodes[2] and Gwenaël Imfeld[3]*

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Atrazine is still one of the most widely used herbicide in many developed and developing countries, despite known and suspected adverse effects for humans and ecosystems. It is a relatively mobile chemical and therefore not consistently removed in passive water treatment systems. In this research, we aimed to provide a detailed characterization of atrazine biotransformation at the soil – water interface of two water treatment systems: a constructed wetland receiving agricultural stormwater runoff and a bioretention cell receiving urban stormwater runoff. A combination of methods including stable and radioactive isotope tools was applied to understand and predict herbicide atrazine transformation at the water-sediment interface. Microcosms with wetland sediments from Rouffach (France) and sediment from a bioretention cell from Vaughan (Ontario, Canada) were set up under both oxic and anoxic conditions. The major differences between the two sediments was the higher organic carbon content (12.1 vs. 2.3 %) and sand content (78.8 vs. 9.0 %) of the bioretention than wetland sediments. Atrazine transformation was monitored over time in both the liquid and the sediment phases. Changes in natural abundance stable carbon isotope ratios of atrazine was done using compound-specific isotope analysis (CSIA) by gas chromatography isotope ratio mass spectrometry; whereas, radio-labeled atrazine and transformation products were analyzed by HPLC with a radioactivity flow detector and an oxidizer with radioactivity trap.

Results from both radio and stable isotopes suggest that atrazine biotransformation in the liquid phase was similar under both oxic and anoxic conditions, but faster in the bioretention than wetland microcosms. The half-life$_{\text{liquid phase}}$ ± 1σ were 290±78 days in the wetland and 54±29 days in the bioretention cell in the oxic microcosms; and 227±67 days in the wetland and 35±16 days in the bioretention cell in the anoxic microcosms. Biotransformation in the sediment mainly varied according to sediment origin rather than prevailing redox conditions. No significant atrazine dissipation was observed in the wetland sediment, whereas half-life$_{\text{sediment phase}}$ was fast and ranged from 18±3 to 29±11 days in the bioretention cell sediment. Hence, the bioretention cell sediment showed larger potential for biotransformation, which may be due to a higher amount and different nature of organic carbon in sediment. Low mineralization (<5% after 50 days), i.e. carbon dioxide production, was found in all conditions suggesting accumulation of transformation by-products. Compound Specific Isotope Analysis will allow to evaluate the occurrence of *in situ* transformation versus other dissipation processes in sediment and tease apart transformation pathways if they differ in oxic and anoxic conditions. Altogether, this study constitutes a preliminary step for process-based interpretation of atrazine transformation at the water/sediment interface, and further use of transformation kinetics and isotope fractionation in predictive field studies.

<u>BIO</u>: Dr. Passeport is an assistant professor at the University of Toronto and Canada Research Chair in Environmental Engineering and Stable Isotopes. Dr Passeport's research focuses on studying the fate and removal of contaminants from water using passive water treatment systems such as constructed wetlands, algal ponds, and bioretention cells.

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EFFECT OF INDUCED AERATION ON NIRS AND NOSZ GENE COPY NUMBERS IN THE FILTER MEDIUM OF VERTICAL FLOW TREATMENT WETLANDS

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Induced aeration and the addition of carbon sources to improve TN removal in treatment wetlands (TW) are effective strategies for the treatment of wastewater with a low C/N ratio. Induced aeration in the wetland bed provide the oxygen needed for NH_4-N removal (nitrification) and the carbon source is a key element for NO_3-N removal (denitrification).

Four pilot vertical flow TW (VF) were built for the ECORKWASTE project (LIFE14 ENV/ES/460). The 1 m^2 pilots were built inside 1000 l IBC tanks. Two pilots were filled with cork by-product granulates (7 mm Ø, previously washed) and the other two were filled with gravel (5 mm Ø), with the objective to compare the pollutants removal efficiency between both substrates. One gravel pilot and a second cork pilot were operated with a non-aerated VF, whereas the other two were operated with a saturated aerated VF. An air pressurized system introduced atmospheric air to the substrate at a 30 l min^{-1} airflow rate.

Phragmites australis (4 plant/m^2) were planted at the beginning of a 3 months stabilisation period (Aug-Oct, 2017). The testing of the pilots started in November 2016 through March 2017. Synthetic wastewater (SW) with a 1 COD/N ratio was prepared with 300 g of corn starch, 3 l of nitrogen fertilizer and 150 g of sugar. The SW was pumped to the pilot beds in 25 l cycles (pumping rate of 0.5 l min^{-1}). Monthly, the hydraulic and TN loading rate, and aeration time were progressively increased from 50 l d^{-1} to 200 l d^{-1}, 10 $g{\cdot}m^2\ d^{-1}$ to 73 $g{\cdot}m^2\ d^{-1}$, and 1.6 h d^{-1} to 6.6 h d^{-1}, respectively. After the aeration time, a non-aerated period was carried out in the wetlands. The Influent and effluent were sampled on a monthly basis campaigns, three consecutive days per month. qPCR real time of denitrification genes was used to study nirS and nosZ gene copy numbers in the biofilm for both substrates.

Influent sample results showed a monthly increase for NH_4-N (5-59 $g{\cdot}m^2\ d^{-1}$) and NO_3-N (1-10 $g{\cdot}m^2\ d^{-1}$) loading rate. The aerated VF with cork as granular media, compared with the other pilots, showed a significant ($p < 0.05$) higher removal efficiencies for NT (28-40 %), NH_4-N (20-76 %), and NO_3-N (50-91 %). The denitrification genes copy numbers were higher in the aerated VF compared to non-aerated VF ($p < 0.001$). The nirS gene copy numbers were more abundant than the nosZ gene.

In addition to increasing the removal efficiency for NH_4-N, induced aeration increase the denitrification genes copy numbers on the filter media in treatment wetlands. Therefore, cork by-product used as a filter media has the potential of being an effective carbon source for wastewater treatment with a low C/N ratio. Both combined strategies, aeration and cork as a filter media, can be used to enhance the removal efficiencies for NT in treatment wetlands.

BIO: Lorena Aguilar is a researcher with 5 years of experience in the design, construction, operation, monitoring and maintenance of treatment wetlands. She has developed projects for enhancing the technical, environmental, economic and social aspects of the technology.

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RESPIROMETRIC TESTS FOR DETERMINING STOICHIOMETRIC PARAMETERS OF A FULL-SCALE HSSF CONSTRUCTED WETLAND

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This research studies the measurement of microorganisms' growth in biofilms from a full-scale CW treating municipal wastewater. The aim is to obtain heterotrophic growth yield coefficient values (Y_H), to establish a better understanding of the treatment process and to develop stoichiometric parameters for modelling. This research follows the work of Ho (2018) and transposes it from a lab-scale to a full-scale HSSF type CW with soil as filling media (Kickuth system) and planted with *Phragmites australis*.

The WWTP under study is located in Barroca D'Alva, 20 km from Lisbon. Wastewater treatment is achieved by a septic tank followed by 4 CW operating in parallel. Filling media samples were collected from one of the CW, at 9 evenly spaced locations, and were then placed inside the LSF respirometer (liquid phase, static gas, flowing liquid) which allows for fixed-biomass testing. The respirometer includes a closed box where the sample is placed, and water is recirculated between the outlet and the inlet. During the tests DO concentrations of water from an aerated tank placed before the inlet are measured and also at the outlet of the box. A tracer test was used to determine the exact HRT. VSS and TSS were measured to obtain the biomass in each sample.

Initially the main concern was the low hydraulic conductivity of the soil. The reactor box was adjusted with a gravel inlet and outlet cross-section so water would flow easier through the sample. The Y_H values obtained throughout the CW varied significantly, exhibiting storage in most of them. The growth yield resulting from direct substrate consumption (Y_H) and through storage mechanisms (Y_{STO}) were between 0.80 – 0.95 mg COD/mg COD, with outliers. During the tests of different samples three different types of OUR profiles were obtained (Figure 3), according to the classification proposed by (Pisoeiro et al. 2017).

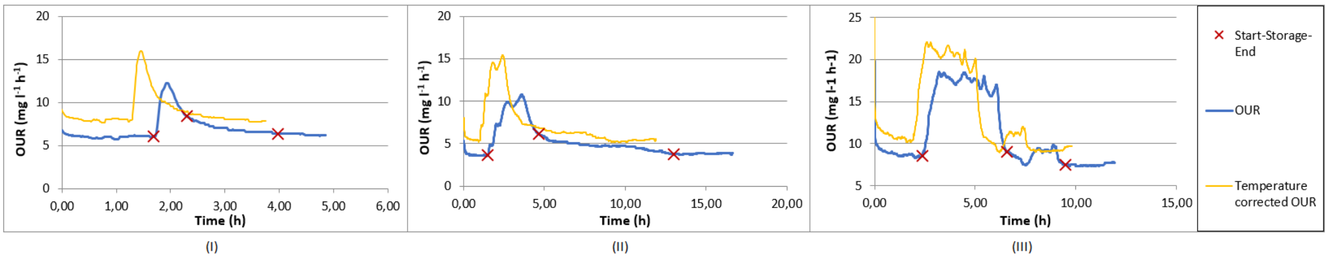

Figure 3: Three different types of OUR profiles obtained during respirometric tests

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Pisoeiro, J. et al., 2017. Determining stoichiometric parameters of detached biomass from a HSSF-CW using respirometry. *Ecological Engineering*, 98, pp.388–393.

BIO: Ana Galvão is an Assistant Professor at Instituto Superior Técnico, where she has been studying constructed wetland systems for more than 15 years. Her recent research interest also includes the adaptation of wetland processes to green walls, in order to provide greywater treatment for reuse in urban areas.

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SPECIAL SESSION 10

EFFECTS OF CLIMATE WARMING ON COASTAL WETLAND SERVICE

Siyuan Ye

UNRECOGNIZED CONTROLS ON MICROBIAL FUNCTIONING IN BLUE CARBON ECOSYSTEMS: THE ROLE OF MINERAL ENZYME STABILIZATION AND ALLOCHTHONOUS SUBSTRATE SUPPLY

Peter Mueller[1], *Dirk Granse*[1], *Stefanie Nolte*[1], *Stefan Hoth*[1], *Magdalena Weingartner*[1] *and Kai Jensen*[1]
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Tidal wetlands are effective carbon sinks, mitigating climate change through the long-term removal of atmospheric CO_2 from the atmosphere. Studies along flooding-frequency gradients in tidal wetlands are often used to understand the effects of accelerated sea-level rise on carbon sequestration, a process that is primarily determined by the balance of plant primary production and microbial decomposition. While clear and reproducible patterns of primary production in response to varying flooding frequency have been described, studies on the microbial-decomposition response yield a wide range of outcomes and equivocal results. The present study aims at improving our mechanistic understanding of how flooding frequency affects microbial decomposition processes by investigating exo-enzyme activities (EEAs), as the first and rate-limiting step of the decomposition process, and microbial abundance (fungi + bacteria) along a coastal ecotone stretching an elevation gradient from tidal flat to high marsh. Because exo-enzymes are substrate specific, their activity is not only a measure for the rate at which decomposition can proceed; it also represents the microbial demand for different nutrients, thus revealing insight into energy and nutrient constraints on the overall decomposition process. Our findings suggest two previously unrecognized mechanisms that may contribute to stimulated microbial activity despite decreasing oxygen availability in response to higher flooding frequencies. First, we demonstrate that the stabilization of exo-enzymes to mineral sediments leads to high specific EEAs at low substrate concentrations in frequently flooded, sediment rich zones of the studied ecotone. We argue that the high background activity of a mineral-associated enzyme pool could provide a stable decomposition matrix under these highly dynamic conditions. Second, we demonstrate that microbial communities are less nutrient limited in frequently flooded zones, because inputs of nutrient-rich marine organic matter are higher. This was reflected in both increasing exo-enzymatic carbon-vs.-nutrient acquisition and decreasing fungal-vs.-bacterial abundance with increasing flooding frequency.

<u>BIO</u>: Peter Mueller is a postdoctoral researcher with interest in plant-soil interactions, microbial ecology, and tidal wetland biogeochemistry.

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NUTRIENT REDUCTION REVERSES CARBON LOSSES IN COASTAL WETLANDS

***Thomas J Mozdzer*[1], *Joshua Caplan, Sophie Drew, Paige Weber and Bridget Reed*

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Coastal wetlands are highly productive ecosystems and coastal blue carbon sinks due to their high carbon sequestration rates, low decomposition rates, and negligible levels of CH_4 emissions. Recently, there has been a surge in studies inventorying blue carbon in coastal ecosystems; however, the influence of nutrient enrichment on carbon cycle processes and blue carbon pools is poorly understood. Previously, we reported that chronic nutrient enrichment increased ecosystem respiration by 20%, reducing the carbon storage capacity of tidal wetlands.

To evaluate how landscape-level nutrient management practices, such as nutrient reductions, can influence carbon cycle processes, we initiated a new study to evaluate the potential for ecosystem processes to return to reference levels with the cessation of nutrient enrichment. We measured CO_2 and CH_4 fluxes over two growing seasons post nutrient enrichment using static chambers in two paired previously nutrient enriched creeks (fertilized for 13 years) and two long-term reference creeks.

We found that the cessation of nitrogen enrichment reduced ecosystem respiration, returning rates back to reference levels within two years. As before, there was no discernable effect of previous nutrient enrichment on net ecosystem exchange (NEE) between our reference and the previously N-enriched ecosystems. Our results suggest that landscape-level management practices to reduce nutrient pollution can quickly reverse carbon losses from enhanced ecosystem respiration, restoring the carbon sink function of coastal wetlands.

BIO: Dr. Mozdzer is an associate professor in Bryn Mawr's Biology Department. He has nearly 20 years' experience researching coastal wetlands. His research is focused on understanding the effects of global change on greenhouse gas fluxes, carbon storage, plant ecophysiology, and invasive species.

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SOIL ORGANIC CARBON STORAGE CHANGES IN COASTAL WETLANDS OF THE LIAOHE DELTA, CHINA

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Stocks of soil organic carbon (SOC) are a key component in carbon capture and storage which can mitigate CO_2 increase and the global greenhouse effect. The Liaohe Delta (LHD) is among the large river deltas of the world and is an area that is heavily impacted by anthropogenic activities along with the severe impact of land-ocean interaction. Our purposes were (a) to identify the landscape area changes in coastal wetlands of the LHD, (b) to illustrate the spatial distribution of SOC pool, and (c) to estimate the SOC storage changes relative to landscape change in coastal wetlands of the LHD from 1991 to 2011.

Appling Landsat TM digital images of 1991 and 2011 for LHD, the landscape of LHD were divided into nine different landscape types. The soil organic carbon density was calculated based on the laboratory data of soil samples from field investigations in 2012. The soil organic carbon density was spatially interpolated by Kriging interpolation method of ArcGIS. Combined with areas of landscape types, the soil organic carbon stocks (0-20 cm) of the LHD in 1991 and 2011 were estimated. The results showed that the soil organic carbon densities varied in the range from 0.58 kg/m^2 to 9.75 kg/m^2 and the soil organic carbon storages were estimated about 1935.92×10^4 t in 1991 and 1863.87×10^4 t in 2011. There was 5750 km^2 (95.5 % of the total landscape area in 1991) involved in the transformations during 20 years. More and more natural wetlands were transformed to artificial landscapes or constructed wetlands by human activity. More than 79.73% of carbon storage was lost in tidal flats. We attribute this large loss of carbon in the soil profile to rapid land use changes. Constructions of levies along the shoreline have triggered large instantaneous losses of sequestered sediment carbon through the destruction of 278.06 km^2 of tidal flats. Our results revealed that LHD may not serve as a net sink of carbon. These results may serve as scientific guidance for decision makers in determining an effective way to maintain the soil carbon pool in the wetlands of LHD.

BIO: Dr. Zhao is a senior scientist with more than 10 years of experience on Geological Evolution, Habitat Succession, Carbon Cycle, Biogeochemistry of Coastal Wetlands

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EFFECTS OF CLIMATE WARMING ON COASTAL WETLAND VEGETATION ALONG A LATITUDINAL GRADIENT

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Global climate change is expected to affect plant performance and distribution, and the effects are expected to differ between latitudes, as higher latitudes will undergo stronger temperature increases than lower latitudes. Warming affects biological processes such as photosynthesis, respiration, but also litter breakdown and mineralization of nutrients. Changes in these processes can alter ecosystem productivity and thereby the ability to sequester carbon. Most natural wetlands have anoxic and highly reduced soils combined with very high primary productivity, and thus sequester carbon from the atmosphere and deposit it as organic carbon in the soil. Therefore, wetlands are mitigating the effects of climate change, but there is urgent need for understanding the effects of warming on wetlands ability to sequester carbon
Here, we present novel data from a manipulative, large-scale field study, where temperature was passively increased using open top chambers. The study was conducted in natural wetlands dominated by the tall grass *Phragmites australis,* at three sites along a 700 km north-south gradient at the northeastern coast of China.

Changes in carbon sequestration were evaluated based on photosynthetic gas exchange measurements and plant morphological and biochemical traits, such as plant height, basal stem diameter, Carbon:Nitrogen ratio and elemental composition. In addition, decomposition and breakdown of organic matter in warming and ambient temperature plots will be evaluated. Our results show that warming has an effect along the gradient and that the effect is strongest at high latitudes. Our results indicate how carbon sequestration in natural wetlands are altered by increased temperature and that natural wetlands can be used to sequester carbon thereby mitigating global changes.

BIO: Emil Jespersen is a PhD student working on how global climate change is affecting plant ecophysiology in natural wetlands.

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WARMING EFFICIENCY OF AN OPEN-TOP CHAMBER AND ITS EFFECTS ON PLANT MORPHOLOGIC TRAITS ACROSS LATITUDE GRADIENTS AND HABITATS IN THE COASTAL WETLANDS OF NORTHERN CHINA

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Global warming is evidenced by higher atmospheric temperatures, decreased snow and ice cover, and increasing sea levels. Projected increases of temperatures will likely alter the rates of soil chemical reactions and biogeochemical processes in wetlands, and facilitate a shift in the seasonal cycles of production and decomposition of organic matter. This may intensely change the ecosystem services provided by coastal wetlands both qualitatively and quantitatively. To study the effects of climate warming on coastal wetlands, a set of six open-top, passive-warming chambers (OTC) were established at each of four sites along a latitudinal gradient in Northern China: Yancheng, Yellow River Delta, and Liaohe River Delta. Sites were dominated by *Phragmites* but on 1 site (Yancheng) *Spartina* was also included in our design. We tracked the warming efficiency of the OTC designs using in-situ continuous environmental data collection, and combined these with plant observations to rate the influence of chamber warming to plant morphologic traits. Our results show that the physical process of warming these chambers depends greatly on heat sources of incoming radiation in the daytime versus soil heat flux at night. Warming effects were often instantaneous and influenced OTC air temperatures from -3 to 10 °C dependent on various meteorological conditions. Nighttime temperature depression events within the OTCs were due to the low turbulence inside the OTCs and the surface soil-atmosphere heat transfer. Significant responses of plant morphologic traits were detected, including plant shoot density and biomass decreases, and plant height and stem diameter increases. Extensive pest damage to plant leaves were noted, and warming facilitated soil dehydration in the OTCs deployed on the 3 *Phragmites* sites.

BIO: Dr. Siyuan Ye Senior Scientist and the Director of Key Laboratory of Coastal Wetland Biogeosciences, China Geological Survey (CGS). She has been worked as a coastal wetland scientist with the Institute of Marine Geology, CGS for 28 years, and led more than ten projects dedicated to geochemistry and carbon cycles.

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SPECIAL SESSION 11

CONSTRUCTED WETLANDS PROJECTS UNDER HOT AND ARID CLIMATES

Alexandros Stefanakis

SLUDGE TREATMENT REED BED TECHNOLOGY UNDER HOT AND ARID CLIMATE

***Steen Nielsen*[1]**
[1] Orbicon A/S, Denmark

In order to test the application of Sludge Treatment Reed Beds (STRB) in hot and arid climate conditions. Pilot projects in Wacol, Coolum and Pimpama were established in 2016-2019 in Australia. The pilot plant in Wacol, Southeast Queensland. Did operated for 18 months. European systems generally sustain loading rates between 30-50kg DS/m2/yr, the pilot trial in Wacol demonstrated better efficiency rates, achieving sustainable loading rates between 60-80kg DS/m2/yr due to efficient airdrying and high plant evapotranspiration rates. This paper outlines the results, opportunities and challenges from the implementation of STRB in a subtropical climate, and the design and operational adjustments required to ensure longevity and efficiency of the system. The pilot plant involved four – five sludge treatment reed beds built using Intermediary Bulk Containers (IBC's), each with a treatment surface area 1.2m2. The filtrates were collected, the flow rates were measured and evaluated as an indicator of dewatering efficiency. The monitoring and testing activities included analysis of inlet sludge (RAS) as well as filtrate from all IBCs. Monitoring of inlet sludge quality was critical to accurately establish the total areal loading rates applied onto the system (kg DS/m2/yr), and monitoring of the filtrate quality highlighted the filtration potential of the system. Visual plant health monitoring was analysed in parallel with soil moisture data and filtrate flow rates to establish the optimal loading rates and program for the system. After completing a series of loading programs, it was established that the system in Wacol could achieve a sustainable loading rate of 60-80kg DS/m2/yr. A sustainable loading rate for a STRB system was a loading rate at which plant health was maintained, and the efficiency rate of the system was stable over several loading rotations. The high efficiency rates achieved were attributed to the efficient air drying of the sludge residue facilitated by high ambient temperatures, as well as plant evapotranspiration rates. The trial also revealed that local climatic conditions achieved such a high dewatering efficiency which required modification of the loading patterns traditionally used in cooler climates in order to maintain optimal plant health and therefore system longevity. It is not uncommon in cooler climates to operate STRB with the same loading program all year round, without significant operational changes between summer and winter seasons, and rest/drying periods for each bed between loadings can reach up to 9 weeks. The results of the trial show that over the summer season, when temperatures can be in excess of 40C for extended periods of time, moisture levels in the soil layer (located directly below the sludge residue build-up) can drop extremely fast to critical levels below 20%, affecting plant health when sustained for more than a few days at a time. Effects on plant health was visually noticed through wilting. In order to maintain plant health while ensuring efficiency and longevity of the system, the loading program was altered to allow for a winter and a summer loading schedule which maintained the annual loading rate, while modifying the patterns of loading and the rotation time between beds. The results from the pilot plans demonstrated the opportunities and challenges arising from the implementation of STRB in a hot climate, and outline the requirements for design and operational adjustments necessary to ensure efficiency and longevity of the system. The fast and more efficient drying of the sludge residue allows for higher areal loading rates to be applied and shorter resting periods between basin rotations, which can allow for a reduced number of basins needed than for systems in cooler climates.

BIO: Steen Nielsen is a senior manager with more than 30 years' experience with Sludge Treatment Reed Bed System dimensioning and operation in relation to climate and sludge quality and with construction, rebuilding and operation of more than 70 full scale and test system. He has authored and coauthored more than 30 papers.

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THE AQUIFER RECHARGE AND RECOVERY PROJECT: INTEGRATED RESERVOIR, WETLAND AND SAND FILTER FOR NATURAL TREATMENT OF MINE STORMWATER

James S. Bays[1] *and Raphael Vazquez-Burney*[1]
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The Aquifer Recharge and Recovery Project (ARRP) is a multiple purpose water resource project designed to process 7 megaliters per day of phosphate mine stormwater in an existing above-ground water storage area and to treat that water naturally through reclaimed wetlands and sand tailings. Constructed between 2010-2011, the system was operated and monitored from January 2012 through January 2014. Stormwater collected from mine drainage ditches is pumped to a 169 hectare (ha) Storage Reservoir, two Wetland Cells (39 ha and 115 ha) connected in series by two weir structures, and a 0.8 ha lined engineered Sand Filter. Future application was intended to include a deep recharge well to return treated water to the aquifer for water supply enhancement.

The ARRP was monitored from January 2012 through January 2014 during establishment and initial operation. This demonstration period allowed assessment of system response to water depth control and hydraulic loading and allow operational guidance to be developed. The sequence of open water reservoir, dense marsh, open water marsh, and sand filter functions created environments supporting sedimentation, precipitation, and biological transformation of a wide range of common water quality pollutants.

Turbidity, total suspended solids and volatile suspended solids decreased by 77%, 84%, and 88%, respectively. Algal biomass, as measured as chlorophyll a, decreased by 72%. Color decreased on average by 23%. Calcium and sulfate declined significantly through the system by 33% and 46%. Total phosphorus decreased by 92% and orthophosphate decreased by 96%. Total phosphorus averaged 0.44 mg/L from Cell 2 and 0.23 mg/L from the Sand Filter. In contrast, total nitrogen showed a net gain through the system from vegetative leaching, internal recycling and algal-mediated nitrogen fixation. Total nitrogen averaged 3.9 mg/L from Cell 2 and 2.0 mg/L from the Sand Filter.

Much of the improvement in water quality can be attributed to the Sand Filter. While the operations of the Sand Filter require further optimization, the data indicate that the filter can receive a very high hydraulic loading (56 centimeters per day), and with that, a significant organic load. An operational schedule developed to dry down or rest the system periodically to help sustain long-term performance was developed and other full-scale sand filters are in operation or in design by phosphate operations in Florida to manage stormwater flows.

BIO: Mr. Bays is a senior wetland ecologist specializing in the planning, design and monitoring of natural treatment systems for water quality improvement and habitat creation. His projects have been implemented nationwide and outside of the United States in Australia, Asia, Canada, Europe, and Latin America.

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TREATMENT WETLANDS IN ARID CLIMATES: NEW PILOT-SCALE RESULTS AND EXPERIENCE WITH FULL-SCALE SYSTEMS IN JORDAN

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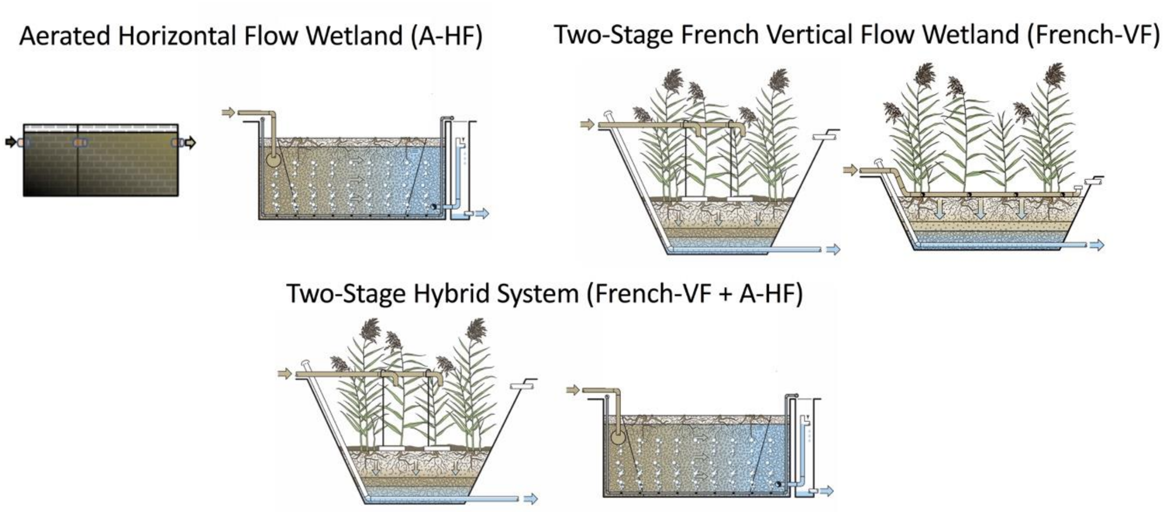
There is a recognized lack of reliable data available on treatment efficacy of constructed wetlands in arid climates. Moreover, operation and strict discharge regulations for Total Nitrogen (TN) TN and *E. coli* in arid climates have been identified as sever constraints for conventional vertical flow wetland. Over the last ten years, intense work has taken place to identify operational and design modifications that can improve treatment efficacy for these pollutants. This study reports the first results from three pilot-scale treatment wetland trains as well as strategies to adapt existing wetland designs at a decentralized wastewater treatment research and demonstration facility in Fuhais, Jordan. Three new wetlands were designed with the aim to provide improved TN and/or *E. coli* removal compared to the conventional VF treatment wetlands already installed at the facility (Figure 1). The first system is an aerated horizontal flow wetland (A-HF); the second system is a two-stage French vertical flow wetland (French-VF), and the third system is a hybrid, first-stage French VF followed by an aerated HF wetland (French-VF + A-HF).

Figure 1. The three treatment wetlands. Wetland drawings are modified from Dotro et al. (2017).



This presentation will cover the first year of monitoring for the three treatment systems for classical wastewater parameters (COD, $CBOD_5$, TN, NH_4-N, NO_3-N, and *E. coli*). Influent and effluent water quality was monitored once per month for each system. Lessons learned from the construction and operation of treatment wetland systems, including two full-scale aerated HF, in Jordan will also be discussed.

Reference: Dotro G., Langergraber G., Molle P., Nivala J., Puigagut J., Stein O., von Sperling M. (2017) Biological Wastewater Treatment. Volume Seven: Treatment Wetlands. London, UK: IWA Publishing.

BIO: Thomas Aubron is a research engineer with over 10 years of experience in decentralized wastewater treatment. He specializes in the planning, design, implementation, and optimization of aerated treatment wetlands.

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CONSTRUCTED WETLANDS FOR HORTICULTURAL WASTEWATER TREATMENT IN ETHIOPIA: AN OVERVIEW

Frank van Dien
ECOFYT, The Netherlands

More than eight years ago ECOFYT was contacted by a design department of the government of the Netherlands to help investigate if constructed wetlands could give a solution for the waste water problems of the biggest rose farm in the world, in Ethiopia.

We had several meetings with one of the directors (who had never heard of CWs and was not very confident) before arrangements for an investigation in situ were set. After that, designs were made for a pilot project, consisting of four individual beds, in different locations.

We investigated both horizontal and vertical flow and knew that we could not afford to do in depth research: visual results were most important to get consent. And just a few meters like pulse counters and time counters for the pumps, combined with weekly reports of the readings by local workers, would help us to keep track of the technical well being of the wetlands.

When it was operational for a few months, the same director was shown the in- and effluent, in a glass. And that is where he became enthusiast: "I want this all over the farm!"
We explained him that 'just the water being clear' would not be enough, it should also be analysed on the usual parameters, in order to see if the systems were working properly.

The pilots were sponsored by the Dutch government and so was the following research project: Funds were given to an Ethiopian NGO to take the lead, whereas Alterra (Wageningen University) and ECOFYT would do the field work and the writing, while the chemical analyses were done both by an Ethiopian and a Dutch lab.

When all data was gathered, in a series of samples, and put in excel sheets and evaluated, and the entire pilot described in a report, the document was peer reviewed by the RIVM, a governmental department dealing with environment and health issues.
And after approval, it was published.

But the work continued: the four wetlands were for two lines of greenhouses but there were thirteen lines at that time - and expansion was already envisioned.

The evaluation of the pilots led to choosing for vertical flow systems and calculations for the size of the next systems were made.

The pilots were made by the local workers, supervised by Alterra and ECOFYT but the rest of the wetlands should be made under supervision of the company's own technical staff.

ECOFYT remained closely involved for occasional technical visits and most of all: weekly reports over a growing number of working wetlands and pumps. In 2018 the last wetland was set to work, nr 67!

In my part of this session, I will elaborate on a few of the problems we encountered over the years.

BIO: Founder and Director of ECOFYT

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CONSTRUCTED WETLANDS FOR MUNICIPAL AND INDUSTRIAL WASTEWATER TREATMENT IN MIDDLE EAST: AN OVERVIEW

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The Middle East region is the driest region of the world with only 1% of the world's freshwater resources, while agriculture and domestic needs are the two main water consuming sectors. Around 50% of domestic, municipal and industrial wastewater generated in the Middle East region is treated. The Middle East region has an opportunity for beneficial reuse of wastewater but only few countries in the region have been taken initiatives to enhance their wastewater treatment sector and activities and also further promote and apply reuse programs. Almost 70% of the total available water in these countries is allocated to agricultural purposes, where water losses due to inadequate irrigation techniques are also significant. Climate change and population growth will make the water allocation under the water demanding sectors more difficult in the near future. In addition, there is a growing scientific consensus that climate change will further reduce precipitation levels and will further increase temperatures in Middle East countries; both of these trends seem likely to add on the existing stress on regional water resources.

In recent years, rapid levels of urbanization and population growth have created a need to improve the water infrastructure in urban and peri-urban areas across the region, though there are still many remote settlements. Till today, governments and municipalities prefer a centralized approach, where the wastewater is conveyed and treated away from the urban context. Despite the benefits of this approach (e.g., cost efficient systems for large volumes), their main disadvantage is that the treated effluent needs to be pumped to the locations where it is needed. This translates to significant infrastructure and energy requirements. Under this frame, the decentralized approach is gaining interest; it can be applied on different scales, has lower transport costs, provides security of supply, flexibility to adapt to local changes and the produced effluent is closer to the area where it can be exploited/reused. Additionally, mechanical treatment systems such as activated sludge and membrane bioreactors, although widely used, have high-energy demand and high operating and maintenance cost, while lack of local expertise and poor governance is often an issue. Hence, nature-based technologies such as Constructed Wetlands are expanding in MENA region, as their multiple economic and environmental benefits are slowly but increasingly better realized.

This paper will present the status of nature-based solutions in the Middle East, through a number of constructed wetland projects from different countries in the region, as reference and exemplary designs that have been implemented. These case studies cover a wide range of wastewater types and sources, such as domestic, municipal, runoff and various industrial wastewaters. Finally, experiences gained from the implementation of wetland projects in Middle East will be summarized, with focus on the challenges as well as the opportunities that occur in this region.

<u>BIO</u>: Dr. Stefanakis is a professional Engineer, Researcher and academic Lecturer with more than 13 years of experience in designing, managing and implementing wetlands construction and research projects internationally. He has extensive experience with wetland systems for various industrial applications, sludge dewatering and/or municipal wastewater, as well as reuse of treated effluents for irrigation.

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SPECIAL SESSION 12

ELECTROACTIVE BACTERIA BASED TREATMENT

Abraham Esteve-Núñez

A NOVEL DEVICE TO INCREASE THE ELECTRON SINK IN METLANDS

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Base on the concept of METland®, Microbial Electrochemical Wetland, this experiment has incorporated a novel device to increase the electron sink. Therefore, the efficiency of the wastewater treatment process improved.

Wastewater treatment is based on biological degradation of the sewage through oxidative reactions where microbes generate electrons. These treatments are usually limited by the availability of electron acceptors, such as oxygen. Microbes operating at METs, the so-called electroactive bacteria (EAB), break down organic compounds while forming a biofilm on an electroconductive material. EAB are able of giving electrons extracellularly directly to the bed material. All those electrons are finally consumed by soluble electron acceptors present in the water. The presence of the conductive material has been proved to accelerate the biodegradation rate of bacteria through Direct Interspecies Electron Transfer (DIET).

In order to reduce the bottleneck that involves the electrons transport from the electroconductive bed to the last electron acceptor, electrons sink was designed. E-sinks were buried in the electroconductive bed, thus the concentration of electron acceptor in the system was increased. This allowed the degradation reactions of organic matter to be much faster throughout the electroconductive biofilter depth.

To evaluate the effect of these devices, three laboratory-scale electrogenic biofilters have been implemented each one with a different bed material coke, biochar and gravel. The systems were fed with urban wastewater and the efficiency was evaluated. For this purpose, different physical-chemical parameters have been measured, such as COD, BOD_5, NH_4^+, NO_3^-, pH and conductivity. In addition, Electric Potential (EP) profiles were analyze in order to evaluate the electrons flow, depending on the electron acceptors available in the system.

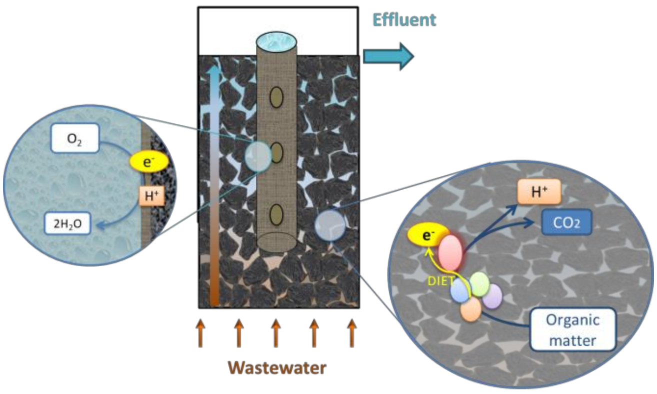

Figure 1. Outline of the electrogenic system for wastewater treatment.

BIO: Amanda Prado de Nicolás is a predoctoral researcher part of Bioe group. She is currently working on her doctoral thesis focused on the wastewater treatment through the use of electrogenic wetlands, METlands®. In addition, she has been linked to different European H2020 projects, notably the iMETland project.

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MICROBIAL FUEL CELL-CONSTRUCTED WETLAND: SOME FORESEEABLE RESEARCH DIRECTIONS

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Conventional wastewater treatment system, i.e. activated sludge process, has been well argued as energy-intensive approach of using massive energy to destroy potential pollutants' energy for wastewater treatment. Microbial fuel cell-constructed wetland integrating system (MFC-CW) is an emerging wastewater treatment technology. It converts potential energy in wastewater into bioelectricity during wastewater treatment process via bioelectro-chemistry. There are serious of mechanisms within MFC-CW such as physical and chemical absorption, redox reactions, biological digestion, and plant uptake etc. Increasing studies worldwide have demonstrated its promising as wastewater treatment and simultaneous bioelectricity production. This paper wishes to discuss some foreseeable research directions for the peers regarding R&D of this technology.

For the time being, we proposed the directions which have the most potential and worth to be further explored in the near future (Fig. 1). They are: 1) extended study on enhanced wastewater treatment efficiency, especially the biorefractory compounds removal, like Pharmaceutical and Personal Care Products (PPCPs) or Micro-Plastics (MPs) etc. In addition, the electrode based autotrophic nitrogen removal in CW-MFCs also deserves to be deliberately studied; 2) bio-sensor development; 3) heavy metal Ions removal & recovery (R&R) via the concept of the modularized "electrode wall", which could be attempted as a "filter" to capture and then accumulate these metal ions in the form of precipitations; and 4) the green house gas (GHG) emission reduction via the MFC-CW system. This MFC in MFC-CW enables it use CH_4 as the fuel to sustain the anodic reactions. Therefore, the concept of retrofitting CWs with CW-MFCs has the potential and ability to further reduce the supposed CH_4 emissions from CWs. This extension of MFC-CW could be a very interesting and meaningful direction for further investigation.

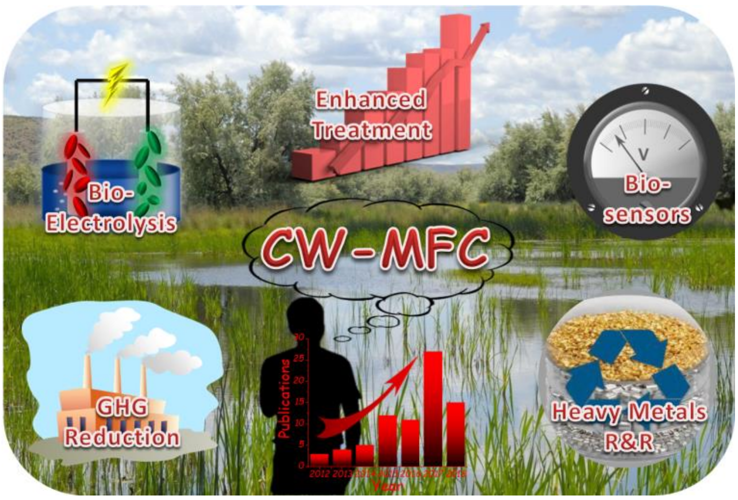

Figure 1. Overview of the future development of the CW-MFC technology

BIO: Dr Yaqian Zhao is a Professor in Xian University of Technology and he is also a visiting professor of University College Dublin, Ireland. He has been working in constructed wetlands for 20 years regarding R&D of this technology. He has made great efforts to promote constructed wetlands in China in the last ten years.

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ELECTRIC POTENTIAL IN ELECTROACTIVE BIOFILM-BASED CONSTRUCTED WETLANDS: CURRENT FLOW DENSITY AS A PERFORMANCE INDICATOR

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An Electroactive Biofilm-based Constructed Wetland (EABB-CW) is a wastewater treatment system that relies on the presence of electroactive bacteria (EAB) to enhance the degradation of pollutants. Compared to other microbial electrochemical setups, EABB-CW is designed in short-circuit mode (dispensing of external circuits) and uses an electro-conductive substrate acting as a single-piece electrode. A major challenge of this type of system is to correlate the EAB metabolism with the electrical current generation and hence with the removal of pollutants. In environments with the presence of EAB, electric fields are created by anodic and cathodic reactions, therefore generating ionic/electron currents that can be quantified. That quantification can be done by measuring electric potentials (EP), with the aid of sensors insensible to redox active compounds, but able to collect low current signals in highly conductive matrixes.

The aim of this research was to test the removal of organic matter and nutrients in an EABB-CW, and their correlation with the presence of EAB through measurements of electron current density *(J)* and electron transfer rates *(R)* in the tested columns. The experiment was carried out testing mesocosm (EABB-CW) with two different types of electro-conductive materials (PK-A and PK-LSN), fed with real wastewater at two different flow regimes (up and downflow). The results show that the electroconductive systems are able to reach removal efficiencies between 85% and 95% for COD, between 29% and 48% for NH_4-N, up to 20% for NO_3-N, and between 82% and 89% for PO_4-P.

The EP profiles show differences among the tested systems, indicate the development of different conditions for the establishment of EAB. Derived electron current densities *(J)* indicate that electroconductive systems have maximum values of 0.015 mA cm^{-2} for PK-LSN systems and of 0.024 mA cm^{-2} for PK-A, whereas 0 mA cm^{-2} for gravel systems.

The measure of electric profiles (EP), electron current densities *(J)* and electron transfer rates *(R)*, seems to be a promising approach to characterize the dynamics inside electro-conductive systems that uses electro-conductive matrixes like in the EABB-CW systems tested in this study. For example, the correlation between COD concentrations at outlet and J densities could be used to monitor the performance of this kind of CW set-ups.

It was possible to identify a positive impact in the removal of organic matter and up to certain extend the removal of nutrients with the tested electroconductive systems. The obtained results open the possibilities of exploring the development of modifications to improve nitrification that will redound in better total nitrogen, like implementation of unsaturated zones, assisted aeration at minimal rates, recirculation of part of treated effluent, among others.

BIO: Dr. Ramirez-Vargas is a postdoc fellow with interest in the combination of constructed wetlands with microbial electrochemical technologies as treatment intensification alternative. He has an experience of 10 years as contractor and research assistant in different projects related with engineering and management of water and sanitation alternatives, including constructed wetlands.

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EMERGING CONTAMINANTS REMOVAL IN CONSTRUCTED WETLANDS OPERATED AS BIOELECTROCHEMICAL SYSTEMS

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Emerging organic contaminants (EOCs) removal has been investigated in CWs operated as bioelectrochemical systems (BES). Samples for EOC analysis have been taken and are now being processed. The implementation of BES, such as microbial fuel cells (MFC) or microbial electrolysis cells (MEC), in constructed wetlands (CW) have only recently been investigated in the last few years and the majority of experiments have been designed as lab-scale systems working under unrealistic hydraulic conditions using synthetic wastewater. The present experiment used CW meso-scale systems with a more realistic horizontal flow regime and continuous feeding of real urban wastewater, comparing duplicates of conventional CW control and CW systems incorporating closed-circuit MFCs and MEC cells.

EOCs encompass a large and diverse set of active compounds, ranging from pharmaceuticals and personal care products to plasticizers, surfactants and herbicides. These substances reach the environment mostly via wastewater treatment plant discharges with yet unknown potential ecotoxicological effects to the environment and human health. EOC removal in BES systems has shown promising results (Cecconet *et al.* 2017) and the one publication known to the authors on EOC removal in CW-BES claims good removal results as well (Berná et al., 2018).

The seven investigated EOCs - namely ibuprofen, carbamazepine, diclofenac, sulfamethoxazole, naproxen, tris (1-chloro-2-propyl) phosphate and benzotriazol were doped into the experimental system´s feeding tank during each refill (all weekdays). Five days before the first sampling, the systems were doped for the first time (system HRT is ca. 2 days). Five sampling campaigns were conducted within three weeks, in which grab samples were taken from the feeding tank before (background concentration) and after doping (initial concentration) as well as from the CW influent and effluent. Samples were filtered (0.7 µm Whatman™ glass microfiber filters GF/F), pre-concentrated by solid phase extraction (SPE) (Strata™-X cartridges, 33 µm polymeric reversed phase) and are now being analyzed by GC-MS/MS as described by Matamoros and Bayona (2006). The authors expect improved EOC removal in CWs incorporating MFC and MEC cells as compared to the CW control, generally due to previously described improved COD and ammonium removal, and with regards to EOCs especially if they are hydrophobic (better adsorption onto electrodes) and positively charged (better interaction with the negatively charged biofilm) (Cecconet *et al.* 2017).

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BIO: Marco Hartl is a PhD researcher at UPC Barcelona and the University of Gent on the topic of combining constructed wetlands and bioelectrochemical systems for improvement of treatment efficiency and operation of CWs. Before that, he worked in the industry coordinating a CW research project in the Sultanate of Oman.

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MICROBIAL ELECTROSYNTHESIS CELLS FOR THE ENHANCEMENT OF PURIFICATION PROCESSES IN TREATMENT WETLANDS

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Rising nitrogen concentration in waterbodies has led to situation where enhanced water purification systems are needed to overcome environmental issues such as groundwater pollution and eutrophication. With nitrogen pollutants, the main problem is low organic carbon (TOC) to total nitrogen (TN) ratio in water, thus inhibiting heterotrophic denitrification where nitrate (NO_3^-) is reduced to nitrogen (N_2). To overcome this problem, often different types of organic carbon compounds are added. However, when it comes to groundwater, such purification practice is not possible, because adding organic carbon causes secondary pollution. That is why another type of purification process is necessary. One possible solution is considered to be the use of microbial electrosynthesis cells (MECs), where electricity is used to drive autotrophic denitrification. In this process the need for organic carbon is relieved by electrons which are provided by electrodes. Some laboratory scale studies have been conducted where MEC are used and the results are promising but much research is needed to develop systems that can be widely used.

To get better understanding about different factors in these systems, a two-chamber MEC, with total volume of 5.85 L was constructed and operated on synthetic wastewater for 45 days. Carbon cloth and stainless steel mesh, processed with carbon powder, were used for cathode and anode electrodes respectively. Both chambers where separated by cation exchange membrane and sludge from wastewater treatment plant was used as inoculum in cathode chamber. For inoculation the cathode was polarized at +150 mV vs saturated calomel electrode (SCE) for 7 days. After that the polarization was changed to −550 mV vs SCE to enhance denitrification. During the experiment pH and oxygen concentration were measured to evaluate how much electricity affects abiotic conditions in the reactor. In water samples total carbon (TC), TOC, TN, NO^-_3, nitrite (NO^-_2) and ammonium (NH^+_4) concentrations were measured to assess nitrogen removal efficiency and gas samples were taken to analyse carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) fluxes. Cyclic voltammetry measurements and electrochemical impedance spectroscopy were performed for electrochemical analysis.

Total nitrogen removal efficiency was 83% and 79.4% in MEC and control reactors, respectively. Average NO^-_2 concentrations were higher in MEC than in control (0.63±0.70 and 0.18±0.24 mg NO_2-N/L). Because of electric manipulation MEC reactor managed to sustain lower oxygen concentration in cathodic chamber than in control reactor (0.20±0.10 and 0.38±0.29 mg O_2/L) however in MEC reactor pH raised, which had to be suppressed by adding acid. MEC also acted as a CO_2 sink while control reactor acted as CO_2 source (−2.07±10.96 and 30.49±20.86 mg CO_2-C/($m^2 \cdot h$), respectively).

This work was supported by the European Structural and Investment Funds.

BIO: PhD student of environmental technology

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SPECIAL SESSION 13

NATURE BASED SOLUTIONS IN CIRCULAR ECONOMY - DISSEMINATION AND PRACTICE

Katharina Tondera

NEVER TOO EARLY: KICK-STARTING NATURE BASED SOLUTION SYSTEM EDUCATION

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[2]Royal Military College of Canada, Environmental Sciences Group, Kingston, Canada

Treatment wetlands are able to treat a large diversity of wastewaters ranging from domestic wastewater to industrial wastewaters of various origins. They can handle organics, nutrients, pathogens, pharmaceuticals, nanoparticles; almost any contaminant evaluated has been handled by treatment wetlands to some degree. Treatment wetlands have been shown to be resilient to perturbations including operational upsets, and even large amounts of antibiotics. They can operate year-round with the proper design, and in some cases with minimal maintenance requirements. Yet, treatment wetlands are still not seen as a viable water treatment solution in some jurisdictions. There are many potential reasons for this, however, one way to assist in treatment wetlands gaining further acceptance in some jurisdictions is through dissemination.

It is often said that the field of treatment wetlands requires a collaborative and multi-faceted approach due to the complexities involved. Hydrology, geology, microbiology, botany, and many other scientific fields intersect when it comes to treatment wetlands. This makes comprehensive and mechanistically informing research difficult to achieve in any single study. However, it could be also said that treatment wetlands are relatively modest in terms of their operation due to the innate “self-design” they offer. It is this interesting duality which make them a great example or central point for teaching about nature-based solutions, specifically when it comes to waste- and storm water purification. Perhaps if treatment wetlands are seen as a more common or conventional water treatment solution to the greater population (i.e. beyond a selection of engineers and scientists) the technology will gain additional acceptance and use in jurisdictions where they are currently underutilized. One way in which to accomplish this is to introduce the concepts behind treatment wetlands to individuals at a younger age.

This presentation will describe an approach being taken by the authors to develop a children’s book based on the main scientific concepts behind the abilities of treatment wetlands to purify water. Using the pedagogical concepts of discovery, and connections/concept-mapping the story is primarily meant as the basis for a science technology engineering and math (STEM) book for children. The story is centered around young twins and their family in a situation/area impacted by combined sewer overflows. The pedagogical construction of the story as a STEM book will be presented along with the main reader learning outcomes, and how the story construct can be transferred to learning and education at a higher level and other educational forums or contexts.

<ins>BIO:</ins> Dr. Weber is an Associate Professor working in the area of treatment wetlands for over 10 years. Kela’s main focus is in better understanding the fundamental mechanisms and dynamics involved in treatment wetland operations. Kela is also passionate about teaching, helping to currently fuel two collaborative book projects.

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THE COST ACTION CA17133 CIRCULAR CITY

Günter Langergraber [1] *and Natasa Atanasova* [2]
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Resource depletion, climate change and degradation of ecosystems are challenges faced by cities worldwide and will increase if cities do not adapt. In order to tackle those challenges, it is necessary to transform our cities into sustainable systems using a holistic approach. One element in achieving this transition is the implementation of nature-based solutions (NBS). They can provide a range of ecosystem services beneficial for the urban biosphere such as regulation of micro-climates, flood prevention, water treatment, food provision and more. However, most NBS are implemented serving only one single purpose. Adopting the concept of circular economy by combining different types of services and returning resources to the city, would increase the benefits gained for urban areas.

The COST Action CA17133 "*Implementing nature based solutions for creating a resourceful circular city*" aims to establish a network testing the hypothesis that a circular flow system that implements NBS for managing nutrients and resources within the urban biosphere will lead to a resilient, sustainable and healthy urban environment.

To tackle this challenge the Action comprises five working groups (WGs):

- WG1: Built environment
- WG2: Sustainable urban water utilisation
- WG3: Resource recovery
- WG4: Urban Farming
- WG5: Transformation tools

The network of researches, companies and stakeholders from more than 40 countries spread over whole Europe brings together a large diversity of disciplines and is therefore well equipped taking holistic approach on embedding NBS within circular economy. In the presentation we will present the first results already achieved and the future plans of the Action.

Acknowledgement: The work is carried out within the COST Action CA17133 (22.10.2018-21.10.2022). The authors are grateful for the support.

BIO: Günter Langergraber is senior scientist at the Institute of Sanitary Engineering at BOKU University Vienna in Austria with more than 20 years' experience in treatment wetland research. His wetland research focusses on optimising vertical flow wetlands for domestic wastewater and numerical modelling for subsurface flow treatment wetlands, respectively.

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BLUE GREEN INFRASTRUCTURE IN URBAN DRAINAGE – DO WE GET IT RIGHT IN GREY WHITE CLIMATES?

***Godecke Blecken*[1]**
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Urban stormwater management has traditionally focused on fast discharge of runoff water in pipe-based systems, largely without taking environmental issues, natural water cycle etc. into consideration. Today, a paradigm shift happens which involves a more holistic view by incorporating issues such as water quality treatment and receiving water ecology on the one hand and safe, attractive built environments on the other hand. Concepts as e.g. Water Sensitive Urban Design (WSUD) or Sustainable Urban Drainage (SUDS) include the implementation of Blue Green Infrastructure (BGI), Nature Based Solutions or, a bit less fancy term, Stormwater Control Measures. These techniques involve natural wetland features in different ways and scales.

In Sweden, due to interpretation of the Water Framework Directive and the *Weser Case*, stormwater quality treatment has gained very much in focus in the last few years. Also flood risk protection and/or climate change adaptation are often targeted; awareness has raised due to some severe storm events in recent years and updated recommendations by the Swedish Water Association. Thus, currently a huge number of BGI facilities, many of these in very small scale, for quality treatment and flow/volume retention are implemented or planned. Besides these more technical objectives, livability, amenity, urban greening etc. are also commonly targeted with these facilities. While very little effort was spent on BGI in the early 2000's, this has changed completely and (provocatively said) the market increases more than the knowledge about BGI design and functionality. In this context, some questions arise which will be discussed in the proposed presentation.

Despite explicitly expressed technical targets (treatment, retention), in many projects landscape architects or planners are solely responsible for the design of BGI. (How) can it be assured that these facilities will deliver the intended technical functions? Are there indications, that implemented facilities will not work? Or are the main beneficiaries of BGI simply not water quality and flood risk protection, but livability and amenity?
While the facilities always are "blue-green" on the provided drawings, during large parts of the year (autumn, winter, partly spring), Sweden's weather is black, grey or white. Are the proposed facilities adapted to these conditions or are simply copy-pasted solutions from warmer temperate climates implemented? How will that affect the function and appearance of BGI over time? Are there solutions that can be better adapted? Do we need Blue-green-white solutions?
Many small scale BGI facilities are planned and implemented and de-central Stormwater management within the catchment is prioritized. It is commons sense not to propose end-of-pipe solutions. This may imply challenges, which will be discussed.

It can be concluded, that WSUD and SUDS are promising concepts, but that many questions regarding their implementation still have to be answered. Especially in more demanding climates (cold climate in Sweden's case) implementation of BGI faces challenges which are currently ignored. This poses threats for the function and public acceptance of BGI in the longer term.

<ins>BIO:</ins> Godecke Blecken is associate professor at Luleå University of Technology in Sweden. His research focus is design and function of stormwater control measures. A special focus here is on cold climates. Another main research topic is related to the long-term function of stormwater control measures and their maintenance needs.

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SNAPP – WATER, SANITATION AND NATURE AND THE IWA TASK GROUP ON NATURE-BASED SOLUTION

***Fabio Masi**[1], Florent Chazarenc[2], Anacleto Rizzo[1] and Katharina Tondera[2]*
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There are 2.4 billion people living without sanitation properly separating them from their biological waste. For another 2.1 billion, wastewater drains directly into surface waters. Despite improvements over past decades, unsafe management of fecal waste and wastewater still presents a major risk to public health and the environment. There are various natural solutions which can be part of wastewater treatment systems, supporting the removal of wastewater contaminants such as bacteria, heavy metals and high levels of nutrients. These include: constructed and natural wetlands, wastewater treatment ponds and soil infiltration systems, and green roofs and vertical gardens. However, it is often difficult for wastewater utility managers to know whether to incorporate natural infrastructure into their planning, how best to find a suitable mix of grey and green infrastructure, and how to choose among the menu of possible types of green infrastructure. Many professionals, technicians and regulators, are hesitant to implement nature-based solutions, because the mechanisms at play are not well understood and controlled.

The interdisciplinary Science for Nature and People Partnership (SNAPP) will develop guidance on nature-based sanitation solutions that can be implemented into wastewater treatment facilities in a way that benefits ecological and human health. The working group will be guided by the BRIDGE Collaborative principles as an approach to enable more effective cross sector collaboration, with the ambition to inspire wastewater utilities and regulatory authorities to incorporate the guidance into their operation and planning.

Since inception, SNAPP, through its working groups, has provided science and user-friendly tools backed by hard data to identify and quantify nature's role and value in preventing, and solving some of the most complex challenges the world faces around food and water security, climate change, and energy.

The main goal is to understand how, where and when wastewater utilities and their regulators can implement nature-based sanitation solutions into wastewater treatment facilities while also providing benefits to nature and encouraging biodiversity. Achieving this goal will be facilitated by creating interactive, publicly available guidance which consolidates information from across a variety of applied cases with scientific evidence that will inspire and influence sanitation providers and regulators to design and integrate wastewater treatment facilities with ecosystems in a way that benefits ecological and human health.

The SNAPP Water and Sanitation Working Group partners are: International Water Association (Headquarter and Task Group on NBS for Water and Sanitation; The Nature Conservancy; Arup Group; Catalan Institute for Water Research (ICRA); University of Ljubljana; Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture (IRSTEA); Humboldt State University; National Water and Sewerage Corporation, Uganda; BOKU University; IRIDRA; Bridge Collaborative (Duke University); Bremen Overseas Research and Development Association (BORDA); Consortium for DEWATS Dissemination Society (CDD).

The Nature Conservancy Wildlife Conservation Society NCEAS National Center for Ecological Analysis and Synthesis

BIO: Fabio Masi is R&D Manager and Technical Director of IRIDRA Srl, since 1998 and Vice-President of Global Wetland Technology since 2012. His is PhD in Environmental Sciences and MSc in Environmental Chemistry (1991). He has almost 25 years of experience in sustainable water management and nature-based solutions for wastewater treatment.

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S.S. 14

SPECIAL SESSION 14

CLIMATE EFFECT ON THE SLUDGE DEWATERING AND MINERALIZATION PROCESSES IN SLUDGE TREATMENT REED BED SYSTEMS

Steen Nielsen

DEWATERING MECHANISMS IN PILOT-SCALE SLUDGE TREATMENT REED BEDS IN THE NORTH MEDITERRANEAN REGION

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Sludge treatment and handling is a major issue in wastewater treatment plants (WWTPs). The main processes for sludge treatment include stabilization, thickening, conditioning, dewatering, drying and reduction. Dewatering can be mechanical (e.g., vacuum filters, belt filter presses, centrifuges and membrane filter presses) or natural. The use of Sludge Treatment Reed Beds (STRB) for sludge dewatering using natural forces is rising over the last years. STRBs are less expensive than mechanical methods and require far less power, since they rely on the force of gravity, solar radiation as the source of energy for dewatering, and biological processes. for sludge stabilization The dewatering process in STRBs results in increased dry matter content of the sludge residue, significant decrease of the sludge volume and organic matter decomposition. The final treated sludge (often referred to as biosolids) is a useful product which can be further used as an organic fertilizer for land application.

Several studies report that the main dewatering mechanisms are evapotranspiration (ET) and draining; however, there is very limited published research on their quantification and estimation of their role on the performance of a STRBs. A research study was carried out aiming at quantifying the dewatering mechanisms and the water budget in various experimental pilot-scale STRBs under the North Mediterranean climate, in an effort to evaluate, through parallel experiments, the effect on these processes of various design and operational parameters, i.e., the sludge loading rate, vegetation, porous media size and origin, presence of aeration tubes, presence of chromium in the sludge feed and various meteorological parameters.

The dewatering efficiency of the planted STRB exceeded 96% volume reduction and the final dry matter content varied between 50-64%, depending on the applied sludge loading rate. Under the studied climate, it was found that draining accounted for more than 40% of the water losses, while evapotranspiration rate was increased at higher sludge loading rates. Low loading rates and respectively limited available water volume might adversely affect plant growth. Results showed that the presence of plants significantly enhances the dewatering process due to increased evapotranspiration rates by plants. A fine-grained material also enhances the system dewatering performance, while the presence of perforated aeration tubes with open top allows for better substrate aeration, thus preventing anaerobic conditions. Moreover, intermittent sludge loading followed by a resting period length dependent on the season is crucial for the clogging prevention and maintaining the dewatering capacity of the bed. The top layer of the sludge cake with fresh sludge was black, due to iron sulfide, and of aqueous composition, while the lower parts had a brown color and soil texture, which indicates the presence of aerobic conditions and mineralized material. A black colour of the deepest sludge cake parts implied that the mineralization was limited (anaerobic conditions).

BIO: Dr. Stefanakis is a professional Engineer, Researcher and academic Lecturer with more than 13 years of experience in designing, managing and implementing wetlands construction and research projects internationally. He has extensive experience with wetland systems for various industrial applications, sludge dewatering and/or municipal wastewater, as well as reuse of treated effluents for irrigation.

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CONSIDERATIONS IN VEGETATION SELECTION FOR SLUDGE TREATMENT WETLANDS - IS THERE ANY SUBSTITUTE FOR PHRAGMITES AUSTRALIS?

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Sludge Treatment Wetlands (STWs) take advantage of the high evapotranspiration rates and root-zone microbial activity of emergent wetland plants, to dewater and mineralize waste sludge from sewage treatment, septage and potable water treatment plants. Most experience to date has been in relatively cold northern European countries (e.g. Denmark, Sweden, Norway and Germany) primarily utilizing the Common Reed *Phragmites australis*; hence why STWs are commonly refered to as Sludge Drying Reed Beds. There is growing interest in applying this technology in other parts of the world, such as Australia, New Zealand, North America, the Middle East, South-east Asia, Africa and tropical island countries. In many of these regions, *P. australis* is not native and is considered an invasive weed. Thus, species other than *P. australis* need to be used. This presentation aims to review the reasons why reeds are so suitable for sludge treatment and to explore potential candidate species that can be considered as alternatives.
STWs are an example of a constructed wetland system in which the wetland plants, with their unique traits adapted to growing in waterlogged soil, are indispensible for the successful long-term functioning and efficiency of the system; without the services provided by the wetland plants, the system would cease to function effectively. The rhizomes grow through the accumulating sludge profile providing long-term pathways for drainage. The movement of the plant stems in the wind mechanically opens and cracks the crust on the upper surface of the sludge residue, facilitating drainage. The plants enhance ventilation of air throughout the sludge residue layer, helping to keep it oxic, promoting mineralisation and preventing odour generation. After initial drainage of the free-water from the loaded sludge, evapotranspiration (ET) becomes the main process responsible for further dewatering, removing water held by capillary forces. It is ET which enables high DM contents to be achieved. The plant biomass (roots, rhizomes, leaf litter and stems) adds structure to the biosolids, improving its characteristics as a soil amendment product compared to dried sludge alone.

Why has *Phragmites australis* been the species of choice in STWs for the past 30 years? *P. australis* is a large (up to 6m tall), robust, fast growing perennial emergent aquatic macrophyte that is well adapted to growing in inundated anoxic sediments. It has a unique combination of physiological and morphological traits which make it ideal for STWs, including an extensive robust rhizome system, high transpiration rate, ability to develop adventitious roots from nodes in the stem if they become submerged, habit of producing new shoots from buried rhizomes, ability to grow with an upright or prostrate form depending on conditions, and capability to promote gas exchange through its rhizome-root system. To date, there has been limited long-term experience in full-scale systems to verify if other emergent macrophytes are equally well adapted to flourish in STWs and provide the equivalent functions as *P. australis*. The important characteristics that potential candidate species should posses in order to be suitable for use in STWs will be reviewed in the presentation. Species of the *Cyperus*, *Schoenoplectus* and *Typha* genera show promise for use in STWs. However, long-term studies are still required to confirm their successful operation in STWs loaded with sludge for several years. More information is also required as to the impact, if any, on the design, sizing and operating regimes of STWs planted with species other than *P. australis.*

BIO: Dr. Tom Headley is a constructed wetland specialist with over 20 years' international experience in the research, design, construction and management of eco-technologies for treatment of a broad range of wastewater types. Tom is based in Australia where he leads the specialized wetland consulting company: WET Systems.

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SEPTAGE TREATMENT BY STRB: FROM MECHANISM TO DESIGN AND PERFORMANCES

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An Electroactive Biofilm-based Constructed Wetland (EABB-CW) is a wastewater treatment system that relies on the presence of electroactive bacteria (EAB) to enhance the degradation of pollutants. Compared to other microbial electrochemical setups, EABB-CW is designed in short-circuit mode (dispensing of external circuits) and uses an electro-conductive substrate acting as a single-piece electrode. A major challenge of this type

Sludge Treatment Reed Bed (STRB) represents an ecological solution for satisfactory local treatment of fecal sludge and appropriate reuse of residual products compared to co-treatment in wastewater treatment plants. It allows implementing treatment system close to source production and avoids high transport and handling costs. However, sludge coming from septic tanks is quite different physically and organically than activated sludge which have been largely studied. How to design the beds, how to load the beds, for which performances? Septages coming from septic tank are much more concentrated than activated sludge, more mineralised and composed of fine particles. They consequently trends to retain more capillary water and appears to dewater less easily than activated sludge. Nevrtheless, drying performance of STRB does not only depend on the ability of sludge to dewater. Indeed, as septage are highly concentrated, the hydraulic loads applied on the beds can be very low. Consequently, evapotranspiration can very quickly dewater the sludge. A too high dewatering can lead to hinder biological activity (organic matter mineralisation) and even induce excessive water stress on plants. Loading, the number of bed and the feeding strategy have to be adapted to ensure a sludge biological treatment allowing an aerobic stabilisation of the organic deposit. As septage can vary in composition according to the type of septic storing system and its withdrawal frequency it is of importance to be aware of the link between septage composition and stabilisation performance.

Based on the work done at pilot scale during two PhD studies and a consecutive full-scale experiments during three years this presentation will focus on dewatering and mineralisation processes of septage and the associated design and operation that ensure good treatment performance. The full scale validation took place on a treatment unit in the south of France treating 11 000 m3/y of septage.

Figure 1. Pilot and full scale device for septage treatment.

BIO: Pascal Molle is a Research Director at Irstea. He develops researches on treatment wetlands for wastewater, sludge and storm water since more than 20 years.

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THE DEVELOPMENT OF SLUDGE TREATMENT REED BED SYSTEMS DESIGN AND OPERATION UNDER COLD AND HOT CLIMATE CONDITIONS

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The dimensioning of the Sludge Treatment Reed Bed Systems (STRB) is based on sludge production (tons of dry solids per year), quality, and climate. Sludge Treatment Reed Bed Systems have been used for dewatering and mineralisation of both sewage and water works sludge in Europe since 1988, with the experience mainly from the relatively cold northern European countries, such as Denmark, Sweden, Germany and England. The dimensioning criteria define the process area, the area load (kg $DS/m^2/yr.$), the number of basins, loading and resting periods. Today there are operations experiences from pilot- and full-scale systems in more extreme climates such as cold climates in Sweden and Norway and hot climates in Greece and Spain. Recently the method has been tested in pilots systems in Australia and New Zealand.

Two full–scale system in Sweden in Skövde (10 basin, an area load of 50 kg $ds/m^2/yr.$ and a total process area of 24,000 m^2) and Tidaholm (eight basin, an area load of 60 kg $ds/m^2/yr.$ and a total process area of 6,000 m^2) have operate 18-20 years in a cold and temperate climate. The average yearly temperatures of 5-7°C and cold winter conditions with average temperatures below -3.5°C. The operation results demonstrated challenges with the lower evaporation because of shorter growths period, freezing sludge in the loading pipes after loading and freezing of the sludge residue surface down to approximately 10 cm. On the other hand the sludge residue do dewater better after a freezing period. The slow and relatively more inefficient dewatering of the sludge residue allows for longer resting periods between basin rotations, which can respectively allow for an increased required number of basins than for systems in warmer climates. A main solution was found to avoid loading in the 4 winter months. The results from a pilot plan in Wacol (SE Queensland, Australia) demonstrated very high sludge dewatering capability and challenges from the implementation of the STRB in a hot, subtropical climate. The climate is characterized by mild, dry winters with mean daily temperatures between 20-25°C and lows of 10°C, and hot and humid summer conditions with daily temperatures above 30°C and even exceeding 40°C several times a year. The hot climate enabled faster and better drying of the sludge residue due to airdrying and higher plant evapotranspiration rates allowed for increased total annual loading rates. A sustainable loading rate of 60-70kg $DS/m^2/yr.$ was established for the sludge quality from Wacol WWTP. A similar loading rate of 75 kg $DS/m^2/yr.$ was also determined for a pilot STRB operating under the Mediterranean climate, with mild winters and warm summers. The hot climate also imposes the challenge of maintaining plant health. Extended resting periods without loadings lead to water stress conditions for the plants. These indicate that water stress may need to be managed more actively in the first few years of operations, until a layer of approximately 20-25cm or more of sludge residue has building up. This layer will retain more moisture than the filter layers, enabling the plants to use capillary bound water in periods of water depletion between the loading periods. Two main solutions were found, an adapted loading program and a design response to the problem where the basins were designed to fill up with water within the filter below the drying sludge residue. The fast and more efficient drying of the sludge residue allows for shorter resting periods between basin rotations, which can respectively allow for a reduced required number of basins than for systems in cooler climates.

BIO: Steen Nielsen is a senior manager with more than 30 years' experience with Sludge Treatment Reed Bed System dimensioning and operation in relation to climate and sludge quality and with construction, rebuilding and operation of more than 70 full scale and test system. He has authored and coauthored more than 30 papers.

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PROCESS OF SLUDGE STABILIZATION AND NUTRIENT RECOVERY FOR AGRICULTURAL PURPOSES OF SLUDGE TREATED IN SLUDGE TREATMENT REED BED SYSTEMS

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Circular Economy package accepted by the European Union in December 2015 promotes close-loop flows of materials. The main targets provided in the documents refer to the prevention of waste landfilling, efficient use of resources and energy, as well as re-use waste and by-products.
According to this concept, sewage sludge should be treated as secondary raw material and used as a valuable source of nutrients and organic matter.

In Sludge Treatment Reed Bed Systems (RBSs), sewage sludge is periodically loaded onto the surface of vegetated basins over several years, where it is dewatered, stabilized and turned into biosolids with a high dry solid content for use as an organic fertilizer on agricultural land. Sludge stabilisation occurring in RBS is a very complex process, given that it is resulting from the synergic action of plant, organic matter and microorganisms, and it is characterized by a dynamic process of loading and resting phases.

Data collecting from several monitoring campaigns (2004-2018) on 20 RBS systems located in Italy and Denmark have clearly proven that sludge stabilisation process in RBS follows general rules.
A reduction of organic matter (eg. volatile solids < 40 % ds) and an impressive decrease of overall microbial activity in terms of dehydrogenase activity (DHase) and butyrate esterase activity (eg. DHase < 10 mg INTF kg ds^{-1} h^{-1}) highlighted the process of fresh organic matter mineralisation.
The stabilization process occurring in RBS allowed to mitigate the risks arising from heavy metal content (eg. bioavailable fraction of heavy metal < 25 %), toxic organic compounds (eg. nonylphenol ethoxylates NPE < 10 mg kg ds^{-1}) and pathogens content (eg. *E. coli* <1000 MPN g ds^{-1}) generally present in sewage sludges, thus enabling a safe reuse of stabilized sludge as biosolids for land application.
Moreover, the process of stabilisation in RBS allows valorizing nutrient content normally present in sludge, given that nitrogen and phosphorus, and other macronutrients (eg. Ca, Mg, K) are maintained in bioavailable forms for agricultural purposes. Hence, sludge stabilised with RBS technology can be considered as a valuable source of nutrients and organic matter, in line with the circular economy strategy.

BIO: Dr. Eleonora Peruzzi is a researcher with 15 years of experience in monitoring of sludge treatment reed bed systems. She belongs to a research team specialized in developing of nature-based solutions for environmental remediation.

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CONTRIBUTED PAPERS 1

AGRICULTURAL RUN-OFF

Christopher Tanner

MODELLING OF A FULL-SCALE DRAINAGE WATER TREATMENT WETLAND TO GAIN IN-DEPTH UNDERSTANDING AND DESIGN SUPPORT

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The drainage water from agriculture land generates nitrogen pollution and can include dissolved or particulate pesticides when part of the agricultural practice. This diffuse pollution poses a significant eutrophication problem in receiving surface water bodies (Borin and Tocchetto, 2007). Treatment wetlands (TWs) are a low-cost solution for the treatment of such waters (El Hawary and Shaban, 2018; Vymazal and Březinová, 2015). In this study three full-scale experimental TWs, functioning as denitrification barriers for nitrate reduction are setup, with different filter media and flow characteristics in the Czech Republic. The purpose of the system is to capture and reduce the pollutants directly at its source. The monitoring campaign for all three systems includes measurements of quality parameters, namely NO_3, TOC, TN, and TP, as well as tracer experiments. Two wetlands are filled with a mixture of gravel and birch woodchips in the ratio of 10:1 while in the third wetland the gravel filling is topped with 20 cm layer of woodchips. Two wetlands are being run as subsurface flow units (horizontal and vertical flow), but in the third, the water level is approximately 15 cm above the surface.

Based on the measured data as well as literature data (e.g., Vymazal and Březinová, 2015) a modeling study is carried out. Therefore the HYDRUS Wetland Module is used. HYDRUS numerically solves variably saturated water flow and solute transport. The solute transport equations consider convective-dispersive transport in the liquid phase, diffusion in the gaseous phase, as well as non-linear non-equilibrium reactions between the solid and liquid phases. In the Wetland Module, a process based biokinetic model formulation is implemented to describe the biochemical transformation and degradation processes (Langergraber and Šimůnek, 2012).
The aim of the proposed modeling study is to (i) getting a better understanding of the underlying processes influenced by the different filter media and flow conditions, (ii) quantify the efficiency of TW treating water from agricultural drainage systems to enhancement of landscape´s water residence time and improvement nutrients and selected pesticides reduction and (iii) evaluate and improve the design criteria.

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BIO: Mr. Rous is an external Ph.D. student at the Faculty of Environmental Sciences, CULS Prague. He is working on identifying the possibilities of treatment wetlands intensification within the Czech Republic.

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MONITORING OF A FULL-SCALE SURFACE FLOW CONSTRUCTED WETLAND FOR TREATMENT OF AGRICULTURAL DRAINAGE WATER IN ITALY.

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Agriculture is one of the most important non-point sources of pollution. In order to protect downstream ecosystems, it is important to intercept this pollution and treat agricultural drainage water. Surface flow constructed wetlands (SFCWs) can be an effective solution to this problem, since they have lower costs and easier operation mode compared to conventional systems. The objective of this research was to explore the capacity of a matured SFCW for pollutant removal from agricultural drainage water, taking into account its water balance and providing a relevant case study on this topic.

The SFCW studied, a non-waterproofed system built in 2000, is located on an experimental agricultural farm (12.5 ha) near Bologna, Italy. The system (3% of the total farm surface) drains all the farm area, and it is divided into four meanders (Figure 1). A detailed monitoring of this full-scale system was possible since it is equipped to measure a large range of parameters, related to both water quality and quantity (i.e. flow rates, water levels, vegetation growth, weather conditions, chemical and physical parameters). Since September 2017 four parameters typical for agricultural sources of pollution were analyzed: total suspended solid (TSS), chemical oxygen demand (COD), total nitrogen (TN) and total phosphorus (TP).

Furthermore, the removal of pesticides (e.g. Imidacloprid) and system water balance (evapotranspiration and infiltration) analyses are in progress, expected to be finished over the next few months. Table 1 gives the summary of the main results obtained so far. The inflow and outflow water volumes were 18181 m^3 $year^{-1}$ and 12293 m^3 $year^{-1}$, respectively. The SFCW performed well in terms of three pollutants (TSS, COD and TN). Their loads decreased from inflow to outflow, while that was not the case for TP - its load increased from 0.4 kg $year^{-1}$ (inflow) to 0.62 kg $year^{-1}$ (outflow). The highest retention rate was obtained for TSS, 64%, followed by 41% for TN and 24% for COD (Table 1).

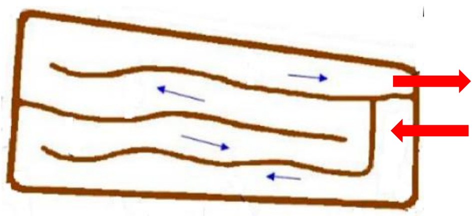

Figure 1 - Hydraulic scheme of the SFCW studied.

Table 1 - Water quality parameters during the experimental period.

	TSS	COD	TN	TP
Inflow (kg $year^{-1}$)	2549	285	207	0.40
Outflow (kg $year^{-1}$)	928	216	122	0.62
Retention rate (%)	64	24	41	-54

The reason for negative TP retention might be flushing out of the sediments that contained it, and that have accumulated over the past few years (Lavrnić et al, 2018). Interestingly, this did not affect TSS retention. The removal of TN, one of the main causes of eutrophication of water ecosystems, is similar to the one obtained for the initial operation period of the SFCW. Therefore, it can be concluded that the system is functioning well even after 18 years of continuous operation.

BIO: Dr. Lavrnić is a research fellow at the University of Bologna, working on wastewater treatment and reuse, particularly focusing on nature based solutions such as constructed wetlands.

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MITIGATION OF AGRICULTURAL DIFFUSE POLLUTION IN COLD CLIMATE WITH TREATMENT WETLANDS: ESTABLISHMENT YEAR OF MESOCOSM STUDY

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Agricultural diffuse pollution impacts the quality of water and the health of ecosystems. Many phytotechnological solutions are used all over the world for diffuse pollution control, e.g. buffer strips, sedimentation ponds and treatment wetlands (TWs). However, there is still lack of integrated solutions that would efficiently remove the excess concentrations of nutrients and pesticides in the watersheds. Similar issues have risen in the agricultural context of the Southern Quebec (Canada), especially in the Lac-Saint-Pierre watershed. This area is characterized by its cold climate and intense production of corn and soy. According to the provincial monitoring data (from 1999 to date) the main pesticides in surface water are common herbicides (e.g. atrazine and glyphosate), insecticides (e.g. different neonicotinoids) and new replacements for latter ones, e.g. chlorantraniliprole (CAP).

The main objectives of our project are: a) to determine the impact and fate of pesticides on the Lac-Saint-Pierre watershed and b) to develop efficient treatment solutions by applying different TW technologies, that are customized to the northern climate and agricultural practices. The main goals of our large-scale mesocosm study are to determine: a) the potential of horizontal subsurface flow (HSSF) TWs in removal of pesticides; b) the role of selected macrophytes, and c) the effect of filter media enhancement (biochar addition) on overall treatment performance.

During year 2018 we were mainly focusing on construction of the mesocosm experiment (in the Montreal Botanical Garden research area) and on macrophyte establishment. Such preparations are required for studies on the role of wetland plants, as it is necessary to gain the results with mature plants that are well established to the study environment. The study consists of total 14 HSSF mesocosms (L×W×H = 130×80×46cm) planted with 3 Canadian species (*Phragmites australis americanus* (PA), *Scirpus cyperinus* (SC) and *Sporobolus michauxianus* (SM) – each in 3 replicates). Additionally, 3 replicates planted with SC have 15% (by volume) biochar (B) addition into the main media – granite gravel (G; Ø3-7 mm). Both filter medias have one unplanted control (GC and BC). All the mesocosms are equipped with 3 water sampling pipes on different distances from inflow and 2 rhizotrons. The mesocosms were watered ones per week with acidified tap water and ones with nutrient solution comparable with Hoagland's for promoting rapid plant development. The pH, temp., EC and DO were measured from influents, effluents and inside the mesocosms. The evapotranspiration rate (ET) and general plant growth and physiological parameters (e.g. photosynthesis rate and stomatal conductance) were monitored. The ET rate in August 2018 was median 5.2mm with SM, 3.2mm with SC, 2.9mm with SCB and 2.8mm with PA compared with evaporation of 1.4mm in GC. The aerial biomass increased median 21 times with SM, 13 with SC and 12 with PA and SCB. In conclusion, all plants reached required maturation and density for the main experiment starting 2019. Overall, SM showed the best performance. Results from 2018 will be compared with data collected in next two years. This comparison will give us more information about the effect of pesticides on plant development and TWs performance and if the biochar enhancement has extra benefits for TW systems.

BIO: Dr. Kõiv-Vainik is a research fellow in environmental technology in the University of Tartu and adjunct professor in the University of Montreal working for more than 10 years on process-based research and enhancements of treatment wetlands, on ecological waste- and stormwater treatment and on enhanced phosphorus removal with reactive materials.

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GENETIC POTENTIAL OF NITROGEN CYCLING PROCESSES IN SEDIMENTS OF A SURFACE FLOW CONSTRUCTED WETLAND TREATING POLLUTED AGRICULTURAL RUNOFF

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Constructed wetlands are proposed as an effective and low-cost solution to decrease nutrient concentrations in polluted surfaces and subsurface waters. Microbial communities are the drivers of the removal of excessive nitrogen from polluted water and therefore it is crucial to understand the factors affecting the composition and abundance of microbial communities. The aim of the current study was to evaluate the genetic potential of different nitrogen cycling processes and determine the environmental factors affecting the key genes of those processes and relate them with nitrous oxide (N_2O) and nitrogen (N_2) gas emissions in the Rampillon constructed wetland.

The artificial wetland at Rampillon watershed outlet (Seine et Marne, France) was built in 2010 to test complementary actions to control non-point source pollution due to intensive agricultural activities in the Champigny aquifer, which is highly vulnerable due to karstic phenomena. According to the water regime, the wetland (5300m²; 2500m^3) works as fully in-stream system in the growing season and off-stream system in winter. It is divided into sedimentation pond, intermediate march and outlet pond. The inflow from the arterial ditch is controlled by sluice gate and it fluctuates 0–120 L/s. A fifth of surface area is vegetated by *Phragmites australis, Juncus inflexus, Carex riparia* and *Callitriche palustris,* while microalgae are spread all over the wetland. Sediment samples from the 0–10 cm top soil layer of ten different sampling points were collected in the years 2014 (May and November), 2015 (March and October) and 2017 (May). In all the sediment samples, pH values and NH_4-N, NO_3-N, TOC, TC, DOC, Mg, P, K and Ca content were measured. Bacterial and archaeal 16S rRNA genes and functional genes of denitrification (*nirS*, *nirK, nosZI* and *nosZII)*, nitrification (bacterial and archaeal *amoA*), anaerobic ammonium oxidation (ANAMMOX, specific 16S rRNA), nitrite dependent anaerobic methane oxidation (N-damo, specific 16S rRNA) and dissimilatory nitrate reduction to ammonium (DNRA, *nrfA*) processes in the sediments were determined using the quantitative PCR method. In addition, N_2O emissions were measured *in situ* using 12 automatic chambers connected to Aerodyne QCL system and six manual opaque chambers. Gas samples from manual chambers were analyzed using Shimadzu GC and potential N_2 emissions were determined from the sediment using He-O incubation technique in the laboratory.

According to the gene quantification data, the dominant nitrogen cycling processes in wetland sediments were denitrification and nitrification, which were relatively stable in spatial and temporal scale. The abundance of different types of *nir* and *nosZ* genes was fairly similar during the studied period. Denitrification associated genes were positively related to sediment TC and TOC values and *nosZ* gene parameters negatively to N_2O emissions. According to the *nosZ*/*nirS+nirK* values, denitrification is likely the source of N_2O emission from the wetland and it was negatively correlated with *in situ* N_2O emissions. The genetic potential of nitrification was lower compared to denitrification, but it can also contribute to N_2O gas emissions from the wetland. The ratio of archaeal and bacterial *amoA* genes was higher in inflow and outflow areas and *amoA* genes were positively related to the pH and NO_3-N values and *in situ* N_2O emissions and negatively to TC and TOC values. ANAMMOX genetic potential was higher in the inflow and outflow areas, while N-damo was detected only from the inflow.

BIO: Dr. Ligi is a scientist who has experience in studying microbial community composition and nitrogen cycle in different types of wetland systems.

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CONTRIBUTED PAPERS 2

PALIDICULTURE

Dennis Konnerup

STRATEGIES AND POLICIES TO FOSTER PALUDICULTURE AS CLIMATE-SMART AGRICULTURE ON PEATLANDS IN THE BALTIC COUNTRIES

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While peatlands only cover approx. 10% of land in Europe, they comprise Europe's largest terrestrial carbon stock. Drained for agriculture, forestry, and peat extraction, however, they turn into disproportionately important sources of greenhouse gases and nutrients (nitrogen, phosphorus). The Baltic countries (Estonia, Latvia, and Lithuania) harbour 21,000 km^2 of peatlands of which more than 50% are drained and degraded. They all rank among the EU's Top 10 of greenhouse gas emitters from drained peatlands (LV 5th, EST 8th, LT 9th).

Climate-smart land use with close-to-surface groundwater levels (paludiculture) could reduce or even stop emission, thus considerably contribute to reach Baltic States' climate mitigation targets. However, adapting peatland agriculture to higher water levels is a challenging task for society. It needs to be incorporated into national and regional strategies to steer spatial and rural development planning, including delineation of target areas of organic soils to create common understanding for all affected stakeholders (farmers, but also water management, administration, conservation, tourism and others) and authorities. Therefore, a feasibility study on the use of peatland areas in Baltic countries Estonia, Latvia, Lithuania has been conducted. It includes maps of each country indicating the physical, social and economic suitability of peatland areas for paludiculture and a pan-Baltic synthesis map. Preliminary results of the GIS based analysis show that in total 691,100 ha in the Baltics are directly available for paludiculture. The results will feed into national climate, agriculture and rural development plans.

Additionally, EU's Common Agricultural Policy (CAP) remains arguably the single most important EU policy instrument for peatland management as the majority of peatlands is drained for agriculture. 1st and 2nd Pillar payments support drainage-based peatland use whereas the implementation of large-scale paludiculture to stop degradation is hindered by contradicting regulations and missing economic incentives for farmers. To identify the specific obstacles and chances, we conducted a legal assessment on existing CAP instruments implemented in the Baltic States like agri-environmental and climate schemes (AES). We found that only little attention is given so far to the special conditions of peat soils and to incentives for raising of water levels, which is precondition for paludiculture. Major obstacle remains the risk of losing direct payments after rewetting and establishment of paludiculture crops.

Further prerequisites are awareness raising, participation and communication with all stakeholders, cooperation within the hydrological catchment area, knowledge transfer and professional advisory services. We tackled different approaches of initiating and facilitating the transition to paludiculture in the Baltic States with adapted information material and stakeholder workshop in national languages.
The findings of our research is largely transferable to other peatland-rich EU Member States and opens up new integrated policy solutions to bring paludiculture to large-scale implementation.

BIO: J. Peters is head of working group "Peatland & Climate Change" at Succow Foundation. He is involved in peatland conservation and restoration projects focusing on GHG emission reduction, biodiversity and solutions for sustainable use. He works in Germany, but also in international cooperation mainly in Eastern Europe and in policymaking processes.

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INTRASPECIFIC TRAIT VARIATION OF PHRAGMITES AUSTRALIS: IMPLICATIONS FOR ITS USE AS A BIOMASS CROP

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Phragmites australis (Cav.) Trin. ex Steud. (common reed) is a highly productive, cosmopolitan wetland plant with traits including rapid growth, high productivity and a broad tolerance to biotic and abiotic stresses. These traits are highly desirable for the cultivation of biomass. Indeed, *P. australis* is already widely used for thatching, in constructed wetlands for wastewater treatment and for paper production. However, due to the great intraspecific variability of *P. australis*, it produces very different phenotypes, depending on its geographical origin. In this study, we compared different genotypes of *P. australis* from a worldwide geographic distribution to determine their suitability for bioenergy production. We assessed trait differences along geographical and bioclimatic gradients, and the resulting suitability for bioenergy application. We found both aboveground and belowground intraspecific trait variations that were significantly related to the latitudes of the populations' origins, due to local adaptation. Apart from these absolute differences, genotypes of *P. australis* also showed phenotypic plasticity in response to environmental differences. Both biomass productivity and quality were significantly different between genotypes and environments, indicating that the great intraspecific trait variation of *P. australis* strongly affects its suitability for bioenergy. Our results help to understand these trait-environmental linkages and provide detailed information for choosing appropriate genotypes for various applications.

Key words: functional traits; trait-environment linkages; latitudinal gradients; ecosystem functioning

WATER QUALITY MANAGEMENT AND THE IDEA OF SIMPLICITY

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In a holistic vision, the ecological transition is a paradigm shift for human action, which is not circumscribed to sustainability, as commonly understood by the idea of sustainable development – a broadly criticized notion due to the inherent ambiguity between growth and environment protection –. It is a way to economically thrive while respecting the environment, through efficiency and low-energy, low-carbon and low-resources requirements. Today in France, the notion of ecological transition is used in the regulation to promote the idea of a new (and post-growth) society model; this model explicitly links economic, ecological and human progress. The ecological transition concept lays on four pillars: space (delocalized and place-based systems), time (in accordance with natural cycles and meant to be long-lasting), material (decreasing resource use and thinking in a frugal way) and solidarity (acting so that others can benefit from a given resource).

To achieve this transition, we suggest that practices should be characterized through a structuring notion; we posit that it could be the French notion of sobriety, or simplicity. From the Latina root *sobrietas* and the Greek root *sophrosyne*, this term – 'sobriété' in French – indeed defines the restraint, moderation or simplicity as opposed to *hubris* (excess and intemperance). It thus comes down to moderation, temperance, or wisdom. More generally, it is a virtue of human action as Plato (The Republic) defined it in the sense of temperance, and later Aristotle in the sense of wisdom (Dictionary of Vices and Virtues). Simplicity could thus be a measure for this new societal paradigm, harmoniously blending moderation and temperance in possessions (i.e. having) and thoughts (i.e. being).

We will study water quality management through the lens of simplicity and will especially focus on the topic of stormwater and wastewater treatment using constructed wetlands. On many aspects, such as the localization of the treatment systems or the low energy requirements, these systems seem to be actually characterized by a substantial level of simplicity. Yet some aspects of simplicity in this field may be questioned: are these systems in accordance with natural cycles and meant to be long-lasting? Is the underlying framework for these systems based on a frugal way of thinking? How well is environmental justice taken into account with this type of systems? Through these questions we test the adequacy between practices and the four aforementioned pillars. Eventually, we will couple these thoughts with an existing framework on the notion of transition; this will allow us to highlight locking points and to suggest trails for evolution.

This communication leads to delineating the practice of simplicity in the field of wetland-mediated water quality management as being mostly resources-oriented, while behavioral simplicity seems scarcely implemented. From this point on, practices analyzed from a transition perspective can be a starting point of possible evolution towards a trajectory that would fit with this new paradigm.

BIO: Dr. Bois is an assistant professor in the field of wastewater treatment at the University of Strasbourg. He is working mainly on storm- and waste-water quality management through the use of constructed treatment wetlands, expanding his research to the numerous ecosystem services these systems provide.

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BIOAVAILABILITY OF PHOSPHORUS BOUND TO DIFFERENT ENGINEERED MATERIALS

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Phosphorus (P) is an essential element for the growth of plants and it makes up about 0.2 % dry weight of a plant, where it is essential in many macromolecules, such as nucleic acids, phospholipids and ATP. Today, P is mostly obtained from mined rock phosphate and is often combined in mineral fertilizers, but P is a non-renewable resource, so there is a limited amount of P to be obtained this way. Although the total amount of P in the soil may be high, it is often present in unsuitable forms for plants or in forms that are only available outside of the rhizosphere. Up to now, sustained P-removal has proven elusive regardless of the wastewater treatment system, often resulting in outlet waters containing P-concentrations higher than permitted. Hence, water with P is often one of the by-products of wastewater treatment. For this reason, the aim of this project is to understand if we can reuse P that has been recovered from wastewater by material sorption, as a P source for plants, creating a more closed nutrient cycle.

In order to test the bioavailability, we saturated two different substrates with different particle size with a solution of P (KH_2PO_4), representing the filter media from wastewater treatments. Compared to their sorption capacity, which was calculated by previous experiments, we reached 7,6 mg P/g of material for the first substrate and 12,0 for the second one. At this point we made 6 different treatments with different concentrations of P from 0 up to 100 g P/m^2 and an extra treatment with commercial fertilizer for plants containing P, N and K. The different amounts of our P medium was then mixed in 3 L pots with sphagnum and sand together with the other macronutrients (N and K), keeping the normal ratio between these elements. In this way, we just focused our attention on the lack or on the differences of P in the soil. We have 5 replicates per treatment, so now 60 *Zea mays* plants are growing in a growth chamber with controlled parameters of light, humidity and temperature.

During the growth, plants morphological and physiological parameters are checked such as the height of the plants, number of leaves, chlorophyll, respiration and photosynthesis efficiency. After the growth, also the amount of phosphorous taken up by the plants will be calculated, trying to establish a correlation between the performance of the plants and the amount of available P.

BIO: C. Esposito is a master student in Environmental Biology at the University of Florence (Italy) and is doing her master thesis at the Department of Bioscience at Aarhus University (DK). Her research is mainly focused on removal and recovery of nutrients from wastewater treatments. She has been involved in the INCOVER project, working with optimization of treatment wetlands.

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PEATLAND CHARACTERISTIC ECOLOGICAL FACTORS AFFECT *SPHAGNUM* SPORE PERSISTENCE

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Plant diaspores have been found to attain extreme longevities of hundreds and perhaps a few thousand years in peatlands. Peatland characteristic ecological gradients including oxygen-deficiency and allelopathy likely play an important role in diaspore persistence, but have received little attention. We determined the initial viability of *Sphagnum* spores and then stored the spores for 60 days, either dry, in ultrapure water, peatland surface water or *Sphagnum* leachate water (the latter two solutions rich in allelochemicals from *Sphagnum*). We varied oxygen concentration by injecting air at three different levels during the storage. After retrieval from experimental storage, spore germinability index (calculated as final germination percentage/initial germination percentage) was assessed. Germinability index in peatland surface water and *Sphagnum* leachate water was both higher than in ultrapure water, respectively, under anoxia. Germination index after air injection was lower than under oxygen-deficiency. Overall, dissolved oxygen and high pH had negative effects on spore germinability index and, consequently, on viability. However, a significant interaction between water type and air injection suggests that such negative effects only occur in natural waters (peatland surface water or *Sphagnum* leachate water). These results indicate that once dispersed onto bryophyte substrates or waterlogged hollows, *Sphagnum* spores can maintain viability better than when exposed to dry conditions or deposited in water without allelochemicals. Extreme longevity of *Sphagnum* spores, and possibly other plant diaspores, may be attributed to the acid, waterlogged and oxygen-deficiency, *Sphagnum*-dominated peatland habitat.

Keywords: *Sphagnum*; spore longevity; allelochemicals; dissolved oxygen; pH; peatlands

<u>BIO</u>: Dr. Feng is a young researcher with more than 7 years of experience studying *Sphagnum* spore longevity and persistent spore bank formation mechanism. She has participated in 4 projects and published more than 10 papers about *Sphagnum* spore extreme longevity in peatlands and how environmental factors affect spore persistence.

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CONTRIBUTED PAPERS 3

WETLAND MEDIA AND PLANTS

Franziska Eller

POSSIBILITY OF USING HIGH SURFACE AREA PLASTIC MEDIA IN CONSTRUCTED WETLAND

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The aim of the present study is to evaluate the possibility of high surface area (HSA) plastic media and its possibility of usage in the constructed wetland (CW). Preliminary study compares the treatment performance HSA plastic media based CW system with other traditional CW systems. The HSA plastic applied system consists of media with a specific surface area of about 150 m^2/m^3 (internal surface only) while gravel of 2-3 mm diameter was used in traditional CW system. HSA Plastic media was found to be of interest due to no clogging issues and high surface area which may lead to more biofilm growth and furthermore high treatment performance in comparison to the constructed wetland. Void volumes of traditional CW, HSA plastic media based system and hydroponic system were 1.92 L, 3.7 L and 3.73 L respectively which concludes a high loading capacity by HSA plastic media system and its feasibility to employ as media in the constructed wetland. These all systems are running in continuous mode from more than 2 months with 700 mg/L of glucose load and were basically investigated for their organics substance removal and nitrification. Preliminary results for COD studies shows removal efficiency of 90%, 70% and 49% in CW, HSA plastic media based CW system and hydroponic system respectively whereas in case of ammonium removal there was no significant removal in CW whereas, 30.23 % and 20.2% ammonium removal was found in HSA plastic media and hydroponic system respectively.

Keywords: Wastewater, nitrification, HSA plastic media, constructed wetland

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BIO: Yamini Mittal is a PhD scholar in CSIR-IMMT, Bhubaneswar, Odisha. She is working on enhancing the treatment rate of CWs to improve it in terms of feasibility and cost effectiveness for large scale application. Additionally she is also dealing with the problems associated with field scale use of constructed wetlands.

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MOBILITY OF ELEMENTS - LESSONS LEARNED FROM FOUR YEARS PROFILING SEDIMENT WATER INTERFACES

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Sediment water interfaces (SWIs) are often characterized by steep biogeochemical gradients determining the fate of inorganic and organic chemical species. Important transport processes at the SWI are sedimentation and resuspension of particles and fluxes of dissolved chemical species. A microprofiling and micro sampling system (*missy*), enabling high-resolution measurements of sediment parameters (O_2, pH and conductivity) in parallel to suction based sampling of sediment pore waters (SPWs), was constructed and published in 06/2014 (Fabricius et al. 2014). Taken from this publication Fig. 1 shows the initial set up. Consecutively, the this setup was stepwise adopted to different questions on the mobility of As, C, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, P, Pb, S, Sb, Tl, U, V and Zn including chemical fractionation and speciation (Fabricius et al. 2016, Schroeder at al. 2017 and 2018, all documents are open access).

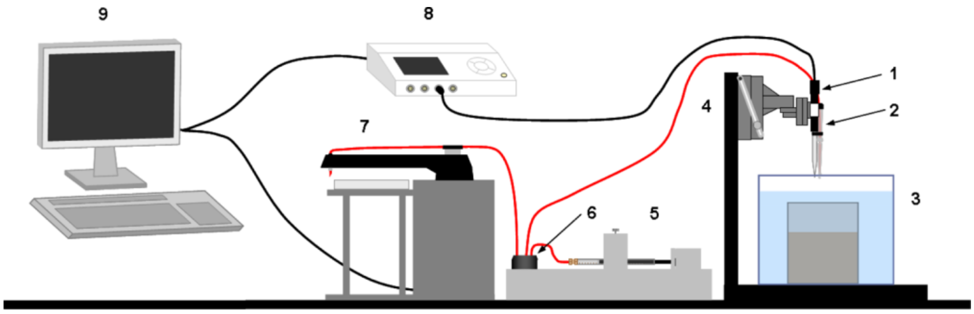

Fig. 1: Schematic drawing of the initial *missy* setup. 1, microelectrode; 2, sample probe; 3, aquarium with sediment core; 4, laboratory stand with two profiling motors (X- and Z-axis); 5, syringe pump; 6, Rheodyne valve; 7, fraction collector: positioning system with a microwell plate; 8, microsensor multimeter; 9, PC.

In the presentation the impact of mechanical disturbance on the mobility of the examined elements as well as the relevance of the colloidal fraction is going to be discussed. In addition to already published data, insights are delivered in recently finished field campaigns at the Baltic sea, including a comparison between results from *in situ* Peeper (diffusion based) sampling and mesoprofiling (suction based) sampling in the laboratory.

Fig.2: A Peeper after exposure and sampling at the Baltic coast SWI. The Peepers were installed and removed by a scuba diver. In parallel sediment cores were sampled. These were incubated in the laboratory and SPWs were sampled with a modified *missy* setup. All samples were analyzed with inductively coupled plasma triple-quadrupole-mass spectrometry.

BIO: By end of 2010 Lars Duester joined the department Aquatic Chemistry of the Federal Institute of Hydrology. In 2017 he became head of the department Environmental Radiology and Monitoring. Current research interests are: fate of stable and radioactive chemical species in the aquatic environment. https://www.bafg.de/DE/08_Ref/G4/05_Mitarbeiter/duester_l/duester_l_node.html https://www.researchgate.net/profile/Lars_Duester

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SUSTAINABLE TREATMENT OF DOMESTIC GREYWATER BY GREEN WALLS FOR REUSE

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The rapid growth in world population, together with rising standards of lifestyle and intensive exploitation of natural environment, has resulted in resource scarcity and water pollution with a widening gap between water demand and supply. The emerging scenario pertaining the future global trends in matter of water demand and water management is calling for the development of more efficient treatment technologies and innovative ways to recycle and reuse wastewater, that represents a cheap and sustainable secondary source of energy and nutrients.

Domestic wastewater can be separated in two different components: greywater – including wastewater produced by showers, bathtubs, washing machines, and hand washing sinks – and blackwater – including the most organic-rich fraction of wastewater generated from toilets. Greywater represents the most suitable fraction of wastewater to treat because the contaminant content is much lower than in black water. The lower level of pollution, consequently, facilitates a removal degree that make greywater suited for non-potable reuses such as irrigation, industrial purposes, toilet flushing, and others, that would otherwise employ clean water. The reuse of wastewater represents a valid and convenient solution to water scarcity and water management problems. The use of nature-based solutions (NbS) has been proposed to find innovative solutions for greywater treatment, coupling environmental, economic and energetic benefits. However, it is still not clear if nature-based solutions are appropriate for greywater treatment, efficiently removing the contaminants.

In this work, a sustainable and innovative system consisting in green walls for treatment and reuse of greywater in urban areas is shown. The system is composed of several panels with pots disposed in vertical columns and filled with different materials and plant types. An irrigation system guarantees a batch feeding with synthetic greywater, reproducing a flow vertical constructed wetland system. The input greywater is chemically analyzed with regards to different pollution parameters (BOD, COD, nitrogen, phosphorus, E.coli, etc.), together with the effluent of each column. In this way, the removal efficiency of the wall is evaluated for each contaminant so as to identify the most efficient configuration in terms of treatment capacity. First analyses showed good removal efficiencies, indicating good treatment performances and promoting the use of green walls as suitable systems for purification of greywater. A wider set of experiments is currently being performed to verify differences in removal efficiency among different system configurations in terms of type of growing material.

BIO: Prof. Fulvio Boano is Associate Professor in Hydraulics and Fluid Mechanics at the Politecnico di Torino. His main research topics are self-depuration processes in stream sediments, constructed wetlands, and water supply networks.

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FLOODING TOLERANCE IN WETLAND PLANTS – THE EFFECTS OF LEAF GAS FILMS

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Flooding can result in partial or complete submergence of terrestrial plants, which is a severe abiotic stress. Partial or complete submergence is a stress for the plant as it involves waterlogging of the root system and the shoot being submerged in floodwater. During submergence, the approx. 10 000-fold reduction in diffusion of gases in floodwaters limits the availability of O_2 and CO_2 for aerobic underwater dark respiration (R_D) and underwater net photosynthesis (P_N), respectively. Terrestrial plants can, however, still photosynthesize under water if both light and CO_2 levels are sufficient. In air, CO_2 enters the tissue via open stomata, but, under water, the stomata are assumed to close.

A leaf trait present in some leaves, which enhances exchange of O_2 and CO_2 with the floodwater, is the ability to retain a gas film around the leaves when submerged. The formation of a leaf gas film is caused by superhydrophobic cuticle surfaces, and the gas films have been demonstrated to increase underwater gas exchange and thus CO_2 entry to sustain underwater P_N during the day and improve internal aeration during the night (Fig. 1).

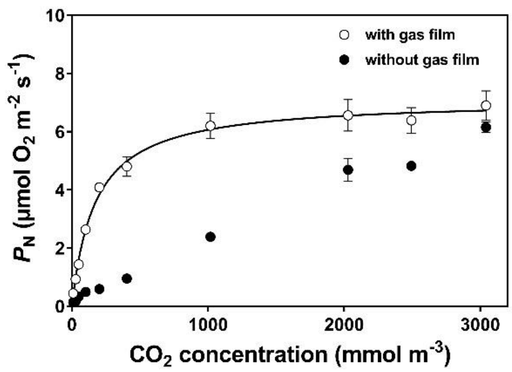

Figure 1. Underwater net photosynthesis (P_N) vs. CO_2 concentration in leaves of *Glyceria fluitans* with and without gas film.

The improved underwater gas exchange provided by leaf gas films has been suggested to result from a large gas–water interface and rapid gas-phase diffusion within the gas film to open and functional stomata. This results in an approx. 5-fold reduction in total resistance to gas exchange between the leaf and the floodwater compared with a situation where the gas film had been removed experimentally. Leaf gas films provide immediate benefits upon submergence in contrast to leaf traits associated with formation of aquatic leaves with reduced cuticles that may take days or weeks to develop.

BIO: Dr. Dennis Konnerup is a plant physiologist specialising in plant adaptions to flooding and submergence. His research is focused on photosynthesis under water and internal transport of gasses in plants in addition to treatment of wastewater using plants.

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CONTRIBUTED PAPERS 4

STREAMS AND SOILS

Tenna Riis

ASSESSING THE RISK OF PHOSPHORUS LOSS FROM WETLAND SOILS

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Preventing over-fertilization of agricultural soils with phosphorus (P) is crucial, as diffuse P losses can contribute to water eutrophication. Recently, an equation linking the degree of P saturation (DPS) to the amount of water-soluble P (WSP) has been proposed as a universal method to assess potential dissolved P losses from agricultural soils (Pöthig et al., 2010). Justified mainly for well-drained soils, whether this equation could apply to cultivated fields set in wetland areas is unclear. Actually, soils in wetland areas are known to undergo biogeochemical processes which may alter their P adsorption properties (e.g. anoxic dissolution of soil Fe-oxyhydroxides during waterlogging) which could influence the applicability of this equation. This question is critical because wetlands are lowland zones receiving inputs of eroded soils from upland fields and could become P-enriched over the long-term.

The studied catchment is the Yvel river catchment (300 km^2), an intensively cultivated catchment located in Western France in which the analysis of historical water monitoring data (2008-2017) revealed increasing trends in soluble reactive P (SRP, <0.45µm). More recent stream-network monitoring results suggest that wetland areas could be the sources of the SRP causing these increasing trends, which in turn indicates that the soils in wetland zones could be at high risk regarding dissolved P losses. Therefore, we conducted P sorption experiments on several wetland soils from this catchment with the aims of evaluating their potential risk of dissolved P loss and, meanwhile, evaluating whether the P risk assessment equation established by Pöthig et al. (2010) could be used to accurately assess P loss risk in wetland areas. For this purpose, 10 soils (0-20 cm and 30-50 cm) were sampled from 4 different wetlands, including in each case cultivated wetland and vegetated buffer strip (VBS) zones in one of the most SRP-contributive headwater sub-catchment of the Yvel river catchment. DPS and WSP values determined from these experiments were used as indicators to evaluate the potential risk of P losses from these soils.

We found significantly higher DPS in surface soils than deep soils, and slightly higher DPS for cultivated wetland soils than for VBS. In surface soils, WEP were significantly higher in cultivated wetland soils than in VBS, while no difference among sites was observed in deep soils. P maximum sorption capacities (Qmax) were not significantly different between surface and deep soils, though a slight increase was observed from cultivated wetland soils to VBS soils. A principal component analysis comparing these data with soil characteristics showed that Qmax was more closely controlled by soil oxalate-extractable Al/Si and fine loam (2-20 µm) contents than by oxalate-extractable Fe content. Comparison of the present dataset with the P risk assessment equation of Pöthig et al. (2010) showed that the risk of P loss is significantly under-estimated by this equation for DPS values >50%. We attribute this mis-prediction to the difference in soil properties between wetland and well-drained soils. The high organic matter content and frequently waterlogged conditions of wetland soils could influence the crystallinity of Fe/Al oxides and result in fewer strong sorption sites in these soils as compared to well-drained soils. The present study suggests that great care should be exercised when applying the existing P risk assessment equations to soils from wetland areas, and claims for the development of specific assessment tools for the soils of these presumably high-risk zones as regards dissolved P emissions.

BIO: Dr. Gu is a junior scientist working on the biogeochemical release and transfer of phosphorus at the catchment scale.

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THE ROLE OF MACROPHTYES AS SOURCES OF DISSOLVED ORGANIC MATTER IN LOWLAND STREAMS

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Macrophytes are abundant in many lowland streams throughout the world and play a crucial role in carbon (C) storage in those ecosystems as main primary producers. However, a fraction of the amount of C that macrophytes fix photosynthetically is released back into the streamwater as dissolved organic matter (DOM). Macrophytes therefore can also be relevant DOM sources in aquatic ecosystems, yet most of the studies on authochonous DOM sources are based on algal derived compounds. Plant leachates are mostly composed by small DOM molecules, such as amino acids and simple sugars, which represent high-rich substrates for heterotrophic bacteria, and thus might promote large respiration heterotrophic rates. Here, we investigate the role of macrophytes as sources of DOM in two lowland agriculture streams in Jutland (Denmark). In particular, we had two specific questions i) does macrophyte coverage increase stream DOM concentration? ii) Does macrophyte coverage influence DOM composition and reactivity? To respond to these questions, we first characterized the main stream DOM sources (sediment, macrophytes and leaf litter from riparian trees). Second, we applied a before and after control-impact design and measure DOM concentration and composition in control and impacted reaches before and after macrophytes removal. Third, we conducted biodegradable dissolved organic C experiments measured in dark incubations for 28 days to assess DOM reactivity. Overall, our study will contribute on our understanding to what extent macrophytes influence DOM quantity and reactivity in lowland streams, which is essential to trace the fate of C in aquatic ecosystems.

BIO: Dr. Pastor is an early-stage scientist with her main research focus on aquatic biogeochemical processes. She has participated on several international research projects aiming to examine nutrients and organic matter cycling across aquatic ecosystems differing in their human impact.

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MORPHOLOGICAL TRAITS AND PHYSIOLOGICAL PERFORMANCE OF AMPHIBIOUS SPECIES IN RELATION TO NUTRIENT LEVELS AND LIGHT EXPOSURE

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Stream ecosystems have been affected by a complex mixture of stressors resulting in a range of anthropogenic impacts and climate change, which have influenced aquatic plant communities. It has been shown that aquatic plants respond to abiotic factors with morphological changes (response traits), however the understanding of the underlying response mechanisms of these responses and their impact on physiological performance is still limited. In this study we demonstrate how response traits of amphibious species (*Butomus umbellatus, Berula erecta*) change along a gradient of nutrient concentration and light conditions and examine the relationships between plant morphological responses and their effects on multiple aspects of physiological performance (effect traits). Plants were grown in mesocosms (90 L plastic tubs) for 14 weeks during summer 2018. They were exposed to two factors: nutrient enrichment (five different nutrient concentration levels), and shading (0% and 50% shading). At the end of the experiment, response traits were measured, including plant height, number of leaves, plant dry and fresh weight (roots and stem), leaf chlorophyll content and tissue C:N:P concentrations (roots and stem). Also, photosynthesis-irradiance responses were tested by comparing P_{max}, the light saturation point, light compensation point, dark respiration rate and quantum yield, together with Relative Growth Rate (RGR). We expect to find changes in plant morphological traits and physiological performance with different nutrient and light conditions, but even more novel to this study we also expect to find an ecologically relevant relationship between response and effect traits.

BIO: Dr Manolaki is a postdoctoral researcher at Aarhus Institute of Advanced Studies (AIAS). Her research interests include functional aspects of aquatic plant communities; effects of global changes on aquatic ecosystems; evaluation of stream ecological quality; ecosystem processes in streams; and dynamics of aquatic and riparian vegetation.

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THE EFFECTS OF WEED CUTTING PRACTICES ON NUTRIENT RETENTION AND METABOLISM IN LOWLAND AGRICULTURAL STREAMS

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Macrophytes are abundant in many lowland streams, where they are considered ecosystem engineers due to their important effects on stream structure and functioning. Macrophytes enhance nutrient retention in streams via direct plant uptake and indirect pathways such as via uptake and transformation by microbial epiphytic biofilm on leaves or roots. Stream nutrient retention by assimilative uptake is positively linked to the biomass of the plants themselves and the epiphytic biofilm growing on the plant surfaces; therefore, nutrient retention are likely to be strongly disrupted by current stream management such as weed cutting (i.e. mechanical removal of macrophytes). In this study, we aimed to determine the effect of stream management practices (i.e. weed cutting) on nitrogen and phosphorus retention and metabolism in lowland agricultural streams. To do that, we designed a before and after control-impact (BACI) experiment and measured whole-reach nutrient uptake and metabolism in four stream reaches (two control and two impacted reaches) before and after weed cutting. We quantified nitrogen and phosphorous uptake metrics using pulse nutrient additions of phosphate and ammonium and estimated stream metabolism using two-station diurnal oxygen method. Overall, our results based on field experiments will increase our knowledge on the functional role of stream macrophytes and provide information for best management practices to optimize stream management to reduce nutrient export to coastal areas.

BIO: Tenna Riis is associate professor and has more than 20 years led research on the ecology of freshwater macrophytes focusing on their important role in structuring and functioning of freshwater ecosystems.

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C.P. 5

CONTRIBUTED PAPERS 5

AERATED SYSTEM

Scott Wallace

EFFECT OF TEMPERATURE ON OXYGEN TRANSFER AND CONSUMPTION RATE IN A TREATMENT WETLAND FILLED WITH CORK'S BYPRODUCT

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Over the last years, treatment wetlands (TW) design and operation have been improved. Understanding the interaction of all the complex internal factors that influence the pollutants removal processes in the wetland bed and how these are influenced by operational parameters, is a key subject to enhance this technology. Induced aeration is an intensive operational strategy that can successfully increase the oxygen in the wetland in spite of the increasing operational cost due to the energy consumption.

Corks byproduct granulates (7 mm Ø) were used as filter media in an aerated saturated vertical flow TW operated as a tertiary treatment for winery wastewater. The TW was built inside a 20' open top shipping container for the ECORKWASTE project (LIFE14 ENV/ES/460), with a 14 m^2 surface area, a 1.0 m depth filter cork layer. A drainage gravel layer and an insulation gravel layer (both 32 mm Ø and 0.20 m deep) were used to engulf the drainage pipes and to prevent the cork from floating, respectively. *Phragmites australis (4 plants/* m^2) were planted in the wetland. The average hydraulic loading rate was 2,000 l d^{-1}.

Cork filter was aerated with atmospheric air by a pressurized system (90 l min^{-1} airflow rate). Sensors were fitted in the wetland bed to monitor Dissolved Oxygen (DO), pH, and Temperature (T). The sensors were placed 30 cm below the water level (90 cm water deep) inside a vertical ADS 4-in corrugated perforated pipe inserted in the cork layer, next to the outlet well. From July to November 2018, all parameters were daily measured every 5 minutes (n = 288). A One-hour aeration cycle (an aerated period followed by a non-aerated period) was performed four times per day, starting at 9:30 h. A Victron Energy Color Control GX was used for energy consumption monitorization.

The daily variation in the environmental temperature did not affect the temperature inside the wetland bed. The minimum and maximum environmental temperature on July 17th and November 4th was 19-31 °C and 7-21 °C, respectively, whereas the average wetland bed temperature was 30 °C (± 0.4) on July 17th, and 14 °C (± 0.1) on November 4th, because of the thermal insulating properties of cork. For both days, the DO concentration measured before the first aeration cycle (40 minutes aerated – 20 non-aerated) was 0.2 mg l^{-1}. On July 17th, the higher DO concentration measured was 2.6 mg l^{-1}, registered at 13:20 h. From this time the DO concentration decreased, and a 0.5 mg l^{-1} concentration was registered at 14:30 h. On November 4th, the higher DO concentration, registered at 10:05 h, was 4.0 mg l^{-1}, and the 0.5 mg l^{-1} were registered at 21:00 h. The energy consumption for the aeration cycles was 0.6 kW/h·d.

Cork byproduct granulates could enhance the efficiency of NT removal in wetlands for cold climates. The results have allowed to improve calculated design parameters for the combination of aeration and cork. Understanding the dynamics of the DO depending on T and filter medium, allowed control of the aeration time and, therefore, reduce energy consumption and the footprint of the treatment wetlands.

BIO: Ángel Gallegos is a project manager with 10 years of international experience developing cooperation and environmental restoration projects. The design, construction, operation, monitoring and maintenance of treatment wetlands, working in partnership with multidisciplinary teams, are the main focus of his work.

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AERATED FLOATING TREATMENT WETLANDS FOR ENHANCED WASTEWATER TREATMENT

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INTRODUCTION: Floating Treatment Wetlands (FTWs) are an alternative approach for treatment of contaminated water involving emergent macrophytes growing on buoyant mats or rafts Headley and Tanner 2012). Water is treated in the submerged root-mass suspended beneath the mats. The extensive root mass and attached microbial biofilms create a large respiratory biomass, commonly resulting in anaerobic zones beneath the mats (Tanner and Headley 2011). Organic sediments accumulating in the quiescent water beneath the FTWs can exert further oxygen demand, exacerbated by shading of algal photosynthesis and restricted gaseous exchange through the floating mat. Depending on the extent of FTW coverage, water depth, degree of exchange with surrounding waters and oxygen demand of the waters being treated, deoxygenation can be localised in the root mass and biofilms or extend through the whole water column. Although anaerobic conditions such as these can favour anaerobic biogeochemical processes such as denitrification and sequestration of metals (Tanner and Headley 2011, Borne et al. 2014, Ladislas et al. 2015), they inhibit the aerobic processes necessary for efficient treatment of organic and ammonium-rich wastewaters. This study evaluates the treatment benefits of aerating the initial stages of FTW systems treating primary domestic wastewaters.

METHODS: A pilot-scale trial was carried out at the Pukete Wastewater Treatment Plant in Hamilton, New Zealand Physicochemical conditions (DO, electrical conductivity and pH) and concentrations of wastewater contaminants (TSS, CBOD, NH4-N, NO¬3-N, TN, DRP, TP and E. coli) were compared side-by-side over a year at multiple points along two differently configured FTW treatment trains. Each system comprised 5 or 6 tanks (1 m3) in series supplied with primary-settled domestic wastewater. One of the treatment train involved sequential flow through 2 initial aerated tanks, followed by 4 unaerated tanks. The other treatment train included an initial anoxic tank followed by an aerated tank recirculated (4:1) back through the first tank, followed by 3 unaerated tanks. The aerated stages were fitted with racks of geotextile to support attached biofilm growth. Mature 1 m2 FTWs constructed from 200 mm thick polyester fibre mats injected with buoyant foam (WaterClean Technologies, NZ) and planted with Carex virgata were positioned on the top of each tank.

RESULTS AND DISCUSSION: Aeration of the initial stages of the FTWs substantially improved treatment performance enhancing, in particular, removal of CBOD, NH4-N, TN and E.coli. The recirculating system achieved >95% of TSS and >85% removal of cBOD5. The single-pass system showed slightly better removal with >97% of both TSS and cBOD5, maintaining the final effluent TSS and cBOD5 concentrations at below 2.5 and 2 mg/L respectively. The recirculating and single-pass FTW systems achieved 66 and 75% overall TN removal respectively. For the recirculating system, ~90% NH4-N removal (from 36.3 to 4.4 mg N/L) was achieved in the aerated FTW via nitrification, while the initial anoxic stage FTW (which receiving nitrified effluent of the aerated FTW) removed ~40% of NOx-N (from 20.6 to 12.7 mg N/L) through denitrification. Little further NOx-N reduction occurred in the subsequent FTWs 1-3, suggesting that low organic carbon level (BOD5: <3 mg/L) was likely limiting denitrification. While the single-pass system had lower levels of nitrification than the recirculating system (NH4-N removal 76.9%), it achieved higher denitrification (NOx-N removal 81.3%), thus resulting in ~10% higher overall TN mass removal (single-pass system: 75.7%; recirculating system: 65.3%). The partly aerated FTW systems also achieved ~47% and 32% of TP and DRP removal, respectively, and had ~3-log E. coli removal (from 106 to 103 MPN/100 ml) during the experimental period. This one-year mesocosm-scale FTW study showed that FTWs supplemented with mechanical aeration of~15% of the total FTW area can provide satisfactory level of secondary wastewater treatment and nitrogen removal for a retrofit to existing waste stabilisation ponds or a new sewage treatment option.

CONCLUSIONS: Supplementing FTWs with mechanical aeration in the initial stages enabled high levels of treatment of primary-settled wastewaters. Operational advantages of aerated FTW systems over other constructed wetland approaches will be discussed, including: ability to retrofit existing pond systems and adjust to changing waste loads and water depths; lack of requirement for specialised mineral media; low susceptibility to clogging and ready accessibility beneath the mats for removal of accumulating sludge.

WETLAND AERATION AND ORGANIC OVERLOADING: WHICH STRATEGIES? HOW TO PREVENT AND HOW TO RESORB CLOGGING?

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Forced bed aeration treatment wetlands have been applied to a wide range of effluents: from domestic wastewater, to wastewaters from petroleum industries, agroindustry or airport runoff containing deicing products. Wetland aeration allows systems to achieve lower discharge levels with a smaller footprint area compared to passive systems.

Since aerated wetlands can achieve very high levels of treatment, the organic loading rates applied are often much higher than those on passive systems. When flow and load conditions are variable, this can "push" systems beyond the clogging threshold, leading to performance issues. Recurrent and extreme organic loading rates may lead to insufficient excess sludge mineralization in the core of the filter, eventually inducing so-called biological clogging. Severe cases can affect the system hydraulics and discharge levels until subsurface flow is no longer feasible.

However, it is sometimes difficult to accurately and reactively assess effective organic loading rates. Thus, online monitoring methods have been developed in order to have a real-time control of the system, including O_2/redox and blower pressure sensors. Advanced data processing of these parameters will be discussed. The presentation will deal with advisable monitoring scheme and threshold values, through comprehensive case-study descriptions.

Once clogged, passive wetlands sometimes do not leave other alternative than replacing the filter's media, washing media, or application of chemical agents such as H_2O_2. Aerated wetlands bring up the interesting possibility that clogging matter can be digested in situ through a combination of continuous aeration and reduced inlet loading.

The presentation will address the suitable minimal operation to enhance the systems recovery after severe biological clogging issues. Criteria for decision making regarding getting the system back to normal operation will also be discussed.

BIO: Stéphane TROESCH has a Ph.D in environmental engineering, with 10 years' experience as Head of Research and Development department of SYNTEA / EcoBIRD and 15 years of experience in the field of extensive wastewater treatment.

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DENITRIFICATION GENES (NIRS AND NOSZ) AND 16S RRNA GENE ON CORK'S BY-PRODUCT USED AS FILTER MEDIUM IN AN AERATED SATURATED VERTICAL FLOW TREATMENT WETLAND FOR TN REMOVAL

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The LIFE ECORKWASTE project developed an Integrated and sustainable management for cork waste generated in the cork industry (LIFE14_ENV/ES/460), using 7 mm particle size cork by-product as filter media in a treatment wetland (TW) operated as tertiary treatment for winery wastewater. The main objective of the project is to minimize landfilling by turning cork byproduct into value. Several studies have been used cork as biosorbent for pollutants removal (metals and organics) from water. In TWs, the metabolic reactions of microbial communities are the major responsible for wastewater treatment, considering that microorganisms responsible for nutrient removal can easily attach to the cork surface.

A 20' Open Top shipping container (14 m^2, previously waterproofed) was used to hold the elements of the treatment wetland. A 1 m depth cork filter media was used, with a 0.80 deep water level. The wetland bed was planted with *Phragmites australis* (4 plants/m^2). From April through December 2017, the plant was operated as a non-aerated saturated VF. Two different aeration phases, Jan-Jun and Jul-Oct 2018, of 25 and 40 minutes (both at a 90 l min^{-1} airflow rate) supplied atmospheric air to the flooded wetland. After each aeration period, the wetland bed was non-aerated during 35 and 20 minutes, respectively. The first cycle (aerated and non-aerated period) started at 9:30 h and the last one, the four cycle, started at 12:30 h. For both operational modes the hydraulic loading rate was 2,000 l d^{-1} and parameters such as COD, BOD5, all N species, alkalinity, OD, REDOX, pH and temperature were monitored with monthly intervals and three consecutive days campaigns.

Saturated surface cork samples were monthly collected from June-17 through October-18 at three different points of the wetland bed. The molecular analysis was focused in the specific genes 16S rRNA, and denitrification gene markers such as nirS and nosZ, main responsible bacteria for nitrogen removal. The biofilm on the cork surface was concentrated for DNA extraction using Dneasy PowerSoil Kit and and quantified using quantitative real-time PCR (Roche Lightcycler 1.5). Average removal efficiency in both the aerated/non-aerated periods for NT, NH_4-N an NO_3-N were 37-79 %, 21-72 %, and 45-95 %, respectively. The abundance of the total bacteria (16s RNA) and denitrifying bacteria (nirS, nosZ) increased during the aeration period. The nirS abundance was slightly larger than nosZ gene. The results from the statistical analyzes performed do not showed statistically significant differences between the 3 sampling sites and the same comparing different depth sampling sites.

Induced aeration enhanced the abundance of microbial communities on the cork filter medium and, therefore, enhanced the pollutants removal efficiency of the TW. Understanding the behavior of microbial communities under different operational modes is one of the key factors for optimizing TW.

BIO: Lorena Aguilar is a researcher with 5 years of experience in the design, construction, operation, monitoring and maintenance of treatment wetlands. She has developed projects for enhancing the technical, environmental, economic and social aspects of the technology.

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FORCED AERATION VERTICAL FLOW TREATMENT WETLAND FED BY RAW WASTEWATER: DESIGN AND AERATION MODE TO ENHANCE TN REMOVAL

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TN removal by treatment wetlands requires using different treatment stages that impacts both the investment cost and the footprint. Recently, the use of unsaturated/saturated vertical flow treatment wetlands has been studied. By implementing two different zones it is possible to maintain aerobic and anoxic conditions in the same system, thus treating TN. Nevertheless, TN removal performances cannot reach high enough values to guarantee low outlet concentrations. The use of intermittent forced aeration (Boog et al., 2014) is a valuable means to boost performances, including TN removal by sequencing aeration phases. In the aim to reduce footprint and improve performances, Opure company developed a unsaturated/saturated vertical flow treatment wetland in which saturated zone can be aerated artificially (patented under the name Oxyphyltre®). In that context, the aim of this study was to determine the optimal designed parameters such as saturation layer depth, aeration density and flow in order to optimize nitrification-denitrification processes.

The experimental pilot-scale site is based at L'encloitre (47°55'N; 0°64'E) and was commissioned in September 2016. The system is composed of 7 pilots of 1 m² feeding with real raw wastewater. Each pilot is equipped with 2 aeration networks at the bottom, supplied intermittently by a compressor to test different aeration density and air flow. Saturation layer depth was tested at 40, 55 and 70 cm. Based on weekly pollutant monitoring the study has been divided in two phases. A first one to determine the optimal saturation layer depth, aeration density and air flow from February 2017 to October 2017. A second phase to optimize the nitrogen removal rate by studying the aeration frequency (from October 2017 to November 2018).

The higher nitrogen treatment performances were observed for the pilot with a 70 cm saturated layer depth and only one aeration network. Average performance removed were 94.9%, 96.1%, 89.0% and 53.9% for COD, TSS, TKN and TN. In second phase, saturation layer depth has been fixed at 70 cm for all pilots and only one aeration network has been used. During this period, the CWs system reach high average removal rate with 93.5%, 96.2%, 91.7% for COD, TSS, TKN and increased to 79% for TN. The major parts of residual TN is composed of N-NO3. The experiments showed that denitrification is not always total due to a lack of carbon.

Aeration appears as a technology with a very high potential allowing to reach high performance with only one stage I order to reduce the footprint.

BIO : , I am a PhD student in the OPURE Company, in collaboration with IRSTEA. I started my PhD in September 2016 and my subject talks about of the optimization of vertical constructed wetland combining saturated layer and forced aeration.

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C.P. 6

CONTRIBUTED PAPERS 6

CONSTRUCTED WETLANDS PERFORMANCE

Diederik Rousseau

PILOT TESTING A FREE-WATER SURFACE CONSTRUCTED WETLAND TO TREAT HYPEREUTROPHIC LAKE WATER

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The San Antonio Water System (SAWS) owns and operates Mitchell Lake, a 270 ha (670 ac) on-channel impoundment located near San Antonio, Texas. The lake is a historic remnant of the City of San Antonio's sewage treatment operations and was used to store raw or partially treated wastewater from 1901 to 1987. Because of its prior history, Mitchell Lake is subject to a discharge permit issued by the state of Texas. The lake discharges periodically in response to extreme or extended rainfall events. When this occurs, the permit requires SAWS to sample for several constituents named in the permit. Due to the hypereutrophic nature of the lake, the facility has periodically not met permit limits for pH, BOD_5, DO and TSS. In order to improve the quality of water discharged from the lake, SAWS is moving forward with a plan to construct a 44.5 ha (110 ac) free-water surface (FWS) treatment wetland located downstream of the dam. Under this plan, stormwater runoff will be stored within the lake and routed through the wetland at a controlled rate before the wetland outflow is discharged to the original receiving stream.

The addition of a downstream wetland would trigger the need for an amended permit. Regulated constituents in an amended permit are expected to include BOD_5, DO, TSS and ammonia. A desktop evaluation was performed that identified target flow rates to the downstream wetland for BOD_5, DO and TSS. However, since relatively few full-scale wetlands or long-term studies have been conducted on FWS systems treating eutrophic or hypereutrophic lake water, little data are available that could be used to accurately model the nitrogen transformation and removal rates needed to estimate the outflow concentration of ammonia, considering the inflow form is predominately particulate organic nitrogen. Another question related to the development of the downstream wetland involves whether an emergent macrophyte community can be established within the marsh areas, since very little aquatic vegetation currently exists around the lake fringes. Because of these uncertainties, SAWS is conducting a pilot test to produce data that will be used in the design of the full-scale downstream wetland system.

The FWS pilot wetland consists of three trains with two cells in each train and a total wetted area of 5,450 m^2 (58,650 ft^2). Each train will receive water pumped from the lake and will operate at hydraulic loading rates of 1.7, 5.9 and 12.5 cm/d, respectively. V-notch weirs with data loggers will be used to monitor and record inflow and outflow rates to/from each wetland train. Climate data from an on-site weather station and the flowrate data will be used in conducting a water balance analysis. Water quality samples will be collected at the inflow and outflow from each train. Wetland vegetation from local area lakes will be used to plant the system with growth and percent coverage monitored monthly through the duration of the study. After a two-month grow-in period, the pilot wetland will be operated as a steady-state system for at least twelve months. Early results of the pilot test will be available by Summer 2019.

Bio: Mr. Noack is a principal engineer with 20 years of constructed wetland experience with projects ranging in size from 1.0 to 810 hectares and total construction cost of over $80 million. Applications have included municipal and industrial wastewaters; indirect potable reuse; and restoring wetlands for compensatory mitigation and habitat improvement.

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ENHANCED REMOVAL OF MICROCYSTIS BLOOM AND MICROCYSTIN-LR USING MICROCOSM CONSTRUCTED WETLANDS WITH BIOAUGMENTATION OF DEGRADING BACTERIA

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The prevalence of cyanobacterial bloom (Cyano-bloom) and hepatotoxic microcystin (MC) pollution caused by eutrophication poses serious problems to aquatic ecosystems and public health. However, conventional water treatment technologies are inefficient for removing cyanotoxins. In this study, the performance of microcosm constructed wetlands (CWs) in the removal of Cyano-bloom, microcystin-LR (MC-LR), and nutrients was investigated following repeated loading of pollutants. The effects of plant and bioaugmentation of selected MC-LR degrading bacteria on removal efficiency, degrading gene mlrA abundance, and bacterial community structure were examined. More than 90% of the MC-LR and chlorophyll-a was eliminated by CWs after 3 d of hydraulic retention time (HRT) without a lag phase. No significant differences between planted and unplanted CWs were found in the MC-LR and Cyano-bloom removal and mlrA gene abundance. Nevertheless, the plants improved nutrient removal to reduce eutrophication. Bioaugmentation markedly enhanced the degradation of MC-LR from 16.7 μg L^{-1} to below the threshold value within 12 h, which could help shorten the HRT of CWs by increasing functional MC-LR degrading bacteria. In the soil of CWs, the following six bacterial genera with MC-LR-degrading potential were found: Sphingopyxis, Methylotenera, Pseudomonas, Methylosinus, Novosphingobium, and Sphingomonas. Among them, the first three also significantly proliferated in CWs with bioaugmentation during MC-LR degradation, indicating their high adaptability and MC-LR removal contribution. These results suggested that CWs could provide suitable conditions for MC-LR degrading microorganism proliferation, and CWs with bioaugmentation could be effective and practical measures for the remediation of eutrophication and MC pollution.

BIO: Dr. Wang is engaged in the research on the microcystis bloom remediation using intensified constructed wetland.

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PERFORMANCE OF HYBRID PEANUT SHELLS BIOFILTERS WITH SCHOENOPLECTUS CALIFORNICUS TO REMOVE ORGANIC MATTER FROM DOMESTIC WASTEWATER

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Biofiltration is a low-cost passive technology based on organic/inorganic filter media. Specifically, organic wastes are being used within filter media by their adsorbent properties (porosity, OH groups). Thus, peanut shells abundantly produced in the Ecuadorian coast will be a good filter media. On the other hand, the hybridization between biofilters and constructed wetlands could improve the performance, due that roots of aquatic plants would increase superficial area (biofilm), oxygen supply and organic matter adsorption. Shoenoplectus californicus is a cosmopolite macrophyte, which has proven to be feasible to use in constructed wetlands treating wastewaters. Therefore, the aim of the study was evaluate the performance of hybrid peanut shells biofilters with Shoenoplectus californicus to remove organic matter from domestic wastewater.

The experimental model used 6 biofilter assays or cylindrical columns (12 x 100 cm) made of polypropylene. On the one hand, 3 columns were biofilters control (without plants, B) and the rest biofilters hybrid (with plants, BPM). Each column (30 cm) was filled by three layers: active (25% peanut shells, ϕ=850μm-2mm), intermediate (sand, ϕ=1-2mm) and support (gravel, ϕ=10-25mm). Moreover, three hydraulic rate (0.5, 1 and 1.5 m3/m2-day) intermittent (8 hours of daily operation) were studied in each one. Organic matter removal from synthetic domestic wastewater and measured as COD (Chemical Oxygen Demand) and VS (Volatile Solids) was monitored during 90 days. Moreover, allometric measurements (apical height, basal diameter, chlorophyll a and b) on plants were evaluated during this period.

Results reported stable control operation conditions within all biofilters with values of pH, temperature and humidity from 7.0 to 7.5, 66 to 83 % and 18 to 24°C, respectively. The highest COD and SV efficiency removal were reached by BPM at an optimized hydraulic rate of 0.5 m3/m2-day, and whose average values were 82.7 and 64.5%, respectively. However, only SV removal within BPM was significantly ($p < 0.05$) higher than B. According to the plant behavior, apical height (21.8 cm), basal diameter (15.1 cm) and chlorophyll a/b (1.1/0.4 mg/g) were the highest when BPM operated at 1.0 m3/m2-day. However, clogging (up to 0.24 cm) and hydraulic conductivity (up to 4.1 mm/h) decreased up to 24 %when BPM were operated. Definitely, BPM is a feasible alternative to improve the biofilters performance.

BIO: Dr. Villamar is a researcher with 8 years of expertise in the study and operation the different passive technologies (constructed wetlands, vermifilters and biofilters) at laboratory and industrial scale.

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SUSPENDED SOLIDS AND NUTRIENT RETENTION IN TWO CONSTRUCTED WETLANDS AS DETERMINED FROM CONTINUOUS DATA RECORDED WITH SENSORS

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Constructed wetlands (CWs) are recognized as a useful method to reduce sediment and nutrient loading from arable land to surface waters. Automatic monitoring systems with continuously measuring sensors were utilized to obtain accurate, up-to-date information of the retention performance of two differently dimensioned and located CWs in agricultural catchments in southern Finland. Here, results derived from the data recorded by the sensors measuring height, turbidity and nitrate-nitrogen (NO3-N) concentration of the water entering and exiting the Hovi (established in 1998) and Rantamo-Seitteli (est. in 2009) CWs are presented. Study periods ended in autumn 2014 and they lasted 7 years at Hovi and 4.5 years at Rantamo-Seitteli.

Annual total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN) per cent retentions were much higher in the older, more generously dimensioned (CW-to-catchment area ratio 5%) Hovi CW (TSS 74%, TP 58% and TN 54% on average during 7 years) than in the newer, more scantly dimensioned (CW-to-catchment area ratio 1.3%) Rantamo-Seitteli CW (TSS 7%, TP 12% and TN 9% on average during 4.5 years). Moreover, the annual retentions of the Rantamo-Seitteli CW appeared to decrease with increasing runoff, while the retentions at Hovi were not affected by runoff fluctuations. In terms of TSS and TP retentions in the Hovi CW, they were in this study at similar levels to those observed shortly after the establishment of the CW. Meanwhile, the retention of dissolved nutrient fractions, i.e. NO3-N and dissolved reactive P (DRP, based on water sampling) at Hovi were clearly higher in this than in the previous study.

The results confirm the importance of CW dimensioning and locating near the sources of loading, and refer to improved performance as CWs get older with increasing vegetation and biological activity. Our experiences of CW measurements with sensors have been positive. The information obtained with new technology has provided retention estimates that are more accurate than they would have been if they were derived from sparse grab sampling.

BIO: Dr. Jari Koskiaho is a research engineer with 20 years of experience in wetland studies. He also has experience in watershed modeling as well as in assessments of diffuse pollution and mitigation methods.

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CONTRIBUTED PAPERS 7

GHG AND EMISSIONS

Otto Stein

NITROGEN OUTGASSING (N_2, N_2O) BY DENITRIFICATION IN WETLAND ECOSYSTEMS WORLDWIDE: A MODELING APPROACH

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Wetland ecosystems are interfaces between land and water ecosystems distributed worldwide. Even if a definition that satisfies all users has not yet been developed, wetlands are characterized and protected global scale by the Ramsar convention (Matthews 1993).

Currently, surface water pollution by fertilizers, pesticides and high biogenic elements inputs (like nitrates and phosphorus) is one of the major environmental issues in a context of global changes.
Because wetland ecosystems are able to capture carbon and release nitrogen as N2 through denitrification, their proper functioning plays an important role in counteracting the deterioration of water quality as buffer zones between soils and surface/groundwater water. Denitrification is an anaerobic process carried out by facultative soil bacteria community, resulting in the reduction of soil nitrates (NO-3) to gaseous molecular nitrogen (N2) and a small fraction of nitrous oxide (N20).

At a global scale, previous studies have monitored the application of fertilizers to crops and the combustion of fossil fuels in the last two centuries and reported the atmospheric impact of these activities, in the increasing annual NO and N2O emissions (Tian and Yang 2017). At the same time, a decline in natural biological N2 fixation activity in terrestrial ecosystems has been reported, due to the reduction of area (Galloway et al. 2004).

It is the scope of this research to quantify the outgassing associated to microbial denitrification process that occurs in wetlands worldwide. We aim to generate a dynamic model with a spatial resolution of 0.25 km × 0.25 km (at the equator) able to show monthly variation of denitrification outgassing in wetlands over a period of 14 years, from 1993 to 2007.
The model is built up on a denitrification equation in function of the main controlling factors that could lead to spatial and temporal variations: (I) wetland ecosystems typology (marshes, swaps, coastal wetlands, saline wetlands and bogs) (GLWD(Lehner and Döll 2004)); (II) soil properties (carbon content, nitrogen content, soil porosity and carbonates content) (WISE30sec (Batjes 2015), NEWS 2 (Mayorga et al. 2010); (III) nitrogen fertilizers input (Lu and Tian 2016), (IV) climate variability (temperature) (CHELSA (Karger et al. 2017)), and (V) inundation regime (aerobic/anaerobic conditions)(GIEMS (Prigent et al. 2007)).

This combination of worldwide databases, satellite images and modelling will allow us to identify key factors of wetland denitrification in a dynamic way: (1) the main controlling factors in different wetlands, (2) the potential and tangible denitrification outgassing, and (3) the hotspots and hot moments of denitrification outgassing. These results would be useful to better understand the nitrogen flow and relation with carbon and aerobic/anaerobic dynamics in wetlands and to provide solid evidence of the value of wetland ecosystem services, in order to improve decision making on water management.

BIO: MSc. Martínez-Espinosa is a biologist specialized in tropical ecology, currently a 2nd year PhD student. She has been involved in projects of improvement of water supply and sanitation with natural based solutions in Mexico and Egypt. For her MSc thesis she conducted an assessment of mangrove forest management in Malaysia.

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WARMING EFFECTS ON N2O FLUXES IN A BOREAL PEATLAND OF PERMAFROST REGION, NORTHEAST CHINA

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Climate warming in boreal permafrost peatlands may result in degradation of permafrost, changes in the intensity and duration of soil frost, and alterations in rates of nitrogen mineralization. However, the effects of warming and freeze-thaw event on N_2O fluxes and the N_2O budgets were ignored in boreal peatlands. Here, we conducted two experiments to examine how warming and freeze-thaw event affect N_2O fluxes in a boreal peatland of permafrost zone in Northeast China.

Firstly, we conducted warming experiment to investigate the effects of warming on N_2O fluxes in Betula. Fruticosa community (B. Fruticosa) and Ledum. palustre community (L. palustre) during the growing seasons from 2013 to 2015. The Results showed that: (i) warming treatment increased air temperature at 1.5 m aboveground and soil temperature at 5 cm depth by 0.6°C and 2°C, respectively. (ii) The average seasonal N_2O fluxes ranged from 6.62 to 9.34 μg m^{-2} h^{-1} in the warming plot and ranged from 0.41 to 4.55 μg m^{-2} h^{-1} in the control plots. Warming treatment increased N_2O fluxes by 147% and transformed the boreal peatlands from a N_2O sink to a source. (iii) Soil temperature and active layer depth were the main controlling factors of N_2O fluxes. These results indicated that warming stimulated N_2O fluxes by increasing soil temperature and active layer depth in a boreal peatland of permafrost zone in Northeast China. Moreover, elevated N_2O fluxes persisted in this region will potentially drive a noncarbon feedback to ongoing climate change.

Secondly, an incubation study were carried out to investigate the influence of different N addition levels and N addition forms (AC: ammonium chloride, NS: sodium nitrate) on the emissions of N_2O under FT and non-freeze-thaw (NFT) conditions in boreal peatlands of Northeast China. Results indicated that: (i) the FT condition significantly increased N_2O emissions compared with the NFT condition and peaks occurred during thawing. (ii) Compared with AC treatments, NS treatments significantly elevated the accumulation of N2O emissions under the FT condition, exhibiting significant differences in different NS levels. (iii) N_2O emissions were also positively regulated by soil NO_3^- concentrations to supply nitrate for denitrification. Nitrate-N addition was mainly responsible for the burst of N_2O with denitrification as the main process during FT events. Therefore, these results suggest that N_2O emissions potentially increase during FT events with increasing nitrate-N deposition in permafrost peatlands, which would contribute to global climate warming.

BIO: Dr. Cui is a young researcher with more than 6 years of experience studying warming effects on carbon and nitrogen cycle in boreal Peatland of Permafrost. She has participated in more than 4 projects and published more than 7 papers about warming effects on greenhouse gas emissions.

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FLUCTUATING GROUNDWATER TABLE ENHANCES N_2O EMISSION FROM INCOMPLETE DENITRIFICATION IN A FLOODPLAIN FEN

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Nitrous oxide, a major greenhouse gas, is found to be emitted largely from organic soils. We have investigated the effects of water table and soil oxygen (O_2) content on N_2O fluxes from a drained floodplain fen in Estonia. We also studied the effects on natural abundance of nitrogen isotopes ^{15}N & ^{14}N in the soil to understand how the isotopic nature changes during nitrification and denitrification as we raise the water table and decrease O_2 in the peat. During the field experiments in autumn 2018, we studied three soil environments under varying O_2 content which were: oxic, suboxic and anoxic. Opaque truncated conical manual chambers (65 L) were used to sample gas from each site during one-hour sessions. The suboxic environment was connected to variation in water table, both in time and depth. We created an anoxic environment by experimental flooding. We observed low N_2O emissions under oxic conditions (Figure 1). Under suboxic conditions (0.4–6 mg O_2 L^{-1}) N_2O emissions peaked at 6 mg O_2 L^{-1} and decreased gradually with decreasing O_2. In the anoxic soil (<0.4 mg O_2 L^{-1}) N_2O emissions were found to be lowest.
The isotopic analysis of peat showed high ^{15}N content in the top 10 cm layer which gradually decreased with depth to 30 cm for anoxic soil. In the suboxic soil, ^{15}N was found to be increasing with depth. In the soil fluctuating between suboxic and anoxic, ^{15}N was abundant ($\delta^{15}N$ = 7–9‰ air N_2) indicating intensive microbial processing of nitrogen. The results indicate incomplete denitrification in the suboxic soil as the source of N_2O. We will continue our field research and conduct the same experiments in laboratory by creating mesocosms in 12 columns containing peat samples from the same site.

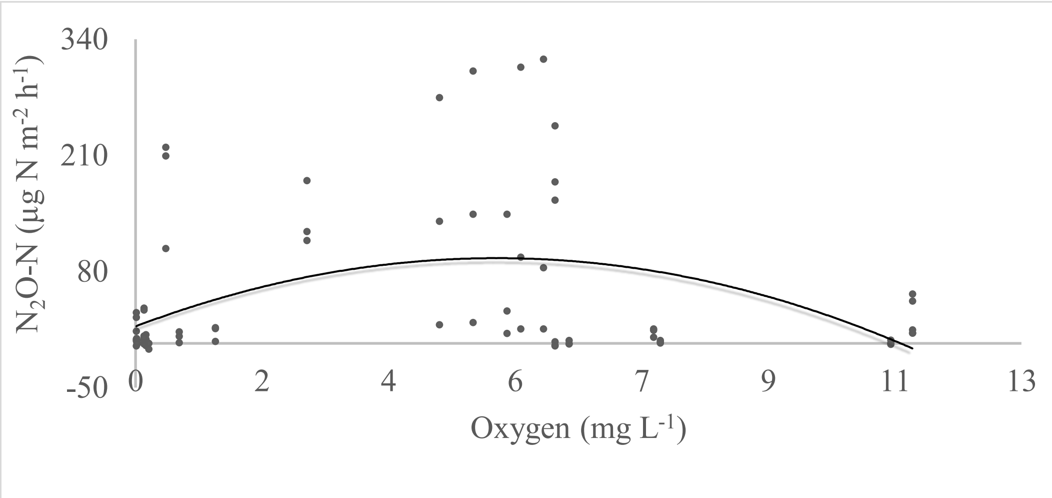

Figure 1. N_2O emissions vs oxygen concentration in soil (n = 80 ; R^2 = 0.19 ; $p < 0.001$).

BIO: Mohit Masta is a PhD student at University of Tartu who is currently working on isotopomer analysis of N_2O production-consumption mechanism in artificial wetlands.

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LONG-TERM EDDY-COVARIANCE MEASUREMENTS OF GREENHOUSE GASES FLUXES (CO_2, CH_4, H_2O) OF A TEMPERATE MIRE IN CENTRAL EUROPE (BIEBRZA NATIONAL PARK, POLAND)

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Natural wetlands are one of the most important areas in global greenhouse gases budget. In spite to the fact, that they cover a relatively small fraction of the Earth's land surface, they are major areas of the methane emission to the atmosphere. The carbon dioxide, captured from the air by wetland vegetation in the photosynthesis process is next accumulated in peat for a long time. An intensive evapotranspiration reduces sensitive heating of the air and in consequence affects climatic conditions in local/regional scale (depending on wetland size). However, the quantification of the intensity of the surface-atmosphere exchange of major GHGs for these ecosystems is still inadequate, especially for the eastern borders of Central Europe.

The above was a motivation to establish in the end of 2012 an eddy-covariance measurements site in Biebrza National Park (northeastern Poland) – one of the biggest coherent lowland wetland area in Central Europe. The site (53°35'30.8"N, 22°53'32.4"E, 110 m a.s.l.) is locates on fen in a central basin of Biebrza river valley. The nearest surroundings characterized by a relatively homogenous mixture of reeds, sedges and rushes typical for the Biebrza wetlands. The open-path eddy-covariance sensors (the gas analyzers Li7500 for CO2/H2O and Li7700 for CH4 and 81000 R.M.Young sonic anemometer) are mounted at the height of 3.7 m. The eddy-covariance system is complemented by slow-respond sensors. The fluxes are calculated on a 1-hour basis using EddyPro (Li-cor) software. The quality of data is checked by three stationarity tests. The continuous data sets are obtained by combination of different gap-filling methods.

The measurement results indicate a clear inter-annual variability of GHGs fluxes on Biebrza wetlands.
In wet years the ecosystem acts as a significant sink of CO_2 with the annual uptake up to almost 1000 $gCO_2m^{-2}year^{-1}$, while in dry years it can turn into CO_2 source with release up to 500 $gCO_2m^{-2}year^{-1}$. At the same time, a CH_4 emission vary from less than 5 $gCH_4\ m^{-2}\ year^{-1}$ (in dry years) to almost 30 $gCH_4\ m^{-2}\ year^{-1}$ (in wet years). Unexpectedly, only small differences between wet and dry years are recorded in a water vapor flux (latent heat flux).

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BIO: Prof. Fortuniak is a climatologist with more than 15 years of experience in fluxes measurements with eddy covariance method. The main areas of his interest are long-term variability GHG fluxes and energy balance components on wetland, farmland and urban areas and the factors determining their variability.

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GREENHOUSE GAS EMISSIONS AND NUTRIENT REDUCTION IN A SURFACE FLOW CONSTRUCTED WETLAND TREATING AGRICULTURAL DIFFUSE POLLUTION

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Diffuse agricultural pollution causes water quality degradation and may trigger eutrophication due to the increased concentration of nutrients. One of the best measures to improve water quality and reduce diffuse pollution is to use constructed wetlands (CW). Greenhouse gas (GHG) emissions from different parts of a wetland and their relation to wetland design are less studied than water treatment efficiency. However, it is necessary to consider both when designing treatment wetlands.

The Vända in-stream surface flow CW in southern Estonia consists of two shallow water parts under varying water depths and is planted with cattail (*Typha latifolia*) and common reed (*Phragmites australis*). We measured nitrous oxide (N_2O) and methane (CH_4) emissions from the CW. Gas samples were collected biweekly from May through November 2018 from 12 sampling points (total of 24 chambers) in each wetland. At each sampling point, N_2O and CH_4 emissions were measured from the water surface using closed floating chambers. In addition to the gas samples, water samples were collected biweekly from March 2017. Water temperature, O_2 concentration, redox potential and electrical conductivity were analysed on site and nutrient concentration were measured in the water samples taken from the inlet and outlet of both parts. Aboveground biomass was collected twice a year in 2018.

Average water depth varied between 5 and 65 cm. Our results showed significant negative correlation ($p<0.05$) between the emissions of N_2O and CH_4, and water depth ($r_s=-0.69$, $r_s=-0.30$, respectively). Highest CH_4 and N_2O emissions were produced in the shallowest parts of CW during the summer period. In the outflow area of the first CW, average water depth during the study period was 5 cm and average N_2O emission was 780.1 µg N m^{-2} h^{-1}. However average N_2O emission from the deeper parts was 59.2 µg N m^{-2} h^{-1}. Highest CH_4 emissions were also produced in the shallow parts (up to 474.3 µg C m^{-2} h^{-1}), while average CH_4 emission from the deeper parts was 145.1 µg C m^{-2} h^{-1}. Higher water temperature increased the GHG emissions whereas the combination of low water table and high temperature resulted in the highest CH_4 and N_2O emissions.

We saw strong negative correlation between flow rate and phosphorus removal, especially during the summer when water level and flow rate were low. Annual total phosphorus removal efficiency was 26.9 % (48.4 % during the summer). However, concentration of nitrogen compounds increased in the wetland during the low flow due to groundwater seepage. The increase mostly occurred in the ditch between the two wetland parts whereas the downstream part showed better nutrient removal efficiency. The amount of biomass per m^2 in winter was higher in the upstream part of the wetland, but in summer, it became almost equal between the two parts. With the increase of biomass, nutrient concentration in biomass increased during the summer.

BIO: Keit Kill is a PhD student in University of Tartu. The title of her forthcoming thesis is “Constructed wetlands for treating polluted water from intensively managed agricultural fields”. Her master thesis was about the efficiency of a constructed wetland reducing agricultural diffuse pollution. She has experience in sampling various environmental characteristics in wetlands.

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CONTRIBUTED PAPERS 8

WARM CLIMATE WETLANDS

Leonardo Vera

NUTRIENT RETENTION VIA VEGETATIVE UPTAKE AND SEDIMENTATION IN CREATED WETLANDS IN SUBTROPICAL FLORIDA

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Nutrient removal by a 4.6-ha urban stormwater treatment wetland system in a 20-ha water/nature park in southwest Florida has been investigated for several years, suggesting that the wetlands are significant sinks of both phosphorus and nitrogen. The last two years of water quality studies have indicated a slightly decreasing ability for total phosphorus reduction to 55%, whereas nitrogen retention has remained consistent at about 26% reduction compared to studies done several years earlier. This study investigates the importance of vegetative and sedimentation intra-system processes in affecting nutrient concentrations and fluxes through these wetlands. Vegetation samples are collected every six months in the dry and wet seasons to estimate net primary productivity, biomass, and nutrient storage/retention in the vegetative tissues. Additionally, gross sedimentation measurements along with sediment nutrient analyses every six months allowed us to estimate gross sedimentation rates of 0.26 ± 0.03 mm day^{-1} and nutrient retention rates of approximately 81.7 g-N m^{-2} yr^{-1} and 7.8 g-P m^{-2} yr^{-1}. With sedimentation of nutrients higher than nutrient loading into the system, we theorize that resuspension is a major influence on the system and have ongoing research focused on the extent to which resuspension plays a role in net nutrient retention. The role of vegetation community shifts on nutrient cycling and wetland lifespan will also be discussed.

BIO: Lauren Griffiths is pursuing a Geology Ph.D. in the School of Geosciences at the University of South Florida and is a graduate assistant and courtesy faculty at FGCU's Everglades Wetland Research Park in Naples, Florida. Current research focuses on carbon sequestration in mangrove systems, red tide dynamics, and water quality and nutrient cycling in created freshwater wetlands.

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BIOAUGMENTATION OF FRENCH SYSTEMS WITH MYCHORIZED PHRAGMITES

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In the last years, French vertical-flow constructed wetlands have proven to be a reliable, economical and robust solution for the wastewater treatment of small communities (<5000 PE). However, the first two to three years of start-up period for plant and biofilm development until optimal filter function as well as weed intrusion, can be delicate period in term of maintenance and leads to un-optimal functioning.
Bioaugmentation may provide promising solutions to improve the filter performance by means of mycorrhization of young reed plants or by inoculation of the filter systems with specialised bacteria. The acceleration of plant growth and development through symbiotic interactions of *Phragmites australis* and certain associated bacteria and fungi in constructed wetlands have been only rarely investigated in the past.

Table 1: Specific search syntax and results for plant-mycorrhiza interaction in constructed and natural wetlands

Search engine search on 23/01/2019	Phragmites		wetland	
Webofknowledge.com	(mycorrhizal OR mycorrhiza OR myc*) AND (growth OR survival)	48	(mycorrhizal OR mycorrhiza OR myc*)	360
Sciencedirect.com (limited to review and research articles)		194		783

In a systematic literature review, a combination of total of 1385 publications were gathered. Table 1 summarizes the specific search match results. After removing duplicates, a total of 1167 publications remained. In reviewing these publications, 896 were later removed, as they did neither describe the interaction between plants and mycorrhiza in constructed and natural wetlands nor in inundated agricultural areas such as paddy fields.

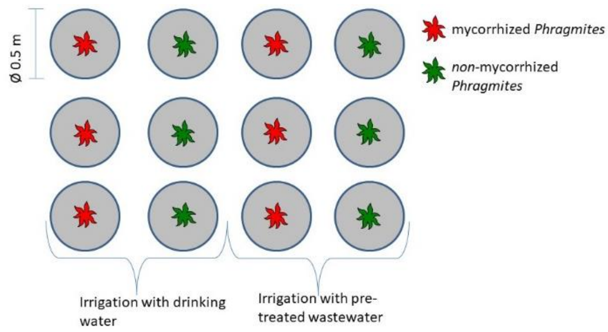

Figure 4: Tested conditions of the plant trial

However, less than 50 controlled studies on the effect of mycorrhiza on plant establishing and growth were found, and only one dealt with domestic wastewater as feeding source and conditions comparable to a French system. Hence, in the project STAR ELITE supported by the EFRD and the French Region Council "Pays de la Loire", a plant trial was setup at the greenhouse of the experimental hall of Irstea, Lyon-Villeurbanne center, with pilots mimicking a second stage French system (typically vertical flow system using sand). Tested conditions are described in Figure 1. The aim is to evaluate if artificial mycorrhization provides an accelerated plant growth and establishment. The trial starts in the middle of February for a duration of 12 weeks which allows a presentation of the results and a comprehensive literature review at Wetpol.

BIO: Dr Katharina Tondera is working since May 2018 as a postdoc on bioaugmentation of constructed wetlands (French system) in France. After her PhD on advanced treatment of combined sewer overflows in 2016 in Germany, she investigated the effect of saline conditions on Floating Treatment Wetlands for runoff treatment in Australia.

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APPLICATION OF MASS-BALANCE MODELLING TO ASSESS THE EFFECTS OF ECOLOGICAL RESTORATION ON ENERGY FLOWS IN A SUBTROPICAL RESERVOIR, CHINA

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Eutrophication is a leading cause of impairment of lentic water bodies in the world. To inhibit algal blooms and remove excess nutrients, a 10000 m^2 restoration project of vegetation establishment and fish manipulation was conducted in the eutrophic bay of the Yantian Reservoir, southern China. Three Ecopath models were constructed to assess the recovery effects at the system level, and time series data were simulated to propose a harvest policy. During the restoration, 1) the redundant production (*P*) flowing back to detritus decreased due to the increased predation of stocked fish; 2) the transfer efficiencies (TEs) through trophic levels increased due to the reinforced energy flows along the planktivorous, herbivorous, and molluscivorous food chains; 3) groups that had the highest keystoneness shifted from carnivorous *Pelteobagrus fulvidraco* to invertivorous *Rhinogobius giurinus* and molluscivorous *Mylopharyngodon piceus*, indicating the shift of mixed trophic impacts from top-down to wasp-waist control; and 4) the changing indices of flow fluxes, energy cycling, and systemic information showed that the restored ecosystem was more mature, developed, and self-organised than before. To sustain the long-term energy balance and functioning of the ecosystem, the maximum sustainable yields (0.37-8.53 $g/m^2/year$) were determined to maintain the relative biomass (~1) and TE of stocked fish through harvesting their annual production.

Key words: Ecopath with Ecosim; trophic level; transfer efficiency; mixed trophic impact; keystone species; ecosystem characteristics

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START-UP OF SUB-SURFACE CONSTRUCTED WETLANDS USING HELICONIA STRICTA TREATING DOMESTIC WASTEWATER UNDER HIGHLANDS TROPICAL CONDITIONS

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Constructed wetlands are a feasible sanitation alternative for rural zones from developing countries, due to fact that are low-cost (< 56% energy) without sludge generation. Commonly, constructed wetlands (CW) have been studied under template zones using cosmopolite's aquatic plants. Studies under highland conditions (2000 – 4000 m.a.s.l.) from tropical countries using autochthonous aquatic plants (genre Heliconia) are still few. Therefore, the aim of this study was evaluate of start-up of sub-surface constructed wetlands using *Heliconia stricta* (Ecuadorian autochthonous specie) treating domestic wastewater under highlands tropical zones.

The experimental model was carried out with 2 sub-surface constructed wetlands (0.08 m^2 area, 16 L volume) one vertical (VFS-WC) and other horizontal flow (HFS-WC) working in series. Both constructed wetlands were planted with 3 and 4 seedling (1 month of birth) of *Heliconia stricta* specie under media environmental conditions of 26.3 °C (dry season) and 2850 m.a.s.l. The operation strategy was the monitoring by 7 weeks of VFS-WC + HFS-WC with hydraulic retention time of 3 and 4 days, respectively. Synthetic domestic wastewater was used during the operation, evaluating analytical parameters, such as: COD (Chemical Oxygen Demand), nutrients (NH_4^+, NO_3^-, NO_2^- and Total Phosphorous or TP). Allometric measurements (apical height, basal diameter, relative abundance) from seedlings were monitored, too.
The experimental model operated under control parameters of pH (6.3 – 7.9), water temperature (18.1-36.1 °C) and filter media humidity (> 47.5%). The organic matter efficiency removal within VFS-CW and HFS-CW was up to 87.8 and 32.3 %, respectively. Meanwhile, nutrients efficiency removal for VFS-CW and HFS-CW reached values up to 92.8 and 85.51 % for NH_4^+, 50.7 and 9.1 % for NO_3^-, 53.2 and 75.0 % for NO_2^-, 52.7 and 66.3 % for PT, respectively. Indeed, nitrification began to generate within VFS-CW, but both were in nitritation phase, suggesting nitrogen removal by microbiological transformation (nitrification-denitrification) and plant uptake. The last phenomenon is reflected by higher apical height, basal diameter and relative abundance within VFS-CW than during the HFS-CW operation. Finally, plants contributed as microbial support and adsorbent media during the removal of organic matter removal and phosphorous, respectively.

BIO: Dr. Villamar is a researcher with 8 years of expertise in the study and operation the different passive technologies (constructed wetlands, vermifilters and biofilters) at laboratory and industrial scale.

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CONTRIBUTED PAPERS 9

AGRICULTURAL DRAINAGE

Carl Christian Hoffmann

LARGE SCALE MICROPOLLUANTS INVENTORY AND POTENTIAL MIGRATION IN STORMWATER CONSTRUCTED WETLAND

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Road runoff water is a potential source of micropollutants (e.g. oil derivatives, metals, plasticizers…) that need to be managed to protect our environment. More and more sophisticated pavement and parking materials or landscape designs are available to directly infiltrate rain water before runoff, or very close to where it fell, to avoid floods or overload of wastewater treatment plants (WWTP). As an example, stormwater constructed wetlands (SCW) are implemented near the roads and motorways to collect runoff water and permit its management. These facilities allow the settling of sediments in an impervious pond, before release of a clarified water to an infiltration pond where it can slowly infiltrate. This way, part of the macropollutants, micropollutants and sediments are sequestered. As the risks for micropollutants remobilization and release due to hydrology and physicochemical variations are real, infiltrated waters may significantly impact the flora, the fauna, the underground as well as the groundwater. This study aims at investigating the fate of a large panel of micropollutants from road runoff water before and after infiltration using hydrodynamic and metabolomic approaches.

Metabolomics is a very useful field to draw up a large-scale inventory of micropollutants in different matrices of this specific environment. Liquid and gas chromatographies coupled to mass spectrometry were used to investigate the micropollutants content in road runoff water and soil of the SCW. They are complementary tools allowing a large-scale survey of micropollutants, which presence was assessed by the use of a specific analysis method coupled to dedicated databases, regarding their retention time, exact mass and specific fragmentation patterns.

The samples were collected from a SCW situated in Wolfisheim (Alsace, France). Surface water, sludge from the impervious SCW, plants and soil (from surface to 1.6m depth) from the infiltration pond were collected and analyzed to investigate their micropollutants content. The SCW water budget was assessed thanks to an on-site weather station (for rainfall characteristic and evapotranspiration estimation), water height probes (for flow rates estimation) and piezometers (for groundwater monitoring). The joint use of hydrodynamic and metabolomic approaches allowed the monitoring of micropollutants potential migration through the soil, and consequently helped to determine if this kind of facility is efficient to manage runoff micropollution.

The first results showed that the micropollutants detected in all the matrices come from very diverse origins: polycyclic aromatic hydrocarbons (PAH), phytosanitary products, industry chemicals, drugs. Surprisingly, PAH were not the most represented category; work is in progress to check the presence of micropollutants in the nearby soil as a control sample to eliminate the pollutants coming from the fields situated next to the road and SCW.

BIO: Claire Villette is a postdoc researcher specialized in the metabolomic analysis of environmental samples (water, sludge, plants), using high resolution mass spectrometry (HRMS). She is in charge of the high-resolution analysis in the Plant Imaging and Mass Spectrometry (PIMS) team (IBMP, CNRS) and project coordinator at ENGEES in Strasbourg.

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HOW TO IDENTIFY PROPER PLACE FOR DESIGNING OF REMEDIATION MEASURES ON DRAINAGE OUTLETS

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This paper presents e new method for identification proper areas to design remediation measures on drainage outlets. In the Czech Republic, around 30% of agricultural land is tile-drained, and in some regions land drainage exists on every field. Excessive draining have often negative effects on countryside, as e.g. shortening water residence time in the drained area, lowering the ground water table, and polluting shallow subsurface water with nitrates and pesticides. One of possibilities how to mitigate this problem is to design some remediating measures eg. drainage bio-filters, constructed wetlands, pools placed on outlets.

First step is to choose the most vulnerable areas (sub-catchment) using the Catchment Measures Need Index (CAMNI), which assessed the vulnerability of the water quality and quantity caused by subsurface (drainage) runoff and pollution. The CAMNI consisted of the i) catchment arable land ratio, ii) catchment drained land ratio, iii) catchment low-retention grassed soils ratio, and iv) catchment pond or water surfaces ratio. The CAMNI values were classified into five categories from 1 - negligible catchment measures need - to 5 - high catchment measures need. The CAMNI was computed for small catchments (2-40 km2) and sub-catchments (5-300 ha) in the experimental area.

Next step is to identify proper place in this vulnerable areas for designing measures. Here, precise knowledge about tiles and outlets placement is crucial. One way to get this knowledge is to find, to scan and to ortho-rectify the detailed construction plans. The crux is that many of these plans were lost during the huge economic and proprietorial changes (end of socialistic period) in the 90s.
Another option is to use the surface and the aerial thermography, which were tested, as new methods for identification of drainage outlets. The preposition is, that the drainage water and the stream water have different temperatures especially in winter (drainage water is warmer than stream water) and in summer (drainage water is colder than stream water). Monitoring water temperature along the stream course is able to find places with changed water temperature, which usually represent the drainage outlets placement. According the results presented in this pater, the thermography proved as very useful method. Especially the aerial thermography by an unmanned aerial vehicle showed its big potential for future.

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BIO: Dr. Zajíček is has been dealing with subsurface runoff, agricultural drainage and water quality in agricultural catchments for 15 years. He has experience with delimitation of vulnerable areas of non-point agricultural pollution. https://www.researchgate.net/profile/Antonin_Zajicek

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SEASONAL EFFECTS OF VEGETATION AND FLOW RATE ON MIXING AND POLLUTANT TRANSPORT IN CONSTRUCTED WETLANDS – FINAL RESULTS.

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A field-based experimental study has been undertaken within two full-scale constructed wetlands, designed to treat runoff from agricultural land in Knapwell, Cambridgeshire, UK. The effects of natural vegetation variation and flow rate variation on the mixing characteristics and hydraulic residence times were investigated over an eight month period. Detailed fluorometric measurements were conducted to examine the longitudinal spreading of a solute within the two wetlands, i.e. CW1 and CW2. Between a UK November winter period, and June summer period, a series of repeatable tracer tests were conducted for a range of dry weather and storm flow conditions, using an automated daily injection tracer system. The systems are of same size, scale and plantation, however, their bathymetry differs, being irregular in CW2. In CW1, the longitudinal dispersion results showed that the dispersion is influenced by the flow rate for low discharge conditions, whereas, for higher discharges, the longitudinal dispersion becomes independent of discharge. Residence Time Distribution (RTD) curves were examined through a series of flow conditions for each testing month, ranging from transitional (Re~2000) to turbulent (Re~7000) flow conditions. For the conditions measured, different flow rates result in changes in the RTD, demonstrating that higher flow rates cause shorter mean residence times, generating predominantly an advective flow regime. The effects of plant variation are prominent on the mixing pattern during the dormant season. Towards the end of the annual plant cycle, February/March for this micro-climate, mixing pattern approaches complete mixing, longitudinal mixing increases significantly due to long tails on the RTDs, and mean flow velocity is retarded. This indicates that the dormant plant period, which normally lasts for 5-6 months (October to March), alters progressively the mixing pattern in the system in such a way that it is significantly different from the mixing pattern during the growing plant season, indicating the necessity to not be overlooked.

In CW2, seasonal plant variation appeared to be a secondary factor in affecting the hydrodynamics of the system, when bed irregularities exist. Irregular bed topography was shown to be the dominant factor affecting short-circuiting compared to seasonal vegetation variation, as demonstrated during the dormant season tests. This result is in agreement with Min & Wise (2009), who found more affinity of short-circuiting with bathymetry than with vegetation heterogeneity. Overall, CW2 suggests minor variation in mixing processes (i.e. steady mixing conditions) between dormant and growth plant seasons, and continuous increase of advection with discharge independent of the season.
Summarising, the differences in the mixing and flow characteristics between the two wetlands are attributed to internal design parameters, i.e. irregular bed channel in CW2 fosters preferential flow.

BIO: Dr. Ioannidou is an academic and researcher with significant field experience in contaminant/solute transport in waterways (esp. in wetlands, ponds, streams), having conducted and led several consultancies in the UK. She has a strong background and interest in water resources management, water resilient cities and hydro-hazards using eco-hydrology, and land surveying.

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WET OR DRY SEDIMENTATION PONDS FOR RETENTION OF PHOSPHORUS AND SOIL PARTICLES FROM AGRICULTURAL RUNOFF IN NORWAY

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A traditional constructed wetland (CW) in Norway consist of a deeper sedimentation pond (1-2 meter deep), followed by a shallow vegetation filter. (20-50 cm deep), covering about 0,1 – 1 % of the watershed. More than 1000 such constructed wetlands have been established in agricultural areas in Norway the last 20 years. Several studies point out that the wetlands have greatest effect in watersheds where surface erosion occur, and in watersheds with high P-levels in the top soil. The main effect of CW's is due to particle sedimentation, and then most effective for P retention. A survey (Hauge, 2008) from 30 CW's show that the medium retention of P was 44 g/m2/year, but large variation. The results also show that 70-75 % of P retention happened in the first 25 % of the wetland, mainly in the sedimentation pond. This is because particles coarser than silt sediment almost immediately, and that large amounts of particles eroded from the surface of agricultural soils are as aggregates. Clay amount in sediments are then surprisingly high due to aggregate sedimentation. Heavy precipitation episodes where erosion danger occurs seem to increase in Norway over the last 20 years, also increasing the effect of small CWs.

Aggregates, that are so important to the sedimentation process, seem to break up after some time. On this background, the idea came to construct smaller sedimentation ponds in the end of erodible sloping farmland to stop particles before entering the waterways. The ponds can be with standing water table, or normally dry. Dry ponds only fill up during heavy rain, when surface runoff occur. A couple pilot studies have been made, (Hauge 2018) showing that these small ponds are highly effective. One 225 m2 pond near Stavanger measured in 2017-2018 showed a retention of 118 tons of particles in one year, meaning that the pond was almost filled in one year. The watershed area (7,5 ha, but only 3 ha had surface runoff to the pond) was in intensive vegetable production, and had a slope of 1:13 and fairly high P level, (P-Al of 59 mg/100 g air dw). The Tot-P retention in the pond was 195 kg/year, 0,87 kg/m2. The sediments showed a little lower P level than the soil above, especially in the inlet of the pond where mostly sand settled, probably because diluted P and single clay particles did not stay in the pond.

Several designs for sedimentation ponds have been tried out as pilot studies; Wet ponds, dry ponds, ponds around manholes, shallow dry ponds along the stream and ponds in open drainage ditches. Some ponds filled in only one day during heavy rainstorms. It will therefore be crucial that these sedimentation ponds are maintained and emptied regularly.

CARBON SEQUESTRATION AND NUTRIENTS ACCUMULATION IN TWO FISHPONDS IN THE CZECH REPUBLIC

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Wetlands are considered as important carbon sink on the planet. The high carbon sequestration and nutrients accumulation in fishpond littorals are influenced by a very high productivity of macrophytes and anoxic/anaerobic conditions at the bottom causing incomplete decomposition of decaying litter. Fishponds in the Czech Republic are highly eutrophic due to intensive manuring and supply of feed for carps. The objective of this study was to evaluate carbon sequestration and nutrients accumulation in two fishponds in the Czech Republic in relation to water depth in the littoral zones.

The study was carried out in two fishponds that belong to the Czech University of Life Sciences. The fishponds are located about 30 km east of Prague. Both fishponds have a rich littoral zones overgrown by *Phragmites australis* which continues to about 50-100 meters above the water line. During the years 2013 - 2015 three sites in each fishpond were selected for the study. The sampling sites included deep water littoral (average depth 30 and 44 cm), shallow water littoral (1 and 3 cm depth) and sites above the water line (water level averaged -11 and -28 cm below the surface). At each site, water chemistry was recorded biweekly and aboveground biomass was recorded twice a year during 2013-215 period. At all sites, sediment/soil accretion rates were measured – above the water line, the feldspar method was used while in the littoral the sediment depth was simply measured as at both fishponds sediment was completely removed down to clay layer nine and five years before the study was carried out. At all sites, triplicate samples of soil/sediment were taken by a steel corer and cut into 2-cm segments. In the segments, bulk density and concentrations of organic carbon, nitrogen and phosphorus were determined.

The results revealed that the highest accretion rates were found in deep water sites (2.10 and 2.31 cm yr^{-1}) followed by shallow water sites (1.26 and 2.02 cm yr^{-1}) and sites above the water level (1.0 and 0.8 cm yr^{-1}). The accretion rates in the flooded sites are quite high, but typical for the Czech fishponds. Concentrations of organic carbon were highest in the top layers ranging between 13.7% and 21.7% at dry and deep sites respectively and decreased gradually to about 10% at the lowest layers in flooded sites. Concentrations of nitrogen and phosphorus were also the highest in the upper layers but decreased less rapidly along the vertical gradient as compared to carbon. Nitrogen concentrations varied between 1.11 and 1.98% in the upper layers while at the lowest layers N concentrations varied between 0.7 and 1.65%. Phosphorus concentrations varied between 600 and 1168 mg kg-^{1} and between 328 and 863 mg kg^{-1} and the upper and lowest layers, respectively. The highest aboveground biomass was found in deep water (up to 4770 g/m^2 during 2013-2015) followed by shallow water stands (up to 4200 g/m^2) and dry areas (up to 2870 g/m^2). Using the bulk density values, the accumulation rates were calculated as 521 and 577 g C m^{-2} yr^{-1} in deep water, 392 and 447 g C m^{-2} yr^{-1} in shallow water and 127 and 225 g C m^{-2} yr^{-1} at the sites above the water level.

BIO: Prof. Vymazal is a head of Department of Applied Ecology at CULS. He has been working with wetlands since the early 1990s focusing on carbon and nutrients cycling in the water-soil-plants system in natural and constructed wetlands.

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CONTRIBUTED PAPERS 10

STORMWATER AND RUN-OFF

Günter Langergraber

EFFECT OF ROADSIDE VEGETATION MANAGEMENT ON THE QUANTITY AND QUALITY OF HIGHWAY STORMWATER IN COLD CLIMATE CONDITIONS: A PILOT STUDY

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The increase in urbanization has led to a surge in number of roads and vehicles. Therefore, a concern about the impact of the road runoff on the surrounding environment has increased. Different phytotechnologies like bioswales, vegetated filter strips and vegetated buffers are already used for treatment and management of highway runoff. However, there is still not enough scientific evidence about the impact of roadside vegetation management on runoff quantity and quality in cold climate conditions. Therefore, this project aims to: a) study the impact of highway roadside vegetation management on runoff quantity and quality in cold climate conditions; and b) to establish ecological management practices.

On year 2019, a total of 11 highway runoff collection sites will be built on the vegetated side-slope of the Autoroute Jean-Lesage near Sainte-Julie town, Quebec, Canada. The experimental plan consists of: a) 5 replicates with minimal vegetation management (cutting only road edge according to road safety rules); b) 5 replicates with maximal management (cutting all the roadside 3 times per season); c) one site with current management (ones a season cutting all the roadside and twice only the edge of the road). One monitoring site includes 3 collection systems with gutters and water tanks. The gutters are positioned at 3 different distances: 0m, 3m and 6m from the highway edge.

The pilot study at one collection site was performed (August – November 2018) for testing and optimizing the experimental design. The runoff volume was monitored on 10 and quality on 4 events. During pilot study, the vegetation was cut low in the beginning of gutter installations and plants were re-growing during monitoring period. Following analyses were carried out: pH, EC, TSS, COD, TOC, NO_3-N, TKN, TP, PO_4-P, total and mineral oil and grease, hydrocarbons (C10-C50), chlorides, and Zn, Ni, Cr, Cd.

The results from pilot site show runoff volume reduction by 81% just 3m down the slope and extra 65% 6m down the slope (total reduction 96%). When comparing the results of 0m, 3m and 6m gutter we can see a clear reduction in pollutants concentrations. The COD, TSS, NO_3-N, TP and hydrocarbons concentration decreased by 64%, 85%, 50%, 38% and 93%, respectively. The pilot study provided us with necessary information for further modifications in the collection system design and gave us extra knowledge for continuation of the project.

Our further research will determine if vegetated highway slopes in cold climate conditions are performing similarly to other road runoff treatment technologies and whether the unmanaged and managed slopes have the same removal patterns. Furthermore, the potential role of reduced vegetation management of the highway slopes as a Low Impact Development practice will be determined.

BIO: Dr. Kõiv-Vainik is a research fellow in environmental technology in the University of Tartu and adjunct professor in the University of Montreal working for more than 10 years on process-based research and enhancements of treatment wetlands, on ecological waste- and stormwater treatment and on enhanced phosphorus removal with reactive materials.

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TEN YEARS OF IMPROVING WATER ENVIRONMENT BY CREATED STORMWATER WETLANDS IN SOUTHERN FINLAND

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The development of a chain of two water environment mitigation wetland parks in Southern Finland is presented. The wetlands named Gateway and Niittu were designed to provide multiple ecosystem services including stormwater treatment from a 550-hectare urban and urbanizing 35% impervious watershed. The wetlands were implemented in 2010 and 2013-2015 at the mouth of the urban stream Kilsoi by the Lake Enäjärvi of Vihti. The later implemented Niittu is located shortly upstream from the Gateway. During mean water levels the wetlands cover 0,1% (Gateway) and 0,2% (Niittu) of their contributing watershed. The Gateway wetland is formed around a wide berm and three islands. The Niittu wetland has a long waterdrop shape with several shallow areas across the width and two islands. The Niittu wetland park also includes a created wide clay stream area, a deeper emergent vegetation pond, and a flood meadow which are areas without fish. The Gateway wetland includes a deeper inflow and outflow pond. The Niittu wetland main pool includes a deeper inflow, center and outflow pond. Water quality was the main driver in establishing these wetlands. The receiving lake suffers from cyanobacterial blooms, which benefit from clay particle bound phosphorus. To assess the success of the wetlands in improving water quality, water monitoring was conducted at 10-minute intervals, and monthly and annual averages were calculated. The removal of phosphorus was used as key indicator for water quality improvement. Field monitoring was also conducted for vegetation development, amphibian egg cluster counts, water invertebrates, as well as greenhouse gases methane and carbon dioxide. Finally, locals' attitudes on water quality mitigation by created wetlands was addressed.

Water quality was found to improve every year following vegetation establishment and improved retention time. Phosphorus removal was found relatively (%) highest during the summer growing season when water flows are low. In absolute terms (kg) phosphorus removal was highest during the fall rainy season and the spring snowmelt season when vegetation is dormant and water flows are high. During an unusually warm winter there was no high spring flow nor removal event. Stormwater inflow to the wetlands varied from 2 l/s to 1800 l/s. At an annual level the only 0.1% of its watershed area Gateway wetland reached over 20% total phosphorus removal the fifth year after construction. The wetland *Typha latifolia* and *Carex* spp. mixed vegetation areas were the highest average methane emitting areas within the parks. The total annual release of methane from the Gateway wetland was 5.0 g m^{-2} a^{-1} which is roughly half of a typical boreal fen. Biomass of the emergent wetland vegetation was ten-fold higher than of a typical park lawn. Vegetation developed fast: the number of species at the Gateway wetland tripled from 50 to 147 in five years. Water invertebrate range resembled a natural wetland the third year after construction. Amphibian egg cluster count reached 700 from the beginning value zero at the Niittu wetland the fifth year after construction. The locals valued most water quality improvement, biodiversity and recreational aspects of wetlands and were willing to pay more for stormwater management with wetland parks than the current cost for conventional management is. This work was kindly funded by the EC Life+11 ENV/FI/911 grant and by the Maa- ja vesitekniikan tuki ry foundation.

BIO: Outi Wahlroos is a senior scientist, engineer and landscape architect with 20 years of experience in planning, designing, implementing and monitoring urban wetlands and other nature-based stormwater management solutions. She works on creating safe habitats and near-home nature in urban areas and acknowledges wetlands a key element in compensating the many challenges of urbanization.

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TREATMENT OF COMBINED SEWER OVERFLOW UPSTREAM CENTRALIZED TREATMENT PLANTS WITH NATURE-BASED SOLUTIONS: THE CONSTRUCTED WETLAND SYSTEM OF CARIMATE WWTP, ITALY

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The centralized WWTP of Carimate treats the wastewater from the combined sewer serving 11 towns in Como province (70,040 inhabitants). Combined sewer overflows (CSOs) upstream the Carimate's WWTP occur frequently with an almost constant discharge rate, sometimes lasting for several days even during dry weather (on average 75 CSO events per year with up to 10 consecutive CSO days, data from 2012 to 2014). The centralized WWTP is equipped to provide pre-treatment (grit removal) and a primary treatment of CSO (sedimentation) up to 3000 m^3/h. However, the biological secondary treatment can receive a maximum of 2000 m^3/h, which is below the 2700 m^3/h authorized for discharge in the Seveso river. Therefore, a constructed wetland (CW) system was designed to treat the 700 m^3/h required by the authorization as well as to intercept a portion of the diluted pollutant load, which was estimated equal to 104 t_{COD}/year (contained in about 890.000 m^3/year).

The CSO events were characterized in two groups: (i) CSO-A. i.e the first day of the CSO event after a minimum dry period of 2 days, more polluted due to washout effect of roads and sewer; (ii) CSO-B, i.e. the second fraction of the CSO event or the CSO event below a dry period of 2 days, less polluted with a pollutant load assumed due only to diluted domestic wastewater. The CW has been designed by IRIDRA to treat the most polluted fraction of CSO-A and a portion of CSO-B events as following defined: (i) treated CSO-A, maximum CSO flow rate of 1300 m^3/h per maximum 7 hours/day (maximum treated CSO-A 9000 m^3/event) for a maximum of 20 CSO-A event per year (180.000 m^3/year – 36 t_{COD}/year); (ii) treated CSO-B, maximum CSO flow rate of 970 m^3/h per maximum 6.5 hours/day (maximum treated CSO-A 6300 m^3/event) for a maximum of 50 CSO-A event per year (315.000 m^3/year – 32 t_{COD}/year). In this way, the CSO-CW is able to intercept up to 500.000 m^3/year (about 58% of the total estimated average volume per year) and a COD load of 60 t_{COD}/year (about 60% of the total estimated COD load per year). In other words, the CSO-CW is planned to intercept a pollutant load of 7700 p.e. (expressed in terms of COD), which were previously discharged untreated in the Seveso River.

The CSOs are treated with a multistage system CW. The 1st stage comprises two vertical subsurface flow (VF) CW beds, each one further divided into 2 separated hydraulic sectors for a total area of 8500 m^2; the four sectors are planned to work alternate and regulated by PLC to guarantee sufficient dry periods for the VF beds. The 2nd stage is a free water surface (FWS) CW of 4500 m^2. The results of the first year monitoring campaign will be presented at WETPOL 2019.They include the data registered by the PLC – i.e., flow rate influent and effluent the CW system, water table level within the VF stage, duration of CSO events, dry period between CSO consecutive events – and the results of water qualities sampling campaign – CW treatment efficiencies in terms of mass balances for COD and nitrogen, treatment efficiencies of the overall WWTP (i.e. activated sludge plus nature-based system).

<ins>BIO</ins>: Fabio Masi is R&D Manager and Technical Director of IRIDRA Srl, since 1998 and Vice-President of Global Wetland Technology since 2012. His is PhD in Environmental Sciences and MSc in Environmental Chemistry (1991). He has 20 years of experience in sustainable water management and nature-based solutions for wastewater treatment.

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A SYNTETIC STORMWATER RECIPE FOR ASSESSING A PILOT HYBRID CONSTRUCTED WETLAND RELIABILITY IN MEDITERRANEAN CLIMATE

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Decentralized systems for effective water management has been clearly described as one of the best practice (BMPs) strategies for promoting the circular economy. The recovery and reuse of natural resources, water *in primis*, can be pursued through different approach and technologies, variously engineered and/or more likely as nature-based solutions (NBs). In the cities of the future, the chance to rely on unconventional and diffuse water source like stormwater runoff is becoming necessary, but more knowledge on stormwater treatment facilities and performances are required. This study investigates the reliability of a pilot hybrid constructed wetland (H-CW) (Fig. 1) in treating contaminants typically found in stormwater runoff.

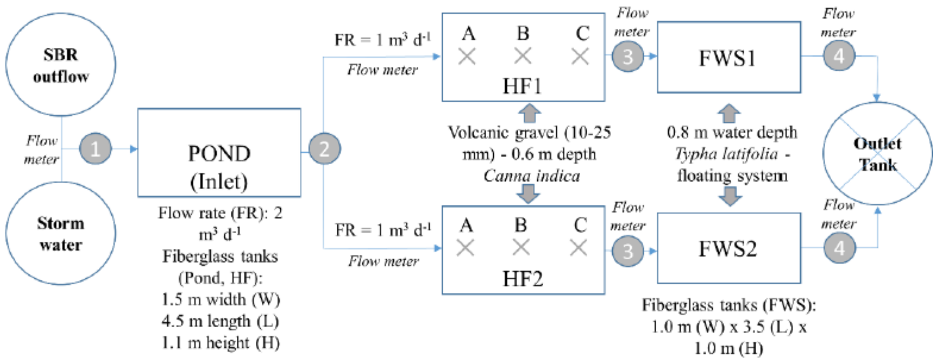

Figure 1. Pilot-scale hybrid constructed wetland (H-CW) layout and monitoring design (grey circles and crosses, respectively, for water quality and hydraulic/sediment quality surveys). Sequential batch reactor (SBR); retention pond (POND) and free water surface CW (FWS).

To cope with the uncertainty in performing representative sampling during storm events, particularly in Mediterranean conditions, with increasingly longer periods of drought and short intense precipitations, a recipe for synthetic stormwater has been proposed and tested for documenting the removal efficiency along the length of the treatment train (μgL^{-1} Cd, Cr, Fe, Pb, Cu, Zn, total hydrocabons: 5,30,3000,100,80,500,30000).

Intensive monitoring activities were conducted during one month and quality analyses regarded the three matrices of the system: water, biomass (*Canna indica*, *Typha latifolia*) and filtering medium (volcanic gravel, porosity 0.4).

First evaluations showed very high removal efficiency for all the metals (97-99%, except for Fe, 67%) and the total hydrocarbons (95%), mostly at the outlet of the HF units (sampling point #3, Fig.1). Furthermore, among the analysed macrophytes organs, the hypogeal parts presented higher metal concentrations, generally more prevailing in the roots than in the rhizomes, assuming probable biostabilization processes.

<ins>BIO</ins>: Delia Ventura is currently completing her PhD at the University of Catania, within the Hydraulics and Soil Conservation group. During the MSc she got involved in microalgae wastewater treatment at the University of Cádiz, and now in the promotion of hybrid constructed wetland use in decentralized system for water recovery and reuse.

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ECOLOGICAL CRISIS AND ECOLOGICAL RESTORATION OF PULICAT LAKE, SPSR NELLORE DISTRICT, ANDHRA PRADESH INDIA

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Pulicat Lake is India's second largest salt water lake along the east coast of India bordering the Bay of Bengal after Chilika Lake in Odisha. It is an important feeding ground for variety of aquatic and terrestrial birds. It is adjacent to the Bay of Bengal, formed out of the back waters of the sea. Its length is about 70Kms and width varies from 1Km to 20Kms. The lagoon's boundary limits range between 13.33° to 13.66° N and 80.23° to 80.25°E, with a dried part of the lagoon extending up to 14.0°N.; with about 84% of the lagoon in Andhra Pradesh and 16% in Tamil Nadu.. It is separated from the adjacent sea, the Bay of Bengal, by a wide sand-strip, the Sriharikota Island, on which the SDSC-SHAR project of the ISRO is located.

Pulicat lake suffers from rapid siltation and morpho-metric changes, which has larger impact on the bio–resources of the region. The recent changes in and around the Pulicat lagoon indicates wide array of social, ecological and economic problems in the region. The lake mouth is a major determining factor for the hydrology, biodiversity and fishing activities. The lake is now shrunk to about 35% by area and 75% by depth with an average depth reduction from 3.8m to 1.0 m. Pulicat Lake has been getting silted roughly at the rate of one meter per century according to the estimation of Cartini's (1994) carbon-dating technique on the bottom sediments. The pace of the shrinkage of the Lagoon prompts prediction on its virtual disappearance in another 50 years. This renders lack of shelter to various migrating birds and aquatic life which has multi-dimensional repercussions on various eco-friendly species.
Pulicat lake ecosystem has undergone significant degradation with negative impacts on biological diversity and peoples' livelihoods. There is now a growing realization that we will not be able to conserve the earth's biological diversity through the protection of critical areas alone. This paper explains about "ecological restoration" which becomes a fundamental element of ecosystem management. Ecological restoration needs to address four elements which are critical to successful ecosystem management. They include improvement of biodiversity conservation, human livelihoods, ecosystem productivity and empower local people. Specific research on the impacts of climate change and drought on the sustainability of the environment particularly on threatened species and regionally significant flora and fauna including migratory birds of Pulicat Lake. The major challenge for future PLMB (Pulicat Lake Management Board) is to achieve natural water flow while optimizing economic and environmental outcomes in the context of a climate which is highly variable and non-stationary. The approaches of the past which assume an equilibrium climate are no longer adequate. The present paper concentrates on the four elements to achieve ecological restoration of Pulicat Lake for the future generations.

BIO: Dr.S.K.M.BHASHA is a Associate Professor in Botany with more than 16 years of experience planning designing and implementing wetlands construction projects. He has extensive experience with wetland restoration and habit cretat on and has one project dedicated to preserving and restoring wetlands.

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C.P. 11

CONTRIBUTED PAPERS 11

INDUSTRIAL TREATMENT

Shubiao Wu

CONSTRUCTED WETLANDS RELEASE LESS GREENHOUSE GAS EMISSIONS THAN ACTIVATED SLUDGE: A KEY POINT FOR THEIR IMPLEMENTATION IN THE WINE SECTOR

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The aim of this study was to measure and compare the greenhouse gas (GHG) emissions (i.e. CO_2, CH_4 and N_2O) from constructed wetlands (CWs) and activated sludge (AS) systems treating winery effluents. This research has been carried out in the frame of the WETWINE project which aims to promote environmentally friendly solutions to treat winery effluents in the South West of Europe.

The system promoted by the project (the WETWINE system) consisted of two vertical subsurface flow constructed wetland in parallel (VFCW, 30 m^2), a horizontal subsurface flow constructed wetland (HFCW, 30 m^2), and a one-stage sludge treatment wetland (STW, 20 m^2). The activated sludge system consisted of a reactor with extended aeration (200 m^3) followed by a secondary settler (26 m^3), and a sludge tank (18.4 m^3). The WETWINE and the AS systems have been implemented in two wineries located in Galicia (Spain) which treat an annual flow of 1,400 m^3 and 4,800 m^3 respectively. Two campaigns were carried out during the vintage season were higher organic/hydraulic load was expected (August/September 2018) and the rest of the year (February/March 2018).

GHG emissions were monitored using the Gasmet DX4015 Fourier transform infrared (FTIR) gas analyzer. Results showed that the GHG emissions from the WETWINE system were lower than those generated by the AS system in both periods considered (Fig. 1). This was mainly due to the intensive aeration, the consumption of chemicals (i.e. urea and phosphoric acid), and from the high concentration of sludge accumulated in the tank from the AS system.

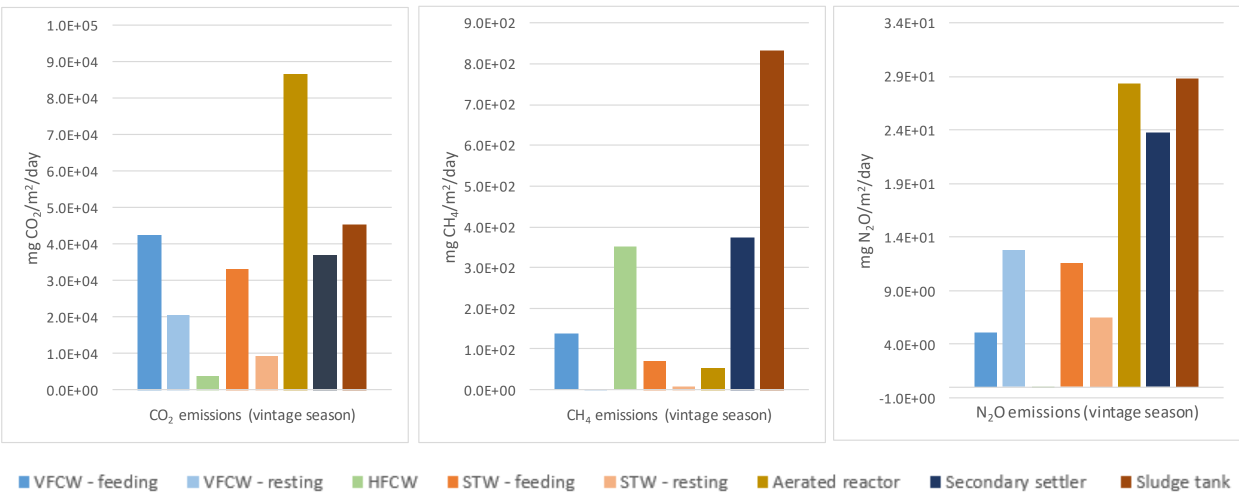

Figure 1. Comparison of the GHG emissions (CO_2, N_2O and CH_4) for the CW and the AS systems during the vintage season. Note: results obtained during the second campaign (i.e. rest of the year) are not shown, but follow the same pattern.

BIO: Laura Flores is a civil engineer and a PhD student in Environmental Engineering. Her research is focused on constructed wetlands for wastewater treatment, taking into account technical and environmental aspects.

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CONSTRUCTED WETLANDS IN WINERIES: WETWINE PROJECT

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A natural based technologies treatment plant has been applied to valorized winery wastewater in order to obtain irrigation water and fertilizer to be used in vineyards. This work has conducted in the framework of WETWINE project, funded by the 2015 Interreg Sudoe Programme. This project will be carried on South-West Europe (Portugal, Spain, and South of France) were wine sector has an important impact.

In the frame of WETWINE project, a demo-plant has been operated in a winery (Bodega Santiago Ruiz, Spain). The main objective is validate operation conditions in different seasons. Wineries have significant differences in wastewater production (flow and organic load) during the year. In WETWINE case study, corresponding to young white wine production, high organic load and flow (5-10 g/L COD and 5 m^3/d) is expected during grape harvest season and last for 3 months, from September to November. Out of this season, wastewater has low flow and load (0.1 g/L COD and 0.5-1 m^3/d).

WETWINE system is a combination of subsurface flow constructed wetlands (SSCW). First, a HUSB (hydrolytic upflow sludge blanket) anaerobic reactor was selected as pretreatment. In HUSB reactor, wastewater solids are retained and hydrolysed. Upflow water will be treated in a combination of vertical and horizontal SSCW. SSCW are planted with reeds. Solids from HUSB bottom will be treated in a sludge treatment wetland in order to dewater and stabilize it and obtain a fertilizer.

WETWINE plant has been validate both in grape harvest season and out of campaign. Inlet flow was around 1 m^3/d, in order to maintain wetland organic load in 100 g COD/m^2d in harvest season. pH below 5 and low nutrients (nitrogen and phosphorous) was observed in inlet wastewater, making plant performance more difficult. Despite that, results were 80% COD and 90% suspended solids elimination, although COD in outlet was over 0.5 g/L during some days in harvest season.

Out the campaign, all wastewater flow was treated. High evapotranspiration was observed during summer time due to hot temperatures and drought weather. Outlet flow fulfilled current FAO specifications and national wastewater reuse regulations, so vineyard irrigation with be possible in other to reuse treated water.

BIO: Dr. Pena is a senior researcher in AIMEN. She holds a Ph.D. in Environmental and Chemical Engineering. She has expertise in industrial environmental issues: waste and water management and valorization, including natural based technologies such as constructed wetlands. She also has experience in environmental LCA methodology application and circular economy.

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INTEGRATED TREATMENT OF DISTILLERY WASTEWATER THROUGH CONSTRUCTED WETLANDS

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An experimental treatment system was designed and constructed under the framework of the R&D regional project UVATEC, with the purpose of testing the constructed wetland (CW) technology on the treatment of distillery effluent. The wastewater produced at the distillery was contained in an equalization tank, before it was pumped into a 1.5 m^3 settler. Subsequently, water was pumped into two 15-m^2 vertical subsurface flow CW cells alternating cycles of feed-rest of 3.5 days, before it flowed by gravity into a 30-m^2 horizontal subsurface flow CW. All CW were planted with *Phragmites australis.* Moreover, the sludge collected in the lower part of the settler was treated in four 5-m^2 sludge treatment wetland cells, each operated one day and followed by 13 resting days. The plant was monitored for its first 9 months of operation. Samples from influent and effluent of each treatment unit were grabbed weekly and immediately taken to the laboratory for analysis of conventional water quality parameters.

The regime of the pilot plant over the study period depended on the seasonal variations of the distillery production, and thus the current study has been divided in two main periods accordingly (i.e. high loading rate and steady-state operations). After a short start-up period of one month, the distillery started producing effluent, which was majorly characterized by low pH values (4.7-5.6), very high suspended solids (up to 13.6 g/L) and organic matter (66-150 g COD/L) contents, high concentration of nitrogen and phosphorus (average of 1.0 g TN/L and 1.5 g PO_4/L) and potassium (4.6-9.4 g/L) and a strong brown color. During this period, the system received an organic loading rate of 94 ± 55 g $BOD_5/m^2 \cdot d$ or 260 ± 128 g $COD/m^2 \cdot d$ (for the area of the 2 vertical flow CW). Subsequently, water flowed into the horizontal flow wetland with an organic load of 26 ± 36 g $BOD/m^2 \cdot d$, which are rates well above recommended values. The performance of the system was very robust during this period, with overall removal efficiencies for the water line of 92% COD, 88% BOD_5, 95% TSS, 91% TN and 82% PO_4^{3-}. Nevertheless, the vegetation of the vertical flow step had problems on its adequate development given the low pH and the high loads, and a high proportion of solids was accumulated on the surface of these two cells.

After 4 months of continuous operation under high load, the distillery paused its production and in order to continue the system's operation and reach steady-state conditions, recirculation was applied from the final effluent up to the equalization tank. The organic loading rate gradually decreased during this phase down to an average value of 15 g $BOD_5/m^2 \cdot d$. The vegetation of the vertical and horizontal flow CW showed a clear improvement in its growth, and previously deposited solids largely mineralized. The performance of the system during this period was high for organic matter and nitrogen removal (87% COD, 90% BOD_5 and 76% TN) and moderate for solids (52% TSS) and phosphorus (49% PO_4^{3-}). Further analytes were also determined during this period in the final effluent of the treatment plant, with the purpose of defining the optimal operational parameters so as to comply with the existing legislation on discharge to the sewerage system.

BIO: Dr. Cristina Ávila is a senior researcher with above 10 years of experience on urban & industrial wastewater treatment through constructed wetlands, and on the assessment of emerging organic contaminants in wastewater. She has participated in 16 projects at regional, national and international scale on decentralized wastewater treatment and reuse.

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CORK`S BYPRODUCT USED AS FILTER MEDIUM IN AN AUTOMATED TREATMENT WETLAND FOR WINERY WASTEWATER TREATMENT

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Different strategies have been engineered to enhance the efficiency of treatment wetlands (TW). Induced aeration (artificial aeration), addition supplementary carbon sources to improve TN removal, the use of reactive media to remove specific pollutants or the use of microbial communities to increase performance are some of the examples of recent intensifications. The ECORKWASTE project (LIFE14 ENV/ES/460) combined induced aeration and the use of byproducts from cork industries in order to treat secondary treatment for a winery wastewater.

The project called for building a 14 m^2 TW plant, filled with cork granulates -byproducts of cork processing- as a filter medium. The plant was built using 20 ft. shipping containers. The filter bed was 1.4 m deep layer and consisted of a bottom 0.20 m gravel layer (32 mm Ø) engulfing the drainage system, a 1.0 m layer of cork granulates (7 mm Ø) as filter medium, and a top 0.20 m gravel layer (32 mm Ø) engulfing the distribution system. The TW was planted with *Phragmites australis* at a four plants/m^2 density. The pilot was built to operate Vertical Flow (VF) or Horizontal Subsurface Flow TW. The system was also automated, making possible the complete monitorization, remote operation and full control for all operational parameters (water deep, influent-effluent rates, aeration time). The automation allows the selection of different operation strategies to determine the best performance and improvement of pollutants removal by changing operational schemes (recirculation of the effluent, tidal flow operation, batch mode, or induced aeration). A Victron Energy Color Control GX was also used for energy consumption monitorization.

The TW was operated as a saturated VF TW from April 2017 to October 2018. During the first period the bed was not aerated (Apr-Dec, 2017). During a second testing period (Jan-Oct, 2018), the TW operated as an aerated system. The aeration cycle included a 25 minutes aerated period with atmospheric air (airflow rate of 90 l min^{-1}) followed by a 35 minutes non-aerated period, performed four times per day starting at 9:30 h. The average hydraulic loading rate for both operating modes was 2,000 l d^{-1}.

Results from the first period (non-aerated) during September 2017 (when wastewater production peaked), showed removal efficiencies for NT and NO_3-N ranging from 21-57% and 26-58%, respectively. Removal efficiencies during the second period (aerated) clearly increased and ranged from 64-83% and 92-95% for TN and NO_3-N, respectively. The energy consumption in the aerated period was 3.1 kW/h·d.

Both strategies used in the treatment wetland, the induced aeration and the cork byproduct granulates used as a filter medium, were effective for TN and NO_3-N removal from wastewater. The monitoring and control of the operational parameters of the wetland allowed an optimization on both design and process operations to further improve the quality and cost of the wastewater treatment.

BIO: Ángel Gallegos is a project manager with 10 years of international experience developing cooperation and environmental restoration projects. The design, construction, operation, monitoring and maintenance of treatment wetlands, working in partnership with multidisciplinary teams, are the main focus of his work.

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EVAULATION OF WETLAND CONSTRUCTION, TREATMENT AND MANAGEMENT: A CASE STUDY OF CHERLAPALLY INDUSTRIAL AREA, HYDERABAD, INDIA

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Constructed wetlands (CWs) have gained considerable significance for the treatment of wastewater and are considered as a very successful alternative for wastewater treatment. The use CWs for wastewater treatment is quickly gaining attention as an eco-friendly method as compared to conventional wastewater treatment. A case study related to a successful field application of a CW to treat industrial wastewater in Cherlapally, Hyderabad City, India, is discussed in this paper.

In India, waste from many urban areas are conveyed by "nallahs", which are open water channels often carrying a combination of sewage, stormwater and solid waste. In the case of industrial estates (as was the case in Cherlapally), this situation is further complicated by the addition of industrial wastes into the nallah flow.

CW technology was selected to provide a simple, robust treatment solution. The design flow for the project was 35 m^3/d (although flows eventually increased to 60 m^3/d). A holding tank of 35 m^3 was constructed to provide primary treatment prior to the CW system. The CW consists of nine cells. The first wetland is a vertical flow surface flow wetland; the 2nd, 3rd, and 4th are horizontal flow surface flow wetlands; 5th is a vertical surface flow wetland and 6th, 7th, 8th and 9th are horizontal surface flow wetlands. The dimensions of the first eight wetlands were 10 m x 4 m x 1.25 m (l x b x d). The average depth of each wetland was 1.25 m and the gravel depth in each was 0.75 m. In the surface flow wetlands, 40 cm was the water depth. 15 cm was kept as the free board. The wetland system operates by gravity and no electricity is required for the treatment process. The CW was planted with a variety of native plant species, including *Canna indica*, *Cyperus papyrus*, *Cyperus altenifolia*, *Thalia dealbata*, *Thalia geniculata*, *Typha angustfolia*, and *Canna indica variegata.*

Samples were collected periodically and tested for a variety of parameters. The removal efficiencies obtained for the constructed wetland after 21 weeks of operation were 97 % for BOD, 95 % for COD, 62 % for TDS, 99 % for TSS, 75 % for ammoniacal nitrogen and 81% for total phosphorous. In addition, good removal of oil and grease and fecal coliform were also obtained. The effluent met water quality standards and could be further released into the environment without any further treatment.

BIO: Mr. Sravan Banda is a Director and Subject Matter Expert at Blue Drop Enviro, with offices throughout India. Mr. Banda has been responsible for the design and implementation of over 40 constructed wetland projects in India, dealing with treatment of domestic sewage, nallah drains, industrial wastewater, and lake restoration.

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C.P. 12

CONTRIBUTED PAPERS 12

OPERATION AND MAINTENANCE

Carlos A. Ramírez-Vargas

EXPERIMENTAL INVESTIGATION IN CHANGE OF SOIL HYDRAULIC- AND TRANSPORT PARAMETERS IN VF SAND FILTERS DUE TO BIOCLOGGING USING REAL WASTEWATER TO SUPPORT CLOGGING MODEL DEVELOPMENT

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One of the biggest challenges for the design and operation of a vertical flow (VF) treatment wetlands (TWs) is to avoid the clogging of the pore space. Two main factors can alter the pore space in the filter media, namely particulate matter and the biofilm growth. Mechanical pre-treatment can address particulate matter removal while the main key factors to manage bioclogging can be identified as the organic loading rate (OLR) and the resting period between each loading. Additionally, the used filter media, the distribution system and the actual wastewater composition play a significant roll (Knowles et al., 2011). The altering of the pore space is changing the soil hydraulic properties of the filter media, reduces the porosity and can lead to exclusion zones within the media. This leads to a change in the water flow behavior and influences the re-oxidation, the treatment performance and can also lead to surface ponding.

In this study experimental work is carried out to monitor bioclogging within several sand columns fed with real wastewater. Besides a control column with an OLR of 20 gCOD.m-2.d-1 (dosed intermittently four times per day according to the Austrian design standard ÖNORM B 2505, 2009), 9 other columns are fed with up to 100 gCOD.m-2.d-1 and different loading intervals. The change in the soil hydraulic properties and transport parameters of the filter media is monitored by measuring the water content, the hydraulic conductivity and the matrix potential in the columns. Tracer tests give information on the overall change of water flow and the transport parameters. In a second stage of the experiment, the emphasis will lie on the determination of the biomass growth in the media at different depth. Therefore, grab samples are analyzed using loss on ignition (Tanner and Sukias, 1995).

The collected data is used to support the development of a clogging model which shall be coupled with the HYDRUS Wetland Module (Langergraber and Šimůnek, 2012). As the processes contributing to clogging are complex with several parameters involved which are non-linear and cross influential a process based mathematical description is from upmost importance (Samsó et al., 2016). The full publication will describe the experiments required to provide parameters for the model development as well as discuss the ongoing process of experimental work and model development.

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BIO: Mr Pucher is a junior scientist at the institute of sanitary engineering. For his PhD he is working on the development of process based models to describe bioclogging and particular transport in TWs to get better understanding of the contribution factors leading to clogging.

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EVALUATION OF DIFFERENT MESUREMENT TECHNIQUES TO INVESTIGATE THE CLOGGING PHENOMENON IN CONSTRUCTED WETLANDS

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Constructed wetlands require a thorough understanding of system hydraulics for their correct design and efficient operation. As part of the treatment process, filter media will gradually become clogged due to factors related to influent characteristics, system designs and bed activities. The development of clogging can be detected by the appearance of water on the surface of the granular medium and it could reduce the_treatment performance. Despite preventative and restorative strategies could be carried out to reduce the phenomenon, the clogging is a widespread operational problem and it has become increasingly important to identify practical methods for its measurement. Hydraulic behavior of constructed wetlands (CWs) could be investigated *in situ* by means of hydraulic conductivity (K_s) measurement, clog matter characterizations as well as hydrodynamic visualizations. The suitability of available measurement techniques, in terms of accuracy, repeatability as well as time and skill required, can vary depending on the substrate type, system design as well as clogging degree and distribution.

In order to investigate to which extend some of the available measurement techniques are suitable to assess the spatial and-temporal evolution of clogging in pilot and full scale CWs, a monitoring campaign started few years ago. The full scale CW works as secondary wastewater (WW) treatment system of the Ikea®, located in the industrial district of Catania, Eastern Sicily, Italy. The pilot scale CW treats alternatively storm water from the Ikea® parking area and the sequential batch reactor WW produced from the retail store. Hydraulic conductivity measurements were carried out only in the horizontal subsurface CW beds by falling head tests specifically developed to detect high K_s values. In particular, different schemes and equations for the Lefranc's test were compared employing also a new type of *in situ* permeameter cell. The implemented pervious permeameter used with a calibrated equation for estimating K_s (Licciardello et al., 2019) was the most suitable method to assess K_s to obtain an estimations of K_s that account also for the horizontal component of flow. In order to validate this new scheme – equation combination, other hydraulic measurement techniques were tested. In particular, tracer tests were carried out by pulse–injecting a sodium chloride solution into the inlet pipe of the hydraulic system and then measuring WW electric conductivity at different sites within the bed to assess the K_s variations. Moreover, pump test recovery data from a single observation well and cumulative drainage outflow data were analyzed to evaluate the contribute of these techniques to better understand the hydraulic behavior of CW beds.

Licciardello F., Aiello R., Alagna V., Iovino M., Ventura D., Cirelli G.L. 2019. Assessment of clogging in constructed wetlands by saturated hydraulic conductivity measurements. In press on Water Science and Technology, IWA Publishing

<u>BIO</u>: Dr. Licciardello is a scientist with a 20 year - cooperation with the hydraulic section of the Department of Agriculture, Food and Environment of Catania University. The section has a very long experience planning, designing, and implementing constructed wetland projects. The section has led numerous national and international projects on constructed wetland management.

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PREFERENTIAL FLOWS IN TREATMENT WETLANDS

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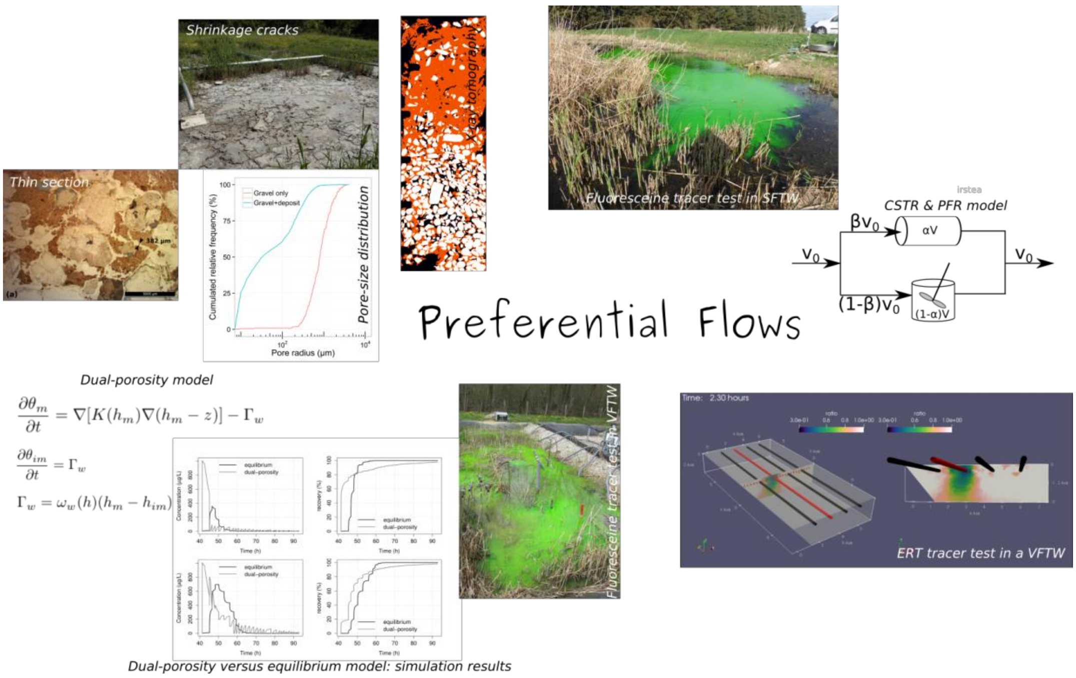
Preferential flows (PFs) in soil are long-known phenomena and are well documented and classified although challenges remain in the understanding of their driving phenomena and in their modeling. In Treatment Wetlands (TW) literature, such classification does not exist and the terminology “preferential flows” is indistinctively used to describe various phenomena.

Based on the experience accumulated at Irstea over the last ten years and on the existing literature, we first aimed at providing a better description of what are PFs in TW. For example, a distinction must be made between hydraulic shortcuts, where flow is significantly faster in an area of the TW creating dead zone with limited contribution to treatment and preferential flows through macropores that exchange water and solute with a much slower matrix flow. Then, we described experimental methodologies to characterize PF based on their assumed nature and the type of TW. Single or multiple tracers experiments are the most common approaches but innovative and complementary methods exists ranging from a macroscopic description and quantification of macropores using thin section or X-ray tomography to full-scale imaging of hydraulic shortcut using electrical resistivity tomography. Finally, we introduce models used to predict PF, their domain of validity, their advantages and drawbacks. Continuous Flow Stirred Tanks Reactors (CSTR) in parallel with Plug Flow Reactors (PFR) can efficiently model hydraulic shortcuts but their applicability is limited to the wetland on which the model has been calibrated. On the other hand, dual-porosity and dual-permeability could be used to predict preferential flows in a TW when design it but their calibration remain challenging.

Knowing the nature and mechanisms of PF is a key to understand current limitations of existing TW. If used appropriately, numerical models may be a powerful tool to improve TW design in order to prevent PFs.



<u>BIO</u>: Dr. Forquet is a scientist with more than 10 years of experience in Treatment Wetland research. His main research interests are on flow characterization and modeling, and clogging.

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RESPIROMETRY OF BIOFILMS FROM SUB-SURFACE FLOW CONSTRUCTED WETLANDS: THE RELEVANCE OF STORAGE MECHANISMS

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Models describing the biochemical processes in CWs are usefull tools to better understand CW functioning and their increased accuracy in water quality prediction could help to define design guidelines. Current models are mostly based in Activated Sludge Model 1, where a death-regeneration approach is considered and readily available organic substrates are directly used by heterotrophic biomass for either biomass growth or energy production. This study presents the main findings of using respirometry tests to examine readily biodegradable substrate use in horizontal subsurface flow CW.
Respirometry tests were conducted in a suspended-biomass respirometer (Galvão et al., 2019) and in an attached-biomass respirometer (Ho, 2018) installed in the Environmental Laboratory of IST in Lisbon, Portugal, using biomass extracted from experimental beds fed with synthetic sewage. Biomass was analyzed from beds receiving mass loads from 7 to 35 g COD/m^2/day.
Three different OUR-time profiles were identified, following the classification proposed by Pisoeiro et al. (2017)(Figure 1).

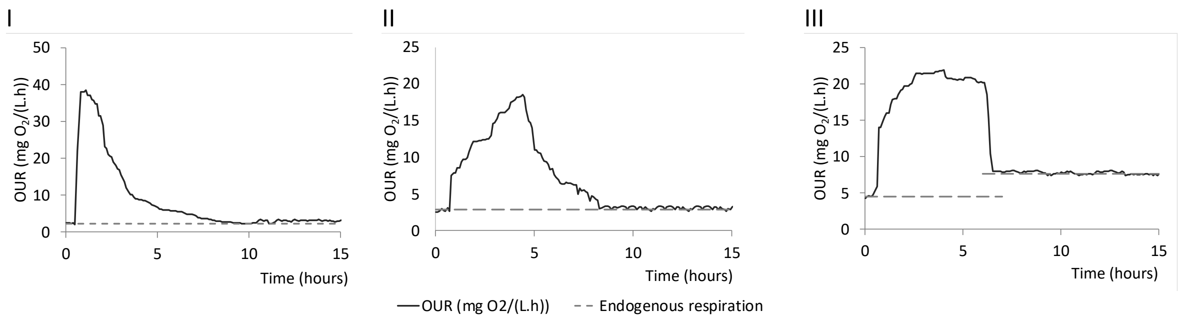

Figure 1: Classification of respirometry tests.

The majority of the tests showed storage evidence, and both the suspended biomass as well as the attached biomass studies provided similar results. The OUR profiles can reveal different kinetics according to the different types. Type I profiles corresponds to non-saturated, Monod type metabolic kinetics, indicating an apparent low affinity of the biomass for the substrate. This response was mostly found on the samples retrieved from beds with lower organic mass loads. Type II profile provide evidence of biomass growth on the added substrate, with kinetics closer to saturation, revealing a higher apparent affinity for the substrate than in type I profiles. Type III area characterized by a plateau which indicates saturation of the energy metabolism rate by the added substrate. During this plateau the substrate is being consumed at the maximum rate, indicating its preferential use for the production of energy, with negligible biomass growth.

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BIO: Ana Galvão is an Assistant Professor at Instituto Superior Técnico, where she studies constructed wetlands for more than 15 years. Her research interests includes biofilm growth in CW as well as the adaptation of wetland processes to green walls, in order to provide greywater treatment for reuse in urban areas.

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BACTERIAL ACTIVITY AND BIOMASS ASSESSMENT IN CONSTRUCTED WETLANDS BASED ON THE ELECTRIC SIGNAL OF MICROBIAL FUELL CELLS

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Biological activity and biomass development in constructed wetlands (CW) are key parameters regarding treatment efficiency and management of constructed wetlands. However, current available tools for the assessment of both parameters are time consuming, encompass in some cases invasive methodologies that reduce the reliability for the assessment of on-site processes, and are difficult to apply on a regular basis (continuous monitoring) (Faulwetter et al., 2009; Knowles et al., 2011). The main objective of this study was to determine the potential use of the electric signal of microbial fuel cells (MFC) implemented in horizontal flow CW as an indirect measure of both overall heterotrophic bacterial activity and biomass development during the treatment of real domestic wastewater. For the purposes of this work, lab-scale models simulating a core of a shallow un-planted wetland were monitored for six months. Once the working hypothesis was validated under lab-scale conditions, a follow-up experiment that lasted six months was carried out in a CW pilot plant. Characteristics of both, lab-scale and pilot-scale systems used in the present work, are described in detail elsewhere (Corbella et al., 2018). Microbial activity was determined by means of the fluorescein diacetate technique (FDA). Activity was measured using extractable gravel cores from experimental systems for 50 minutes every 10 minutes and the heterotrophic activity was calculated as an average of the slopes between sampling events following the method described elsewhere (Weber and Legge, 2011). Biomass was estimated by performing COD analysis on gravel cores placed within the systems at the end of each experiment. In spite of quite variable results (most probably due to the daily variation of the real domestic wastewater employed during the whole study period), results showed that both heterotrophic bacterial activity and biomass were linearly correlated with MFC current density (A/m^2). Accordingly, linear correlations using all the data from the present work (lab and pilot-scale systems altogether) were statistically significant, with R^2 of 0.85 (p-value: 0.0001; F: 46.36; DF:6) and 0.97 (p-value: 0.002; F: 32.2; DF:6) for the linear correlations of current density vs activity and current density vs biomass, respectively. Overall, the authors can conclude that the electric signal of MFC systems implemented in constructed wetlands can be used as an indirect tool for the assessment of overall heterotrophic bacterial activity and biomass development. The reported findings open new possibilities for improving constructed wetlands operation and optimization and has potential to be applied to model validation.

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BIO: Jaume Puigagut is a biologist and holds an Associate Professor position at Technical University of Catalunya.

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CONTRIBUTED PAPERS 13

MICROBIAL AND ENZYMATIC PROCESSES IN CWS

Vincent Gagnon

MICROBIAL COMMUNITY FUNCTION IN ELECTROACTIVE BIOFILM-BASED CONSTRUCTED WETLANDS

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The performance enhancement of constructed wetlands can be achieved through the coupling with microbial electrochemical technologies (MET). MET is a setup designed to mimic metabolic electrons exchange with insoluble donors and acceptors with the aid of electroactive bacteria and external electrical circuits. An alternative MET that dispenses of electrodes and circuits but uses an electro-conductive biofilter is called Microbial Electrochemical-based Constructed Wetland (METland).

Previously it has been demonstrated that a METland has higher biodegradation rates than horizontal flow constructed wetlands, however given its novelty there are still uncertainties related to the removal of pollutants, including their microbial activity. The genetic characterization of microbial communities of a METland is desirable, but is time and resource consuming, then a characterization alternative could be based on functional analysis of the microbial communities. Community-level physiological profile (CLPP) is a useful method to evaluate the functional diversity of microbial communities based on the carbon source utilization pattern (CSUP).

Therefore, this study was focused on the microbial characterization of laboratory scale METland based on CLPP analysis. The study included the characterization of microbial communities attached to two carbon-based electro-conductive materials (calcined petroleum coke from crushed electrodes – PK-A; calcined petroleum coke with low sulphur and nitrogen content – PK-LSN), in planted and non-planted set-ups. Variations on the metabolic activity of tested systems were identified and it seems to be related to the characteristics of the material, rather than the presence / absence of plants. In general, CSUP show differences along flow pathway, as well as among the tested systems, being carbohydrates and carboxylic/acetic acids the most consumed carbon sources, followed by polymers, amides/amines and amino acids. Also, were established some correlations between the utilization of carbon sources and the removal of pollutants. The obtained results provide useful insight into the spatial dynamics of METland systems.

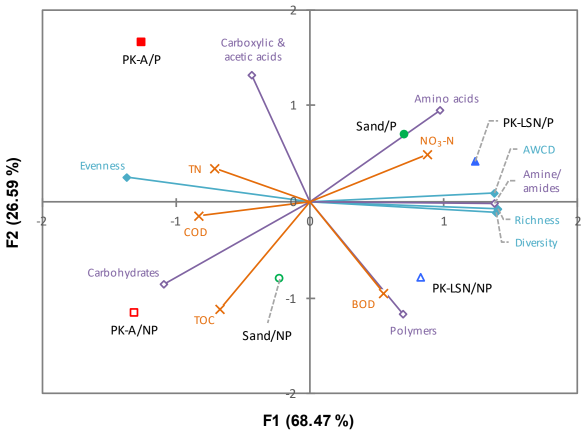

Figure 1. Correlation biplot of microbial metabolic activity indexes (AWCD, richness, diversity and evenness), carbon guild utilization (Amine/amides, Amino acids, Carbohydrates, Carboxylic & acetic acids and Polymers) and removal efficiency of organic matter (BOD_5, COD and TOC) and nitrogen (NO_3-N and TN) per tested system.

BIO: Dr. Ramirez-Vargas is a postdoc fellow with interest in the combination of constructed wetlands with microbial electrochemical technologies as treatment intensification alternative. He has an experience of 10 years as contractor and research assistant in different projects related with engineering and management of water and sanitation alternatives, including constructed wetlands.

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DECLINE OF FITNESS OF *JUNCUS EFFUSUS* DURING LOW-DOSE EXPOSURES WITH ANTIMICROBIALS COINCIDES WITH MAJOR CHANGES OF THE ENDOPHYTIC BACTERIAL COMMUNITY

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Recent studies on the plant-bacteria partnership have revealed the importance of bacterial endophytes for plant fitness. This partnership is particularly important in constructed wetlands treating wastewater. Here we asked whether antimicrobials commonly found in wastewater may disturb the plant-microbe interplay. To this end, we exposed wetland model systems planted with the common wetland plant, *Juncus effusus*, with sulfamethoxazole (SMX) and trimethoprim (TMP) at low aqueous concentrations. Plant fitness was evaluated based on evapotranspiration rates and by visual inspection. Changes of endophytic communities in roots and shoots of exposed and unexposed plants were tracked via culture-dependent (CFU, isolation of strains) and culture-independent (qPCR, 16S amplicon sequencing, FISH) approaches. The plant defence response was determined via recording reactive oxygen species (ROS) generation. We found that evapotranspiration decreased during exposure to SMX and TMP. After several exposures, plants became infested with insects and plant tissues turned necrotic. Total and phylum specific abundances of endophytes increased significantly in exposed roots but not in shoots. Culture-dependent and independent approaches revealed substantial changes in community composition, which were particularly pronounced in the roots. FISH analysis showed microbial colonization in the vascular bundles of the exposed plant roots. The presence of harmful bacteria was indicated by intense ROS production by the plant. In conclusion, a lasting change of the bacterial endophytic community was observed in plant roots. The observation is analogous to the animal gut where microbes play key roles in disease, health, growth and host development. The wetland's performance may be affected by disturbance of the plant-endophyte interplay.

BIO: Jochen A. Müller is a senior scientist working on microbiological transformation processes in wetlands. A further agenda of his research group is the development and implementation of hydroponic treatment systems.

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ENZYMATIC PROFILE OF RETENTION SOIL FILTERS TREATING EFFLUENT OF A SEWAGE TREATMENT PLANT

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Sewage treatment plants based on activated sludge process (STP) provide wastewater purification since decades, significantly decreasing the negative impact on water bodies. However, STPs are designed for removal of easily degradable organic matter and nutrients. Slowly and non-biodegradable substances, such as pharmaceutical residues and ingredients of household chemicals, remain unaffected. These organic micropollutants (OMP) may pose significant threat exhibiting carcinogenic, mutagenic or reprotoxic effects when reaching the environment. To solve the problem, STPs are upgraded with tertiary treatment, which includes ozonation and sorption to activated carbon. High costs and energy consumption, formation of toxic by-products during ozonation are drawbacks of these technologies.

A retention soil filter (RSF) amended with granular activated carbon (GAC) is proposed as a cheap and environmentally friendly post-treatment for STP effluent. RSF is a vertical flow subsurface wetland with alternate feeding to allow for aerobic conditions in a filter bed. Two pilot-scale planted RSFs with a filter surface of 1.5 m^2 and a depth of 1.2 m have been operated for treatment of the effluent of Rheinbach STP (Erftverband water board, Germany). The first filter, RSF-A, was filled with sand and $CaCO_3$, whereas the second, RSF-G, had the same medium amended with biochar (0-10 cm of the bed) and granular activated carbon (60-90 cm of the bed). Both RSFs were monitored for 150 OMPs, with 14 OMPs present in >75% of the samples. RSF-G showed outstanding performance for OMP removal even after 2.5 years of operation. This could not be attributed to adsorption to GAC solely, because GAC has limited sorption capacity. Enhanced biodegradation of OMPs in GAC layer is expected to be the governing mechanism.

The enzymatic profile of the RSFs was studied to reveal possible biocatalysts involved in OMP degradation. Water samples were collected from different layers of both RSFs. Each sample (ca. 1 L volume) was filtrated through glass fiber filter to collect proteins and the filters were subjected to protein extraction and mass-spectrometry based proteome analysis. The MS/MS spectra were compared against Uniprot Bacteria database and tailored soil metagenome database using MetaProteomeAnalyzer software for protein identification.

Identified proteins belonged primarily to *Proteobacteria*, which is the most abundant bacterial phylum in soil and particularly constructed wetlands. The water samples, procured from the depth of 80 cm (middle of the GAC layer) has shown the largest number of unique peptide sequences, that correspond to proteins with enzymatic functions (19% of the total number of sequences identified). Ammonia monooxygenase and aminopeptidases, which could be potentially involved in cometabolic micropollutant degradation, were detected only in the GAC layer of RSF-G. Revealing the mechanisms underlying enhanced micropollutant biodegradation in GAC-amended RSF will help to design these systems in most efficient way for treatment of STP effluent.

BIO: Dr. Butkovskyi is a young scientist, who obtained his PhD in Environmental Technology at Wageningen University in 2015. Since 2017 Dr. Butkovskyi works at Helmholtz Centre for Environmental Research – UFZ. His research interests focus on improving design of nature-based treatment systems for micropollutant removal.

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OPENING THE BLACK BOX: FLUORESCENCE-BASED IMAGING OF SPATIAL PATTERNS OF MICROBIAL ENZYMATIC ACTIVITY IN A VEGETATED WALL FOR DOMESTIC GRAYWATER TREATMENT

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Green walls are vertical vegetated structures located on the unused surfaces of the buildings. They have positive effects on life quality and have also important environmental benefits (e.g. CO_2 absorption, heat island mitigation, biodiversity preservation). Unfortunately, their maintenance requires a considerable amount of water for irrigation. Water consumption is becoming a central issue nowadays, even in countries that do not traditionally suffer water crisis. Domestic wastewater can be used to irrigate green walls, thus reducing their water footprint and obtaining treated wastewater that can be reused. Light greywater (i.e. household wastewater from hand basins, showers, bathtubs and laundry machines) is the best target for these nature-based solutions in urban areas, due to its low pollutant content. Modular green walls work as small vertical flow constructed wetlands and their efficiency is usually evaluated comparing inflow and outflow properties. The microorganisms living in the plant rhizosphere play an important role during the treatment, releasing enzymes that contribute to the pollutants degradation, but few information are available on their activity.

The aim of this study is to employ a non-invasive method to better understand microbial reactions in a porous medium by visualizing enzymatic activity responsible for pollutant removal. This methodology uses fluorescein diacetate (FDA), which becomes fluorescent when enzymes break part of its chemical bond during its degradation. Since we need to measure fluorescent light emission, a dark room has been built to contain a Canon EOS 800D camera, transparent pots (10x10x15 cm) filled with monochromatic porous media and two blue LED lights. Unvegetated pots have been used with fluorescein to calibrate the optical system and correlate light intensity with solution concentration. Different materials (both for pots and porous medium), light configurations and camera options have been tested during the calibration step. A vegetated pot (the smallest component of the green wall) is daily fed by synthetic greywater to facilitate biofilm growing into the porous medium. To measure the enzymatic activity, the pot will be filled to saturation with a FDA solution on a periodical basis. Several pictures will be taken at short time intervals while the microbial enzymes break down FDA to its bright fluorescein compound.

The fluorescent concentration is measured by analysing the green band in each image, without disturbing the pot system. Calibration curves have been built, revealing linear correlation between green light intensity and fluorescent concentration. During the next months, spatial resolution will be refined as much as possible to control optical effects. Comparing the pictures of the vegetated pot rhizosphere at different instants after the injection of the FDA solution, an enzymatic activity reaction rate map will be drawn, providing important insight on microbial process into the porous medium. Knowledge of these processes will contribute to a better design process for the pots, increasing green walls treatment efficiency.

BIO: Elisa Costamagna is a first year PhD student. She is working on enzymatic activity analysis using image processing and fluorescent tracer. She is involved in SUPERGREEN project, building and testing a real scale green wall for synthetic greywater treatment.

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C.P. 14

CONTRIBUTED PAPERS 14

COASTAL WETLANDS

Brian K. Sorrell

WARMING IMPACT ON DOMINATING PLANT SPECIES IN CHINESE COASTAL WETLANDS

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Global mean temperature is projected to increase by 1 - 3.7 °C by 2100. Increased warming can stimulate the productivity in marsh ecosystems, which already are among the most productive on earth. We examined the effects of increased temperature on two tall grass species that are dominant in Chinese coastal wetlands (*Phragmites australis* and *Spartina alterniflora*). *Spartina alterniflora* is an invasive species in China, and it has spread rapidly since its introduction in 1979, replacing native species. This shift in species composition in Chinese coastal wetlands, from native macrophytes such as *Phragmites australis* to invasive species such as *S. alterniflora*, might also be exacerbated by increasing temperatures. Open top chambers (OTCs), passively elevating the air temperature, were set up in two locations in the Yancheng salt marsh area in eastern China. One site was dominated by *S. alterniflora* and the other by *P. australis*. Both sites were equipped with six OTCs and six control plots (CP). Photosynthesis, height, flowering percentage and chlorophyll content was measured on site in August 2018, and biomass was collected for elemental tissue analysis of shoots. Despite the contrasting photosynthetic strategies, which both species employ, we found no difference caused by the warming in either species' photosynthetic properties. However, *P. australis* was significantly taller within the OTCs, but no such pattern was found for *S. alterniflora*. While other effects of climate change, such as increased flooding and elevated saltwater intrusion in coastal wetlands, would potentially favour the highly salt-tolerant invader *S. alterniflora* in interspecific competition, our study shows that a temperature increase might provide *P. australis* with an advantage.

BIO: Gro Havskov Kirk is a PhD student in biology, working with coastal wetland plants.

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AGRICULTURAL CONVERSION OF PAPYRUS WETLANDS LEADS TO LOSS OF DENITRIFICATION POTENTIAL, NAMATALA WETLAND, UGANDA

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Conversion of wetlands to agriculture causes a decline in regulating ecosystem services such as nutrient retention and carbon storage. In sub-Saharan Africa, papyrus wetlands are commonly converted to smallholder farms as well as to commercial systems for rice and sugarcane. Some wetlands are fully drained, while others are cultivated during dry seasons and flooded again in wet seasons. Conversion usually occurs along a hydrological gradient, with intact native vegetation in the wettest areas and drier areas that are permanently converted. The effects of conversion on retention processes are rarely quantified. Here we examine the impact on denitrification, an anerobic, heterotrophic, microbial process that removes nitrogen via the conversion of nitrate (NO_3) to nitrous oxide (N_2O) and dinitrogen gas (N_2). We measured denitrification enzyme activity in 5 land cover types in Namatala wetland, Uganda, approximately monthly from Nov. 2016 – Oct. 2017. We used the acetylene block technique, which blocks conversion of N_2O to N_2, and allows denitrification rate to be measured on a gas chromatograph. The incubations were done under anaerobic atmosphere with a labile source of organic matter (glucose) and excess NO_3. Chloramphenicol prevented the production of new enzyme. Due to these ideal conditions, this technique provides a measure of the potential denitrification rate (PDR). Controlling factors were assessed by relating soil properties in each land cover type (soil moisture, soil carbon (TOC), NO_3 availability and pH) to PDR. We also assessed whether NO_3 or TOC was limiting PDR by adding NO_3 alone, glucose alone, and both together in the enzyme assay.

PDR ranged from 0.02 to 9.3 µg N_2O g^{-1} DW hr^{-1}, with significantly higher rates in papyrus and rice compared to sugarcane, seasonal, or mixed crops (repeated measures two-way ANOVA; $p<0.05$). These land cover types occurred along a soil moisture gradient, with papyrus having the highest PDR, followed by rice, then sugarcane, seasonal and mixed crops. Along this gradient, soil carbon decreased while NO_3 availability increased. This led to significant positive relationships between PDR and soil moisture and TOC, and to negative relationships with NO_3 (ANCOVA; $p<0.05$). The results of the bioassay also confirmed that PDR was limited by NO_3 in papyrus and rice and by TOC in sugarcane, seasonal and mixed crops. pH was important only in papyrus which had pH <5, but not enough to diminish PDR compared to the other land cover types. An effect of seasons was evident in the wettest months when PDR was higher in almost all land cover types.

In conclusion, the conversion of papyrus wetlands to agriculture leads to a decline in the nitrogen retention capacity via the denitrification pathway, likely through a loss of soil-moisture and, subsequently, carbon. In East Africa where wetland conversion is rapid, and where wetlands are also often used for waste-water treatment and food production, it must be recognized that this function is diminished, and these wetlands may not be effective in protecting sensitive downstream ecosystems from excess nitrogen inputs.

BIO: Dr. Anne van Dam is Associate Professor of Environmental Systems Analysis and has been involved in research on sustainable use of wetlands for over 15 years. He represents IHE Delft at the Ramsar STRP and is a co-author of the Global Wetland Outlook (2018).

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EFFECTS OF DRYING-REWETTING FREQUENCY ON VERTICAL AND LATERAL LOSS OF ORGANIC CARBON IN A TIDAL SALT MARSH: A LABORATORY EXPERIMENT

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As "blue carbon" ecosystems, tidal salt marshes play a key role in carbon sequestration. However, changes of drying-rewetting frequency induced by various natural and anthropogenic factors, such as sea level rise, dam construction and exotic species invasion, might regulate vertical and lateral carbon loss of soil organic carbon in tidal salt marsh. A mesocosm experiment was conducted to identify the effects of drying-rewetting frequency changes on vertical (CO_2 and CH_4) and lateral (DOC) carbon loss of soils in tidal salt marsh. Here the results showed that less frequent drying-rewetting cycles followed by more CO_2 and less CH_4 emissions. Soil DOC produced in drying phase, however, decreasing of drying-rewetting frequency reduce soil DOC concentration. CO_2 emission rates were significantly affected by soil gravimetric water content, total organic carbon (TOC), total nitrogen (TN) and C/N, while CH_4 emission rates were significantly affected by soil gravimetric water content, salinity, TOC, total carbon (TC), and TN. Increasing soil gravimetric content significantly decreased cumulative CO_2 emissions and increased cumulative CH_4 emissions, while increasing soil salinity only significantly decreased cumulative CH_4 emissions. However, no significant relationship was found between DOC loss (ΔDOC) and gravimetric content as well as ΔDOC and salinity. Remarkably, as a labile component of soil organic carbon (SOC), DOC had significant impact on CO_2 emissions. Our results suggest that changes of tidal action and drying-rewetting cycle induced by global change can affect the function of blue carbon storage in tidal salt marsh.

BIO: Dr. Guangxuan Han is an ecological scientist with more than 10 years of wetland ecology research experience. He has extensive experience with carbon cycling, wetland succession and wetland restoration, and has led more than 10 projects dedicated to wetlands ecology, published more than 50 research articles.

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SALINITY INTRUSION AND DEGRADATION OF SUNDARBANS COASTAL MANGROVE WETLAND ECOSYSTEM IN THE GANGES-BRAHMAPUTRA-MEGHNA DELTA (BANGLADESH)

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The Sundarbans is one of the largest productive mangrove coastal forest wetland site located in the Ganges-Brahmaputra-Meghna rivers delta region in Bangladesh. The coastal mangrove wetland is playing a potential role in balancing ecology, community socio-economy and livelihoods of the coastal community in Bengal coastal region. It has been declared by UNESCO as world Natural Heritage site in 1997. The water salinity (NaCl) intrusion is the most sensitive and new threat for ecological issue in the coastal region in Bangladesh. It is hotspot of mangrove biodiversity with 373 faunal and 324 floral species. Over 3.5 million inhabitants are directly or indirectly dependent on the Sundarbans mangrove goods and services. Moreover it is a unique position not only forestry but also in terms of deltaic landscapes, eco-tourism, culture and heritage. The importance of the site is its floristic composition and economic uses. Furthermore it is a dynamic, fragile, complex ecosystem is delicate with the factors of soil water and environment. Climate change and human disturb on the Sundarbans, have transformed natural landscapes through the process of fire, hunting, agriculture, shrimp farming. The result has demonstrated that the large river's water has crossed the water salinity threshold value (43220 dS/m) in 2013. In previous the average water salinity value was 54025 dS/m which is harmful and possess threats to mangrove wetland ecosystem in the Sundarbans coastal region in Bangladesh. Whereas, the present highest water salinity value is 69152 dS/m which is much higher and more harmful and poses threats to mangrove wetland ecosystem. The present coastal mangrove wetland ecosystem conservation planning policy is inadequate. The Sundarbans natural heritage site which has outstanding universal values to humanity is diminishing on a global scale. Almost 45% mangrove has already declined in the Sundarbans region. Therefore, it is important and essential for conservation. The objective of this study is to understand and analyze the present degraded status of mangrove ecosystem and negative impacts on coastal mangrove wetlands. Propose recommendations for better management, monitoring and conservation of the Sundarbans mangrove wetland ecosystem in the Ganges-Brahmaputra-Meghna Rivers delta region in Bangladesh.

Keywords: Sundarbans mangrove, wetlands, ecosystem, salinity intrusion, management and conservation

C.P. 15

CONTRIBUTED PAPERS 15

TROPICAL WETLANDS

Maria Alejandra Maine

REFLECTIONS IN A DESERT SPRING: PLANNING AND IMPLEMENTATION OF CONSTRUCTED WETLANDS IN ARID SOUTHERN CALIFORNIA

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With the rising urbanization of the coastal watersheds of southern California, requirements for municipal control of runoff quantity and quality have created a demand for wetlands as effective, low-cost best management practices (BMPs) to improve surface water quality and attenuate storm flows. There is equal pressure to restore, enhance, and create wetlands with multiple objectives (i.e., habitat support, treatment of nonpoint source pollution, flood attenuation, and recreation). One survey completed in 2008 documented 40 constructed wetlands designed to provide multiple functions in six southern California counties. Within this region, annual precipitation totals vary from 76 mm in Imperial County to 415 mm in San Bernardino County. Pan evaporation totals for these same locations total 2,677 mm and 1,494 mm, respectively, pointing to intense competition for water for human use and significant seasonal variation in water availability, with rain falling during the winter primarily in response to frontal storms. In addition, concerns have been voiced and documented about the potential hazard of vector production and the need to periodically remove excess wetland vegetation growth in a perennially warm climate.

Planning wetlands within these environmental constraints requires careful attention when assessing the wetland water balance when modeling to ensure that summer dry periods are limited in duration to the tolerance levels of plant species present. Minimization of evaporative loss is a common planning objective, which complements the general need to minimize wetland area in locations with spiraling land costs. These factors often lead to project designs that minimize wetland vegetative coverage. Finally, the fact that most of the water available for wetland habitat creation is contaminated by stormwater, treated effluent, agricultural returns, or dry weather urban runoff requires some measure of integration of wetlands treatment (e.g., sediment removal) into habitat design (e.g., mixed marsh).

Projects completed within the last decade illustrate how constructed wetland planning can adapt to and overcome these constraints through imaginative water conveyance, wetland layout design, and taking advantage of site-specific factors. Key features of four selected case studies will be presented to demonstrate this approach: Imperial County Mitigation Marsh Phase I (121 ha); Orange County Prado Wetlands (188 ha); Dominguez Gap Wetland Recreation Area (15 ha); and the Southern California Inventory of Existing Urban and Treatment Wetlands, which quantified type, distribution, function and ecological value of wetlands in this arid, highly developed region.

BIO: Mr. Bays is a wetland ecologist with Jacobs Engineering Group specializing in the planning, design and monitoring of natural treatment systems for water quality improvement and habitat creation. His projects have been implemented nationwide and outside of the United States in Australia, Asia, Canada, Europe, and Latin America.

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CONSTRUCTED WETLANDS AND EFFLUENT REUSE IN IRRIGATION FOR LATIN-AMERICAN COUNTRIES: ANALYSIS AND BRIEF ANSWER FROM CHILE FOR ARID CLIMATES

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In economic terms, Latin American countries (LACs) can be classified as "Upper or Lower-middle income countries" (World Bank, 2018). Regarding to sanitation data, only 20% of the municipal wastewater is treated (Hernández-Padilla et al., 2017). Therefore, the new treatment facilities in LACs should be shifting towards solutions, which are resource oriented and sustainable. In this regard, Constructed wetlands (CWs) is a promising technology because it meet these conditions, and for example, effluents can be reused in irrigation of agricultural products (Almuktar et al., 2018). In LACs this kind of reuse could be very important for their territories or particularly for arid areas of Mexico, Chile, Peru and Argentina. Therefore, the aim of this work was to analyze the reuse state in some LACs taking into account their regulations and the relationship with CWs' effluents quality. Additionally, the results of one laboratory experiment reusing effluents from CWs as irrigation water to cultivate Lily Tresor in Atacama Desert (Chile) are showed.

Brazil, Chile, Colombia, Costa Rica and México have regulations or guidelines for irrigation water coming from natural sources or reused from treated wastewater. Regulations in LACs include between 2 to around 35 water quality parameters. Microbiological parameters include coliforms, helminths, protozoans, salmonella and enterococcus, and for example, fecal coliforms vary between $1x10^3$ MPN/100 ml and $1x10^5$ MPN/100 ml. On the other hand, analysis of CWs from some LACs showed two important things: a) CWs with subsurface flow were the most kind of CWs used for treating municipal wastewater, and b) effluents quality has a huge variability regarding to values included in their regulations. However, one important aspect to be considered is that agricultural products of LACs are exported to different markets (mainly USA and Europe). Therefore, water quality for irrigation in LACs should be analyzed under national or international regulations depending on the final destination of agricultural products.

Finally, experiments in Atacama Desert (Chile) showed that CWs effluents can be used as irrigation water to the cultivation of Lily Tresor (ornamental flower) (Vera-Puerto et al., 2019). However, its commercialization would be limited to national markets because its height is below 0.65 m (Vera-Puerto et al., 2019). Height problems' can be explained by salinity in water (Electrical Conductivity above 2000 µS/cm) and luminosity intensity (above 38 klux) (Vera-Puerto et al., 2019). In addition, the CWS effluent´s quality must be improved by additional treatment stages because the Chilean or international guidelines for irrigation are not being met. In this way, CWs can be useful as wastewater treatment technology to increase the coverage in LACs, and CWS has to be integrated to other treatment stages in facilities that want to produce effluents that are to be reused as irrigation water for agricultural products in LACs.

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BIO: Dr. Vera-Puerto has 13 years of experience dedicated to wetlands use to restauration projects and wastewater treatment. He has experience with specials support mediums, nutrients removal and effluent reuse.

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MICROCOSM DESIGN OF INDIGENIZED ONSITE CONSTRUCTED WETLAND FOR GREYWATER TREATMENT IN GHANA

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Introduction and aim: Greywater management is largely ignored in Ghana likely due to poor general management of wastewater. With only 10% sewerage coverage nationwide, the risk of environmental pollution and public health threats are inevitable. The study developed and tested indigenized horizontal flow constructed wetland (HFCW) for onsite greywater treatment within a neighbourhood of five households (with 24 inhabitants) at residential staff bungalows of a University campus in Kumasi.

Methodology: The study used HFCW design approach and incorporated indigenous knowledge of local vegetation in greywater treatment practiced via informal subsurface infiltration. The HFCW were developed around two local and lesser known wetland vegetation– taro (Colocasia esculenta) and sugarcane (Saccharum officinarum), and local media (gravels and laterite-gravel mix, 1:1 v/v). Eight wetland basins (length 104cm, 56cm diameter, 0.57m2 open surface area) were created from a 250L capacity plastic barrel, and filled with media (gravels of d10 =5.5mm and laterite-gravel mix of d30 to 60 = 0.1 – 7mm). The HFCWs including two controls were operated and monitored between June and October 2018 for performance with 3 residence times (HRT 1, 2 & 3 days) on five repeated batch runs. Wetlands TT1-TT3 and TT6 were filled with laterite-gravel media and TT4 & TT5 filled with gravels. TT2 & TT3 were planted with only taro and sugarcane respectively and the rest were planted with both.

Results: All wetlands were associated with increased effluent levels of EC, DO, TDS, NH3 and Iron for all 3 HRTs. Sulphate removal was almost always 100% and likewise nitrite which followed quite closely especially for laterite-based beds. Generally, all other contaminants turbidity, TSS, BOD5, COD, P, nitrate and anionic surfactants were significantly removed. The order of major contaminants' removal in planted beds from the highest is ranked as follows: nitrate >BOD5 >COD >TSS >anionic surfactants >Orth-P with their corresponding average removals around 89% >87% >80% >72% >65% >61%. Contaminants' removal efficiencies were mixed with increasing HRT among different wetlands and significant differences were identified by paired T-test statistics: TSS, BOD5 and nitrate were not significant for different HRTs (p>0.05, i.e. 0.193 – 0.960); all HRT pairwise comparisons for COD were significant (p<0.05; 0.00 – 0.04); Ortho-P showed no significant difference for 1&2 and 2&3 HRT pairwise comparisons (p>0.05; 0.97 – 0.271) unlike the 1&3 pair (p=0.023); and contrary anionic surfactants showed significant difference for 1&2 and 2&3 HRT pairwise comparisons (p<0.001) unlike the 1&3 pair (p=0.944). The topmost ranked wetland follows the order: TT2 & TT6 >TT4 & TT5 >TT3 >TT1 and this corresponds to their frequencies of achieving the highest level of contaminant removal (26%s >16%s 16% >11% >5%). The level of oxygen transfers was not consistent and/or sometimes fell short of the recommended 20 g-O2/m2d for most planted wetlands for the different HRTs except for taro (TT2) and sugarcane (TT3) monoculture setups.

Conclusion: The bed media and vegetation used in the HFCW have shown strong potential for application in wetland designs especially for greywater treatment. The Indigenized HFCWs are promising, the high efficiency for also a short retention time of a day has positive consequence on land requirement and potential odour challenges. Further research on systems is warranted specially for further improvement and establishing the robustness and sustainability of performance levels on a long-term basis.

Keywords: constructed wetlands, greywater, indigenous plants, local media, Ghana

<u>BIO:</u> Mr Dwumfour-Asare is a senior lecturer at UEW and also a PhD student at KNUST. He has strong background in the areas of water, sanitation, wastewater systems and environmental health. He is passionate about the potential to use wetland systems for safe management of wastewater in developing countries. He believes the wetland technology must be on the research and development agenda of developing countries for successful adoption.

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UNDERSTANDING THE DIFFERENTIAL ROLE OF BIO-PHYSICAL COMPONENTS OF FLOODPLAIN WETLANDS IN WATER PURIFICATION: A CASE STUDY OF A TROPICAL FLOODPLAIN WETLAND IN BARAK RIVER BASIN, NORTHEAST INDIA

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Seasonal flood pulses in floodplain wetlands cause variations in wetland- basin dimensions and vegetation characteristics, which altogether lead to changes in the ecosystem processes within the wetland. Considering this, we hypothesized that floodplain wetlands which are subject to periodic flooding and seasonal inundations are impacted by changes in basin morphometry and vegetation characteristics, which might have a differential role in water purification potential of the wetland. To test this hypothesis, we studied the biophysical components of a typical tropical floodplain wetland in Barak river basin, North-east India. The components included were basin morphometry, lower vascular plant groups and the surface water of the wetland during three broad flood phases, viz., early- flood, mid-flood, and late-flood. Strategic sampling and subsequent analysis of the selected biophysical components of the wetland were done considering the major inlet points, middle points and outlet point along the wetland. Besides, two main effect water variables viz., water quality index (WQI) & trophic state index (TSI) were also ascertained across the flood phases.

The present study confirms that water purification in wetlands is governed by the individual effect of wetland basin morphometry and wetland vegetation characteristics across different flood phases. Water phosphate-P was significantly positively correlated with vegetation biomass, & TP stocks of the wetland vegetation, indicating the potentiality of wetland vegetation in the uptake of available phosphorous from the surface water. The WQI values were close to 'good' threshold; and, TSI revealed 'good to fair' quality of the wetland water during the flood phases. Also, the good water quality during the late flood phase with fewer vegetation assemblages can be attributed to the possible role of wetland basin morphometry towards water purification. During late flood phase, increased water detention time as a consequence of less water discharge rate might have also facilitated sedimentation process within the wetland. Thus, the present study highlights the regulating service attribute of tropical floodplain wetlands in water purification through its biophysical components like basin morphometry and vegetation characteristics during the flood phase by increasing water detention time which facilitates sedimentation & nutrient uptake by the wetland vegetation and thus, enhances the downstream water quality. However, it is to mention that morphometric- and vegetation characteristics of floodplain wetlands are influenced by the hydrology of adjacent systems viz., rivers, streams etc. Hence, any hydrological changes in those systems would subsequently affect the biological- & physical integrity of the connected wetlands, ultimately affecting its water purification service. In this regard, the findings of the study would be helpful in acknowledging the role of basin morphometry and vegetation characteristics for adopting better management options for maintaining the natural integrity of tropical wetlands towards the perpetual flow of significant ecosystem services.

BIO: Priyanka Sarkar is interested in understanding how various ecological aspects of floodplain wetlands in the tropics are related to socio-economic dimensions, livelihood sustenance, and human well-being. For her doctoral research, she is studying the role of various bio-physical processes of natural wetlands in improving the surface water quality by nutrient removal.

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C.P. 16

CONTRIBUTED PAPERS 16

MICROBIAL FUEL CELLS

Arantxa Aguirre-Sierra

NOVEL TECHNIQUE FOR THE HYDRAULIC CHARACTERIZATION OF HORIZONTAL SUBSURFACE-FLOW CONSTRUCTED WETLANDS BASED ON THE ELECTRICAL SIGNAL PROVIDED BY MICROBIAL FUEL CELLS.

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Hydraulic characterization of horizontal-flow treatment wetlands (HF TWs) is essential during both the start-up and subsequent operation of the system. Initial hydraulic characterization will allow us to detect defects during the construction phase of the system; whereas subsequent hydraulic characterization will reveal preferential water flows or dead zones that may end up compromising the treatment efficiency of the system. Therefore, hydraulic characterization of HF TWs is of key importance in order to optimize plant management and operation. HF TW are generally hydraulically characterized by performing a tracer test (TT). A TT is based on a pulse injection of a non-reactive compound (i.e common salt) that can be easily monitored from influent to effluent of the treatment bed. Although the results of a TT will provide insight of the hydraulic functioning of the system (i.e dead zones or preferential water flows) the exact zone of hydraulic malfunctioning is generally unknown. Furthermore, because of the time consuming nature of a TT, this cannot be performed on a regular basis (continuous monitoring is not possible). In this work we have validated the concept of using microbial fuel cells (MFC) as hydraulic sensors within the treatment bed of a HF TW pilot plant. The rationale behind the work is that the magnitude of the signal produced by a MFC is dependent on the amount of substrate available for the MFC, which, in turn, depends on the amount of flow circulating around/across the MFC. In order to address the objective of the present work a pilot plant of 0.2 m^2 and 0.25 m depth fed with pre-settled domestic wastewater was equipped with 27 MFCs. The average flow-rate of the pilot plant was 5.3 L/day and it was operated at a design HRT of 3.6 days. The pilot plant was fed aboveground centrally at the influent and the effluent was drained from the bottom center of the opposite side. The MFCs used for the experiment were monitored for ca. 3 months and provided a continuous bioelectric 3D map of the treatment bed. The power produced by the 27 MFCs was converted into flow rate by applying a certain percentage of overall power production to the HF TW flow rate, giving a continuous 3D map of wetland flow distribution. Results of the flow rate distribution within the treatment bed described an eye-like pattern following the diagonal described between influent and effluent points. A hydraulic model of the HF TW was built using AQUASIM software, with the assumption that the treatment bed behaved as a set of 27 compartments (one compartment per MFC considered), and a theoretical TT was simulated. The results of the TT simulation provided a theoretical HRT of 3.3 days, which matches the nominal hydraulic retention time. Results here reported need to be validated with a real TT test, but open a new scenario for a continuous-like hydraulic characterization of HF TW treatment bed that may be of use for the optimization of plant management and modelling.

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THE WASTEWATER TREATMENT CONTRIBUTION OF MICROBIAL FUEL CELL AND CONSTRUCTED WETLAND IN MICROBIAL FUEL CELL-CONSTRUCTED WETLAND SYSTEM (MFC-CW)

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MFC-CW system is a kind of bio-energy generator while treating wastewater. There are serious of treatment mechanisms within MFC-CW such as physical and chemical absorption, redox reactions, biological digestion, and plant uptake etc. Generally, each of these mechanisms comes from either CW or MFC. Studies reported that wastewater treatment efficiency of CW can be enhanced by integrating with MFC. In order to better understand and promote the performance of MFC-CW, it is interesting and important to distinguish how much the enhancement can be achieved when integrating MFC into the CW. This is the special focus of the current study.

In this study, three identical up-flow MFC-CWs were built and operated under same working conditions. Each MFC-CW has two anodes which embedded in different depths of CW. There was only one cathode situated on the top of the MFC-CW. The first MFC-CW was operated with open circuit MFC which was regarded as CW only. MFC circuit was closed in the second and third MFC-CW. Therefore these two MFC-CWs had dual treatment pathways of CW and MFC, respectively. The only difference between the last two MFC-CWs was that only one influent point at the bottom of the second system and two influent points which just under each anode in the third system. All of MFC-CWs were fed by different concentrations of COD (100 mg/L, 300 mg/L, 500 mg/L, and 1000 mg/L). After long term trials, the results showed that in MFC-CW system, 36.74% of COD was removed by MFC which was the highest MFC contribution (Fig. 1(A)). As the strength of influent was increased, treatment contribution of MFC was decreased. Therefore the NER (net energy recovery) of MFC was getting lower as well (Fig. 1(B)). In terms of feed mode, more energy was recovered from wastewater by two inlets MFC-CW. It was because feed points were closer to anodes in two inlets MFC-CW, so more organic matters were available in anodes for power output.

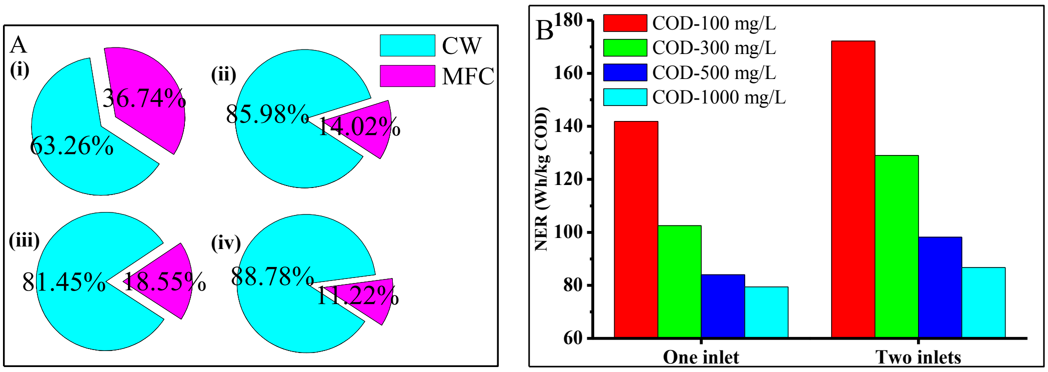

Fig. 1. The percentages of COD removal achieved by CW and MFC under different strength wastewater (i: COD-100mg/L; ii: COD-300mg/L; iii: COD-500mg/L; iv: COD-1000mg/L) influent (A) and NER of different feed mode MFC-CWs (B).

BIO: Ms. Yi Mao is a PhD student in School of Civil Engineering, University College Dublin. She is working on the integrated system of Microbial Fuel Cell and Constructed Wetland, and the Electrocoagulation technique.

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EFFECT OF LOCAL WATER CIRCULATION IN THE CATHODE CHAMBER ON THE PERFORMANCE OF MICROBIAL FUEL CELL-CONSTRUCTED WETLAND

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Microbial fuel cell-constructed wetland integrating system (MFC-CW) is an emerging wastewater treatment technology. Because the bio-electrochemical effect in MFC promotes pollutants removal, wastewater treatment efficiency of MFC-CW is higher than conventional CW. In terms of the configuration of MFC-CW, keeping cathode of MFC in aerobic condition is the key factor for obtaining an effective MFC in CW. Biofilm overgrowth on cathode (called biofilm foul) can inhibit oxygen diffusion to the cathode and make cathode in anaerobic environment. With low energy consumption, circulation of effluent in the cathode chamber was a practical for maintaining aerobic condition in the cathode chamber in MFC-CW. However, its role seemed not explored in detail in MFC-CW studies. This forms the main focus of the current investigation.

In this study, a lab-scale up flow MFC-CW with two anodes and one cathode was built in order to investigate a novel water circulation mode in cathode chamber. Three water flow circulation modes in the cathode chamber of MFC-CW were applied. In the first circulation mode, water in the cathode chamber was discharged intermittently by siphon effect meanwhile water was pumped back to the cathode chamber. In the second and third modes, water was circulating while keeping the water level at the bottom (low level) and top (high level) of cathode, respectively. The results showed in Fig. 1, that potentials of cathode were similar in all circulation modes. Voltage outputs of MFC-CW were determined by anode potentials in all circulation modes. The highest voltage outputs (580 mV of cathode vs top anode, 414 mV of cathode vs bottom anode) were reached in siphon circulation mode. Compare with the other two circulation modes, water body was moving intermittently under siphon circulation mode. Therefore dissolved oxygen in cathode chamber was consumed by cathode reaction rather than diffused to anode. Thus, siphon circulation mode was recommended for achieving high voltage outputs in MFC-CW.

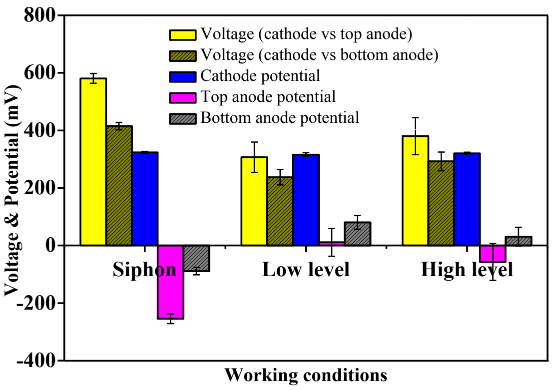

Fig. 1. Voltage outputs and potentials of electrodes in different circulation modes

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EXPLORATION OF HIGHER TOTAL NITROGEN REMOVAL IN HYBRID CONSTRUCTED WETLAND INCORPORATED WITH MICROBIAL FUEL CELL

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Nitrogenous pollutants are the critical pollutants to be treated in the field of wastewater treatment. Ammonia is one of the primary forms of nitrogen pollutant which need oxidation for its treatment from wastewater. Most of the time ammonium is treated in energy intensive aerobic process. Aerobic processes of ammonium treatment are costly and thus, there is urgent need of developing a low-cost process for ammonium treatment. In traditional constructed wetland (CW), an appreciable amount of ammonium removal/oxidation is always a challenge but reduction of oxidized forms of nitrogen (like nitrite and nitrate) to nitrogen gas is found to be satisfactory. Overall, complete removal of nitrogen is rare in CW, because of its designing and nature.

In recent years, some of the works are being initiated in the direction of electrode dependent anaerobic ammonium oxidation. This work also explores the possibility of total nitrogen removal using a set of hybrid CW integrated with microbial fuel cell (MFC) for complete removal of nitrogen. MFC also uses electrodes. The experiment is designed which consist of a horizontal CW integrated with MFC (H-CW-MFC) followed by vertical up-flow CW integrated with MFC (V-CW-MFC). Preliminary experiments were performed with a fixed hydraulic retention time (HRT) of 24 hr and 40 mg/l of NH_4Cl as an ammonium nitrogen source in designed wastewater. Preliminary results are encouraging where total nitrogen removal in hybrid CW-MFC system was found to be nearly 70% as compared to 45% in normal traditional CW. The maximum voltage achieved in CW-MFC was found to be 80 mv in V-CW-MFC and 75 mv in H-CW-MFC. Further work is in progress. Early results indicate the possibility of development an integrated hybrid CW-MFC system for higher total nitrogen removal from wastewater.

BIO: Pratiksha is a Ph.D. candidate in University of Tasmania and having 4 years experience in the field of Constructed Wetland (CW) - Bioelectrochemical technologies (BETs). She is having wide experience on the incorporation of BETs into CWs and published many research papers and book chapters.

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C.P. 17

CONTRIBUTED PAPERS 17

VERTICAL FLOW CWS

Carlos A. Arias

PERFORMANCE OF DIFFERENT SUBSTRATES IN VERTICAL SUBSURFACE FLOW CONSTRUCTED WETLANDS

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Objectives

The objective of this study was to: 1) analyze the treatment efficiency of four vertical constructed wetlands (CW), a laboratory-scale, filled with different substrates, in term of *Escherichia coli* reduction and organic matter (COD) removal and to 2) investigate flow distribution within the different types of gravel.

Methods

The experimental plant consists of eight columns, 90 cm in height and 20 cm in diameter, functioning in parallel and filled with different materials combined each other: volcanic sand, volcanic gravel, organoclays, PET flakes and biochar (i.e., the same medium configuration was used in two columns to have a replication). Volcanic sand (diameter of 0-3 mm) was used at as top layer, coarse volcanic gravel (diameter of 12-15 mm) was used as drainage layer while different types of substrate were used as main layer. In particular, V1A and V1B were filled with volcanic sand, V2A and V2B with organoclays and volcanic sand, V3A and V3B with PET flakes and volcanic sand, V4A and V4B with biochar and volcanic sand.

The columns were intermittently loaded with synthetic wastewater (six loadings per day). Wastewater flowed from the top of the columns and was discharged from the bottom through a tap. Four hydraulic loading rates (HLR) of 30, 90, 160 e 240 mm d^{-1} were applied to the CW system, each one for a period of about 21 days. An increasing organic loading rate (OLR) of 10,7, 17,4 e 28,8 g COD m^{-2} d^{-1} was applied while *Escherichia coli* concentration was 10^7 UFC/100 mL. The removal efficiencies for COD and the log reduction for *Escherichia* coli were calculated as mean value of two columns with the same gravel configuration. The distribution of flow within the gravel substrate was investigated by means of the geophysical electrical resistivity tomography (ERT).

Results and Conclusion

The role of granular substrates in the removal of *Escherichia coli* and organic matter (COD) was evaluated in four vertical subsurface constructed wetland plant, a laboratory-scale, each one containing a different type of granular medium. *Escherichia coli* reduction ranged between 3 and 9 log10 CFU/100mL, with a general reduction of removal efficiency as the HLR increased. The lowest *Escherichia coli* content (less than 1 CFU/100mL) was obtained at the outlet of the beds filled with biochar, also under high HLR of 160 mm d^{-1}, meeting both the Italian standard (*E.coli* <50 CFU 100 mL-1) and the limit (<10 CFU 100 mL^{-1}) proposed by EU for agricultural reuse of reclaimed water in class A (all food crops, including root crops consumed raw). The COD removal was high and it raged between 89,9% in beds filled with PET flakes and 98,9% in the beds filled with biochar. The electrical resistivity tomography (ERT) technique was useful to characterized the resistive properties of the different substrate.

BIO: Dr. Marzo has more than 10 years of experience in planning, designing and monitoring constructed wetlands for wastewater treatment. Her scientific activity is mainly focused on hydraulic proprieties of constructed wetlands, the use of constructed wetland for pollution control and for wastewater reuse in agriculture. She was involved to prepare and carry out many national and international research projects.

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COMBINATION OF VFCW AND SOLAR DRIVEN ELECTRO-CHLORINATION FOR SAFE WASTEWATER REUSE IN SPAIN

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This paper presents the findings of a four-month trial evaluating the disinfection performance of a combination of a Vertical Flow Constructed Wetland (VFCW) and an electro-chlorination (ECl2) sys-tem designed to polish treated wastewater (WW) for its reuse. Both systems were installed on the Sewage Treatment Plant (STP) El Toyo in Almeria, Spain. Throughout the trail the system combina-tion was able to produce pathogen free water, meeting the highest Spanish standard on WW reuse.
The trial was conducted within the EU H2020 INCOVER project, which aims to develop and promote technologies for a resource recovery-based treatment of WW. The main feature of the here installed ECl2 system - originally designed for drinking water disinfection - is the production of chlorine from the chloride ion concentration, naturally present in the treated WW. The disinfection performance of the ECl2 system largely depends on the STP effluent quality and only slight changes affect the sys-tems disinfection capacity. In order to assure constant operating conditions a VFCW, with a surface area of 50 m² and a design capacity of up to 4 m³/d was installed prior to the ECl2 system. The VFCW was made up of a 15 cm drainage layer (8-15 mm) a 62 cm deep filter sand layer (0-4 mm) and was planted with Arundo Donax. The chlorine was continuously produced by a Dimension Stable Anode (DSA) at a current densitiy of 16mA/cm² at a constant current of 4.8 A. With the high natural chloride concentration in the STP effluent of 780 ± 235 mg/L a chlorine stock solution of 301 ± 108 mg/L was achieved and stored for dosing. The VFCW effluent was pumped through media filter (AFM®) for additional turbidity removal and the chlorine solution was dosed at an effluentVFCW/Cl2Stock-ratio of 25 directly behind the filter. The disinfected water was then stored in a 5 m³ tank. The complete process was powered by solar produced electricity using a 600 Wp PV generator and 2x120 Ah battery set-ting. Turbidity and ammonium values were measured every two days before and after the VFCW as well as after the AFM and in the storage tank. At the same points samples for total coliform, E.coli, and COD were taken weekly. Free Available Chlorine (FAC) was measured twice per week after dos-ing and in the storage tank. An excerpt of the results is presented in Figure 1a-c.

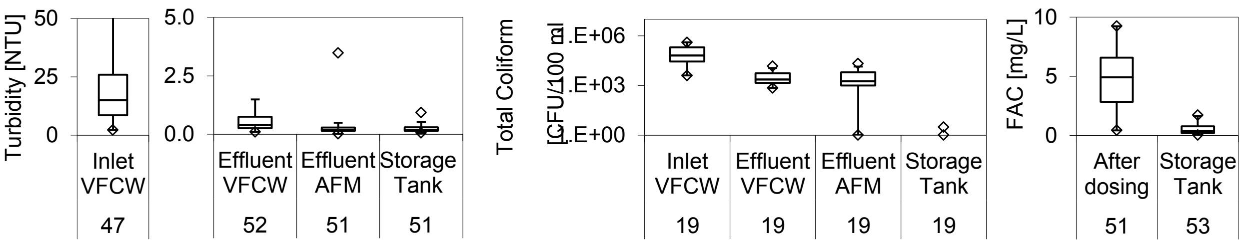

Figure 1a-c: Filtration and disinfection performance of the presented VFCW+ECl2 water treatment system

The trial has shown that the VFCW + ECl2 combination is capable in providing constantly pathogen free water allowing its reuse even in residential applications and for groundwater recharge following e.g. Spanish (Real Decreto 1620/2007), as proposed by EU (COM(2018) 337 final) and USEPA (US EPA Guidelines for Water Reuse, 2012) standards. The energy requirements for the disinfection sum up to 0.2 kWh/m³ and can be completely covered by PV.

Bio: Mr. Philipp Otter, M.Sc. in Environ. Eng. He PhD student at TU Dresden working on decentralized water treatment and shareholder of AUTARCON GmbH. Philipp has conducted pilot plant research for adapted drinking water and WW treatment technologies in India, Nepal, Tanzania, Germany and Brazil.

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STEP FEEDING RATIOS AFFECT NITROGEN REMOVING COMMUNITIES IN A MULTI-STAGE VERTICAL FLOW CONSTRUCTED WETLAND

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Step feeding (SF) with wastewater is a viable approach of carbon source addition into constructed wetland (CW). Although, the SF ratio is proposed to be crucial to nitrogen removal efficiencies by CW due to its influence on the nitrogen transformation-related microbial communities. To enhance the nitrogen removal, four SF ratios (0%, 10%, 20% and 30%) were fed into the second stage of the multi-stage vertical flow constructed wetlands (MS-VFCWs) treating domestic wastewater at a total hydraulic load of 100 mm d^{-1}. The main environmental factors (Redox potential (ORP), pH, COD, total nitrogen (TN), ammonia nitrogen (NH_4–N), Nitrate nitrogen (NO_3–N), Nitrite nitrogen (NO_2–N) and C: N) along the flow path were monitored and calculated. We also studied the activity and abundance of nitrogen transforming bacteria using short-time incubation and real-time qPCR method. Features of wetland microbiota were analyzed by 16s rRNA gene sequencing method. Redundancy analysis (RDA) was used to examine the main environmental factors affecting both the nitrogen functional genes and the relative abundance of bacteria.

The differences in TN removal among the four SF ratios were significant ($p<0.05$), with the highest TN removal (61.7%±4.5%) at the SF ratio of 20%. The same trend was observed for the nitrification and denitrification turnover rates. The genomic material of Ammonia-oxidizing archaea (AOA) was detected at all points in the CWs especially at the third stage with a copy number between $9.4\times10^3$and 1.4×10^5 copy number g^{-1} sample, outnumbered ammonia-oxidizing bacteria (AOB) by a ratio of 2.5 to 20.1, it suggested that AOA was a major contributor to the ammonium consumption processes. The system at the SF ratio of 20% had the lowest NO_3–N accumulation (4.21±0.77mg l^{-1}) and the highest narG / nxrA ratio (2.3). RDA indicated pH and C: N had a strong influence on nitrogen functional genes ($p < 0.05$). AOA amoA abundance responded positively to pH while negatively to NH_4–N. The increasing ratios of C: N was related to a shift in the composition of denitrifiers towards strains containing nirS gene. The results of 16s rRNA gene sequencing indicated that Proteobacteria was the dominant bacteria in the four systems at the phylum level. Proteobacteria contains nearly all of the nitrifying bacteria and most denitrifying bacteria. With the increase of SF ratios, the relative proportion of Proteobacteria increased in the second stage. At the genus level, dominant denitrifer were related to *Nitrospira*, *Nitrosomonas*, *Nitrosospira*, *Denitratisoma* partial nitrification species in the first and second stages, these revealed that the partial nitrification process was the dominant nitrogen removal pathway in the first and second stages. The main denitrifying bacteria were *Thiobacillus*, *Denitratisoma*, *Arcobacter*, *Thauera*, *Rhodobacter*, *Hydrogenophaga*, *Pseudomonas*. RDA indicated nitrifying bacteria responded negatively to C: N and denitrifying bacteria responded positively to NO_3–N ($p < 0.05$). The relative proportion of denitrifying bacteria in the four systems were higher than those of nitrifying bacteria. Nitrification might be the key factor restricting the nitrogen removal efficiency of the system. Our study indicated SF ratio of 20% could be recommended in application of the MS-VFCWs to achieve sound treatment performance. Analysis of wetland microbiota indicated the presence of AOA and partial denitrification pathways in the MS-VFCWs. SF ratios influenced wetland microbial communities mainly through different C: N ratio inputs and substrate concentration.

BIO: Ying Wang is a PHD candidate in environmental engineering at the Tongji University. Her research focuses on the microorganism in the constructed wetland

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CHALLENGES IN NITROGEN REMOVAL IN FRENCH VERTICAL-FLOW CONSTRUCTED WETLANDS

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Constructed wetlands have gained importance in France and other countries over the last 2 decades because of to their efficiency, reliability and cost-effectiveness. More than 4000 VCFW treatment plants are in operation over the country today and significant research endeavors have consolidated the technology as a standard solution for small communities. The so-called French VFCWs are fed with unsettled wastewaters and comprise two stages of vertical flow filters. They offer high performance levels but increasingly stringent environmental regulations are still pushing research & development actions to further increase N and P removals.

Nitrification is very efficient in VFCWs due to the well aerated conditions they provide. The good availability of inorganic carbon sources, which are formed by the mineralization of organic matter, is also favorable to the autotrophic bacterial process of nitrification. In French VFCWs however, the growth of the sludge layer at the surface of the first filter may retain the major part of the organic load. The availability of organic carbon sources deeper in the filters may then become a limiting factor to the heterotrophic bacterial process of denitrification (2, 3). The other key factors include pH and dissolved oxygen concentration. The influence of these 3 factors on denitrification is considered as equivalent. In order to improve nitrogen removal, the French company SCIRPE has patented AZOE® technology associating a trickling filter with 2 stages of vertical flow filters In this process, phosphorus is precipitated by iron chloride addition, and nitrogen is treated by promoting the alternance of unsaturated (oxic) conditions at the top of the filters and submerged anoxic to anaerobic conditions in the bottom (4). Although this treatment configuration shows very good performances, the trickling filter influence is not sufficiently optimized. Ours goals are (i) to better control the complex nitrogen removal process (ii) to optimize the treatment at each step of the specific treatment chain AZOE®.

Recent monitoring campaigns on French VFCW plants in operation have shown good and stable efficiencies in carbon and phosphorus removal and in nitrification, whereas denitrification rates were more variable. Denitrification was even sometimes inexistent in the second stage. This study focuses on the influence and interdependence of each stage of the treatment line, namely screening, trickling filter (when present), 1st and 2nd stages, especially with regard to nitrogen removal. Such a feedback is the main step to gain control on nitrogen removal and to identify the major parameters of influence on denitrification. Influence of carbon availability for denitrification from sludge retention and leach out will notably be discussed.

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BIO: K. Maciejewski is a PhD student in DEEP laboratory (Wastes Water Environment Pollutions) in INSA Lyon (France). He is working with the French company SCIRPE which designs constructed wetland. The research topic is the optimization of nitrogen removal performances on classical French and AZOE® system.

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EFFECT OF ORGANIC AND HYDRAULIC LOADING INCREASE ON TREATMENT PERFORMANCE OF FRENCH SYSTEM CONSTRUCTED WETLANDS

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Vertical flow constructed wetlands (VFCW) have been widely used in France for the treatment of domestic wastewater since the early eighties. The process has come to be known as the "French system". It uses two vertical flow wetlands in series, the first has a surface area that ranges between 1.2 and 1.5 m^2/PE and the second one between 0.8 and 1.0 m^2/PE. The hydraulic load (HL) used for design and sizing of the first stage is 0.37 m/d.

A recent survey showed that among 119 systems in operation in South-West of France, more than 75% received half or less of their nominal hydraulic and organic loading capacity, 0.37 m/d and 0.3 kg $COD \cdot m^{-2} \cdot d^{-1}$ respectively for the first stage of treatment. Since the performances observed for TSS and COD always exceeded the French Standards (50% for TSS and 60% for COD), this led us to questioning the maximal organic loading that can be applied to the French system while maintaining acceptable removal performance.

In this context, 8 VFCW mesocosms (1 m^2 each) were installed in a full scale French System in operation for more than 10 years in South West France. Each pilot was filled using material (roots, gravel 4-8 mm + accumulated sludge) taken from the existing first stage of the full scale French System. The accumulated sludge was added to reproduce the characteristics of a mature system. Rhizomes of the reeds (*Phragmites australis)* in the full scale system were also planted in each mesocosm.

VFCW mesocosms were fed in duplicates during a year with raw domestic wastewater according to 4 increasing loading rates levels: (1) 100%, (2) 133%, (3) 167% and (4) 200% of the nominal hydraulic and organic loading for a first stage of treatment. This means hydraulic and organic loadings going from 0.37 m/d and 0.3 kg $COD.m^{-2}.d^{-1}$ up to 0.75 m/d and 0.6 kg $COD.m^{-2}.d^{-1}$. Inlet and outlet 24 hour composite samples were taken every two weeks for COD, TSS, TN, NH_4^+-N and NO_3^-- N analysis.

After 6 months of operation results shows that mesocosms fed with levels 1-3 show slightly higher mean removal rates compared to level 4: 75% for TSS, 80% for COD and 65% for TKN compared to 70%, 70% and 60% respectively. However, this difference is not statistically significant and all mean removal rates are higher than the legal requirements. Plants had a healthy and uniform development in all the mesocosms, comparable to that of the full scale system.

Long-term impact of organic loading increase will also be studied regarding pilot lifespan and clogging issues. Tracing test will be conducted twice for each bed, in order to assess the differences in hydraulic behavior of each mesocosm in respect to their inlet loading and its evolution. It is hypothesized that biofilm development will increase with each increasing level of loading thus affecting removal performance.

BIO: Sebastian Rodriguez is an industrial PhD candidate working for the French company SADE CGTH on a joint project with IMT Atlantique for the optimisation of constructed wetlands for the treatment of domestic wastewater. He holds a chemical engineering degree from the Universidad de Los Andes in Bogota (Colombia) and a master's degree in environmental engineering from IMT Atlantique in Nantes (France).

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PERFORMANCE EVALUATION OF PILOT-SCALE SATURATED VERTICAL UPFLOW CONSTRUCTED WETLAND: EFFECTS OF DIFFERENT OPERATIONAL CONDITIONS

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This study evaluated the influence of plants, namely *Cyperus Altenifolius* and *Iris pseudacorus*, aeration mode, namely continuous aeration (CA) and intermittent aeration (IA), aeration time, namely 0, 1, 2, 4, 6 and 8 hrs; and different COD/TN ratio on organics, nitrogen (N) and phosphorus (P) removal in pilot-scale Saturated Vertical Upflow Constructed Wetlands (SVU-CW). The preferential contaminant removal in CA and IA was NH_4^+-N > COD > TN > TP and COD > TP > NH_4^+-N >T N, respectively. Removal efficiencies in both SVU-CWs under CA mode for COD, NH_4^+-N, TN and TP were about 93, 100, 86 and 84%, respectively at low COD/TN ratio (2.6- 2.7). In the IA mode, the maximum removal of pollutants was achieved when the aeration time was 8hrs at COD/TN ratio of 3.56. SUV CWs with *I. pseudacorus* showed better performance than that with *C. altenifolious*, except for COD and TN in CA and IA mode, respectively. In general, COD/TN ratio had a significant effect when the system was operated in CA mode, contrarily to IA mode, where aeration time influenced the pollutant removal. Our results suggested that continuously aerated SUV-CWs with *I. pseudacorus* could be used to treat domestic wastewater for small communities efficiently.

<u>BIO</u>: Jixia Yan is a postgraduate student working in Prof. Zhai's group. Her research focuses on the application of constructed wetlands in the wastewater treatment processes to remove nutrients as well as emerging contaminants.

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C.P. 18

CONTRIBUTED PAPERS 18

EAB-CW TECHNOLOGY

Yaqian Zhao

WATER LEVEL IN DETERMINING CATHODE POTENTIAL IN CONSTRUCTED WETLAND-MICROBIAL FUEL CELLS

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Bioelectricity production is always restricted by the limited cathode performance in integrated constructed wetland-microbial fuel cells (CW-MFCs) due to limited supplier and reaction rate of oxygen at the cathode. Currently, the cathodes are generally located at water-air interface to provide an oxygen-rich environment in CW-MFCs with buried single-layer electron collector. However, the cathode performance is still poor and result in a low bioelectricity production.

Based on our long time trial of failure to achieve a high cathode performance, it has been found that the distance between electron collector and water level significantly impacts on cathode performance in CW-MFCs. By 27th Jan, 2019, there are 36 articles in the literature by searching the topic of "constructed wetland-microbial fuel cells (CW-MFC)" from "web of science". Only three studies stated the importance of water level variation within the CW-MFCs.

In our study, the electrode performance and power density were evaluated in a vertical up-flow CW-MFC when the electron collector of the cathode was at the water-air interface and above the water level, respectively. Results showed that the average cathode potential increased from -126.3 mV (water-air interface) to 143.2 mV (above water level), while redox potential of the two anodes were undisturbed. This brings a great advantage in terms of increasing the bioelectricity generation compared to other approaches like recirculation and aeration, which could simultaneously interrupt and improve the anode redox potential. Furthermore, maximum power density was increased from 17 mW/m^2 to 113 mW/m^2 when the electron collector was changed from the water-air interface to 1.5 cm above the water level. Our work concluded that by locating electron collector of cathode above the water level and keeping it wet, the bioelectricity production of CW-MFCs can be significantly enhanced.

BIO: Dr. Yan Yang is a Postdoctoral Research fellow in School of Civil Engineering at University College Dublin. She has been working on improving constructed wetland-microbial fuel cells (e.g., plants, material and configuration of cathode, water level, etc.) for wastewater treatment and bioelectricity production. Her aim is to apply this green technology in field scale.

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METHODOLOGICAL PROPOSAL FOR THE OPTIMAL LOCATION OF NEW METLANDS® CONSTRUCTION

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The water crisis has created an imperative to improve the technologies related to reclaiming water. From this need has arisen the METlands®, an integration of microbial electrochemical technologies (MET) with the constructed wetland. METlands®, bioelectrogenic constructed wetlands, are an innovative environmentally sustainable water treatment technology with low associated operating costs. Having been tested at a pilot scale, full scale implementation is desired.

In order to obtain the optimal locations for construction, a methodology has been proposed base on Multi Criteria Evaluation (MCE) techniques applied to Geographic Information Systems (GIS). To define the optimal geographic location, criteria were evaluated and weighted in the context of Saaty's analytical hierarchies. These criteria were divided into two groups environmental and socioeconomic. Finally, a Sensitivity Analysis (SA) was performed using the Sobol method, taking into account these factors and their associated weights for resources optimization.

The model was applied in two areas of Spain with different demographic distribution and climatic conditions. The application of the MCE-GIS process concludes that the most suitable sites for METlands® are located near residential areas and rivers. The SA determined what are the most influential factors in the final model. It was concluded that METlands® are a system whose implementation can be achieved across wide range of locations in the areas surveyed.

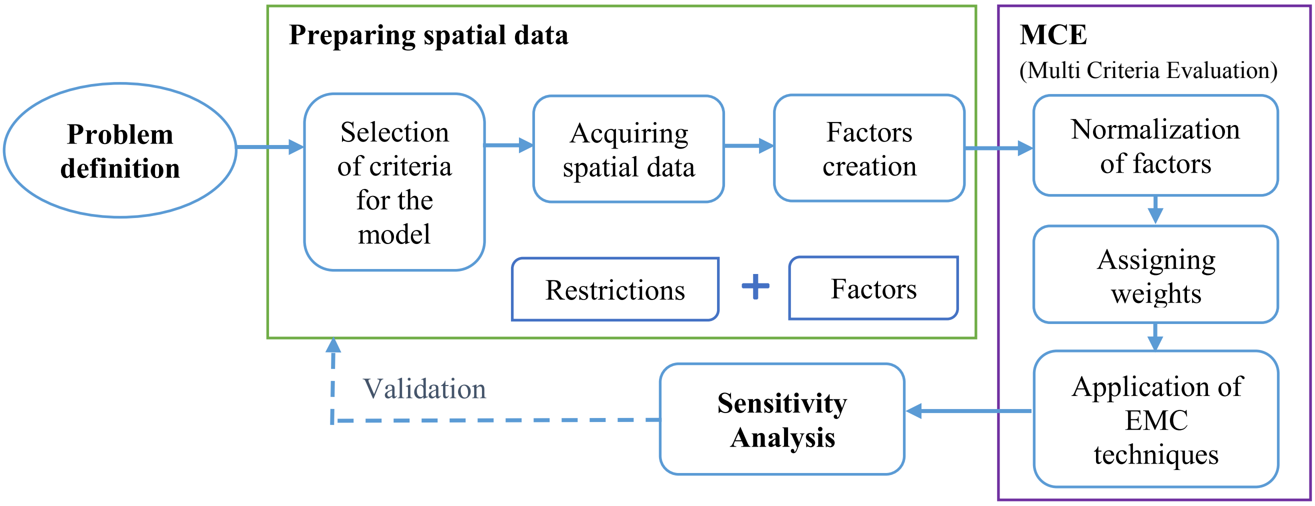

Figure 1: Scheme of MCE-GIS process for the optimal location of METlands® construction.

BIO: Lorena Peñacoba Antona is a predoctoral reseacher specialized in civil engineering, GIS and hydrology. Contracted by the company METfilter, she joined IMDEA Water as an associated researcher. She currently works on her doctoral thesis in the Bioelectrogenesis group. Specifically, she investigates the application of METlands® for the treatment of wastewater.

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TREATING WASTEWATER FROM SMALL COMMUNITIES WITH VERTICAL FLOW ELECTROCHEMICAL-ASSISTED WETLANDS (METLANDS®)

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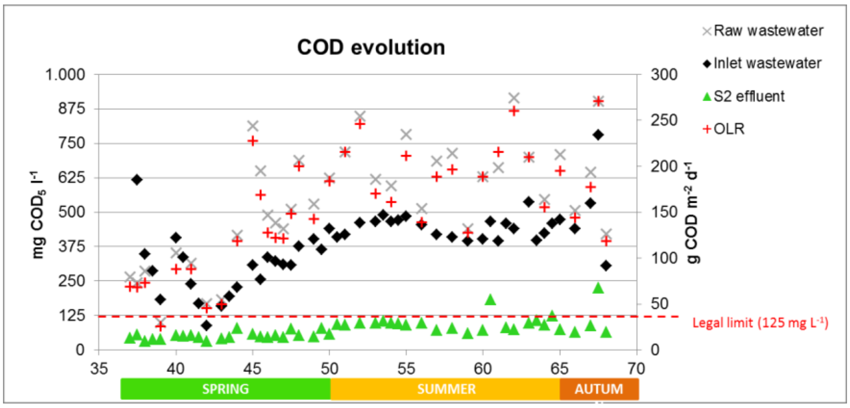
We present the results of a new full-scale hybrid device called METland®, coming from the integration of Microbial Electrochemical Technologies (MET) with constructed wetlands, which was assayed to treat urban wastewater from a small community. At METs, the electroactive bacteria use the electroconductive (EC) material to transfer the electrons generated in the organic compounds break-down, acting those materials as unlimited electron-acceptor. All those electrons are finally consumed by soluble electron acceptors present in the water. The mere presence of EC material has been proved to accelerate the biodegradation rate of bacteria by mediating the so-called Microbial Interspecies Electron Transfer.

The research was developed within the framework of the iMETland project (H2020), which purpose was to construct and validate a full-scale application of a low-cost, eco-friendly system to treat urban wastewater from small communities at zero-energy operation cost. The main goal of the project was to develop a METland to treat urban wastewater for 200 population equivalents. The iMETland project is indeed pioneering in using EC material for large-scale applications.

With that purpose, four METland® *units* with a surface area of 24 m^2/unit were constructed and different configurations were tested. The systems were tested at different flow rates and organic loading rates (OLR). Best results were achieved by one of the units that removed 88% of TSS, 94% of BOD_5, 83% of COD, 30% of TN and 75% of NH_4-N, at an OLR of 107 g BOD_5/m^2 d in average, without showing clogging symptoms after 70 weeks. This unit was no water saturated and no additional aeration was provided. The excellent performance allows operating the system at high organic load, which will translate into a reduction of the required area per population equivalent.



BIO: Dr. Aguirre-Sierra is a scientist expert in planning, designing, and implementing METland®. Her doctoral thesis was specially devoted to operate METland®

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NOVEL RHIZOCHANNEL APPARATUS FOR IN-VIVO RHIZOSPHERE MICROELECTRODE PROFILING OF WETLAND PLANT ROOTS

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The complex and interrelated biogeochemical processes that determine performance of treatment wetlands (TW), including organic carbon degradation, nitrification and denitrification, depend upon poorly quantified relationships between plant roots and associated biofilm communities. Wetland plants contribute not only oxygen, which diffuses from the aerenchyma tissue in their roots, but also exudate organic carbon including simple carbohydrates to the rhizosphere microbial community. Chief among the knowledge gaps inhibiting the understanding and optimization of TW systems is the potentially complicating influence of these plant root exudates on the attached microbial community structure and activity

In this research, a novel rhizochannel apparatus enables in-vivo micro-profiling of the rhizosphere to help elucidate the fundamental influence of root exudates on microbial activity associated with plant roots. The rhizochannel apparatus was developed to enable wetland plant roots to grow through predefined channels with zones that allow for the insertion of micro-scale sensors for oxygen, pH and other compounds. A prototype rhizochannel consisted of an opaque cartridge affixed to the side of existing wetland microcosms. Each cartridge contained five internal square channels. At three locations above the channel rubber stoppers were used to cover access points to the channel. This prototype rhizochannel provided a proof of concept, enabling repeatable spatial profiles of dissolved oxygen (DO) in an anoxic, BOD rich, fluid surrounding plant roots. Root from two species, *Carex utriculata* and *Schoenoplectus acutus* were investigated, and in both cases relatively higher levels of DO were measured at the surface and inside of the plant aerenchyma. A DO minimum was reached very near the root surface, which was likely due to microbial activity within the rhizosphere. Preliminary results and images of the system can be found in Figure 1.

A second version of the rhizochannel apparatus has been developed that includes an open topped glass flow-cell which addresses several limitations of the first prototype and permits microscopic imaging. The flow cell allows for fluid to flow past the plants roots during measurement, while the open top increases microelectrode access and allows for the addition of paraffin oil to act as a liquid oxygen barrier. Current investigations use a combination of DO and nitrous oxide micro-electrodes to enhance our understanding of the influence plant root exudates have on rhizosphere structure and function during denitrification.

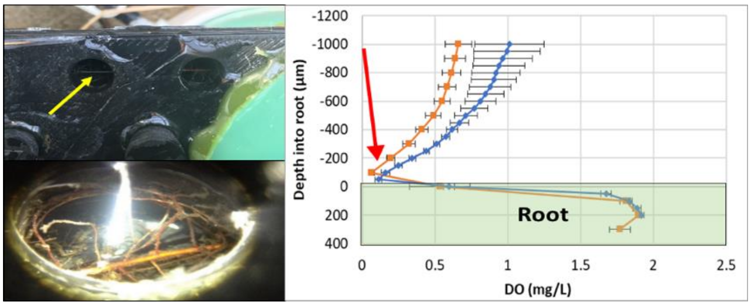

Figure 5. Upper left, Rhizochannel prototype top view, looking down into channel with plant root. Lower left, Prototype rhizochannel with microelectrode inserted. Right, Micro profile data for C. utriciulata (orange squares) and S. acutus (blue circles) illustrating low DO concenrations in the area immediately above the root surface.

BIO: Dr. Chris Allen is an Assistant Teaching Professor at Montana State University, a Senior Scientist with the WGM Group and a Principal at Constructed Wetland Designs. His research focuses on nutrient cycling in wetlands, plant microbe interactions and the application of treatment wetlands for nutrient removal in cold climates.

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HISTORICAL EVOLUTION OF BIOELECTROCHEMICALLY-ASSISTED CW: FROM LAB SCALE TO FULL SCALE OF METLAND CONCEPT

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The integration of bioelectrochemical concepts in the field of constructed wetlands took place during the last decade. The fascinating world of the so-called electroactive microorganisms, those able to interchange electron with exocellular electron acceptor was rapidly identified due to the high potential in treating wastewater. The different redox environment generated in constructed wetlands makes this configuration suitable for hosting electrically conductive material and generate electrical current from bacterial biodegradation of pollutants. Although harvesting energy was the very first goal, there was a number of electrochemical limitation that suggested to focus first on the main target of already existing CW: removing pollutants. So, in 2010 the group Bioe from IMDEA water (Spain) together with CENTA Foundation (Spain) accepted the challenge of replacing inert material like gravel by carbon-based electrically conductive material. Since then, 8 different R&D projects have accelerated the growth of this newborn to convert a concept into a final product already available in the market. The evolution of the field during this period will be presented. Successful assays, but also mistakes and failings will be critically presented in order to understand this emerging field that ended in the development of novel configuration so-called METland. The concept was born in southern Europe but now has been tested in Denmark by the expert guide of Aarhus University and the SME Kilian, in southamerica under the supervision of INTEMA (Argentina) and IMTA (Mexico). Furthermore, new configurations will be shortly implemented in India and China, through the startup METfilter funded by H2020 programme from EU.

INFLUENCE OF ELECTRICAL RESISTANCE ON TREATMENT EFFICIENCY IN A CONSTRUCTED WETLAND MICROBIAL FUEL CELL

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Constructed wetlands are used worldwide for wastewater treatment due to its low cost, simplicity in construction, of easy operation and environmentally friendly. In addition, microbial fuel cells (MFC) have been recently developed as a promising technology for improving wastewater treatment efficiency and/or for power generation. In these MFC, bacteria interact with electrodes to gain energy and produce an electrical current as consequence. The combination of both systems, constructed wetlands and microbial fuel cells, has been studied in the last decade, and are known as constructed wetland microbial fuel cell (CW–MFC) (Doherty et al., 2015).

The configuration generally includes an anode, near to the plant roots, a cathode, a material for separation of the two electrodes, and an external electrical circuit, conformed by an external electrical resistance. The electrical resistance influences the microbial community in electrodes, which influences the treatment and electrical performance of the system installed in a wetland.

The present work shows the study of using different values of electrical resistance connected to the circuit, under different periods. The study includes the effect of each resistance on the treatment and electrical performance of the reactors. The experimentation was divided into 10 stages established by the change of resistor every 20 days, changing the values of 20, 18, 15, 10, 5, 1 KΩ, 560, 100 and 10 Ω.
Five (5.30 L) CW-MFC were used in the experimentation with the vegetal species *Typha latifolia*. The reactors were packed with volcanic slag (tezontle) and the electrodes were made of graphite felt. The inoculum applied was anaerobic sludge from a wastewater treatment plant. The wetlands were fed continuously by means of a peristaltic pump with a flow of 1.3 mL/min and had a hydraulic residence time of 3 days. These systems were operated under natural temperature and light conditions, under shade. The synthetic wastewater simulated a domestic wastewater. The chemical oxygen demand, the ammonia nitrogen, nitrates, nitrites and sulfates concentrations were determined.

All parameters measured were affected by the electrical resistance. Statistical analysis showed a significant difference between the experimental stages established by the resistor change for each reactor, but not among reactors. The highest removals measured by COD, correspond to the period with the 18000 Ω resistance in all reactors. Besides, the highest values for power density correspond to reactor 3 on the 10000 Ω stage. The voltages output of the CW-MFC decreased when decreasing the resistor loads following the typical trend (Villaseñor et al., 2013).

The concentration of nitrates followed the same behavior than sulfates, in the first experimental stage, the concentration was high, and from day 46 in the experimental stage with external resistance of 20000 Ω, it decreased and was similar for all the reactors.

Doherty et al., 2015Water Research 85 (2015) 38-45.
Villaseñor et al., 2013, Water Research 47(2013) 6731-6738.

BIO: Dr. Salinas-Juárez is a researcher with more than 10 years of experience studying constructed wetland systems for wastewater treatment. She has the first study in Mexico about the implementation of bio-fuel cells in constructed wetlands. Now, she conducts investigation in the improvement of wetlands efficiency by means of bio-electrochemical systems.

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C.P. 19

CONTRIBUTED PAPERS 19

URBAN CWS

Fabio Massi

NATURE-BASED SOLUTIONS AND THE CHALLENGES IN URBAN WATER QUALITY

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In the past years we have seen new terminology emerging in the water sector. Is urban water something new? Or in reality just a rebranding of existing concepts (e.g. stormwater, wastewater)? The same questions can be raised for nature-based solutions. Are we talking about revolutionizing solutions?

Urban development and water management are undergoing fast changes to cope with the most recent challenges: water scarcity and climate changes. Climate change adaptation projects are demanding integrated solutions and breaking traditional barriers (e.g. drinking water vs. wastewater). A relevant element in this transition is the implementation of nature-based solutions (NBS) [1]. NBS can provide a range of ecosystem services beneficial for the urban biosphere such as regulation of micro-climates, flood prevention, water treatment, food provision and more, to enhance the resilience of our cities.

The EU agenda is launching new calls for NBS covering broader topics such Biodiversity and ecosystems, Natural resources management, Sustainable urban development, Climate change adaptation and mitigation, and Disaster risk reduction. Water (and urban water) plays a key and central role for these formulations aligning a diversity of increasingly popular disciplines such as Urban Forestry and Urban Greening, Urban Farming, Natural and Green infrastructures, Ecosystem restoration or Ecosystem-based management. Therefore, also wetlands (constructed wetlands and restored wetlands) have a key role. However, there is also a landscape of new solutions being developed that, although not being pure wetlands, share similar processes and services with our dear wetlands. Such systems, initially linked with urban drainage have diversified into a palette of terms and functions [2]. Putting classification aside, green roofs, green walls, SUDS, trenches, curb extensions, swales, ponds, wet and dry basins are examples of structures mainly employed for water drainage. Hydraulically, these solutions are normally well studied and planned, but little is known about their effect on water quality. If rain water in itself has reduced amounts of pollutants, stormwater from urban areas can present a diversity of pollutants (biocides from paints and construction materials; heavy metals from the most diverse sources; microplastics, rubber, PAHs, oil and greases linked with car traffic) besides the traditional organics, nutrients and pathogens. A recent life-cycle assessment study has pointed that “green infrastructure” is only environmentally sustainable if the best practices are applied in the end of the life of the solutions, strongly linked by the limited efficiency to remove pollutants [3].

I will overview some examples of NBS applications in the Danish urban landscape and engage on an open discussion identifying the new challenges for urban water quality and pollution control.

[1] Nature 541, 133–134, 2017, doi:10.1038/541133b
[2] Urban Water Journal 12(7), 525-542, 2015, doi:10.1080/1573062x.2014.916314
[3] Water Research 106, 394-404, 2016, 10.1016/j.watres.2016.10.024

BIO: Dr. Carvalho is a researcher in environmental chemistry and water treatment technology. He has more than 10 years of experience working with organic micropollutants in the environment and for the past years has been studying their treatment by constructed wetlands. His interests spread from pollutant metabolomics to water reuse.

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URBAN WETLANDS

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Cities of the future will become productive. This is already visible for energy, with plus-energy houses and increasing surface areas of solar collectors and PV-panels on houses. A similar development can be observed with urban agriculture, where food is grown right in the middle of cities, on roofs, on facades, along streets, in parks and free spaces between buildings. With all these plantations and for other purposes, where nature based solutions (NBS) are sought, water is needed. Thus next to energy and food clean water is the third resource, which can be made available from what is already present in the city.

Keeping water in cycles is a water issue of course but also leads also to dealing with other substances, not least with plant nutrients, which should kept in cycles, too. This may change our present water and above all sanitation systems to make keeping nutrients in efficient cycles. The necessity for a better water retention, local storage and of increased evapo-transpiration for cooling demands new water structures, less relying on piping networks and more on the interaction between soil or particular substrates and plants. Many of these new infrastructure elements come close to the characteristics and functioning of wetlands. They often have a particular treatment purpose to make a given water fit for an intended use, they ought to provide space for plant growth, store water and make available for the use they are planned for, from evapo-transpiration to domestic and industrial uses to replenishing natural water bodies.

This study collects the experience of several projects and examines what functions will be needed for sustainable urban water management, especially using low energy, resource efficient NBS. It discusses the ability of wetlands to perform many of the functions needed serving several purposes simultaneously. A few applications will be presented. Finally an outlook will be given, how wetlands will change urban water systems and make cities more climate resilient, flexible and sustainable.

BIO: Regelsberger is a senior scientist with more than 30 years of experience planning, designing, and implementing wetlands construction projects. He has extensive experience with wetlands in a circular economy aiming at closing loops of water and substances contained in the water.

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FRACTIONATION OF TRACE METALS FROM URBAN STORWATER CONSTRUCTED WETLAND: COMPARISON OF THREE WATERSHEDS IN FRANCE

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Trace metals are identified as the most toxic compounds for the fauna and flora [1]. Stormwater from urban catchments is identified as a source of these elements in the aquatic media. The level of contamination is variable and influenced by many factors such as initial rain water quality and atmospheric pollution, runoff on different surfaces…
Stormwater constructed wetlands (SCWs) are used worldwide to mitigate stormwater runoffs pollutants. They are defined as engineered systems designed and constructed to use natural processes to assist in treating wastewater or urban stormwater [2]. In SCWs, metals can be trapped in the filter media or released in water phase depending on hydrological, physical or chemical conditions variations. It has been shown that seasonal variability significantly impacts the physico-chemical conditions occurring in the wetland [3], which could lead to modifications of metals speciation and fractionation. Trace metal behavior is therefore a key issue i) to evaluate the long-term efficiency of these treatment facilities and ii) to improve SCW's sludge management practices.

The present study aimed at exploring the occurrence and fractionation of trace metals (Cd, Cu, Pb, Zn) in three SCWs at the downstream of three French urban catchments located respectively in Strasbourg (Catch. 2ha; filter 100m^2), Moulin-lès-Metz (Catch. 36.5ha; filter 2200 m^2), and Leuville-sur-Orge (Catch. 24ha; filter 2000m^2). The 3 systems are made up of sedimentation ponds followed by a vertical subsurface flow constructed wetland. Each site belongs to different hydroclimatic areas (modified oceanic, modified continental and semi-continental) and differ in sizing and conception (shape, feed pipes position…).

Trace metal accumulation was investigated during 2 years by determining the total concentrations in the system compartments (water, soil and plants) and different spatial filters zones (inlet area, intermediate area and poorly fed area). For soil, samples from different depths were analyzed (organic deposit, intermediate layer, mineral substrate). Then, trace metal fractionation was investigated in soil substrate using the Tessier fractionation protocol [4]. This allows to anticipate their behavior during potential physical and chemical condition changes and to improve SCWs management.
As results: i) most of the cadmium is in the reducible fraction while lead was mainly linked to the organic fraction; ii) copper was stored in stable condition in the oxidizable and residual fractions; and iii) zinc stability was strongly linked to physico-chemical conditions. Finally heavy metals behaviors in SCWs was discussed in term of mobility and release risks.

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BIO: Dr. Laurent is an assistant professor in the field of wastewater treatment at the University of Strasbourg. He is working mainly on water resources recovery facilities design and modeling, using pilot and full-scale data for models calibration and validation.

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PHYTOREMEDIATION STRATEGIES FOR BOTTOM SEDIMENTS CONTAMINATED WITH HEAVY METALS: UPTAKE AND ACCUMULATION IN PHRAGMITES AUSTRALIS ORIGINATING FROM NATURAL AND URBAN CATCHMENT

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Presence of heavy metals (HMs) in bottom sediments in streams flowing through the urban and industrial areas is of major environmental concern. Several studies indicate the bottom sediments analysis as an important tool of assessment of the urban environmental quality. HMs entering the aquatic ecosystem are associated with the fine-grained fraction of sediments and suspended solids particles due to their large surface areas and high sorption capacities. Throughout the hydrological cycle 99% of HMs are stored in sediments, that therefore are the major sinks and carriers for contaminants in aquatic environments. Far less than 1% of pollutants remain dissolved in water; the water quality is therefore a temporary reflection of environmental pollution. However, HMs may also directly pollute the raw water, resulting in sublethal effects or death in aquatic organisms and accumulate in crops through irrigation. Contaminants in rivers and streams sediments carried out with the water flow are of concern due to their potential impact on distant areas located away from the potential sources. The well recognized phytoremediation strategy to harvest HMs from contaminated water, sediments and soils has been proven as an effective and economical technique. Wetland macrophytes (i.e. *Phragmites australis*) have been reported to have a larger or comparable capacity for metal accumulation. However, the studies concerning the analysis of the possibility of a *Phragmites australis* originating from different environments – natural (uncontaminated) and urbanized (contaminated) for harvesting heavy metals are less known.

During the *Phragmites australis* growing season in 2018 (6 months) research on the possibility of using phytoremediation techniques on bottom sediments deposited in retention tanks located on 2 municipal streams (Gdansk, Poland) were carried out. Bottom sediments were collected from 3 retention tanks with the highest concentrations of HMs ranges from 189 to 803 mg Zn/kg d.w., from 23.9 to 128 mg Cu/kg d.w., from 97.9 to 667 mg Pb/kg d.w., from 0.301 to 0.552 mg Cd/kg d.w., from 6.92 to 23.4 mg Ni/kg d.w. and from 24.9 to 60.4 mg Cr/kg d.w. The test stand consisted of 3 columns with drainage in which contaminated sediments were placed and *Phragmites australis* seedling planted. The 20-30 cm seedlings were collected at the turn of April/ May from 2 different fields: (1) lake located in a natural area - referred as uncontaminated and (2) roadside ditch collecting surface runoff from high traffic road. The HMs concentrations in roots, stems and leaves were investigated. The HMs concentrations in *Phragmites australis* seedings from (1) environment were as follows: Zn-23.1, Cu-3.19, Pb-2.88, Cd-0.107, Ni-1.69 and Cr-6.83 [mg/kg d.w], while from (2) environment were definitely higher: Zn-691, Cu-66.2, Pb-4.43, Cd-0.833, Ni-12.4 and Cr-3.81 [mg/kg d.w]. The general conclusion is associated with the ability of *Phragmites australis* to uptake HMs during the investigation period. The seedlings originating from (1) accumulate at least a 2 to 10 times higher dose of HMs in the roots, while from (2) accumulation of HMs was not recorded; in the case of Zn, Cu and Cd the tendency was reversed - the content of these HMs in the roots after 2 months from the test stand starting have decreased 2-3 times. The leachates from the test stand were analyzed during the investigation period. It has been observed that metal leaching with time increases for Ni and Cr and decreases for Zn, Cu and Cd. At the end of the research period, HMs sequential extraction in tested sediments was carried out.

BIO: MSc. Nicole Nawrot, Environmental Engineering PhD Student at Gdansk University of Technology. Her doctoral dissertation is focused on bottom sediments at urban streams contaminated with heavy metals. She is interested in the phytoremediation technologies and they implementation in the urban agglomerations.

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10 YEARS EXPERIENCES ON NATURE-BASED SOLUTIONS FOR WASTEWATER TREATMENT IN THE ARID COUNTRIES OF PALESTINE AND TUNISIA.

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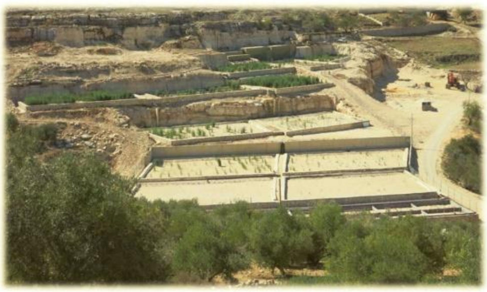
The aim is to present the experience gained in the next 10 years by the IRIDRA firm in designing nature-based solutions (NBSs) for wastewater treatment in arid climate. Particularly, it will be presented the wastewater treatment plants (WWTP) designed in two arid countries, i.e. Tunisia and Palestine, with a particular attention on the potential of treated wastewater reuse in line with circular economy concepts. The Tunisian case study regards the WWTP of Chorefech, realized in 2008 under the Zero-M project. The Chorefech WWTP is a constructed wetland (CW) three-stage system (horizontal subsurface flow – HF – plus vertical subsurface flow – VF – plus HF) serving about 500 inhabitants, and provides excellent secondary treatment of wastewater under variable operative conditions. Moreover, Chorefech CW WWTP reaches removal efficiencies in line for appropriate treated wastewater reuse. IRIDRA's Palestinian experience present three case studies, i.e. the CW WWTP for the villages of Hajja and Sarra, and the CWs for treatment and reuse of grey water from Bedouin villages. The Sarra CW WWTP was designed to serve 4300 PE with a two stage system (VF + HF) and to reuse treated wastewater for olive cultivation. The Hajja CW WWPT treats raw wastewater with a French Reed Bed (FRB) at first stage, followed by an HF system; the treatment capacity of the CW WWTP is 700 PE. Finally, grey water CW treatment systems (VF) were realized to serve Bedouin villages in Palestine, under an OXFAM action financed by EU (ECHO), FAO and Sardinia Region; the treated grey water is reused for irrigation of olive cultivation and fodder.

Chorefech (Tunisia) CW WWTP under construction in 2008

Hajja (Palestine) CW WWTP, 2013



Sarra (Palestine) CW WWTP, 2013

Bedouin Villages (Palestine) greened by NBSs, 2012

<u>BIO</u>: Fabio Masi is R&D Manager and Technical Director of IRIDRA Srl, since 1998 and Vice-President of Global Wetland Technology since 2012. His is PhD in Environmental Sciences and MSc in Environmental Chemistry (1991). He has 20 years of experience in sustainable water management and nature-based solutions for wastewater treatment.

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CONTRIBUTED PAPERS 20

SLUDGE

Joan García

COULD THE ADDITIONAL AIR SUPPLY ENHANCE THE DECOMOPSITION PROCESSES IN SLUDGE DRYIN REED BEDS?

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During the decomposition process occurring in sludge drying reed beds (SDRB) oxygen (O_2) availability in the process zone is an important factor allowing aerobic decomposition. The research was set up to observe the influence of additional O_2 that is introduced into the filter layer via active (A – diaphragm blower) and passive aeration (P – chimney with rotation cowl). Third observation is control (C – no additional aeration).

The experiment was initiated in October 2017. In the first year of operation around 40 kg DM/m^2 was applied to three replicated beds of each investigated treatment. To assess the gas and temperature regime, each bed is equipped with sensors for continuous measurements of O_2 and temperature in filter layer. Monthly sludge respiration (Rs) is also measured using Li 6400-09 soil chamber (Li-Cor Inc.). To investigate the contribution of plant and microbial respiration to the sludge CO_2 efflux, stable isotope analyses of respired CO_2 ($\delta^{13}C_{CO2}$) was conducted. For this purpose the C4 species miscantus (*Mischantus x giganteus*) plants instead of common reed (*Phragites australis*) have been planted. By inserting 30 decomposition bags (filled with dry sludge) into each bed sludge mineralization was examined.

The results reveal that both active and passive aeration influenced gas regime in the filter layer. After each loading of sludge, the O_2 constantly decreased. It is also evident that O_2 concentration increased faster in aerated and passively aerated beds compared to control. The higher observed concentration differences between aerated, passively aerated and control were 17.76, 11.83, and 2.17 % respectively.

The results of $\delta^{13}C$ values of respired CO_2 showed the contributions of both plant roots and microbial decomposition. Significant differences between treatments in the contribution of microbial decomposition were shown. The relative contribution of microbial respiration was significantly lower at control treatment. In active and passive aeration treatments microbial portion to CO_2 effluxes were estimated to be 42 and 41%, while at control microbial contribution comprised only 29%. This indicates that additional air supply to the filter layer via both active and passive aeration stimulates microbial production and could have some influence on sludge decomposition.

Until now two series of decomposition bags were analyzed. In the first series, collected after four months no significant differences in mass lost were noticed. In the second series significant differences in mass loss were observed. The highest mass lost were measured in passive aeration (42.1%), second were active aeration (41,4%) and 38.5% in control. There were no significant differences between active and passive aeration. We expect to measure even higher differences between aerated observations and control in series to come.

BIO: The main focus of dr. Plestenjak in the CW field is sludge treatment on SDRB. So far he was engaged in planning, developing and construction of several projects.

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SURFACE SLUDGE DEPOSITS LAYER: A KEY COMPONENT IN FRENCH VERTICAL FLOW CONSTRUCTED WETLANDS

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Vertical Flow Constructed Wetlands are widely used for the treatment of wastewaters from small communities all over the world. In the so-called French system, which is predominant in France, unsettled wastewater is percolated through two successive stages of filter-cells planted with reeds, inducing the formation of a surface sludge layer. This layer has received increasing attention in the recent years to better understand its role in the system. Although the growth of its depth over the years of operation induces potential risks of clogging, it has been shown that the sludge layer also largely contributes in the performance of the system, depending on its properties.

The investigations clearly demonstrated a mineralization of the fresh particulate organic matter during the first months of operation of the treatment plant. Regarding some parameters such as biodegradability or humification rate, it was observed that the organic matter reached a steady state after a few years of operation. The role of the sludge layer in the retention of a selection of organic and metallic pollutants in VFCW systems has also been evaluated by analyzing sludge deposits from a panel of French VFCWs. Metals and detergents were observed at significant concentrations, and some pharmaceuticals and personal care products (PPCP) were also found in the sludge, showing the role of the sludge in the treatment of these pollutants through the process. The role of the organic fractions was clearly highlighted in the retention of some micropollutants (copper, zinc, some PPCPs…). Finally regarding nutrients recovery, the sludge plays a key role for phosphorus (P) removal. For nitrogen, the water retention in the sludge after the feed periods favors the nitrification of ammonium during the rest periods.

The particulate organic matter of the inflow wastewater was also shown to undergo modifications within the treatment chain of the vertical flow constructed wetland. The implementation of a biological trickling filter as an additional treatment prior to the filter stages was found to induce the transformation of soluble and particulate organic matter through mineralization and hydrolysis, and to contribute to humification. The injection of ferric chloride used to precipitate phosphates was found to promote aggregation within the sludge deposits.

In VFCWs, sludge accumulates progressively by filtration of suspended solids during the percolation of unsettled raw wastewater. Sludge Treatment Reed Bed (STRB) systems are loaded in cycles with higher quantities of sludge and dewatering occurs by draining and evapotranspiration. Despite these operational differences between the 2 systems, several similarities can be observed notably in the processes of mineralization and stabilization the organic matter.

BIO: 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.

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DISTRIBUTION AND BIOAVAILABILITY OF HEAVY METALS IN EARTHWORM ASSISTANT SLUDGE TREATMENT WETLAND

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Sludge treatment wetlands (STWs) have been used for sludge treatment in recent years, however, heavy metals (HMs) are one of the limiting factors for the final sludge application, and the fate of HMs in STWs are still not well studied. Invertebrates, such as earthworms, play an important role on purifying wastewater in STWs, and they can enrich heavy metals in vermicomposting process, thereby reducing the content of heavy metals in sludge. In addition, earthworms are also used in STWs to improve the sludge treatment efficiency in recent years. However, no study focus on the effect of earthworms on the removal of heavy metals in STWs, and the detailed effects of earthworms on heavy metals removal processes are still not known. Therefore, the aim of this study were to: (1) clarify the distribution of heavy metals in STWs with earthworm addition; (2) evaluate the effect of earthworms on heavy metals bioavailability in accumulated sludge of STWs.

Six STWs with two plant species and earthworm addition were investigated to evaluate their effects on HMs distribution and bioavailability. The results showed that plant uptake of HMs was insignificant with earthworm addition. Earthworm had the highest enrichment for Cd with bioaccumulation factors of 6.9-7.3. Moreover, earthworm had a positive effect to remove HMs in accumulated sludge. Meanwhile, the bioavailability of Cd in accumulated sludge was decreased by earthworm addition, with the acid-soluble fraction decreased from 16.5-22.7% to 7.2-10.1%. Furthermore, HMs mass balance in the STWs revealed that HMs were widely distributed in the accumulated sludge, leachate and others, while their (except Cd) accumulation in the plants and earthworm are less than 1%. The Cd toxicity in the accumulated sludge can be reduced by the addition of earthworm with enrichment of 3.6-8.2%.

Overall, earthworm addition has positive effects on distribution and bioavailability of HMs in STWs.

BIO: Dr. Chen is an Associate Professor at the Czech University of Life Sciences Prague. He has worked extensively in the field of constructed wetlands regarding organic contaminants and sludge treatment. He was PI of five projects, and has been participated in other six projects on national and international levels.

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SIMULTANEOUS WASTE GAS PURIFICATION AND WASTEWATER TREATMENT IN A NOVEL ALUM SLUDGE BASED CONSTRUCTED WETLAND

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Constructed wetlands (CWs) are environmentally friendly option for wastewater treatment. However, insufficient oxygen supply is identified as one of the major factors limiting organic pollutant and nitrogen removal in CWs. Therefore, artificial aeration has been developed as major dissolved oxygen optimization processes. Unfortunately, the corresponding operational costs greatly limit its popularity. On the other hand, odorous gases releasing from wastewater treatment plant has attracted broad attention, as a result, biofiltration was developed for controlling odor in an ecological way. Thus, it is of great interest to integrate CWs with waste gas biofiltration, using waste gas to improve the pollutant removal in CWs along with the waste gas abatement. This could be a promising simple solution for achieving dual goals of waste gas purification and wastewater treatment.

The experiment (as illustrated in Fig .1) was composed of three parallel alum sludge-based aerated vertical down flow CWs (Al-VFCW, alum sludge cakes as main substrate), Column 1 (diameter of 15 cm) was intermittently aerated with waste gas (200 ppm H_2S based on air); Column 2 was intermittently aerated with air, while Column 3 was unaerated and served as a control. Synthetic wastewater (influent) with the COD, TN, TP approximately of 300, 30, 10 mg/l, respectively was used and each wetland was operated by batch model with HRT of 3 days and intermittently aerated for four hours per day. The long-term performance in purifying wastewater as well as H_2S was identified and compared.

Despite TP was completely removed (100%) in all three columns, Column 1 was the effective system and the COD, TN, NH_4^+-N removal efficiency were 90.3, 75.3, 80.9%, respectively. It indicated that the introduction of H_2S improved the growth of microorganisms and facilitate the nutrients removal. Moreover, the waste gas ingredient, H_2S was completely removed (100%) after passing through Column 1, while biodegradation of H_2S occurs in the biofilm. This study opens a new aspect of simultaneous purification of the waste gas and wastewater in an intermittently aerated Al-VFCW.

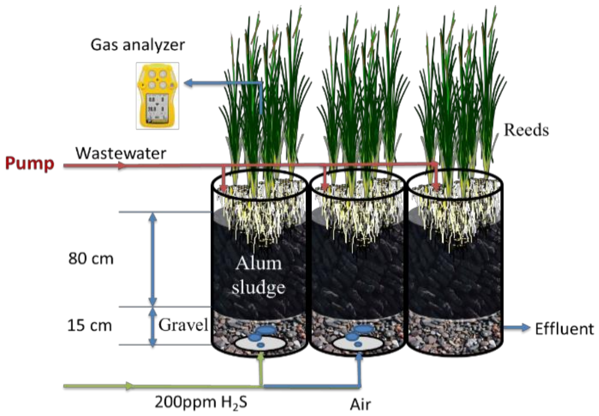

Figure 1 Schematic diagram of the experimental setup.

BIO: Baiming Ren is a joint PhD researcher between University College Dublin, Ireland and IMT-Mines Albi, France, with more than 10 years of experience specializing in wastewater treatment and beneficial reuse of the waterworks residual (alum sludge).

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WETLAND SYSTEMS FOR INDUSTRIAL EFFLUENT TREATMENT IN ARGENTINA

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Constructed wetlands (CWs) are a wastewater treatment technology applied worldwide. In Argentina, although the optimal conditions for their implementation, this technology is still scarcely developed. Our research group has designed two wetlands for the final treatment of effluents from two metallurgical industries, which have been operating for the last 15 years. Both systems are free-water surface wetlands (FWSWs) that treat together industrial effluent and sewage of the factory facilities. Once optimized, they worked efficiently, presenting high contaminant removals. Metals were removed efficiently, being retained in sediment and roots of the plants. The retention mechanisms depended on the dominant vegetation. In the CWs studied, unexpected events occurred that were studied to evaluate the robustness and durability of these systems. With the good results obtained in the treatment of these effluents, this technology began to spread in our country. Different companies requested the implementation of this low-cost and environmentally friendly technology for the final treatment of their effluents. For this reason, we studied their application for the treatment of different effluents. We designed and studied a hybrid wetland (HW), composed by a FWSW and a horizontal subsurface wetland (HSSW) for the treatment of sanitary effluents from a pet care center. We studied complex effluents as landfill leachates using a VFW and a HW (VFW and FWSW). We compared the performance of two HW configurations (HSSFW-FWSW and FWSW-HSSFW) constructed in parallel at pilot scale for the final treatment of the effluents rich in nitrogen from a fertilizer manufacturing plant. Effluents from the paper industry were treated with FWSWs and HSSFWs. In Argentina, large areas are generally available at manufacturing facilities while operation and maintenance costs are limiting factors. For these reasons, the use of FWSWs are a suitable alternative.

Santa Fe (Argentina), our region, are located in the most important milk basins of Latin America. Wastewaters from the numerous dairy farms and dairy factories are either poorly treated or discharged untreated into surface water courses. We studied a HSSFW for the final treatment of dairy farm effluents. Treated effluent is used to clean the floors of the dairy farm. As the characteristics of dairy factory effluents depend on the manufactured milk product, different configurations of HWs are been studying for their final treatment.

Santa Fe city is surrounded by natural wetlands receiving urban runoff effluents. Floating treatment wetlands (FTWs) are being studied to mitigate the impacts of urban runoff on receiving environments. Polishing treatment of metallurgical effluents with FTWs area also studied. The results of the aforementioned cases will be presented.

BIO: Dr. Maine is a senior scientist with more than 25 years of experience in the study of contaminant dynamics in natural and treatment wetlands. She has been designing, implementing and studying constructed wetlands for the treatment of industrial effluents. She is the President of the Pan-American Wetland Network (HUPANAM). She has published more than 70 journal articles, one book, 14 book chapters, and more than 200 presentations in Scientific meetings. She is a reviewer of articles for publication in international journals. She has been leading more than 15 research projects, undergraduate and postgraduate students and researchers.

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C.P. 21

CONTRIBUTED PAPERS 21

PHOSPHORUS REMOVAL

Alexandros Stefanakis

ASSESSMENT OF SORPTION MATERIALS FOR P-REMOVAL TOWARD CIRCULAR ECONOMY

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Phosphorus compounds are considered as the main determinant of nutrient enrichment in the water bodies. Presence of phosphorus in the surface water, despite the natural one, is mostly caused by over fertilized agriculture areas but also it came from untreated or inadequately treated domestic and industrial wastewater discharged directly to the aquatic ecosystems.

The conventional phosphorus removal in the wastewater treatment plants (WWTP) is frequently provided with chemical reagents as ferric chloride and polyaluminum chloride, although applying such methods does not allow recovering phosphorus from the sludge. The possibility of potential elements recovery is getting much more attention due to the circular economy regulation since December 2015. Growing awareness of the limited resources of phosphorus brings the necessity to discover a sustainable way for P-removing from the wastewater toward its reuse for industry or agriculture. A promising alternative method in the terms of recovery potential is the application of sorption materials. Many adsorbents of the different origin, both natural and anthropogenic, have approved ability to phosphorus removal. Unfortunately, some of them are so expensive that their appliance is not economic. Response to that issue may be the application of waste materials or waste byproducts, which also follow the assumption of the circular economy.

The main objective of the study was to assess the several sorption materials efficiency in P-removal. Investigated materials were (1) a lanthanum modified bentonite clay (LMB), an expensive, man-made product, (2) a byproduct remaining after thermal treatment of carbonate-siliceous rock with high content of calcium oxide (CaO), and (3) a drinking water treatment residuals (DWTRs) from various drinking water treatment plants. The main feature of DWTRs was different content of iron (27.5-99.0 mgFe/g dry weight) and manganese (1.9-50.3 mgMn/g dry weight). The research was conducted to assess sorption materials capacity as well as determine kinetics and equilibrium adsorption parameters according to the pseudo-second order model. The graphical analysis includes orthophosphate adsorption isotherms. The assumption of the study was to measure the concentration of orthophosphate after certain contact time (up to 48 hours). Various amounts of adsorbents (0.5-15.0 g) and various initial concentrations of orthophosphates (5-300 mgPO_4-P/L) were analyzed.

The results from the investigation shows a significant ability to orthophosphates removal in case of both types of the adsorbents (commercial and waste products). The sorption capacity of tested materials reached 9.1 mg/g for LMB, 9.6 mg/g for CaO rich byproduct, and 6.4 mg/g for DWTRs. Achieved results proved the possibility of waste materials and byproducts appliance according to the circular economy idea.

BIO: Ph.D.D.Sc. Magdalena Gajewska, associate professor in the Department of Water and Wastewater Technology, GUT. She specializes in technologies related to eco-engineering and natural methods of wastewater treatment, an author or co-author of 60 papers listed in the Web of Science database, six books, and over 100 peer-reviewed publications.

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FATE OF PHOSPHOROUS AND CLOGGING IN SOIL-BASED CONSTRUCTED WETLANDS

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In France, soil-based constructed wetlands for discharge of treated wastewater have become a popular technique to reduce flow to surface receiving water bodies and to perform complementary treatments. This study focuses on describing (i) the fate of pollutants flowing in and out three different soils and (ii) the development of clogging for a low (6 cm/j) applied hydraulic load as well as for periods of hydraulic overload (12 cm/j; 24 cm/j). Special attention was given on phosphorus and its fate in these soils.

The experimental setup consisted of three lysimeters containing three soils selected to be representative of those that can usually be found near a wastewater treatment plant. Lysimeters are undisturbed soil monoliths (1.5 m^3), which masses are continuously monitored in order to obtain accurate water mass balance. Lysimeters were intermittently fed during 3.5 days and put to rest for 3.5 days. The experiment lasted twenty months and major pollutant (TOC, NH_4N, NO_3N, Nt, PO_4, Pt) fluxes in and out were monitored as well as water content, oxygen content and redox potential at different depths. Phosphorus fractionation in soils was performed to better understand its distribution and to know the proportions adsorbed or precipitated. One of the objectives was to identify which fraction can be mobilized either by plants or during an overload period.

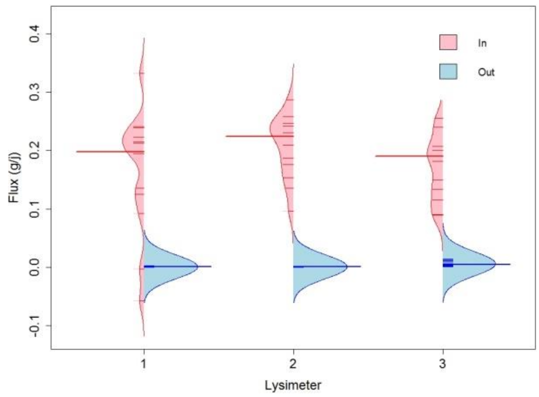

Figure 6: The three lysimeters containing the three soils studied (left); Phosphate fluxes measured at the inlet and outlet of the three lysimeters (right)

The soil which has the thinnest texture and the lowest infiltration capacity clogged rapidly and this clogging could not be easily reversed. The soil drained little during the rest periods limiting oxygen renewal and consequently low nitrification of the adsorbed ammonium was reported.
Low phosphate concentrations were measured at the outlets of all lysimeters highlighting a good phosphorus retention in the three soils (removal efficiencies > 80%). No phosphorus release was observed during overload periods (two weeks).
The presence of preferential flows has been identified in one lysimeter. There result in part of the water by-passing most of the porous media and consequently affect the removal performance, especially of carbon.

BIO: Dr. Ania Morvannou is a scientist with about 10 years of experience researching in the field of wastewater treatment by constructed wetlands. She obtained her doctorate in 2012 and since then she has been working on databases, modeling as well as collecting data through field measurement campaigns.

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GEOCHEMICAL AUGMENTATION FOR PHOSPHORUS TREATMENT: RESULTS FROM A 55 MLD PILOT STUDY

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Clayton County Water Authority discharges approximately 55 MLD (55,000 m^3/d) from the W.B. Casey Water Reclamation Facility to the 108 ha (1,080,000 m^2) E.L. Huie surface flow wetland. Outflow discharges to reservoirs that supply drinking water to two water treatment plants. Mean total phosphorus (TP) of wetland inflow is approximately 0.5 mg/L, outflow 0.4 mg/L. Wetland construction was completed in 2010.

The reservoirs are hypereutrophic. Improving wetland TP removal will complement reservoir water quality management projects underway (hypolimnetic oxygenation with ferric chloride feed). Soluble (non-flocculating) doses of aluminum chlorohydrate (ACH) were injected continually into wetland inflow. Doses were calculated to keep Al concentrations below the continuous concentration criterion (CCC) as based on pH, dissolved organic carbon, and hardness (US EPA 2018).

TP removal performance, dose response, and Al depletion rates were goals of full scale pilot studies in OCT-DEC 2017 in the entire wetland and JUN-JUL 2018 in Site A (45% of inflow, 54 ha, parallel step feed into three cells with accumulated flow through a fourth cell to the outfall). Results suggest that long term ACH dosing in the 1 to 4 mg/L range should reduce wetland outflow TP below 0.1 mg/L (Figure 1), while maintaining Al below the CCC (Figure 2). Variability of CCC is due pH sensitivity. A permanent installation will investigate sustained dosing results in the 1 to 4 mg/L ACH range. The combination of winter and summer pilot studies demonstrate geochemical augmentation can sustainably improve TP polishing performance in surface flow wetlands.

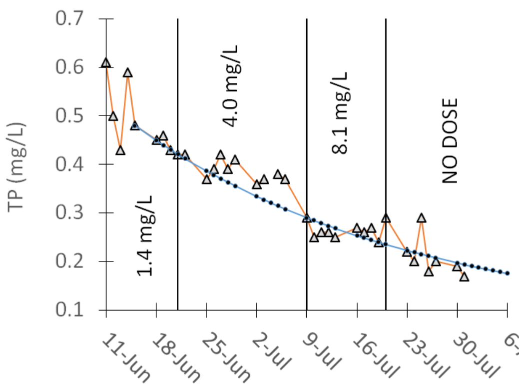

Figure 1. TP at Site A outfall (2018). Triangles-data. Circles-fitted model.

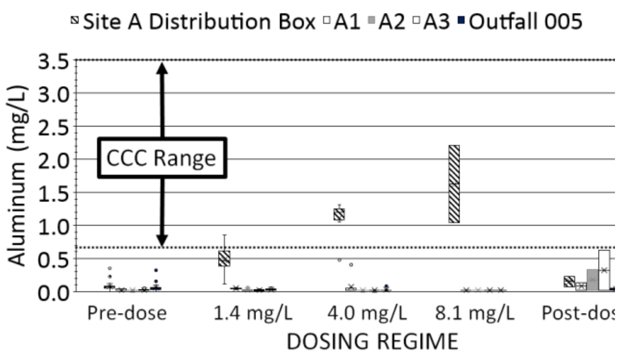

Figure 2. Total Al concentrations at Site A. Inflow is the distribution box.

BIO: David Austin is the Natural Treatment Systems Lead for Jacobs Engineering Group. He is a professional engineer and certified senior ecologist (Ecological Society of America). Mr. Austin has had extensive experience with wetland technology development since 1996.

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PHOSPHOROUS RETENTION IN GRANULATED APATITE: AN ASSESS OF MAXIMUM SATURATION LEVEL, KINETICS AND REACTION MECHANISMS

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Natural apatites have a great capacity for phosphate retention from wastewater. Accordingly, a granulated apatite product called Phosclean® has been developed and manufactured in a similar way fertilizers pellets does, by using a binder product in order to control the particle size distribution (3-6 mm) of the filtration bed. Like natural apatites, this product is supposed to remove phosphorus (P) from wastewater by means of adsorption, at the very beginning of its lifespan, followed by precipitation of calcium phosphate as a long-time retention mechanism. About 20 full-scale treatment wetlands plants have been implemented with Phosclean® filters in France, however, a survey pointed out some limits in terms of the performance durability without defining the causes.

New experiments are carried out in laboratory to assess the maximum saturation level of Phosclean® and the kinetic rate, in controlled conditions. Anions and cations' concentrations are also monitored for a better understanding of P retention mechanisms. The experimental setup consists of two vertical flow Phosclean® columns with equidistant depth sampling points to assess the kinetics at different retention times. They are fed with a synthetic tap water solution with 14.8 mg $P\text{-}PO_4^{-3}$/L and 70 mg Ca^{2+}/L for column 1 and 14.2 mg $P\text{-}PO_4^{-3}$/L and 115 mg Ca^{2+}/L for column 2.

Results of column 1 have shown that Phosclean® behaves as a low rich natural apatite as the kinetic rate stabilizes at low values. For column 2, the higher concentration in Ca^{2+} has improved the kinetic rate at low saturation levels, as well as it has quickly increased the saturation of the media in terms of g $P\text{-}PO_4^{3-}$/kg of material. Samples from column 2 have been analysed by SEMx (saturation = 6.2 g $P\text{-}PO_4^{3-}$/kg of Phosclean®). Images have shown the formation of a crystal deposit at the pellet's surface (Figure 1.c), identified as a calcium phosphate (Ca-P) precipitate by X-ray analyses. SEM images have also shown that the surface of apatite particles in the granule are not readily accessible to act as seeds for Ca-P precipitation (Figure 1.a). It may means that the extra Ca^{2+} addition promotes the oversaturation of the solution leading to a nuclei formation by homogeneous precipitation onto the granules surface. Instead, little Ca-P precipitation occurred without an excess of calcium ions (column 1) and P retention may preferably happen due to adsorption phenomena, leading to low kinetic rates at high saturation levels. Presentation will detail kinetics dynamic and explain in which conditions P retention is limited or not.

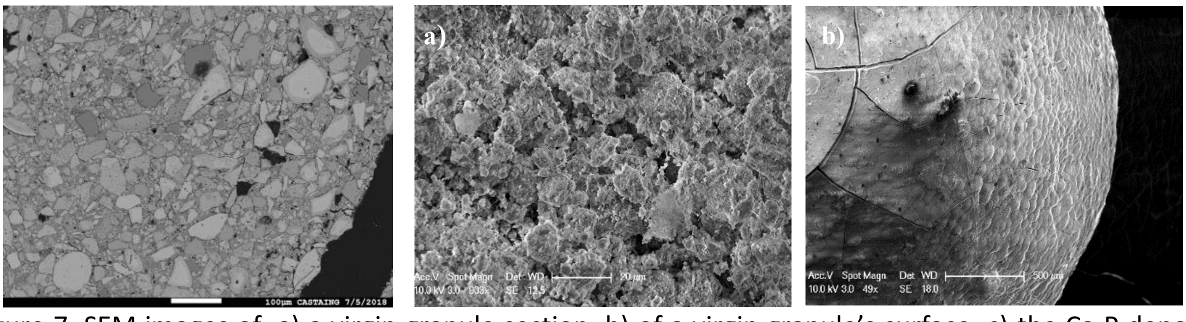

Figure 7. SEM images of: a) a virgin granule section; b) of a virgin granule's surface; c) the Ca-P deposit onto the granule's surface.

BIO: Laura Delgado is a PhD student at Irstea. Her research work is called "Apatite for P removal and valorization: an evaluation" (APPROVE) and it is co-funded by Syntea SAS. and the French Water Agencies AG and RMC.

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WHAT IS THE FATE OF TRACE METALS AND PHOSPHORUS IN CW RECEIVING TREATED WASTEWATER? CONTRIBUTIONS OF FREE WATER, PLANTS AND SOIL

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Constructed Wetlands receiving Treated Wastewater (CWtw) are systems downstream of Wastewater Treatment Plants (WWTPs) before the receiving water bodies. They have recently become attractive in France under the perception that they improve water quality of the WWTP effluent (e.g. removal of excess suspended solids, or sorption of some dissolved pollutants). Depending on the historical background of the site close to the WWTP, trace metals are often present in the soil. The aim of this study is to determine the fate of the main trace metals (As, Ba, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn) and phosphorus (P) in the different compartments of CWtw: free water, soil and deposits (when relevant) and plants at two different sites.

The first site (MAG) is a Surface Flow (SF) CW (10 000 m^2) consisting of 2 watertight ponds in series. They receive an average of 1500 m^3/d of TW from a WWTP that had occasional dysfunctions (sludge loss). The second site (BTT) consists of a SF CW (150 m^2) built on semi-permeable (infiltration) clay soil contaminated with metals that come from construction waste and former viticulture. It receives an average of 250 m^3/d of TW. Both sites have *Phragmites australis*.

For both sites, the daily water balance was determined using inlet and outlet flowmeters associated with a weather monitoring. Free water samples were collected at the inlet and outlet: 4 2-day flow proportional composite samples. The BTT site had silicon carbide porous suction cups (0.3 m deep in the soil) to collect 4 composite samples of pore water. The plants and soil (BTT) sampling was performed at both sites by using quadrats (0.5 x 0.5 x 0.2 m). At MAG site, only deposits were sampled as there is no infiltration. Total phosphorus (TP) and metals were analyzed in plants, deposits (MAG) and soil (BTT).

A mass balance for each metal and P is estimated thanks to daily hydraulic loads, infiltration flux (BTT), metals and P concentrations in free and pore water, in the plants and in the soil (BTT). The concentration of most metals does not change in the free water along both CWtw. In the soil (BTT), there is a substantial adsorption of P (80%) and As (75%) confirmed with lower concentrations in the pore water. In contrast, Cd and Pb are found in higher concentrations in pore water compared to the inlet (12 to 200 times higher for Cd). Moreover, the concentrations of metals in *Phragmites* roots on the contaminated soil (BTT) are much higher than in MAG, respectively 8, 14 to 45 and 17 times higher for As, Cd and Pb. On MAG, most metals and P come from the occasional dysfunctions of the WWTP and are mainly stored in the deposits of the first pond. Finally, an evaluation of the mass balance for metals and P within the different compartments of both CWtw will be discussed.

BIO: Sandrine Papias is a process and environmental engineer. After she graduated, she has worked on the 4 past years at Irstea (France) on a project which aims at studying and assessing constructed wetlands receiving treated wastewater.

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CONTRIBUTED PAPERS 22

NITROGEN REMOVAL

Cristina Ávila

TREATMENT OF ALKALINE AMMONIA STRIPPED EFFLUENT IN INTENSIFIED CONSTRUCTED WETLANDS: NITROGEN TRANSFORMATIONS AND REMOVAL PATHWAYS

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Discharged effluent of ammonia stripping process often has a high alkalinity with pH>10, which may give rise to another environmental issue by adversely affecting aquatic ecosystems. The most conventional management option for high alkaline wastewater is confined to direct chemical neutralization as the priory treatment. However, this requires a sustained capital input that may not be suitable for low-income farmers and/or agricultural industries in developing countries. Constructed wetlands (CWs) are man-made systems that have already been acknowledged in recent years for the treatment of polluted waters, owing to their cost-effectiveness, easy maintenance, and efficient performance. Most of the published work, however, only focuses on the alkalinity buffering potential of these wetlands and ignores the removal performance of associated pollutants and degradation pathways. Nitrogen transformation dynamics and respective pathways could be strongly influenced by and interact with highly alkaline conditions, but knowledge in this field is still insufficient. Associated with such various nitrogen transformations, the knowledge on how the abundance and functioning of the microbial community response to the alkaline environment and operational strategies should be investigated.

In this study, three lab-scale horizontal subsurface flow CWs have been established to 1) investigate the treatment feasibility of highly alkaline ammonia-stripped digestate effluent in CWs; 2) determine the influence of volumetric hydraulic loading rates (HLRv) and intensifying strategies (bottom aeration and effluent recirculation) on pollutant removal under the highly alkaline conditions; and 3) discuss the nitrogen transformation dynamics and removal pathways by N-isotopic fractionation assessment and microbial community response.

The results show that the intensified horizontal subsurface flow CWs coupled with aeration and effluent recirculation were effective in treating alkaline ammonia-stripped digestate effluent with high alkalinity consuming capacity. The higher aeration ratio and presence of effluent recirculation in the present study showed a positive effect on the alkalinity and pollutant removal. The N-isotopic fractionation assessment indicated the predominant role of microbial transformations in nitrogen removal, but lower enrichment factors reflected the inhibitory effect of nitrifiers in the high pH alkaline environment. Biological nitrogen transformations account for 94% of the alkalinity consumption and NH3 volatilization contributes to a maximum of 5% of total ammonium removal.

BIO: Shubiao Wu has been organizing many research projects as principal investigator and have established solid collaborations with experts worldwide. He has published 115 peer-reviewed scientific papers in total and 68 papers in the last five years. Among these, 34 papers have been published in journals with an impact factor higher than 5.0. Four articles have been selected as Highly Cited Papers from 2015 to 2018 in Web of Science.

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INTENSIFIED NITROGEN REMOVAL OF CONSTRUCTED WETLANDS BY ADDITION OF ALGAE CARBON SOURCE

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When constructed wetlands (CWs) are used for the tertiary treatment of the effluent of wastewater treatment plant (WWTP), they are always inefficient due to a lack of carbon sources. With this being the case, additional carbon sources would be the solution. In previous studies, low molecular weight compounds, plant biomass and high molecular polymers have been used as external carbon sources to enhance the denitrification in CWs, but each is flawed for either its expenses or unstable performance. Microalgae is rich in saccharides, fatty acids and protein, which is believed to be easily used by the denitrifying bacteria. It has been demonstrated that algae ponds can strengthen the nitrogen removal of CWs, but there is still limited knowledge about how algae affect denitrification. This study aims to investigate the effect of external algae carbon source on water treatment efficiencies, especially the nitrogen removal of CWs.

In this study, small scale horizontal subsurface flow (HSSF) CWs were set to treat the effluent of WWTP. By adding different amount of algae powder to the inlet of each CW, we compared the treatment efficiency of CWs under different inlet C/N ratios (2.7, 3.7, 4.7, 5.7, 6.7, respectively). We also collected and analyzed water from different inner part of CWs in order to understand how the algae carbon source influence the nitrogen removal of CWs.

The results showed that there was a steady improvement in the nitrogen removal before the C/N ratio of the influent water rose to 4.7. For the C/N=2.7, 3.7, 4.7 groups, lineal relationship was built between the algae dosage and the TN removal rate. The C/N=4.7 group ended up with 80.0% removal of TN while C/N=3.7 group was 48.9%. Additional algae carbon also affected ORP of CWs significantly. When the inlet C/N was 5.7 and 6.7, too much ammonium-nitrogen was introduced to CWs and the ORP of CWs was too low for nitration, resorting in low nitrogen removal.

In conclusion, addition algae carbon source would significantly improve nitrogen removal in the CWs, and an inlet C/N=4.7 would be recommended.

BIO: Ms. Huai is studying for her doctorate at present. Her work of the past 5 years has been focusing on the enhancement of nitrogen removal of constructed wetlands, and the combining system of algae ponds and constructed wetlands.

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LONG-TERM WASTEWATER TREATMENT BY ALGAL BACTERIAL BIOMASS IN HIGH RATE ALGAL POND (HRAP): IMPACT OF NUTRIENT LOAD AND HYDRAULIC RETENTION TIME

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Harmonious cooperation between algae and bacteria has been studied and applied in wastewater treatment for 8 month long period. As a result of early studies on photosynthesis in sewage wastewater (Oswald and Gotaas, 1957), high rate algal pond (HRAP) system was developed enhancing natural processes between algae and bacteria and hence improving wastewater treatment efficiency. HRAP also allows a denser algal culture to develop, thus supporting biomass production from wastewater (Park et al., 2010). In addition, in recent years, anaerobic digestion has become a popular solution for bioenergy production and the use of its liquid effluent as nutrient source of HRAP system promoting nutrient recovery has been attracting(Sawatdeenarunat et al., 2016). Hence, the impact of high nutrient load from anaerobic digestion effluent on the algal bacterial dynamic deserves serious attention. In this study, long-term pilot-scale HRAP operation was conducted aiming to study the impacts of high nutrient load condition and hydraulic retention time (HRT) on the system performances and functionning. The performance of the system was assessed in terms of treatment efficiency, biomass production and recovery under different nutrient loads as well as HRTs. The experimental data allowed us to calibrate black box model coupling RTD and mixed order kinetic model to predict HRAP performances.

The pilot HRAP experiment was conducted indoor over 246 days containing 3 phases. In the first phase (135 days), primary treated wastewater and HRT of 4 days were applied to collect long term data on the performance of the HRAP. In the second phase (53 days), a mixture of primary treated wastewater and centrated wastewater (2v:1v) was fed to the HRAP with similar HRT to study the impact of high nutrient (nitrogen and phosphorus) load on performance of the system. Finally, a HRT of 8 days was applied to the HRAP for 57 days to investigate the impact of variation in HRT on performance of the HRAP treating high nutrient loading wastewater.

Results of the first phase indicated that the system provided good treatment levels of primary treated wastewater satisfying French discharge norm with 4 days of HRT. Around 99% of biomass recovery efficiency was achieved during the entire experiment via simple gravity settling which reconfirms the advantage of Al-Bac biomass in enhancing settleability. Hence the HRAP showed potential for a simple and efficient secondary treatment application. However, high nutrient load wastewater in phase 2 and 3 resulted in poor TN and TP treatment efficiencies and decreasing in COD removal, yet high removal of TKN as well as NH_4-N were still obtained. High HRT of 8 days in phase 3 showed improvement in COD removal, but minor impact was observed in the case of TKN, TN and TP removals. Nitrification was identified as the main mechanism in TKN and NH_4-N removals of high nutrient load wastewater. Over all, the system may require much higher HRT to significantly remove TN and TP from high nutrient load wastewater or it can be used to remove quickly COD and TKN from the wastewater before applying another treatment for NO_3-N and TP removals. Despite of the variation in operational conditions, constant production rates of Al-Bac biomass and Chl-a were obtained during the entire experiment. Higher HRT and lower harvesting rate in phase 3 resulted to an increasing SRT and Al-Bac biomass level in the reactor. Finally, a black box model was constructed by coupling residence time distribution (RTD) and mixed-order kinetic models in order i) to simulate HRAP performances and ii) to provide a sizing chart.

BIO: Adrien Wanko is a scientist working at ICUBE Laboratory in Strasbourg University. He does research in Chemical Engineering, Computer Engineering and Ecological Engineering. His current research areas are: Phytoremediation of polluted soil, Stormwater treatment by constructed wetlands, Stormwater management, Wastewater treatment by constructed wetland, Numerical modeling.

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ROBUSTNESS OF TANK IN SERIES APPROACH TO SIMULATE NITRATE RETENTION IN ARTIFICAL WETLAND USING HIGH FREQUENCY MONITORING

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The issue of nitrate pollution in water remains current, especially in subsurface drained area with intensive agricultural practices. An artificial wetland, as an end of pipe solution, could help in mitigating nitrate fluxes between agricultural drained plots and receiving water bodies. In 2012, a pilot catchment of 355ha at Rampillon (Seine et Marne District, in the South-East of Paris suburb), was selected and equipped with artificial wetlands, following a 5-year period of stakeholder negotiations.

The Rampillon artificial wetland (1.5ha, 2500m^3) is composed of 3 compartments with different water depth areas: sediment ponds (1-1.3m in depth), a wet vegetated area (0-0.5m in depth) and a final pond (0.5-0.8m in depth). The Rampillon artificial wetland intercepts drained water from the upstream agricultural catchment (winter crops, sugar beet, corn), stores drained water between 3h to 1 month depending on hydrological period, before flowing fully back to the arterial network. It was equipped in 2012 in order to monitor nitrate concentrations and fluxes and to assess nitrate removal potential with a high frequency measurement station. Inlet and outlet were instrumented with a Doppler probe to convert water depth and velocity into discharge at a 15min time step; with a UV-spectral device monitoring turbidity, DOC and nitrate concentrations at hourly time step; air and water temperatures at hourly time step. Finally, we have a period of 4 full hydrological years (2014-2018) with measurements covering more than 97% of flowing time, ideal to be useful for a modelling approach. A tank in series concept (TIS) was introduced by Kadlec (2012) for its simplicity and efficiency to simulate nitrate behavior in the artificial wetland. The TIS model requests inflow data (discharge and concentration). TIS transforms them between several tanks (one to five) in which first order kinetic equations represent denitrification. The model was set up using two parameters k20 and θ. We performed the TIS simulation efficiency by using Nash criteria (-∞…1, 1 being the perfect performance of the model).

The first hydrological year 2014-2015 was used for parameter calibration (number of tanks=3; θ = 1.048 and k_{20} = 24.9, which were congruent with Kadlec approach, Nash=0.98). We performed the simulation keeping the same parameters for the 3 other hydrological years. In parallel, we tested a different configuration of tank's number, using transient and steady state volumes in the wetland, and finally annual calibration of parameters to evaluate their temporal evolution.
Nash criteria were "very good" ranging between 0.92 and 0.98, with annual mass balance error between 0 and 12%. The sensibility analysis was also performed showing that a unique set of parameters led to the optimal simulation.

The TIS approach was then used for the design purpose. According to annual nitrate removal objective (between 0 to 50%max), for an average hydrological year (not including extremes such as wet or dry years), the TIS approach provided the optimal dimension of the artificial wetland. For instance, the 1.6% of artificial wetland per upstream area reduced about 44% of annual nitrate flux.

BIO: Dr. Tournebize is a senior scientist at the IRSTEA, Antony, France. He is an internationally renowned expert in catchment hydrology, particularly in design and performance of constructed wetlands and riparian zones in various countries of Europe.

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EFFECT OF COLD CLIMATE CONDITIONS ON THE REMOVAL OF SULPHATE AND NITROGEN FROM MINING WASTEWATERS IN TREATMENT WETLANDS

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Good retention of e.g., sulphate and nitrogen compounds in treatment wetlands purifying mining waters are reported. However, seasonal variations can occur with lesser amounts removed during cold periods. In the effort to better understand the factors leading to variations in purification efficiency, the influence of e.g., retention time and flow regime has received substantial attention, while less focus has been directed to the effect of harsh winter conditions such as soil frost formation, snow cover, etc. on pollutant removal processes. The work reported here was conducted as part of Min-North (Interreg Nord funded) project. The goal was to improve our understanding regarding pollutant removal efficiencies in treatment wetlands stablished on pristine mires throughout the year and the role of snow and soil frost in the treatment performance. To achieve those objectives, combined field-monitoring data and purposely-built pilot systems were used to investigate purification processes and factors affecting removal efficiency.

Two constructed wetlands treating mining water (pre-treated process water and drainage waters) at a mine site in Northern Finland were selected as study sites. Influence of low temperatures and freeze-thaw cycles on purification efficiency was investigated via evaluation of long-term monitoring data (inflow and outflow concentrations, etc.) and field measurements such as soil sampling, measurements of water table level, ground frost depth, snow- and ice-cover, soil temperature and greenhouse gas emissions . Inflow and outflow samples were collected periodically and analysed for e.g., nitrogen fraction, sulphate and metals. Monitoring data and operational parameters (e.g., water residence time, average frost depth,) from the treatment wetlands studied were the base for the design of pilot-scale wetlands (two replicate units). The pilots (50 cm x 38 cm x 30 cm) were constructed with undisturbed top soil taken from one of the studied sites and loaded with pre-treated mine process water (loading rate 1-2 L/d). Freezing was conducted from top-down and the sides of the pilots were insulated to simulate freezing under *in situ* conditions. Sensors were used to monitor temperature (determination of frost depth), pH and redox potential in different peat depths. Inflow and outflow water samples were collected once or twice a week. Two freeze/thaw cycles were conducted. The first freeze-thaw cycle lasted 5 weeks while the second cycle lasted 7 weeks.

Based on results obtained, soil frost formation and other winter-related conditions weaken the removal of some pollutants, which are based on biological processes (e.g., nitrogen and sulphate removal). Although some biological processes became slower (e.g., nitrification-denitrification) during frost period, they continue to occur as indicated e.g. by winter-time gas measurement. Flow conditions (e.g., residence time of water) can change with the development of ground-frost and snow accumulation. Changes in flow conditions will have an effect on pollutant removal, as processes such as sorption, biodegradation and precipitation are dependent on contact time and media surface area as well as temperature, redox conditions and oxygen availability. (Complete results to be presented at the conference)

BIO: Dr. Elisangela Heiderscheidt is a Post-Doctoral research fellow at the University of Oulu and has more than 20 years' experience in wastewater treatment systems (industry and academia). She manages a number of national and EU projects related to diffuse pollution control, mining and municipal wastewater treatment.

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C.P. 23

CONTRIBUTED PAPERS 23

EVAPORATIVE SYSTEMS

Ülo Mander

WATER BALANCE IN EVAPOTRANSPIRATIVE WILLOW SYSTEM

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In an evapotranspirative willow systems (EWS) all the water that enters the system is used for evaporation and plant growth resulting with no outflow to the environment. EWS are mainly used for onsite treatment of domestic wastewater in sensitive areas with strict discharge limits and in areas where there is no recipient or percolation is limited due to low soil permeability. The areal foot print is one of the major obstacles in the implementation of such systems since 40-60 m^2 are needed per PE. The main parameters when dimensioning EWS have been based on the amount of wastewater to be treated, the precipitation, the reference evapotranspiration at the site and the crop coefficient of the selected willow clone, which shows the capacity of selected clone to evapotranspire water. Our research shows that precipitation does not have a significant impact on water balance in EWS.

The research was carried out on a pilot EWS constructed in Ajdovščina, Slovenia (45°52'32"N 13°54'20"E) for three years (2016-2018). A pilot EWS consists of nine test beds. Each 3 m x 1 m bed is lined with impermeable liner, filled with local soil and equipped with a distribution pipe and a piezometer. On the surface of each bed, drainage pipe was installed to collect rainwater that is transported and discharged to a rainwater collection tank. Moreover, 10 cm below the soil surface of each bed, a 5 cm clay layer was installed to reduce percolation of rainfall inside the system. Each bed was planted with 3 willows of the same clone; three clones were tested in three parallel beds; however, the differences between the clones are not the focus of this paper. The test beds were placed by each other to make a uniform willow stand. Throughout vegetative seasons a known volume of mechanically pretreated municipal wastewater was added to each bed on a weekly basis. Before and after wastewater addition, water level in the beds was measured. At the same time also, rainwater level in a collection tank was measured. Data on precipitation and reference evapotranspiration (ETr) were gained from Slovenian environmental agency for the period of research.

Water use of the EWS was lower than ETr during the first vegetative season (534±18 mm) due to the trees were young and the canopies and root system were not yet well established and increased significantly in the second vegetative season, namely to 1165±66 mm (ETr 1032 mm). At the end of second vegetative season, the trees were cut to 10 cm aboveground. Despite this, the water use in the third vegetative season was high again (922±45 mm) and close to ETr. The majority of total water use in EWS in all years was wastewater and the results show that only 11% or 9% of rainwater percolated to the depth of the system for the first and second year, respectively; moreover, the results of the third year show no rainwater percolation. The rainwater collection system did not catch significant amounts of rain, meaning that the rain was intercepted mainly by tree canopies and/or was retained and evaporated from the top soil layer. The results indicate that the amount of precipitation may not be a key factor for dimensioning of EWS as was stated by previous research.

Acknowledgement: The authors acknowledge the project (Z2-6751) was financially supported by the Slovenian Research Agency.

BIO: Dr. Istenič is a senior scientist with more than 10 years of experience in research and implementation of different nature-based solutions (constructed wetlands, stormwater ponds, willow systems) with a focus on nutrient and water reuse. She has cooperated in more than 10 research and development projects from this field.

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TREATMENT OF BIOGAS PRODUCTION RUN-OFF IN A WILLOW EVAPOTRANSPIRATION SYSTEM IN NORTHERN GERMANY

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Biogas production has become a widely used form of renewable energy production in northern Germany. Run-off from material stored for biogas production is heavily loaded with organic matter and nutrients. Therefore, it has to be collected in a pond-like system. The common practice of transporting this water to the agricultural fields again is very costly and bears the risk of soil compaction and possible leaching of organics and nutrients to the groundwater.

Wastewater treatment in Short Rotation Coppice (SRC) willows offers multiple benefits like achieving greater production yields and effective water purification. At the biogas plant in Eckhof near Kiel a willow SRC was therefore constructed to treat the run-off water. While irrigated SRC systems have been shown to perform successfully with other waste waters, they have not yet been investigated for this particular purpose. Our research focuses on (1) treatment efficiency, (2) biomass production and (3) risks of groundwater pollution in such systems.

A comprehensive sampling and monitoring program was started in 2018, including pond water, soil water sampling in three depths (20 cm, 40 cm, 80 cm) in four willow fields with suction cups, in groundwater wells and nearby located surface waters. Samples are analyzed for COD, TOC and several N and P species in the laboratory. Flow meters and a meteorological station deliver data for water balance calculations, soil moisture and tension in the willow fields are recorded in profiles (20 cm, 40 cm, 80 cm). Surrounding shallow groundwater levels are monitored with pressure sensors. The SRC fields are in different stages after harvesting. An experimental variation of hydraulic loading rates adapted to weather conditions is conducted.

The concentrations in the pond water are highly variable. In 2018, they ranged from 22-41 mg TP l^{-1}, 35-108 mg TN l^{-1}, and 215-2389 mg COD l^{-1}. Experimental irrigation rates started from 1,3 mm d^{-1} and were increased to up to 8,4 mm d^{-1} resulting in loads of 35-304 mg TP m^{-2} d^{-1}, 75-701 mg TN m^{-2} d^{-1}, and 280 mg-6 g COD m^{-2} d^{-1}. First results from the concentrations in the soil water as well as soil moisture data indicate a significant reduction of organics and nutrients within the first 40 cm of the soil.

Mass balances are currently calculated by taking into account actual evapotranspiration rates influenced by seasonal growth data and regrowth after coppicing. Complete mass balances and our ongoing results will be presented at the conference.

BIO: Dr. Rücker and Prof. Dr. Schrautzer are senior scientists with expertise in wetland ecology, hydrology, chemistry, and restoration. They have more than 20 years experience in mire ecosystem research as well as nutrient retention studies in natural and constructed wetlands. Mahmuda Sharmin wrote her Master Thesis in the project.

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POTENTIAL OF A SHORT-ROTATION WILLOW COPPICE LAND APPLICATION SYSTEM FOR VOLUME REDUCTION, TREATMENT AND VALORISATION OF LANDFILL LEACHATE

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Engineered landfill disposal is the main means of waste management in the Province of Quebec, Canada, accounting for over 96 % of the disposed waste. The leachate generated from these installations is of concern due to the high volume discharged to the environment and the high concentrations of organic compounds, ammonia nitrogen and metals that need to be treated. In fact, the rate at which a landfill can dispose of waste is often limited by the permitted treated leachate flowrate discharged to the environment. The use of a short rotation willow coppice (SRWC) land application system was considered as a potential solution to less concentrated leachate generated by older landfill cells. The objective of this research was to establish the potential volume reduction and removal efficiency of SRWC under Eastern Canadian climatic conditions through rigorous water balance in a mesocosm experiment.
The experiment was conducted in southern Quebec with 18 HDPE tanks (1 m^3) planted with *Salix miyabeana* 'SX64' in either sandy or clayey soil (3 treatments x 2 types of soil x 3 repetitions). Irrigation started mid-July and ended mid-October, which allowed for a wide range of climatic conditions in the study region. Two loadings of leachate (L1: 3.3 mm/d, 0.39 g COD $m^{-2}d^{-1}$ and 0.90 g NH_4-N $m^{-2}d^{-1}$; L2: 6.6 mm/d, 0.79 g COD $m^{-2}d^{-1}$ and 1.8 g NH_4-N $m^{-2}d^{-1}$) and a control effluent of potable water (L0: 3.3 mm/d) were applied on every weekday. The effluent of every tank was collected, weighed and sampled daily.

Table 1. Removal efficiency of chemical oxygen demand (COD), ammonium (NH_4), total nitrogen (TN) and volume

	Clay				Sand			
Loading	**COD**	**NH_4**	**TN**	**Volume**	**COD**	**NH_4**	**TN**	**Volume**
Units	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
L0	--	--	--	74	--	--	--	62
L1	91	100	71	76	86	98	59	59
L2	83	100	62	73	67	93	43	43

The main results of this experiment showed: (i) a high COD and NH_4 removal efficiency for both leachate loadings (Table 1). COD removal efficiency variation between soils is hypothesized to be caused by a greater contaminant adsorption potential of clay over sand. Excellent nitrification capacity was observed in both sand (more aerobic) and clay (less aerobic), which could be attributed to the low loadings applied. (ii) A greater volume reduction potential was observed for fine textured soil (73 % for clay vs 43 % for sand, for the L2 loading). This difference can be explained by the greater water retention capacity (field capacity) and lower hydraulic conductivity of clay which allowed an extended contact time between willow roots and water, and thus, a greater potential for plant transpiration.
This study supports the potential of implementing SRWCs on fine-textured soils for reducing the volume of old landfill leachate, without compromising treatment efficiency. This system could be installed on older landfill covers, often capped with fine soil, to meet their loading and flowrate discharge limits. Pursuing the experiment over several seasons will allow to detect negative effects of leachate irrigation on willows (toxicity) or soil (clogging, structural degradation) and to evaluate the long-term sustainability of SRWCs for treatment and volume reduction of lowly concentrated leachate.

BIO: Mr Barbeau is a junior engineer working on phytotechnology as part of the Research & Development team of Agro Énergie. He graduated with a Bioresource Engineering degree from Laval University in 2017. The study was a research component of his Master of Engineering degree obtained from Polytechnique Montreal in 2018.

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CONSTRUCTED WETLANDS - TAKING ADVANTAGE OF NATURE NATURAL PROCESSES TO MINIMIZE ENVIRONMENTAL PROBLEMS

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Natural wetlands have long been used as uncontrolled discharge sites for different sources of wastewaters due to their recognition for water quality improvement. Constructed wetlands (CWs) are low tech approach with specific wastewater treatment purposes in a controlled and optimized manner inspired in natural wetlands processes. These engineered wetlands relay on natural processes involving soil, wetland vegetation and their associated microbial assemblages to assist the treatment of wastewaters or other polluted water sources.
CWs can be used for primary, secondary and tertiary treatment of municipal or domestic wastewaters, storm water, agricultural wastewaters (such as landfill leachate) and industrial wastewaters (such as petrochemicals, pulp and paper, food wastes and mining industries). Through a combined action among plants, microorganisms and matrix components, the concentration of the compounds can decrease to levels that are safe for the aquatic biota. Physical, chemical and biological processes, such as volatilization, sorption and sedimentation, photodegradation, plant uptake and microbial degradation, may occur simultaneously, contributing to eliminate several types of compounds. CWs are able to efficiently remove total suspended solids, organic matter, nutrients (e.g., ammonia and phosphorus) and metals. Recently, CWs have been also used to remove organic pollutants, including the so-called emerging pollutants, such as antibiotics. Although CWs have been applied to different types of wastewaters, CWs use to treat livestock wastewaters is more complicated do to waters characteristics very high organic matter, suspended solids contents and nutrients. Pharmaceuticals (namely antibiotics) removal from livestock industry wastewaters in CWs is still unexplored. Even though antibiotics are normally found at low concentrations in the environment (ng L^{-1} to µg L^{-1}), these compounds can cause serious toxic effects in organisms and promote antibiotic resistance.
Over the last years we have been investigating the potential of CWs for antibiotics removal from livestock and aquaculture wastewaters. Results obtained so far have shown *Phragmites australis*-planted beds could be used for removal of pharmaceuticals from livestock wastewater. CWs have potential to mitigate the release of veterinary drugs into the environment. Although plants had no evident role in drugs removal, they were very important for the entire system functionality (e.g, prevented clogging). Adsorption of the drugs to the substrate may be a predominant mechanism of removal but microbial degradation probably occurred. Moreover, CWs microbial communities were able to adapt to antibiotics presence without significant changes in their diversity or depuration capacity. Systems were able to simultaneously remove antibiotics, nutrients and metals. CWs application to saline aquaculture wastewater has also shown promising results: >99% removal of each antibiotic and >95% removal of total and antibiotic resistant bacteria.
Research carried out so far indicates CWs are a valuable alternative to remove conventional pollutants (nutrients, metals and organic matter), as well as antibiotics, from livestock and aquaculture wastewater and attenuate the environmental impact of these industries. Careful assessment and system performance is needed, as well as knowledge about important removal processes to fully optimize and potentiate the use of CW, namely as decentralized wastewater treatment facilities. In addition, the potentialities of CW treated wastewater for re-use must be fully assessed.
Acknowledgments – To VALORALGA project

BIO: Dr. Almeida is a senior researcher at CIIMAR since 2005. With a PhD in Chemistry her main research area is bio and phytoremediation, being actively engage in studies aiming to enhance the use of bio and phytoremediation as biotechnology tools for remediation of aquatic environments contaminated with different pollutants.

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NON-TARGETED MICROPOLLUTANTS IDENTIFICATION BY HIGH RESOLUTION MASS SPECTROMETRY IN A TERTIARY TREATMENT WETLAND ECOSYSTEM

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In the last decades, micropollutants have become a major environmental and health concern. There presence in the environment has different origins. Nevertheless, WWTP dealing with urban wastewater is one of the biggest contributors of diverse class of micropollutants (for example: drugs, personal care products). As many urban wastewater are also mixed with road run off and stormwater the complexity of micropollutants that flow through WWTP ecosystem is of huge diversity and complexity. Even though, studies investigated the micropollutants' removal in Constructed Wetland (CW)[2] for some of them, these systems are still a micropollution discharge point. Therefore, a wide variety of micropollutants should be investigated to obtain a global view of this pollution. These non-targeted analyses can be performed, thanks to the improvement of high-resolution mass spectrometry hyphenated liquid chromatography (HRMS- MS/MS) based on analytical methods and the use of metabolomics databases.

The non-target analysis should help estimating the impact of micropollutants' release by the CW and prioritizing the micropollutant mitigation strategy. The analyses were first focused on sludge matrix of the tertiary wetland, located at the outlet of the CW, which accumulates micropollutants that bring environmental and health risks. On the other hand, micropollutants should also be examined in wastewater and in plants, to explain their potential origins, dynamics and transfer mechanisms and potential metabolism. In this way, a new method of extraction (reproducible, non-selective, and easy to implement) based on freeze-drying and a double extraction was developed to be in accordance with the non-targeted analysis. Then this non-targeted investigation of micropollutants was performed using a LC -HRMS-MS/MS. The identification method developed by Schymanski et al3 was used to identify the different metabolites in each compartment.

A large diversity of metabolites (around 2000 metabolites) was identified according the 3rd level of the Schymanski (tentative identified). Databases containing plant metabolites, lipids, drugs, pesticides, industry toxics were interrogated. By this strategy we could identify several emerging substances that were not revealed in other studies with the same scope. Furthermore, the wide variety of molecules identified allowed us not to focus on a family of compounds or some molecules from different groups. Besides, our data showed that most of these families were found in each compartment. Furthermore, most of the compounds were found at least in 2 compartments (more than 66%). In this way, these results highlight the dispersion of potentially toxic molecules in the whole environment

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C.P. 24

CONTRIBUTED PAPERS 24

WETLAND IMPROVEMENTS

Ana Galvão

CONSTRUCTED WETLAND DESIGNED WITH SYSTEMIC APPROACH

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Water supply, its treatment and its reuse need to be designed through a holistic approach, which considers the whole complexity of the issue. Systemic design approach is a supportive tool that helps designers and engineers to cope with complex problems and to generate sustainable solutions.
Indeed, it is based on the main principle that “that the output of a process can be the input for another one” and it focuses on the importance of relationship between system’s components.
The “output-input” principle overturns the concept of intervening at the “end of the pipe” and it suggests reusing treated water for productive processes, re-considering the quality of water for the reuse and minimizing the waste production. The systemic approach aims to re-think the linear water supply chain toward circular processes. It is particularly important in the framework of constructed wetland ecosystems, because the “circularity” of water reuse can generate new productive activities at local scale. Constructed wetlands with their rich biodiversity of plants, animals and microorganisms, need to be considered not only as a nature-based solution to the problem of grey water treatment, but also as the opportunity to improve local territories and to sustain the ecosystem health.

Based on these considerations, the systemic approach has been successfully applied, to create constructed wetland in several sites in the Piedmont Region (Italy). The research presents some study cases, i.e. small producers, that aim to recycle water in their production cycle, or farmers, that aim to maintain natural ecosystem and habitat in their farms, regardless of the crops they grow. Figure 1 show an example of a case study.

The study will highlight the positive and negative aspects together with the difficulties that arise from the application of this methodology.

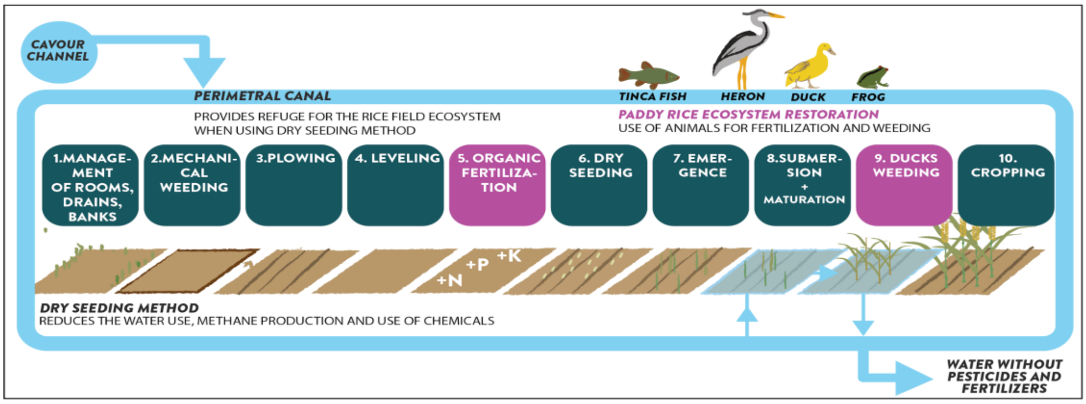

Figure 1. Example of Case study. Italian rice producer, that uses a dry seedling method. A perimetral constructed wetland has been designed as a canal, in order to restore and integrate the rice field ecosystem.

BIO: Elena Comino is professor in Applied Ecology for Environmental Engineering at Politecnico di Torino, she has long experience in laboratory as well in field. She has lead project on river restoration and on environmental education.

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CONSTRUCTED WETLANDS IN LATINAMERICA, A SUMMARY OF EXPERIENCE DURING THE LAST DECADE

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During the decade of 1970, many European countries start to research about the advantages and the limitations of Constructed Wetlands. Denmark as example, publish the Danish Guide Lines for Constructed Wetlands in the 1980 decade, based on different scientific results obtained at the local universities. After two decades to promote the technology, some European countries start to centralize the wastewater treatment using the technology, now days, only for the small communities and storm water. In the other hand, Latin-America only start to consider this technology until the 90´s decade, after the washout of the expensive and unfordable activated sludge systems (implemented around the continent during 20 years because the influence of the American model of wastewater management, based on effective and strong institutional framework). Many science men around the continent start to develop experiments and projects to prove and implement the technology in the Latin American conditions, however the efforts have been disjointed and now a days there is no reference about the state of the art of constructed wetlands in the region. This study aims to draw a general view of the technology to stablish a base for new steadies in order to obtain effective results, useful for the engineers, society and local governments. The results that are shown in this study, condense the local experience and knowledge of the most important constructed wetlands researchers around the continent, including experts from: Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, Paraguay and Peru. Finally, the study shows the result of analyzing different experiments in other countries like Jamaica and Barbados.

BIO: M.Sc. Marco A. Rodríguez-Domínguez is the Technical Secretary of the Panamerican Nerwork of Constructed Wetland (HUPANAM), part of the Bioscience Department as PhD student at the Aarhus University and Technology Director at Green Growth Group Mexico. He has nine years of experience related with constructed wetlands and water resources management.

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THE USE OF BIOASSAYS TO ASSESS THE TREATMENT EFFICACY OF CONSTRUCTED WETLANDS

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According to the German Federal Institute for Risk Assessment, more than 19 million substances are registered at the Chemical Abstracts Service (CAS). Approximately 100,000 of these chemicals are frequently used in the European Union and are subsequently released to the environment. Bioassays, also known as effect-based methods, are a complimentary approach to conventional water quality analysis, and are used to assess the sum effect of all pollutants in a given water sample (Neale et al., 2015). Effect-based methods have recently been applied to assess the performance of treatment wetlands (Nivala et al., 2018). This study uses bioassays to evaluate the removal efficacy of different constructed wetland designs over the course of an entire year.

Four pilot-scale treatment wetlands were investigated and sampled on a weekly basis. The systems include a classical horizontal constructed wetland (CW) with a saturated depth of 50 cm (H50p: 5.6 m^2 treating approximately 200 L/d), a horizontal saturated CW with aeration (5.6 m^2 treating approximately 580 L/d), a vertical saturated CW with aeration (6.2 m^2 treating approximately 580 L/d) and a reciprocating system (13.2 m^2 treating approximately 1,440 L/d). All constructed wetlands in this study are located at the research facility in Langenreichenbach (near Leipzig, Germany). A septic tank serves as a primary treatment step for all of the wetland systems. The wetlands have been in steady-state operation since 2010. A municipal wastewater treatment plant treating the same source wastewater as the wetlands was also included in the study. The systems were monitored weekly over the course of one year for classical wastewater parameters ($CBOD_5$, TOC, TSS, TN, NH_4-N, NO_3-N, NO_2-N and *E.coli*), selected micropollutants (caffeine, ibuprofen, naproxen, benzotriazole, diclofenac and acesulfame) as chemical indicators of treatment quality (Kahl et al., 2017), and a battery of bioassays was applied to quantify the mixture effects of organic micropollutants extracted by solid-phase extraction. The set of bioassays cover relevant steps of cellular toxicity pathways (xenobiotic metabolism, hormonal activity and adaptive stress reactions) and have been shown to serve as robust treatment quality indicator (Nivala et al., 2018).

This presentation will present and discuss the first year of monitoring results from the four treatment wetlands and compare them to the municipal wastewater treatment plant.

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BIO: Nadine Sossalla is a second-year PhD student at the Helmholtz Center for Environmental Research in Leipzig, Germany. The focus of her research is to identify and optimize the treatment performance of constructed wetlands by combining methods from toxicology, analytical chemistry and engineering.

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EXPERIENCES IN O AND M DEFICIENCIES OF A CONSTRUCTED WETLAND – MATURATION POND HYBRID TREATMENT PLANT

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Mexico has several experiences dealing with systems that apparently were properly calculated, designed, constructed, even community participation, and still do not comply with the discharge and reuse due to operation and maintenance deficiencies.

In the city of Acamixtla, Taxco, Guerrero, in México a hybrid system (constructed wetland and maturation pond) was established to treat domestic wastewaters at a rate of 3.2 L/s. The treatment plant includes a pretreatment, bar rack, follow by a sand trap, a three-stage anaerobic biodigestor, and follow by two parallel treatment lines, each on with a subsurface flow constructed wetland, sludge treatment constructed wetland, a surface flow constructed wetland to treat supernatant a maturation pond and a final polishing step by subsurface flow constructed wetland.

The first two years, the system complied with the discharge demands stated by the national authority in NOM-001-SEMARNAT-1996, that regulates discharges to water courses to protect aquatic life as well as for water reclamation. After the two years of operation, an additional raw wastewater sewer was connected to the systems. The new connection added raw wastewater form several communities at flow as high as 15 L/s. Consequently, the increased flow severely reduced the hydraulic residence time; increase the solids reaching the plant as well as the accumulation causing clogging, overflows, therefore preferential flows, and bad odors. Thus, life quality and health of the neighboring residents was affected, pollutant removal performance decreased affecting the receiving river biodiversity and the environment. An additional consequence was the reduction of the systems lifetime and a significate increase of O and M costs.

To refurbish the system a diagnosis was performed that included the actual pollutant removal (BOD, COD, TSS fats and oil and fats, TN, TP, FC, and helminth eggs), the assessment also included a revision of the dimensioning, identification of the construction errors and the entire systems was reengineered. The evaluation also studied the operator personnel training level to produce a list of actions to improve and refurbish the system. The main refurbishing actions included a new design of the biodigestor, replace the clogged media from the beds, as well as to change the hydraulic regime, new vegetation and the construction of an overflow channel to evacuate excess rains. Additionally, to the physical changes, the process included the participation of the local stakeholders and an awareness campaign, training of the plant personnel and involvement the state officials.
The construction process is already finished and the system is currently undergoing start-up and stable operation process. Analytical data is being regularly gathered and will be presented at the meeting.

Keywords: Operation deficiencies of treatment wetlands, treatment wetlands refurbish, maturation ponds.

ATTRIBUTE VALUE EXTRACTION MECHANISM OF CONSTRUCTED WETLANDS INFORMATION DATA

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Regardless of the importance of Constructed Wetlands (CWs) as pollution control technology, a survey conducted by *UNU-FLORES* in 2017 showed a clear demand for a global platform on CW. UNU-FLORES has taken up the challenge of developing a global online platform *"CWetlands - the Constructed Wetlands Knowledge Platform (CWKP)"* in which data from more than 7000 peer-reviewed journal articles are to be integrated. Given the number of articles and many more non-scientific documents, manual inspection and input of data into the database would be time-consuming and error-prone. This study aims at developing an attribute value extraction mechanism tool for the CWKP in R to extract meaningful information from peer-reviewed journal papers in a reliable and less time-consuming way. It focuses on the extraction of the following 18 attributes: *1) Country name 2) Name of the municipality 3) Latitude 4) Longitude 5) Wastewater type 6) System area 7) Plant species 8) Plant genus 9) Type of Constructed Wetland 10) Title of the article 11) Year of Publication 12) Journal name 13) Publisher 14) First name of the author/s 15) Last name of the author/s 16) DOI of the article, 17) Average BOD_5 inflow concentration 18) Average BOD_5 outflow concentration*, which describe the main characteristics of constructed wetlands systems and information about associated literature.

The process developed contains four sub-processes 1) the peer-reviewed articles in .PDF files are downloaded and converted to .txt format 2) the .txt files are processed to a) remove disordered strings, punctuation characters, multi-white spaces and stop words that otherwise hinder the text mining, and b) divide the text into sub-sections: Abstract, Introduction, Materials and Methods, Results, to allow for more targeted word searches. 3) the attributes are extracted by either one of the following data mining techniques: *3.1.1) Keyword Match:* the tool matches a Text Document Matrix created by the tool based on two pre-established criteria and a dataset of keywords created by the authors, and *3.1.2) Web Scrap*: the attribute value is extracted directly from the web page where the peer-reviewed article is available 4) the values extracted are exported to a database.

13 papers were used for the development and testing of the tool. The tool achieved a mean success rate of 79% in 30 minutes; less compared with the 480 minutes needed with a manual approach. Attributes like *Country name, Plant species,* and *Plant genus* showed high success rates (90-100%); on the contrary attributes as *Name of the municipality, Average BOD5 inflow concentration,* and *Average BOD5 outflow concentration* showed lower success rates (22.2-75%), so further improvements of the tool should focus on those attributes.

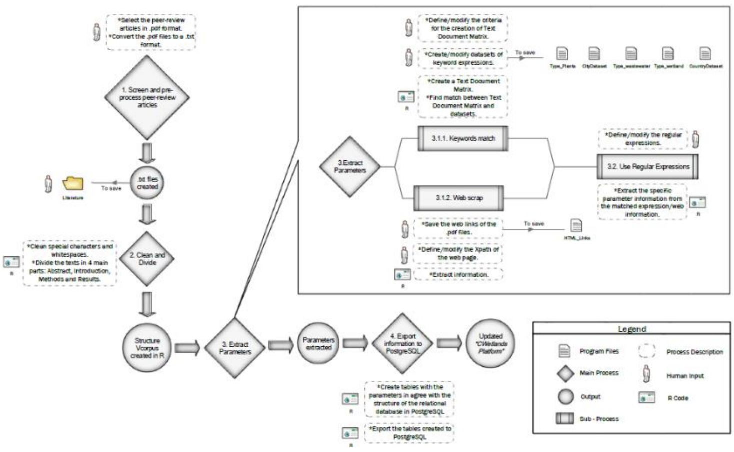

Figure 1. Graphical Abstract from article "Attribute value extraction mechanism of Constructed Wetlands Information data" (Submitted to the journal: MethodsX Elsevier)

BIO: Nevado is a junior researcher working as an intern in the project *"The Multifunctionality of Constructed Wetlands"* with Dr. Avellan, and carrying out a master degree in Hydroscience and Engineering in Technische Universität Dresden. Also, he will write his master thesis about Constructed Wetlands.

CONTRIBUTED PAPERS 25

P REMOVAL

Magdalena Gajewska

BIOSOLIDS FILTRATE NITROGEN MANAGEMENT IN A TIDAL FLOW ZEOLITE BED: AMMONIUM ADSORPTION, NITRIFICATION, AND ANAMMOX

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The Roseburg Urban Sanitary Authority, Oregon, USA treats approximately 15 MLD (15,000 m^3/d) of domestic wastewater by conventional activated sludge. Approximately 20 m^3/d of biosolids dewatering center screw press filtrate (~1,000 mg/L NH_3-N) requires ammonia-N removal.

Filtrate is treated using the zeolite-anammox process in a two-cell (parallel flow), tidal flow wetland constructed at the bottom of an unused aeration basin (Figure 1). Each cell is 3.4 m wide and 18.5 m long with 38 cm clinoptilolite over basalt drain rock. Cells discharge by siphon, flooding and draining the clinoptilolite bed about 10 times per day but leaving drainage rock flooded. Outflow is pumped back to the wetland dosing siphon or the activated sludge aeration basins as determined by a level sensor in the drainage basin. Operation started in November 2016.

The NH_3-N bed loading rate started at 11 g NH_3-N/m^3·d, rising to 207 g NH_3-N/m^3·d in OCT 2017, and is currently at 542 g NH_3-N/m^3·d. In the first year of operation 95% of NH_3-N was removed, but lagged nitrification from adsorbed NH_4^+ created NO_3-N outflow concentrations greater than inflow NH_3-N MAR-OCT 2017 (Figure 2). Alkalinity demand dropped to zero in OCT 2017 with pH consistently > 7. Peak NO_2-N was 50 mg/L in JUN 2017. Outflow NO_2-N dropped to non-detect in NOV 2017 where it has since remained. Outflow NO_3-N has averaged 81 mg/L from NOV17. Oxidation of inflow NH_3-N was 95% NOV16-OCT17 and dropped to 50% NOV17-JAN19. Outflow NO_3-N has averaged 81 mg/L from DEC17.

Loss of outflow NO_2-N concurrent with loss of alkalinity demand indicates that most DIN removal was via anammox, which is alkalinity neutral and NO_2-N consuming. Complete NH_3-N oxidation up to bed loads of 20711 g NH_3-N/m^3·d but approximately halving thereafter suggest that the zeolite bed is currently absorption-limited.

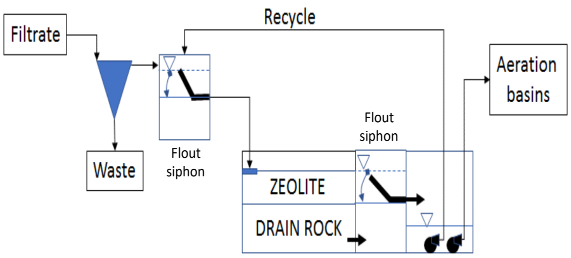

Figure 1. Section flow schematic

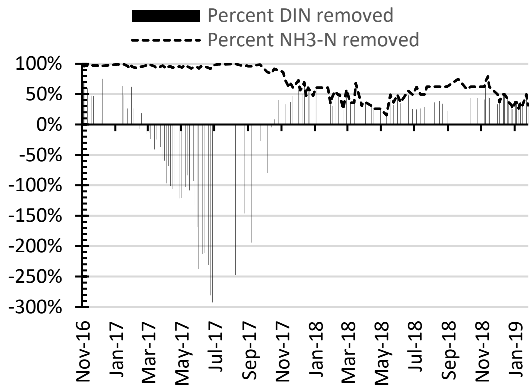

Figure 2. Percent DIN and NH_3-N removal

BIO: David Austin is the Natural Treatment Systems Lead for Jacobs Engineering Group. He is a professional engineer and certified senior ecologist (Ecological Society of America). Mr. Austin has had extensive experience with wetland technology development since 1996.

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NEWLY DEVELOPED MATERIALS FOR PHOSPHORUS REMOVAL, RECOVERY AND REUSE FROM TREATMENT WETLANDS

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Treatment wetlands (TWs) are engineered wetlands targeting pollutants in waters affected by anthropogenic activities using biological processes occurring in natural wetlands. These systems have gained popularity, as they are robust, reliable, easily maintained, and require low external energy input, which make them an appropriate technology for decentralized wastewater treatment. TWs have proven efficient at removing certain pollutants; however, sustained phosphorus (P) removal has proven difficult. Overall, P removal, recovery and reuse is important, as the global supply of mineral P is becoming exhausted, while P demand is increasing. The available strategies in P removal include media adsorption, chemical precipitation, sedimentation, and vegetation uptake with subsequent harvest, and the strategies have been evaluated with diverging success.

One of the objectives was to evaluate P sorption by newly developed materials to improve P removal. We screened more than 20 materials by testing P removal potential using adsorption isotherm experiments, and the screening determined P binding capacities ranging from -0.3 to 23.5 mg P g^{-1} dw. After the removal potential was confirmed, the materials with P removal capacity were submitted to different coating processes to improve P binding capacity, mechanical characteristics, and hydraulic performance. Once coated, the improved materials were also tested using isotherms experiments to confirm P removal potential. Subsequently, long-term column experiment is currently being performed on selected materials from the screening process to determine total P binding capacity. The experiments are still running, and for an entire year results have revealed consistent P binding capacities.

Two coated materials that showed the highest potential, hence, high P binding capacity, good hydraulic and mechanical performance, are currently being tested under real operational conditions. Two external filters of 1 m^3 filled with one of the materials have been installed at two wastewater treatment plants in Spain, both receiving secondary treated wastewater with a P concentration of 14 mg L^{-1} and consistently producing effluent concentration below 1.5 mg L^{-1}, hence a P-removal rate of approx. 90 % from both treatment facilities.

Additionally, since one of the objectives was to recover and reuse nutrients, the bioavailability of P sorped in materials is being evaluated in mesocosms to determine if P bound to the material is bioavailable for plant uptake in Maize.

BIO: S.M. Jensen is a PhD student at Aarhus University working with nutrient removal, recovery and reuse in plant-based TWs. She has been involved in two projects, PLANTNAT and INCOVER, working with optimization of TWs, and she has worked in the field of TWs the last three years.

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IRON-ENRICHED ALUMINA AS AN ADSORBANT MEDIUM FOR P-REMOVAL AND RECOVERY FROM CW'S EFFLUENTS

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Since the first realizations in the early 1990's, CW's have become the standard process for waste-water treatment for small rural communities in France. Over 5000 plants are operating today, with capacities up to 5000 PE. This success story is due to the great advantages of this process, compared to the other techniques available, mainly

- competitive investment and operation costs,
- high outlet standards for TSS, COD, BOD, KN, and TN, and
- great high reliability, even under insufficient maintenance or overloading.

Nevertheless, P-removal remains the CW's Achilles' heel, with poor and irregular performances. Over the past few years, a lot of research has been done on this topic. Various filtration media have been proposed for this purpose: apatite, furnace slags, green rust clays, Bauxaline®, PhosClean®, etc. But none so far has proven sufficient performance and reliability to be implemented as a standard for P-removal from CW's effluents.

Iron oxides are well-known for having a strong adsorption affinity for phosphate ions. We developed with IFPEN (Institut Français du Pétrole-Energies Nouvelles) an engineered filtration medium, using a micro porous alumina granulate as a substrate, on which ferric oxide is grafted. A previous lab work has proven the feasibility of P-removal and P-recovery from CW's effluents by simple filtration through this medium (Patent n°FR3062849).

A pilot-scale field unit is presently under trial in a VFCW near Toulouse (France) since march 2018. Two sets of 3 reactors are filled with 85 L of either pure, or iron-enriched, alumina. Increasing hydraulic loads (flow/volume) of 0.30, 0.60, and 1.20 h^{-1} are applied to each set.

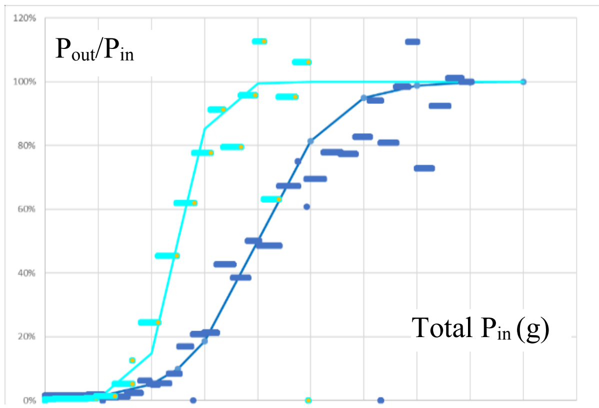

Figure 1: P break through curves trough pure (light blue) or iron-enriched (dark blue) alumina.

Total saturation of the medium was achieved after 25 weeks of quasi-continuous feeding under 1.20 h^{-1} hydraulic load. The total sorption of Phosphorus was monitored at 23.4 gP/kg of substrate. Results show that iron-enrichment of the alumina substrate brings an 68% increase in P-sorption capacity, compared to pure alumina.

Further work will include the effect of regeneration of the two media on their total P-sorption capacity.

BIO: François CORNET is a senior waste-water engineer, specialized in constructed wetland design and construction for municipal waste-water treatment. He has realized over 50 plants, from 50 to 5000 PE. In 2016, he founded MAANEO, a startup company, to develop an innovative process for Phosphorus removal and recovery from CW's effluents.

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EFFECTIVENESS OF WETLAND SYSTEM TO RETAIN NUTRIENTS: CASE STUDY OF SMILTELE STREAM (LITHUANIA)

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Constructed wetlands or ponds are one of ecological engineering approach to clean river, streams or even wastewater. In 1996 engineering tool of 6 cleaning ponds (2 – sedimentation ponds, 3 – ponds covered by vegetation to induce aerobic nutrient removal and 1 – pond for anaerobic conditions) was applied in Smiltele stream (Lithuania). This system was used to treat water by decreasing negative influence of organic pollution and increasing self-cleaning capacity of Smiltele stream due to an ecosystem importance for sea trout juvenile's migration. It is calculated that the watershed was roughly loading 4.6 t/yr of total phosphorus (TP). During 12-year period ponds system were overgrowthed by plants and sediments overfilled with settlements, consequently in 2018 the study of nutrient retention in ponds were measured. Monthly nutrients (total, particulate and dissolved P) samples were taken from each ponds system and metabolic process between sediments and water interface was evaluated. Results showed that yearly into the pond system is loaded 6.8 t of TP and the highest input was during November-January periods containing about 13-41 % of yearly input. Lowest input was measured during summer entering 1-3% of yearly input. Created sedimentation ponds was accumulating entered TP (~23% of entered) during autumn-winter period while in summer the TP regeneration was measured (27 % of entered TP). Aerobic removal part was taking up phosphorus during all year with highest uptake in summer (~46 % of TP entered from sedimentation pond). Anaerobic pond is not working properly while entered lower TP from aerobic pond was regenerated especially during summer period (around 13% of entered TP). P forms analysis demonstrated that P uptake was determining for DIP in ponds and generating mostly particulate P form. Only in sedimentation and aerobic ponds during July and August months DIP was generated. It was fate of internal P regeneration from sediments while in summer measured fluxes reached 13.0, 6.2 and 1.9 mg/m^2h in sedimentation, aerobic and anaerobic ponds, respectively. Study demonstrate that ponds are not working properly and some ponds may become the nutrient source releasing nutrients from sediments.

Keywords: wetlands, nutrients, pollution.

PILOT HYBRID CONSTRUCTED WETLANDS FOR COOLING TOWER WATER TREATMENT

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The uptake of fresh water for cooling processes accounts for a significant part of the total fresh water uptake in industrialized countries. The reuse of discharged cooling tower water (CTW) in the cooling tower itself could significantly mitigate future fresh water scarcity problems caused by industrial fresh water withdrawal. Discharged CTW has a moderate electric conductivity of 1500-4500 mS/cm, while an EC of <1000 mS/cm is typically required for reuse in cooling towers (Groot et al., 2015). Hence, reuse of the CTW in the cooling tower itself requires physicochemical desalination. However, physicochemical desalination of the CTW is hampered by different fractions of the CTW, such as TOC, PO_4, NO_3 and added conditioning chemicals (Lowenberg et al., 2015). These conditioning chemicals, such as biocides, corrosion inhibitors and antiscalants, are used to prevent fouling, corrosion and mineral scaling of the water circuit. The removal of these conditioning chemicals and TOC, PO_4 and NO_3 prior to physicochemical desalination could enhance the desalination efficiency. A potential pre-treatment method to remove these conditioning chemicals prior to physicochemical desalination is the use of constructed wetlands (CWs).

To test the potential of CWs for cooling tower water pretreatment prior to desalination, pilot hybrid constructed wetlands consisting of an open water flow, horizontal subsurface flow and vertical subsurface flow compartment in various sequences were constructed. These hybrid-CWs were fed with a synthetic cooling tower water. The objectives of this study were i) To study the removal of cooling tower water fractions that hinder physicochemical desalination technologies, such as PO_4, TOC, NO_3 and micro-pollutants in the different parts of the hybrid-CWs; ii) To study the dominant removal mechanisms that are responsible for the removal of these fractions; ii) To study the influence of biocides in CTW on the microbial activity in the CW; iv) To study the influence of West-European winter conditions on the pre-treatment efficiency of the CW; v) To study whether there is an optimal sequence of CWs with different flow-types for the treatment of CTW.

In this oral presentation, we will show that CTW fractions, such as NO_3, PO_4 and TOC are sufficiently removed to increase the lifespan of desalination technologies. In addition, the hybrid-CWs are efficient in removing micro-pollutants, such as corrosion inhibitor benzotriazole and biocides DBNPA and glutaraldehyde. The horizontal subsurface flow CW and vertical subsurface flow CW showed a significantly higher removal efficiency than the surface flow CW. The removal mechanisms responsible for this efficient removal are biodegradation, adsorption and plant uptake. Biocides in realistic CTW have been shown to influence the microbial activity in preliminary batch experiments. In the presentation, we will show the actual impact of the biocides on the hybrid-CWs. In addition, the impact of the winter 2018-2019 on the hybrid-CW functioning will be provided and conclusions will be drawn on the most optimal design of a hybrid-CW for CTW treatment.

BIO: Thomas Wagner is a 4th year PhD-candidate working on the design of constructed wetlands for the treatment of saline industrial wastewater. His focus is on elucidating relevant removal mechanisms for various micro-pollutants and determining their effects on potential toxicity. This knowledge is used for the optimal design of constructed wetlands.

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C.P. 26

CONTRIBUTED PAPERS 26

METALS

Gijs Du Laing

METALS AND SALTS FRACTIONING IN A REED BED – FREEZING BED SYSTEM TREATING SEPTAGE

***Chris Kinsley**[1,2], Kevin Kennedy[1] and Anna Crolla[2]*
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[2]Ontario Rural Wastewater Centre, University of Guelph, Guelph, Canada

Metal partitioning between the raw septage and filtrate was evaluated over a four year period from two reed beds (RB1,RB2) and one sand bed filter (SF). Overall very high percent removal of heavy metals was observed with strong correlation to TSS removal. Ni was found to be the most water soluble of the heavy metal species 10.9% concentration of Ni observed in the filtrate, which is consistent with literature. Metals in the filtrate were lower than the recommended maximum concentrations for irrigation (WHO, 2006), with the exception of Mn, which was just above the recommended limit value. At these concentrations, manganese can be toxic to a number of crops, but usually only in acidic soils.

Lower removal rates were observed with salts (Ca, K, Mg and Na), which are all water soluble. Significantly higher concentrations of salts (Ca, K, Mg, Na) as well as Mn were observed in the SF filtrate compared with at least one of the reed bed filters and significantly lower concentrations of Co and Ba in the RB2 filtrate were observed compared with the other two filters; generally reflecting higher average hydraulic loading rates in SF throughout the study. Filtrate SAR was calculated to be 2.0, which falls within the typical range for irrigation water and poses no risk of affecting soil infiltration rates. (WHO, 2006). The limited differences in filtrate concentrations observed with hydraulic loading rates mostly relate to readily dissolved salt species, indicating that varying HLR had little to no impact on filtrate heavy metal concentrations.

The effect of operating period (Freeze-thaw (FT) vs Growing (G)) was evaluated over the four year study. Metals with the highest removal rates were found to have higher filtrate concentrations in the FT periods than during the G periods and were negatively correlated with raw septage quality, suggesting that FT cycles in sludge increased mobilization of metals through increased migration of colloids through preferential pathways. The remaining metals exhibited decreased concentrations during FT periods as compared to G periods, likely relating to positive correlations with raw septage concentrations.

The effect of year, which represents the accumulating sludge cake, was less evident, with only 6 of 15 metal species exhibiting a significant difference; with Ba, Mn and Ti decreasing with time as As, Ca and Zn increased with time. Decreases could relate to more effective filtering through the accumulated sludge cake, while increases could relate to increased desorption or solubilisation and release. Even with the slight variations observed, the data indicated that heavy metals were stable within the sludge cake with variations by season and time very small compared with raw sludge concentrations.

The regulated metals were evaluated in the dewatered septage cake at the end of year 4 and had lower concentrations than municipal sludge for most metal species, with similar values observed for Cu, Mo, Se and Zn and meet the threshold for restricted land application in Ontario, Canada.

BIO: Dr. Kinsley is an Assistant Professor in Environmental Engineering at University of Ottawa and Associate Director of the Ontario Rural Wastewater Centre with 20 years of experience developing and studying constructed wetland systems for rural and industrial wastewater applications.

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ANOXIC CONDITION IN SEDIMENT CHANGES THE PHYTOEXTRACTION OF METALS BY SUBMERGED MACROPHYTES

***Juan Wu**, Yangyu Song and Shuiping Cheng*
Tongji University, Shanghai, China

Eutrophication in wetlands is usually accompanied by anoxic condition in the sediment, which is followed by complex chemical and biological processes, consequently affecting the biogeochemical behaviors of metals in the sediment. Although using aquatic macrophytes for phytoremediation of heavy metals in the eutrophic water bodies has been studied for decades, knowledge about the influence of the anoxic condition of sediment on phytoremediation of metals and the fractions of metals in the sediment is still lacking. The present study investigated the effects of anoxia of sediment on phytoextraction of metals and their fractions in the sediment, which would provide some support for ecological remediation of eutrophic water bodies and metal pollution control.

With simulating different levels of sediment anoxia using adding different dose of sucrose into the sediment, we investigated the relations between redox condition and other physicochemical parameters, and the effects of redox condition and submerged macrophyte *Potamogeton crispus* L. on the mobility and releasing potential of metals in sediment.

The results indicated that the sediment anoxic treatments reduced the pH and redox potential (ORP) in sediment, conversely improved the total organic carbon (TOC) concentration in porewater. The effects of sediment redox condition on the reactivity of metals are metal species specific. Sediment anoxia increased the concentration of Fe, Mn and Cr in porewater, especially for Fe and Mn, which had a mean concentration in the sever sediment anoxic treatment as high as 15.4 and 4.0 times of that in the non-anoxia treatment. However, sediment anoxia showed somewhat inhibitive effect on the release of Ni and Zn during the initial phase of the experimental duration (0-56 days), although which became negligible thereafter. The concentration of Cu in porewater was not affected by the redox condition of sediment.

In conclusion, the mobility and releasing potential of metals in sediment are significantly affected by the redox condition of sediment, and compared to which the influence of submerged macrophytes on their biogeochemical behaviors is not notable.

BIO: Dr. Wu has a more than 10 years' experiences of research on interactions between freshwater environment and marophytes, and the technologies of ecological restoration in aquatic waterbodies. Her work is also focused on water treatment with constructed wetlands.

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A CONSTRUCTED WETLAND POPULATED WITH TYPHA AND VETIVER FOR GOLD MINE TAILING STORAGE FACILITIES SEEPAGE TREATMENT

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Gold mine tailing storage facility (TSF) seepage causes a threat to the mining site and nearby environment. The potential impacts of such untreated seepage are the contamination of soil, surface water bodies and groundwater. A pilot constructed wetland (CW) has been built and populated with two plant species, namely *Typha domingensis* and *Chrysopogon zizanioides*, at 30 plants per m^2. The CW consisted of a 1.5 mm thick High Density Polypropylene sealed trench, of 50 m length by 1.5 m width and containing 0.15 meter of soil for root growth. Three liters per minutes of seepage from the tailing dams was fed to the CW. This seepage had a pH of 7.70 ± 0.26, an ORP of 147.87 ± 70.47 mV, a TDS of 3275 ± 559 mg/l, a conductivity of 6541 ± 1116 µS/cm and trace metals of 84.63 ± 47.30 µg/l, 777.95 ± 2012.83 µg/l, 59.67 ± 32.60 µg/l and 18.35 ± 18.23 µg/l for As, Co, Pb and Zn respectively. Weak acid dissociable cyanide was 0.3 mg/l. The ability of both plant species to grow in these specific conditions of carbon in leach (CIL) using cyanide sodium and calcium carbonates based processing of the gold was estimated by measuring the biomass production. Secondly trace element uptakes by the two species were evaluated.

Biomass production of *T. domingensis* is time dependent and highest biomass production was found during the first two weeks with 0.29 ± 0.06 g/day per plant (dry weight, dw). Comparatively *C. zizanioides* biomass production was slow and constant at a rate of 0.04 ±0.02 g/day per plant, dw. Trace element analysis of the two species revealed uptake of trace elements from the seepage to the aboveground parts with *C. zizanioides* level higher than *T. domingensis* for As, Cr and Zn. *T. domingensis* aboveground parts bioaccumulation factor (BF) were 5.11, 1.46, 4.69 and 371.05 for As, Co, Pb and Zn. *C. zizanioides* aboveground parts bioaccumulation factors were 7.99, 1.11, 4.42 and 523.52 for As, Co, Pb and Zn respectively.

In the CW receiving gold processing tailing dam seepage, *T. domingensis* exhibited higher biomass production than *C. zizanioides* and exhibited higher standing stock after six months growth. Mixed species subsurface wetland shown interesting results for gold processing tailing seepage treatment, particularly their different behavior according to inlet flow rate, which is under investigation in the context of flow rate fluctuation over time.

BIO: M. Wendkuuni Florentin COMPAORE is PhD student in Environmental Technology at Ghent University Campus Kortrijk. At the Department of Green Chemistry and Technology, M. COMPAORE is working on industrial wasteland reclamation with special focus on mining site rehabilitation. M. COMPAORE is working for Burkina Mining Company.

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PASSIVE HYBRID TREATMENT SOLUTION FOR MINING EFFLUENT IN ARCTIC CONDITION

Sepideh Kiani[1], *Mirkka Hadzic*[3], *Elisangela Heiderscheidt*[1], *Kaisa Heikkinen*[3], *Satu-Maaria Karjalainen*[3], *Anne Korhonen*[3], *Katharina Kujala*[1], *Kaisa Lehosmaa*[2], *Heini Postila*[1], *Ritva Nilivaara-Koskela*[3], *Anna Maria Pirttilä*[2], *Anna-Kaisa Ronkanen*[1], *Anna Liisa Ruotsalainen*[2] *and Piippa Wäli*[2]

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[3]Finnish Environment Institute, Freshwater Center, Finland

Acid mine drainage (AMD) is one of the most serious sources of contamination to surface and ground waters that results from mineral processing activities. Such activities often generate substantial volumes of wastewater, which contain high concentrations of sulfate, dissolved metals and other potentially toxic compounds. For countries inheriting a historical legacy in mining, such as Finland, together with harsh climatic conditions, efficient treating of AMD has become a prominent issue. Traditional active wastewater purification methods are generally not cost-effective for treatment of large volumes of AMD produced in a number of active and closed mining sites. Hence, there is an essential need for simple, low cost and low maintenance technologies to be used, developed, or optimized for reducing pollutant loads. This study is part of the ERDF-funded project "Passive hybrid treatment solutions to remove nitrogen and heavy metals from different types of waters in arctic region (HybArkt)". One objective of the project was to design and construct an on-site passive hybrid treatment system for removal of sulfate and metals at a mining site (Pyhäsalmi) in Finland. The wastewater used in this study consists of tailing pond leachates, runoff from forest and old metal contaminated area.

Based on water quality and site characteristics, as well as intensive literature research on the most suitable passive and innovative methods for sulfate and metal removal, a hybrid system of five main units and a parallel unit of moss-based biofilter was designed and constructed (fall 2018). The main system combines in sequence oxic alkalinization channels, oxidation wells, sedimentation units, biofilter mushroom units, and solid passive bioreactors, and both units are combined into a vertical wetland. The oxic alkalinization channels were designed to raise the pH of the mining water (pH <4) and consist of two parallel channels, one packed with crushed concrete (particle size 2-4 cm) and the other with calcite (3-5 cm).The water is then aerated in aeration wells and directed to sedimentation units (0.47 m^3), where precipitation and removal of metals (e.g. Fe, Mn and Al) by settling is achieved. The subsequent biofilter system consists of woodchip bags inoculated with mushroom culture. In the mushroom and parallel moss (*Warnstorfia fluitans*) units, metals are removed via biosorption, adsorption, absorption and sedimentation, and they may also contribute to nitrogen and phosphorus removal. The water is next introduced to two different parallel solid passive bioreactors (10 m^3), one packed with woodchip and other with a mixture of woodchip and biochar to provide additional sulfate and metal removal (e.g. Fe, Al, Cd, Cu, Mn and Zn) due to the activity of sulfate reducing bacteria (SRB) fueled by the added solid carbon. The last treatment stage is a vertical wetland planted with common reed (*Phragmites australis*). The wetland functions as a polishing stage, which captures nutrients and metals potentially leaching from previous units.

The hybrid system is under continued monitoring for comprehensive assessment in winter and summer conditions in the arctic region. Results over the first 4 months of operations (winter) will be presented.

BIO: MSc. Kiani is PhD candidate at University of Oulu focusing on passive bioreactor systems. She is working as part of the ERDF project focusing on passive treatment solutions. Moreover, she is working on innovation recirculating aquacultures systems combined with passive treatment units.

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CAN SUNLIGHT INFLUENCE EFFECTS OF NANOSIZED ZNO ON STREAM FUNCTIONING: A CASE STUDY ON LEAF LITTER DECOMPOSITION

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As one of the emerging contaminants, manufactured nanomaterial has been widely used in a variety of commercial productions due to their unique physicochemical characteristics. With the increasing production and application of nanomaterials, their toxicological effects on freshwater ecosystem have been received more and more attentions recently. Among the most abundantly used nanomaterials, zinc oxide nanoparticles with an output between 100 and 1000 tons per year worldwide are used in a wide range of products such as food, sunscreens, cosmetics, coating, rubber manufacture, medical materials, and facade paints. Extensive use increases the probability of ZnO nanoparticles discharge to the environment, thus increasing the potential threat to various organisms.

To comprehensively assess the effects of ZnO nanoparticles on freshwater ecosystem functioning under natural sunlight, we conducted an indoor microcosm experiment on *Populus nigra* L. leaf decomposition with ZnO nanoparticles (5, 10, and 20 mg L^{-1}) under simulated sunlight. A significant and negative relationship between decomposition rate and ZnO nanoparticle concentrations was observed after 30 days of exposure. The ZnO nanoparticles showed significant inhibitions on extracellular enzyme activities, dehydrogenase activities and fungal biomass as well as impacts on fungal community structure. Additionally, exposure to ZnO nanoparticles increased microbial antioxidant activity and 5 mg L^{-1} of ZnO nanoparticles achieved the strongest promotion. Importantly, the activities of carbon-related enzymes were significantly inhibited by ZnO nanoparticles, but leaf carbon decomposition were promoted in the microcosms containing 10 and 20 mg L^{-1} of ZnO nanoparticles, suggesting the possible contribution of ZnO nanoparticles physicochemical property under sunlight to leaf decomposition. Therefore, information on the effect across different concentrations of ZnO NPs under sunlight will help us to better evaluate the impacts of ZnO NPs on stream functioning.

BIO: Dr. Du is an associate professor with more than 5 years of experience assessing and restoring freshwater ecosystem projects. She has extensive experience with river restoration and assessment, and has participated more than 5 projects dedicated to preserving and restoring freshwater ecosystem.

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C.P. 27

CONTRIBUTED PAPERS 27

EMERGING CONTAMINANTS

Pedro Carvalho

CONSTRUCTED WETLAND BIOREMEDIATION OF CHLORINATED ORGANIC COMPOUNDS IN A GROUNDWATER CAPTURE AND REINJECTION SYSTEM

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Background/Objectives: Control and treatment of a mixed inorganic and chlorinated VOC groundwater plume emanating from a historical unlined waste storage lagoon was required as part of an overall strategy to remediate a complex mixture of dissolved chemicals in an alluvial aquifer with sands and silts. Constituents requiring treatment included nitrate (>500 mg/l), sulfate (>350 mg/l), tetrachloroethylene (PCE) (~5,000 µg/l), carbon tetrachloride (CT) (~250 µg/l), cyanide (CN) (~200 µg/l), and molybdenum (Mo) (~200 µg/l). Previous operations to treat the groundwater through conventional ex-situ approaches, while successful, were found to be costly. Therefore, one of the primary objectives was to develop a system to treat this complex array of constituents in a cost-effective manner and to manage long term operation and maintenance (O&M) costs. Factors such as groundwater conservation and sustainability also factored into the decision-making process.

Approach/Activities: Based on the results of a technology screening it was decided to utilize hydraulic control with upgradient reinjection as the primary means to control plume migration. An evaluation of treatment methods for the extracted water identified biological treatment utilizing constructed wetlands as a viable treatment alternative to conventional methods. The design included an anaerobic horizontal subsurface flow (HSSF) wetland to function as a bioreactor to remove nitrate, sulfate, Cr^{6+}, Mo, PCE and CT followed by an aerobic vertical flow (VF) wetland to remove ammonia, cyanide, and reduce the biological oxygen demand prior to filtration and reinjection to the aquifer. The HSSF wetland was filled with a layer of locally-sourced wood chips (~2 m) to provide a carbon source and create reducing conditions. Water level is maintained just below the top of the wood chips as it moves laterally through the HSSF wetland. The VF wetland includes a sand layer (~1.5 m) with an underlying gravel drainage layer. Water is introduced at the top of the sand and moves downward via unsaturated flow. Both the HSSF and VF wetlands are topped with 0.5m of peat and indigenous wetland plants. Parameters including mass loading, temperature variation, degradation rates, evapotranspiration and the rate of carbon release from the wood chips were used to determine the HSSF wetland bioreactor volumes.

Results/Lessons Learned: Reducing conditions were quickly created in the HSSF wetland after being filled with extracted groundwater and have been consistently maintained throughout the HSSF wetland with only minor addition of biologically available carbon in the colder months. Nitrate and sulfate reduction greater than 99% and 75%, respectively within the first 25 percent of the wetland is observed, and effluent concentrations for all parameters continue to be less than discharge limits. After approximately 6 months of operation and data collection, it has been observed that reductive dechlorination commenced without the addition of cultured dehalococcoides and chlorinated VOC initial concentrations of greater than 10 µg/l are consistently reduced by more than 99% in the effluent of the HSSF wetland. This supports the reductive dehalogenation of PCE to vinyl chloride, degradation of CT and CN, and removal of Mo through the remainder of the wetland. The second-stage VF wetland has been successful in reducing BOD (75%) and vinyl chloride (88%), but residual BOD and vinyl chloride in the effluent are a concern and are being evaluated to determine if adjustments to the VF wetland are needed. Data collection is ongoing, and approximately 1 year of data will be compiled for presentation at the conference.

BIO: Scott Wallace is a technology expert with more than 25 years of experience designing, constructing and operating wetland treatment systems. He is the co-author of *Treatment Wetlands, Second Edition*, widely considered the definitive textbook on wetland design, and is a pioneer in the development of intensified wetlands.

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REMOVAL OF THE PESTICIDE TEBUCONAZOLE IN CONSTRUCTED WETLANDS: DESIGN COMPARISON, INFLUENCING FACTORS AND MODELLING

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Constructed wetlands (CWs) have become widely used to treat pesticide contaminated wastewater as an economical, robust and sustainable technology, but its implementation is impeded by lack of data to optimize designs and operating factors. Unsaturated and saturated CW designs were used to compare the removal efficiency, kinetics and mechanisms of triazole pesticide, tebuconazole, in unplanted mesocosms and mesocosms planted with five different plant species: *Typha latifolia, Phragmites australis, Iris pseudacorus, Juncus effusus* and *Berula erecta*. The main influencing factors (system design, HLR, initial concentration and plant species) of tebuconazole removal in both types of CW design were investigated. Moreover, artificial neural network (ANN) and traditional linear regression models were compared in order to explore a simple and robust methodology suitable for predicting tebuconazole removal in CWs.

Tebuconazole removal efficiencies were significantly higher in unsaturated CWs than saturated CWs, showing for the first time the potential of unsaturated CWs to treat tebuconazole contaminated water. The artificial neural network model was demonstrated to provide more accurate predictions of tebuconazole removal than the traditional linear regression model. Also, tebuconazole removal could be fitted an area-based first order kinetics model in both CW designs. The removal rate constants were consistently higher in unsaturated CWs (range of 2.6 - 10.9 cm d^{-1}) than in saturated CWs (range of 1.7 - 7.9 cm d^{-1}) and higher in planted CWs (range of 3.1 - 10.9 cm d^{-1}) than in unplanted CWs (range of 1.7 - 2.6 cm d^{-1}) for both designs. The low levels of sorption of tebuconazole to the substrate (0.7 - 2.1%) and plant phytoaccumulation (2.5 - 12.1%) indicate that the major removal pathways were biodegradation and metabolization inside the plants after plant uptake. The main factors influencing tebuconazole removal in the studied systems were system design, hydraulic loading rate and plant presence. Moreover, tebuconazole removal was positively correlated to dissolved oxygen and all nutrients removal.

BIO: Dr. Tao Lyu is a Postdoc Research Fellow in Nottingham Trent University, UK. His research focuses on the modelling and removal intensification of emerging organic pollutants in Constructed Wetlands. His current research projects also cover the eutrophication control and sediment remediation by advanced nanomaterials.

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EVALUATION OF THE EFFICIENCY OF REMOVAL OF EMERGING POLLUTANTS THROUGH WETLANDS CONSTRUCTED OF HORIZONTAL SUBSUPERFICIAL FLOW

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The presence of pharmaceutical micropollutants and personal care products (PPCPs) in ecosystems have become an important environmental problem due to their high consumption and the potential threat they represent in ecosystems since they can be toxic to living beings affecting vital activities such as its growth and reproduction. The problem increases when it is demonstrated that wastewater treatment plants (WWTPs) are not efficient in the elimination of most of these pollutants. Due to their physical and chemical properties, they are recalcitrant and therefore suffer little or no degradation during treatment, consequently, a high proportion of these compounds and their possible metabolites can reach the water bodies. Faced with this situation, biological systems have been studied as alternatives to reduce the risk of the presence of PPCPs in the environment, achieving high elimination efficiencies at low cost. This research evaluated the removal efficiency of two drugs: Carbamazepine (Cbz) and Sildenafil (Sil) and a personal care product: methylparaben (Mp), in constructed wetlands of horizontal subsurface flow at pilot scale, planted in polyculture with Heliconea Zingiberales and Cyperus Haspan, and without planting. The (PPCPs) were incorporated in synthetic wastewater in concentrations of 0.2 mg / L. The work flow was 15 mL / min and the hydraulic retention time of three days. In order to know the internal conditions of the systems, physicochemical parameters were evaluated, such as: Organic load, dissolved oxygen, temperature, conductivity, dissolved solids and pH. Removal efficiencies greater than 97% were obtained for the Mp, while removals of less than 10% were obtained for Cbz, both in the planted and unplanted wetlands. The Sil was removed efficiently in the planted systems, with removal percentages up to 97%, while in the unplanted the removals decreased by almost 30%. The average elimination efficiency for organic matter was 95%. It was determined that constructed wetlands efficiently remove compounds of complex molecular structure, such as Sil, as well as simple structure, such as Met. The Cbz remained a recalcitrant pollutant.

INTENSIFIED CONSTRUCTED WETLANDS FOR CSO/SSO-TREATMENT TO ACHIEVE IMMISSION-ORIENTED THRESHOLDS FOR PHOSPHORUS, MICRO POLLUTANTS AND PRIORITY SUBSTANCES ACCORDING TO WFD

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The German regulation for the protection of surface waters (OGewV) supplements and substantiate the requirements regarding the implementation of the Water Framework Directive (WFD) and contains detailed regulations regarding the classification, presentation and monitoring of the ecological and the chemical status of surface waters including thresholds for phosphorus. The quality of Germany's water bodies has greatly improved in recent decades. Despite the considerable advances that have been made in the sewage treatment domain, point source pollution from certain nutrients and pollutants remains unduly high and thus needs to be reduced. This applies, for example, to phosphorus, as well as micro-pollutants (MPs) that in many cases cannot be adequately eliminated at wastewater treatment plants. In addition such inputs from combined sewer and rainwater (separate sewer) overflow (CSO/SSO) are also still a problem in certain water bodies.

Sub-surface vertical flow constructed wetlands (SSVF) have been used since the late 1990s for CSO/SSO because of its high mechanical and biological efficiency. To achieve in particular a stable and long-term phosphorus reduction iron-containing substances are blended so far to large-scale SSVF as additives during the construction. However, some disadvantages in this type of substrate improvement must be stated. High and thereby costly material and installation costs are required and a subsequent melioration of a SSVF under continuous operation is impossible. The only possibility exists in the cost-intensive replacement of the entire soil body including replanting. All disadvantages can be avoided if instead of a substrate melioration a separate sorption stage, which is filled exclusively with iron-containing additives, is connected downstream of the SSVF. The material consumption is limited only to this sorption stage. This paper gives the results of an appropriate 3 year large-scale investigation including reduction rates and operational data concerning the standard parameters with the main focus on phosphorus as well as selected MPs and selected heavy metals as four of the six heavy metals investigated are classified as priority or even priority hazardous substances.

The sorption stage consisted of two reactors, operated in series. The first reactor was filled with FerroSorp® (granular iron hydroxide), the second reactor with GAC. The P-removal of SSVF and sorption stage is in a load-related magnitude of 94% (oPO_4-P), resulting in concentrations mainly less than 0.1 mg oPO_4-P/L. Considering the FerroSorp® load capacity of 40% after two years of operation it can be estimated that a separated sorption stage might achieve a minimum lifetime of 4 years. Current German standards for meliorated SSVF generally recommend an amount of filter substrate of 10% by mass to achieve P-removal rates of 80% for two years of lifetime. This lifetime is half as long as with the investigated downstream sorption process and this with the thirtyfold increased use of iron-containing additive. Commenting the MP elimination, a substantial MP-loading of the CSO as well as a substantial MP-removal in the SSVF can be stated. Ten out of eleven MPs are reduced by the SSVF between 20% up to 80% (Metoprolol). The final downstream GAC sorption reactor eliminated all MPs almost completely as expected. The analyzed heavy metals cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn) are retained in the entire three-stage plant (SSVF, two sorption reactors) with high efficiencies between 80% and 97%. Mercury (Hg) was analyzed only at very low concentration level.

BIO: Dr. Schier is deputy head at DESEE with more than 20 years of experience in the field of Sanitary and Environmental Engineering. He has extensive experience with SSVF constructed wetlands for CSO or SSO meeting advanced nutrient requirements and has led two appropriate long term projects.

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VERTICAL ECOSYSTEM FOR DECENTRALISED GREYWATER REUSE IN A EURO-MEDITERRANEAN RESORT: LONG TERM MICROPOLLUTANTS REMOVAL

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A horizontal subsurface flow constructed wetland (HSSFCW) was integrated, in a cascading vertical set-up (vertECO), in a Mediterranean tourist facility for decentralized treatment of real low load greywater streams. 15 different plant species were tested in light expanded clay aggregate substrate at three different hydraulic retention times (HRTs: 1.9, 1.4 and 1.0 days) and monitored for 22 months. Organic standard parameters were analyzed jointly to several organic micropollutants (14 pharmaceutical organic compounds and 12 endocrine disruptive compounds). The removal efficiency for standard parameters was very high, on average more than 90% for many parameters (COD, BOD_5, TSS, VSS and turbidity) and more than 80% for TOC. BOD_5 removal could be correlated with the temperature, while TN, TKN and $N\text{-}NH_4^+$ showed the highest removal efficiency with the lowest HRT. The effluents at all three HRTs consistently met the standards for various reuse applications, according to Spanish Legislation (RD1620/2007) and EU draft. In terms of organic micropollutants, the greywater was characterized by high concentrations (up to 256.08 ± 875.25 µgL^{-1} for acetaminophen, 88.68 ± 424.51 µgL^{-1} for ibuprofen). The micropollutants removal achieved by the vertECO was more than 95% for most of the compounds (acetaminophen, ibuprofen, salicylic acid, caffeine, estradiol, progesterone, testosterone, triclosan, methyl-, ethyl- and propylparaben) and more than 80% for diclofenac, atenolol and trimethoprim. On the other hand hydrochlorothiazide, sulfamethoxazole and salbutamol could not be removed or lower than 30%. Significant differences were found at different HRTs for acetaminophen, atenolol, ibuprofen, ethylparaben, TCPP and TBEP ($p < 0.05$). Conversely, most of the other studied micropollutants were consistently removed without apparent influence from temperature.

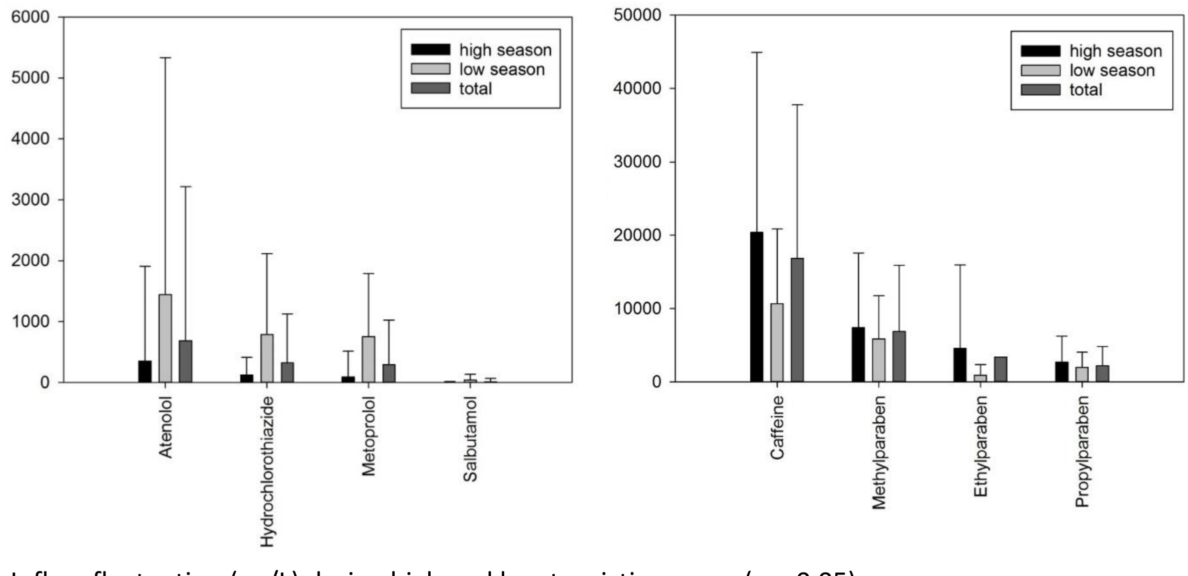

Figure 1. Inflow fluctuation (ng/L) during high and low touristic season ($p > 0.05$)

BIO: Dr. Gianluigi Buttiglieri, PhD in Sanitary and Environmental Engineering from Politecnico di Milano, is research scientist at ICRA. His research activity is on the fate of organic micropollutants in the environment and in water and wastewater technologies as well as on water reuse, decision support systems and circular economy issues.

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C.P. 28

CONTRIBUTED PAPERS 28

NUTRIENTS

Darja Istenic

NITROGEN DENITRIFICATION IN CONSTRUCTED WETLANDS WITH WOODCHIPS BIOREACTOR

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To fulfil the EU WFD the Danish Water Area Plans has set out, that nitrogen emission to coastal waters must be reduced with 6,900 tonnes in 2021. Around half 3,400 tonnes must be achieved through collective measures. The other half 3,500 tonnes - the targeted regulation - must be achieved by means the individual farmer should establish. The collective measures include the establishment of constructed wetlands, wetland projects and afforestation. The actions are paid by the state, solves problems for a larger area (sub-catchment), and benefits farmers in that given sub-catchment. A big national research project was launched in 2017 - in total 31 million DKK (15 million from MFVM) - to construct and run six bioreactors with wood chips located in different geo-regions and climates in Denmark. The main focus of the project is to study effects of different bioreactor design on nitrogen reduction efficiency when the reactors serve drainage uplands varying from 16 to 120 ha located in regions with a yearly precipitation varying from around 600 to 1100 mm. Further, the project includes research on bioreactor long time stability and negative side effects, especially how to reduce emission of greenhouse gases. All facilities are up running, but only two of the six (Gyldenholm and Spjald) gave results in the drainage season 2017-18.

The constructed wetland (CW) at Gyldenholm Manor includes a bioreactor that receives drainage water from a systematically drained upland of 120 ha. The plant consists of a smaller sedimentation well for sedimentation of colloid-bound phosphorus. Drainage water is pumped flow proportional into the bioreactor by activation of one to two frequency pumps. The woodchips bioreactor consists of three even sized basins (L: 20, W: 15, D: 1.5 m) each with 828 m^3 willow woodchips. A surface layer with a depth of 0.4 m is kept "dry", not wetted by the drainage water. At the outlet of a basin, the drainage water is let into an oxidation well and a final oxidation takes place in a common outlet for all three basins before discharge to a small watercourse. On a yearly basis, it is expected that the bioreactor at a water residence time of 10 hours can remove 50-70% of the nitrogen in the drainage water. The first results obtained in April-May 2017 showed a reduction of 80%.

The constructed wetland at Spjald consists of an open pond (35 x 10 x 1 m) connected to a subsurface flow unit with a matrix of willow woodchips (30 x 10 x 1.5 m), the upper 0.5 m serving as an unsaturated covering layer. The CW receives drainage water from a 16.2 ha upland. In the calendar year 2018 mean annual inlet concentrations of TN and nitrate-N were 14.1 ± 1.1 and 13.1 ± 1.0 mg N l^{-1}, respectively. The open pond removed 22 % TN and 21 % nitrate-N. At the outlet from the bioreactor with willow woodchips the mean annual concentration decreased to 4.7 ± 0.9 mg TN l^{-1} and 3.6 ± 0.9 mg NO_3^--N l^{-1}, and thus the overall annual removal efficiency was 67 % TN and 73 % nitrate-N. Total removal of TN for the 650 m^2 CW was 81 kg TN or 1244 kg TN per ha wetland per year.

BIO: Dr. Finn Plauborg is an experienced scientist and has since 1995 participated in and been project leader of several joint national and international projects within water, environment and agriculture. He is responsible for the national research project on constructed wetlands and bioreactors designed to denitrify nitrogen from agricultural drainage water.

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WILL PLANTING OF SURFACE-FLOW WETLANDS IMPROVE NITROGEN REMOVAL IN THE LONG RUN?

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Initial planting of created wetlands is common practice in order to, for instance, improve nitrogen (N) removal. It has been shown that vegetated surface-flow wetlands remove more N than non-vegetated surface-flow wetlands. However, changes in N removal as differently vegetated wetlands progress from an early successional stage to a mature system are less investigated.

In our study, we followed three different wetland types of initial planting over the course of 12 years, with the aim to examine how planting of newly created wetlands affects long-term N removal. All our data were collected in the experimental wetland facility near Halmstad in south-western Sweden. The facility consist of 18 small (ca. 25 m^2) surface-flow wetlands, equal in age, shape and size. At the time of creation, the 18 wetlands were randomly divided into three types. One type was then planted with emergent vegetation, one was planted with submerged vegetation and the last type was left unplanted for free development. Succession of vegetation was thereafter allowed to progress uninhibited in all wetlands.

Our results confirmed that emergent vegetation wetlands initially removed more N than submerged vegetation and free development wetlands. In addition, our results showed that N removal in submerged vegetation and free development wetlands increased with ecosystem age, whereas N removal in emergent vegetation wetlands did not. N removal in all three wetland vegetation types converged when the wetlands reached a more mature state, around year 9 after wetland creation. However, although all wetlands contained emergent vegetation in year 9, proportion cover of emergent vegetation and vegetation composition still differed substantially between wetland types.

We therefore conclude planting of created surface-flow wetlands with emergent vegetation will have a positive effect on N removal, but only during an early successional stage. Our study indicates it is not the emergent vegetation *per se* which results in higher N removal in more mature wetlands, but the maturation process in itself, since mature wetlands with different emergent vegetation cover achieved similar N removal. Initial planting will not result in higher N removal once the system has reached maturity.

BIO: Josefin E. Nilsson is a PhD student in Environmental Science, with a specialisation in Ecology and Wetland Research. She wrote both her Bachelor's and Master's thesis on N removal in created wetlands, and in her current studies she additionally focuses on phosphorous removal in created wetlands.

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NITROGEN AND DISSOLVED CARBON BALANCES IN THE AZHUREV CONSTRUCTED WETLAND

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The Azhurev horizontal-flow constructed wetland is a large-scale demonstration wetland built at the outlet of the Grand Reims wastewater treatment plant (WWTP). Three 20,000 m^2 basins (rectangular shape with different depth distribution within each basin) have been created: the initial vegetation (mainly *P. australis*, *S. lacustris* and *G. maxima)* density was also different in each basin. Their aim is to polish a part of the treated wastewater (250 m^3/h) from the Grand Reims WWTP, as well as to treat part of the Grand Reims stormwater.

The wetland has been operated since July 2017. Flowmeters have been installed at the inlet and the outlet of each basin, as well as conductimeters and temperature sensors. Sampling campaigns have been organized on a monthly basis: the samples have been collected at the inlet and exit of each basin as well as in the basins with an aquatic drone. They have been analysed in terms of nitrogen species (total dissolved nitrogen, nitrates, nitrites, ammonia) and dissolved inorganic and organic carbon. The dissolved organic matter has been further characterized by optical methods (synchronous fluorescence and UV-visible spectroscopy). Plants have been collected and their carbon and nitrogen content has been determined.

There is no infiltration from the basins to the aquifer, as evidenced by the hydraulic balance. The results obtained after more than one year of operation show a global nitrogen removal rate of 50% (equivalent for nitrates and ammonia). An increase of the dissolved organic carbon has been observed between the inlet and the outlet in summer and fall: this is due to anaerobic decomposition of aquatic plants underneath a thick layer of *L. minor*, which has gradually covered the basins.

In November 2018, a large maintenance of the site has been set up with plant cutting and removal, in order to promote vegetation development in spring. The presentation will describe the complete carbon and nitrogen balance over the two years of operation of the wetland and compare the basin efficiency in function of the vegetation.

BIO: N. Maurice is a Ph.D student with a soil and water remediation background.

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REMOVAL PROCESSES IN START-UP PERIOD IN HYBRID CONSTRUCTED WETLAND FOR EFFLUENT FROM ANAMMOX TREATMENT

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This paper presents the results of a hybrid constructed wetland (HCW) performance, being a part of a pilot plant that was conducted at the WWTP in Gdańsk (Poland). Pilot scale HCW is a two-stage system consisting of subsurface horizontal flow bed (HF) followed by vertical flow bed (VF). The objective of this research is to analyse removal processes in the wetland system cooperating with Anammox-based reactor, depending on the quality of influent wastewater and applied hydraulic loads.

Removal efficiencies of total suspended solids (TSS), organic compounds expressed as chemical oxygen demand (COD), nitrogen fractions ($N\text{-}NH_4$, $N\text{-}NO_2$, $N\text{-}NO_3$), total nitrogen (TN) and total phosphorus (TP) were observed after each stage of HCW. In the start-up period TSS average removal effectiveness was 67%. Efficiency of TN reduction was about 43% as average and did not exceed 82%. Organic matter removal varied in range from 12 to 48%. These differences may result from fluctuating hydraulic loads as hydraulic loading rate varied between 0.27 to 0.90 $m^3\ m^{-2}\ d^{-1}$. Removal of $N\text{-}NH_4$ and $N\text{-}NO_3$ over the start-up period is presented in Figure 1.

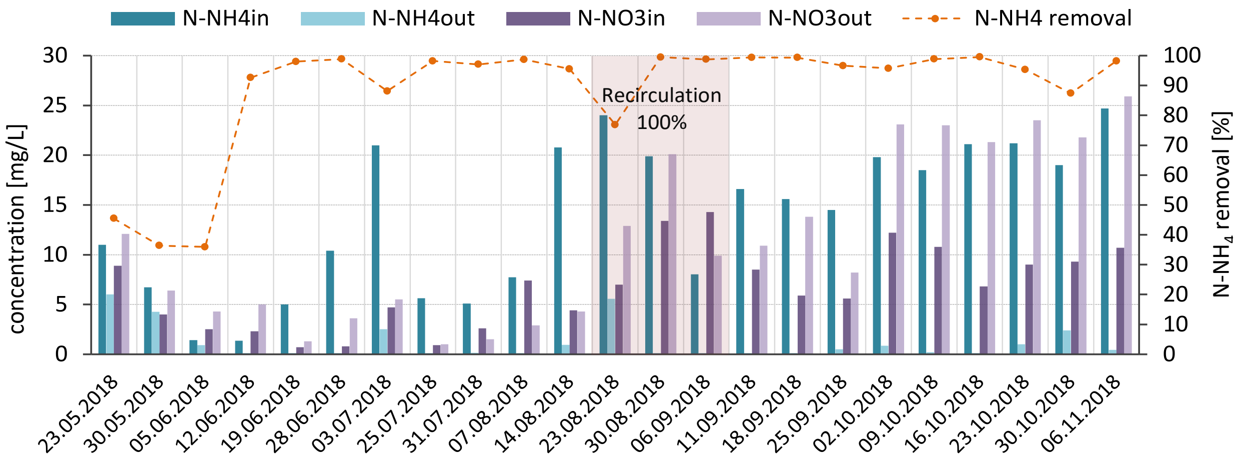

Figure 2. Concentrations of $N\text{-}NH_4$ and $N\text{-}NO_3$ in influent and effluent of HCW system.

The study showed that the HCW creates favourable conditions for nitrification process, especially in VF bed. Overall effectiveness of ammonium nitrogen removal was over 88%. On the other hand, the concentrations of nitrate nitrogen in effluent were increased for most of the time, which proves the production of these compounds and difficulties in obtaining conditions for denitrification.

As part of this study, the results of genomic analysis will be presented in order to identify processes and biodiversity of HF and VF bed.

BIO: MSc Eng. Skrzypiec is a doctoral student at Gdansk University of Technology, specializing in wastewater treatment in constructed wetlands. Currently she is working in project entitled "Interactive Water Management" (funded by INTERREG BSR) where she is gaining experience by conducting research on a new pilot plant.

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ADDITION OF CORN COB IN THE FREE DRAINAGE ZONE OF PARTIALLY SATURATED VERTICAL WETLANDS FOR TOTAL NITROGEN REMOVAL - A PILOT-SCALE STUDY

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Partially saturated vertical wetlands represent an alternative to increase the efficiency for total nitrogen removal in treatment wetlands (TW) (Martínez-Valles et al., 2018; Pelissari et al., 2017). These systems are designed to promote the processes of nitrification-denitrification; nevertheless, if biodegradable carbon content in the influent is low, it is consumed during the free-drainage zone (FDZ) through aerobic respiration, resulting in a poor denitrification in the saturated zone (SZ) (Yang et al., 2018). Due to this, the addition of a carbon source (CS) is required because it is essential for facultative heterotrophs, which are the mediators of denitrification process. In a previous study we evaluated the use of corncob (CC), an abundant agricultural lignocellulosic residue in Mexico, which was placed in the ZS in PSVWs and obtained good efficiencies for TN removal that tended to decrease after some months of operation (Martínez-Valles et al., 2018). So that, in order to prolong such efficiencies, the aim of this study was to evaluate and compare TN removal in PSVWs with CC as a CS placed in two different heights in the FDZ.

Two PSVWs (SI and SII) whose dimensions were 48 length, 48 width and 80 cm height were evaluated in duplicate for TN removal with CC as an internal CS and tezontle as filter media, for 60 weeks. The height of the SZ was 30 cm while the height of the FDZ was 40 cm. In both systems CC was added in the FDZ, but in SI it was placed in the first 20 cm directly above the SZ while in SII, it was added in the last 20 cm. Each system was planted with *Iris Sibirica* and fed with 4.2 L/3 h of pretreated wastewaters from a university Campus. After 12 weeks of stabilization, water quality parameters were measured in a weekly basis for 48 weeks in the influent and effluents, i.e., BOD_5, COD and TSS, organic N, ammonium, nitrite and nitrate (measured also in the interface), in addition to the measurements of the internal conditions (ORP, dissolved oxygen, pH and electrical conductivity).

Despite the presence of CC, a significant decrease of BOD_5, COD and TSS was registered in both systems along the study ($P<0.05$), reaching average removal efficiencies of 91.9%,66.6% and 89.9% respectively in SI, and 92.3%, 75% and 92% respectively in SII, without difference between the systems ($P>0.05$). With regard to the nitrogenous compounds, organic N was reduced in 70% and 77.7 in SI and II, respectively; while ammonium decreased in 82.5% and 83.4%, respectively. A significant increase of nitrate was observed in the interface ($p<0.05$) and was in similar values in the effluent of the two systems. Finally, average TN removal were 68.2 % for SI and 66 % for SII without significant difference between the two PSVWs ($P>0.05$). Such efficiencies were higher than those reported by Martínez et al. (2018) (59.8 and 64.2 %) in two similar PSVWs but with the CC in the SZ and during the period in which the efficiencies decreased when treating the same influent. On the other hand, the internal conditions in the SZ were adequate for denitrification; however, this process did not take place because apparently biodegradable carbon content was not enough; denitrification took place mainly in the FDZ. The findings of this study demonstrated the advantages of placing the CC in the FDZ of PSVWs (without affecting the removal of BOD, COD and TSS) such as a more constant efficiency without a trending to lower values after 12 months of operation and the easiness for the CC replacement after its exhausting as CS because it can be placed in the last 20 cm of the FDZ.

BIO: Dr. Zurita is a full time professor in the Centro Universitario de la Ciénega of the University of Guadalajara in Mexico. She has conducted different research projects for more than 10 years about constructed wetlands and phytoremediation for the removal of conventional and emergent pollutants from water and wastewater.

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CONTRIBUTED PAPERS 29

FLOATING SYSTEMS

Tom Headley

THE EVOLOTION OF FLOATING WETLAND SYSTEMS AS A TOOL TO ACHIEVE ECOSYSTEM SERVICES IN HEAVILIY MODIFIED URBAN WATERBODIES

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Urban areas and their associated water quality impacts have expanded significantly in the last decade, presenting new challenges for wetland conservationists and water quality managers.

Efforts are increasingly being applied to find ways to restore some of the natural pollution control functions of historic wetlands as well as to engineer new wetland systems to manage water in the urban environment. In this process, Floating Wetland technology and science has evolved considerably and is increasingly recognized as a beneficial solution, integrating engineering with wetland ecosystems and plantings to help manage the increasing loading from storm water, CSO's and diffuse pollution entering urban watersheds while also providing amenity and habitat benefits. The challenge is that establishing wetland functions in heavily Modified Waterbodies is difficult because as the gradual slopes and shallow waters which make wetland habitat and function possible are largely absent or constrained by encroachment and re-alignment in urban areas.

In the evaluation of the efficacy of these various approaches we examine several example projects from the USA and EU. For example in Rennes France the municipality has recently installed 268 interlocking structural floating ecosystem modules in a new floating river bank wetland planted with 6800 native aquatic plants, the installation forms largest Floating Riverbank of its kind ever constructed and provides wetland habitat in constant deep water with regular flood events rising over two meters.

In a second example A series of Floating Ecosystems installed in the town of Hastings UK is actively treating sewage-contaminated runoff and has been a key feature to improving water quality on a public beach. The process calculations to calculate the performance of the system where derived refrenceing material Published by WETPPOL 2019 key note speaker Dr. Robert H. Kadlec. Water treatment by the floating wetlands in this system helped to reduce Enterococci by over 80% and E-Coli by > 90% in this project. Similarly in another project in Manchester UK a series of Floating Ecosystems on a public pond has been key in reducing chemical oxygen demand (COD) from >40mgl to <10mgl from while increasing the water clarity from 0.3m to over a meter. In the USA in Chicago the NGO Urban Rivers has been carrying out Mesocosm research and tests in partnership with the Chicago Botanic Gardens using water drawn from the Chicago River on a controlled experiment focused on evaluating the nutrient sorption capacity over time. Meanwhile in the Chicago river itself a series of Floating Wetlands have been installed with funding from sponsors including the Shedd Aquarium, National Geographic, Patagonia and Whole Foods Market with plans set to expand the project in to a mile long engineered urban wetland park "The Wild Mile".

This presentation investigates these case studies examples in detail comparing water quality results before and after conditions and the resulting project outcomes and impacts.

Bio: Galen Fulford is a wetland restoration and creation enthusiast and author of four patents for engineered ecological technologies. Born in Vermont USA and A graduate of Prescott College in Arizona, Galen manages Biomatrix Water Solutions in Scotland responsible for the installation of over 800 floating wetland modules in 2018. Above all Galen is an avid environmental restoration and his work has enabled the creation of wetland ecosystems in challenging urban environments in major cities in ten countries.

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FLOW RATE IS A DETERMINANT FACTOR IN THE EFFICIENCY OF FLOATING TREATMENT WETLANDS FOR MICROCYSTINS AND POLLUTANTS REMOVAL AT FIELD SCALE

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Floating Treatment Wetlands (FTWs) are an ecological friendly and low cost technology. However, there is limited work evaluating their efficiency at field scale (*in situ*). Our group has previously shown the high efficiency of FTWs combining *Pontederia sagittata* and *Cyperus papyrus*, to improve the water quality in a polluted urban pond during a long-term assessment at field scale. On the other hand, there is little work done in relation to the efficiency of FTWs to counteract nocive algae bloommings, especially in relation to the presence of *Microcystis aeruginosa* and microcystins, the very toxic molecules they release into the water column. The objective of this work was to assess the impact of the flow rate of the influent into the pond, over the efficiency of 4 FTWs combining *P. sagittata* and *C. papyrus* for the removal of major pollutants and microcystins from the water column.

The FTWs are located in a group of four eutrophic urban ponds in Xalapa, Veracruz, México (19°31´24.89” N, 96°55´28.69” O). The evaluation was carried out throughout the whole year, comparing 2 FTWs (33m^2 and 17 m^2) located in Pond 1, receiving an influent at a flow rate of 0.295 ± 0.01 l s^{-1} and 2 FTWs (25 m^2 and 33m^2) located in Pond 4, receiving an influent at a flow rate of 0.085 ± 0.003 l s^{-1}. Average flow rate (FR) in the influent of Pond 1 and 4 was calculated using the following equation: FR=(water speed)(cross-sectional area); water speed was determined recording the time for a dye-spot to transit a known distance (0.796 m), on a white PVC-tube (0.00159 m²).

The two FTWs in Pond 1 showed a high removal percentage for coliforms (from 34.28% to 70.9%, especially from July to November), nitrate (from 24.87% to 48.68%), as well as a high increase in the dissolved oxygen concentration (12.18% to 101.82%) in the water column. In contrast, the FTWs were not functioning efficiently in Pond 4, especially after a punctual domestic wastewater discharge occurred in this pond in the month of May. The most striking results are that microcystins concentrations were approximately from 3 to 5 times above the permissible level according to World Health Organization (1 µ L^{-1}), in Pond 4. In contrast, in Pond 1, microcystin concentrations were always below such permissible level throughout the year.

It was concluded that the influent flow rate is a determinant factor affecting highly the efficiency of FTWs for the removal of nutrients and especially microcystins. To the best of our knowledge, it is the first time that this factor was evaluated at field scale.

BIO: Eugenia J. Olguín is a Professor with more than 40 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 40 projects and founded the Latin American Society of Environmental and Algal Biotechnology.

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EFFICIENCY OF FLOATING TREATMENT WETLANDS TO TREAT HIGHWAY RUNOFF

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Concrete retention tanks for stormwater runoff from interstate roads and highways in Germany show limited remove non-settleable solids only to a limited extend. In an ongoing pilot scale study, we are testing the removal efficiencies of Floating Treatment Wetlands (FTWs) on two stormwater retention tanks, each consisting of two chambers, at highways surrounding the city of Cologne (Mülheim [MH] and East [E]). One third of one chambers' water surface is covered with an FTW and the other chamber serves as a control. We are investigating various parameters such as suspended solids (SS), mineral oil hydrocarbons (MOH), heavy metals, chloride and the change in conductivity (Table 1).

Table 2: Average removal efficiencies for stormwater tanks covered to 1/3 with FTWs and uncovered control chamber

		Cr^{MH}	MOH^{MH}	$Conductivity^{E}$	$Chloride^{E}$	SS^{E}	Pb^{E}
Control	n	11	12	8	8	7	6
	Mean value	50%	17%	-107%	-229%	64%	72%
	Median	56%	18%	-87%	-56%	99%	97%
FTW	n	14	14	14	15	14	12
	Mean value	60%	11%	-16%	-68%	88%	86%
	Median	72%	29%	-6%	-27%	98%	97%
Improvement by FTW [%-points]	Mean value	10%	-6%	91%	161%	24%	13%
	Median	17%	11%	81%	29%	0%	-1%
	MH: Cologne Mülheim; E: Cologne East						

Since de-icing salts are used during the winter months, high concentrations of chloride could be found in the outflow of both chambers, but even higher concentrations were measured in the outflow of the control chamber. Additionally, the FTW chamber in Mülheim showed a better removal of Cr and in most cases of MOHs in comparison to the control chamber. Although both setups – FTW-covered chambers and uncovered chambers – showed median removal efficiencies for SS of almost 100%, the higher mean value for the FTW-covered chambers indicates fewer events with low removal efficiency. Overall, the preliminary results are promising and further investigations are ongoing.
The investigation of the different plant species on-site and in accompanying microcosm studies showed varying production of biomass and oxygen diffusion (Table 2). Therefore, we recommend combining different plant species in order to improve conditions for a root layer formation.

Table 3: Results of on-site and microcosm investigations on the different plant species used

Plant Species	Effect of NaCl	Effect of Wastewater	Effect of Highway runoff
Juncus effusus	None	Decreased oxygen diffusion	None
			Development of biofilm
Lythrum salicaria	None	Decreased growth of roots	Increased oxygen diffusion
Iris pseudacorus	None	Increases growth of roots	No negative effect on oxygen diffusion
Salix species	Restrain, but recovery		

BIO: Jan Ruppelt is a PhD Student at the Institute of Environmental Engineering (ISA) of RWTH Aachen University. His research focuses on the remediation of CSOs and Highway runoff using Retention Soil Filters (RSFs) and Floating Treatment Wetlands (FTWs), respectively.

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EFFECTS OF DRINKING WATER TREATMENT RESIDUAL AND IRON SULFIDE INVOLVEMENT IN FLOATING TREATMENT WETLANDS FOR SECONDARY EFFLUENT TREATMENT

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Nutrients in the secondary effluent from wastewater treatment plant discharging into surface water will cause environmental problems, such as hypoxia and eutrophication. Floating treatment wetland (FTW), with the advantages of low cost, no need of additional land, and landscape features, has been widely applied to treat secondary effluent. However, the purification efficiency of traditional FTW is fully plant-roots depended, causing embarrassed situation in application such as low and unstable nutrients removal efficiency in deep water or in winter time. Although additional bio-carriers in FTW has been trailed to enlarge the surface area for microbe attachment, lack of extra electron donor is still a problem in nitrate removal. In the winter, the low sediment redox potential with a more basic water pH caused phosphorus (P) release from sediment and the death of plants may release P into water body. Therefore, new approaches should be trialed to address this problem.

In the present study, four different groups of materials were used as bio-carriers in FTW to enhance its treatment performance, namely drinking water treatment residual (DWTR), DWTR-pellet, DWTR combined with woodchip, and iron sulfide. DWTR is a kind of by-product in drinking water purification when aluminum-salt was used as coagulant, which shows great affinity towards P adsorption. DWTR-pellets are artificially made pellets with DWTR and alginate. DWTR and woodchip are believed to release organic matter for carbon-driven heterotrophic denitrification. Iron Sulfide (pyrite and pyrrhotite) are mostly considered as gangue being disposed of in mine wastes. Recently, it has been reused as autotrophic denitrification biofilters to simultaneously reduce N and P.

Here, DWTR, DWTR-pellet, DWTR combined with woodchip, and iron sulfide were applied in FTWs to overcome the drawbacks of the traditional FTWs, especially the low removal efficiency of nutrients in winter time. The results of lab-scale experiments showed that all the four group materials as additional bio-carriers can enhance the N and P removal rate. The peak N removal rate of the FTW with iron sulfide could over 80% in winter time, which is nearly four times high than that of the traditional FTW (the control group in the experiment). The P removal rates of the four enhanced FTWs (FTW with DWTR, DWTR-pellet, DWTR and woodchip, and iron sulfide) during the whole experiment period were stable. Even in the winter time, P removal rate could reach 90%, and the adsorption is the main mechanism of P removal in these four systems. Overall, using DWTR, DWTR-pellet, DWTR and woodchip, iron sulfide as additional bio-carriers in FTW could improve both the P and N removal efficiency at the same time, and it owns potential to be applied in larger scale application.

BIO: Ms. Shen is a Ph.D candidate in UCD Dooge Centre for Water Resources Research (CWRR). She has been working on improving the treatment performance of floating treatment wetland (FTW) for polluted surface water. Her aim is to apply this green technology in field scale.

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TEMPORAL VARIABILITY OF PESTICIDE REMOVAL FROM ARTIFICIAL WETLAND RECEIVING AGRICULTURAL DRAINED WATER

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To reduce agricultural pollutants in agricultural drained watershed, artificial wetland showed a real potential as a management practice for pesticide removal. Several publications carried out such experimentations for short period but few are dealing with long term efficiency. This study aims to fill the gaps in our knowledge in this field.
An off-stream artificial wetland (5270 m², 0.1 to 1 m deep), designed to abate pesticide pollution, intercepts drainage water from a 355 ha watershed in Rampillon, France (03°03'37.3'' E, 48°32'16.7'' N). Farms are conventional and the crop rotations include mainly winter crops (winter wheat, barley), corn, sugar beet and rape. A sluice gate at the inlet of artificial wetland controls the INLET drained flow during peak events specially during winter season The flow entering the wetland fluctuates from 0 to 120 L s-1. The wetland is partially covered by sedges, reed, cattails and algae. Since 2012, an automatic water quality monitoring system measures water discharge, temperature, in both inlet and outlet. Weekly flow weigh samples help to assess pesticide flux removal between INLET and OUTLET artificial wetland, receiving agricultural drained flows. Water samples were then sent to chemical analysis sub-contractor to evaluate about 500 different pesticides, with a detection limit lower than 0.005µg/L.
Agricultural practices survey showed that among the 100 applied pesticides corresponding to 1.7 kg/ha of active molecules, about 40 were exported for a very stable inter-annual amount about 1.5g/ha per year. The 6 years monitoring INLET/OUTLET (2012-2018) showed 1) an average removal of 30% depending on seasonal hydrological response; 2) a mitigation efficiency according pesticides: from 100% for fungicide pesticides like tebuconazol, epoxyconazol to 0% for pesticides playing as water tracers (mesotrione, imazamox). To go deeper in the removal efficiency, we performed statistical analysis based on pesticides properties, temperature, application period and transfer, hydrological response and hydraulic residential time. The main results showed that temperature and HRT controlled global efficiency in which Koc and a new dissipation factor (far away from the classical DT50), helped to forecast removal efficiency.

0 → 10%	10 → 20%	20 → 40%	40 → 60%	60 → 100%
Mesotrione	Cyproconazole	Clopyralid	Clomazone	2,4-D
Imazamox	Imidaclopride	Bentazone	Aclonifen	Benoxacor
Chlortoluron	Atrazine déséthyl	Metamitrone	Dimethenamide	Chlorméquat
Ethofumesate	Mesosulfuron mtl	Chloridazone	Atrazine	Triflusulfuron mtl
Fluroxypyr	Isoproturon	Florasulam	S-metolachlor	Ethephon
2,4-MCPA	AMPA	Boscalid	Azoxystrobine	Napropamide
		Dimetachlore	Diflufenican	Tebuconazole
		Nicosulfuron	Lenacile	Epoxyconazole
		Propyzamide	Glyphosate	Pendimethaline
			Propiconazole	Fluoxastrobine
			Quinmerac	Métazachlor

BIO: M. Chaumont is a senior engineer at the IRSTEA, Antony, France. He developed coupled approaches for monitoring water quality in aquatic media. He is expert in catchment hydrology, particularly in design and performance of artificial.

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C.P. 30

CONTRIBUTED PAPERS 30

WETLANDS, PEATLANDS AND MODELLING

John White

THE 4G RANCH WETLANDS RECHARGE AQUIFERS: 2 YEARS OF OPERATION

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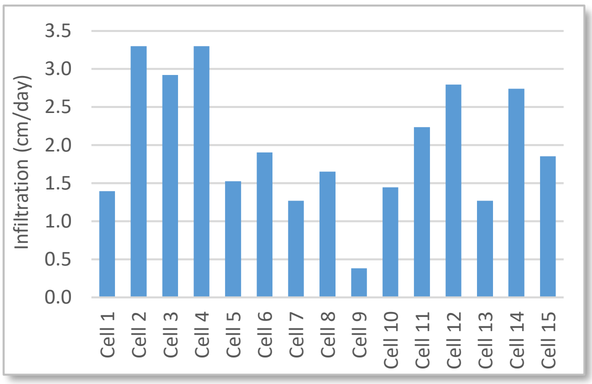
This six-time award winning groundwater recharge wetland project consisting of 15 constructed wetland cells with a total area of 70 hectares began receiving secondary treated wastewater in March 2017. Benefits include recharge of the aquifer, nitrate reduction, rehydration of natural wetlands, and creation of wetland habitat. Pasco County is the home of regional wellfields that provide potable water supplies to the Tampa Bay Region and the impacts have severely affected the health of nearby lakes and wetlands. To offset these impacts, Pasco County Utilities in partnership with the Southwest Florida Water Management District planned, designed, and constructed a groundwater recharge wetland system sized to receive up to 19.000 m^3/d of secondary treated wastewater from the Pasco County Master Reuse System to purify and return this water back where it came from.

This treatment wetland was sized based on capacity to infiltrate water. This wetland has no outfall and is operated to achieve hydroperiods of 10 cm to 60 cm of inundation by balancing rainfall, evapotranspiration, and infiltration, with wastewater inflow. Detailed hydrogeologic investigations during design resulted in a design infiltration of 3 cm/d during average rainfall conditions of 1.3 m per year. After two years of operation and monitoring a groundwater flow model was calibrated to evaluate infiltration and system performance. Figures 1 and 2 present daily and annual flow to the 4G Ranch Wetlands and the infiltration measured in each cell respectively.



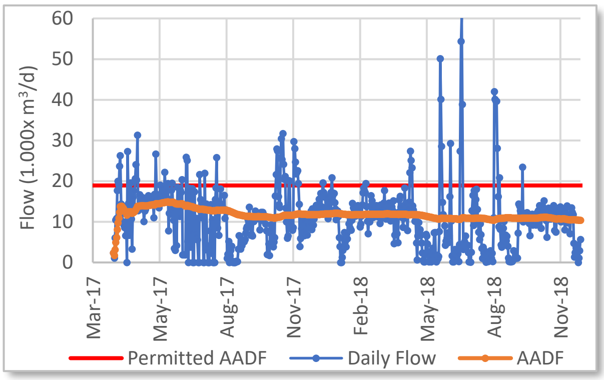


FIGURE 1. Flow to 4G Ranch Wetlands

FIGURE 2. Calculated Infiltration Rate per Cell

Flow and infiltration measured were approximately two thirds of the predicted rates during design under average rainfall conditions. However, rainfall totals during the operational period were 1.6 m in 2017 and 1.8 m in 2018, significantly higher than the average rainfall total. Based on groundwater modelling results using operational data and regional groundwater response, the system is operating as predicted during design. Secondary treated wastewater applied to the wetlands has nitrate levels of approximately 8 mg/L. Since July 2017, all monitoring wells on the site have non-detectable levels of nitrate except for one located along the berm right at the inlet of Cell 2 with concentrations ranging between 1.32 and 1.49 mg/L. This represents approximately 80% removal immediately underneath the inlet of Cell 2 by only the infiltration through the wetland subsoils without the opportunity for water to pass through the wetland for treatment. Based on the infiltration rate a kinetic rate constant (k_{20}) as used in the first-order areal model P-k-C* was calibrated for the wetland subsoils. It is estimated that the wetland subsoils k_{20} is 21 m/yr which corresponds to median rate constants assessed for mature treatment wetlands. As the wetland matures and the organic layer in the wetland subsoils increases, treatment for nitrite is expected to improve. If evaluated as a treatment landscape, however, the system is performing as expected producing concentrations to below detection limits as the water reaches the underlying aquifer.

BIO: Mr. Vázquez-Burney is a Professional Engineer and Principal Technologist with Jacobs in Tampa, FL, USA. He has 13 years of experience studying, designing, permitting, and constructing treatment wetland systems for wastewater, stormwater, and industrial water with a focus on treatment intensification.

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DEVELOPMENT OF A RESIDENCE TIME DISTRIBUTION TECHNIQUE COMBINED WITH THE CONSTRUCTED WETLAND MODEL 1

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Recently there has been a great deal of research published displaying efforts to model the processes taking place in constructed wetlands (Langergraber, 2016). In order to make more effective use of this treatment technology, it is important to understand their inner workings. (Samsó & García, 2014). The aim of numerical modelling is to do just that. With a deeper understanding of the various processes, current design criteria can be improved and the efficiency of the treatment technology may be increased (Samsó & García, 2014). This paper gives the development of a new residence time distribution theory to describe the hydraulics of constructed wetlands and combine it with an existing and widely accepted biokinetic model, the Constructed Wetland Model No. 1.

The effect of time on a constructed wetland is often under estimated and if not accounted for can cause under or over estimation of design parameters. While residence time distribution modelling has been done in the past, an assumption of an ideal reactor type (either PFR or CSTR) or a combination of reactor types is used to describe the hydraulics of a system, and constructed wetlands are non-ideal reactors. The concept of the model is that no assumption is made about the reactor type, but rather data taken directly from the system is used to describe the hydraulic behaviour of the wetland. The residence time of the system is not represented by one single mean residence time and a deviation from that, instead a summation of times with a weight factor is used. This technique is then combined with the existing CWM1.

The residence time distribution was measured using both impulse-response and step-change tracer experiments according to the methodologies described by Bonner et al (2017). These experiments were completed on three indoor wetlands of dimensions 1m x 0.15m x 0.3m; one gravel bed and two hydroponic systems were used. Uranine was used as a tracer for both the step impulse response and step change experiments and ammonium nitrate, sodium acetate and sodium benzoate were also included in the step change experiment. The data obtained from these will be compared with the outlet concentrations predicted by the model.

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(Bonner, Aylward, Kappelmeyer, & Sheridan, 2017)

BIO: Ruth Stephenson is a PhD candidate at the University of the Witwatersrand in South Africa. Her research interests include environmental biotechnology for wastewater treatment, focusing on constructed wetlands.

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A FRAMEWORK FOR AN ECOLOGICAL-ECONOMIC RESTORATION VALUATION MODEL

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In today's world, practicable wetland restoration requires a balance of sound science with the evaluation of cost, funding resources, and long-term benefits. Historically, the long-term benefits of restoration have focused on ecological benefits. However, recent studies have attributed immense value to economic activity and commerce related to water resources throughout the world, as well as to the outcomes of restoration activities. A science-based approach to prioritize restoration activities can add even more benefits to the social, ecological, economic, and cultural significance of restoration activities.

The Office of the Great Lakes (OGL) in Michigan, USA is embarking on an important project to help prioritize future restoration activities and to calculate and communicate the full economic value of degraded wetland and surface water restoration to residents and policymakers throughout the region. The project fills a critical data gap for the OGL, one shared by communities around North America that lack sufficient data with which to value ecosystem services and understand the full benefit of their investments. The goal of this project is to develop a tool that allows the OGL to communicate the value of past and future investments in restoration to citizens and policymakers, as well as to identify the proposed restoration activities that will generate the greatest economic value. Restoration activities in the region often include woody wetland restoration, herbaceous wetland restoration, stream/river habitat restoration, shoreline restoration, nutrient management, and invasive species treatment.

We present here the development of a user-friendly tool that reliably estimates changes in ecosystem functions that ultimately drive improvements in ecosystem services. Criteria important to developing such a tool include broad applicability across the region; allowing for the ability to assess the value of changes in ecosystem service functionality for past, current, and future restoration efforts; and a user friendly tool interface that is readily utilized by non-economists and non-ecologists.

Many ecological models produce measures that are too granular and for which there is little or no economic valuation literature. Other models are too general and produce results that are neither believable nor actionable. The goal of this framework is to find the balance point to produce a tool, dataset, and supporting methodology that increases understanding and demonstrates the impact and importance of ecosystem restoration to surrounding communities.

We discuss the challenges of developing a coupled ecological and economic modeling approach given these objectives, for application to future projects with similar goals and objectives. This framework includes identifying valuation goals, identifying key restoration activities; grouping and classifying restoration activities; dealing with inconsistent datasets across a broad region; balancing resolution, realism, precision, and usability; achieving parsimony in complex modeling; addressing timescales; mapping outputs to ecosystem services; and best methods for communicating model dynamics. We also discuss integrating stakeholders into the modeling process and keys to successful collaboration.

BIO: Sara Phelps is a graduate research fellow at the University of Florida studying aquatic biogeochemistry and anthropogenic impacts to biogeochemical cycling in urban watersheds. She has almost a decade of experience in watershed management and wetland restoration.

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THE EFFECTS OF DIFFERENT RESTORATION STRATEGIES ON TOPSOIL CONDITIONS IN A DRAINED MEDITERRANENAN PEATLAND (ITALY)

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A pilot experimental field of about 15 ha was set up within the basin of Lake Massaciuccoli (Tuscany, Italy) in order to compare different strategies for peatland restoration after almost a century of drainage-based agricultural use. The different strategies combined peatland rewetting and water phyto-treatment to reduce the nutrient loads in waters (before they were delivered to the Lake) and to slowdown the annual rate of subsidence.

A paludiculture system (PCS), a constructed wetland system (CWS) and a natural wetland system (NWS), were put in comparison with the usual cropping systems (UCS) adopted in the research area.

Changes in peat soil quality (depth layer 40-60 cm) among the different systems were investigated from a chemical and biochemical point of view. Moreover, the evaluation of different forms of bioavailable and not available phosphorus were also carried out, considering the importance of the biogeochemical cycle of phosphorus in wetlands and in peatlands management. Hence, a sequential phosphorous extraction was applied to assess the following fractions: easily available P for plants, intermediate available P, organic matter blinded P and, not available P.

The soil in the traditionally cultivated area was mainly characterized by oxidant conditions (redox potential range = 255-370 mV), by higher content of overall microbial activity (butyrate esterase activity range = 1997-2349 mmol MUB kg^{-1} h^{-1}), by low levels of easily available phosphorus for vegetation (NH4Cl-P = 4.96 - 9.30 mg P kg^{-1}) and by medium total carbon content ranged from 25.0 to 30.7%.

In the paludicultural systems, the levels of total carbon and the content of bioavailable P were higher (35.6-41.9 % C and NH_4Cl-P 12.34 - 17.99 mg P kg^{-1}, respectively), while the oxidant conditions were lower (97-145 mV). As expected, the soils in the CWS and NWS were characterized by more reducing conditions (11-113 mV and 5-54 mV, respectively) and by higher level of arylsulphatase activity (108-281 and 221-524 mmol MUB kg^{-1} h^{-1}, respectively), enzyme links to S cycle. It was noteworthy that soils in the CWS were associated to the highest level of carbon content and of enzymatic activity, while NWS systems are characterized by the highest level of not available P (more than 80% of available P).

The choice of the restoring strategy showed to have significant effect of the dynamics of chemical and bio-chemical conditions of soils. The most conservative effects seemed to be attributed to the no-cultivation options (CWS and NWS).

BIO: Dr. Giannini is a post-doctoral fellow with a research experience in peatland restoration and paludiculture, Since 2013, she has studied peatlands sustainable cultivation in the Mediterranean Region aiming at the identification of the most suitable crops and their possible use in different energetic chains.

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C.P. 31

CONTRIBUTED PAPERS 31

MICROPOLLUTANTS

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URBAN STORMWATER CONSTRUCTED WETLAND EFFICIENCY: COMPARISON OF MICROPOLLUTANTS REMOVAL AND ECOTOXICITY ASSESSMENT

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Stormwater is identified as a major source of pollution in waterbodies. Particularly, heavy metals (HMs) and Polycyclic Aromatic Hydrocarbons (PAHs) in stormwater are highly toxic compounds for living organisms. To limit the impact of these micropollutants on hydrosystems quality, stormwater constructed wetlands (SCWs) have been built worldwide. A classical approach to determine SCW efficiency is to assess micropollutants loads during rain events (Bavor et al., 2001; Birch et al., 2004; Bressy et al., 2012; Lee et al., 2006; Mays and Edwards, 2001; Schmitt et al., 2015; Scholes et al., 2005; Yeh et al., 2009). Yet in temperate countries, SCWs work mostly during dry weather (70% of the time for the studied SCW). Furthermore, SCW can have ecological benefits: they attract species whose growth, survival and breeding may be compromised because of the stored water in SCW during dry periods (Hale, 2018).

This study is a combined approach to assess the efficiency of an urban SCW. The micropollutants loads and removal efficiencies of a sedimentation pond followed by a vertical flow sand filter in urban area (Strasbourg 67, France) have been determined during 18 wet sampling sessions (from October 2015 to July 2018). Then the potential ecotoxicity of the SCW has been studied during 5 campaigns during dry and wet periods (general toxicity on bacteria, seaweed, yeast and human cells, genotoxicity on prokaryote and eukaryote, endocrine disruption on human cells).

Table 4: Removal efficiency (RE) of the total SCW, the pond and the filter to remove dissolved (D), particulate (P) metals and PAHs (minimum – maximum [average])

Micropollutants	Pond RE (%)	Filter RE (%)	SCW RE (%)
	Mass	Mass	Mass
Chromium-D	87	100	100
Chromium-P	−67–100 [44]	97	94–100 [97]
Cobalt-D	100	*	100
Cobalt-P	58–100 [86]	93	97–100 [98]
Copper-D	59	99	100
Copper-P	48–100[83]	99	100
Lead-D	75–100 [90]	94–100 [99]	100
Lead-P	63–100 [88]	91–100 [98]	100
Zinc-D	100	*	100
Zinc-P	100	*	100

Removal efficiencies varied from 50% (naphthalene) to 100% (particulate Zn) (Table 4, results for HMs along the treatment system). Then, the ecotoxicity essays highlight a difference between wet and dry periods. During wet periods, the arrival of polluted stormwater in the SCW leads to a high ecotoxic potential in the treatment system (figure 1) which decrease during dry periods. Finally discussion was done on the link and complementary approaches of analytical and biological surveys.

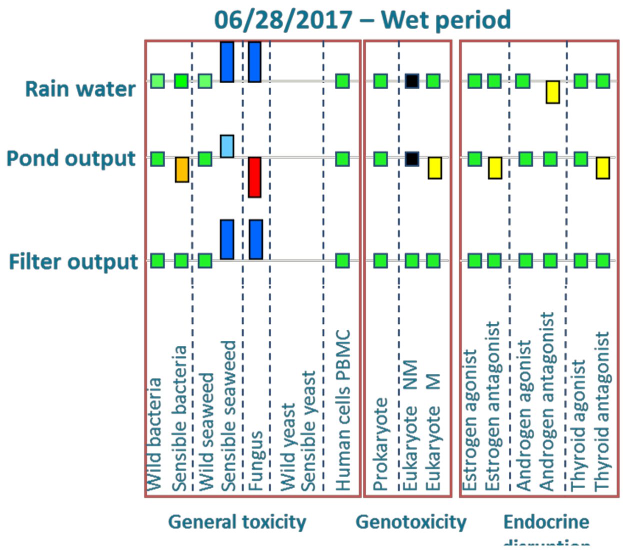

Figure 9: Results of ecotoxicity essays performed on SCW waters sampled during a wet period

BIO: Dr. Walaszek wrote her doctoral thesis about hydrodynamic numerical modelling, micropollutants removal and storage efficiencies in urban stormwater constructed wetland.

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FATE AND DISTRIBUTION OF PHARMACEUTICALLY ACTIVE COMPOUNDS IN MESOCOSM CONSTRUCTED WETLANDS

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Removal of pharmaceutically active compounds (PhACs) in constructed wetlands (CWs) is a complex interplay of different processes, mainly photodegradation, sorption, biodegradation, and phytoremediation. In this research, we studied the fate and distribution of seven PhACs in mesocosm CWs and the effect of irradiation via pre-photocatalysis, substrate (mainly sediment) composition through addition of litter (dead plant biomass), and plants.

First of all, results show that mesocosm CWs were functioning as treatment systems by actively removing organic matter and PhACs in the influent. CWs were started up within 10 days and showed a varying removal performance for the PhACs tested: low to moderate removal for carbamazepine (CBZ, 7% median) and diclofenac (DFC, 46%), and high removal for caffeine (CAF, 99%), naproxen (NAP, 89%), metoprolol (MET, 85%), propranolol (PRO, 84%), and ibuprofen (IBP, 79%).

Secondly, all seven PhACs were detected in substrate and plant tissues, including roots and rhizomes (RR tissues), and stems and leaves (SL tissues). Intermediate hydroxyl-IBP was detected in the aqueous phase, substrate and plant tissues as well. Another intermediate glucopyranosyloxy-hydroxy-IBP was observed in RR tissues. Thirdly, mass balance of PhACs in CWs was estimated, from which we found sorption dominated PRO removal while other six PhACs were mainly removed by biodegradation and/or phytodegradation.

Finally, pre-photocatalysis significantly increased removal of PhACs except for CAF and IBP, through photodegradation in the light compartment and further removal enhancement in the subsequent plant compartment. Litter addition in CW significantly enhanced removal of PRO, CBZ, and IBP via biodegradation and/or phytodegradation. Substrate composition did not affect removal of the other four PhACs. We conclude that plants played an essential and positive role in the removal of all the seven PhACs, resulting from direct phytoremediation (uptake and phytodegradation), and indirectly enhancing sorption and biodegradation.

Our study provides knowledge to understand removal mechanisms of PhACs in CWs and to potentially enhance the performance of CWs toward PhAC removal by enhancing the removal processes. Recommendations include the development of pre-photocatalysis, addition of dead plant biomass, and optimization of vegetation.

References

He, Y.; Sutton, N. B.; Lei, Y.; Rijnaarts, H. H. M.; Langenhoff, A. A. M. Fate and distribution of pharmaceutically active compounds in mesocosm constructed wetlands. https://doi.org/10.1016/j.jhazmat.2018.05.035. Journal of Hazardous Materials 2018, 357, 198-206.

<u>BIO:</u> Dr. He is a research associate in Nanjing University, China. She has rich experience in studying pharmaceutical removal processes, including photodegradation, sorption, biodegradation, plant uptake and phytodegradation in constructed wetlands. She is now leading/participating 6 projects dedicated to exploring removal mechanism of micropollutants and removal enhancement techniques in constructed wetlands.

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ROLE OF TARGETED BIOCHAR-ACTIVATION IN THE REMOVAL OF MACRO- AND MICROPOLLUTANTS FROM SECONDARY EFFLUENT WASTEWATER

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Biochar is a carbon-rich solid material obtained by heating biomass, e. g. wood under temperatures (600 – 800°C) lower than those conventionally used for activating carbon with standard pyrolysis. Its physical properties such as large specific surface area, porous structure, enriched surface functional groups and mineral components make biochar being an excellent adsorbent for removing pollutants e.g. from municipal wastewater. Recently, biochar has been considered as a possible new generation substrate for vertical flow constructed wetlands.

To improve its properties, biochar can be activated by fermentation (targeted biological activation) where the desired bacteria and fungal groups are established. The advantage of the presence of the fungi is their link with metabolic processes where inert micropollutants can be destroyed. A key role in these metabolic processes is plaid from the sorption capacity together with the pore volume of the biochar (surface area of activated biochar is < 500 m^2/g). These properties make the biochar activated by targeted activation a very promising substrate in terms of removing not just macro- but also micropollutants.

As a case of study, the performance of sand as well as other soil-filters (activated biochar, non-activated biochar, zeolite – all the substrates mixed in different ratios with sand) for the removal of macro- and micropollutants (pharmaceuticals, pesticides, surfactants etc.) from secondary effluent wastewater (experiments with synthetic wastewater) was compared in the Interreg Greater Region founded EmiSure project. In this research the removal of 27 xenobiotics in wetland system environment is investigated.

At the pilot scale installation, 3 substrates resulted equal rates in terms of micro and macropollutants removal, where 24 of 27 substances were eliminated with more than 90 %. Among the substrates, sand is one of the most conventionally used support matrix materials in vertical flow constructed wetlands. Eventhough this filling does not show a comparable hydraulic conductivity as the other mentioned fillings, it shows good results in terms of removing of micropollutants. Zeolites, thanks to their extensive porosities and specific surface area are also very promising agens in terms of contaminant removal. Nevertheless it was founded, that the increase of amount of zeolite from 15 to 30 % does not improve the performances of the substrate. On the other hand, the increase of amount of activated biochar in the same range does improve its performance in terms of removal of micropollutants (e. g. Cyclophosphamide, Mecoprop and fluorosufactants).

The aim of the further research is to obtain representative results at the test upscale installation at a full-scale plant operation at wastewater treatment plants under ‘real’ conditions (fluctuaction wastewater, temperature,…).

<u>BIO:</u> Hana Brunhoferova is in her first year of PhD at the University of Luxembourg. The main focus of her research is the elimination of micropollutants from wastewater with help of constructed wetlands and looking for the optimal conditions for the elimination of micro- and macro-pollutants (Phosphorus, Nitrogen, COD, etc.)

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MODELING PAHS TRANSFER FROM POLLUTED SOIL TO HERBACEOUS SPECIES IN PHYTOREMEDIATION ATTEMPTS

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Soil-plant transfers of organic pollutants depend not only on the physico-chemical properties of the molecules under consideration, but also on the physiological processes involved in plant development. A mechanistic model of soil-plant transfer of PAHs has been developed based on the concept of fugacity, which includes processes such as advective absorption in plants, diffuse absorption, chemical equilibrium, xylem and phloem transport, growth dilution and deposition of soil and air particles (Trapp and Legind, 2011). This model integrates the physiological characteristics of plants, as well as the different exchanges that can occur between the plant and environmental media (air, soil and/or water). In this study, the model applied to short-lived herbaceous plants takes into account the physico-chemical properties of soils, plant physiology and the main transfer processes between plant compartments. This work therefore aims to see the accuracy of the model in terms of comparing the soil-plant transfer of PAHs between simulated results and experimental ones from the phytoremediation attempts (Nguemté et al., 2018). The consideration of sap flow *via* xylem and phloem vessels has been considerably improved compared to the original version of Hung and Mackey (1997).

Three plant compartments that includes roots, stems and leaves of 3 plant species - *Eleusine indica, Cynodon dactylon* and *Alternanthera sessilis* - are concerned to predict the PAHs concentrations as a function of time and their initial air and soil concentrations. For each plant species, a system of linear differential equations was solved analytically to calculate the fugacity factor of each compartment. Input parameters of the model consist of both experimental and literature data, including initial PAH content inside the soils, physico-chemical properties of PAHs (partition coefficients, Henry constants…), flowrates, retention times and transport half-lives of PAHs inside the plant. Using in situ weather data and Penman's law, xylem flows was estimated as evapotranspiration for each plant. While employing a Generalized Reduced Gradient (GRG2) nonlinear optimization solver method, phloem vessels flows were calibrated thanks to experimental data from phytoremediation of hydrocarbon polluted soils.

Overall, the simulated PAH concentrations in the different plant compartments are significantly similar to the experimental concentrations according to the student's *t*-test. Compared to the Mackay_1997 model, the improved model corresponds more closely to the experimental model. The physico-chemical properties of PAHs play an important role in their soil-plant transfer. In fact, the 10 heaviest PAHs, having 4 to 6 benzene rings, gave better simulation results. While the 3 lightest PAHs (Fluorene, Anthracene and Phenanthrene) showed greater differences between the simulated and the measured values, regardless of the plant compartment and species. This study therefore confirms the accuracy of the improved model to predict the soil-plant transfer of PAHs. The model can then be effectively used to predict the soil-plant transfer of organic compounds, especially those with properties similar to PAHs.

BIO: Pulchérie Matsodoum is a finishing PhD student in Plant Biotechnology. Her interest on environmental sciences led her to work on an eco-friendly remediation process of hazardous pollutants during her PhD. She has 4 publications on both composting and remediation works.

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NATURE-BASED SOLUTIONS FOR WASTEWATER TREATMENT: CAN THEY STOP MICROPLASTICS POLLUTION?

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Microplastics (MPs) has been recognized as a global environmental problem since they may endanger the biodiversity of aquatic ecosystems and represent also a concern for human health. MPs are produced for 80% by land based activities which discharge them into aquatic systems. Sewage treatment plays a crucial role in preventing MPs entering aquatic systems.

Constructed wetlands (CWs) are sewage treatment systems broadly used worldwide, however there is no mention in the literature of studies on MPs treatment using CWs. The present research project aims to fill this gap by studying the removal efficiency of a Horizontal Flow CW(HF CW) system in Aalbeke (Flanders, Belgium), providing tertiary treatment after a Rotating Biological Contactor.

Wastewater and macroinvertebrates samples were pretreated in order to remove the organic matter. While wastewater samples underwent a wet digestion using a solution of 30% H_2O_2, macroinvertebrates were digested using a solution of 10% KOH. In both cases, the digestion of organic matter was enhanced by constantly heating the samples at 70°C. After the digestion step, a density separation method was applied to divide plastic particles from non plastic particles. Wastewater and macroinvertebrates sample were processed using a saturated solution of 40% $CaCl_2$ (d=1.4 g/cm^3), the samples centrifuged and, finally, the supernatant was collected onto a glass membrane filter. The analysis of MPs was performed by visually counting the MP particles under a stereomicroscope. All the particles counted as plastics were previously tested with the hot needle technique to assure their plastic nature.

Preliminary results have shown that the HF CW is able to remove most of microplastics present in the wastewater. Indeed, we have found a reduction of 93.6% of MPs after the treatment. Moreover, we characterized the MPs by shape and size and observed that the HF CW was able to greatly remove both fibers and particles with an efficiency of 91.4% and 96%, respectively. Removal of MP particles of different sizes (from 5 mm to 40 µm) was relatively constant for all the sizes, ranging from 87.4% (MPs between 425 and 150 µm) to 100% for large MPs (from 5 mm to 1 mm). Further results will be presented during the conference.

BIO: Mr. Marcello Santoni is a PhD student at Ghent University. He conducted his Master's thesis at the Helmholtz Research Center (Leipzig), dedicating his research to studying the removal efficiency of constructed wetlands for organic pollutants. Lately, he has been investigating microplastics as ubiquitous, emerging pollutants.

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C.P. 32

CONTRIBUTED PAPERS 32

NITROGEN

Margit Kõiv-Vainik

NUTRIENT MITIGATION PRACTICE IN CONSTRUCTED WETLANDS IN LATVIA

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Three different types of constructed wetland systems were included in this field study to compare nutrient retention under the meteorological and farming conditions in Latvia. The research sites were located in the Zemgale region, the central part of Latvia, which can be characterized as intensive in terms of agricultural activities.

A horizontal subsurface flow constructed wetland was built to treat contaminated surface runoff from a farmyard with solid manure and agricultural equipment storage on a waterproof surface cover. The surface area of the wetland was 1.2% of the catchment area. A surface flow constructed wetland was constructed to treat drainage water collected and routed from agricultural areas. The surface area of the constructed wetland and catchment area ratio was 0.5 % in this study. Three water level control structures were installed in open ditches to provide suitable flow conditions for nutrient and suspended solids retention and treat surface and drainage runoff from agricultural area.
In order to evaluate the nutrient retention efficiency of the water treatment systems, water samples were collected at the inlet and outlet of the system, since June, 2014 using a grab sampling approach once or twice per month depending on discharge patterns.

Nutrient retention efficiency in the wetland systems was affected by various meteorological and hydrological factors. Air temperature during the winter period was below 0°C on average 51 days per year during the time period of 2014 – 2017. Average monthly precipitation was 49.5 mm and varied from 3.7 mm to 150.5 mm per month during the same time period.

The monitoring results obtained during this study showed that on average the concentrations of total nitrogen and total phosphorous were reduced by 53% and 89%, respectively, in the horizontal subsurface flow constructed wetland. The surface flow constructed wetland on average reduced nutrient concentrations of total nitrogen and total phosphorous by 19% and 50%, respectively. Three water level control structures demonstrated reduction of total nitrogen on average by 3%, 4% and 5%, and reduction of total phosphorous on average by 25% and 6% for two of the structures during the study period. In general, all the approaches examined during this study showed a potential to remove nutrients from agricultural runoff.

BIO: Linda Grinberga is a PhD student in study program of Environmental Engineering. She is international coordinator, lecturer and researcher at the Department of Environmental Engineering and Water Management. She has experience in planning, designing, and implementing pilot projects of wetland construction in Latvia. She has participated in 9 scientific projects.

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ENHANCING TRICLOSAN PHOTODEGRADATION IN WETLANDS: EFFECTS OF PH, DISSOLVED ORGANIC CARBON, AND NITRATE CONCENTRATION

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Triclosan is a common antimicrobial molecule that is frequently detected in aquatic environments due to its wide use in many consumer products. Its potential toxicity and bioaccumulation potential have led to rising concern for the health of humans and ecosystems. Constructed wetlands have shown potential to reduce triclosan pollution, in particular via aqueous phototransformation. However, to date, the effect of common factors on triclosan phototransformation in wetlands are unknown. A better characterization of such effects could help improve wetland design for sustainable triclosan removal. This study investigated the role of pH, nitrate concentration, and dissolved organic carbon (DOC) concentration on triclosan phototransformation. A three-parameter three-level Box Behnken experimental design was used in lab-scale reactors. Nitrate and DOC are known to generate radical species that promote triclosan phototransformation, while pH was selected given that triclosan's pKa, at 8.2, is within the range of typical wetland water pH values. Triclosan phototransformation followed pseudo first-order kinetics in both the direct and indirect phototransformation experiments. Direct phototransformation increased with pH; whereas, in the indirect phototransformation experiments, both an increase in pH and a decrease in DOC concentration significantly increased the rate of triclosan phototransformation. Transformation products such as 2,4-dichlorophenol were formed and either accumulated (at pH 6) or were depleted (pH 8 and 10). Traditional surface flow wetlands allowing for ample open water for light penetration should be able to support active ticlosan phototransformation.

<u>BIO</u>: Dr. Passeport is an assistant professor at the University of Toronto and Canada Research Chair in Environmental Engineering and Stable Isotopes. Dr Passeport's research focuses on studying the fate and removal of contaminants from water using passive water treatment systems such as constructed wetlands, algal ponds, and bioretention cells.

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NITRATE-REMOVAL CAPACITY OF AN ARTIFICIAL WETLAND IN A SUBSURFACE-DRAINED RIVER BASIN

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As a management practice to reduce agricultural nitrate pollution in agricultural river catchments, artificial wetlands have showed potential. Several publications have reported relevant experiments at plot scale but few have worked at river-basin scale. However, their long-term efficiency and greenhouse gas emission potential are largely unknown. This study aims to fill the gaps in our knowledge in this field.

An off-stream artificial wetland (5270 m², 0.1 to 1 m deep), designed initially to abate pesticide pollution, intercepts drainage water from a 355 ha catchment in Rampillon, France (N 48°32'16.7'', E 03°03'37.3''). A sluice gate at the inlet controls the inlet drain flow during peak events especially during the winter. The inlet flow fluctuates from 0 to 120 L s^{-1}. The wetland is partially covered by sedges, reed, cattails and algae. Since 2012, an automatic water quality monitoring system measures flow, temperature, dissolved O_2, conductivity pH, NO_3– and DOC in both the inlet and outlet. High-frequency monitoring is performed (discharge with an ADCP probe and nitrate concentration with a UV spectral device at an hourly time step), supported by weekly flow-weighted samples to assess nitrate removal between the artificial wetland receiving agricultural drainage water. In May and November 2014 and March, November 2015 one-week high-frequency measurement campaigns were conducted to study N_2O fluxes using 6 manually operated opaque floating static chambers and 12 floating automatic dynamic chambers (ADC). The latter were operated via multiplexer and had an incubation time of 5 minutes, whereas the gas flow was continuously measured using the Aerodyne TILDAS quantum cascade laser system. During the campaign, the reduction of nitrate concentration was measured in nine reactor pipes. Also, water samples were collected for N_2O and N_2 isotope analysis, and sediments were collected for potential N_2 emission measurements using He-O_2 method.

The 5-year monitoring showed contrasting hydrological seasons with cumulative drain flow ranging between 89 up to 269 mm/year. The average nitrate concentrations at the inlet were above 54 mg N L^{-1}, whereas the concentrations at the outlet were 19% lower for the 5-year period. The time during which nitrate concentration exceeded the 50mg N L^{-1} limit was reduced from 45% to 17% of the year. Denitrification removed about 24% of nitrate that entered the wetland. N_2O emissions were low with an average of 1.1 µg N_2O-N $m^{-2}h^{-1}$, ranging from -25 to 62.8 µg N_2O-N $m^{-2}h^{-1}$. Extrapolated N_2O fluxes of N_2O were not significant with less than 3 kg N_2O-N emitted of the 312 kg N-NO_3 removed (<0.1%).
In conclusion the nitrate removal potential of the artificial wetland is high. However, high variation in the efficiency must be considered during the year due to changes in hydraulic residential time and temperature. Denitrification is the main process involved, without significant N_2O emissions (less than 0.1% of the removed nitrate).

BIO: Dr. Tournebize is a senior scientist at the IRSTEA, Antony, France. He is an internationally renowned expert in catchment hydrology, particularly in design and performance of constructed wetlands and riparian zones in various countries of Europe.

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NITROGEN REMOVAL AND NITROUS OXIDE EMISSIONS IN A SUB-SURFACE CONSTRUCTED WETLAND TREATING AGRICULTURAL DRAINAGE WATER

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Leaching of nitrogen from agricultural lands to river networks, lakes and seas contributes to the eutrophication of these ecosystems and can lead to, for example, hypoxia, loss of biodiversity, and degradation of drinking water quality. To mitigate eutrophication, constructed wetlands are recognized as an effective option to remove nitrogen from agricultural drainage water. Constructed wetland primarily relies on denitrification, a microbial process that converts nitrate (NO_3^-) present in the water into gas as dinitrogen (N_2) and nitrous oxide (N_2O). Although N_2 is generally the main end-product of denitrification, the release of N_2O is problematic because N_2O is a potent greenhouse gas responsible for stratospheric ozone destruction. Hence, it is important to ensure that mitigation measures aiming at improving water quality do not contribute to climate forcing.

Here, we present the results of nitrogen removal efficiency and N_2O emission in a sub-surface constructed wetland (SSCW) test unit located in Denmark. The test unit consists of two independent constructed wetlands (CW1 and CW2) with horizontal flow receiving drainage water from an agricultural catchment. The matrix in the wetlands consisted of a mix of willow woodchips and mussel shelves (50:50 in CW1 and 75:25 in CW2). Inlet and outlets of the wetlands were monitored for TN, NO_3^- and NH_4^+ from 2017 to date using time-proportional automatic samplers. Dissolved N_2O was measured in the inlets and outlets every three weeks. N_2O emission from the wetland was measured using static chambers every three weeks.

Preliminary data analysis shows thatNO_3^- was effectively removed with average rates of 6600 and 7000 kg N ha^{-1} yr^{-1} in CW1 and CW2, respectively. Most N_2O losses occurred as dissolved N_2O in the water whereas only weak N_2O emissions were measured directly at the sites. However, the fraction of N_2O exported corresponded on average to 1.4% (range 0–10%) of the NO_3^- that was removed in CW1 and 0.6% (range 0–2.3%) in CW2. We will further explore how the hydraulic load affects the yields of N_2O and provide suggestion for management to mitigate N_2O losses while maintaining high NO_3^- removal.

BIO: Joachim Audet is a researcher at Aarhus University and his research interests are nutrient cycling and greenhouse gas emissions from freshwater ecosystems. His current projects focus on nutrient removal in restored and constructed wetlands in agricultural landscapes.

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HOW TO REDUCE THE NUTRIENT LOADS DELIVERED FROM SMALL AGRICULTURALLY DOMINATED CATCHMENTS IN NORTHERN POLAND?

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The need for food production and intensification of agricultural production received through increased use of mineral fertilizers has led to the increase of nutrients concentrations in the fresh and marine waters observed globally. In the last decades in Western European rivers the nutrients fluxes through the rivers have increased by even 10-15 fold; the contribution of aerial run off from agricultural lands is providing the largest source of nutrients. Eutrophication of the Baltic Sea continues to be the priority problem of the entire region, giving the highest rank also to the quality of inland waters in the Baltic catchment.

The Puck District is located in the direct catchment of the Bay of Puck, southern Baltic Sea. The Bay of Puck is the most shallow, western part of the Gulf of Gdansk. The area of the Puck Bay is 356 km^2, and the maximum depth is 55 m. In combination with the inland location it is highly sensitive to the eutrophication caused by the inflow of nutrients. Since the primary land use is agriculture, significant loads of nutrients get along with surface runoff to fresh water bodies and are finally discharged to the Bay of Puck by several watercourses draining the area.

Within the WaterPUCK project, funded by The National Centre for Research and Development under the Strategic Programs - BIOSTRATEG III, the concentrations of organic matter and nutrients (NO_3-N, NO_2-N, NH_4-N, N_{tot}, PO_4-P and P_{tot}) in the watercourses outflowing to the Bay of Puck are systematically measured. The research has been launched in June 2017. The fertilization schedule was inventoried by the survey of farms located in the Puck commune. In all analyzed farms plant production is carried out, while in approx. of 80 % of farm the livestock breeding is provided. Crop rotation is used by over 95% of the surveyed, while clusters are used only rarely - in 19% of farms. The average consumption of mineral nitrogen and phosphorus fertilizers per 1 ha of agricultural land in the entire population of surveyed farms was 11.9 kg $N \cdot ha^{-1}$ and 9.3 kg $P \cdot ha^{-1}$ respectively. Fertilization is carried out within the period from March to October. The concentrations of nutrients ranged from 0.28 to 7.55 mg NO_3-N /L, from 0.01 to 0.13 mg NO_2-N /L, from 0.02 to 0.58 mg NH_4-N/L, from 0.51 to 8.68 mg N_{tot}/L, from 0.02 to 0.45 mg PO_4-P/L, from 0.04 to 2.51 mg P_{tot}/L. The maximum COD was noted in November 2017 and ranged from 41.3 mg/L in Mrzezino Canal to 45.9 mg/L in Gizdepka. The seasonal changes of nutrients concentrations were observed, with maximum concentrations of nitrates in August and September after application of fertilizers to arable land. The research so far revealed that land use structure strongly influenced the nutrients concentrations in drains and streams. According to HELCOM agreement Poland is obliged to reduce nutrients loads discharged to the Baltic Sea. These drastic reductions, re-calculated per average annual outflow of Polish rivers lead to the conclusion that N and P concentrations should be below 2.5 mg/l and 0.07 mg/l respectively, which is often commented as being as low as pre-anthropogenic or at least prior to intensive agricultural production. Nevertheless, the actions towards improvement of the Baltic Sea quality need to be undertaken since the eutrophication status is alarming.

Basing on the land use structure, fertilizers consumption in the watersheds and the concentrations of nutrients in the streams, the hot spot areas within the Puck municipality were identified. The measures to prevent nutrient losses to fresh water bodies: rationalization of fertilizers consumption, society education. Next step: formation of buffer zones along the streams in the areas most intensively used for agriculture to reduce nutrient flows with the run-off. Final step: constructed wetlands developed for improvement of water quality from the most polluted ditches discharging to the watercourses. In the article the detailed view of the planned actions will be described with respect to location of constructed wetland facilities, their configuration, location of buffer zones and re-calculated loads of nutrients needed to be captured.

<u>BIO:</u> Ph.D.D.Sc. Ewa Wojciechowska, professor at Gdańsk University of Technology is a scientist with more than 20 years of experience with planning, designing and implementing wetlands construction projects. Her research interests cover water and wastewater treatment, constructed wetlands, mitigation of storm water impact in the urbanized areas.

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POSTERS

Dennis Konnerup

DIEL AND SEASONAL COMPARISONS OF GREENHOUSE GAS EMISSIONS IN A NOVEL, OPEN WATER WETLAND AND MATURE, VEGETATED WETLAND

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The Prado Wetlands, located in southern California, contain a system of wetlands designed to treat river water impaired by secondary treated municipal wastewater effluent prior to injection in a groundwater recharge system. This system of wetlands includes unique open water cells designed to remove nutrients, pathogens, and trace organics. These open water cells are characterized by a shallow water column (< 30 cm), geotextile lined bottom, and absence of macrophytes, selecting for a benthic microbial community that is largely responsible for contaminant attenuation. Phylogenetic inquiry revealed this thick (5 – 15 cm) photosynthetic 'biomat' assemblage to contain diatoms (predominantly Staurosira construens var. venter) complemented by a diverse array of heterotrophic bacteria. Previous research to characterizing nitrogen removal pathways has shown enhanced rates of denitrification within this biomat. However, the impact of this biomat on greenhouse gas production has not been assessed. The purpose of this study was to compare the production of methane (CH4), carbon dioxide (CO2), and nitrous oxide (N2O) in this open water wetland design with that of a mature, deep water (~1.3m) vegetated cell utilized to treat the same municipal wastewater effluent impaired riverwater.

To this end, we conducted a series of seasonal field campaigns within the Prado wetland system to quantify both diel and seasonal shifts in greenhouse gas production while comparing these two proximal treatment systems. Gas fluxes for CO_2, CH_4, and N_2O at the air-water interface were recorded in each type of wetland utilizing a Picarro G2508 during the three different time periods: (1) peak photosynthesis (dusk -3 hours), (2) dark shoulder (dusk +3 hours), and (3) deep dark (dawn -2 hours).

During the winter sampling period the open water cell, with its reliance on a benthic biomat for nitrate removal through denitrification, had the largest variation in CO_2 flux, acting as a sink during peak photosynthesis (-74 +/- 33.8 mg-C/m^2/d) and producing CO_2 during the deep dark period (451.66 +/- 72.9 mg-C/m^2/d). For the mature vegetated cell, accounting for only the aqueous gas flux, the flux during the deep dark period the flux was shown to be 1660 +/- 511 mg-C/m^2/d. As for CH_4, the trends were less apparent though the data showed the open water cell to have a higher emission rate during the deep dark period (31.5 +/- 41.5 mg-C/m^2/d vs 4.6 +/- 1.9 mg-C/m^2/d) when compared to the mature vegetated cell. Both wetland configurations appear to be sources of N_2O, with the open water cell emitting less in comparison to the mature vegetated cell (e.g. 0.46 +/- 0.14 mg-N/m^2/d vs 2.11 +/- 2.73 mg-N/m^2/d during the peak photosynthesis period). This work improves our understanding of the biogeochemical mechanisms associated with pollutant removal in both open water and mature vegetated wetlands, while providing additional insights to other work focused on the characterization of nitrogen removal pathways within the open water wetlands. Work continues on the seasonal operation of these novel wetlands and the characterization of their processes and products with the goal of providing a holistic assessment of their impacts on the environment.

BIO: Adam Brady is a PhD student at the Colorado School of Mines focused on quantification and optimization of novel wetland designs. Working with collaborators, Adam's interest is in improving the sustainability and resilience of managed and engineered natural system analogues with a specific focus on open water wetlands.

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HCH REMOVAL IN BIOCHAR-AMENDED WETLANDS

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Wetlands are well recognized as an efficient solution for various environmental problems including pollution by wide range of toxic substances. The hexachlorocyclohexanes (HCH) and especially γ-HCH (lindane) are long banned pesticides, however still present in large quantities at many contaminated sites in EU and other countries. Besides HCH, chlorobenzenes (ClB) are typically found in the same zones as HCH degradation products. Main objective of this study was to evaluate efficiency of HCH and ClB removal by biochar installed in constructed wetland system. The main advantage of a biochar bed is in its simplicity and its immediate performance in contrast to wetland modules with surface vegetation.

Installation of biochar in a HCH-polluted site was set-up in two versions: as a loose (E1) and bagged into jute packaging of 40 kg (E2). A total of 750 kg of biochar has been installed in each of the two chambers. The concentration of target substances (HCH, ClB) have been monitored in the inflow of the all chambers (E1, E2) and the outlets together with three reference wetlands (A,B,C) of higher succession stage.

Biochar has shown a high efficiency in cleaning drainage water from HCH and ClB. Bagged biochar (E2) showed 80-90% removal of target pollutants while free biochar (E1) reached over 90%. This high efficiency of free biochar was even increased to 96% when the initial high flow rate (15 l /min) decreased. In E2, the lower efficiency was due to the preferential flow of water between the individual bags. In the reference wetlands, biochar efficiency was similar to wetland (C) filled with iron chips (87-95%). Classical constructed wetland with soil substrate (A) and biodegradation wetland filled with corn, grain and wood chips (B) removed about 85% HCH.

Amplicon sequencing revealed dominance of iron- and sulfur-oxidizing bacteria such as *Gallionella sp*. and *Sulfuricurvum sp*. in E outlet, while in E sediment these taxa were not present at all. Sediment samples turned out to be rich of *Simplicispira sp*., *Rhodoluna sp*., *Rhodoferax sp*. and *Flavobacterium sp*.
Effectiveness of biochar wetlands may encourage the use of biochar filling, e.g. for temporary installations of water purification during the construction of other wastewater treatment technologies or as final solutions at contaminated sites.

BIO: Aday Amirbekov is 2nd year PhD student of Technical University of Liberec. His work focused on biodegradation of pesticides with microorganisms. He is also involved in the project dealing with constructed wetlands for pesticide elimination (TH02030766).

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FINE ROOTS DYNAMICS IN HARDWOOD FLOODPLAIN FORESTS AT THE MIDDLE ELBE RIVER

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Hardwood floodplain forests are among the most productive ecosystems in Central Europe and are affected by opposing extremes of environmental factors. Trees in floodplain forests at the Middle Elbe River experience periodic flooding succeeded by summer drought. Under flooding oxygen concentration in the soil becomes critical, and reduced water availability in the summer leads to drought stress. Both of these factors are hypothesized to bring about a high mortality level of fine roots especially of young trees with shallow root systems, which in turn leads to chronical nutrient and water deficiency. This could result in reduced resilience and finally in the vitality loss of young trees in floodplain forests. Thereby factors interfering with fine root health are believed to be crucial for the success of reforestation efforts. Despite a high number of studies on fine roots in different ecosystems, belowground processes in floodplain forests are in general poorly understood.

In our study, we aim to compare fine roots parameters of two stand-forming tree species of hardwood floodplain forests – *Quercus robur* and *Ulmus laevis.* We tested to which extent the tree age and environmental factors such as drought affect vitality and productivity of fine roots. We sampled soil next to three oaks and three elms on four randomly chosen plots (two plots in young forests and two plots in old forests) along the Elbe River during the growing season of the year 2018. We analyzed the amount of living and dead roots in soil samples by microscoping and scanning fine roots in the lab.

The results are currently analyzed; first findings will be shown on the poster. Our next steps will involve quantification of mycorrhiza and the study of fine root dynamics of *Q. robur* and *U. laevis* using minirhizotrons and in greenhouse experiments. The aim of the project is to understand belowground biotic interactions in floodplain forests and its potential relevance for conservation management approaches of floodplain ecosystems.

This study is a part of the multidisciplinary MediAN project (http://uhh.de/median) and funded by the BMBF (Bundesministerium für Bildung und Forschung).

BIO: Anastasia Leonova is a PhD student at the Applied Plant Ecology Group at the University of Hamburg. Currently, she is working on experiments examining the relationships between fine roots of trees and environmental factors in hardwood floodplain forests.

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DESIGN OF REVITALIZATION MEASURES ON MAIN DRAINAGE FACILITIES

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A new approach to Main Drainage Facilities (MDF) revitalization is presented in this paper.
In the Czech Republic, around 30% of agricultural land is tile-drained, and in some regions land drainage exists on every field. Drainage systems were usually built as systematic tile drainage with conducting drains discharged into MDFs. These facilities were mainly built as open straight channels or pipe lines and they have some negative effects on the environment such as shortening water residence time in the drained area, lowering the ground water table, and polluting shallow subsurface water with nitrates and pesticides.
One way to mitigate these effects while conserving systematic drainage function and landscape productive services is to revitalize the MDFs. The methodology was tested in the pilot area of Žejbro (in the vicinity of the town of Skuteč, Czech Republic). First, the most vulnerable area (sub-catchment) was chosen using used the Catchment Measures Need Index (CAMNI), which assessed the vulnerability of the water quality and quantity caused by subsurface (drainage) runoff and pollution. The CAMNI consisted of the i) catchment arable land ratio, ii) catchment drained land ratio, iii) catchment low-retention grassed soils ratio, and iv) catchment pond or water surfaces ratio. The CAMNI values were classified into five categories from 1 - negligible catchment measures need - to 5 - high catchment measures need. The CAMNI was computed for small catchments (2-40 km^2) and sub-catchments (5-300 ha) in the experimental area.
A precise field survey was conducted in the selected vulnerable area. Then, plans of the drainage systems in the surveyed area were scanned and ortho-rectified in Arc GIS.
The main and supplemental revitalization measures were designed based on all these data. The tubular upper section of the MDF was redesigned as an open stream with vegetative strips. In the middle section of the MDF, a pool with permanent flow was designed with a protective grassed area and a service road. This pool will affect biodiversity in the area and, consequently, it will increase water retention, nitrates denitrification, and pesticide decomposition. In the lowest section of the MDF, the channel was redesigned as a gently winding stream with vegetative strips. The function of the drainage systems was preserved because of intensive farming in this area. This measure will retard runoff from this locality, especially during rainfall-runoff events, prolonging the channel length and improving the water self-purification of the stream.
All the measures were laid out in “Type A Measure Lists”. Each list describes one particular measure in one particular area. All the measures designed should shift MDF characteristics closer to a natural stream and preserve farming in the revitalized area as well.

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The research was supported by the project TH02030397 “New approaches to the revitalization of main drainage facilities in relation to drainage systems in terms of water retention in the landscape” provided by the Czech Technological Agency.

BIO: Dr. Zajíček is has been dealing with subsurface runoff, agricultural drainage and water quality in agricultural catchments for 15 years. He has experience with delimitation of vulnerable areas of non-point agricultural pollution. https://www.researchgate.net/profile/Antonin_Zajicek

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POTENTIAL OF ESTUARINE SALT MARSH PLANTS FOR PHYTOREMEDIATION OF BEZAFIBRATE AND PAROXETINE

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Continued worldwide industrialization has led to an increased release of several types of pollutants to the environment, including contaminants of emerging concern, such as pharmaceuticals. Most water treatment stations are not equipped to deal with these pollutants, increasing their discharges in the environment.

Estuaries are sinks for contaminants, being one of the most affected environments by the release of these pollutants. Thus new remediation strategies for these areas are imperative.
This study aimed to evaluate the potential of a salt marsh plant (*Phragmites australis*) and its rhizosphere microorganisms for the removal of two pharmaceutical compounds, namely an anti-lipid, bezafibrate, and an antidepressant, paroxetine, from estuarine environments. For that, a 7-day-long experiment, in which the plants were subjected to a simplified estuarine medium, elutriate solution with or without estuarine sediment. Tested were carried out in the absence and presence of nutrients, as well as in the absence and presence of another pollutant, copper.

Selected salt marsh plant, alone or together with the sediment, showed to play a role in the degradation/ removal of both pharmaceutical compounds In the presence of *P. australis* a removal percentage of 65% for paroxetine was observed, whereas microorganisms present in the sediment lead to a removal of 85%. For bezafibrate, removals were slightly lower, attaining 34% in the presence of *P. australis* and 59 % due to microbial degradation. In the presence of Cu, a removal efficiency of 75% for bezafibrate and 95% for paroxetine was observed, which demonstrates that in some cases Cu might influence the retention/degradation of the compounds.

Overall, the plant and mostly it rhizosediments and the microorganisms associated have potential to remove these contaminants from estuarine areas and eventually degrade the selected compounds, a feature that requires more research. Present results indicate that phytoremediation could be a viable option for eliminating/diminishing the environmental impact of pharmaceutical compounds in water and sediments

Acknowledgments – To VALORALGA project

BIO: Dr. Almeida is a senior researcher at CIIMAR since 2005. With a PhD in Chemistry her main research area is bio and phytoremediation, being actively engage in studies aiming to enhance the use of bio and phytoremediation as biotechnology tools for remediation of aquatic environments contaminated with different pollutants.

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ASSESSMENT OF FLOATING WETLAND ISLAND IMPLEMENTED IN A PORT MARINA

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A Floating Wetland Island is a technology based in phytoremediation processes, that intents to enhance water quality, promote biodiversity and ecosystem rehabilitation, mimicking natural processes. It has been tested in multiple contexts worldwide such for remediation of eutrophic lakes and stormwater, showing good results regarding reduction of nutrients levels and other types of pollutants. However, knowledge associated to the biocenosis of the platform and their ability for contaminant removal is still scarce and more research is needed to support this low cost and eco-friendly biotechnology.

The present study final goal is to investigate the application of Floating wetland islands to promote biodiversity and water quality enhancement in port marina environments. This is a harsh environment due to water salinity, the influence from tides and maritime traffic combined with uneven distribution of organic and inorganic pollution. To our knowledge this has not yet been explored being an important issue to address. Having that in consideration a collaboration was established with APDL-Port of Leixões to implement in the marina of the Porto Cruise Terminal, in Matosinhos, pilot floating wetlands islands. The pilot system was assembled with three interconnected floating modules of agglomerated cork (Cork Floating Island®, provided by the company Bluemater), and planted with several plant species: *Sarcocornia* sp., *Juncus* sp., *Halimione* sp. and *Phragmites* sp.

The first step of this study involved the implementation of the Floating wetland islands, the assessment of plants viability and the characterization of the water in the area under study. For the later, nutrients levels, organic matter content (through chemical oxygen demand), salinity, pH and total petroleum and polycyclic aromatic hydrocarbons concentrations were determined. In parallel environmental DNA was also extracted to further study the biotic diversity associated with the root system of the plants. This approach will support the knowledge about the biotic communities associated to these platforms, mainly to the root system, in order to understand their dynamics along the colonization time and possible relations with the processes of water purification.

BIO: Marisa Almeida is a senior researcher at CIIMAR and holds 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.

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EVALUATION OF CHILEAN CIVIL ENGINEERING PROGRAMS IN NBS COMPETENCES

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The role of the engineer in Sustainable Construction goes beyond the realization of construction projects (Valdes et al, 2018). Latin-American countries have to develop and implement new solutions in order to fill the gap of existing infrastructure for urban water management (Noyola et al., 2012). In this regard, the future of technology for urban water management is shifting towards solutions, which are resource oriented, integrated, sustainable, distributed, and nature based (Masi et al., 2018). Precisely, Nature Based Solutions (NBS) are presented as a group of technological solutions (constructed wetlands are included), which are inspired in these principles. However, in countries such as Chile, the engineer´s education has been traditionally oriented to develop "gray infrastructure" and not "green infrastructure". An example of this is the low participation of constructed wetlands in Chilean rural wastewater treatment. According to Vera et al. (2016), constructed wetland technology has a participation below to 2%, meanwhile, the different kinds of activated sludge have a participation above 70%.

Therefore, the aim of this article is to present the preliminary results in determining the NBS skills for future Chilean civil engineers. The methodology used to establish these skills consists of three stages: i) Theoretical phase, ii) Validation Phase (Delphi Method) and iii) Evaluation Phase (STAUNCH method) (Lozano & Peattie, 2011). The theoretical phase consists of a systematic review of literature to determine competencies in NBS. For this study, 4180 published articles from 2012 were analyzed and coded. The articles were divided into: NBS 4.8%, constructed wetland 50.2%, water harvesting 11.2%, green spaces 30.7% and permeable pavements 3.1%. 345 articles are analyzed to determine the NBS competencies. From the theoretical Phase, 21 general competencies were identified. These competences were grouped into 4 domains: 1) context of implementation, 2) environment and ecosystem, 3) infrastructure life cycle and 4) water management and its byproducts. Now, many of the competencies are not developed in the traditional civil engineering schools in Chile and a reformulation of the current curriculum is required. For solving this, a new specialty within civil engineering programs, focused on the design, construction and operation of infrastructures based on NBS is highly recommended.

Finally, this research is currently in progress, and stages ii and iii, are being developed now. The results of these two stages are expected to provide a model and methodology for updating civil engineering curricula towards sustainable construction.

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Vera I. et al. Tecnol. y Ciencias del Agua 2016, 7 (3), 19–35.

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EFFECTS OF HARVEST TIME AND NUTRIENT SUPPLY ON FUEL QUALITY OF PALUDICULTURE PLANT SPECIES

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Conventional drainage-based agriculture on organic soils leads to soil degradation, subsidence, high greenhouse gas emissions and water, accelerating peatland loss and climate change. Worldwide, drained peatlands cover only 0.4 percent of the land area but emit almost 5 percent of the global CO2 emissions. Raising water levels to near the soil surface maintains the peat body, reduces emissions and may provide habitats for rare and threatened species. Paludiculture (Latin ‚palus' = swamp) is a land use strategy for rewetted peatlands that provides perspectives for a sustainable peatland agriculture. The production of wetland biomass for energetic use, e.g. as a solid biofuel for combustion, is one promising use option.

In comparison to wood herbacous biomass is more problematic for combustion. Generally, they are characterized by higher concentrations of critical elements that are problematic for the combustion process and emissions. For several grass species a late harvest in winter is recommended to improve fuel quality because nutrients and other elements (N, S, Cl) are reduced in plant tissues by leaching or translocation processes during plant die-off. The combustibility of herbaceous fuels depends on plant species, site specific parameters and harvest time. There are some studies about the suitability of Paludiculture plants for combustion, but little is known about effects of nutrient supply.

We studied fuel quality of *Typha latifolia*, *Typha angustifolia, Arundo donax*, and four European clones of *Phragmites australis* (Denmark, Netherlands, Romania, and Italy), harvested in summer and winter on three different nutrient levels (0, 75 and 500 kg N/ha/a). We analysed the total concentrations of C, H, N, O, S, Cl, K, Na, P, Ca, Si and ash content as well as Higher Heating Value in the above ground biomass. A comparison of plant species, harvest time and nutrient levels will be used to decide for an optimal cultivation type and management for Paludiculture purposes. The main aim is to provide biomass for combustion with high energy yields per hectar combined with the highest possible fuel quality.

BIO: Claudia Oehmke (Landscape Ecologist) has been working on Paludiculture since 2010 at the Institute of Botany (University of Greifswald). In the CLEARANCE project (2017-2020) she focuses on management and biomass quality of productive wetland plant species for energetic and material use. Claudia is an active member of the Greifswald Mire Centre.

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HYBRID SUBSURFACE SATURATED AND PARTIALLY SATURATED CONSTRUCTED WETLANDS FOR SEWAGE TREATMENT

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Subsurface flow constructed wetlands (SSF) have been shown to be effective for the Organic Matter (OM) (75-95%) and suspended solids (≥90%) removal. However, for total nitrogen (TN) removal has been less effective (30%). Due to the biological cycle, TN removal by SSF need aerobic conditions for nitrification processes, as well as anaerobic conditions for denitrifies. So, to achieve the complete nitrogen cycle, a hybrid constructed wetland (HB) was designed. This system combines the advantages of vertical subsurface flow (VSSF) and horizontal (HSSF) constructed wetlands, to generate conditions for nitrification and denitrification, respectively. To optimize the level of oxygen in the SSF the water level is the clue for the optimization the TN removal. Due to this, it is necessary to know the behavior of the HB when modifying the water level on the TN removal efficiencies.
The goal of this research was optimize the water level of a HB to improve the TN removal efficiency. To carry out the objective, HB (subsurface vertical wetlands (VSSF) and horizontal wetlands (HSSF)) with different water level were implemented: a) shallow: VSSF (0.6 m)-HSSF (0.15 m); b) deep: VSSF (0.8 m)-HSSF (0.3 m). To know the behavior of each unit were measured: pH, temperature and reduction potential of oxide and dissolved oxygen. Besides that, to evaluate the efficiency of the treatment, the influent and effluents were analyzed, regarding the following parameters: Chemical oxygen demand – COD, TN, ammonium, nitrate and nitrite. Results show that both hybrid systems show similar removal efficiencies of COD with values of 69 and 70% for the shallow and deep system, respectively. On the other hand, nitrogen in the ammonium form shows removal of efficiencies higher than 90% for the shallow system and 85% for the deep system.

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<u>BIO</u>: Dr. Daniela López Leyton is a postdoctoral scientist with more than 10 years of experience environmental sciences, biotechnology and constructed wetlands. She has experience with constructed wetland, specifically in areas of gas emission and nutrient removal of rural wastewater.

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MACROPHYTE AND SUBSTRATE SELECTION FOR THE TREATMENT OF WASTEWATER FROM CHEESE PRODUCTION

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A hybrid wetland (HW) system will be constructed for the treatment of cheese production wastewater. The aim of this study was to select the macrophytes and the substrates to be used in the horizontal subsurface flow wetland (HSSFW), second stage of the HW. HSSFWs were simulated using plastic reactors of 20 L capacity arranged by duplicated outdoors under semi-transparent plastic roof. The reactors were planted with *Typha domingensis* and *Canna glauca,* collected from natural wetlands. LECA (light expanded clay aggregate) and river gravel were used as substrates. In each treatment, one of the two types of substrates and macrophytes were used. The experiment began after a period of acclimatization of three months to achieve a good development of the roots and rhizomes and to increase the microbial biomass in the substrate. Real wastewater from cheese production was used. It receives a previous treatment to eliminate fats and to reduce the organic load. Hydraulic residence time (HRT) was seven days. The duration of the study was three months. Wastewater samples were collected before and after each loading. Chemical oxygen demand (COD), biological oxygen demand (BOD), total Kjeldahl nitrogen (TKN), ammonium (NH_4^+-N), total phosphorus (TP) and soluble reactive phosphorus (SRP) were determined in all wastewater samples according APHA (2012).

The chemical composition of the initial wastewater used in the experiment and the mean removal efficiencies are showed in Figure 1. The BOD/COD ratio was higher than 0.5 in all cases. HSSFW proved to be efficient for COD and BOD removals, without significant differences among treatments. For the other studied parameters, HSSFWs with river gravel and planted with *T. domingensis* presented the lowest removal efficiencies. The highest removals of TKN and NH_4^+-N was obtained in HSSFWs planted with *C. glauca*. The removal of TP and SRP did not present significant differences between the plant species using LECA as substrate. HSSFWs proved to be efficient for the treatment of cheese production effluent. HSSFWs with LECA or river gravel planted with *C. glauca* would be the best option for this wastewater treatment.

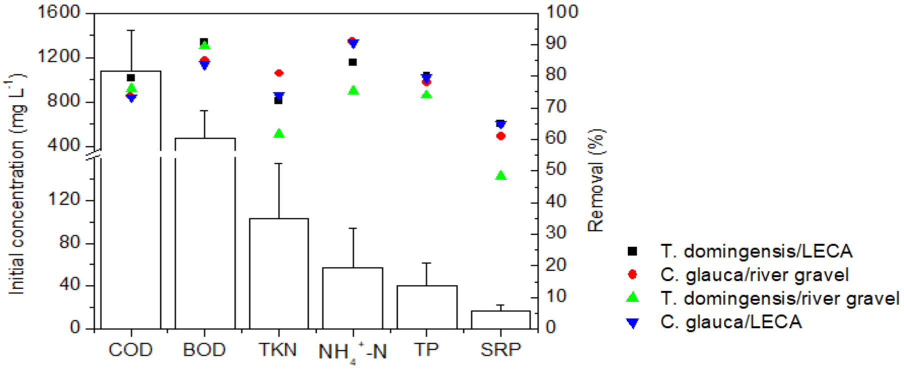

Figure 1: Chemical composition of the initial wastewater (columns) and mean removal efficiencies after the treatments (symbols).

BIO: Emanuel Nocetti is PhD student. His research topic is the application of wetland systems for the treatment of dairy industry effluents.

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COMPARISON OF THREE LIGNOCELLULOSIC WASTES AS A SOURCE OF BIODEGRADABLE CARBON FOR DENITRIFICATION

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Lignocellulosic wastes (LW) seem a good option to be used as an internal source of biodegradable organic carbon in partially saturated vertical wetlands (PSVW) which is a recent alternative to increase total nitrogen(TN) removal. TN removal is mainly achieved through the process of nitrification-denitrification, with nitrification taking place in the aerobic zone (AZ) and denitrification, presumably, in the saturated zone(SZ). In addition, it is also possible to have heterotrophic aerobic denitrification in the AZ. In a recent study, we found that denitrification took place in the SZ with the presence of corn cob, but also in the AZ (Martínez-Valles et al., 2018). On the other hand, the presence of a LW might affect some effluent quality parameters such as BOD_5, COD, color and TSS. Consequently, in order to optimize the efficiency of PSVWs for TN removal without affecting the removal of other pollutants, it is necessary to deepen in the study of some LWs. Therefore, the aim of this study was to evaluate three LWs with respect to their capacity for biodegradable carbon release, under aerobic and anaerobic conditions simulating those conditions that prevail in PSVWs.

Three LWs were evaluated in duplicate, under aerobic conditions (AC) and anaerobic condition(AnC) for 14 weeks. Before beginning the experimentation, the content of the main components, i.e., cellulose, hemicellulosa and lignin were quantified. For the evaluation in AC, 100 g of corn cob (CC), agave bagasse (AB) and pine wood shavings (PWS) were place in 1 L-container and fed with a flowrate of 0.180 L/6 h with tap water enriched with adequate minerals for bacteria growth. Similarly, for the evaluation in AnC, 100 g of each residue was place in a similar container and was fed with 0.72 L of enriched tap water and drained and replaced every 2 d. Every day, the total volume of the effluent was measured and one portion was conserved in refrigeration to make a weekly composite sample for the water quality parameters, i.e., BOD_5, COD and TSS, turbidity, apparent and true color, pH and conductivity.

The content of cellulose, hemicellulose and lignin were 49.62%, 29.53%, and 12.16%; 51.79%, 26.06% and 15.35%; and 54.38%, 17.21% and 28.34% in CC, AB and PWS, respectively. As expected, due to their different composition, the behavior of each residue was different, as can be seen in Table 1.

Table 1. Mean values of parameters measured in the effluents of the systems with LWs along 14 weeks

LW	Aerobic Conditions				Anaerobic Conditions			
	BOD (mg/L)	COD (mg/L)	TSS (mg/L)	Color Pt-Co Un	BOD (mg/L)	COD (mg/L)	TSS (mg/L)	Color Pt-Co Un
CC	92.9	81	28	65	1983	797	64	107
AB	1587	243	35	48	1248	1587	119	111
PWS	455	73	16	21	243	146	22	33

It was possible to identify that AB is not recommendable because it released a very high content of BOD in both AC and AnC, in addition to its impact on TSS and color in AnC. CC released low content of BOD in AC but high content in AnC, while PWS released a moderate content in both conditions. According to this results, CC and PWS could be used in combination depending of the desirable content of BOD for a specific wastewater.

<u>BIO:</u> Dr. Zurita is a full time professor in the Centro Universitario de la Ciénega of the University of Guadalajara in Mexico. She has conducted different research projects for more than 10 years about constructed wetlands and phytoremediation for the removal of conventional and emergent pollutants from water and wastewater.

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EFFECT OF NITROGEN LEVEL ON THE COMPETITION BETWEEN *SUAEDA SALA* AND *SUAEDA GLAUCA* IN THE YELLOW RIVER DELTA

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To reveal the impact of nitrogen (N) input level on the competition between congeners, a competition experiment in a target-neighbor design was conducted in the Yellow River Delta, with two typical congeners, *Suaeda salsa* and *Suaeda glauca*, as target plant and neighbor plant reciprocally. Three N input levels (low, 0 $g \cdot m^{-2}$; medium, 15 $g \cdot m^{-2}$; high, 30 $g \cdot m^{-2}$) and three neighbor plant densities (0 plants, 2 plants, and 4 plants per pot, respectively) were setup in a factorial design. The results revealed that biomass accumulation of both species was enhanced along with increasing N input, with *Suaeda uaeda salsa* being stimulated more. N input level had significant impact on the reciprocal relative competition intensity (CI_r) between two congeners. At low N supply level (0 $g \cdot m^{-2}$), the relative competition intensity (CI_r) that S*uaeda salsa* imposed on S*uaeda glauca* was almost the same as the reversal. However, it increased along with N input level, while the reversal decreased. Consequently, the relative competition intensity (CI_r) that S*uaeda salsa* imposed on S*uaeda glauca* became higher than the reversal at medium (15 $g \cdot m^{-2}$) and high (30 $g \cdot m^{-2}$) N input levels. With increasing N input, the interaction strength per unit biomass (I) of the two species both decreased; the relative crowding effect (D_r) that S*uaeda salsa* imposed on S*uaeda glauca* increased, while the reversal had no significant change. With neighbor S*uaeda salsa* density rising, the relative competition intensity *(*CI_r) and the relative crowding effect (D_r) which *Suaeda glauca* suffered increased, while the interaction strength per unit biomass (I) suffered changed little. The same pattern exhibited when *Suaeda* S*uaeda glauca* was neighbor plant. The reciprocal relative competition intensity between two congeners at different N input levels depended on the relative crowding effect (D_r).

Key words: Nitrogen level; plant density; *Suaeda salsa*; *Suaeda glauca*; competition.

CONSTRUCTED WETLANDS IN NORTH-EASTERN GERMANY – YET ANOTHER APPROACH

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Until today, constructed wetlands are not widely applied in north-eastern Germany. Although the benefits of treating agricultural wastewater and surface runoff for improving water quality of riverine systems are shown by researchers all across the world, only very little action was taken to apply this technology.

In a german research project , the question "Would Constructed Wetlands (CW) be more interesting for stakeholders if they could be combined with the production of renewable ressources?" is being examined. The innovation project "MeerGewinn" focuses on the role of constructed wetlands in Mecklenburg-western Pomerania for nutrient retention for the baltic sea. In this EIP agri project "Nutrient retention by the cultivation of renewable resources in constructed wetlands" (MeerGewinn) companies, local communities and farmers are working together for implementing constructed wetlands within the landscape and the regional economy. The basis for the management and cultivation of plants is the wet agriculture and forestry on peatlands – Paludiculture.

In 2017 Germany was sued by the EU for failing the contract goals of water quality improvement of several riverine systems. Agriculture plays a big role in this matter as a source of pollutants.
A possibility to enhance the implementation of constructed wetlands in agriculture is to find ways to make having a constructed wetland profitable for farmers and other stakeholders. By introducing new plants that are able to grow under the given parameters, new value chains can be established. For more clear and concise results three different sizes of Constructed Wetlands were considered.

Small scale	100 to 2000 m²
Medium scale	2000 to 20.000 m²
Large scale	20.000 – 100.000 m²

Results
The use of herbs, ornamental plants and even medicinal plants as cultivars within constructed wetlands seems to be quite promising. Besides the small-scale application, a bigger paludiculture-site can also be managed as a constructed wetland. Within this context it is possible to realize large-scale production sites that also retain nutrients from riverine systems. By harvesting the renewable resources in form of plants like Phragmites australis (Cav.) and Typha spp. (L.), additional nutrients can be removed from the system. This biomass can then be used to produce feed for cattle, plants for energetic use or substance-based products like insulation panels.
In this presentation, we give an insight to the project-results such as possibilities of cooperation between farmers, businesses and local authorities, rising the state-of-acceptance within the farmer community, creating win, win, win situations and cultivation methods for different plants within constructed wetlands in north-eastern Germany.

BIO: Hier dein Lebenslauf Henning, Researcher ins the field of agriculture and nature conservation since 1992 Working at the University of Greifswald and the Institute DUENE e.V in different projects since 1996, Project manager of the German EU funded research project MeerGewinn since 2015

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CRUSHED AUTOCLAVED AERATED CONCRETE (CAAC) - A POTENTIAL REACTIVE FILTER MEDIA TO ENHANCE P REMOVAL AND RECOVERING - BATCH STUDIES

***Joana Castellar*[1,3], *Joan Formosa*[2], *Josep Maria Chimenos*[2], *Joan Canals*[1], *Montserrat Bosch*[3], *Jordi Morato*[1], *Hans Brix*[4] *and Carlos Arias*[4]**

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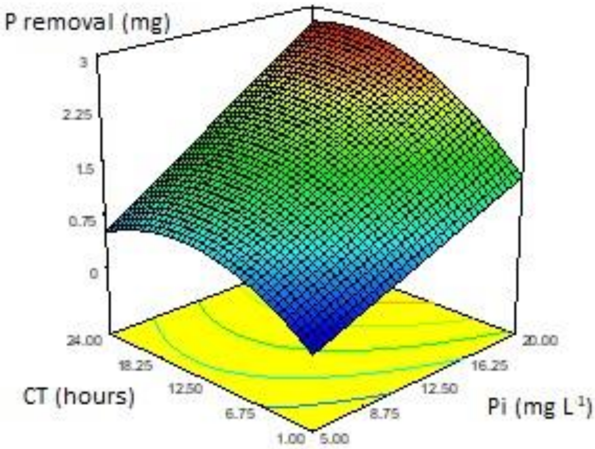
Phosphorus (P), besides being a limited resource, can cause several environmental effects due to its accumulation in the environment, such as eutrophication of water streams. In this regard, reusing Crushed Autoclaved Aerated Concrete (CAAC), a by-product from demolition, has shown potential to bind P and can be used to recover phosphorus (P) from wastewater and therefore becoming an environmental friendly way to preserve natural capital (P and water). Through our study, the potential of CAAC to be used in nature-based solutions as a P reactive external filter media was evaluated by performing preliminary batch essays. The interaction and main effects of P initial concentration (P_i - 5, 10 and 20 mg $L^{-1)}$, particle size (PS - 4 and 5 mm) and contact time (CT - 60, 180, 360, 720 and 1440 min) were studied to assess the capacity of the material, to determine design parameters when used as a nature-based solution (NBS) for the recovery of P. Physical and chemical characterization were performed to understand the removal processes involved. Moreover, the data collected were fitted in adsorption Kinetic models (Pseudo-First and Second order). The statistical analysis showed a significant interaction between CT and Pi, being the combination of its main effects stronger on the removal of P than each one separately. Although, it was noticed that as higher P_i the faster and higher the removal of P. Indeed, the results suggested that the equilibrium it is dependent on P_i. Contrary to expectations, PS 5 mm showed higher removal rates than PS 4 mm, indicating that besides adsorption, a removal process highly dependent on the specific surface of the material, other unidentified chemical process appeared. The latter assumption is reinforced by the presence of calcium carbonates in the adsorbent and the increment of pH along time. Both facts suggest that the precipitation/crystallization of P can be occurring. Further studies using columns and pilots are recommended to optimize the removal of P in nature-based solutions by reusing CAAC as P reactive filter medias.



Effect of Contact time (CT) and Phosphorus initial concentration (P_i) on the removal of Phosphorus (P) (Design-expert software).

BIO: Joana Castellar is a PhD candidate at sustainability program of Polytechnic University of Catalonia (UPC). She has experience with ecological engineering focused in nature-based solutions treating wastewaters, such as living walls and constructed wetlands. Besides, the researcher integrates circular economy into NBS design process by reusing materials as reactive filter medias.

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ENHANCED HORIZONTAL TRANSFER OF ANTIBIOTIC RESISTANCE GENES IN AN AERATED CONSTRUCTED WETLAND

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Wastewater treatment systems are known to release antibiotic resistant bacteria (ARB) into the environment. Treated wastewater often contains novel ARB in addition to those types present already in the influent wastewater. Antibiotic resistance genes (ARG) can be transferred between various bacteria in the sewage mixture. Wastewater treatment systems have hence been coined as 'breeding grounds' for ARB. The driving forces for ARG transfer are unclear. It has been questioned whether antibiotics themselves, typically present only at sub-inhibitory concentrations in wastewater, constitute a selective pressure for acquisition and maintenance of resistance genes. An alternative mechanistic explanation is that gene transfer is induced by cellular stress.

In this study, we investigated the effect of aeration in a pilot-scale constructed wetland (CW) on the fate of indicator ARG as well as class 1 integron, which is an important mobile carrier of ARG. A non-aerated CW was investigated in parallel as reference. Both CW received pre-treated wastewater from the same source. In addition to measuring standard wastewater parameters, we quantified concentrations of the antibiotics sulfamethoxazole (SMX) and trimethoprim (TMP) by LC-MS, enumerated abundances of *sul1*, *sul2*, *dfrA1*, *intl1*,*uidA*, and 16S rRNA gene copies by qPCR, and carried out ARG host profiling by cultivation-dependent means.

Overall, ARG numbers were significantly reduced in both wetlands, with the aerated system achieving a greater reduction. However, the abundance of some ARG and class 1 integrons were observed to increase within the aerated wetland. Since SMX and TMP were present only at very low concentrations in both CW, this increase suggests that environmental stress factors may influence the abundance of ARG, depending on their genetic context. Cultivation-dependent and cultivation-independent quantification of *Escherichia coli* suggested that this important carrier of ARG is under stress in the aerated CW. Thus, using CW as model systems, our results indicate that aeration during wastewater treatment drives horizontal transfer of mobile ARG.

BIO: Jochen A. Müller is a senior scientist working on microbiological transformation processes in wetlands. A further agenda of his research group is the development and implementation of hydroponic treatment systems.

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LOWNITRATE PROJECT: DEVELOPMENT OF A PASSIVE ELECTROCHEMICAL MICROBIAL SYSTEM FOR NITRATE REMOVAL IN FREE SURFACE WATER

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The goal of LowNitrate is to design a passive microbial electrochemical technology applicable in artificial wetlands or other similar ecosystems for nitrogen (NO3-) removal. The system is based on the harvesting of diffuse energy from sediment to induce a low-cost and efficient denitrification. A key idea is to induce local anoxic zones to promote denitrification without affecting the ecosystem. The system we propose is a low-cost 3D-electrode allowing a more active microbial denitrification at the sediment-water interface. Microbial oxidation of organics from sediments will produce an electron flux that is transferred to the upper zones at which microbial O2 and NO3- reduction occurs. This system is based on the principle of a sediment microbial fuel cell, but contrarily to this latter application, the energy taken from sediments will not be recovered but directly used for remediation. In this configuration, the microbial electrochemical system becomes passive and fully integrated in the artificial wetland with minimum upkeep. No additional electrochemical set-up is needed because no electric energy is extracted from the system. Nitrate reduction occurs at the sediment water interface and is inhibited in the presence of oxygen. The quantitative objective is at least to double the denitrification rate that is typically below 350 mg N-NO3-/m2/day. We have the ambition to produce a detailed study of the ecology associated with denitrification reactions in the wetland of Rampillon. A microbial indicator of the technology will be developed. A quantitative model of the denitrification in the flow conditions of the wetland will be elaborated. The final product developed in the project is a low cost/efficient 3D-electrode for faster denitrification in artificial wetlands.

BIO: Dr. Tournebize is a senior scientist at the IRSTEA, Antony, France. He is an internationally renowned expert in catchment hydrology, particularly in design and performance of constructed wetlands and riparian zones in various countries of Europe.

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STORMWATER MANAGEMENT AND TREATMENT IN CIRCULAR ECONOMY STRATEGY

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One of the priorities of the circular economy in relation to the water and wastewater management is maximum water saving and reusing.

Quality of the rainwater runoff depends mainly on the catchment management, but also type and degree of surface sealing, intensity of traffic, precipitation parameters and length of rainless periods. Depending on the place of origin and environmental conditions, chemical and physical composition of rainwater runoff varies significantly. Runoff from industrial areas and city centers are considered as the highly contaminated and therefore most dangerous. On the other hand, runoff formed in the residential areas or non-urbanized areas is treated as normal or relatively less polluted. Such runoff is characterized by a higher concentration of organic matter due to the higher participation of green areas in its structure. However, suspended solid is considered as the most important parameter of rainwater quality. Concentration of suspended solids is closely related to the level of rainwater contamination, because suspension is an excellent carrier of pollutants. It was proved that there is a correlation between presence of suspended solids in rainwater and associated pollutants such as: organic compounds (including petroleum-based products), microorganisms and heavy metals. Typical characteristic of suspension can be complemented by particle size analysis. As a result of measurements carried out with the laser granulometer, proportion of particular fractions in the suspension might be obtained. It enables to determine the percentage share of coarse and fine-grained suspension. Especially, it is important to define contribution of the smallest particles in formation of the total suspension. Due to the expanded specific surface area, fine particles have the largest share in the migration of pollutants.

This paper presents results of selected analyses of rainwater runoff. Samples were collected from stream which was receiver of stormwater overflows from the city (catchment I) and from the roof surface of individual household, situated in rural area (catchment II). The study included total suspended solids analyses and particles sizes measurements. Suspended solids concentrations varied, depending on the catchment. They ranged from 141.7 to 193,9 mg/L (catchment I; samples from the stream), whereas for catchment II rather not exceed 0.02 mg/L (pretreated samples - obtained from the storage tank). Diversity of fractions was additionally confirmed by granulometric measurements.

Furthermore, usefulness of rainwater/stormwater treatment methods was also considered. In the first case constructed wetland system was applied, whereas microfiltration was used to purify the roof runoff. On the basis of the obtained results, it was possible to compile appropriate solutions for sustainable rainwater management.

BIO: Dr Fitobór is a young researcher and assistant professor, specializing in issues related to the treatment of water and wastewater. The quality of rainwater is a subject of her special interest. She is also involved in educational activity connected with sustainable use of environment and its resources towards circular economy.

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GROWTH AND PHYSIOLOGICAL CHARACTERISTICS OF NATIVE AND NON-NATIVE *PHRAGMITES AUSTRALIS* RESPONDING TO CLIMATE

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Phragmites australis is widespread throughout the coastal wetlands in North China. The potential invasion from non-native *Phragmites australis* may threaten the growth status of native populations, thus further affecting the ecosystem structure and functions, geomorphology, photosynthetic carbon sequestration, and surface water/groundwater equilibrium prediction in coastal areas. As one of the main factors is closely related to the success of plant invasion, climatic environment can affect the setting and diffusion of non-native plants. Comparative studies between non-native and native *Phragmites australis* in response to climate is very useful to identify traits associated with potential invasiveness, which is also important for predicating and controlling the spread of non-native species. In this study, we compared morphological and physiological parameters between native populations collected in China and a genetic-closely relative non-native population collected from Fast East Asia and Australia. The native populations were collected from the Yellow River Delta (estuarine population) and inland freshwater areas in China (inland population). The experiments were conducted in Fanggan and Panjin common garden sites. Both the two sites have temperate monsoon climates, but the former site is warmer and more humid than the later site.

The results show that the total biomass, height, shoots number, specific leaf area, and stomatal conductance of native population are higher than that of the non-native population. This indicates that the native populations are more capable of intercepting light energy and thus accumulate more photosynthetic products with faster growth rates and higher primary productivity. The chlorophyll content of non-native population in Panjin is relatively higher than the native population, which may be related to its lower specific leaf area. The non-native population shows much lower stomatal conductance than the native population, which may be responsible for its low growth rate. The ETRmax and light saturating irradiance values of non-native population in Panjin are higher than that of the native populations, indicating that the former has larger utilization range of photosynthetic active radiation than the latter, and the former can adapt to high irradiance. The final biomass of estuarine and non-native population show no significant differences between two common gardens. Whereas, the inland population performed better in warmer and more humid climate conditions. The biomass allocations were similar between the native and non-native populations and were not affected by the climate conditions. All the *Phragmites australis* populations present higher height and chlorophyll content in Fanggan than that in Panjin, whereas the shoot number, specific leaf area and stomatal conductance show opposite trend. However, we also need to be cautious that some genotypes in non-native *Phragmites australis* population shows relatively strong invasive potential.

BIO: Dr. Xie is a research assistant and interested in how coastal wetlands respond to climate change and anthropogenic activity. Her current research focuses on plant ecology, carbon cycling, and soil organic matter in coastal wetlands.

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SIMULTANEOUS REMOVAL OF NUTRIENTS AND HEAVY METALS WITH SORPTION MATERIALS FROM LANDFILL LEACHATE

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According to European Union Council Directive 1999/31/EC on the landfill of waste, the leachate was defined as each liquid which percolate through the deposited waste from landfill. This specific effluent is characterized with high variability in quantity as well as quality especially in terms of total suspended solids (TSS), chemical oxygen demand (COD), and concentration of nutrients but also the presence of heavy metals. It depends on the type of stored waste, precipitation, landfill age.

Landfill leachates treatment is still an issue. Usually applied treatment include biological, chemical, and co-treatment with municipal wastewater. Leachates discharged to municipal wastewater treatment plants (WWTPs) are causing many difficulties in the treatment process due to their fluctuations, high COD/BOD ratio, high total nitrogen concentration and presence of hazardous substances which may disturb the biological treatment process. Also, a different approach is getting considered in case of landfill leachate treatment. Hybrid Treatment Wetland designed to treat leachate from the landfill was investigated with quite satisfactory results but still, each way of treatment needs further investigation.

The aim of that study was to assess the applicability of sorption materials in landfill leachates treatment process. The research was conducted in batch reactors under steady conditions. To each batch reactor filled with landfill leachates, a proper dose of the sorption material was added (depending on the concentration of contaminants). After the sorbents addition, mixing and settling time was provided.

The investigated landfill leachates were obtained from the municipal landfill "Eko Dolina Lezyce", located near Gdynia in northern Poland and serves approximately 460,000 people. The landfill site is composed of two separate prisms: the "old" one, which was exploited in years 2003-2011, and the "new" one, which works since 2011. The object is generating the leachates quantity of over 100 m^3/d. The quality of landfill leachates from "Eko Dolina Lezyce" is highly variable. The wide range of analyzed parameters was following: TSS 170-650 mg/L, COD 2500-7000 mg/L, BOD_5 300-2500 mg/L, $N\text{-}NH_4$ 650-3000 mg/L, $N\text{-}NO_3$ 6-20 mg/L, $N\text{-}NO_2$ 0.2-0.7 mg/L, TN 700-3000 mg/L, TP 6-30 mg/L, $P\text{-}PO_4$ 2-20 mg/L, Cl^- 1300-3500 mg/L.

The analyzed sorption materials were (1) lanthanum-modified bentonite clay, which is successfully used for lake restoration and (2) byproduct, which consists mostly of calcium oxide and shows significant ability to phosphates removal.

In each sample, a quality of treated landfill leachates was tested. Concentration of following parameters was designated: pH, conductivity, chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), nitrogen compounds (TN, $N\text{-}NH_4$, $N\text{-}NO_3$, $N\text{-}NO_2$), phosphorus compounds (TP, $P\text{-}PO_4$), chlorides (Cl^-), sulphates (SO_4^{2-}) and heavy metals.

BIO: Ph.D.D.Sc. Magdalena Gajewska, associate professor in the Department of Water and Wastewater Technology, GUT. She specializes in technologies related to eco-engineering and natural methods of wastewater treatment, an author or co-author of 60 papers listed in the Web of Science database, six books, and over 100 peer-reviewed publications.

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DAIRY WASTEWATER TERTIARY TREATMENT USING A HORIZONTAL SUB-SURFACE FLOW WETLAND

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As a result of their operation, Argentinian dairy companies generate a large volume of effluents. Although wastewaters are treated through different methods, they often exceed discharge limits established by current regulations. Therefore, after biological treatment, a polishing wastewater treatment is required. The aim of this work was to evaluate the efficiency of a horizontal sub-surface wetland (HSSW) for the final treatment of a dairy wastewater. Effluent is treated by a sequence of 12 aerobic ponds (biological treatment). A fiberglass pilot scale HSSW was located after the ponds. Its dimensions were 0.95 m width, 2.5 m length and 0.70 m depth. River gravel was used as substrate and *Typha domingensis* was planted. Wetland feeding was carried out using a pump. Hydraulic residence time was 7 days. In order to evaluate contaminant removal efficiencies, pH, electrical conductivity (EC), suspended solids (SS), total Kjeldahl nitrogen (TKN), ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-), total phosphorus (TP), chemical oxygen demand (COD) and biological oxygen demand (BOD) were analyzed in the effluent before and after treatment during 3 months.

Mean concentrations of different parameters measured at the inlet wastewater were: pH: 9.08$\pm$0.11; EC: 5.33$\pm$0.34 (mS cm^{-1}); SS: 172$\pm$47 (mg l^{-1}); COD: 345$\pm$49 (mg l^{-1}); BOD: 88$\pm$25 (mg l^{-1}); TKN: 44.3+7.0 (mg l^{-1}N); NH_4^+: 8.4$\pm$1.5 (mg l^{-1}N); NO_3^-: 15.9+11.1 (mg l^{-1} N); NO_2^-: 28.7$\pm$4.5 (mg l^{-1}N); TP: 44.4$\pm$11.1 (mg l^{-1} P). pH showed significant differences before and after treatment, presenting a mean value of 9.08 and 8.40, respectively. Electrical conductivity decreased significantly from 5.33 to 4.70 mS.cm^{-1} after the treatment. High removal efficiencies were obtained for SS (86.3$\pm$5.3 %), COD (74.7$\pm$5.5 %), and BOD (64.3$\pm$6.7 %). Nitrate and nitrite showed satisfactory removals of 56.3$\pm$11.6% and 99.9$\pm$0.2%, respectively. These performances are in agreement with those reported in literature for HSSWs.
Ammonium concentrations in the effluent were higher before than after the treatment (8.4 $\pm$1.5 mg l^{-1} and 22.2+9.2 mg l^{-1}, respectively). Nevertheless, mean ammonium concentrations at the outlet remained under legislation limit. TKN removal efficiency was low and presented a high variability (16.1$\pm$10.3%), probably due to mineralization of proteins but low nitrification of ammonium.
TP concentration decreased satisfactorily, with a mean removal percentage of 51.4$\pm$16.4%. Removal efficiencies of TP in HSSW with commonly used substrates like river gravel are usually low.

Studied HSSW planted with *T. domingensis* was efficient for the final treatment of dairy wastewater, reaching high removals of SS, COD, BOD, TP, nitrate and nitrite. The quality of the effluent was significantly improved, complying with state regulations for its discharge to the environment.

BIO: Dr. Maine is a senior scientist with more than 25 years of experience in the study of contaminant dynamics in natural and treatment wetlands. She is the President of the Pan-American Wetland Network (HUPANAM). She has published more than 70 journal articles, book, book chapters, 200 presentations in Scientific meetings. She has been leading more than 15 research projects.

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METAL REMOVAL FROM LANDFILL LEACHATE USING A VERTICAL FLOW AND A HYBRID WETLAND

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Landfill leachate is usually composed of high concentrations of organic matter and ammonia and low concentrations of toxic pollutants, such as heavy metals. Vertical flow wetlands (VFWs) are commonly used as a first stage for leachate treatment focusing on ammonium removal. In the last years, there is a growing interest in metal removal from leachate using constructed wetlands (CWs). The aim of this work was to evaluate Cr(III), Ni(II) and Zn(II) removal from a landfill leachate using mesocosms-scale VFWs and a hybrid wetland (HW), composed by a VFW and a free water surface (FWS) wetland.

In the first experiment, VFWs with free drainage, filled with coarse sand and light expanded clay aggregates and planted with *Typha domingensis* or *Canna indica* were studied. Real leachate was diluted and spiked with metals to reach the following concentrations: 0.2 mg/L Cr + 0.2 mg/L Ni + 0.2 mg/L Zn, and 1.0 mg/L Cr + 1.0 mg/L Ni + 1.0 mg/L Zn. The effluent was dumped daily. Leachate samples were taken twice a week during 3 months. Removal efficiencies for VFWs planted with *T. domingensis/C. indica* were: 43/36, 24/20, 39/32 % for Cr, Ni and Zn at 0.2 mg/L, and 68/62, 60/49, 56/45 % for Cr, Ni and Zn at 1.0 mg/L, respectively. VFWs planted with *T. domingensis* presented higher metal removal efficiencies than those planted with *C. indica.*

To improve metal removal efficiencies, a HW composed by a VFW and a FWSW was studied. Both wetlands were planted with *T. domingensis*. Real leachate was diluted and spiked with metals to reach the following concentrations: 1.0 mg/L Cr + 1.0 mg/L Ni + 1.0 mg/L Zn and 5 mg/L Cr + 5 mg/L Ni + 5 mg/L Zn. Removal efficiencies for the lowest concentration of metals studied were 82, 55 and 64% for Cr, Ni and Zn, respectively after the VFW. After the FWSW, removals were 98, 90 and 95 % for Cr, Ni and Zn, respectively. In the experiment with concentrations of 5 mg/L of metal, removals of Cr, Ni and Zn were 62, 49, 49%, respectively after the VFW. After the second stage (FWSW), the removals reached 95, 88 and 90 % for Cr, Ni and Zn, respectively. The HW studied was not only highly efficient in metal removal but also in ammonium, TN and COD removal from landfill leachate. Plant biomass and metal concentrations in roots increase significantly at the end of the experiment. It was determined by X-ray microanalysis that Cr, Ni and Zn were accumulated within the root and to a lesser degree in its epidermis, which would suggest that the metals are absorbed by the root tissues and, to a lesser extent, adsorbed on the epidermis.

BIO: Dr. Maine is a senior scientist with more than 25 years of experience in the study of contaminant dynamics in natural and treatment wetlands. She is the President of the Pan-American Wetland Network (HUPANAM). She has published more than 70 journal articles, book, book chapters, 200 presentations in Scientific meetings. She has been leading more than 15 research projects.

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PLANT SELECTION TO BE USED IN VERTICAL FLOW WETLAND FOR LEACHATE TREATMENT

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Sanitary landfilling is the most preferred solid waste management strategy all over the world, being the generation of landfill leachate one of the main environmental problems arising from this practice. Leachates are result of undergoing physicochemical and biological changes in landfill body, percolation of rainwater through the wastes and their inherent moisture content. Landfill leachate is a complex wastewater that requires treatment prior to its release into a receiving water body in order to avoid and mitigate environmental pollution. Villa Dominico municipal landfill is located near Buenos Aires (Argentina). This landfill was in operation until 2004, and then it was closed. A wetland system is proposed to treat the leachate. The main objective of this work was to select plants to be used in vertical subsurface flow wetlands (VFWs) for the leachate treatment. The tolerance to leachate of the following wetland plants: *Typha domingensis, Scirpus americanus, Sagittaria montevidensis, Cortaderia* selloana, *Iris pseudacorus Echinodorus grandiflorus, Ruellia brittoniana, Bambusa vulgaris, Bambusa tuldoides, Zantedeschia aethiopica* and *Hibiscus striatus,* was studied. Some of them are used as ornamental plants. Removal efficiencies were determined in the VFWs planted with the most tolerant of the studied species. Twenty-liter lab-scale VFWs were filled with sand and crash stone 30-60 and planted with the studied macrophytes. The experiment lasted 16 months. The leachate used in this study was collected from the Villa Dominico municipal landfill. At the beginning of the experiment, 1:10 diluted leachate was used. Then, dilutions of 1.5:10, 2:10, 2.5:10, and 3:10 were used. Electrical conductivity (EC), pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total dissolved solids (TDS), ammonium (NH_4^+), and dissolved oxygen (DO) were measured in leachate before and after treatments.

The chemical composition of the studied raw leachate was: pH= 8.2-8.6, EC= 18,900-23,800 μmhos cm^{-1}, Total phosphorus (TP)= 22.3-27.7 mg l^{-1}, Nitrate (NO_3^-)= 39.9- 60.9 mg l^{-1}, NH_4^+= 948.9-3097.6 mg l^{-1}, BOD= 636.5-837.9 mg O_2 l^{-1}, COD= 2411.4-3022.8 mg O_2 l^{-1}. All plant species showed high tolerance to studied diluted landfill leachate, except for *Hibiscus striatus* that only tolerated 1:10 diluted leachate. *Sagittaria montevidensis, Cortaderia selloana* and *Echinodorus grandiflorus* presented injury symptoms and decreased their growth at 3:10 diluted leachate. In consequence, these species were discarded. For VFWs planted with the other species, using 3:10 diluted leachate, the removal efficiencies ranged between: 40-67% for NH_4^+, 20-35% for BOD_5 and 60-70% for COD. Electrical conductivity decreased 24-30%. DO increased in leachate after all treatments, presenting the highest increase in the treatment planted with *Scirpus americanus*. No significant differences in TDS was verified.

Typha domingensis, Scirpus americanus, and *Iris pseudacorus* presented the highest tolerance, and VFWs planted with these species presented the best removal efficiencies in the leachate treatment.

BIO: Marisa Iturria is a phD student with more than 10 years of experience in landfill leachate treatment operations. She has extensive experience with constructed wetlands, and she is dedicated to the implementation of new technologies in landfill operations.

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ADAPTING CULTIVATION SYSTEMS TO CHANGING CLIMATIC CONDITIONS AND ENVIRONMENTAL REQUIREMENTS – PRACTICAL SOLUTIONS IN EXPERIMENTAL AREAS AND IMPACT MONITORING

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Modern agriculture in Finnish conditions requires functioning drainage systems. This infrastructure, which is essential for food production, consists of a basic drainage network fed by field-block scale local draining systems. The basic drainage of agricultural land in Finland was finalized in late 1960s as a result of decades of work, while local drainage has been improved up to these days e.g. by replacing the old contour ditches with subsurface drainage. As the cultivation technology and practices have been evolved, the requirements for local drainage have increased rapidly, which in turn places new demands on long-neglected basic drainage.

Traditionally, the ditches of basic drainage have been dimensioned according to long-term hydrological cycle with minimum depth of the bed according to the ever-increasing load-bearing capacity demands of the field blocks. In principle, drainage systems in Finland are designed for efficient removal of spring floods. Water quality issues came up when the amount of nutrients making the watercourses eutrophic was found to be increasing and transported to the waterways with the agricultural drainage waters. We are now facing a new situation with increasing need for basic drainage refurbishment in changing climate with, for example, more frequent occurrence of mild winters than before.

The above questions will be addressed in the “Shared Waters” project funded by the Finnish Cultural Foundation. One aim of the project is to implement an entire cultivation system in the scale of basic drainage area based on a new way of thinking. The starting point here is to combine high crop yields and low nutrient losses with the basic goals of effective drainage as a sustainable agricultural system where good soil structure and effective water management form a solid base. The key idea is to link farm-level drainage, environmental, and cultivation measures into whole basic drainage area taking into account the initial (present) state of the receiving body of water. As an innovative socio-economical approach, so-called “drainage property manager” idea based on strong local co-operation will be demonstrated in the Uuhikonoja target drainage area in Tammela municipality, southern Finland.

In autumn 2018 sensors (www.s-can.at/products/spectrometer-probes) measuring turbidity, nitrate, organic carbon and water surface level were installed in the Uuhikonoja target area, where a 2-stage basic drainage ditch and sustainable field management practices will be implemented in spring and summer 2019. Similar devices were also installed in two nearby reference areas. The automatic monitoring in the target and reference areas has begun already before the implementation of the measures in order to find out the initial situation. Monitoring will continue for years after the measures for the assessments of long-term effects.

BIO: Mr. Puustinen is an agronomist who has 30 years of experience with agricultural drainage and water protection issues.

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REMOVAL OF NUTRIENTS FROM RURAL DOMESTIC WASTEWATER BY VEGETATED DRAINAGE DITCH

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Nitrogen (N), particularly phosphorus (P) in water eutrophication has become a persistent and one of the most challenging environmental issues in the world. Agricultural runoff influences rivers globally, whereas in developing nations (e.g., China and african nations), rural domestic wastewater is often an extra source of pollution. The majority of rural and remote areas, these domestic wastewaters containing elevated N and P are transported directly from ditches to nearby stream waters without treatment due to the lack of sewage treatment plants. Because of the technological and economic problems in these zones, attention has shifted to evaluating the effectiveness of N nad P mitigation in vegetated drainage ditches (VDDs) because they are cheaper, relatively simple to implement because of the assumption they require little management after demonstrating and have been verified to be effective at mitigating the movement of N and P into receiving waterbodies.

In the current work, a VDD of 300 m length and 2.2 m width was designed and constructed in the downstream section of the upper Yangtze River for field treatment of domestic wastewater containing elevated levels of N and P. Our results demontrated that the reductions of TN, NH_4-N, NO_3-N, TP and PO_4-P from the VDD were about 61, 63, 48, 58 and 51%, respectively. The levels of TN, NH_4-N, NO_3-N, TP and PO_4-P depicted a declining trend with augmenting distance downstream. Uptake by plants and sediment retention were the major mechanisms for nutrient reduction in the VDD, with subsequent microbial uptake and transformation of N and P. The exit of VDD exhibited considerably elevated dissolved oxygen levels and lower levels of electrical conductivity and total dissolved solids in comparaison with the inlet. Reductions of N and P were found to be sensitive to flow velocity and seasonal variation. This study also found that using effective robust overwintering species choice in VDD for the excellent reductions of N and P during winter is imperative to keep elevated N/P reductions year-round. Management strategies in ditches aimed at periodically clearing plants and removing sediment within VDD were essential for managing VDD. Findings of the current work highlight the potential of VDD to destroy N and P from domestic wastewater sewage transported downstream and could be incorporated into local best management practices.
Keywords: Rural domestic wastewater; Vegetated drainage ditch; nutrient

<u>BIO:</u> Dr. Mathieu 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 ditches and wetlands. He was awardeed as 2017 Outsdanting International Graduate Ph.D researcher from UCAS based on his academic achievements. He has received a recognized scientific experience, with 15 publications in peer-reviewed journals; all published in the last 4 years and collected a number of citations of 140.

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QUANTIFYING WATER, CARBON, AND NITROGEN FLOWS IN A CULTIVATED LOWLAND TO IDENTIFY FACTORS IMPORTANT FOR NITROGEN RETENTION

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Denmark is a low-lying Nordic country, where many of the organic-rich lowland areas have been drained for agricultural use. In their original (undrained) state, the lowland areas act as natural filters between upland agricultural areas and lowland aquatic ecosystems. However after they are drained, less water and nutrients are retained by the peatlands and instead drain to groundwater or as runoff. In addition the temperature and aerobic zone of the peat increases, causing higher rates of carbon (C) and nitrogen (N) mineralization, and thereby higher concentrations of organic and inorganic N in the water draining from the peat. It is therefore of great interest to document how C and N species interact and how seasonal nutrient fluxes can be quantified and characterized in a cultivated Danish lowland.

An 8 hectare ditch-drained, cultivated lowland site in the Nørreå stream valley, Vejrumbro, Middle Jutland, is being investigated for quantitative information regarding the seasonal flow and dynamics of C and N. In order to investigate these dynamics, water samples have been collected every 3-4 weeks since November 2018 from surface ditches and up to 206 piezometers with screens at various depths located in two transects running north to south and three transects running east to west across the site. Based on the analyses of these water samples and the monitoring of water flow in and out of the lowland, solute balances depicting the input and output of total organic carbon (TOC), dissolved organic carbon (DOC), total nitrogen (TN), nitrate (NO_3-N), ammonium (NH_4-N), and organic nitrogen (N_{org}) are constructed. Preliminary data indicate that the majority of N entering the lowland site originates from the upland groundwater aquifer in the form of NO_3-N, while N moving within the lowland soils is mainly present in the forms of NH_4-N and N_{org}. The majority of N movement through the lowland is via the drainage ditches, and the forms of N seen in the ditches represent a mix of N-forms contributed directly from the groundwater aquifer (NO_3-N) and from water that been in contact with organic lowland sediments (NH_4-N and N_{org}).

The results generated from this investigation give a good indication of the flow paths of different forms of N through the lowland. Additionally, these indicated flow paths allow for the determination of what the major N transformation processes taking place are and how they are affected by amounts of carbon species. Landowners of similar cultivated lowland areas will benefit from this study so that they can determine optimal land management strategies for the mitigation of nitrate leaching and transport to aquatic systems.

BIO: Merek M. Kesser is a Ph.D. student at Aarhus University in the Department of Agroecology funded by the Ministry of Environment & Food of Denmark. This is research pertaining to the first investigation of nutrient dynamics taking place in a Danish cultivated lowland that began in November, 2018.

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NITROUS OXIDE EMISSION FROM INTEGRATED BUFFER ZONES MITIGATING N LOSS FROM TILE DRAINED AGRICULTURAL FIELDS

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Integrated buffer zones (IBZs) are a novel nitrogen (N) mitigation measure consisting of a pond and a vegetated infiltration zone, and thereby combining attributes from small wetlands and saturated buffer zones. IBZs increase the removal of N in agricultural drainage water by creating conditions favourable for denitrification. However, if denitrification is incomplete the IBZs may increase the emission of the greenhouse gas nitrous oxide (N_2O), which holds a global warming potential of 296 relative to carbon dioxide over a 100-year period. In this study, we investigated if N removal was associated with increased N_2O emission. Furthermore, we investigated the temporal and spatial variation of the emission rates from the pond and the infiltration zone, respectively. The N removal efficiency of IBZs were established as a mass-balance by monitoring inlet and outlet water flows continuously and water sampling for nutrient analysis every third to sixth week for a year in two experimental scale IBZs located in eastern-Jutland, Denmark. The effect of the IBZs in terms of N_2O emission were quantified by ecosystem-atmosphere flux measurements of N_2O using both a closed and floating chamber technique. Additionally, the indirect loss of dissolved N_2O via infiltration to the riverbank was assessed. Thus, in this paper we will present the first results on the entire N-cycling within IBZs focusing on the importance of the N_2O emissions.

BIO: Mette Vodder Carstensen is a PhD fellow working with mitigation of nutrient loss from agricultural land to surface water including constructed wetlands, integrated buffer zones etc. Additionally, she investigates the potential negative side effects associated with these mitigation measures such as GHG emissions.

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GRANULAR FILTRATION AS A TOOL TO IMPROVE THE EFFLUENT QUALITY FROM A CONSTRUCTED WETLAND TREATING GOAT FARM WASTEWATER

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According to the "zoning plan" that is regulated by the Flanders Environment Agency, the goat farm considered in this study is located in a zone that is classified as " collectively optimized remote area". This means that there is currently no available wastewater collection system to serve this zone, and therefore the farm has to operate its own small scale WWTP in order to maintain specific discharge limits. Wastewater is generated from washing the milk carousel and the milk cooling tanks, as well as from the farmer's family. The existing treatment system consists of two septic tanks in series followed by a third septic tank, where the wastewater comes from both the septic tank and the house of the owner. The wastewater is then pumped with a constant flow to two parallel lava filters for organic matter removal and nitrification. Subsequently, denitrification takes place in a sand filter and by recirculating a percentage of effluent to the head of the lava filter. A small portion of the final effluent is used for cleaning purposes, the rest is discharged. A 2-year monitoring campaign has shown that nutrient removal (currently 76% for N and 22% of P) needs to drastically improve in order to meet discharge standards. This improvement will also expand the longevity of the system.

Within the framework of the Interreg project I-QUA, which is a collaborative initiative that aims to provide qualitative innovative solutions for decentralized wastewater treatment, a comprehensive study took place. The study focused first on analyzing and choosing among the best available techniques in collaboration with stakeholders from the various sectors, taking into account environmental legislation, limitations, owner preference, etc. Among others, granular filtration was given the preference. Choosing the appropriate P-sorbing materials is a key when considering a granular filtration.

Therefore, in this comparative study, further P and N removal from goat milk company wastewater effluent through low cost natural and commercial substrates (zeolite, volcanic rock, bark chips, iron oxides coated granules (IOCG), iron oxides coated granules with sand as core material (IOCG+S), granular activated carbon (GAC), anion exchange resin (AEIX) and sea shells) was investigated. A column-adsorption system was built and tested with the various substrates to evaluate the adsorption capacity at equivalent hydraulic loading rate. The results indicate that for phosphate removal, IOCG, IOCG+S, GAC and AIEX performed very well with 98-100% removal. The removal capacity for total nitrogen followed the order: AIEX > zeolite >GAC> wood chips> Lava filter> IOCG+S> IOCS > sea shells. Further, an extended batch adsorption experiment was conducted to estimate the maximum adsorption capacity at a phosphate concentration of 32 mg/L. The effect of various parameters such as adsorbents dose and contact time was investigated. The IOCG+S substrate was found to be the best substrate. Also, different (two-parameter and three-parameter) isotherms were fitted and analyzed. These showed that the interaction of phosphate with the three materials' surfaces is localized multilayer adsorption occurring on a heterogeneous surfaces.

In light of all the recommendations and the laboratory investigations, the system was eventually expanded by adding a granular filter filled with IOCG to be followed by a duckweed lagoon. During the conference, data will be shared on the performance of this new extension.

BIO: Mona Bkheet is currently a Teaching Assistant & a PhD candidate at the Department of Green Chemistry and Technology of Ghent University. She has her Msc. in Water Resources Planning and Management from Colorado State University, Civil and Environmental Engineering Dept. Her research and teaching focus is in water analysis, water treatment, constructed wetlands, respirometry in constructed wetlands ,groundwater modeling and sustainable development.

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SAFE RECREATIONAL LAKE WATERS- SURVEILLANCE, PURIFICATION AND WARNING SYSTEM FOR WET WEATHER SANITARY SEWER OVERFLOW

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Experiences regarding the use of FBA filterbed for diluted overflow wastewater, derived from the Danish MUDP funded project Safe Recreational Lake Waters.

To ensure good bathing water quality along as to meet the increasing demand for fast implementable climate adaptation solutions, the project "Safe Recreational Lake Waters" introduced a new concept for monitoring, early warning and treatment of overflow water from sewer system before reaching the recipients with requirements to comply with bathing water quality.

Based at Skanderborg Lake and targeting bathing water quality, the aim of the project was to develop a solution that combines risk assessment of individual overflows with an advanced warning system that connects microbiological data, weather and wind data as well as hydraulic conditions in the surrounding area and lake. Furthermore, two prototypes of treatment solutions for sewer overflows have been tested; a natural plant-based filter solution and a compact molecular mechanical/chemical treatment method.

The planted filters have a nice and recreational appearance, but require area where they are established. The solution tested in this project had induced aeration (FBA- Forced Bed Aeration) that reduces the required space. The planted filters have been proven to be effective in reducing both organic substances and nitrogen at a flow up to 12 m^3/day (12 h hydraulic retention time), to meet regulatory limits. A strong reduction can also be observed in E.coli and Enterococci numbers as a result of the retention time, meeting the guideline values at a flow rate of up to 12 m^3/day and close to meeting the guideline values at 24 m^3/day (6 h hydraulic retention time). This solution raises challenges in case of sporadic and very strong flows at heavy rainfalls. In this situation, the tested prototype could not operate with the same treatment effect.

The cost-efficiency of the FBA planted filter was assessed, with further recommendations for improving cost-efficiency of the solution.

BIO: René Kilian, Kilian Water ApS, CEO of Kilian Water ApS, entrepreneurial business with 20 years experience within the field of CW wastewater treatment systems.

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NUTRIENT REMOVAL AND GHGS EMISSION IN A HYBRID CONSTRUCTED WETLAND TREATING ANAEROBIC DIGESTATE

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A pilot hybrid constructed wetland (HCW) planting with reed (*Phragmite australis*) and rice (*Oryza sativa* L.) was designed to treat anaerobic digestate of piggery wastewaters in rural area of the Yangtze River Delta, China. The hybrid constructed wetland system was composed of four units: two reed vegetated vertical subsurface flow beds (VSSF: 54 m^2 and 36 m^2, U1 and U2) in sequence followed by a horizontal subsurface flow bed (HSSF: 54 m^2, U3) also planted with reed and Water-saving and Drought-resistance Rice (WDR) vegetated in the fourth surface flow bed (SF: 42 m^2, U4). The media of the first and the third beds were gravel and the second one was filled with zeolite. The last bed was filled with soil from paddy field. The anaerobic digestate was effluent from an anaerobic digestion plant connected with a pig farm and diluted twice for influent. The average loading rate was 3.6 m^3 per day during experimental period. It was monitored from May to September 2016 to determine its efficiency in treating total nitrogen (TN), total phosphorus (TP), and COD as well as measuring greenhouse gases (GHGs) emission. Wastewater samples were collected at the inflow (IN) and outflow of each unit.

The average concentrations of TN and TP in influent were 379±58 mg/L and 29.6±9.2 mg/L, respectively. The average TN and TP removal efficiencies of the wetland system were 94.6% and 88.4%, respectively. Both TN and TP removal efficiencies in the second VSSF (U2) with zeolite appeared the highest removal performance, in which the removal rates of TN and TP were 21.0 g-N/m^2/d and 0.99 g-P/m^2/d, respectively. Similarly, the average concentrations of COD in influent was 2725 mg/L and the second VSSF (U2) appeared the highest removal performance, in which the removal rate was 80 g/m^2/d. On the other hand, the average CH_4 and N_2O fluxes during experimental period were highest in U1 wetland, which were 34.5 mg/m^2/h and 4.0 mg/m^2/h. Both of CH_4 and N_2O fluxes decreased from U1 to U4 significantly. There was significant linear relationship between CH_4 flux and TOC concentration in pore water while similar correlation between N_2O flux and TN concentration was also observed. The results show that the HCW is an effective solution for treating the excess pollutants deriving from anaerobic digestion plant. However, it is necessary to mitigate the greenhouse gas emission, particularly in the first unit of hybrid constructed wetland.

BIO: Dr. Zhou is a senior scientist with more than 20 years of experience researching nutrient removal using by constructed wetland and paddy field. He has extensive experience with elucidating nitrogen and carbon dynamics in wetland and paddy field, and has led several projects dedicated to reducing non-point pollution sources and greenhouse gas mitigation in paddy field.

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PHOSPHORUS ATTENUATION IN A POND – WETLAND SYSTEM TREATING CROPPING SYSTEM RUNOFF IN EASTERN ONTARIO, CANADA

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Nutrient rich agricultural runoff is a leading issue of non-point source pollution. Introduction of excess nutrients and particularly phosphorous, causes algae proliferation effecting water quality in rivers and streams. A pond – wetland system can be an effective BMP to trap nutrients from agricultural fields before discharging into receiving water bodies. A constructed pond-wetland system was established in 2016 to treat the runoff and drainage waters from a 72ha grain farm located in Eastern Ontario, Canada and has been monitored throughout the non-frozen period at field scale to assess its effectiveness in attenuation of Phosphorous.

Daily composite and weekly grab samples were collected from April 2018 to December 2018, from weir control structures at the inlet and outlet of the system in addition to weekly grab sampling at 5 locations across the transverse of the pond-wetland system. All of the samples were analyzed for dissolved, particulate, total phosphorus and total suspended solids. Influent and effluent water flow rates were calculated using HOBO water level loggers at the weirs and combined with concentrations to obtain mass fluxes across the system.

The preliminary results indicate 50% removal of total phosphorous throughout the system, reducing 0.24 mg/l to 0.12 mg/l. The total suspended solids concentrations decrease from an average concentration of 96 mg/l at weir 1 to 24 mg/l at weir 4, indicating a removal efficiency of 74%. The total and particulate phosphorous concentrations correlate to concentrations of total suspended solids. A 39% reduction in soluble reactive phosphorus concentrations is seen at the outlet of the wetland system with average concentrations of 0.08 mg/l at Weir 1 and 0.05 mg/l at weir 4. The pond sampling results suggest most of the removal was occurring within the first pond. The relationship between rainfall intensity and phosphorus mass flux as well as potential phosphorus removal mechanisms will be discussed.

Overall, the results demonstrate the effectiveness of pond-wetland system in phosphorous removal. The outcomes support the use of pond-wetland system as a promising nutrient management practice and can be employed to minimize deleterious environmental impacts of agricultural pollution.

BIO: Ms. Shruti is a 2nd year PhD student in Environmental Engineering at University of Ottawa, Canada. She is currently working on a multi - faceted project involving full-scale study of a controlled tile drainage system and a pond-wetland system to treat nutrient drainage waters from a grain farm. Her work extends to laboratory kinetic studies of pond denitrification.

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POSSIBILITY OF USING DIFFERERNT MEDIA AND SULPHUR REDUCING BACTERIAL ENRICHMENT IN CONSTRUCTED WETLAND FOR METAL CONTAINING WASTEWATER TREATMENT

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Constructed Wetland (CW) is an economical, environment oriented and sustainable, wastewater treatment technology that harnesses macrophytes, microbes, and physio-bio-chemical reactions for its functioning. The engineered CW system develops distinguished anaerobic and aerobic regions along the depth of bed over the time. The anaerobic condition prevalent in the deep bed houses variety of anaerobic microbes, both obligate and facultative, such as Sulphur Reducing Bacteria (SRB). SRB are primitive strict anaerobes that reduce inorganic sulfate or other oxidized sulfur forms to sulfide. Thus, there emerges a possibility of biological removal of metals present in wastewater stream, as metal sulphides.

The present study aims to explore the possibility of using different packing mediums and enrichment of SRB for metal removal. Three lab scale CWs, fabricated using PVC pipes, were packed with different mediums, normal stone gravel, graphite granules, and plastic FRP medium. Each CW was inoculated with the SRB enriched in sulphur reducing medium and fed with synthetic wastewater containing chromium. They were operated in batch mode with detention time of 24 hours.

The preliminary results revealed that sulphate removal was highest in CW-FRP as compared to CW-Graphite and CW-Gravel. The COD removal performance continued to increase for all three CWs and 95 – 100% COD removal was achieved. Chromium removal did not show any significant difference. It fluctuated in the range of 90-100%. The preliminary results reflect the potential of CW-FRP as more efficient biofilter for sulphate and COD reduction, along with high heavy metal abatement.

BIO: Supriya Gupta is a PhD scholar with a research experience of around 2 years in the area of Microbial electrochemical wetlands for wastewater treatment. She is currently engaged in a project and her work is dedicated to the removal of heavy metals in constructed wetlands

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EFFECTS OF SALINITY ON PHOTO- DEGRADATION OF VEGETATION DERIVED DISSOLVED ORGANIC MATTER ALONG AN AQUATIC CONTINUUM IN NORTH FLORIDA

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Sea level rise can greatly change salinities of fresh and brackish water wetlands and waterways, affecting abiotic degradation of dissolved organic matter. Additionally, ultra-violet light is known to readily degrade, oxidize, or mineralize source organic materials in waterways, creating large changes in compositional structure of dissolved organic matter (DOM) near the water surface. Vegetative sources have varying levels of susceptibility to photolytic degradation depending on source lability and chemical structure, and salt concentration affects the refractive index of light and can change how rapidly compounds degrade. To determine the effect of UV light and salinity on degradation of DOM source material of the three dominant vegetative species, *Avicennia germinans*, *Juncus romerianus*, and *Taxodium disticum*, along the aquatic continuum, senescent vegetation was collected and leached in DI for 24 hours. The leachate was then either diluted with DI or 0.2 µ filtered and sterilized sea water to yield an absorbance value less than 1.0. Leachates were then placed into an automated UV-exposure set-up that takes absorbance and fluorescence readings every 20 minutes over 20 hours. Absorbance and fluorescence data was graphed and analyzed in MATLAB which revealed saltwater diluted samples were more degraded after 20 hours than freshwater diluted samples, indicating possible future implications for degradation of dissolved organic matter along Pellicer Creek in a scenario of sea level rise and salinity change. These associated changes can have implications for lability and bioavailability of the DOM pool that drives biogeochemical cycling and affects overall environmental health.

BIO: Tracey Schafer is a third year PhD student in the University of Florida soil and water sciences department studying the effects of climate change associated stressors on dissolved organic matter cycling along an aquatic continuum in St. Augustine, FL, USA under advisors Dr. K.R. Reddy and Dr. Todd Osborne.

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NATURAL STOCK OF WATER AND AQUIFER RECHARGE IN TROPICAL WETLAND

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In Brazil, the water uptake for irrigation is 969 m^3/s, representing the major consumption in the territory. The area installed with irrigation is approximately 7 Mha, with potential to expand by 43.3% (ANA, 2017). Due to the relevance for sustainable management, the collection, analysis and dissemination of data and information on water resources are essential.

In the Brazilian savanna, land conversion has dramatically reduced the natural wetland areas, affecting natural water storage and its ecological functions. Typical wetlands are characterized by periodically shallow inundation resulting from pronounced seasonal rainfall and groundwater elevation, comprising a freshwater system integrated with rivers in the catchment. The surrounding large farms with center-pivot irrigation have been using wetland water to irrigate grain crops. Even though the allocation of water is legally required, there are unanswered questions regarding the balance between input and output of water in wetlands and the connections between land-surface soil and aquifer hydrology in the landscape. Thus, the lack of understanding, measurements, and models related to hydric soils and hydrologic information in natural wetlands poses a challenge for sustainable development.

Geoprocessing by UAV (Unmanned Aerial Vehicle) and electrical resistivity tomography (ERT) were used to compartmentalize the wetland into three different regions according the internal topography. Hydraulic conductivity studies were performed in each of these three regions. Electrical tomography was performed along nine 80-meter cables, spaced 10 meters apart (direction N45), and one 80-meter cable set perpendicular to the others. We used the obtained data to generate a 3D cube (Figure 1).

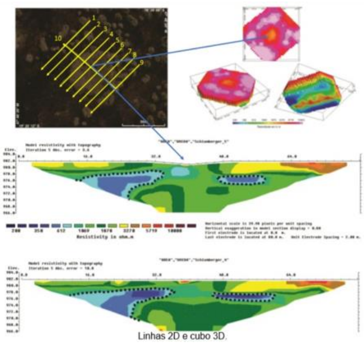

Figure 1: Images 2D and 3D generated by ERT showing the interface soil-surface water and aquifer in the wetland.

The results showed that the wetland can contain 780,922 m³ in total, 265,205 m³ in the region with intermediate flooding, and 49,140 m³ in the central region, where the greatest accumulation of water was observed. Through electrical tomography, we identified vertical infiltration of water up to 6 meters depth in the central region. From 8 meters depth, the water encounters a more resistive layer and beings to infiltrate horizontally, tending to concentrate the recharge of the aquifer in the northeast and southwest of the wetland. The results support the proposal of a management model for the seasonal reservoir.

BIO: Dr. Rosolen is a professor and researcher. She coordinates projects on soil functions and recharge of aquifer in tropical wetlands.

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DESIRE: DEVELOPMENT OF SUSTAINABLE PEATLAND MANAGEMENT BY RESTORATION AND PALUDICULTURE FOR NUTRIENT RETENTION AND OTHER ECOSYSTEM SERVICES IN THE NEMAN RIVER CATCHMENT

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The project „DESIRE", supported by Interreg Baltic Sea Region Programme 2014-2020, started in January 2019. The project is confirmed as a flagship project of the EU Strategy for the Baltic Sea Region, Policy Area Nutri and strongly contributes to the aims of the Interreg Baltic Sea Region Programme. The challenge addressed by the project, the improvement of peatland management in the Neman catchment, is of strong transnational relevance. The project comprises a mixed approach of drafting policy recommendations, generating new knowledge via modelling, and using pilot sites to demonstrate peatland rewetting and implementation of paludiculture. The project aims to increase the capacity of policymakers and other decisionmakers to adopt policies that incentivise peatland management for nutrient retention via enhanced institutionalised knowledge and competence and more efficient use of human and technical resources. Among the target groups are: regional and national authorities in the Neman catchment area, NGOs, decision makers in forestry and water management, farmers associations, and agricultural administrators and consultants. DESIRE focuses on numerous disturbed peatlands in the Neman catchment and will exemplarily restore some of them to act as wetland buffer zones (WBZ). Rewetting stops, inter alia, further soil degradation, decreases uncontrolled water run-off, strongly reduces nutrient- and GHG emissions and is good for biodiversity. Methods are well developed.

Within DESIRE, the ability of rewetted peatlands to catch nutrients will be enhanced with innovative land use practices (paludiculture), i.e. harvesting of nutrient-rich biomass from rewetted peatlands. The few ongoing activities on paludiculture in the focal countries will be supplemented by pilot sites and optimised for nutrient retention. These will be used for awareness raising and communication towards the target group of policy makers. Institutional capacity building will be carried out to scale up the approach across the catchment. Specific policy instruments like river basin management plans and agri-environmental schemes will be analysed and adapted or newly developed within the project to provide instruments and incentives for stakeholders to implement measures following the project's pilot examples. Economic evaluation of the pilot projects/respectively of paludiculture implementation in the Neman river catchment area will showcase cost-effectiveness of the proposed ecosystem-based measures in comparison to other, more technical installations for nutrient filtering and retention. Water quality in the Neman basin will benefit by (1) reduction of nutrient loads from diffuse sources in the catchment area (mainly arable lands) and (2) preventing peatlands to act as nutrient sources and internal-external eutrophication hot spots. The project is led by Greifswald University supported by Succow Foundation (Greifswald), cooperating with partners in Poland (Warsaw University of Life Sciences/SGGW, Polish society for the protection of birds/OTOP, Bialystok Technical University), Lithuania (Vytautas Magnus University, Lithuanian Fund for Nature), and Russia/Kaliningrad oblast (Ministry for Natural Resources and Ecology of Kaliningrad Region, Natural Heritage NGO). Further institutions in Lithuania, Poland, Kaliningrad and Belarus will act as associated organisations.

Keywords: paludiculture, nutrients retention, Nemen catchment, Interreg Baltic Sea Region

BIO: Dr. Wendelin Wichtmann is a senior scientist with more than 25 years of experience in water management and economics esp. referring to land use of marginal lands (peatlands: paludiculture). He has extensive experience with peatland restoration and management and led more than 10 projects dedicated to preserving and restoring wetlands.

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KLIBB – CLIMATE-FRIENDLY AND BIODIVERSITY-PROMOTING USE OF FEN SOILS IN GERMANY

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Drainage-based utilisation of fen soils for agriculture and forestry leads to disproportionally high CO_2 emissions and losses of characteristic biodiversity in fen ecosystems. Rewetting combined with site-adapted land use (paludiculture) can effectively lower emissions and may restore habitats for characteristic fen species. Climate-friendly, biodiversity-promoting land use on fen peatlands would substantially contribute to Germany's obligations and ambitions regarding multi-lateral environmental agreements such as UNFCC and CBD, and the respective national plans. The spatial potential of such land use options and their impacts on greenhouse gas (GHG) emissions and biodiversity have not yet been evaluated in detail in key peatland-rich federal states of Germany. Within the project KLIBB - Climate-friendly and biodiversity-promoting use of fen soils (2018-2019) we develop guidelines for peat-preserving utilisation of temperate fen soils motivated by climate protection and biodiversity enhancement. First, we establish criteria for suitability classes for peat-preserving land use options. According to these criteria, suitability maps for three peatland-rich German federal states are prepared (adding to an existing map for one state published in 2017, and in co-operation with state authorities). The various land use options for wet fen soils (ranging from traditional techniques like reed cutting for thatch and pastures to innovative options like energy generation from fen biomass) are described regarding implementation and economics. The potential reduction of (GHG) emissions is assessed for the land use options and for the studied federal states according to the suitability maps. Based on a literature review regarding the effects of rewetting and various land use on biodiversity, potential benefits, losses and trade-offs for biodiversity are identified. Possibilities to increase benefits for mire-typical biodiversity are described and assessed with respect to costs. This includes, for example, adapted harvesting techniques (cutting instead of rotary techniques), uncut refuge areas, adjusted mowing direction (inside to outside) and cutting dates, and limited stocking density and partial exclusion of livestock. Such measures could be included e.g. in future agri-environmental payments. Via the Federal Agency for Nature Conservation and a working group of all German peatland-rich federal states, the project's results can feed directly into national and regional policies. Furthermore, they provide a baseline for a deeper analysis of agricultural policies with regard to peat soils.

BIO: Dr. Wendelin Wichtmann is a senior scientist with more than 25 years of experience in water management and economics esp. referring to land use of marginal lands (peatlands: paludiculture). He has extensive experience with peatland restoration and management and led more than 10 projects dedicated to preserving and restoring wetlands.

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PALUDICULTURE - CLIMATE SMART LAND USE ON PEATLAND

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Conventional peatland utilisation requires drainage, which results in enormous emissions of greenhouse gases and nutrients. Almost 25 % of worldwide carbon dioxide (CO_2) emissions from the LULUCF sector are caused by drained peatlands. Peatland degradation is also responsible for ongoing land subsidence, with annual height losses of 1–2 cm in the temperate zone. Rewetting of drained peatlands is essential to reduce emissions and peat degradation, but rewetting has hitherto resulted in the loss of productive land. Here we present the basic principles of paludiculture ('palus'– latin for 'swamp'), a new land use concept involving the sustainable use of wet and rewetted peatlands for agriculture and forestry, i.e. combining production with soil conservation and possibly even renewed peat growth. Paludiculture is the agricultural or silvicultural use of wet and rewetted peatlands. Paludiculture uses spontaneously grown or cultivated biomass from wet peatlands under conditions in which the peat is conserved or even newly formed. It differs fundamentally from drainage-based conventional peatland use, which leads to huge emissions of greenhouse gases and nutrients and eventually destroys its own production base through peat soil degradation. Paludiculture allows the re-establishment and maintenance of ecosystem services of wet peatlands such as carbon sequestration and storage, water and nutrient retention, as well as local climate cooling and habitat provision for rare species. It implies an agricultural paradigm shift. Instead of draining them, peatlands are used under peat-conserving permanently wet conditions. Deeply drained and highly degraded peatlands have the greatest need for action from an environmental point of view, and provide the largest land potential. An overview of potential paludiculture plants is given in the Database of Potential Paludiculture Plants (DPPP).

More information: Wichtmann, W., Schröder, C. & Joosten, H. (2016): Paludiculture – productive use of wet peatlands. Schweizerbart. 272 p.

Keywords: paludiculture, greenhouse gas emissions, wet peatlands

BIO: Dr. Wendelin Wichtmann is a senior scientist with more than 25 years of experience in water management and economics esp. referring to land use of marginal lands (peatlands: paludiculture). He has extensive experience with peatland restoration and management and led more than 10 projects dedicated to preserving and restoring wetlands.

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PHYSICAL FACTORS DETERMINING GHG EXCHANGE DYNAMICS ON WETLAND – SELECTED RESULTS FROM BIEBRZA NATIONAL PARK, NE POLAND.

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Determination of greenhouse gases exchange between the ground and the troposphere is one the most important climatological issues. Availability of several chamber method and especially eddy covariance method (most adequate for long-term, regular measurements) caused that many research groups conduct measurements of GHG fluxes on miscellaneous areas. On the majority of these sites carbon dioxide flux is mainly measured, but on the many of them methane flux measurements has also been started regarding to its ~25-fold higher global warming potential. Wetlands are natural areas which in significant degree influence the environmental GHG cycle – in annual scale strongly uptakes CO_2 and releases CH_4. Vertical fluxes of these gases between wet soil and troposphere are mainly result of photosynthesis and respiration processes (CO_2 flux) and methanogenesis (CH_4 flux) determined by several factors like intensity of turbulence in boundary layer, growing phase of plants or physical parameters of soil.

The aim of this work is to present preliminary analysis of relations between selected physical features of wet soil and CO_2 and CH_4 fluxes on the basis of the dataset registered in biggest wetland in Poland (Biebrza National Park, NE Poland). Measurements are conducted by Department of Meteorology and Climatology, University of Lodz since 2012 and contain CO_2 and CH_4 fluxes determined with eddy covariance method and several additional parameters like soil temperature, soil moisture, water table level (since 2013), redox, pH, absorbed PAR or Leaf Area Index (since 2017). Since the beginning of measurements water table level has been changing significantly which hardly influenced FCH_4 variability while FCO_2 seems to depend on this factor in less degree. Other relations like redox/FCH4, acidity/FCH4, absorbed PAR/FCO2 or LAI/FCO2 has been also analysed as well relations between fluxes and selected parameters (redox, soil temperature and soil moisture) measured on 3-5 depths.

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BIO: Dr. Pawlak is a senior researcher with 15 years of experience making greenhouse gases fluxes measurements with eddy covariance method. The main areas of his interest are relation GHG exchange variability/land use and processes which determines intensity of carbon dioxide and methane fluxes on wetland, farmland and urban areas.

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EFFECT OF DIFFERENT MODIFIERS ON THE FORM OF HEAVY METALS IN THE SEDIMENT

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Phytoremediation has become one of the most promising methods for removing heavy metals from sediments. The efficiency of phytoremediation is often limited by the bioavailability of heavy metals in sediments. To activate heavy metals in sediments by adding additives to enhance the extraction efficiency of heavy metals in plants would be an effective technical measure . In this study, the effects of six modifiers: Ethylenediaminetetraacetic acid(EDTA), glycol-bis-(2-aminoethylether)-N,N,N′,N′-tetraacetic acid(EGTA), citric acid, the straw of *Iris pseudacorus L.*, the straw of *Phragmites communis* and bean dregs, on the form changes of heavy metals (Cr, Cu, Mn, Ni, Pb, Zn) in sediments were compared.

The results showed that the chelating agent modifier (EDTA, EGTA and citric acid) could reduce the pH values and change the form of heavy metals in the sediments. The acid-extractable forms of Cr, Cu, Mn and Pb increased with the increase of modifying agents concentration, and the reducible forms reduced. Among them, when the addition amounts of EDTA, EGTA and citric acid were 10 mg/g(dry weight) , respectively, the proportion of acid-extractable form of Cr increased by 26.3%, 25.8% and 27.9%, respectively. Cu, Mn, Ni and Pb also showed the increase of acid-extractable forms, but there was no significant effect on the forms of Zn.The addition of straws (the straw of *Iris pseudacorus*, the straw of *Phragmites communis*) and bean dreg could reduce the oxidation-reduction potential (ORP), and change the composition of humus, which had a very complex effect on the form of heavy metals in the sediments. The different additives showed different activation properties for the different heavy metals. For Cu, the activation properties of the six additives were EGTA>EDTA>citric acid>bean dreg>the straw of *I. pseudacorus* and the straw of *P. communis*.

For the studied heavy metals, the six modifiers, especially chelating agents, could play a better activation role, change the existing forms of heavy metals in the sediments, enable the heavy metals to desorb from the surface of sediment particles, and transform from the insoluble form to the soluble ones, thus creating the favorable conditions for the phytoextraction.

Bio: Xu is studying for his doctorate at present. His work has been focusing on the enhancement of phytoremediation of heavy metals contaminated sediments. Contact information: Xiwei Xu, 308 Room, First Laboratory Building, Tongji University, Shanghai, China, Phone: 86-021-65982552, Email: 1410391@tongji.edu.cn.

EFFICIENCY OF THREE PRETREATMENTS FOR CONSTRUCTED WETLAND SYSTEMS

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Constructed wetlands are presented as a promising technology in order to reduce the lack of sewage treatment, particularly as a decentralized systems for developing countries. Wetlands can be classified according to how they direct the flow (vertical or horizontal), the level of pretreatment of the wastewater they receive (raw or pre-sedimentated sewage), the type of feeding (continuous or pulsed), the possibility of nitrify and denitrify the effluent, the inclusion of forced aeration, among others.

On the level of pretreatment, and under warm climate conditions, the first stage of the French system can be presented as an efficient and economical alternative to conventional technologies such as septic tanks or anaerobic baffled reactors (ABR). This study compares the efficiency of three units installed in a pilot plant at the UNALM, in Lima Peru: French cell, septic tank and ABR reactor from the point of view of reducing the pollutant load of raw sewage as previous treatment to horizontal and vertical flow constructed wetlands. The septic tank operates charges a flow of 2.7 m^3/day and has two chambers. ABR reactor has 3 chambers and operates with a flow of 2.6 m^3/day. The French cell has a bed of gravel divided into two operating areas of 18 m^2 each one; the feeding alternates every 3 days for all selected study points with pulses every 8 hours for a time of 6 minutes.

Wastewater that feeds the pilot plant, enters a pumping chamber from which the flow is distributed to each unit of pretreatment. The sewage has been characterized at the entrance, which presents average characteristics corresponding to a domestic or municipal drain (Table N° 1). Over 3 months, the effluent was analyzed at the output of each pretreatment unit, the preliminary results show a high efficiency of removal of organic matter and solids in the French cell compared to the two conventional treatments; reducing in 100% the presence of helminth eggs and 2 logarithmic orders in the thermotolerant coliforms. The full paper will document the final results of the comparative study.

Table N° 1. Influent and effluent characteristics of the three units evaluated

Parameters	Influent (Raw sewage)	French Cell Effluent		Septic Tank Effluent		ABR Reactor Effluent	
	Concentration	Concentration	Removal efficiency	Concentration	Removal efficiency	Concentration	Removal efficiency
BOD (mg/L)	376.70	24.16	91%	16.46	62%	18.05	68%
COD (mg/L)	844.00	10.66	90%	7.23	61%	9.48	80%
Turbidity (NTU)	542.70	14.93	81%	12.16	66%	13.64	74%
TSS (mg/L)	666.30	14.71	98%	13.06	87%	14.11	94%
TC (UFC/100Ml)	$1x10^8$	$2{,}9x10^6$	97%	NDY*	-	NDY*	-
Helminth eggs (N° org/L)	307	< 1	100%	NDY*	-	NDY*	-

NDY*: not determined yet

<u>BIO</u>: Rosa Miglio is a Senior Lecturer in the Agricultural Engineering Faculty at Universidad Nacional Agraria La Molina in Peru. She is a researcher and consultant in decentralized treatment systems for wastewater with an emphasis on the use of constructed wetlands. Her research work is oriented towards the definition of design criteria for horizontal and vertical flow wetlands in warm climates.

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POTENTIAL OF CONSTRUCTED WETLANDS FOR THE REMOVAL OF CYANOBACTERIA AND MICROCYSTINS (MC-LR)

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Microcystis blooms and the release of hepatotoxic microcystins (MCs) pose a serious threat to the safety of water for human and livestock consumption, agriculture irrigation and aquaculture worldwide. MC-LR is the most toxic variant of MCs with acute pathogenicity that causes allergic reactions and fatal liver hemorrhage. MC-LR has been widely detected in a variety of environments such as water, sediments, plants, and some aquatic products.

Conventional solutions of water treatment are costly requiring specific infrastructures, specialized personal, equipment and energy to operate. In this regard a challenge is placed regarding the solutions to treat surface waters contaminated with toxic cyanobacteria blooms, from lakes, ponds and reservoirs that supply water for agriculture, where the application of conventional technologies is not economically feasible. In addition, many natural eutrophic waters (surface and ground waters) are localized in rural areas with limited access to infrastructures and electricity. In these cases, low-cost and low-technology solutions become most appropriate for water treatment.

Natural wetlands purify water by breaking down and assimilating nutrients, bacteria and other contaminants. Artificial wetlands have been constructed to replicate the process, the so called constructed wetlands (CWs).

CWs are complex systems containing water, substrate, plants (e.g. *Phragmites australis*) in most of cases, and native microorganisms. Physical, chemical and biological processes, such as volatilization, sorption and sedimentation, photodegradation, plant uptake and microbial degradation, may occur simultaneously, contributing to eliminate several types of compounds. In fact, CWs have shown capabilities to reduce significantly the concentration of several persisting water pollutants.

This concept can also be extended to recover environmental surface and ground waters contaminated with cyanobacteria and cyanotoxins. Such systems would suit the treatment of stored waters in the sub-systems of large reservoirs that, for instance, supply water for agriculture. Studies reporting the capability of aquatic plants and microorganism sediment-communities to remove/degrade different cyantoxins from water are encouraging and provide a demonstration of the potential of this technology.

This work aimed to evaluate the potential of CWs for the treatment of water contaminated with MC-LR (produced by *Microcystis aeroginosa*). For that, microcosms (0.4 m x 0.3 m x 0.3 m), simulating CWs, were assembled with *Phragmites australis* to treat lake water contaminated with *Microcystis aeroginosa* and MCs. Obtained results showed up to 90% removal percentages of both *Microcystis aeroginosa* and MCs during one week treatment cycles. CWs maintained their functions, independently of the MCs presence, also significantly removing nutrients and organic matter.

Present work indicates that CWs have the potential for removal of cyanobacterial cells and cyanotoxins. However, it is still unclear the processes and dynamics involved in the removal of cyanotoxins by the CWs and more research on this topic is necessary.

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BIO: Dr. Almeida is a senior researcher at CIIMAR since 2005. With a PhD in Chemistry her main research area is bio and phytoremediation, being actively engage in studies aiming to enhance the use of bio and phytoremediation as biotechnology tools for remediation of aquatic environments contaminated with different pollutants.

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LIMITED ARTIFICIAL AIREATION AS A STRATEGY FOR IMPROVING THE REMOVAL OF CONTAMINANTS IN CONSTRUCTED WETLAND TREATING DOMESTIC WASTEWATER

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Due to its simple operation and maintenance, constructed wetlands are considered a low cost wastewater treatment alternative, being especially suitable for developing countries. Constructed wetlands have been successfully implemented for the control and removal of pollutants in various types of wastewater worldwide, however, their capacity and efficiency for the removal of nutrients continues to be low. In typical wetland configurations, for example, subsurface horizontal flow constructed wetlands (SSHFCW), the removal of total nitrogen is quite variable reaching values around 50% in most cases. Nitrification-denitrification pathway has been identified as the main mechanism for Nitrogen removal, however, limited natural oxygen transfer in affects the process. This is why the purpose of this research is to evaluate the effect of limited artificial aeration as a strategy to improve the nitrogen and organic matter removal SSHFCW.

For the research six (6) laboratory scale experimental units (0.8 m * 0.30m * 0.50m) with gravel as support medium and planted with Phragmites australis has been used. The air supply is made through diffuser stones distributed longitudinally in the bottom of the units and 8 pulses of 30 minutes are applied along the day. The effect of limited aeration applied in different lengths has been compared with units without aeration with a hydraulic retention time of two (2) days during three (3) months of monitoring.

According to the obtained results (Table 1), the units with aeration have achieved higher BOD_5 removal efficiencies in comparison with the obtained values in the control units (without additional aeration). For total nitrogen, the units with aeration have achieved removal efficiencies of 73%, while the control units reached 58%. On the other hand, the removal efficiency of NH_3-N in the units with controlled aeration was around 75%, while the units without aeration 50% removal was obtained. The removal of TSS reached in the units with aeration was 78%, while in the control units were found 54% values.

Table 1. Obtained results in experimental untis

Unit	BDO_5		Total nitrogen		NH_3-N		TSS	
	Average load*	**Removal (%)**	**Average load**	**Removal (%)**	**Average load**	**Removal (%)**	**Average load**	**Removal (%)**
Influent	25.327	-	6.95	-	3.16		6.20	-
Effluent 1/3 aeration	0.885	96	1.89	73	0.96	69	1.06	77
Effluent 2/3 aeration	1.540	93	1.82	74	0.76	76	0.91	80
Effluent control	4.146	82	2.90	58	1.55	50	1.99	54

Surface load (g/m^2*d*)

It is evident that the application of limited artificial aeration constitutes a valuable tool for improving total nitrogen removal in subsurface horizontal flow constructed wetlands.

BIO: Diego Paredes Cuervo is Professor of the Environmental Science Faculty and Head of the Water an Sanitation Research Group at Universidad Tecnologica de Pereira, Colombia.

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POSSIBLE USE OF CONSTRUCTED WETLAND FOR CYANOTOXIN REMOVAL

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Cyanobacteria are one of the oldest life forms on Earth. Due to the ability of oxygen photosynthesis, they are responsible for forming oxygen atmosphere and life, as we know today. Morphologically, they are very diverse and can be found in single-celled form, filaments or as colony. They are present in almost all possible habitats, including extreme environments such as Antarctic lakes, hot springs, deserts, salt lakes, and tropical acidic soils. They can live as symbionts of other algae, fungi, sponges, plants or other organisms, but are mainly known as part of the phyto-plankton in the saline ecosystems and phyto-plankton or phyto-benthos in freshwater ecosystems.

Nowadays climate changes and increasing water pollution effects quality of surface waters around the world. Due to higher temperatures and high loads of nitrogen and phosphorous in waters, cyanobacterial blooms are becoming a more frequent phenomenon. The main problem arises when cells begin to decay at the end of the blooming, releasing different substances, also cyanotoxins that are very harmful to humans and animals.

Also in Slovenia extensive cyanobacterial blooms can endanger human health and the environment. Specially in the NE part of Slovenia, where massive blooms occur annually due to intense agricultural activities. The occasional occurrence of toxic cyanobacterial bloom in Lake Bled is particularly linked to the (over)developed tourism, fishing activities and various recreational activities.

Limnos Company and Aarhus University (Denmark) are partners in a TOXICROP project which is a European project that aims through Research and Innovation Staff Exchange to map agricultural risk areas of cyanotoxin occurrence, to access the fate of cyanotoxins in crops, bioaccumulation in crops and food contamination related to the use of eutrophic waters in crop irrigation. Our mission is to develop environmentally friendly, low-cost techniques of water treatment based on constructed wetland (CW) technology.

In the past CWs have shown capabilities to reduce significantly the concentration of several persisting water pollutants through a combination of physical, chemical and biological processes, including sedimentation, precipitation, adsorption to soil particles, assimilation by plants and microbial transformation. This concept can also be extended to recover environmental surface and ground waters contaminated with cyanobacteria and cyanotoxins. Such systems would suit the treatment of stored waters in the sub-systems of large reservoirs that supply the water for agriculture. Studies reporting the capability of aquatic plants and microorganism sediment-communities to remove/degrade different cyantoxins from the water are encouraging and provide a demonstration of the potential of this technology.

BIO: The main focus of dr. Plestenjak in is developing constructed wetlands for wastewater treatment and co-natural sludge treatment on sludge drying reed beds. So far he was engaged in planning, developing and construction of several projects.

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MINIMIZING IMPACT OF CYANOBACTERIA AND CYANOTOXINS IN CROPS TREATING IRRIGATION WATERS USING TREATMENT WETLANDS - TOXICROP

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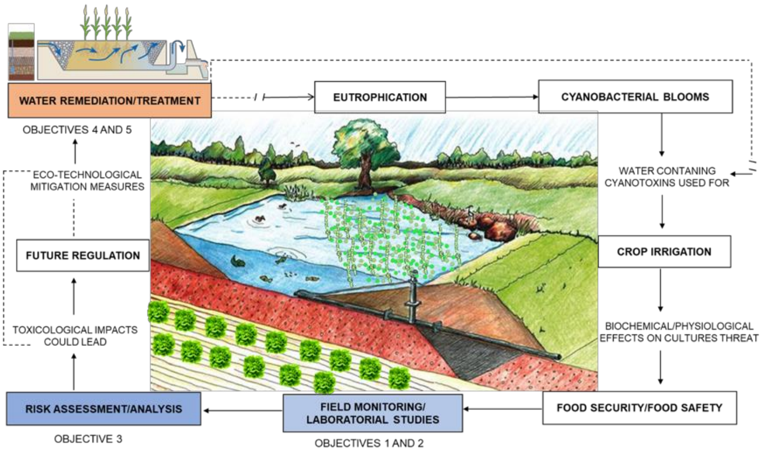
Fresh water resources are increasingly being affected due to their biogeographical and climatic characteristics, as well as anthropogenic pressure. This is very noticeable in the Mediterranean area, where scarcity of water leads to the compulsory use of water containing cyanobacteria and their toxins in agriculture. TOXICROP is a European project funded by the Marie Skłodowska-Curie Research and Innovation Staff Exchange (RISE) programme aiming at:

i) map agricultural risk areas of cyanotoxin occurrence, ii) access the fate of cyanotoxins in crops, iii) access bioaccumulation in crops and food, iii) develop environment-friendly, low-cost technologies for water treatment and iv) improve methods to detect and assess toxicity of cyanotoxins.



We, members of WP6, have the objective to develop cyanotoxins remediation systems based on Constructed Wetlands (CWs) and Multisoil layer systems (MSLs). During the 4 years of the project, we will assess the efficiency of different CW models, under three geographical/environmental conditions (Denmark, Portugal and Colombia). Preliminary studies performed in Portugal have shown promising, thus we are now planning the first trials to determine the most promising configurations and operational parameters. On a second stage, in-depth characterization of the most promising system for both CW and MSL will be performed. Performance will be assessed for both pollutants weathering and toxicity. A report on removal rates, best operating conditions and guidelines for implementation should be delivered by the end of the project.

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 823860.

BIO: Dr. Carvalho is a researcher in environmental chemistry and water treatment technology. He has more than 10 years of experience working with organic micropollutants in the environment and for the past years has been studying their treatment by constructed wetlands. His interests spread from pollutant metabolomics to water reuse.

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CONSTRUCTED WETLANDS AND THEIR CONTRIBUTION TO THE MITIGATION OF CLIMATE CHANGE IN HIGH ANDEAN AREAS

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Nowadays many rivers experiment some changes by climate change and contamination. This leads into flooding episodes and contaminated water in the whole ecosystem. This study aims to: i) to promote constructed wetlands (CWs) as useful profitable alternative for wastewater treatment and ii) to evaluate autochthonous plants with phytoremediation capacity that can act as natural barriers and treat wastewater. Besides, treated wastewater could be released into the environment in a safe manner and it could also be used to irrigate afforestation species on the river banks.

Species used for afforestation, could be affected by many stress factors and their health status and nitrogen content could change. Leaf chlorophyll is the most photochemically active compound that exists in plant cells. And monitoring changes in the chlorophyll content enables to estimate plant interactions with the environment.

Moreover, the present study comparatively evaluates spectrophotometric chlorophyll measurements and atLEAF portable chlorophyll meter measurements in three Andean species: Queñua (*Polylepis incana),* Chachacomo *(Escallonia salicifolia)* and Totora (*Scirpus totora*). Queñua and chachacomo were irrigated with 4 types of water: mountain spring water, riverine water, septic tank effluent and constructed wetland effluent. Among them, totora species acclimate in a vertical constructed wetland and in a horizontal constructed wetland. Two campaigns were carried out and 78 samples were collected in each sampling campaign. Leaf chlorophyll content was measured *in-vivo,* and in the laboratory using atLEAF+ portable chlorophyll meter for all the species. In addition, chlorophyll was measured for all the species using a spectrophotometer in the laboratory, for which chlorophyll was extracted using methanol, in order to validate atLEAF+ measurements. Measurements were made in triplicate. The results showed that chlorophyll measurements with atLEAF and with the spectrophotometer are similar, which is why atLEAF is an instrument to measure Chachacomo and Queñua chlorophyll in the field.
Chachacomo chlorophyll irrigated with clean water was 0.0334 mg / cm2 and with constructed wetland effluent was 0.044 mg / cm2. The *Queñua's* cihlorophyll irrigated with clean water was 0.0448 mg / cm^2 and with constructed wetland effluent was 0.0353 mg / cm^2.

Acknowledgement. This research was funded by CCD-UPC and Diputación de Barcelona.

BIO: Dr. Pastor is a senior scientist at Universitat Politècnica de Catalunya (UPC) with more 20 years of experience in knowledge transfer in natural systems such as constructed wetlands, especially in arid environments like the coastal regions or highlands (>3000m asl). She leaded many water sanitation projects with constructed wetlands to benefit low-income regions.

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MICROBIAL ELECTROCHEMICAL STRATEGY FOR REMOVING NUTRIENTS FROM EUTROPHIC WETLANDS

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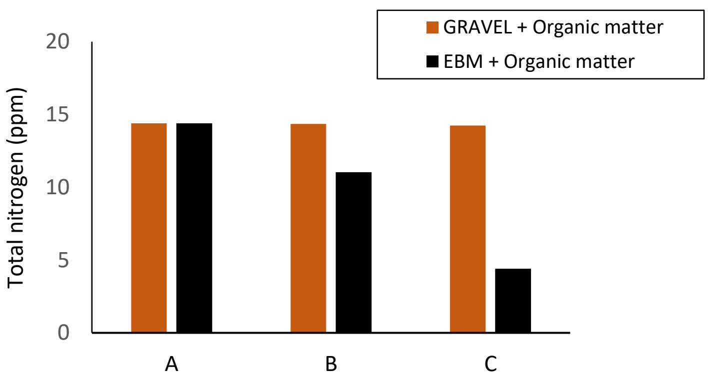
Many natural wetlands in Spain have major eutrophication problems. The decreased amounts of rain due to climate change, and the massive use of fertilizers in agriculture have led to environmental dangers due to eutrophication. This water is difficult to treat due to the high concentration of nitrate. Most of these wetlands are located in rural and isolated communities; therefore, such water treatment needs to be operated under low cost of operation. Our investigation aims to remove nitrate from a polluted wetland located at Carpio (Valladolid, Spain) by combining a Microbial Electrochemical Technology (MET) with the use of organic waste as electron donor.

We investigated four different vegetable substrates as sources of organic matter to increase the denitrification process in MET-assisted constructed wetlands so-called METlands. Willow mulch, willow leaves, wheat straw, and poplar leaves were evaluated as sources of electron donor for denitrification using inert (gravel) and electroconductive biofilter (METland) operating under batch conditions. Our result revealed that wheat straw had the highest rate of total denitrification.

So, our next assay was to operate, under continuous mode (TRH, 12h), a biofilter made of electroconductive bed material (EBM) to treat water from a real nitrate-polluted wetland using wheat straw as electron donor. The electroconductive biofilter removed 70% of the total nitrate, while the gravel control biofilter only removed 20%. These results are strong evidence that this MET-based strategy could be used to clean-up eutrophic wetlands.



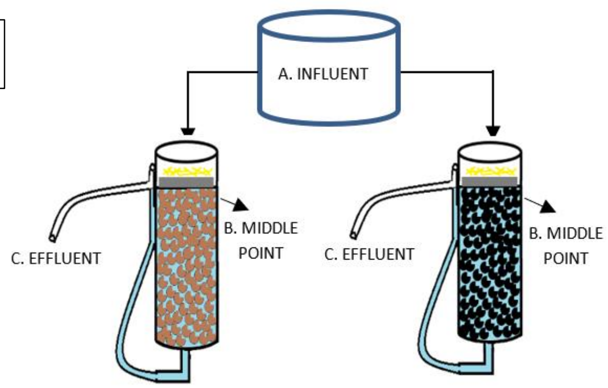


Figure 1: Nitrogen removal by inert and electroconductive biofilters amended with wheat straw.

BIO: Graduated in Environmental Sciences at the University of Salamanca (Spain). Master's degree in hydrology and water resources management (University of Alcalá, Spain). In 2019 he joined the startup company METfilter for conducting an Industrial PhD funded by Madrid Regional Government under the supervision of Dr. Abraham Esteve-Nuñez. He is fully devoted to explore microbial electrochemical strategies for removing nutrients from polluted wetlands.

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INFLUENCE OF MICROBIAL FUEL CELL INTEGRATION ON NITRIFICATION PROCESS IN A VERTICAL SUBSURFACE FLOW CONSTRUCTED WETLAND FOR DOMESTIC WASTEWATER TREATMENT

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The combination of constructed wetland (CW) and microbial fuel cell (MFC) has emerged in recent years with the purpose of enhancing wastewater treatment efficiency of CWs while simultaneously generating electricity (Doherty et al., 2015). In addition to chemical oxygen demand (COD), the removal of nitrogen in wastewater is also an important target. It is well known that during the last decade, the use of vertical subsurface flow constructed wetlands (VSSF) has increased due to their effectiveness as secondary treatment. In VSSF, the nitrification is considered the main pathway for NH_4^+-N removal. However, a limiting factor of this process is the oxygen availability, which has to be higher than 1.5 mg O_2/L (Leiva et al., 2018). Taking the above into account, the aim of this study is to evaluate the influence of MFC integration on nitrification process in a vertical subsurface flow constructed wetland for domestic wastewater treatment. Two experimental systems VSSF were built using acrylic tubes 70 cm in height with an internal square cross section of 15 cm x 15 cm. One VSSF was used as a control system (VSSF) and the other, a microbial fuel cell was integrated (VSSF-MFC). Granular Activated Carbon was used as anode and cathode in the MFC. Both systems were operated under fed-batch mode with synthetic wastewater (14gCOD/m^2 d), hydraulic retention time of 9 days and the plant used was *Schoenoplectus californicus*. The results show that NH_4^+-N concentration reduced from 66.56 ±9.42 at day 0 (influent) to 4.52±0.46 mg/L and 7.03±3.93mg/L for the integrated system and control system, respectively. In terms of the NH_4^+-N removal efficiency, an improvement close to 10 % was achieved due to the MFC integration in VSSF. Moreover, an enhancement of the nitrification rate (ν_{Ni}) was observed when MFC was integrated in VSSF (120.67±1.56 mg/m^2 d for control system and 166.85±2.31 mg/m^2 d for integrated system). The potential reason for a 38.27% increase in ν_{Ni} with MFC integration could be the significant growth of the nitrifiers bacteria on electrodes, as described Du et al. (2014). Furthermore, this improvement would not be related to an increase in the concentration of dissolved oxygen because the values obtained were 1.23±0.04 and 1.38±0.10 mg/L for VSSF and VSSF-CCM, respectively. Otherwise, the average COD removal efficiencies were 89.36±2.67% and 94.25±5.95% in the VSSF and VSSF-MFC, respectively. The oxidation of the organic matter generated in VSSF-CCM a thermodynamically favorable anode-cathode potential difference, obtaining a voltage close to 250 mV. The maximum power density generated was 4.75 mW/m^2. In conclusion, the removal efficiencies of COD and NH_4^+-N in VSSF were 89.4 and 88.4%, respectively, while in VSSF-CCM were 94.3 and 93.2 %. Therefore, the integrating of a MFC into CW does not have adverse effects on the capacity of the CW to efficiently domestic wastewater treatment and can be promising strategy in terms of improve overall nitrogen removal. This work was supported by the grants CONICYT-PCHA/Doctorado Nacional/2016-211160606 from CONICYT (Chile), CONICYT/FONDAP/15130015 and FONDECYT 1140207.

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BIO: Thaís González is PhD candidate in Environmental Sciences by Universidad de Concepción. Chemist with 10 years of experience in electrochemistry. Specifically, in preparation and characterization of electrode surfaces with catalytic activity for the oxidation of organic contaminant. For four years she has been working in the use of integrated MFC into CW for recovery electrical energy from domestic wastewater.

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ENHANCED DEGRADATION OF DIESEL-ORIGINATED POLLUTANTS USING PHRAGMITES PLANTED INTENSIFIED-WETLANDS AIDED WITH AERATION, SURFACTANT AND NUTRIENTS

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Diesel oil spills may considerably damage the environment, especially the sensitive coastal areas and oil drilling sites. A serie of laboratory experiments were conducted for 60 days on diesel oil spiked (2% v/v) intensified wetlands (IW), planted with *Phragmites australis*. In the experiments the IW were externally assisted with aeration, surfactant and nutrients. This novel study assesses the performance of diesel oil spiked IW by monitoring the cumulative as well as individual effect of (1) aeration (dissolved oxygen level, $\geq 7.0 \pm 1$ mg L^{-1}), (2) nutrients (NPK fertiliser, 100mg L^{-1}) and (3) surfactant, tween-20 (0.2% v/v). The performance of IW was evaluated by measuring root length, shoot length, plant biomass (*Phragmites*), diesel oil degradation and its transformation into other compounds using Fourier Transform Infrared (FTIR) spectroscopy. The results showed that a synergistic effect of aeration, nutrients and surfactant have a positive role on the overall growth of *Phragmites* as highest increment in biomass was achieved in IW (30.6%) compared to control (8.5%). However, the individual effect of aeration, nutrients and surfactant on plant biomass was 19.5, 10.1 and 12.4% respectively compared to control (8.5%). The highest plant biomass (fresh weight % increase) was associated with those IW, that received aeration (dissolved oxygen maintained at ≥ 7mg L^{-1}). Furthermore, FTIR data also revealed that synergetic effect of aeration, nutrients and surfactant can completely degrade alkanes (CH2, CH3 angular deformation), aldehydes (C-H stretch), carboxylic acid dimers (C=O stretching), primary amides, Alkenes (C=C stretch), nitro compounds (N-O stretch), aliphatic esters (C-O stretch), sulfoxides (S=O stretching) and aromatic hydrocarbons group (=C–H stretch) present in diesel oil (frequency range 1458-675 cm^{-1}). Thus it can be concluded that synergistic effect of aeration, surfactant and nutrients can degrade diesel oil in Phragmites planted IW and hence can be served as an effective treatment option in the field of wetlands. Moreover, this novel study provides a database for further evaluations and support to design optimal treatments strategies in restoration of diesel contaminated area through intensified wetlands.

BIO: Dr. Hashmat is senior scientists at the Environmental Biotechnology Division of the National Institute for Biotechnology and Genetic Engineering (NIBGE) in Pakistan. His research experience and interest is focussed on the development of technologies for the treatment of industrial effluents, including the study of alternative technologies such as constructed wetlands.

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BIOFILM ELECTRIC CAPACITANCE AS A TOOL FOR DOMESTIC WASTEWATER COD ASSESSMENT IN THE CONTEXT OF CONSTRUCTED WETLANDS

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Research on coupling bioelectrochemical systems, and especially microbial fuel cells (MFCs), to constructed wetlands (CW) has been, up to date, focused mainly on energy production and treatment efficiency improvement. The use of MFCs as an organic matter assessment tool, although a less addressed topic, has been demonstrated to be a promising tool for the assessment of both COD and sludge accumulation (Corbella et al., 2019). In spite of promising initial results, the use of MFCs for COD assessment shows a severe constraint related to the life-span of the tool, which is limited to just few weeks of operation. Therefore, other operation/biondication strategies are required to overcome current limitations of MFCs as a COD assessment tool. The objective of this work was to demonstrate the feasibility of using the electroactive biofilm capacitance (biocapacitance) as a tool for real domestic wastewater COD assessment. Biocapacitance is the ability of any biofilm to accumulate negative electric charges during the temporary absence of a suitable electron acceptor. The anode of a MFC is the final electron acceptor of electroactive bacteria. Therefore, we can artificially remove the presence of the electron acceptor by operating the MFC under open circuit condition). For the purpose of this work, four vessels of about 6 L each were built up and were equipped with an air-cathode microbial fuel cell each, following a similar architecture of that described in Corbella et al. (2019), but using granular graphite as the electrode material for anode and cathode instead of gravel. The MFCs were operated at discontinuous closed circuit conditions, with a charging time (open circuit) of 3 minutes and a discharging time (closed circuit) of 10 minutes. One charging-discharging cycle was applied every hour. These operational conditions allowed us to have both charge-discharge cycles and continuous operational conditions of the MFCs which, in turn, allowed us to test the COD assessment ability of the MFCs under biocapacitance and continuous operation conditions. Raw domestic wastewater was collected and left settle for 2 hours. After the settling, wastewater was diluted to have a wide range of COD values and the electric conductivity corrected to have equal electric conductivity conditions across the whole range of COD values tested. Two COD assessment experiments were conducted and the COD concentration range tested was that of 200, 320, 440 and 630 mgCOD/L during the first trial and 120, 200, 260, 320, 380 mgCOD/L during the second trial. All conditions were tested in quadruplicate. Electric parameters considered for COD bioindication purposes were: a) open circuit conditions reached just at the end of the charging period (mV - OCV); b) Coulombs accumulated during the whole charging period (W.s – DischA); c) the difference between the highest and the lowest value during the charging-discharging cycle (mV – OC/CC) and d) continuous electric signal (mV – E_{cell}). Results showed that all of the electric parameters considered correlates well with COD values tested (r^2 ranged from 0.89 to 0.97). However, bioindication parameters related to the biocapacitance (OCV, DischA and OC/CC) always showed better correlation and more stable results than that of the continuous operation of MFCs (Ecell). More precisely, correlation coeficients (r^2) were, in average, that of 0.89±0.1, 0.94±0.08, 0.96±0.02 and 0.97±0.01 to the E_{cell}, DischA, OCV and OC/CC, respectively. Main conclusion of this work is that of the biofilm electric capacitance of MFC (ecMFC) can be used as a COD assessment tool.Further work on the life-span of ecMFCs for COD assessment purposes are required to assess the true potential of the bioindication tool.

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EVALUATION OF A HORIZONTAL SUBSURFACE FLOW CONSTRUCTED WETLAND AS A SEWAGE TREATMENT PLANT, IN THE CORPORACIÓN MAESTRA VIDA, EL TAMBO-CAUCA.

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In the research, a wastewater treatment system where a horizontal subsurface flow constructed wetlands was established and performance was evaluated for a period of a year. The system was established to treat the water produced from the facilities of an environmental concerned NGO Corporación Maestra Vida that also serves as a demonstration systems for natural wastewater treatment. The system is planted with a native tropical plant Heliconia psittacorum, and all the water treated is reused to irrigate a small scale crop garden. Once the system was established and started steady state operation, periodic sampling of the physicochemical parameters COD, pH, P-PO43, NH3, Coliform (Total and Fecal), SST and Temperature were made following standard methods. The results showed that wetland is effective for treateing the wastewater generated at the site as well as to reclaim the water treated. The performance showed that the systems removes organic matter in terms of COD (42%), P-PO43 (77%), higher than 99.9 % removal of coliforms and successfully nitrifies. Statistical analysis showed significant percentage removal of the influent with respect to the effluent. The Wetlands established positively impacted the site by providing effective treatment of the domestic waters and allowed the reclamation of water for irrigation, has provided the NGO with a demonstration system while the treatment has properly integrated to the local ecosystem.

REED-BED TREATMENT FOR DOMESTIC WASTE LANDFILL LEACHATES JEAN-LUC

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Many active and closed domestic waste landfill produce low volume of leachates. Usual treatment techniques (bioreactor, osmosis, evaporator, …) need oftently processes over-sized, technically complex, costly and energy-greedy in comparison with the relatively low volume of leachates produced.
Objectives of these project were to adapt and optimize reed-bed natural process for the treatment of leachates but also for effluents coming from composting platform, agri-food, …

Domestic waste landfill leachates, contrary to domestic wastewater, are characterized by evolutive biodegradability as a function of age, high nitrogen concentration (mainly Total Kjeldahl Nitrogen) and, very oftenly, non-biodegradable chemical oxygen demand (COD). Hence, these specific characteristics request a perfect control of treatment to reach threshold values required by administrations and convenient with the environment.

Laboratory and field pilot tests were carried out to:

- optimize effluent recirculation (in the first aerobic stage only or in both aerobic and anaerobic filters) in order to degrade all biodegradable part of OCD (BOD) and nitrogen charge.
- Adapt exogeneous carbon substrate for optimized denitrification,
- Size real scale reed-bed unit treatment

After the aerobic and anaerobic stages, another smaller aerobic stage has been constructed to degrade potential overload of exogeneous carbon substrate used for denitrification. Finally, a granular active carbon filter helps to degrade the residual non-biodegradable OCD before release in the environment.

Abatement obtained were comprised between 90 and 98 % of carbon and nitrogen charges.

BIO: Nicolas Seyve is an engineer with 15 years of water treatment and waste landfill. Dr. Antoine Joubert is a biogeochemist with 15 years in research and development in the field of soil and groundwater treatment. His university studies also concerned domestic waste waters treatments.

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SEASONAL VARIATIONS IN THE MICROBIAL COMMUNITY COMPOSITION AND ASSOCIATED COUPLING CARBON, NITROGEN AND SULFUR TRANSFORMATIONS IN A FULL-SCALE HYBRID CONSTRUCTED WETLAND SYSTEM

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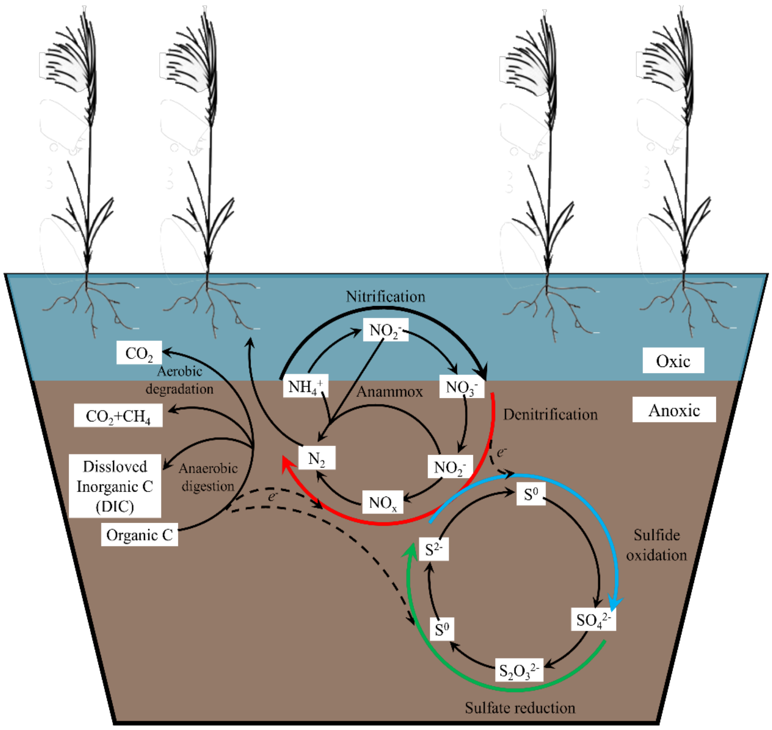
Hybrid constructed wetlands (CWs) can efficiently improve the nitrogen removal in the conventional CW systems, probably due to the coupling CNS transformation processes. In this study, we investigated the microbial community composition and the correlated coupling CNS transformation capacity in a full-scale constructed wetland, including dissolved total organic carbon (TOC), dissolved inorganic carbon (DIC), dissolved total carbon (TC), NH_4^+, NO_2^-, NO_3^-, S^{2-}, and SO_4^{2-}, via both autotrophic and heterotrophic processes. Results showed that the seasonal variations in microbial community compositions were correlated with the transformation of CNS compounds in the CW. Spearman's correlation coefficient and principal component analysis further proved that the removal of N compounds were coupled to the S transformation. The removal of both NO_2^- and NO_3^- was promoted by increasing initial l S^{2-} or SO_4^{2-}. On the other hand, the heterotrophic SO_4^{2-} transformation was closely correlated with initial concentrations of NH_4^+ and NO_3^-. In conclusion, this work provided that the coupling CNS transformation in the hybrid CW is important but less study. The outcomes of this study will contribute to understanding the coupling transformation of CNS, and will help to improve the design and operation of CWs in the future.



BIO: Prof. dr. Zhai is the Regional coordinator (Asia) of the IWA Specialized Group on "Wetland systems for Water pollution Control". He has extensive experience in planning, designing, and implementing wetlands construction, especially for rural areas. He has led and participated many national and international projects on natural-based water treatment.

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ECOLOGICAL TYPES OF WETLAND BUFFER ZONES – HOW LANDSCAPE DEFINES FUNCTIONALITY

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River ecosystems, along with riparian landscapes, are essential for maintaining and regulating natural cycles of water and nutrients between terrestrial and aquatic ecosystems. The key role is played in this respect by riverine wetlands, which can be regarded as hubs of biodiversity and ecosystem services. Yet, due to the large-scale modification of European rivers and wetlands and intensification of agricultural productions, these functions are seriously impaired. CLEARANCE project stresses the necessity of their protection and restoration, indicating wetland buffer zones (WBZ) as the solution.

Although WBZs are commonly formed as strips of land adjacent to rivers, other shapes and locations can sometimes be more operational. These include specific groundwater discharge zones (e.g. fens) and floodplains. Moreover, when considering the role of in-stream nutrient removal processes, also whole section of a water stream can be regarded as a WBZ in reference to the lower reaches of the river or higher-order rivers. The role of WBZ in purifying water is strongly linked to eco-hydrological conditions and vary over time. In addition, the role of WBZ for nutrient removal by harvesting (and further recycling) will depend on the potential to promote high productivity and good access for agricultural machinery.

CLEARANCE takes an operational approach to WBZ that stems from geomorphology, hydrology and landscape functioning. Spatial delineation of WBZs and the level of intervention necessary to optimise their ecosystem services depends on local natural conditions, specific nutrient loads and socio-economic constraints and opportunities. CLEARANCE proposes a hierarchical approach to WBZ classification, where the first level distinguishes between (i) WBZs as linear structures (i.e. section of the water course with its banks/shores) and (ii) WBZs as polygons (wide part of the water course valley). In practice, both types should preferably be combined to optimise nutrient removal and other functions of WBZs. However, the effectiveness of these two categories may vary a lot depending on regional physical circumstances (e.g. organic vs. mineral soils). Within each of these categories, CLEARANCE distinguishes sub-categories that differ with respect to physical constraints on possible WBZ introduction under different landscape circumstances. The considered WBZ types are: wetland banks/shores, two stage channel, meandering channel, undrained fen, rewetted fen, floodplain with organic soil, floodplain with mineral soil, oxbow.

Additionally, we discuss some aspects of social landscape's impact on establishment and maintenance of WBZs, pointing at the role of already performed and planned large-scale hydro-technical projects in rivers.

BIO: Dr. Jabłońska is a scientist with more than 10 years of experience in mire ecology, vegetation ecology and nature conservation of wetlands.

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SOIL SEED BANK PERSISTANCE AND VEGETATION SHIFTS FOLLOWING CHANNEL DIVERSION IN THE YELLOW RIVER DELTA

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Vegetation plays a key role in influencing the morphodynamics of river deltas, yet channelization of most of the world's rivers limits delta movement and thus, our understanding of vegetation dynamics in newly formed and abandoned deltaic wetlands. The artificial channel diversion of the mouth of the Yellow River in 1996 created conditions that mimic a natural delta lobe shift by increasing freshwater, sediment, and nutrient supply to wetlands along the new course (NYR) and allowing seawater encroachment in the abandoned course (OYR). To examine the longer-term effects of this river channel shift on the vegetation community and seed bank structure, aboveground vegetation and seed bank species richness and diversity were examined from the channel to the marsh interior in wetlands of both OYR and NYR. The results showed that the species richness was 17 in the aboveground vegetation, and 16 were found in NYR and 9 in OYR. The diversity index of both vegetation and seed bank in the sea-to-land plant communities of the NYR and OYR courses showed an initial increase from the sea-landward but then declined near the river bank. However, no significant differences of species richness in the seed bank were found. The seed bank groups did not show a clear separation relative to vegetation for the NYR course. However, there was a greater separation between seed bank groups and aboveground vegetation in the OYR course. The findings suggested that after channel diversion of the Yellow River, the abandoned river channel was affected by seawater which caused degradation of the vegetation communities, and therefore differences from the NYR. However, the species richness and diversity of soil seed banks in the OYR were similar to that of the NYR, indicating seed banks had greater tolerance to external disturbance compared with vegetation.

BIO: Dr. Bo Guan is an associate professor with more than 10 years of wetland ecology research experience. He has extensive experience with seed germination, plant adaptation and wetland restoration, and has led more than 4 projects dedicated to wetlands ecology, published more than 30 research articles.

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CHALLENGES IN THE IMPLEMENTATION OF RESTORATION PROJECTS IN POLLUTED RIVER LANDSCAPES

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Riverine landscapes are unique habitats that coevally provide an extraordinary amount of ecosystem functions and services on varying spatial and temporal scales. Changes in the river flow can alter the extent, duration and frequency of their inundation most profoundly. Those changes often occur from water extraction, dam construction, drainage, or river control and mostly end up by dis-connecting rivers from their adjacent floodplains. Consequently, key functions such as biodiversity support, flood mitigation, carbon storage and water quality improvement are negatively affected by disturbed hydrological processes. In addition, rivers and their floodplains face dramatic problems in terms of significantly decreasing freshwater biodiversity due to modified habitats that are mostly caused by changing land use patterns and intensive, mostly, arable land uses in their catchments, the increase in invasive species and also due to pollution.

As far as pollutants are concerned, riverine floodplains can adopt water quality functions for rivers during periods of flooding. And as pollutants are mainly bound to sediments, overbank flooding is the major pathway for diffuse pollution into floodplain soils. Thus riverine floodplains are usually heavily polluted and due to the fact that floodplains display strong spatial as well as seasonal heterogeneity they can be both sinks and sources for pollutants.

By reason of the dramatic loss of floodplains and the poor river water structure restorations measure are highly important to fulfil the requirements of the EU water framework directive as well the EU Biodiversity Strategy. At the same time hydrology may change after the implementation of restoration measures and floodplains may become a source of former bounded pollutants.

In this paper we focus on the investigation of pollutant dynamics related to the remobilization and retention of sediments and pollutants in floodplains influenced by the restoration of natural banks and the reconnection of former river arms. We have previously collected data and will collect data after the restoration work has been completed. At the same time, we assume that the restoration of river floodplain ecosystems has advantages over the possible negative effects of pollutant remobilization. In these considerations, pollution is only one part, since the presented research project collects data on biodiversity, nutrient cycles and other ecosystem functions, all of which play an essential role in the overall synthesis. Multi-functional analyses will be carried out before and after the measures to determine to what extent the positive effects of the measures on the preservation and restoration of ecosystem functions and services in river floodplains will have an impact, even if the system has a certain degree of pollution.

BIO: Dr. Christiane Schulz-Zunkel is s post-doc with special expertise in biogeo-chemical dynamics in floodplain soils and the provisioning of ecosystem functions and services in riverine wetlands. She has experience with floodplain restoration projects and the assessment and mapping of ecosystem functions and services in floodplains.

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EVALUATING PHOSPHORUS REMOVAL EFFICIENCY IN A FIELD-SCALE HORIZONTAL SUBSURFACE FLOW (HSSF) CONSTRUCTED WETLAND

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Phosphorus, along with the nitrogen are nutrients that when discharged to surface waters, they can cause a phenomenon known as eutrophication, which in recent years have been posing as a serious threat for water bodies. Therefore, the phosphorus removal from the wastewater is essential to avoid this phenomenon, since it constitutes the nutrient considered as the most significant restrictive factor that influences the eutrophication of freshwater. The use of Horizontal subsurface flow constructed wetland (HSSF-CW) for the secondary treatment of domestic wastewater is considered to be a sustainable and economic solution compared to the conventional wastewater treatment plants. This technology is effective to remove biochemical oxygen demand (BOD) and suspend solids (SS), but the removal of phosphorous presents some challenge and is an issue that has not been satisfactorily resolved.

The present study aims to evaluate the efficiency of a field-scale HSSF-CW with a surface area of 1120 m^2 to remove phosphorus from domestic wastewater, using sand and gravel as substrate and *Phragmites australis* as wetland plants. Monthly water samples were collected and analyzed for eleven months at the inlet and outlet from wetland bed and phosphorus removal efficiency (RE) of the system was examined. Monitoring results obtained during this study show that on average, the bed did not provide statistically significant abatement ($p>0.05$) in total phosphorus (TP) and dissolved phosphorus (DP) concentration on any sampling periods. The DP is the highest fraction present at the inlet and outlet, however, it was observed that after the wastewater passed through the CW bed that fraction has increased from 67.0% to 69.6%. At autumn-winter period the highest percentage in the influent corresponds to particulate fraction (56.4%) that changes to 50% in the effluent. The RE of P compounds was relatively poor when compared with TSS and organic compounds. Average removal rates of TP were 23%, 27.5% and 12.9% in whole monitoring period, in spring-summer and autumn-winter periods, respectively. The DP was removed in 20% along the entire sampling period, 26.1% in spring-summer period, and it was not removed in the autumn-winter period. Thus, the results allow observing that there were significant differences ($p<0.05$) in the rate of removal of TP and DP between the two seasonal periods considered, with highest percentage removal occurring in warmest period. RE were relatively low indicating that P release from the wetland bed may occur probably due to the soluble reactive phosphorus (orthophosphate) adsorbed and/or precipitated with iron and manganese hydroxides. Findings, also indicate that it has not been observed any statistically significant ($p>0.05$) linear relationship between the HLR and TP removal efficiency, despite the plot shows a decrease in RE with increasing hydraulic loading, linking the increase of TP concentrations in liquid phase to high HLR.

Keywords: constructed wetland, subsurface flow, field scale, phosphorus removal

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COMBINING PLANTED DRYING BEDS TO MATURATION PONDS FOR A COMPREHENSIVE TREATMENT OF FAECAL SLUDGE IN SUB-SAHARAN AFRICA

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Continual increase in population of Sub-Saharan African countries comes about with huge amount of faecal sludge to treat at a given time. As about 90% of households are not connected to a sewerage system for excreta disposal and faecal sludge treatment plant almost absent, there is necessity of developing cost-effective technologies to contain their harmful effect.

In response to this preoccupation, pilot scale experiments combining drying beds to maturation ponds were conducted in Yaounde (Cameroon) for the treatment of faecal sludge. Raw faecal sludge was applied once a week at the load of 200 kg DM/m2/yr. on a 1 m2 section drying bed planted with Echinocloa pyramidalis, a local forage plant for dehydration.

The leachate obtained was subsequently polished in two shallow maturation ponds (50 cm depth) in series, following a varying hydraulic retention time (HRT) of 4, 7 and 10 days. Results showed the set-up to be effective at 10 days HRT in reducing significantly ($P < 0.05$) nutrient and organic pollutants as well as faecal coliforms in the final effluent compared to 4 and 7 days. However, suspended solids removal remained inefficient due to high algal biomass. The performance of the system enabled the treatment to meet the requirements of the Cameroonian guidelines for discharge and reuse in non-restricted agriculture.

These results constitute advancement towards a comprehensive treatment of faecal sludge with the perspective of reuse of the effluent. Validation of this treatment scheme at full scale is ongoing for its adoption and implementation in the Cameroon national sanitation strategy.

Bio: Dr SOH KENGNE Ebenezer is a Lecturer and young scientist implementing contructed wetlands for faecal sludge treatment in Cameroon’s municipalities (Banganté, Douala, Yaounde and Dschang sooner). He is also engaged with the Africa Water Association as Trainer in the RASOP program.

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EFFICIENCY OF PHOSPHORUS REMOVAL IN CONSTRUCTED WETLANDS: STUDY, MODELING AND PREDICTION

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The constructed wetlands are wastewater treatment and/or post-treatment systems that consist of aquatic plants and substrate and promote treatments and removal of several parameters, with special emphasis on nutrients, incorporated in plant biomass, not removed in conventional effluent treatment. The nutrients, such as nitrogen and phosphorus, are present in high concentrations in sewages that are basically organic. In this sense, the constructed wetlands are potentially used as alternative systems for the treatment of such compounds by virtue of their removal efficiency, low operating and construction costs, and viable system deployment and handling, which does not require electricity nor chemicals application. In order to evaluate the efficiency of aquatic plants in the removal of phosphorus, this study evaluated the removal of the constructed wetlands as a post-treatment of a UASB reactor, installed in the campus of the School of Technology - UNICAMP, Limeira - SP, Brazil, using two species of macrophytes: Canna x Generalis and Zantedeschia aethiopica on a substrate consisting of fragments of ceramic tiles. The purposes of this work were to evaluate the performance of the constructed wetland in the removal of phosphorus, comparing these macrophytes, and to predict the behavior of the removal, through mathematical modeling. The wetlands operated of subsurface horizontal stream, with five days of hydraulic detention. The placement of the plants were monitored, proving easy adaptation and the phosphorus removal was evaluating through experimental and predictive performance analysis, via mathematical modeling. In the first six months, the constructed wetlands containing Canna x Generalis and Zantedeschia aethiopica presented mean values of phosphorus removal of 39.07% and 67.91%, respectively, with five days of hydraulic detention. According to the results, Zantedeschia aethiopica presented greater removal of the phosphorus when compared to Canna x Generalis, however, both macrophytes showed to be viable alternatives such as post-treatment of this component.

BIO: Dr. Poletti has been working with mathematical ecology for more than ten years developing studies based on mathematical and computational modeling. Related to wetlands, she has been working with implementation, monitoring and analysis of efficiency of systems (pilot and real scales).

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INFLUENCE OF THE OPERATION TIME ON THE HYDRODYNAMIC BEHAVIOR OF A HORIZONTAL SUBSURFACE FLOW CONSTRUCTED WETLAND

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Constructed wetland (CWs) present advantages related to the operation costs, sludge production, electric energy cost for aeration, variation of applied loads, good efficiency in warm climates and landscape aspects. To improve the efficiency in the treatment of pollutants, it is also necessary to better comprehend their hydrodynamic characteristics, i.e., the flow regime of the liquid phase that influence the velocity of the biological reactions, through changes on the mass transfer rate and on the reactions distribution along the CW.

Stimulus-response pulse-type assays were carried out in a horizontal subsurface flow constructed wetland (HSSFW) (0.1506 m^3) operated with influent flowrate of 2.9 L h^{-1} and hydraulic retention time (HRT) of 23 h in the treatment low-strength sewage (COD < 150 mg L^{-1}). Rhodamine WT 20% concentration was determined in Varian Cary Eclipse fluorescence spectrophotometer (540 nm excitation, 579 nm emission). A volume of 50 mL of the tracer solution (2 g L^{-1}) was injected at 10 s, and the effluent samples were collected at every 2 h during 78 h (> 3 h of HTR) after 10 days (1st assay) and 150 days (2nd assay) of the start of the operation.

The experimental curves of the tracer concentration during the time were normalized (Levenspiel, 1999), resulting in distribution time residence curves. The uniparametric models of number of tanks in series (N_CSTR) and low (LD) and high (HD) dispersion were adjusted to the experimental distribution time residence curves as function of the dimensionless mean residence time. Additionally, volume of dead zones (Peña, Mara and Avella, 2006), presence of hydraulic short-circuiting (Sarathai, Koottatep and Morel, 2010) and percentage of tracer recovery (Dierberg e DeBusk, 2005) were determined.

Peaks were observed at 18 and 26 h in the 1st and 2nd assays, followed by a slow decay in the tracer concentration, i.e., a tailing phenomenon probably due to the tracer diffusion in dead zones and/or short-circuiting or channeling. This effect was more evident in the 2nd assay probably due to the loss of the hydraulic characteristics from the clogging and internal recirculation in the CW that influence the flow of the system and adsorption/desorption of the tracer in the substrate. Experimental HRT were 13% and 39% higher than the theoretical of 23 h to the 1st and 2nd assay, confirming the delay in the tracer response, and possibly the presence of dead zones or tracer adsorption on the substrate. Also, the increase of HRT indicates the presence of micropores that increase the substrate resistance and slow down the flow velocity, and back mixing of the fluid during the operation time.

N_CSTR model better adjusted the experimental data resulting in 4.6 (R^2 = 0.983) and 6.1 (R^2 = 0.945) systems in series in the 1st and 2nd assays, respectively. Regarding LD and HD models, R^2 values resulted in 0.913 and 0.859, and 0.720 and 0.714. The system presents neither dead zone volume (negative results for both assays) nor significant short-circuiting (> 0.3 to for both assays). The tracer mass recovery was 69.2% and 60.9% in the 1st and 2nd assays.

BIO: Ph.D. Fernando Hermes Passig is a is a senior scientist with more than 20 years of experience planning, designing, and implementing biological processes to treat sanitary sewage and industrial effluents.

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QUANTIFYING BIOFILM EFFECT ON PHOSPHORUS SORPTION CAPACITY OF LECA USED IN CONSTRUCTED WETLANDS

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Despite its relatively low sorption capacity, due to its common availability and low price, Lightweight Expanded Clay Aggregates (LECA) have been widely recognized and applied as a substrate used to enhanced phosphorus removal in constructed wetlands (CWs). To overcome phosphorus binding limitation, aluminium and ferric coatings have been included into the LECA manufacturing process, yet until now this approach did not gain enough popularity. In fact, low investment and maintenance costs are the main drivers of CWs implementation, hence any proposed improvements need to be done at the minimum cost and coating process does significantly increase it. However, apart from expensive chemical treatment, LECA can undergo a simple structural modification leading to activation of its internal pool of P binding sites. It can be achieved either by the use of mineral or combustible additives in manufacturing process which increase granule's mantel and core porosity or simply by crushing the material to expose its porous core. To assess the application benefits of structural and chemical improvements in LECA granules, the response towards microbial activity and susceptibility to biofilm development resulting in bio-clogging must be investigated.

This study analyses the effects of application of various types of LECA- modified both structurally (crushed and extensively bloated granular specimens) and chemically (Fe and Al oxides coating)- to increase limited P removal potential of CWs systems in respect to environmental and economic aspects. Phosphorus sorption batch equilibration was carried out for both biologically inactive and 28-days wastewater inoculated LECA. Gathered data proves the hypothesis that structural modification increases the P binding (20-30%) in reference to intact granule. Nevertheless, the observed increase of sorption capacity was still lower (-50%) than Al or Fe coated sorbents. However, the biofilm development showed to affect less P sorption of specimens with higher porosity. Therefore, the lifespan of porous materials could be longer in CWs systems, thus in total capturing more phosphorus. Further research is currently carried out to understand the microbial activity in various types of LECA with respect to P adsorption process and to quantify the economic and environmental benefits of low-cost structural modification of LECA in CWs systems.

BIO: Franciszek Bydalek- PhD student at University of Bath, UK, investigating microbial activity and pathogens removal mechanisms in constructed wetlands. Total of 5 years of research and engineering experience in sustainable wastewater management focused on natural-based solutions, including constructed wetlands. Background in environmental engineer and ecohydrology.

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MICROBIAL DIVERSITY IN EXPERIMENTAL CONSTRUCTED WETLANDS FOR THE TREATMENT OF PHARMACEUTICALS-ENRICHED SWINE WASTEWATER IN YUCATAN, MEXICO

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Introduction: Veterinary pharmaceuticals represent an important source of environmental pollution.[1] Their presence in the environment indicates that conventional wastewater treatments are not adequate to remove them.[2] Constructed wetlands (CWs) offer an alternative for treating pharmaceuticals in swine wastewater due to their relatively low setup and maintenance costs; and easy operation.[3] Because of this CWs have become a good alternative technology for the treatment of swine wastewater in small pig farms in Yucatán, México. Pharmaceuticals removal with CWs can be achieved through physicochemical decomposition, photodegradation, adsorption by wetland soil and plants, and microbial activity.[4] Although some researchers still debate which is the mechanism with more influence on the removal; to clear up this, it is important to identify the microbial communities within the system, which was the aim of this study, leading to understand their role in the removal process in CWs, providing a future guideline for the ideal design and operation.

Methods: Samples of the solid support from an experimental system of CW's used for the removal (from 47% to 97%) of a mixture of 4 pharmaceuticals (oxytetracycline, enrofloxacin, sulfamethoxazole and ractopamine), were taken randomly from each unit (a control without plants, and the other two with *Typha latifolia* and *Cyperus papyrus*, respectively). DNA extraction was performed according to the silica-based method,[5] and Microbial communities were explored by Illumina Miseq sequencing employing PCR amplification of the 16S RNA ribosomal region. Microbial community profiling was performed by RTLGenomics for 16S rRNA data was conducted using the QIIME version 1.9.1 and the microbial diversity indices were analyzed using EstimateS software version 9.1.

Results

Figure 1 shows the taxonomic summary of the microbial communities from the different wetland units, comparing samples from the control units without plants to those with plants. For bacteria, an increase in the class Proteobacteria was observed mostly in the *Typha latifolia* unit, meanwhile for archea, the class Euryarchaeota is more abundant for the control unit. Diversity indices are shown in Table 1.

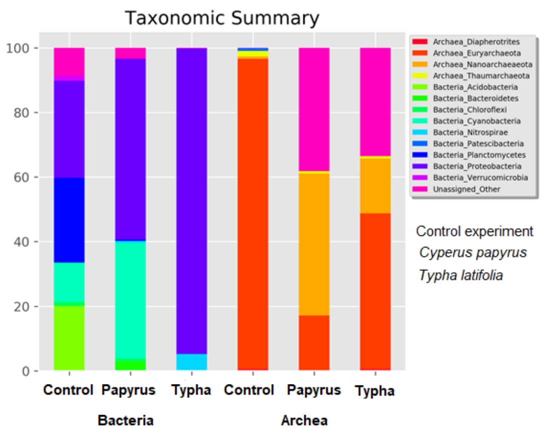

Tabla 1. Microbial diversity indices from constructed wetlands units

	unit	Individuals (computed)	ACE	Chao1	Shannon	Alpha	Simpson
	Control	3885.33	5.32	5.32	0.62	0.63	1.65
ARCHEA	CW *Cyperus papyrus*	7770.66	6.33	6.33	0.75	0.68	1.64
	CW *Typha latifolia*	11656	7	7	0.87	0.72	1.99
	Control	3597.33	44.43	43.86	1.90	7.05	4.22
BACTERIA	CW *Cyperus papyrus*	7194.66	60.30	60.04	2.35	9.01	6.18
	CW *Typha latifolia*	10792	68	68	2.51	9.69	5.60

Fig 1. Microbial communities from the different wetland units

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BIO: Dr. Germán Giácoman-Vallejos is a researcher, professor, member of Academy of environmental engineering and head of the environmental laboratory at Faculty of Engineering, Universidad Autónoma de Yucatán, with more than 30 research publications.

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DETERMINING KINETIC PARAMETERS FOR HETEROTROPHIC BIOMASS IN CONSTRUCTED WETLANDS

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Constructed wetlands (CWs) are simple, robust and inexpensive techniques used to treat wastewater. In these systems a large number of processes occur in parallel and influence each other. Models describing the biochemical transformation and degradation processes in CWs are promising tools to better understand CW functioning. The aim of this work is the use of respirometry to determine kinetic parameters for microbial metabolism modelling, in a lab-scale horizontal sub-surface flow (HSSF) CW.
A series of respirometry tests were conducted in the Environmental Laboratory of IST in Lisbon, Portugal, to analyze the rate constant for decay of heterotrophic bacteria (b_H) and the maximum aerobic growth rate (μ_{Hmax}).
An experimental bed in operation since 2009 was used as filling media (gravel) and biomass source. The bed was fed on weekdays with a synthetic sewage at concentration of 1600 mgCOD/L, and COD, VSS and TSS were analyzed weekly at the inlet and outlet. Gravel samples from the bed were extracted to perform respirometry tests in a LSF respirometer (liquid phase, static gas, flowing liquid) which allows for attached-biomass testing. The respirometer consists of a closed box where the sample of filling media from the subsurface flow CW is placed, and water is recirculated from the outlet to the inlet. In the recirculation circuit there is a small container where water is aerated, while dissolved oxygen (DO) levels are continuously measured at the inlet and at the outlet of the box. The difference between inlet and outlet DO, together with the hydraulic residence time (HRT) in the box allows to calculate the Oxygen Uptake Rate (OUR).
Prior to each test the system was oxygenated until endogenous conditions were achieved. Acetate was then added as a pulse injection into the system to obtain a respirometry test in response to a readily available substrate. Once the endogenous respiration was achieved again, the system was left with only aeration to determine the biomass decay rate in the absence of substrate.
Figure 1 shows values of OUR as a function of time in a respirometry test. The decay rate was calculated between days 13 and 20 and the value of b_H obtained was 0.19 day^{-1} (adjusted to 20ºC), which is lower than the value of 0.4 day^{-1} suggested for the general model CWM1. Further tests are being developed for determining kinetic parameters.

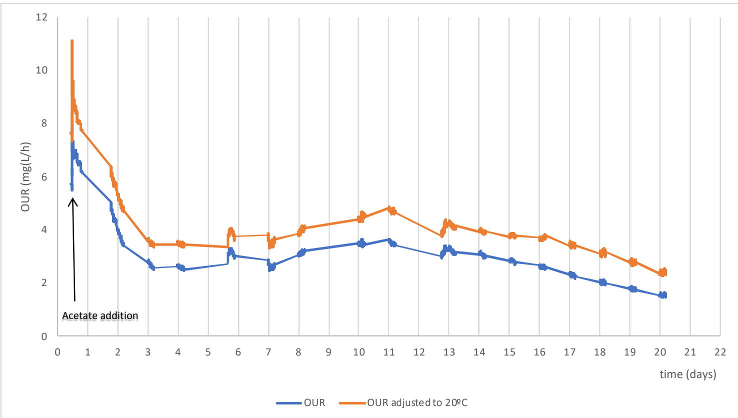

Figure 1: Example of a respirometry test

BIO: Joana Pisoeiro is a PhD student at Instituto Superior Técnico and for the last 5 years she has been studying wastewater treatment and modelling tools for CW. The thesis focuses on bioclogging process (using BIOPORE model and laboratory-scale HSSF-CWs) and obtaining necessary modelling parameters for CW.

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ENGINEERED ECOSYSTEMS, A CYBORG APPROACH TO ECOSYSTEM RESTORATION - *GRAND LAKE ST. MARYS LITTORAL WETLAND RESTORATION*

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Ecosystems processes fluctuate wildly when under stress of changing physical, climatic, biological and anthropogenic inputs as the system seeks to attain equilibrium. They are expressed in the ecosystem through declines in ecosystem services (species abundance/diversity, water quality, flood pulsing, etc.). The amplitude of these fluctuations is symptomatic of the severity of the problem, and predicative of system collapse. Re-establishing the equilibrium within the ecosystem to restore the services it provides, is the basic premise of ecological restoration.

Direct modification of an ecosystem as a whole is beyond the technological, physical and financial limitations of society. However, the resilience of the processes within the ecosystem can be used to synergize an effect on the system as a whole given proper nurturing and support. The initiation of this process may require establishing a symbiotic relationship between engineered systems and natural infrastructure specifically designed and calibrated to enhance targeted ecosystem processes that will yield exponential response within the ecosystem. The created "cyborg system" serves the greater good of the objective by establishing seeds of stable processes that become the foundation for self-sustaining ecosystem restoration.

This approach is being applied to the restoration of the Grand Lake St. Marys (GLSM) Ecosystem. Nutrient loading from the contributing watershed has created hypertrophic conditions within the 21 square mile lake ecosystem. Radical swings in water clarity and temperature fuel massive blue green algae blooms that create a cascade of impacts to system processes, disrupting biological, chemical, and societal services provided by the lake. The frequency and severity of the blooms indicated the system was on the verge of ecological collapse.

GLSM historically supported 2,500 acres of littoral fringe wetlands that maintained a healthy equilibrium, processing nutrients and providing habitat. Loss of the littoral wetland system through anthropogenic actions and invasive species (carp) stressed the system to the breaking point. As a component of the *Critical Response Actions* and *Conceptual Ecosystem Revitalization Model* established by the *Strategic Plan* for the lakes restoration, a series of Constructed Wetlands (Engineered Ecosystems) were established to address the limiting factors to the restoration of the littoral wetland system by targeting water quality degradation.

These systems remove nutrients via a series of interlinked engineered, bio-technical, and natural treatment systems. Water is pumped through the systems at the rate of several million gallons per day, the water is treated by a series of systems including alum injection, constructed wetlands, and restored naturalized wetlands, prior to being discharged back into the lake through a embayment/constructed littoral wetland. The improvement in water quality provided the conditions needed for natural regeneration of littoral wetlands beyond the influence of the engineered systems. Natural re-establishment of littoral vegetation in the embayment and constructed littoral wetland system provides direct evidence of the effectiveness of this approach.

Bio: Mr. Pfeiffer is a Professional Wetland Scientist (PWS) with 30 years of experience in environmental/engineering planning. His expertise includes watershed planning and ecological restoration, wetland design and construction management. He holds a Master of Arts in physical geography and environmental planning and a Bachelor of Science in natural science.

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BEHAVIOUR OF A TIDAL FLOW CONSTRUCTED WETLAND TREATING LOW-STRENGH SEWAGE

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Tidal-flow constructed wetlands (TFCW) were developed to improve mainly nitrification and removal of organic matter by increasing the oxygenation of the effluent and bed (LI et al., 2015). The oxygen transfer rate can achieve 450 g m^{-2} d^{-1} (WU et al., 2011). However, the efficiency of TN removal is not ideal due to the high oxygen content (JU et al., 2014).

A TFCW was composed of a polypropylene container (working volume 116 L, 0.92 x 0.55 x 0.6 m), influent tank (500 L), effluent tank (50 L), and peristaltic pump controlled by pre-programmed timers. *Althernanthera philoxeroides* macrophytes (31 plants m^{-2}) were planted at the top. Clay bricks were the main medium with the first 45 cm of the bottom with particles of 8.3 x 4.8 cm, followed by 10 cm with particles of 2.4 x 1.4 cm, and 5 cm of expanded clay (above the effluent, porosity 16%). The batch-mode system was operated under flooded (48 h) and drained (12 h, downflow) conditions in the treatment of low-strength sewage.

Samples of the influent and effluent of the system were collected before and after each "tide" cycle once a week. The behavior of the system was assessed by determining temperature (thermometer), pH (4500-H^+ B), dissolved oxygen DO (4500-O B'), oxidation-reduction potential ORP (2580 ORP), chemical oxygen demand COD (5220 D) in raw and filtered samples; Total Kjeldahl Nitrogen TKN (4500-N_{org} macro Kjeldahl), total ammonia nitrogen TAN (4500-NH_3-N C), nitrite (4500-NO_2^- B) and nitrate (4500-NO_3^-dimethylphenol) and total phosphorus TP (4500-P I) in samples of the influent and effluent of the systems, according to APHA (2012) for 41 days (Dec. 7, 2018 to Jan. 17, 2018).

Mean temperatures resulted in 21.25 (1.48) and 21.85 (3.5) °C in the influent and effluent samples (after 48 h), and pH resulted in 7.52 (0.18) and 7.23 (0.14) in the influent and effluent samples (after 48 h), i.e., in the range of 6.50-7.50 considered optimal for the denitrification process by Kadlec; Wallace (2009). An average removal of turbidity of 79% was verified after 48 h for the initial value of 0.34 (0.11) NTU.

Average DO concentration was 0.25 (0.16) mg L^{-1} and 0.18 (0.13) mg L^{-1}, and average ORP was -25 mV and 120 mV in the influent and effluent samples. These values indicate anoxic conditions according to Matos et al. (2010) with OD lower than 2 mg L^{-1} and ORP varying between -100 mV and +100 mV. Average removal efficiencies of COD resulted in 57% and 62% for raw and filtered samples with initial concentrations of 130.50 (62.43) mg L^{-1} and 123.25 (26.08) mg L^{-1}, respectively.

Regarding TKN and TAN, average removal efficiencies were 33% and 41% to the average initial concentrations of 46.44 (10.98) mg L^{-1} and 33.01 (10.16) mg L^{-1}, respectively. These values were lower than those obtained by Li et al. (2015) of 84% to TKN and 82% to TAN in a TFCW stabilized treating synthetic effluent with COD of 204.07 (16.51) mg L^{-1}. Nitrite varied from 0.062 to 0.078 mg L^{-1} and 0.043 to 0.624 mg L^{-1}, and nitrate varied from 8.75 to 16.99 mg L^{-1} and 2.86 to 12.45. mg L^{-1} in the influent and effluent samples. Average removal efficiency of TP was 75% to the initial concentration of 10.09 (2.06) mg L^{-1}, lower than Lima et al. (2018) that obtained efficiency of 82% in a CW operated in batch period of 48 h using the same material as substrate.

BIO: Ph.D. Carvalho is a professor with 15 years of experience planning, designing, and implementing biological processes to treat sanitary sewage and industrial effluents.

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THE ASSESSMENT OF BIODIVERSITY AND THE COMPOSITION OF BIOCENOSIS IN SLUDGE TREATMENT REED BED SYSTEMS

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In 2015, the European Commission adopted a new, ambitious package concerning the transformation of existing activities into circular economy. The main goal of this concept is to minimize the impact on the environmental during creating of products. It requires the reuse of the components and energy (pollutants) emitted to the environment. The Sludge Reed Bed Systems (STRBs) are a good example of the implementation of the circular economy concept in the sewage sludge management. First of all they close the water cycle and change the waste (sewage sludge) into the product (fertilizer). They also protect the environment against the uncontrolled release of nutrients from sewage sludge. Additionally STRBs are the complicated ecosystem that affect biodiversity. The genetic biodiversity as well as the composition of biocenosis can be determined using the metogenic analysis.

Biocenosis of reed systems affecting the processes taking place. It depends on the time of operation, settlement of the bed with reeds, as well as oxygen conditions. Higher biodiversity in reed systems may indicate that they will be more stable and have greater flexibility for changing conditions.
The aim of the work is to determine biodiversity in reed systems and to identify the processes of stabilization and removal of pollutants along the vertical profile, under different conditions based on the metagenomic analysis.

Research was carried out in 3 different beds located in the STRBs located at the Gniewino WWTP. The bed 6 was operated for a period of 7 years. The bed no 3 was not operated due to operation problems and it was very poorly covered with reeds, while the bed no 1 was under development (the operation period was only 1 year). The beds were divided along the vertical profile into 25 cm sections.
Based on the analysis, it was found that the largest biodiversity occurred in the surface layer Fig 1.

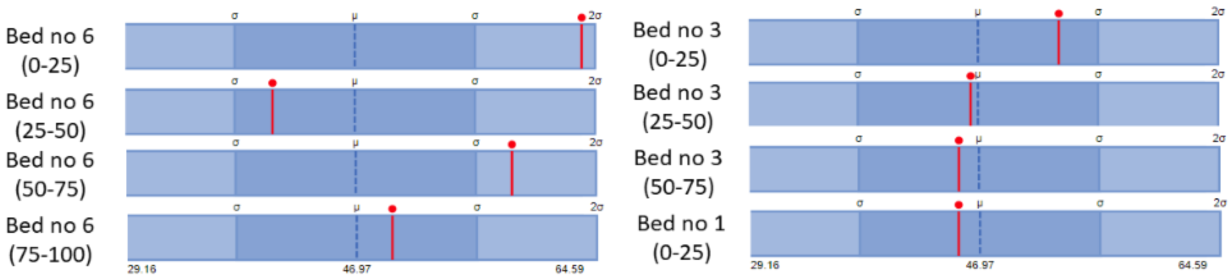

Fig. 1. The biodiversity in sewage sludge from Gniewino STRB

In all the analyzed samples, a significant proportion were microorganisms with an unchanged phylogenetic position. The most numerous were *Bacteroidetes, Firmicutes* and *Proteobacteria*. In all analyzed sludge samples, but less numerous, there were bacteria: *Verrucomicrobia* (3.8 - 6.0%), *Actinobacteria* (0.27 - 7.7%) and *Planctomyctes* (2.1 - 3.3%).

BIO: Dr. Kołecka is an assistant professor, specializing in issues related to the wastewater treatment in natural systems as well as sewage sludge utilization in STRBs (Sludge Treatment Reed Beds). She is also involved in educational activity connected with on-site wastewater treatment plants and quality of water and air.

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APPLICATION OF MULTI-SOIL-LAYERING (MSL) ECOTECHNOLOGY FOR DOMESTIC WASTEWATER TREATMENT IN RURAL AREAS

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Actually, most of rural areas of Morocco are suffering from pollution, and the potential illness caused by untreated wastewater discharged in the environment. Sanitation in this region, where technical and financial resources are usually limited, has a negative impact on the quality of life of the rural population. In order to solve this problem, a number of alternative technologies have been developed as a multi-soil-layering (MSL) system, based on small-scale treatment systems which are adapted to the needs of these areas. Wastewater characteristics and hydraulic loading rate (HLR) are important factors that influence the treatment efficiency of the MSL systems. Therefore, the aim of this study was to evaluate the efficiency of MSL systems to treat rural area wastewater characterized by high concentrations of organic matter (BOD5 and COD) with varying HLRs.

MSL systems were installed at the village Talat Merghen (South of Marrakech, Morocco, +31°33N, -7°94W) in order to treat domestic wastewater of 8 lived houses (72 inhabitants). Three MSL systems were prepared using cylindrical plastic box measuring 65 cm in height and 41 cm in diameter. The MSL systems were composed of local soil mixture layers (SML) and local gravel (3-5 mm) layers that were arranged in a brick-layer like pattern, and this structure keeps the high water permeability and reduces the risk of the system clogging. The MSL comprised sandy soil, charcoal, sawdust and iron on a dry weight ratio of 7:1:1:1. Influent emitter was installed on the top of the system through which the wastewater was discharged into the system. The HLR applied were 1000, 2000 and 4000 L m^{-2} day^{-1} respectively for each MSL pilot. The obtained results showed average reduction efficiency for suspended solids (SS), chemical oxygen demand (COD), total nitrogen (TN) and total phosphorus (TP) of 77-86, 57-78, 51-76, 55-67 and 46-61 %, respectively. The mean removal percentages of SS, BOD5, COD and TP tended to be higher at lower HLRs. An increase in the HLR increased absolute loading rate, i.e. the amount of pollutants loaded to a system per unit time, and reduced the hydraulic retention time in the MSL system, which resulted in the decrease in the removal percentage. However, TN removal was not appreciably influenced by changes in the HLR. Efficiency of the MSL systems in removing TN depends significantly on aerobic and anaerobic conditions in the reactors, which govern nitrification and denitrification. At lower HLR, the system might not be anaerobic enough for denitrification.

Reduction of all pollutants by MSL pilots presented on absolute loading rate, show a satisfactory removal rate. The purification efficiency were 278-1595 g SS m^{-2} day^{-1}, 447-2156 g BOD5 m^{-2} day^{-1}, 612-2823 g COD m^{-2} day^{-1}, 72-293 g TN m^{-2} day^{-1} and 8-32 g TP m^{-2} day^{-1}. To decide a better treatment condition, we have to consider not only removal percentage of pollutants, but also absolute loading rate, clogging and its recovering time and so.

BIO: Mrs. Laila MANDI is a Professor of Water & Environmental Sciences at Cadi Ayyad University (Morocco). She has coordinated several research projects in the field of wastewater treatment using extensive technologies. She has published more than 200 scientific papers. She supervised more than 30 PhD theses.

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PHYTOREMEDIATION OF DOMESTIC WASTEWATER USING A HYBRID CONSTRUCTED WETLAND IN MOUNTAINOUS RURAL AREA

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The purpose of this study is to evaluate the efficiency of a hybrid constructed wetlands (HCW) in a rural mountainous area. The experiment was set up in small rural community named Tidili within the region of Marrakech-Morocco. The wastewater treatment plant (Fig.1) is composed of three vertical flow constructed wetlands (VFCWs) working in parallel, followed by two parallel horizontal-subsurface flow constructed wetlands (HFCWs), with hydraulic loading rate of 0.5 m^3/m^2.d and 0.75 m^3/m^2.d, respectively. The two units were planted with *Phragmites australis* at a density of 4 plants/m^2. Wastewater samples were collected at the inlet of the storage tank and at the outlet of the whole system (VFCWs, HFCWs) stages. The wastewater treatment plant was monitored every 2 weeks during 2 years.

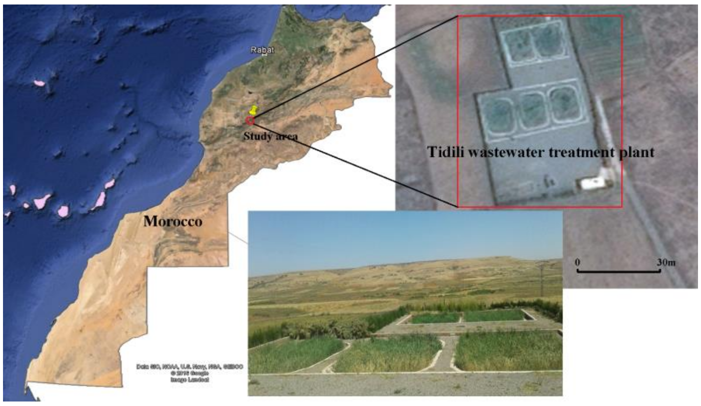

Figure 1: Geographical location of the Tidili wastewater treatment plant

The main removal percentages of TSS, BOD5, COD, total nitrogen, and total phosphorus were respectively 95%, 93%, 91%, 67%, and 62%. The system showed a high capacity to remove total coliforms, fecal coliforms, and fecal streptococci (4.46, 4.31 and 4.10 Log units respectively). The high removal rate of coliforms is probably due to several phenomena such as the physical filtration through the root of *P. australis*, UV action, temperature, oxidation and predation. In addition, the microbial quality obtained by the investigated HCWs met the irrigation standards (<1000 CF/100 ml) during the whole study period. Artificial neural networks (ANNs) were used to model the quality parameters (TSS, BOD5, COD) and coliforms (TC, FS). Based on the obtained results, ANN model could be considered as an efficient tool to predict the studied phytoremediation performances using HCWs. Thus, it can be concluded that hybrid constructed wetlands was proved to be a reliable system for wastewater treatment in the mountainous rural areas.

BIO: Mrs. Laila MANDI is a Professor of Water & Environmental Sciences at Cadi Ayyad University (Morocco). She has coordinated several research projects in the field of wastewater treatment using extensive technologies. She has published more than 200 scientific papers. She supervised more than 30 PhD theses.

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EFFICIENCY OF AMMONIACAL NITROGEN REMOVAL IN WETLANDS

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The constructed wetlands have been recognized as an important alternative for effluent treatment and pos-treatment, and they perform well in the removal of pollutants from effluents, such as nutrients. This treatment system has as main characteristics the ease of implantation and operation and low cost. Hydraulic Holding Time (TDH) is one of the main operating parameters of wetlands, as they guarantee good system performance. In this way TDH has been evaluated in order to evaluate its influence in the removal of important parameters such nutrients. Thus, the objective of this work was to evaluate the post-treatment efficiency of domestic effluent from a real wastewater generation system through a constructed wetland system, as well as to evaluate the influence of different detention times (TDH) on removal of ammoniacal nitrogen. The constructed wetland used consisted of a subsurface horizontal stream containing macrophytes of the *Canna x Generalis* type and substrate of shards of tiles. The experiments considered TDH of 2, 5 and 7 days. According to the results obtained in the present study, the average percentage of removal was 42% with 2 days of detention, 46.7% with 5 days and 49.9% with 7 days of hydraulic detention for ammoniacal nitrogen. The medium nitrogen concentration at the system entrance was 84.9 ± 6.8 mg. L^{-1}, and after 2 days of treatment the concentration decreased to 49.3 ± 6.9 mg. L^{-1}, from 45.3 ± 7.25 mg. L^{-1} after 5 days and to 42.5 ± 6.3 mg. L^{-1} after 7 days of treatment. It should be noted that in wetlands constructed with subsurface horizontal flow, nitrification is generally low, because the process needs available oxygen in the bed, so it would be necessary to increase the aeration of the system to improve the removal of ammoniacal nitrogen. In the literature the average removal of ammoniacal nitrogen in horizontal flow wetlands is approximately 48.4%, so the removal found in the present research is close to the values reported in other studies. The hydraulic detention time showed significant removal efficiency difference for this parameter in the 2, 5 or 7 days of detention, being detected greater removal with longer detention time.

BIO: Dr. Pires has been working has been working with wetlands in real and experimental systems for the removal of parameters for almost 10 years with guidance in the field and experience in the implementation. monitoring and analysis of these sewage treatment systems.

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INFLUENCE OF DIATOM PHOTOSYNTHESIS ON NITROGEN REMOVAL PROCESSES WITHIN A BENTHIC, OPEN WATER WETLAND BIOMAT

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Located in southern California, the Prado Wetlands contain unique open water cells that remove nutrients, trace organics, and pathogens from river water impaired by municipal wastewater effluent. These wetlands are characterized by a shallow water column (< 30 cm), geotextile lined bottom, and absence of macrophytes, selecting for a benthic microbial community that is largely responsible for contaminant attenuation. Phylogenetic inquiry revealed this thick (5 – 15 cm), photosynthetic 'biomat' assemblage to contain diatoms (predominantly *Staurosira construens* var. *venter*) complemented by a diverse array of heterotrophic bacteria. Previous research characterizing nitrogen removal pathways within the biomat demonstrated compelling rates of denitrification with potential contributions from anammox. However, the effect of photosynthesis and respiration on nitrogen biotransformation remains uncertain. The purpose of this study was therefore to explore the temporal and spatial controls on denitrification within the wetland biomat. We hypothesized that denitrification occurs just beneath the zone of photosynthesis and is most pronounced at night, when the distance to the oxic/anoxic interface is minimized.

To this end, we conducted a series of field campaigns to quantify diel shifts in geochemistry and microbial activity at the Prado Wetlands. Biomat porewater was collected using a modified minipoint sampling technique and cores were collected and subsectioned at depths complementary to porewater for genomic (16S rRNA gene and metagenomic/transcriptomic sequencing) and geochemical (carbohydrates) inquiry. Gas fluxes at the air-water interface were measured to better constrain microbial processes.

Benthic diatom photosynthesis causes dramatic oxygen (~100 – 700 uM) and pH (~7.5 – 10) shifts in the water column; however oxygen profiles within the biomat indicate that photosynthesis is limited to the upper ~5 mm. In biomat porewater, nitrate and nitrite are completely attenuated within the upper ~2 cm whereas ammonium concentrations increase significantly with depth. Thermodynamic approximations of denitrification free energies suggest that pH shifts associated with photosynthesis may play a significant role in regulating denitrification activity, and that it is most energetically favorable as pH decreases at night. Gaseous fluxes of nitrous oxide and carbon dioxide, respiratory products of heterotrophic denitrification, also showed pronounced increases at night. Collectively, we conclude that diel shifts associated with photosynthesis and respiration influence the nitrogen removal capacity of shallow, open water wetlands, and that dominant removal pathways (i.e., denitrification) are concentrated within the upper few centimeters of a naturally colonizing, benthic biomat. This work enhances our understanding of the diel dependency of pollutant removal in constructed wetlands and sheds light on how benthic photosynthesis can influence overall denitrification in both engineered and natural systems. Ongoing work aims to explore the effect of diatom-derived carbohydrates on benthic nitrogen biotransformations and the contributions of anammox and dissimilatory nitrate reduction to ammonium (DNRA) processes to bulk nitrogen cycling in this unique wetland biomat.

BIO: Michael Vega is a PhD student at CSM focusing on nitrogen biogeochemistry in open water treatment wetlands. More broadly, he is interested in how microbiology influences the elemental cycling of nutrients and metal(loid)s in both engineered and natural environments.

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CONSTRUCTED WETLAND FOR WINERY WASTEWATER TREATMENT AND IRRIGATION REUSE

Salvatore Barbagallo[1], *Cinzia Caggia*[1], *Alessia Marzo*[2], ***Mirco Milani***[1], *Alessandra Pino*[1], *Cinzia Randazzo*[1] *and Giuseppe Luigi Cirelli*[1]

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Objectives

In this paper the results of experimental activity carried out in a multistage constructed wetland (CW) sited in Italy are presented. The aims of this study was to increase the knowledge on the performance of CWs for treatment of winery wastewater and explore their potential for irrigation reuse.

Methods

The research activity was carried out in a multistage pilot-scale CW, treating part of winery wastewater produced by a farm (i.e. production capacity of about 1,500 hL wine year^{-1}) located in South East Sicily. At the farm, winery wastewater, after a preliminary treatment consists in a coarse screening, is treated by a Imhoff tank and about 3 m^3 day^{-1} of Imhoff effluent are stored in a equalization tank (5 m^3) and treated with a multistage CW. The CW has a total surface area of about 230 m^2 and is made of a vertical subsurface flow (VF) bed, followed by a horizontal subsurface flow (HF) bed and then by a free water (FW) system. The end of the FW section operates as a subsurface flow and it was vegetated with *Iris pseudacorus*. The CW system was planted with *Phragmites australis* (HF), *Cyperus Papirus* var. *siculus* and *Canna indica* (VF), *Nymphaea alba* and *Scirpus lacustris* (FW). The CW effluent is reused for irrigation of a green area close to the experimental plant. Wastewater quality samples were collected, for a four years, at the inlet and outlet of each stage of the treatment system and chemical-physical and microbiological characteristics of wastewater were analysed. CW efficiency was evaluated both in terms of water quality improvement (removal percentage) and achievement of the Italian wastewater discharge and irrigation reuse limits.

Results

The multistage pilot-scale CW exhibited a strong buffer capacity, that was able to mitigate the wide fluctuations of influent quality characteristics. For TSS, COD and BOD_5 concentrations, the CW system had a mean removal efficiencies of about 67%, 75% and 78%, respectively. During the observation period the *E. coli* concentration in the CW influent showed an average value of about 4.3 Ulog CFU 100 mL^{-1} with a decrease of about 1.0 log unit in each treatment stage. The experimental plant, during the monitoring period, has shown an effluent average quality compatible with the limits required by the Italian law for wastewater discharge in water bodies and for wastewater reuse. The *E.coli* concentrations in the CW effluent meeting also the limit proposed by EU for agricultural reuse of reclaimed water in food crops consumed raw.

In conclusion, the results confirm the high potential of CWs for the wastewater winery treatment in small wineries also aimed to the use of reclaimed water for irrigation, especially in arid and semi-arid areas.

BIO: Dr. Milani has more than 15 years of experience in natural treatment systems and use of reclaimed water. He has collaborate in design and management of constructed wetland for small urban communities and isolated settlements (touristic resort, winery, commercial store, etc.).

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FEEDBACK LOOP OF GROWTH AND SENESCENT OF MACROPHYTES ON NUTRIENT DYNAMICS IN CONSTRUCTED WETLANDS

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Constructed wetland (CW) is a green bioreactor and important component of water sensitive urban design approach in Australia to control stormwater nutrients and safeguard downstream sensitive aquatic environment. Among different components of CW, macrophytes can uptake or accumulate nutrients in their above ground biomass i.e., leaves and shoots and below ground biomass i.e., roots and rhizospheres, and therefore, attention is usually higher in vegetated CWs than non-vegetated CWs. However, it is challenging to assess nutrient processing of macrophytes because of their inter-specific completion for nutrients, spatial heterogeneity in biomass and seasonal senescence pattern. This research provides feedback on how macrophytes heterogeneity and inter-specific competition affects nutrients dynamics in stormwater treating CWs in Western Australia. Among different species, *Baumea articulata, B. rubiginosa, B. preissii, Carex appressa, Juncus kraussii, Schoenoplectus validus* and *Typha domingensis* are most widely present in the CWs. However, *B. articulata* stored about 2-3 and 1.5-2 times higher total nitrogen and total phosphorus pools, respectively than that stored in other species, indicating inter-specific competition of nutrient among macrophytes. Below ground biomass showed up to 25 times higher nutrient storage than that in above ground biomass. However, annual macrophytes senescence during low flow and dry summer time caused dead plants to cover the water channel, hindering light penetration into the water column and lowering dissolved oxygen concentrations. Therefore, available anoxic water might trigger denitrification process, while senescent macrophytes can release some stored nutrient to the system or transmit to other pools and convert the system temporarily as a "nutrient source" rather "nutrient sink".

BIO: Dr. Tanveer M. Adyel is a Lecturer of Water Engineering with particular interest integrated multi-functional urban water system for future city.

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EFFECTS OF DISTURBANCES ON MICROBIAL COMMUNITY DYNAMICS AND GREENHOUSE GAS EMISSIONS IN WETLANDS

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Microbial communities play an essential role in all major nutrient cycles on earth. In wetlands, microbes in sediments play an important role in the carbon and nitrogen cycle. In these nutrient cycles, CO_2, CH_4 and N_2O are produced, which are all important greenhouse gasses. How disturbances of wetlands, such as drainage ditches, affect emissions of these gasses is not well known.

One common disturbance is dredging, in which the upper layer of the sediment is removed to reduce nutrient loading. Dredging is a pulse disturbance that completely removes part of the microbial community. Understanding the effect of dredging has both fundamental and applied purposes. How the community develops after dredging, especially from a functional and successional perspective, is not well known. Furthermore, how community changes affect greenhouse gas emissions is also uncertain. Therefore, this project aims to study the effect of dredging on microbial community dynamics and subsequent greenhouse gas emissions.

The first part of the project is a review, in which functional traits of microorganisms are summarized and techniques are proposed to measure functional traits in further experiments. Then, experiments will be setup, both in the field and in mesocosms. In these experiments, dredging will be simulated and the effect on both the microbial community and emissions will be measured. Last, the results will be incorporated into a model, to study the effects of alternative dredging regimes. These results will provide insight into the effect of disturbances on microbial community dynamics and greenhouse gas emissions from wetlands.

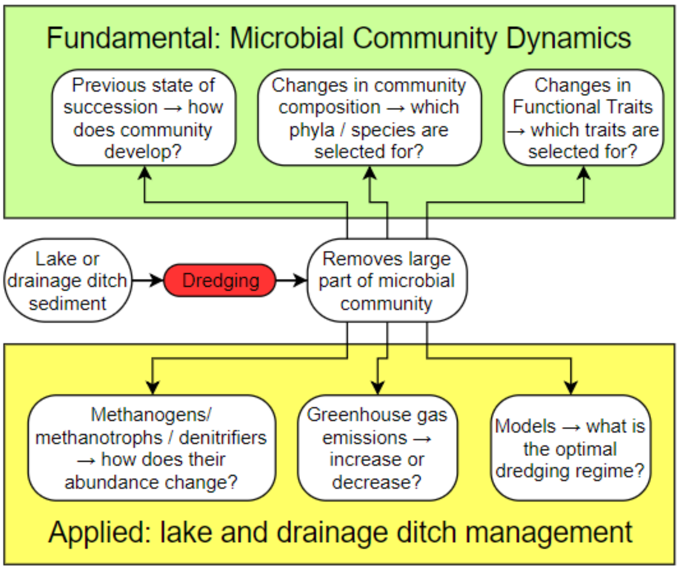

Figure 1: the fundamental and applied aspects of studying dredging in lake or drainage ditch sediments

BIO: Thomas Nijman is a recently started PhD candidate with a background in microbial and plant community ecology. Since July 2018 he has started a PhD project focused on biogeochemistry and microbial community ecology of wetlands.

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DIVERSITY OF MACRO-INVERTEBRATES ASSOCIATED TO ECHINOCHLOA PYRAMIDALIS (LAM.) HITCHC. & CHASE (1917) IN CONSTRUCTED WETLANDS OF BIYEM-ASSI (YAOUNDE-CAMEROON)

Thérèse Line Laure Jokam Nenkam[1,3], *Joceline Momo*[1,3], *Sévilor Kekenou*[2] *and Ives Magloire Kengne*[3]
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From January to July 2014, investigations were carried out in the wastewater treatment plant (WWTP) of Biyem-assi with the aim of studying the diversity of macro-invertebrates associated with *E. pyramidalis* as well as the purification performance of the system. The methodology consisted of monthly catches of macro-invertebrates on planted bed of *E. pyramidalis* and their identification, concomitantly with the collection of wastewater at the entry and the exit of the system, followed by their physico-chemical characterization in the laboratory using standard protocols.

A total of 507 invertebrates were identified, divided into two branches; Arthropods (88.13%) and Molluscs (11.87%). The value of Shannon Index (46) shows that the diversity was low and Piélou equitability index is 0.59. The family Formicidae (22.9%) is the main family of macro-invertebrates find on *E. pyramidalis,* followed Lymnaedae (11.4%), Chrysomelidae (9.4%) Chelodesmidae (9,4%) Lygaeidae (6.4%) and Forficulidae (3.5%). they all represent the ravagers of the plants which could affect the purification performance of *E. pyramidalis.*
The physicochemical analyses have shown that the average concentrations of the tributary and the effluent of the system are respectively of the order of 668 ± 115.17 and 44.25 ± 12.95 mg / l for the TSS; 50.23 ± 28.02 and 12.29 ± 5.68 mg / l for NO_3^-; 84.66 ± 47.24 and 24.12 ± 12.87 mg / l for PO_4^{3-}; 1040.25 ± 154.80 and 347.5 ± 86.38 mg / l for COD; 457.5 ± 65.51 and 27.5 ± 15 mg / l for BOD_5. The pollution abatement rate is estimated at 96.44% (TSS); 86.84% (NO_3^-); 84.68% (PO_4^-); 82.04% (COD); 93.53% (BOD_5). However, the values at the exit point remain higher than the standards of rejection suggested by the Ministry of the Environment and the Protection of the nature for the Sustainable Development of Cameroon. This result could be, among other things, the consequence of the attacks of the purifying plant by the invasive macro-invertebrates that invaded the area.

Table I: Biocenotic index

Diversity index	**WWTP**	**Natural environment**
Family richness	46	54
H’ Shannon and Weaver	2.28	3.27
Equitability J’ of Piélou	0.59	0.81

BIO: Thérèse Line Laure Jokam Nenkam is a PhD student at the University of Yaoundé I, Cameroon. She conducted her master thesis in the constructed wetland systems used for the treatment of household wastewater in the city of Yaoundé. Studying their purification performance and insect attacks of plants.

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PERFORMANCE OF PILOT-SCALE VERTICAL CONSTRUCTED WETLANDS FOR REMOVAL OF PATHOGENIC PARASITES FROM FAECAL SLUDGE UNDER TROPICAL CLIMATE

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In tropical region, where most of the developing countries are located, septic tanks and other on-site sanitation systems are the predominant form of storage and pre-treatment of excreta and wastewater, generating fecal sludge. The fecal sludge is disposed-of untreated, mainly due to lack of affordable treatment options. The use of planted drying beds for fecal sludge dewatering shows great potential to reduce the current negative health impacts of fecal sludge being dumped untreated into the environment.

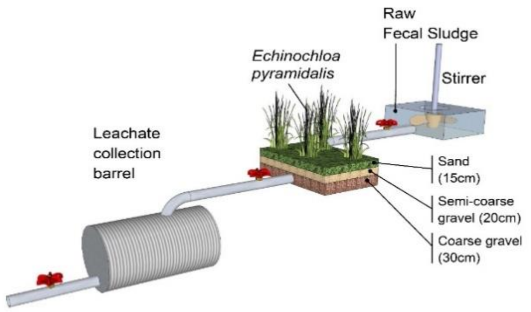

Figure 1. Schematic design of the dewatering facility used.

The aim of this research was to investigate the effect of retention times on the removal of intestinal helminth eggs by planted drying beds for fecal sludge dewatering. The experiment were conducted in pilot-scale planted drying beds located at the University of Yaounde I (Cameroon) (Figure 1). Before application of fecal sludge on the bed units, the physico-chemical parameters (NH4+, DM and pH) know to affect the helminth eggs composition of the sludge were analysed. For each application, raw faecal sludge and leachates from each bed units were collected and analysed as outline in standard methods for the examination of water and wastewater. Parasitological (helminth eggs) parameters were determined in the incoming sludge and outlet leachates in function of the retention times tested (free flow, 7 days and 14 days).

The parasitological quality of biosolids accumulated on the top of the beds were also analyzed. The system performances were assessed for each parameters tested by comparing average values of inputs (raw sludge) and outputs (effluents) for each retention time (free flow, 7 days and 14 days). Removal efficiencies were expressed in terms of percentage concentration reduction and were calculated taking into consideration the inflow and outflow loads. Results shown that the recorded median concentrations of fecal sludge were in the order of 10.30 %, 0.25 g/L and 7.89 respectively for the dry matters (DM), ammoniacal nitrogen (NH4+) and pH. The pathogen analysis of the fecal sludge applied on the beds revealed the presence of high parasitic loads. Indeed, an average total median number of 62.51 helminth eggs/g of DM were obtained. Among these totals, seven main species of helminth eggs were identified. These species included Ascaris lumbricoides, Enterobius vermicularis, Strongyloides stercolaris, Trichuris trichiura, Schistosoma mansoni, Hymenolepis nana and Fasciola hepatica with respective concentrations of 28.95 eggs/g of DM, 18.06 eggs/g of DM, 22.68 eggs/g of DM, 16.18 eggs/g of DM, 9.96 eggs/g of DM, 9.59 eggs/g of DM and 35.88 eggs/g of DM. Biosolids removed on the beds revealed high concentration of helminth eggs almost belong to the class Nematoda, with Ascaris lumbricoides which are the most common species investigated (80%). The physico-chemical removal efficiencies of planted drying beds ranged from 75 to 97% for dry matters (DM) and from 79 to 96% for the removal of NH4+. The removal efficiencies of helminth eggs ranged from 70 to 100% independent of the retention times tested. This study confirmed the effect of constructed wetlands for pathogen reduction. However, the hygienic quality of accumulated faecal sludge on the surface of the bed units need to be addressed for further treatment like composting before safe reuse in agriculture.

BIO : Dr. Wilfried Arsène Letah Nzouebet is a junior scientist with 6 years of experience in the use of constructed wetland for fecal sludge pollution control.

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AUTHOR INDEX

Bolded names represent presenting author or poster

A

B

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

X

Y

Z

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