DWF

Danish Water Forum

16th DWF WATER RESEARCH CONFERENCE
20th April 2022

Technical Abstracts and timetables

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Corporation partner:

2022

Danish Water Forum
Agern Alle 5, 2970 Hørsholm, Denmark.
www.danishwaterforum.dk, dwf@danishwaterforum.dk

OPENING SESSION,

OPENING SESSION, 20 April 09:45-12:25 (All time slots given in the program are CET)
THEME: Water at the crossroad
Auditory 1.
Moderator and Chair: Bjørn K. Jensen, Vice chairman, Danish Water Forum

09:45 Welcome, by Hans-Martin Friis Møller, Chairman, Danish Water Forum
09:55 Logistics, by Jesper Dannisøe, Director, Danish Water Forum
10:00 Water Valley Denmark; A new concept! Ulla Sparre, Director
10:15 The Strategic Sector Corporation Water Programs; Aims and opportunities for Danish Water Stakeholders. Tobias Kvorning, Danish EPA
10:30 DI Water: looking towards 2030! Mads H. Dorff, director
10.45 Central Jutland Commercial lighthouse initiative on water, based on REACT funding. Program leder Thomas Mikkelsen, CLEAN
11:00 Q&A and Break
11:25 The value of attending large-scale water events! Ilse Korsvang, Dansk Export.
11:45 Water Technology Alliance in Europe. Jakob Andersen, Consulate General, Hamburg.
12:05 Water4All, partnership for research and innovation on water in Horizon Europe. Bjørn K. Jensen, DWF.
12:25 Lunch break

NO ABSTRACTS FOR THIS SESSION

Technical sessions:

Session	Title	Chair and co-chair	Where??
Session 1: 13:00 – 15:00	Advances in wastewater treatment; New approaches and techniques. Part 1	Hans-Martin Friis Møller, Danish Water Forum and Kalundborg Forsyning,	**Auditory 1**
Session 2: 15.15 – 17.15	Advances in wastewater treatment; New approaches and techniques. Part 2	Hans-Martin Friis Møller, Danish Water Forum and Kalundborg Forsyning,	**Auditory 1**
Session 3: 13:00-15:00	Drinking water; challenges and solutions	Hans-Jørgen Albrechtsen, DTU Envir. and Torben Lund Skovhus, Via University College	**Auditory 2**
Session 4: 15:15-17:15	Urban water and Climate change	Ole Mark, Krüger	**Auditory 2**
Session 5 13:00 – 15:00	The export strategy for SME's (IN DANISH)	Bjørn K. Jensen, Danish Water and Jesper Goodley Dannisøe, DWF secretariat.	**Room 1**
Session 6: 15.15 – 17.15	Ground water resources and management	Anders Refsgaard, COWI, Anders Bækgaard, IWA Congress President	**Room 1**
Session 7: 13:00-15:00	The Neptun project: Interactive session on Water Climate challenges across the Danish – German border; An interactive session	Lotte L. Andersen, CLEAN	**Room 2**
Session 8: 15.15 – 17.15	Start-ups in water – a way to drive innovation in the sector; An interactive session	Inês Breda, Moderator, Young Water Professionals Denmark	**Room 2**

After the sessions (approx 17:15), you are invited to drinks, snacks and mingling, followed by the nomination for the NIRAS and Grundfos awards.

It is possible to sign up for a post-conference dinner. See conditions in the registration at www.danishwaterforum.dk

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Registration fee incl lunch, breaks, snack, drinks (ex. VAT):

- Students: 400 DKK
- Members of DWF and CLEAN: 800 DKK
- Non-members: 1.200 DKK

The conference does NOT offer online access to the sessions.

Session 1 and 2: Advances in wastewater treatment; New approaches and techniques.

Time: 13:00 – 15:00 and 15:15 – 17:15
Chair: Hans-Martin Friis Møller, Chairman of DWF, Director of Kalundborg Utility
Auditory 1

Time	Speaker	Topic
SESSION 1: 13.00 – 15.00		
13.00	Xavier Flores Alsina	Plant-wide assessment of alternative activated sludge configurations for biological nutrient removal under uncertain influent characteristics
13.15	Vasileios Chrysochoidis	Impact of gas transfer models on the prediction of N2O emissions during wastewater treatment operations
13.30	Morten Haugaard Nielsen	A novel membrane process to achieve zero liquid discharge in desalination and wastewater treatment
13.45	Borja Valverde Pérez	Membrane-aerated biofilm reactors (MABRs) for high-rate nitrification: potential benefits of intermittent aeration
14.00	Guochen Wang	Efficient removal of micropollutants in an anaerobic-aerobic two-stage moving bed biofilm reactor coupling with manganese redox cycling
14.15	Adam Kovalovszki	Strategic food waste disposal to improve the C:N ratio and process economy within Danish wastewater treatment plants
14.30	Carlos A. Ramírez-Vargas	Assessment of real-scale Microbial electrochemical assisted treatment wetlands (METland) for wastewater treatment
14.45	Lasse Ahrenkiel Thyssen	Bacterial community structure and degradation kinetics in relation to cyanotoxin bioremediation in constructed wetland mesocosms
SESSION 2: 15.15 – 17.15		
15.15	Henrik Rasmus Andersen	Offshore biological treatment of oil and gas produced water
15.30	Bastian Kirkebæk	Magnetic micro vehicles to pickup small oil droplets from water
15.45	Adisak Manaying	Minimization of plastic emissions from WWTP through development of biodegradable flocculants
16.00	Christian Lunøe Holmboe	Long-term model based evaluation of flexible Model Predictive Control in Kolding WRRF
16.15	**DISCUSSIONS**	
16.30	Ravi Kumar Chhetri	Disinfection of antibiotics resistant bacteria from wastewater at the hospital
16.45	Kai Bester	The CW Pharma 2 monitoring of Danish Wastewater Treatment plants and implications for advanced treatment for Pharmaceuticals
17.00	Vaidotas Kisielius	Predicted no-effect concentration (PNEC) – based design for removal of pharmaceuticals in wastewater treatment plant

Plant-wide assessment of alternative activated sludge configurations for biological nutrient removal under uncertain influent characteristics

Elham Ramin, **Xavier Flores-Alsina***, Chris Gaszynski**, Theo Harding**, David Ikumi**, Chris Brouckaert***, Barbara Brouckaert***, David Modiri****, Resul Al*, Gürkan Sin*, Krist V. Gernaey**

Abstract

In this study, we present a plant-wide model-based assessment of four alternative activated sludge (AS) configurations under uncertain influent loads and characteristics at Zeekoegat wastewater treatment plant (WWTP) in South Africa. The results provide the basis for effective identification of flexible and robust configurations for biological nutrient removal systems subject to influent uncertainty/variations. The study is framed on the ERASE (Evaluation of Resource recovery Alternatives in South african water treatment systEms) project funded by Danida Fellowship Center

Introduction: The significant advances in wastewater treatment using nitrification-denitrification activated sludge (AS) systems with enhanced biological phosphorus (P) removal have led to the development of complex mathematical models. The most recent developments include an adequate description of physico-chemical processes involved in multi-phase P transformations, which have resulted in a dramatic increase in the number of components and processes in the models. Global sensitivity analysis (GSA) is an effective tool in assessing significance of model input uncertainty on the overall performance. This study is the first attempt in performing GSA of a plant-wide model using the most recent extended ASM and ADM model version to evaluate the robustness of various AS configurations under influent uncertainty.

Methods and data: Zeekoegat wastewater treatment plant (WWTP) has a unique design enabling operation in four different AS configurations: 3-stage Bardenpho (A2O), University of Cape Town (UCT), UCT modified (UCTM), and Johannesburg (JHB). The model was calibrated against historical data (2015-2016). A metamodeling based GSA (200 runs using a trained surrogate model based on 500 Monte-Carlo simulations) on a steady-state plant-wide simulation model was performed using Activated Sludge Model No. 2d with the latest extension of physico-chemical processes describing the plant-wide P transformations. Moreover, we performed a Monte-Carlo based scenario analysis to evaluate the performance of different AS configurations for a range of SRTs (<50 days) under influent load variation.

Results: GSA results (individual effects and interactions)—shown in Figure 1a –reveal that, when the plant is run under design COD load, process configurations affect parameter ranking for effluent phosphate, sludge disposal and methane production. Based on the scenario analysis (Figure 1b), A2O and JHB configurations (left and right graphs) require adjustment of SRT within a wider range depending on the load factor to ensure P removal, whereas UCT and UCTM have a narrower SRT range. This gives an operational flexibility to UCT and UCTM under uncertain influent load.

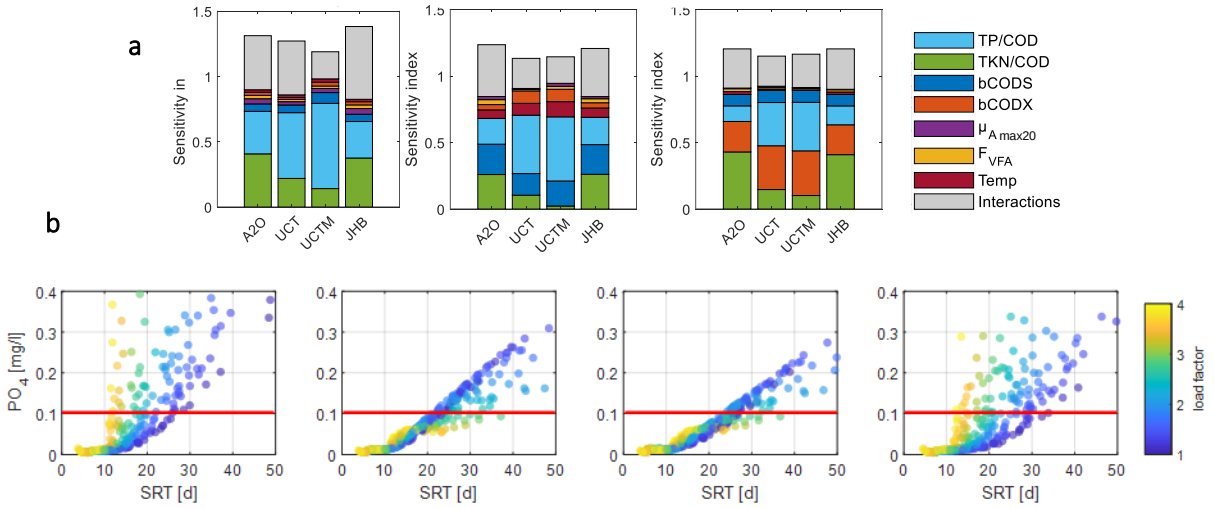

Figure 1 GSA results under design load (a) for phosphate (a, left), sludge disposal (a, middle) and methane production (a, right). Result of scenario analysis for effluent P (b) using A2O (left), UCT (middle left), UCTM (middle right) and JHB (right).

Discussion and take-home message:

This study shows that UCT and UCTM configurations result in a more robust plant-wide performance under influent uncertainty, particularly for P removal, sludge disposal and methane production, at the expense of lower denitrification potential as most of the substrate is used for P removal. The results also revealed the operational flexibility of UCT and UCTM in adjusting the balanced SRT under uncertain influent load.

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Impact of gas transfer models on the prediction of N_2O emissions during wastewater treatment operations

Vasileios Chrysochoidis*, M.H. Andersen**, E.U. Remigi***, C. Domingo-Félez*, B.F. Smets*, B. Valverde-Pérez**

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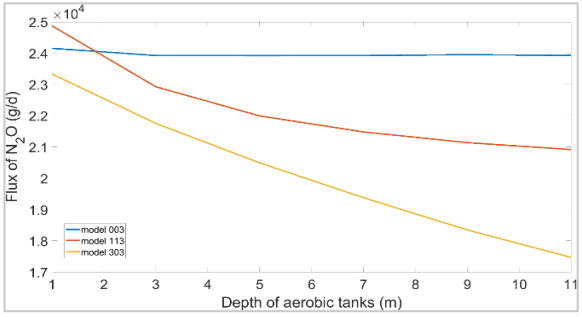
The main goal of this study is to compare the effect of different gas-liquid mass transfer models on estimated N_2O emissions under varying design and operational conditions applied to conventional activated sludge processes. The emission rates of N_2O, the overall mass transfer coefficient for N_2O and the mass transfer coefficient for O_2 are compared across three different mass transfer models (Fig. 1a). The ASM2d-NDHA is used to describe the three pathways responsible for N_2O production during nitrification and denitrification and BSM1 is used as plant model. The model is implemented in WEST (DHI, Denmark). Most of the N_2O emissions occur from the aerobic tanks at low DO concentrations with peak emissions when DO is at 0.6 g/m^3. At this concentration, the largest differences between the three models are observed. Variations in tanks depth result in different N_2O emissions by each model (Fig. 1b). Models 113 and 303, compared to model 003, predict lower emissions of N_2O from deeper tanks due to more efficient aeration as air bubbles have longer contact time with the bulk liquid. Coupled with the tank depth is also the pressure inside the aerobic tanks, which gradient from bottom to top increases with depth. Higher pressure leads to higher solubility of N_2O inside the bulk liquid. By assuming a mean pressure value inside the aerobic tanks, model 303 predicts even lower N_2O emissions compared to the other two models, which use a constant pressure independent of the tank depth. It is shown that modeling aeration rate based on aeration efficiency (i.e., modeling the alpha factor) is an important condition contributing to the accuracy of the selected mass transfer model. Good aeration efficiency (i.e., high alpha factor) leads to lower airflow rate in the aerobic tanks, which results in lower N_2O emissions. Models 113 and 303 adjust their emissions predictions based on the airflow rate unlike model 003. The importance of this phenomenon is highlighted in carbon footprint contributions (Fig.1c), as the difference in predictions between the models can increase by 13% and 9% from low to high-end typical values for the alpha factor. Therefore, it is crucial to use the right mass transfer model to estimate emissions based on soluble N_2O measurements and air flowrates to accurately estimate the c-footprint of WRRFs.

Models	Emission rate of N_2O in aerobic tanks [g N_2O-N m^{-3} d^{-1}]	K_La of N_2O [d^{-1}]	Mass transfer of O_2
Model 003	Model 0 - - $R_{N2O}^{aer} = K_La_{N2O}^{aer}\left(S_{N2O} - S_{N2O_{eq}}\right)$	Model - 0 - $K_La_{N2O}^{aer} = KLa_{O2}\left(\frac{D_{N2O}}{D_{O2}}\right)^{0.5} * 1.024^{T-20}$ (Higbie, 1935)	Model - - 3 $KLa_{O2} = \frac{\alpha p_{atm}^{G} Q_A}{A\left(p_{atm}^{G} + \frac{\rho g H}{2}\right)}$ (van der Lans, 2000)
Model 113	Model 1 - - $R_{N_2O}^{aer} = h_{N_2O} S_{N_2O}\left[1 - \exp\left(\frac{-K_La_{N2O}^{aer} v_R}{h_{N_2O} Q_A}\right)\right]\left(\frac{Q_A}{v_R}\right)$ (Baresel et al., 2016; Schulthess and Gujer, 1996; Sin and Chen, 2016)	Model - 1 - $K_La_{N2O}^{aer} = \left(\frac{d_R}{d_L = 0.815}\right)^{-0.49} * 34500\left(\frac{Q_A}{A}\right)^{0.86} * 1.024^{T-20}$ (Baresel et al., 2016; Foley et al., 2010; Marques et al., 2016)	$R_0^{aer} = Kla_{O2}(beta * S_{O2eq} - S_{O2})$
Model 303	Model 3 - - $R_{N2O}^{aer} = K_La_{N2O}^{aer} AH\left[\frac{S_{N2O} - \frac{h_{N2O}\left(p_{atm}^{G} + \frac{\rho g H}{2}\right) M_{N2O}}{RT} x_{in,N2O}^{G}}{1 + \frac{K_La_{N2O}^{aer} AH h_{N2O}\left(p_{atm}^{G} + \frac{\rho g H}{2}\right)}{2 p_{atm}^{G} Q_A^{G}}}\right]$ (Baeten et al., 2020)	Model - 0 - $K_La_{N2O}^{aer} = KLa_{O2}\left(\frac{D_{N2O}}{D_{O2}}\right)^{0.5} * 1.024^{T-20}$ (Higbie, 1935)	

Figure 1. A) Table summarizing the modeling approaches; b) N_2O emissions as function of tank depth with the three model approaches; c) carbon footprint difference comparing different modeling approaches for different aeration efficiencies (alpha factors) at DO 0.6 mg/L and depth 5m.



Carbon footprint contribution difference		
Model Comparison	alpha factor = 0.6	alpha factor = 1.2
Model 003/113	+9.09%	+22.92%
Model 003/303	+15.70%	+25.00%
Model 113/303	+7.00%	+3.00%

*DO = 0.6 g/m^3

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A novel membrane process to achieve zero liquid discharge in desalination and wastewater treatment

***Morten H. Nielsen**, S.L. Hansen, A. Ali[*], Chemistry and Bioscience, AAU*

Introduction: Zero liquid discharge is a wastewater management strategy where all the water is recovered and the contaminants are left behind in solid form. Percrystallization is a novel membrane process to achieve this ambitious goal where saline solution permeates through a membrane at the same rate as solvent evaporates from the surface of said membrane. As the concentration of ions increases on the permeate side of the membrane crystals eventually precipitate. This process is unique as dry crystals and distilled water are continuously produced within a single process.

Methods and data: The current study aims at developing the percrystallization process with specific focus on the membranes. Various commercially available membranes (polymeric and ceramic) were modified to make them suitable for percrystallization process. The performance of the modified membrane for percrystallization applications was tested by using NaCl and CuSO4 salt solutions as function of operative variables including temperature, concentrations of the feed solution, and degree of vacuum. Throughout the process, the surface of the membrane was recorded to monitor crystallization phenomena at the membrane surface.

Results: Percrystallization of NaCl and $CuSO_4$ was successfully achieved with hollow fiber polymeric as well as tubular ceramic membranes (see figures below). However, it was observed that the stability of the process was more difficult to maintain when hollow fiber polymeric membranes were applied. Ceramic membranes, on the other hand, continuously generated solid crystals under various operative conditions and initial feed concentrations. The formed crystals continuously detached from the membrane surface and were collected inside the shell of the module.

Discussion and take-home message: Polymeric and ceramic membranes were successfully developed to achieve zero liquid discharge in a single step through Percrystallization. The process continuously produced crystals from solutions with different solutes, initial concentrations and while operating the process under various conditions. Further studies to analyze the long-term performance of the process, and to evaluate and compare it with other processes are on the way.

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Membrane-aerated biofilm reactors (MABRs) for high-rate nitrification: potential benefits of intermittent aeration

T. Elad, **Borja Valverde-Pérez**, B.F. Smets, DTU Environment*

Introduction: Membrane-aerated biofilm reactors (MABRs) are receiving large attention in the wastewater management community in the context of nitrogen removal, including in Denmark. MABRs allow for a resource-efficient aeration, as oxygen is delivered to the liquid phase by means of a gas-permeable hydrophobic membrane, on which a biofilm grows directly. In previous studies, we have shown that intermittent aeration can mitigate nitrous oxide (N_2O) emissions and suppress nitrite-oxidizing bacteria (NOB) in both a sequencing batch reactor and an MABR fed with synthetic reject water. In this work, we have studied the effect of intermittent aeration on the performance of MABRs under mainstream conditions with regard to nitrification rate, N_2O emissions, NOB suppression, and the biodegradation of trace organic compounds (TOrCs).

Methods: We operated three laboratory-scale MABRs. One MABR was continuously aerated, while the other two were intermittently aerated with an 8-h cycle (4-h air on/4-h air off) or a 0,5 h cycle (0,25-h air on/0,25-h air off). The MABRs were equipped with a flat-sheet membrane and supplied with a synthetic feed containing 50 mg/L of NH_3-N at a loading rate of 5-7,5 gN/d/m^2. Nitrogen species in the effluent were regularly monitored. N_2O was measured in both the effluent and the off-gas at steady state. Batch experiments were conducted to determine the biodegradation rates of selected TOrCs (pharmaceuticals).

Results: The nitrification rates in all MABRs were comparable to one another, ranging between 2-4 gN/d/m^2 (Figure 1). N_2O emissions were highest in the continuously aerated MABR (1,8% of the N load) and lowest in the intermittently aerated MABR with the 0,5 h cycle (1,1% of the N load). The latter bioreactor also showed faster degradation of specific organic micropollutants, namely atenolol, benzotriazole, and venlafaxine. NOB suppression was not observed in any of the bioreactors.

Discussion and take-home message: We find that intermittent aeration has the potential to increase the oxygen transfer efficiency, reduce N_2O emissions, and improve TOrC biodegradation in nitrifying MABRs. NOB were not suppressed, which may suggest a trade-off between the ammonia removal rate and the nitritation efficiency.

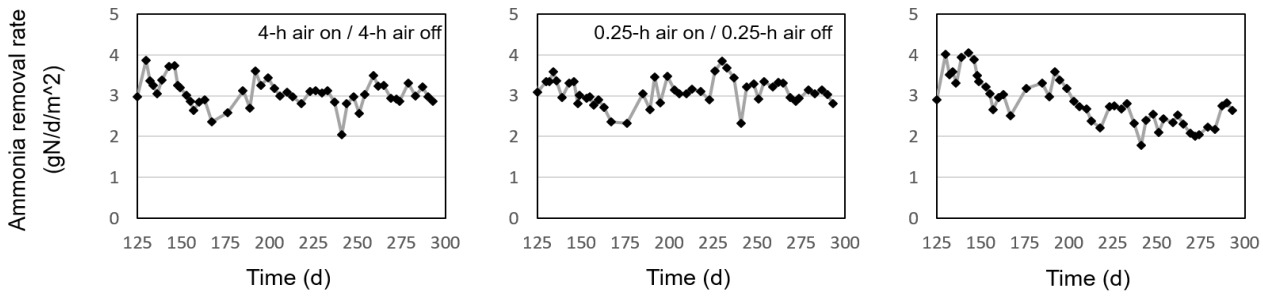

Figure 1. Intermittent aeration can increase the oxygen transfer efficiency. The two intermittently aerated MABRs were provided with half of the air compared to the continuously aerated MABR with the nitrification rate unaffected.

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Efficient removal of micropollutants in an anaerobic-aerobic two-stage moving bed biofilm reactor coupling with manganese redox cycling

***Guochen Wang**, Kai Tang, Henrik R. Andersen , DTU Environment**

Manganese oxides can degrade organic micropollutants, but the effectiveness is short-lived and therefore continuous micropollutant degradation by manganese oxides is not feasible. In this study, an engineered cycle of manganese reduction followed by oxidation was implemented in two-stage moving bed biofilm reactors (staged MBBR), aiming to continuously replenish manganese oxides for the removal of both nutrients and micropollutants. In the anaerobic reactor, additional MnO_2 was reduced to Mn^{2+} by microbial-mediated reaction with organic matter in the sewage. Then, the reduced Mn^{2+} was re-oxidised to biogenic manganese oxides (BioMnOx) in the aerobic reactor. Regularly a part of BioMnOx was recycled to the anaerobic reactor for the next round of manganese reduction. Overall, the manganese redox cycling functioned well and BioMnOx was continuously reformed in the aerobic reactor. For micropollutant removal, bezafibrate, clarithromycin, mefenamic acid and sulfamethoxazole were efficiently removed (over 80%) by the staged MBBR in the batch experiment.

Introduction

In this study, we proposed an anaerobic-aerobic two-stage treatment system using MBBR reactors (staged MBBR) coupling with manganese redox cycling for efficient removal of both nutrients and micropollutants. The aims of this work are: 1) to test the practical feasibility of engineering manganese redox cycle in a wastewater treatment system; 2) to investigate the coupling effect of BioMnOx and suspended biofilm for the removal of nutrients and micropollutant.

Methods and Methods

This study includes an anaerobic reactor (5L) and an aerobic reactor (3L) with 250 K5 carriers each. As shown in Fig. 1.1, manganese redox cycling was inside the staged MBBR by performing manganese reduction in the anaerobic reactor and manganese oxidation in the aerobic reactor. The performance of manganese redox cycling in the staged MBBR was examined after 30 days stable operation. Furthermore, micropollutant spiking experiments were conducted in the batch mode to evaluate the removal capacity of the staged MBBR towards four selected micropollutants.

Results:

Manganese redox cycling functioned well in the staged MBBR, and other nutrients including COD and ammonia were also efficiently removed (over 90%) in the staged MBBR during the continuous operation.

Four selected micropollutants were efficiently removed (over 80%) in the two reactors during the batch experiment.

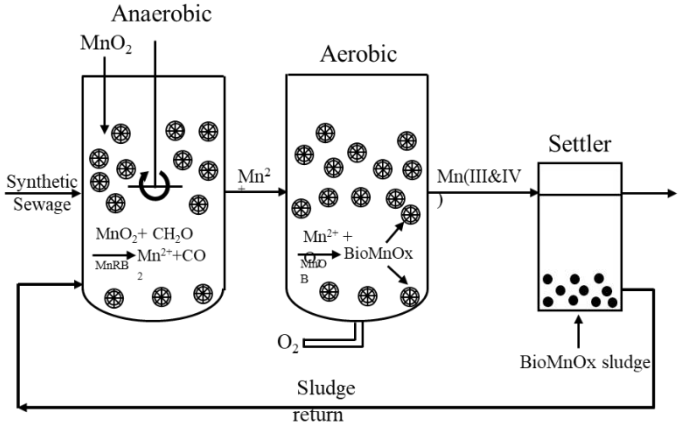
In comparison to previous biofilm systems, the removal rates of four micropollutants for the staged MBBR are several times higher.

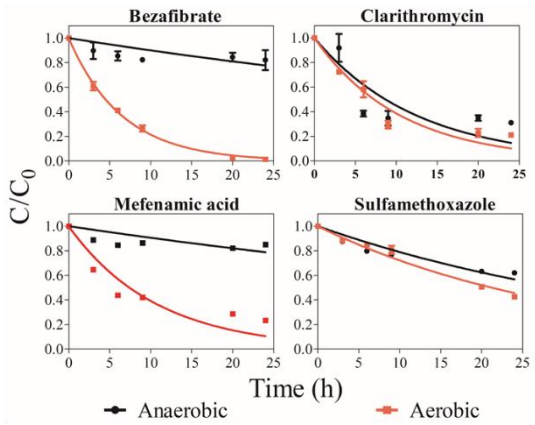
Discussion and take-home message:

Manganese redox cycling was engineered in a wastewater treatment for efficient pollutants removal.

BioMnOx can be continuously replenished in the anaerobic-aerobic two-stage MBBR.

Both biological degradation (suspended biofilm) and abiotic oxidation by BioMnOx contributing to the micropollutant removal in the aerobic reactor.





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Strategic food waste disposal to improve the C:N ratio and process economy within Danish wastewater treatment plants: process modelling and life cycle assessment

J. K. Lyager, **Adam. Kovalovszki***, V. M. E. Edjabou**, V. Takou***, A. Boldrin*, X. Flores-Alsina****, B. Valverde-Pérez**

Introduction: Municipal wastewater treatment (WWT) is a well-established public service that requires expert technical knowledge and good process planning to be cost-effective. One of the key issues of treatment plant operation is the maintenance of optimal carbon to nitrogen ratios, due to the varying composition of influent wastewaters. When these elements are present in imbalanced proportions, the addition of chemical agents or other process control actions might be necessary, thereby increasing operation costs and the risk of process failures. Considering the disposal of domestic food wastes through the sewer network, there is good potential for strengthening this balance and improving process economy, through reduced waste transportation and an increase in local energy recovery. Therefore, the present study aims to investigate how the planned addition of liquid food and source-separated organic household wastes (LFW and SSOHW, respectively) to the WWT network can improve nutrient balances, while reducing plant expenses, environmental impact and human health concerns.

Methods and data: In terms of food waste sourcing, three scenarios were considered in the year 2025. *Scenario 1* was the baseline, assuming that municipal WWT in Copenhagen would be the same in 2025 as it is today. This means that while LFW enters the WWT plants through the sewerage system, SSOHW is collected from households and after mechanical pre-treatment, is delivered to anaerobic digestion (AD) plants for biogas production. *Scenario 2* considered a 70% reduction in LFW volumes, due to possible awareness campaigns aimed at urban communities. Finally, *Scenario 3* was based on the assumption that in the future, SSOHW would be divided into two fractions: 45% being ground and pulpified in kitchen households and entering WWT plants through the sewers, while 55% being treated as before. The scenarios were then compared on the basis of their results in 10 WWT performance indicators, 5 effluent pollutant violation indicators and 8 key environmental impact categories. In terms of tools, the study was carried out using an adaptation of the Benchmark Simulation Model 2 (Jeppsson *et al.*, 2007) for wastewater treatment process simulation and the Easetech software (Clavreul *et al.*, 2014) for life cycle assessment (LCA).

Results: Simulations with the modified BSM2 showed that in almost all WWT performance indicators, Scenario 1 and 2 had the same results, while Scenario 3 performed the same or slightly worse, especially considering effluent pollutant violation indicators. Two exceptions were local methane production for energy that increased by 12%, and external carbon addition, where Scenario 3 achieved an 80% reduction from the baseline. This was due to the improvement of carbon to nitrogen ratios and therefore a lesser need for the supply of external COD sources. A comparison of the LCA results showed that Scenario 1 and Scenario 3 were performing better, while Scenario 2 led to no significant improvements compared to the baseline. Notably, Scenario 1 was best considering its low climate change impact (-22.3 kg CO_2-eq), marine eutrophication impact (0.981 kg N-eq) and water use (0.264 m^3), with Scenario 2 producing almost equivalent results. On the other hand, Scenario 3 had the lowest negative impact on fossil resource scarcity (-18.6 kg oil-eq) and showed a 36% decrease in non-cancer human toxicity impact, compared to the baseline. The latter effect is a result of the safer sludge incineration practices at WWT plants, while AD digestate is used as fertilizer.

Discussion and take-home message: Based on the above results, it is concluded that the existing WWT approach represented by Scenario 1 is a feasible one and might well be considered until and beyond 2025. At the same time, Scenario 3 could offer a viable alternative, especially if an increased methane production for energy recovery, a reduction in external carbon dosage or the process impact on human health are prioritised. Meanwhile, Scenario 2 is not suggested for practical implementation, as it offers no tangible improvements.

References:

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Clavreul, J., Baumeister, H., Christensen, T. H., & Damgaard, A. (2014). An environmental assessment system for environmental technologies. Environmental Modelling & Software, 60, 18-30. https://doi.org/10.1016/j.envsoft.2014.06.007

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Assessment of real-scale Microbial electrochemical assisted treatment wetlands (METland) for wastewater treatment

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Introduction: A METland is an innovative treatment wetland (TW) that relies on the stimulation of electroactive bacteria (EAB) to enhance the degradation of pollutants. METland is designed in short-circuit mode (absence of external circuit) by means of an electro-conductive bed capable of accepting electrons from microbial metabolism of pollutants. Although METland are proved to be highly efficient for removing organic pollutants, the study of in situ EAB activity in full scale systems is a challenge due to the absence of two-electrodes configuration. For the first time, four independent real-scale METland systems were tested in terms of removal of organic pollutants and nutrients; thus, a correlation with the electroactive response generated by the presence of EAB was established.

Methods and data: The study was carried out in two full scale METland systems in Spain (IMDEA) and Denmark (Ørby), allowing to test the technology under different environmental and demographic conditions. In each location, two METlands beds were constructed to treat real wastewater, with different configurations and plants adapted to the climatology. The systems were fed in down-flow mode, and operated under saturated conditions. Both systems were monitored for a period of 6 weeks, once a week, taking samples of the influent and the effluent to analyze organic matter (COD) and nutrients (PO_4^{3-}-P, TN, NH_4, and NO_3) and insitu parameters (pH, EC, temperature, dissolved oxygen, and redox potential). Also was assessed the microbial electrochemical activity with measurements of electric potentials (EP), the estimation of ionic current densities *(J),* coulombic efficiencies (CE), and electron transfer rates.

Results: The removal efficiency of the systems was enhanced by plants and mixed oxic-anoxic conditions, with an average removal of 56g COD $m^{-3}_{\text{bed material}}$ d^{-1} for Ørby 2 (partially saturated system) and 4g TN $m^{-3}_{\text{bed material}}$ d^{-1} for IMDEA 1(planted system). Estimated electron current densities *(J)* provide evidence of the presence of EAB and its relationship with the removal of organic matter. The tested METland systems reached max. values of 188.14 mA m^{-2} (planted system; IMDEA 1), 223.84 mA m^{-2} (non-planted system; IMDEA 2), 125.96 mA m^{-2} (full saturated system; Ørby 1), and 123.01 mA m^{-2} (partially saturated system; Ørby 2); such electron flow values were remarkable for systems that were not designed for energy harvesting and unequivocally show how electrons circulate even in absence of two electrode systems. The relation between organic load rate at inlet (OLR_{in}) and CE, showed a decreasing trend, with values ranging between 8.8-53% (OLR_{in} from 2.0 to 16.4 g COD m^{-2} d^{-1}) for IMDEA systems, and between 0.8-2.5 % (OLR_{in} from 41.9 to 45.6 g COD m^{-2} d^{-1}) for Ørby systems. This pattern denotes that the treatment of complex mixtures such as real wastewater with high and variable OLR should not necessarily imply the result of high CE values. METland technology was validated as an innovative an efficient solution for treating wastewater from decentralized locations.

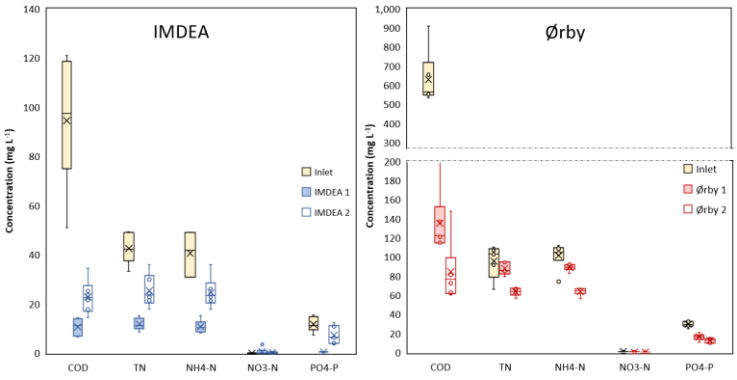

Figure 1. Removal efficiencies of tested METland systems

Discussion and take-home message: METland operated at full scale is an innovative and effective solution for wastewater treatment, capable of reaching removal efficiencies above 90% for COD, and 70% for TN. The study suggests the possibility of using bioelectrochemical parameters *(J)* to monitor the performance of a METland system in terms of organic matter removal. METland technology was validated as an innovative an efficient solution for treating wastewater from decentralized locations.

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Bacterial community structure and degradation kinetics in relation to cyanotoxin bioremediation in constructed wetland mesocosms

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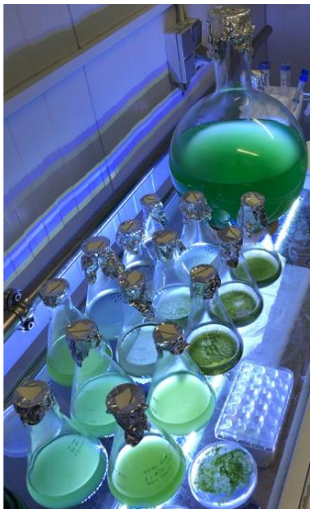
Introduction: Aquatic eutrophication levels are increasing rapidly worldwide because of anthropogenic activities. Both point and non-point cultural discharge of fertilizing compounds such as nitrogen and phosphorous are increasing the extent of eutrophication, alongside the global increase of CO_2 emission rates and rising water temperature. Consequently, harmful cyanobacterial blooms occur with increased frequency and intensity. The cyanobacteria may produce a variety of cyanotoxins such as hepatotoxic microcystin (MC) and cytotoxic cylindrospermopsin (CYN); considered the prevalent cyanotoxins. The presence of cyanotoxins in freshwater constitute a threat to human health and wildlife through direct exposure. Additionally, ingestion of cyanotoxins can occur when crops are irrigated with cyanotoxin-polluted water. On a global basis, the majority of irrigation water used for agriculture is groundwater and surface water. In times of drought and water scarcity, irrigation water may be obtained from cyanotoxin-contaminated freshwater systems. This type of exposure to cyanotoxins poses a threat to humans in areas without effective irrigation-water quality cleaning systems.

As a tool for cyanotoxin removal of surface water, we are exploring the use of vertical flow constructed wetlands (CWs) as a bioremediation approach. There is little but rising evidence linked to the effective removal of cyanotoxins in CWs. The appealing reason for the use of CWs is the low infrastructure requirement, low maintenance of the systems, cheap operation, and potential for effective removal of cyanotoxins. The remediation mechanisms of cyanotoxins from freshwater systems using CWs is not elucidated yet, however, we hypothesize that the removal of cyanotoxins in CWs is based on biodegradation by indigenous bacteria.

Methods and data: We have constructed four unsaturated CW mesocosms all filled with silicia filter sand. Two of them were planted with *Juncus effusus* and two were unplanted. The systems were acclimated to eutrophic conditions and added native bacteria by feeding them with lake water from the highly eutrophic lake Arresø. The system is being continuously fed with synthetic eutrophic water. The intention is to spike the systems with MC and CYN cyanotoxins and follow the degradation kinetics and simultaneously characterize the bacterial cyanotoxin-degrading community by 16S amplicon sequencing, qPCR of 16S and the *mlrA* gene (coding for a MC hydrolyzing enzyme). The major efforts have been employed in establishing and upscaling cultures of cyanobacteria biomass for cyanotoxins production in order to conduct the lab tests. Furthermore, we intend to produce 13C-labelled MC and CYN to identify and validate transformation products, besides trying to isolate MC and CYN degrading bacteria from the CW mesocosms.





Results: The project is ongoing, and data generation is proceeding and therefore results presented will be preliminary.

Discussion and take-home message: The project aim is to study the mechanisms behind MC and CYN biodegradation with the use of CW. This includes characterization of the bacterial degrader community and degradation kinetics.

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Offshore biological treatment of oil and gas produced water

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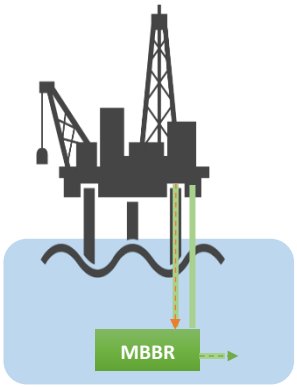
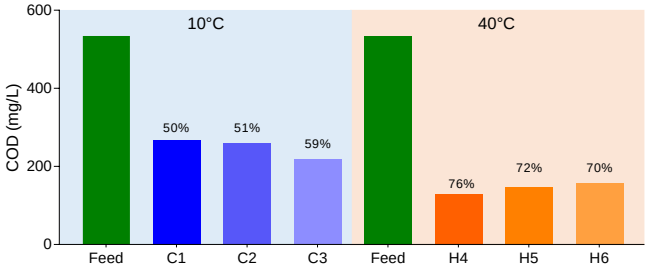
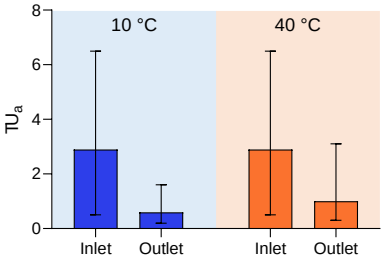


Introduction: Produced water (PW) represents the largest volume waste stream generated in oil and gas production operations. PW has a complex composition, which includes various production chemical residuals and naturally occurring organic and inorganic chemicals that are frequently recalcitrant and difficult to remove.
Currently there is no treatment of PW offshore apart from the oil separation as physico-chemical and biological treatment methods utilized for treatment on land have various operational problems with safety and the footprint of most treatment systems are generally unacceptable large for an oil production platform. PW treatment facilities on land using traditional biological treatment generally struggle with fluctuations in water quality parameters, which makes treatment results unstable. The potential of moving bed biofilm reactors (MBBRs) to treat PW more consistently have been shown in previous research at DTU. It appears bacteria in biofilm are vastly more robust to toxicants and variable salinity and pH as well as more capable to degrade complex organic molecules. In Denmark, a large pilot plant is currently operating in connection with the oil terminal in Fredericia and a full-scale staged MBBR-system will be built in the coming two years. In a project with Danish Hydrocarbon Research and Technology Centre (DHRTC) and supported by Total Denmark we investigate if a similar system could be applied to the effluents of oil and gas platforms in the North Sea which would make it possible to meet future stricter regulation and achieve the goal for zero harmful discharge into the sea. We present elements of the laboratory and pilot work towards designing a MBBR system that can operate on the seabed next to an oil platform in terms of treatment performance, variability in treatability between oilfields and the special possibilities and challenges connected with treating salty, 60 °C water at a depths that yields 3-6 bar pressure.
Methods and data: Two 3-stage MBBR system using AnoxKaldnes™ K5 carriers with attached bacteria adapted to high salinity is being refined for biodegradation of organic compounds present in offshore PW.
The established biofilm-based reactors were tested with different operational conditions such as temperature (10 °C and 40°C), hydraulic loads and salinity while testing PW from different offshore platforms. Many specific chemicals are documented to be removed, along with toxicity and a drastic reduction in total organic matter measured as COD.
Results: Consistently, MBBR is able to degrade organic molecules such as toxic and persistent chemicals (including yellow and red list production chemicals, which are scheduled to be phased out of use) by adapted bacteria that are effectively retained in the reactors by the biofilms. The removal of pollutants concurs with whole water toxicity reduction.
The kinetic studies indicate a high treatment effectiveness with hydraulic retention time of 1 to 4 h at 1 bar pressure and 40 °C. It is expected that higher pressure currently under investigation will allow biofilms to work faster.





Discussion and take-home message:

- MBBR can effectively remove most organic matter and chemicals in produced water along with almost all the measurable whole effluent toxicity.
- From kinetic studies and modelling it appears possible to construct a realistic prototype of about 400 m^3 which is suitable for a typical oil platform.
- Cost estimated indicate that despite a unit cost well above 10 Mkr it is likely directly competitive to produced water reinjecting, which anyway is not geologically possible in part of the Danish North Sea.

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Magnetic micro vehicles to pickup small oil droplets from water

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Introduction: Efficient removal of small concentrations of oily pollutants from water is a challenging but crucial task to meet the increasingly stringent environmental regulations. The current study presents lab-made magnetite particles coated with different amounts of oleic acid (OA) as an efficient and environment-friendly adsorbent for the removal of low concentrations of oil from water. The magnetic nature of the magnetite represents a novel method for recovery and use of the adsorbents. The study takes the case of crude oil in produced water (PW) from North Sea oil rigs and brings oil concentration in PW to or below OSPARS limit of 20ppm

Methods and data: Magnetite nanoparticles were synthesized through the Massart Co-precipitation method under inert N_2 atmosphere. Different amounts of oleic acid were added to different batches to generate different weight fractions of OA-coatings. The nanoparticles were analysed for its crystalline structure by Xray-diffraction and the degree of coating was determined by thermal gravimetric analysis. The nanoparticles were then tested for their ability to adsorb oil from synthetic PW prepared by using crude oil from the North Sea. The emulsion was made and kept pseudo-stable by rigorous stirring and the oil was analysed using triple determination of hexane extraction and subsequent UV-vis analysis hexane phase. The oil catching efficiency of the particles was tested as function of amount of OA-coating on the particles, the PW salinity, the amount of emulsifier in the PW and the particle to oil ratio. Furthermore, regeneration of the particles was analysed by first either centrifugation or solvent washing the particles then TGA analysed for residue Oil on the particles and possible degradation. Afterwards the recovered particles were tested to see if the regeneration restored their oil-catching properties. Lastly, the isothermal properties and kinetics of the particles in regard to their oil catching properties was done by fitting the data achieved from the experiments and comparing them to Langmuir and Freundlich and pseudo first and second order kinetics. The most appropriate fit was then selected and a comparative study of the particles as an adsorbent was done and compared to other adsorbents.

Results: Magnetic nanoparticles of the magnetite (Fe_3O_4) variety was synthesized with different amounts of coating. The particles showed great oil adsorbing abilities reaching final concentrations of 1ppm and below for initial concentrations of 50ppm to 1000ppm (higher concentrations were not explored). All but the uncoated particles were able to readily remove oil from the PW down below the OSPAR limit as shown in left Figure. Emulsifier negatively influenced the oil removal efficiency. The salinity of the PW did not seem to affect the adsorption process on its own but did however have a compounding negative effect when mixed with an emulsifier. The particles were found to be both regeneratable and reusable by solvent extraction, however with centrifugation only 20% of the adsorbed oil was removed and the particles had subpar oil catching abilities compared to fresh particles as seen in the right Figure. The particle kinetics were found to follow pseudo second order(PSO) kinetics and the isotherm had a best correlation with Freundlich. The k_2 found in PSO was seen to change due to the oil to particle ratio but was found to be generally high compared to other adsorbents and the Freundlich constants K_F and 1/n was found to be reasonably high when compared to other similar oil adsorbents. Lastly the oil removal process was modelled by a combination of the chosen PSO kinetics and Freundlich isotherm, and from these, estimations could be made for how much particles should be used for a defined volume of polluted water with a given initial oil concentration.

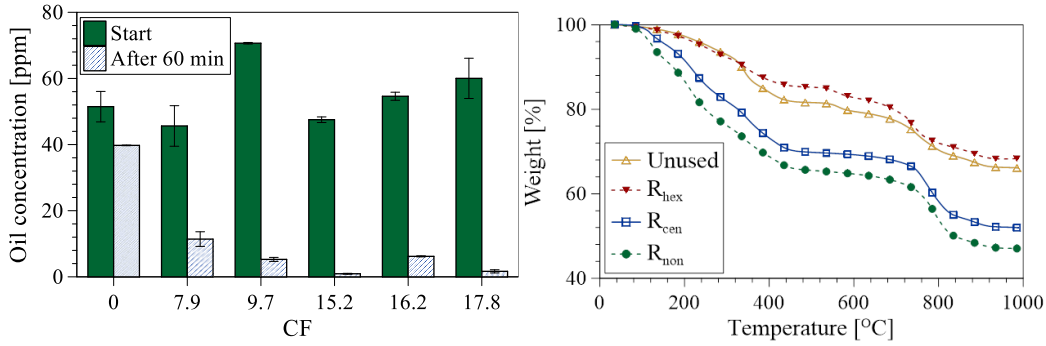

Figure: left: Final oil concentration for particles with various coating fractions (%). Right: TGA data of recovered particles (hex and cen represent the particles regenerated through centrifugation and hexane, respectively)

Discussion and take-home message: Magnetic particles coated with oleic acid demonstrated the ability to lower the crude oil concentration below all international accord. The particles do not require a specific equipment and can be dispersed into any existing body of water, thus have minimum weight and footprint. The performance of the particles could be fully regenerated by solvent washing after the oil removal experiments, thus the particles can be reused without losing their efficiency. Appropriate amounts of particles can be readily calculated.

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Minimization of plastic emissions from WWTP through development of biodegradable flocculants

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One source of plastic pollution are wastewater treatment plants, as flocculants based on polyacrylamide are added for sludge dewatering which subsequently is discharged into agricultural fields. The aim of the project is to benchmark the currently available biodegradable flocculants (so-called 'bioflocculants') and to synthesize new bioflocculants that can replace conventional polyacrylamide (PAM) based flocculants. Existing commercial bioflocculants were characterized and benchmarked against a PAM based flocculant. The flocculant characterization indicated the relevance of flocculant molecular weight and charge density. Different synthesis strategies were executed aiming to incorporate these properties onto starch polymers. The synthesized bioflocculants enabled charge neutralization but required further optimization to yield sufficiently strong floc strength.

Introduction:
Flocculants based on polyacrylamide are used for sludge dewatering with an estimated annually usage of 1,500 tons in Denmark alone. After dewatering, most of the sludge containing polyacrylamide is spread on agricultural fields, thus ending up in nature, where it either accumulates or decomposes into smaller components. PAM is a CMR substance and is included in the Candidate List for problematic substances under Reach. Thus, with this in mind and the increasing focus on plastics in the environment there is a considerable wish to replace polyacrylamide-based flocculants by flocculants that are both biodegradable and do not pose any environmental or health risks.

Methods and data:
The project includes three stages. The first stage was a market screening where >30 commercial 'bio-flocculants' were benchmarked against PAM. A characterization of the bioflocculants were conducted to assess the parameters related to an effective bio-flocculant performance. In the second project stage different strategies were used to synthesize a new high-performance bioflocculant using starch as a backbone. The most optimal synthesis strategies were established using a dynamic DoE. In the third stage a pilot-scale demonstration of the most relevant bioflocculants was conducted.

Results:
A new laboratory method, Modified Higgings Centrifuge Test, was introduced and optimized to enable quantitative comparison of the bioflocculants. Comparison between lab-scale and pilot-scale results revealed that the optimized MCT Higgins test was able to accurately identify the optimal flocculant dosage rate. The chemical characterization highlighted the importance of chain length and, to a lesser extent, charge density to obtain satisfactory dewatering potential. The lab-scale MCT Higgins test were supplemented with dewatering tests on a pilot-scale screw press to evaluate floc strength and resistance to mechanical stress.
All commercially available bioflocculants exhibited weak floc strengths, indicating a significant working point for future bioflocculant synthesis. The results indicated that a bioflocculant with high floc-strength could be achieved through a synthesis strategy aiming to add carbonyl groups to a starch polymer backbone to enable H-cross binding. Positive charges were added to the polymers through grafting. The synthesized bioflocculants exhibited an increased charge density, but further optimization is needed to increase the floc strength.

Discussion and take-home message:
The developed MCT Higgin's method enabled a substantiated and quantitative comparison between conventional PAM flocculants and bioflocculants, which demonstrates its applicability for the optimization of target-directed dosage on full-scale systems. However, when applied on a pilot-scale screw press, the bioflocculant exhibited poor floc strength. Therefore, the MCT Higgins method needs to be supplemented with another method that can measure the floc strength. Despite showing the properties of the added functional groups the synthesized bioflocculants were observed to have low floc strength or low water solubility. For this reason, further optimization of the synthesis strategy is required to produce high-performance bioflocculants. The characterization of commercial bioflocculant gave broad insight in the essential parameters (e.g., molecular weight, charge density and floc strength) related to environmentally friendly flocculants. Considering this and the high demand on bioflocculants, a future project aiming to optimize the synthesis process is of most relevance.

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Long-term model based evaluation of flexible Model Predictive Control in Kolding WRRF

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Model predictive control (MPC) has been proposed as a tool to optimize the operation of Water Resource Recovery Facilities (WRRF) under different performance objectives (e.g., costs, effluent quality, energy or greenhouse gas emissions – Stentoft et al., 2021).
This work aims to assess the long-term performance of MPC by using a modified benchmark model of a WRRF in Kolding, which operates as a biodenitro process. The MPC controls the aeration in the WRRF biological reactors, modifying the plant operations according to the desired management objectives. The biological model simulates both carbon and nitrogen removal processes and N2O emissions based on the NDHA model (Domingo-Félez and Smets, 2016). The model was implemented in the Matlab-Simulink tool (The MathWorks, Natick, Massachusetts, USA). Hourly electricity prices were obtained from the public online databases of the European power exchange Nord Pool. The emission data were obtained from Energinet. The effect of the prediction horizon on the total operational cost was tested on 100 days from 1-jan 2018 to 11-April 2018. In this long period there were varying electricity prices, both high and negative prices. To see how the MPC preform under different scenarios.
Four different control strategies were tested on a 2.5-day period, to test the effect on total cost i.e. sum of electricity costs and effluent tax on N emissions.

Different prediction horizons were tested and then normalized to the run with a prediction horizon of 360 minutes. The mean value of the 100 days and the standard deviation were found (figure 1).
The MPC was run with three different objective functions, including effluent cost, aeration cost, and total cost. While holding the effluent concentration of nutrients below discharge limits (8 g N/m^3), the MPC resulted in lower operational costs compared to the rule-based control (Figure 2).
It was shown that an MPC can be used to control the aeration of a WWRP. The already short calculation time can be shortened by lowering the prediction horizon without sacrificing total cost. The MPC has also shown on the benchmark model that it can lower the operational costs compared to the rule-based method. Due to space constraints, the N_2O is not discussed here, and there are only a focus on the total operational costs.

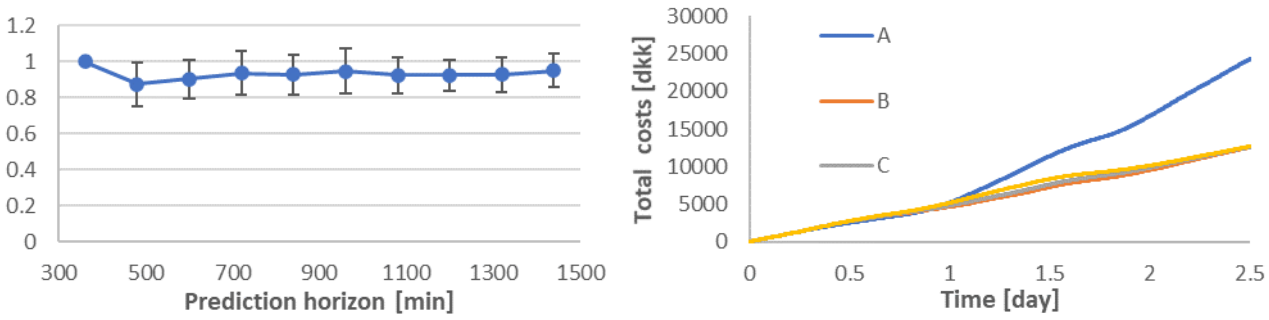

Figure 2 Left: Normalized total operational costs for 100 days (where the total operational cost with a prediction horizon of 360 minutes is used as reference). Right: Cumulative total operational costs (DKK) for four different control strategies. (A) Rule-based, (B)MPC reducing total operational costs (C), MPC reducing electricity consumption, (D) MPC reducing total-N effluent tax.

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Disinfection of antibiotics resistant bacteria from wastewater at the hospital

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Abstract

The spread of antibiotic-resistant bacteria (ARB) in the environment is increasing, due to the excessive use of antibiotics in humans, animals and plants and among many environmental conduits known to spread ARB, wastewater has been reported as an important vehicle. The Danish national hospital service is currently being centralised into super hospitals servicing entire regions and replacing many local hospitals. The wastewater from these large hospitals will be connected directly to the wastewater treatment plant using a direct pipe. This centralization means antibiotic resistant bacteria in hospital wastewater will pose an increased risk to the workers in the few receiving wastewater treatment plant. Risk of infection from antibiotic resistant bacteria from wastewater to the workers in the plant might be reduced by disinfecting this wastewater.

Our work evaluated the removal of antibiotic-resistant bacteria (ARB) from raw hospital wastewater using peracetic acid (PAA). We evaluated disinfection treatment in direct unbranched sewers as is used in the superhospitals and in a traditional branched sewer typical for existing smaller hospitals. Additionally we determined the typical levels of ARB in sewage with and without hospitals connections in order to find the disinfection level needed to reduce hospital wastewater's ARB content to background level for municipal sewage.

The average level of Ciprofloxacin-resistant bacteria in wastewater without hospital contribution was $1.5 \cdot 10^4$ CFU/mL after analysing 78 samples from 7 different WWTPs across Denmark and this value can be used to specify the disinfection level requirements for hospital wastewater. A pilot scale disinfection experiments were conducted in a pilot using raw wastewater from a hospital. The removal of the antibiotic resistant bacteria was studied using high PAA doses with short contact time using raw wastewater from Slagelse hospital at SK forsyning and low PAA doses with long contact time using raw wastewater from Hillerød hospital at Hillerød forsyning. In total eight pilot experiments were conducted where degradation of PAA was studied. Degradation of PAA was fast therefore, there was no residual effect of PAA to the process of wastewater treatment plant. Removal of ciprofloxacin-resistant bacteria from pilot experiments were >99% when 75 mg/L PAA was used with 2 min contact time and 50 mg/L PAA with 10 min contact time. The method appears an ideal technology to minimize the risk of antibiotic resistant bacteria to the sewage workers when new centralized super hospital are constructed in Denmark utilizing the unbranched direct connection of wastewater from hospital to the WWTP or reducing the number of antibiotic resistant bacteria in wastewater pipe from hospital before mixing it to the existing sewer network.

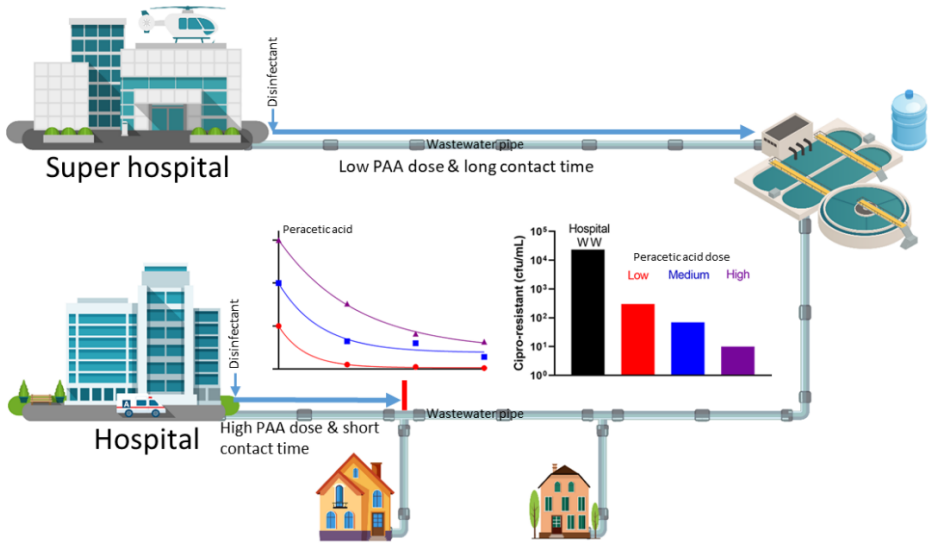

Figure 3: Schematic diagram of disinfection system of hospital wastewater using unbranched direct connection of wastewater from hospital to WWTP and from hospital to existing sewer network.

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The CW Pharma 2 monitoring of Danish Wastewater Treatment plants and implications for advanced treatment for Pharmaceuticals

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Within the CW Pharma project, 34 Danish (80in total) wastewater treatment plants were monitored for 52 pharmaceuticals to test for feasibility for advanced pharmaceuticals removal.

The concentrations of pharmaceuticals varied from below 0.05 to 46 µg/L (Figure 1).

While some compounds were found with very similar concentrations in the whole region, others were somewhat specific for the respective region, while others were specific for the respective catchment.

These differences will be discussed in the presentation.

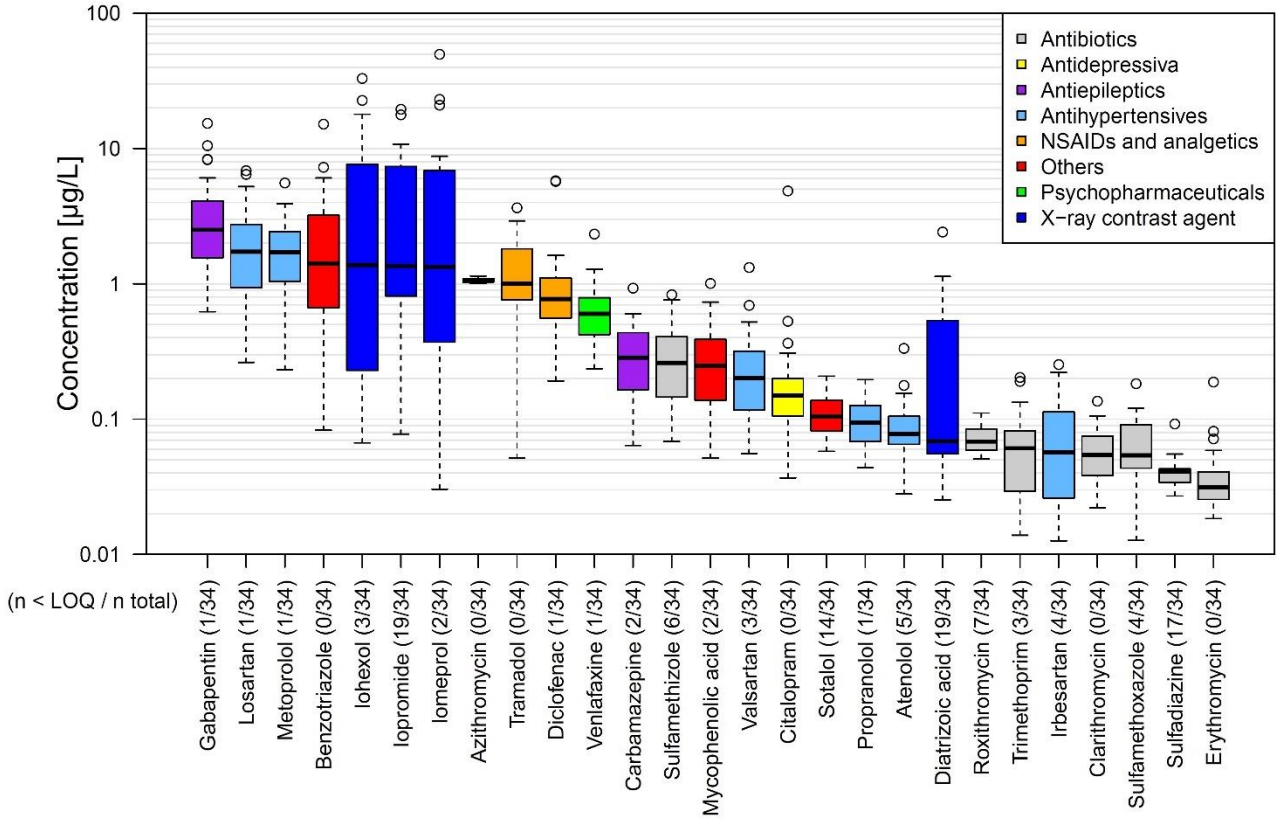

Figure 1. Average concentrations of selected pharmaceuticals in the WWTPs effluents

In Denmark high focus is given on reaching Predicted No Effect Concentrations (PNEC) values in the effluents of those WWTPs that receive wastewater from hospitals (or pharmaceutical companies).

In the talk we will discuss which compounds (often) exceed the PNEC and measures to achieve these concentrations.

It will also be discussed whether the PNECs should be rather used as general motivation to implement advanced treatment or as detailed steering of the design and operation of infrastructure.

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Predicted no-effect concentration (PNEC) – based design for removal of pharmaceuticals in wastewater treatment plant

Vaidotas Kisielius**, AU-ENVS*, S. Kharel AU-ENVS**, J. Skaarup, Hillerød Forsyning, K. Bester, AU-ENVS*****

The new 68,000 PE Hillerød central mechanical/biological wastewater treatment plant launched in 2018 (HCR Syd) started receiving wastewater from households, two large pharmaceutical production companies, industrial facilities and a local hospital which will be replaced by a large regional hospital in 2025. Currently, there are no national demands in Denmark on removal of pharmaceuticals for municipal WWTPs. However, the pollution-related responsibility is of the polluter (the hospital). The municipality wishes to treat the wastewater from the new hospital at HCR Syd. HCR Syd discharges its effluent to a freshwater system classified as environmentally vulnerable, leading to strict effluent quality requirements. It is also being assessed whether the municipal wastewater should also be treated to decrease pharmaceutical loads into the vulnerable stream. Due to a nearly-zero dilution of the HCR Syd's effluent in the receiving water body, the WWTP has been assigned to reach pharmaceutical concentrations in the effluent down to the latest values of Predicted no-effect concentration (PNEC).

Based on recommendations from "Clear Waters from Pharmaceuticals" (CWPharma) "Guideline for advanced API removal. GoA3.4: Optimization and control of advanced treatment" (December 2020)[1] it was decided to test a pilot process in HCR Syd by treating the effluent with ozonation and filtration through granular activated carbon (GAC). The pilot plant was designed to test overall three possible treatment variations (the Figure). S1 – normal effluent from HCR Syd (baseline); S2 – ozone treatment (different tested O_3 intensity); S3 – ozonation followed by GAC filtration; S4 – GAC filtration only. Besides the pilot plant, parallel experimental GAC setup has been operated at laboratory of the AU ENVS.

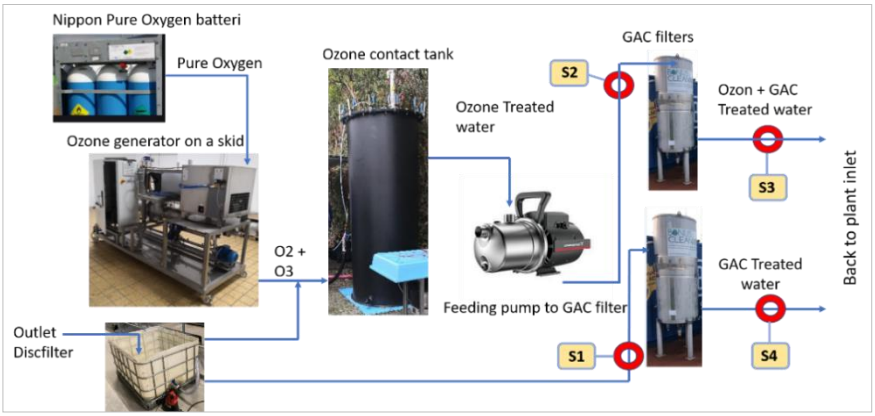

Figure. HCR Syd pilot plant pharmaceutical removal scheme and sampling points: base-line (S1), ozonation (S2), combined ozonation-GAC filtration (S3) and GAC filtration (S4).

An LC-MS/MS quantification of 53 PNEC-referenced medication-related micropollutants (x-ray contrast media and diverse application pharmaceuticals) have been performed.

The GAC filters were efficient but could not be applied without a risk of exceeding target values of certain compounds over time due to their high polarity and decreasing efficiency of GAC with time (observed exceedance of PNEC for clarithromycin, venlafaxine and gabapentin at ≥ 4,500 empty bed volumes). Ozonation was highly effective for most compounds, but ozone-only treatment did not remove enough gabapentin, bicalutamide and oxazepam (concentrations > PNEC were observed even at 1 mg-O3/mg-DOC). Ozonation-only can also lead to formation and discharge of unfavourable ozonation by-products. The combination of ozonation-GAC filtration has been concluded as the most practical method for fitting the purpose (to be presented in the 16th Annual DWF Water Research Conference).

The ozonation followed by GAC-filtration is by far the most appropriate technology for pharmaceutical removal from wastewater. However, depending on wastewater composition and discharge circumstances, the operational costs of the proposed technology may not be economically feasible. The PNEC values for certain compounds still largely lack toxicity data and comprise huge uncertainties. Adoption of more precise national or case-specific pharmaceutical targets for treated wastewater discharge may assist technology assimilation and benefit the aquatic environment.

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[1] https://www.cwpharma.fi/en-US/Publications

Session 3: Drinking water; challenges and solutions

Time: 13:00 – 15:00
Chair: Hans-Jørgen Albrechtsen, DTU Envir. Co-chair: Torben Lund Skovhus, VIA University College
Auditory 2

Time	Speaker	Topic
13.00	Hans Chr. Bruun Hansen	Plant toxins as water contaminants - which are the controlling factors?
13.10	Jawameer R Hama, Presented by Bjarne W. Strobel	Occurrence and Leaching of Alkaloids from Blue Lupin (Lupinus angustifolius L.)
13.20	Mulatu Yohannes Nanusha	Occurrence of phytotoxins fingerprint in waters from Vejle river
13.30	Daniel B. G. Jorgensen	Modeling the environmental fate of the natural toxin ptaquiloside: production, release and leaching to groundwater
13.40	Natasa Skrbic Mrkajic	Removal of phytotoxins in filter sand used for drinking water treatment
13.50		Discussion
14.00	Julie Bruun Jensen	Pesticide removal using microbes
14.10	Martin Bymose	Advanced Water treatment for N, N dimethylsulfamid (DMS) in drinking water
14.20	Xingaoyuan Xiong	Effective fluorine elimination of PFOA by ultrasound
14.30	Torben Lund Skovhus	Effect of early biofilm formation on water quality during commissioning of new PE (polyethylene pipes) at Mosevangen, Aarhus, Denmark
14.40	Martin Rygaard	Some observations on Danish drinking water mineral composition
14.50		Discussion

Plant toxins as water contaminants - which are the controlling factors?

Hans Christian Bruun Hansen*, *Department of Plant and Environmental Sciences, University of Copenhagen*

Introduction: Most plants produce secondary metabolites or plant's specialized compounds that are toxic to humans.There are more than 200,000 of such bioactive compounds covering a huge diversity of molecular designs, chemical-physical properties, toxicities and modes of action. Plants produce these "chemical weapons" in their competition with other species, as regulators, and to defend themselves again pathogens or other stressors. Most of the plant toxins (PT) are produced in large quantities in the order of grams per square meter annually. Also, they are relatively polar and hence shows high mobility in the environment. Rain washoff, exudation and plant debris deposition transfer PT from plants to soil, from where they leach to aqueous recipients. The question is if the PTs are sufficiently stable along the track from plant to sink to eventually result in elevated concentrations in water reservoirs - surface water and groundwater - used for drinking water abstraction.

Methods and data: Sixteen PhD students/early stage researchers in 7 European countries and USA affiliated with 22 partners have been studying natural toxins (plant toxins and cyanotoxins) as environmental contaminants in plants, soils and lakes comprising environmental monitoring and analysis, physico-chemical properties, environmental fate incl. leasching and modelling. The project called **NaToxAq** (https://natoxaq.ku.dk) has resulted in about 50 science papers on the topic. The overarching goal has been to identify natural toxins that makes it all the way from plants to water recipients, and to asess the toxin properties and the environmental variables that excert major control on natural toxin fate and concentrations in the aquatic environment. Here we report results and conclusions for selected plant toxins.

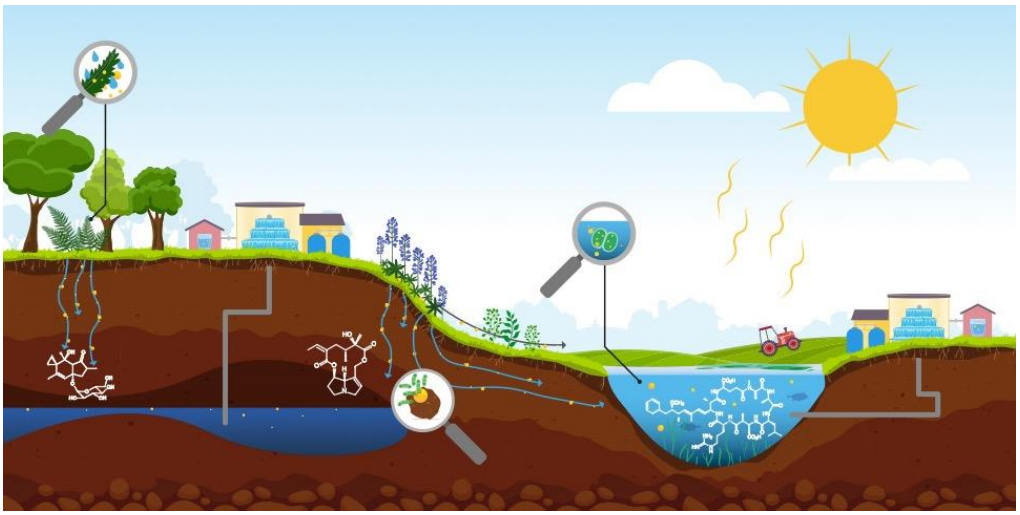

Figure 4: Natural toxins (ptaquiloside, senecionine and microcystin LR) from source to tap; ● represent toxins (reproduced with permission from Springer).

Results: Many new PTs have been found in natural waters including alkaloids, coumarins, flavonoids and terpenoids at concentrations typically in the ng/L to ug/L scale, and typically with peak concentrations during precipitation events. Most of the studied plant toxins have low Koc's and hence sorb only weakly in soils. The fraction of total plant produced PT that leach is often low indicating that PT degradation in plant and in soil is extensive. Alkaloids (nitrogen containing natural compounds) has been identified as a group of prime interest for future studies as these compounds are produced by numerous crop and non-crop plants, some are very toxic and they degrade slowly. Focus in NaToxAq has been on pyrrolizidine alkaloids produced by for instance ragwort and lupin. A crop-soil-water model (DAISY) has been adapted to describe production, transfer, degradation and leaching of the bracken toxin ptaquiloside confirming the very variable and pulse type leaching of natural toxins.

Discussion and take-home message: Plant secondary metabolites are present in any water sample usually with concentrations of specific compounds below 100 ng/L but with peak concentrations that are much higher reflecting a highly variable leaching and temporal exposure to plant toxins. There is a strong need for systematic and time resolved monitoring of plant toxins including availability of more reference compounds. More studies of toxin degradation rates and pathways and on toxin transfer from plants to soils are also highly needed.

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Occurrence and Leaching of Alkaloids from Blue Lupin (*Lupinus angustifolius L.*)

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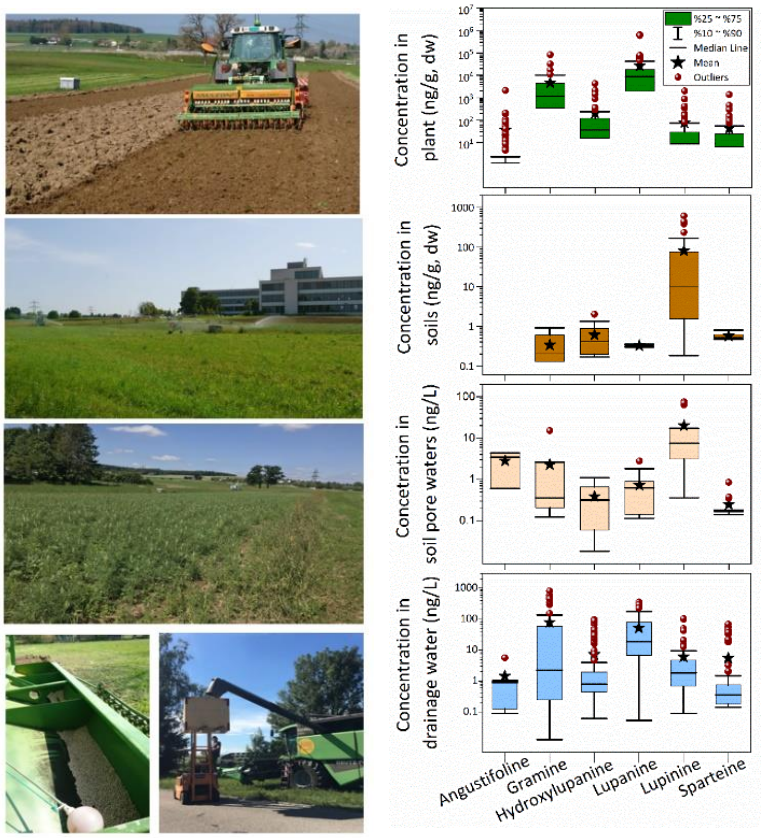
Abstract: Indole and quinolizidine alkaloids are toxic secondary plant metabolites produced by lupin and other plants in *Fabaceae* family. Occurrence and environmental fate of alkaloids remain largely unknown. Therefore, we conducted a field experiment to investigate the occurrence of lupinine, 13-hydroxylupanine, gramine, angustifoline, lupanine and sparteine in lupin plant tissues, soils, soil pore waters as well as their emission via drainage water. During the field experiment, alkaloids were regularly quantified in lupin plant tissues (0.1-6.4x10^5 ng/g dry weight (dw)), and topsoils at depth 0-5 cm (0.3-405 ng/g dw), and depth 15-30 cm (0.2-604 ng/g dw), soil pore water (from below detection limit to 74 ng/L) and drainage water samples (0.1-815 ng/L). Cumulative QAs loads emitted via drainage water were around 0.1-11 mg/ha for individual QAs, this led to 14 mg/ha of total QAs, this is very little amount compared to what found in the lupin tissues (20 kg/ha) and soil (0.55 kg/ha). Nevertheless, these findings indicate that drainage from lupin cultivated areas contribute to surface water contamination. The environmental and ecotoxicological impact of alkaloids as newly identified aquatic micropollutants have yet to be assessed.



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Occurrence of phytotoxins fingerprint in waters from Vejle river

Mulatu Nanusha[1,2], Martin Krauss[1], Bettina Gro Soerensen[1,2], Tobias Schulze[1], Bjarne W. Strobel[3] and Werner Brack[1,2]

Introduction: Only recently the occurrence of natural toxins in water and soil have been reported [1,2,3]. However, we assume that these findings are only the tip of icebergs. Thus, more efforts needed to extend the knowledge on the impact of natural toxin (i.e. phytotoxins) in surface water. Therefore, we performed target screening for 160 phytotoxins on surface water samples collected from three connected rivers in Eastern Jutland, Denmark. The rivers drain through a catchment with agricultural land, forest and grassland.

Methods and data: Water samples were collected following rain event applying online extraction with large volume solid phase extraction (LVSPE) machine. The loaded cartridges were eluted, reconstituted and injected to LC-HRMS for target screening.

Results: In total 27 phytotoxins from different compound classes including alkaloids, flavonoids and coumarins were detected in rivers with a minimum of 13 target compounds per water sample. Among these phytotoxins 12 compounds have not been detected in surface waters before. Maximum concentrations of individual compounds reached up to several hundred nanogram per liter (Fig. 1). The concentration trends for target compounds obtained per river over time reflecting raising water levels and thus rain intensity.

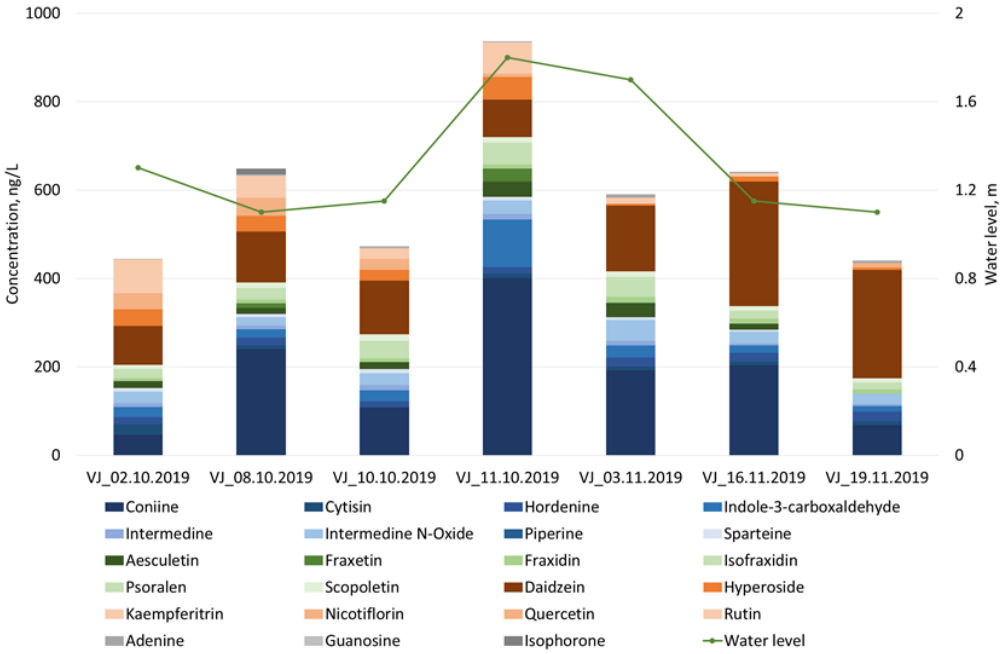


Fig 1. Showing sampling date or rain intensity dependent variation in concentration of target compounds identified in water samples from Vejle river (VJ); Sample ID: river name_sampling or rain event date.

Discussion and take-home message: The study adds to a series of recent results suggesting that phytotoxins occur in relevant concentrations in European surface waters and should be considered in monitoring and risk assessment of water resources. Aquatic toxicity data for PSMs are extensively lacking but are required for involving these compounds in the assessment of risks to aquatic organisms and for eliminating risks to human health during drinking water production.

Reference:

1. Günthardt BF, Schönsee CD, Hollender J, Hungerbühler K, Scheringer M, Bucheli TD, Chimia (Aarau) 2020, 74(3):129–135
2. Nanusha MY, Krauss M, Schönsee CD, Günthardt BF, Bucheli TD, Brack W Environ Sci Eur 2020, 32(1):142
3. Nanusha MY, Krauss M, Brack Environ Sci Eur 2020, 32(1):130

Acknowledgement *- The authors would like to thank Europian comission for funding NaToxAq project (Grant agreement ID: 722493); analyses were run on the high-throughput platform CITEPro (Chemicals in the Environment Profiler) funded by the Helmholtz Association.*

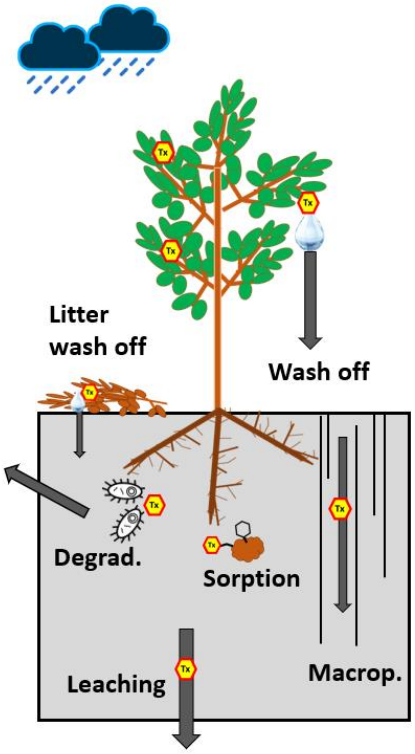
Modeling the environmental fate of the natural toxin ptaquiloside: production, release and leaching to groundwater

Daniel B. García-Jorgensen[a,*], Hans Chr. B. Hansen[a], Per Abrahamsen[a] and Efstathios Diamantopoulos[a].

Abstract

Introduction

Plants produce a wide array of toxic compounds that have been detected in plants, water and soils. Ptaquiloside (PTA), a carcinogenic phytotoxin produced by bracken fern (*Pteridium aquilinum* L. Kuhn), has been detected in surface and ground water surrounding bracken populations. This study presents the first calibrated model for assessing the environmental fate of PTA.



Methods and data

The newly adapted DAISY model was calibrated based on two-year monitoring (2018-2019) performed in a bracken population near Ringsted (Denmark). Several model functions related to the fate of PTA were calibrated, covering processes from toxin generation in the biomass, wash off by precipitation and degradation in the soil.

Results

The good model fit for PTA contents in the biomass indicates that toxin production can be explained based on biomass and bracken development stage. Model results show that only 1.7% of the PTA produced in bracken is washed off by precipitation, from both canopy and litter. Once in the soil, PTA degrades rapidly, especially during the summer due to high soil temperatures. Leaching takes place in form of pulses connected to precipitation events, with simulated concentrations at 50 cm depth up to 1.5 µg L^{-1}. Macropores transport is responsible for the events with highest PTA concentrations, contributing to 38% of the total mass of PTA leached.

Discussion

Soils with high hydraulic conductivity or with important preferential transport are the most vulnerable to groundwater contamination in form of pulses of concentrations posing a risk to human health. The beginning of autumn is identified as the period of maximum likelihood of water contamination, due to the combination of high soil water contents, low soil temperatures and potentially high amounts of toxin being released from wilting plants. Based on the results, we conclude that DAISY offers a good modelling platform for assessing the case of phytotoxins as emerging environmental micropollutants.

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Removal of phytotoxins in filter sand used for drinking water treatment

Natasa Skrbic Mrkajic*, Jawameer R.Hama**, Bjarne W. Strobel***, Hans Chr. B. Hansen****, Lars Holm Rasmussen*****, Ann-Katrin Pedersen******, Sarah C. B. Christensen*******, Mathilde J.Hedegaard ********

Abstract

Introduction: Phytotoxins - toxins produced by plants – are contaminants with the potential to impair drinking water quality. They encompass a large group of toxic, partially persistent compounds that have been detected in seepage waters and in shallow wells used for drinking water production. If phytotoxins enter wells used for drinking water production, it is essential to know if the drinking water treatment processes will remove them from the water phase. However, it is currently unknown whether phytotoxins remain stable during traditional groundwater treatment using sand filters as the main treatment process. The objective of this study is to investigate removal potential of phytotoxins in biological sand filters and to asses if the removal potential is similar at different waterworks.

Methods and data: Microcosms were set up with filter sand and drinking water collected at different groundwater-based waterworks. To be able to monitor phytotoxin removal ptaquiloside, caudatoside, gramine, sparteine, jacobine N-oxide, senecionine N-oxide and caffeine were applied at initial concentrations of 300 µg L-1, which is approx. two orders of magnitude higher than currently detected in environment, but expected to cover extreme environmental conditions. Removal was monitored over a period of 14 days.

Results: Despite the high initial concentration, all filter sands removed ptaquiloside and caudatoside completely from the water phase and at waterworks where pellet softening was implemented (pH 8.4) prior to rapid sand filtration, complete removal occurred within the first 30 min. All filter sands removed gramine and sparteine, primarily by a biological process, while jacobine N-oxide, senecionine N-oxide and caffeine were recalcitrant in the filter sands. During degradation of ptaquiloside and caudatoside we observed formation and subsequent removal of degradation products pterosin B and A. Filter sands with the highest removal potential were characterised by high contents of deposited iron and manganese oxides and hence large specific surface areas. Difference between bacterial communities investigated by 16S rRNA gene analyses did not explain different removal in the filter sands.

Discussion and take-home message: All five investigated filter sands showed similar degradation patterns regardless of water chemistry and waterworks of origin. In drinking water treatment systems biological sand filters might therefore remove phytotoxin contaminants such as ptaquiloside, caudatoside, gramine, sparteine, while for other compounds e.g. jacobine N-oxide, senecionine N-oxide further investigations involving more advanced treatment options are needed.
This work has been published in Water Research Journal, Volume 205. This research project is a part of European Training Network - NaToxAq, which is funded by the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 722493**.**

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Pesticide removal using microbes

Julie. B. Jensen**, Danish Technological Institute*, L. Tang, Danish Technological Institute**, S. Musovic, Danish Technological Institute, E. K. Jensen Danish Technological Institute****, P. F. Dürr Danish Technological Institute*****,*

Abstract

The ongoing occurrence of pesticides in drinking water is very problematic in Denmark and internationally. The problem is urgent and needs to be taken care of to ensure clean drinking water for the consumer. Waterworks use sand filtration to remove unwanted particles from the water, where naturally occurring pollutants such as NH4, Mn etc. easily gets removed using chemically and biologically methods. The current project aims to remove pesticide residues from drinking water using the natural microbes with unique pesticide-degrading capabilities. The main focus is on natural bacteria, which carries the abilities on natural plasmids, that can be transferred to native microbes in sand filters, thereby establishing filterers naturally capability to remove pesticides.

The project run both lab-scale and pilot scale experiments, with columns filled with fresh sand from sand filters at chosen waterworks, and with drinking waters running though the sand filters.

For laboratory studies, columns were set up with fresh collected sand from an established sand filter. To the sand, we induced the model strain *Pseudomonas putida KT2442* containing RP4 plasmid, a broad-host range IncP plasmid. Column one contained clean sand and three columns contained fresh collected sand from Hillerød waterworks. Sand samples were collected over 4 weeks, DNA was extracted, and strain and plasmid selective qPCR was performed to estimate the survival of the introduced strain and the spreading of the plasmid in the sand filter columns, respectively.

A pilot scale experiment was set up at Herning waterwork. Sand from two waterworks were transported to Herning and implemented as a part of the pilot scala experiments, where columns containing 90-95 % sand from Herning were seeded with fresh sand from the mentioned waterworks (sand transplantation trail). These waterworks were selected based on previous lab-findings, showing a biological removal of pesticides. In addition, two columns with sand from Herning were inoculated with MCPP-degrading isolates (pure-culture trial). Water containing MPCC (1,0µg/L) was lead through the columns and samples from each column were periodical taken.

Results from the laboratory studies indicated that the introduced host bacteria can survive and multiply in sand columns that contained fresh sand from a sand filter but could very poorly survive in the column containing clean sand. This suggests that the host bacteria preferred establishment in an already existing, and well-established biofilm on the sand corn from sand filter, over the possibility of creating biofilm itself in the clean sand. The number of plasmid-copies followed the pattern of host bacteria present in columns, making it difficult to distinguish between the survival in the host and the transferred plasmids to the native microbes on the sand.

The preliminary results from the pilot scale experiment indicate that the introduction of pure-culture MCPP isolates and sand transplantation trials significantly increase the MCPP removal in the columns.

The laboratory and pilot scale trials suggested that the model strain bacteria P putida (RP4) in the lab trials, and the introduced MCPP isolates in the pilot trials, could respectively get well established the pre-existing microbial environment and increase the pesticide removal rate in the sand columns. This suggests that the overall biological pesticide removal capabilities can be added to the existing sand filters at waterworks.

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Advanced Water treatment for N, N dimethylsulfamid (DMS) in drinking water using the AOP based RemUVe technology - is it possible?

***Martin Bymose**, DGE*, Peter Lysholm Tüchsen, Novafos*

Introduction:

In Denmark and especially in Novafos operation area the pesticide N, N Dimethylsulfamid (DMS) is becoming an increasingly crucial problem. It´s getting more and more difficult to find new areas with groundwater not affected by DMS and pesticides in general. In the summer 2020 a pilot test was conducted with RemUVe technology showing promising result regarding removal of DMS from the drinking water. Based on the good results from the pilot test, Novafos, together with DGE, Insatech launched a 6 weeklong survey of effects of using the water treatment technology RemUVe to remove DMS.

Methods and data:

The RemUVe technology uses a special UV light system and H_2O_2 to create an advanced oxidation process, where hydroxyl radicals together with energy from the UV light remove DMS, and other contaminant from the water stream.

Result:

The system ran for a period of 48 days and was set to continuously reduce DMS content from 0,06 µg/l to 0,025 µg/l. There was on-going sampling to document the effect of the treatment. The pilot test was very successful with very good results and the technology showed robustness.

Discussion and take-home message:

Based on the good results from the 6 weeklong surveys, Novafos has invested in a full-scale mobile treatment unit placed in a container and have done a series of different test, so this AOP technology can be further evaluated both technical and financial as a possible solution to maintain the usage of the water resource even thug effected by DMS. The results from Novafos´s series of test will be presented at the DWF congress.

The treatment unit

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Effective fluorine elimination of PFOA by ultrasound

Xingaoyuan Xiong*, *Zongsu Wei*****, *Centre for Water Technology (WATEC), Department of Biological and Chemical Engineering, Aarhus University*

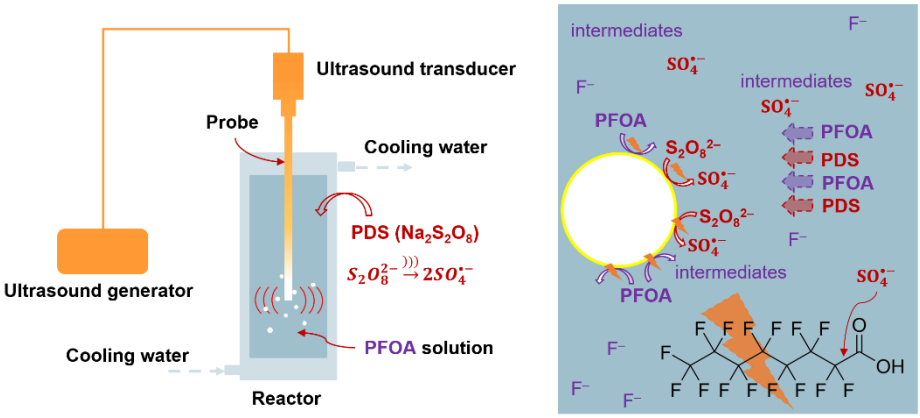
Abstract

Introduction: Per- and polyfluoroalkyl substances (PFAS) are highly persistent, bioaccumulative, and potentially toxic in the aquatic environment. Although ultrasound (US) and sulfate radical ($SO_4^{\bullet-}$) both have been demonstrated to effectively degrade PFAS, there is a lack of solid evidence to elaborate on how defluoridation reactions proceed under US irradiation. In this study, perfluorooctanoic acid (PFOA) was irradiated by US-persulfate (PDS, $Na_2S_2O_8$ converted $SO_4^{\bullet-}$) to determine the defluorination mechanism.

Methods and data: Experiments were carried out in a cylindrical, water-jacketed glass reactor equipped with an ultrasonic homogenizer (sonicator)with the probe immersed in solution. The fluoride and PFOA concentrations in samples were measured by IC and UHPLC/MS, respectively. The PDS concentration was detected by a spectrophotometric method using potassium iodide (KI). A Langmuir-type model was used to describe the PFOA and PDS approach and adsorption behavior on the cavitation bubbles.

Results: US can lead to almost 100% degradation and 90,06% defluorination. However, the addition of PDS to the US system was not conducive to PFOA defluorination; the higher the PDS addition, the lower defluorination was observed, with only 33,84% defluorination at 10mM PDS dosage. A free radical quenching experiment with methanol showed that $SO_4^{\bullet-}$ did not change the PFOA defluorination in US/PDS process, which agrees well with the observation that US alone had better PFOA defluorination performance than the US/PDS system. . The calculated results based on the model showed a 49,47% decrease of the pseudo-rate constant (k) and a 46,46% decrease of the equilibrium constant (K) of PFOA on the cavitation bubble interface when PDS concentration was increased from 1mM to 10mM.

Discussion and take-home message: US can efficiently break the C—F bond of PFOA but the addition of PDS hindered this process. PDS concentration measurements indicated that the PDS was consumed to form $SO_4^{\bullet-}$, which played a negigble role in PFOA defluorination; UV/PDS experiments and the $SO_4^{\bullet-}$ quenching experiments further supported this explanation. The reduced K values demonstrated that the US energy was consumed by the process of PDS activation to $SO_4^{\bullet-}$, thus reducing the energy available for breaking the C—F bond. The reduced k values suggested that the presence of PDS prevented PFOA molecules from approaching cavitation bubbles. In conclusion, US is a promising technology for PFOA defluorination. However, the method of introducing free radicals (e.g., $SO_4^{\bullet-}$) does not strengthen the US performance nor pollutant removal efficiency.



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Effect of early biofilm formation on water quality during commissioning of new PE (polyethylene pipes) at Mosevangen, Aarhus, Denmark

Torben L. Skovhus**, D.A. Søborg & Francisca S. Braga, VIA University College*, B. Højris, GRUNDFOS Holding A/S
*K.L. Hansen & K. Brinkmann, Aarhus Vand A/S****

Biofilm is considered beneficial in the non-chlorinated Danish drinking water distribution systems as it increases the microbiological stability of the water. During commissioning of new pipes in the distribution network, biofilm will start to develop on the new pipe wall being influenced by numerous factors, such as the water quality, pipe material, flow velocity and existence of biofilm upstream. At this early stage of biofilm formation, before a mature biofilm is reached, the development of biofilm may negatively impact the water quality. However, this short-term effect of biofilm during the commissioning phase of newly installed pipe sections remains poorly understood.

In this study, measurements of microbiological water quality parameters (HPC, ATP, qPCR, etc.), upstream and downstream of a newly commissioned PE pipe, showed a clear effect of early biofilm formation on the water quality. In general, high bacterial counts (HPC 22°C =870 CFU/mL) but a low microbiological diversity (Shannon index 2,3) was observed during the first 10 days of pipe commissioning. After approx. 20 days, the bacterial counts and the diversity approached the same levels as the upstream samples (HPC well below the drinking water criterion of 200 CFU/mL and a Shannon Index of approx. 5). Optimizing the commissioning procedures will therefore be of benefit to the utility and the consumers. Further, it highlights the importance of obtaining and maintaining a stable, natural biofilm in the pipes of the non-chlorinated system, improving the water quality for the consumers.

More studies in this area are carried out in the newly funded MUDP project (Functional PE pipes with beneficial biofilm for decomposition of material monomers in the drinking water system), where we will investigate if the biofilm constitute a natural barrier for some monomers from PE pipes and if the biofilm can degrade these compounds. A brief overview of the new project will be presented.

Keywords: Biofilms, Drinking water distribution systems, Polyethylene pipes, Commissioning Guidelines

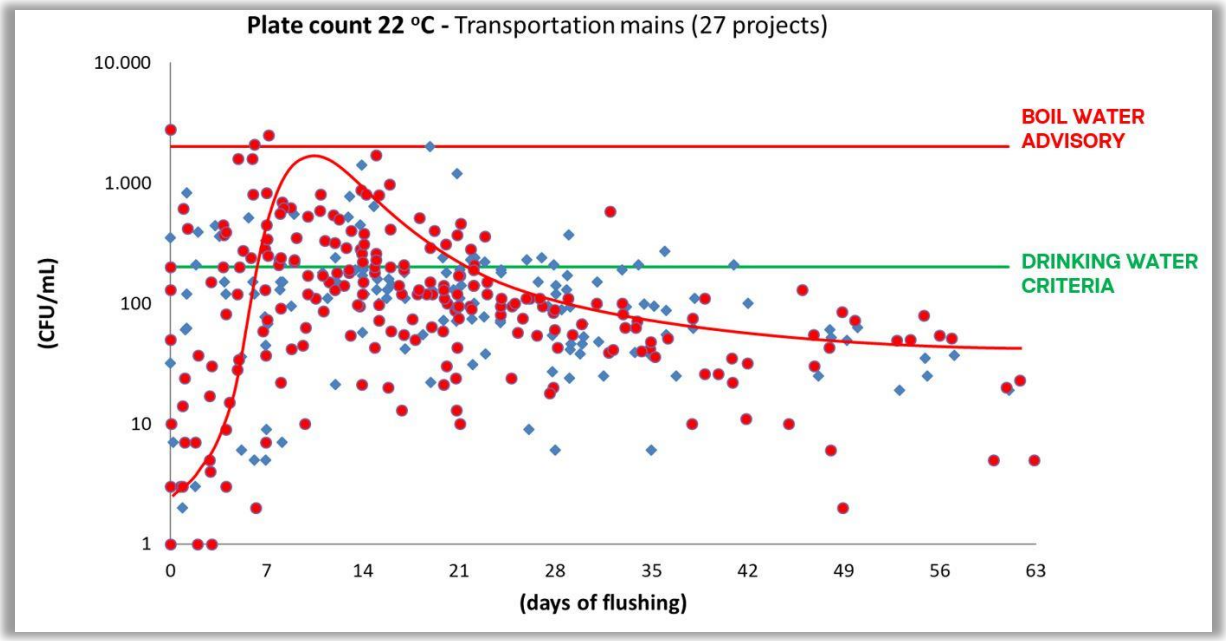

Figure: HPC at 22°C from previous measurements from Aarhus Vand, where it is possible to observe a peak between day 7 and 20.

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Some observations on Danish drinking water mineral composition

***Martin Rygaard**, DTU Environment**

Danish drinking water composition varies considerably across the country. It is well known that drinking water minerals affect our health, water installations, the environment and taste. This presentation provides a selection of insights from an evaluation of the national variance in drinking water mineral composition. The findings are related to effects on our wellbeing and economy. The evaluation covers 2641 Danish waterworks. I used the latest extended water sample (da: udvidet prøve) extracted from GEUS´ Jupiter database in July 2020 to calculate potential health effects and a range of corrosion indices. Calcium carbonate precipitation potential (CCPP) was calculated using PHREEQC.

Interestingly, 40% of the water works delivered water with negative CCPP at 10°C assuming no contact with atmospheric CO_2 (closed system) (Figure 1). Theoretically, a negative CCPP means that the water will dissolve $CaCO_3$ to achieve equilibrium. This is surprising, considering that the *Danish statuary order on drinking water and authority on water supply facilities* (BEK nr 1110 af 30/05/2021) requires drinking water to be non-aggressive towards calcium carbonate. On the other hand, the finding is confirmed by a strong correlation with a manually calculated Langelier saturation index (LSI) for all water works.

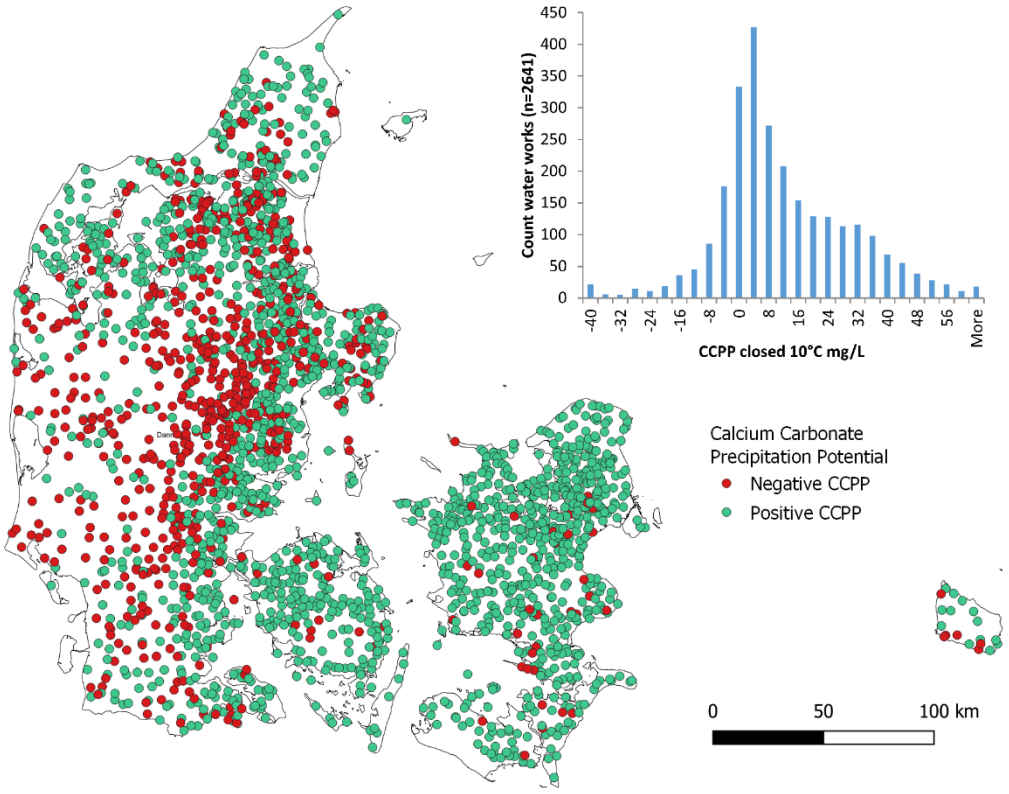

Figure 5. Distribution of CCPPs in the effluent of 2641 Danish water works (histogram) and geographic location of negative and positive CCPP values (map). Negative CCPP is indicative that the water is aggressive towards calcium carbonate.

Other parts of the evaluation highlight the substantial trade-offs that are *de facto* accepted in Danish water supply and which varies substantially across the country with potential implications for dental health, childhood eczema and more. Although health and corrosion implications are being discussed in relation to softening of drinking water, effects can be varying in the same way across the country and caused by the natural groundwater quality. Perhaps, it is about time that we revisit our interpretation of Danish drinking water quality as one uniform and superior water source?

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Session 4: Urban water and Climate Change

Time: 15:15 – 17:15
Chair: Ole Mark, Krüger
Auditory 2

Time	Speaker	Topic
15.15	Cristina Cvitanich	Elimination of H2S in seder systems using data driven electrocoagulation
15.30	Pedro Carvalho	Treatment of organic micropollutants by nature-based solutions: one of the scopes of the MULTISOURCE project
15.45	Kristine Engemann Jensen	Water or waste - Integrating biodiversity and communities towards urban sustainability in South Africa
16.00	Alba Martinez I Quer	Constructed wetlands for the treatment of cyanotoxins: Initial results
16.15	Zhenyu Yang	Management of microplastics in urban aquatic systems using vortex-based cyclone separation: what we learn from de-oiling hydrocyclone technology used in offshore oil & gas produced water treatment
16.30	Song Wang	Electrochemical and Microbiological Response of Exoelectrogenic Biofilm to Polyethylene Microplastics
16.45	Fenjuan Rose Schmidt Hu	Going beyond data-centric—digital models for water cycle management and water facilities
17.00	Solvei Mundbjerg Jensen	Evaluation of seasonal dynamics in the water balance and vegetation for an evapotranspirative willow system

Elimination of H_2S in sewer systems using data driven electrocoagulation

Cvitanich, Cristina[1]; Christensen, Morten L. [1]; Jørgensen, Mads K.[1]; Nielsen, Asbjørn[1];; Lindholst, Sabine[2]; Andreasen, Rune R.[3]; Karlson Kim P.[4]; Hansen, Lasse[5]; Støvring, Jonas[6].

Introduction: Hydrogen sulfide (H_2S) is a poisonous and corrosive gas, which is produced by anaerobic microorganisms. Trace amounts are enough to give the characteristic odor of rotten eggs. Problems with H_2S are commonly associated with pumping wastewater in force mains. Ninety-five percent of the wastewater utilities included in a survey performed by DANVA and Grundfos in 2017 responded to have challenges with H_2S. This gas causes corrosion of concrete sewer pipes and gives rise to odor complaints. The challenges with H_2S are expected to increase in the future because of the centralization of wastewater treatment plants and the separation of rainwater from wastewater.

Iron salts can be used to precipitate sulfide and form ferrous sulfide (FeS) or elemental sulfur. There are two major issues associated with the use of iron salts for sulfide control. Ferric salts are highly acidic and therefore their transport and handling are associated with occupational health and safety concerns. Furthermore, ferric salts will reduce the pH in sewage, which reduces the FeS precipitation efficiency and will require the addition of surplus iron, increasing the cost of the treatment. The lower pH will shift the equilibrium from the dissolved HS^- to the volatile H_2S, and with inadequate dosage can lead to increased corrosion and odor.

According to a report from Silkeborg Forsyning (2020), an average of 5 kg sulfide was produced per day at a single location (Voel-Gjern-Fårvang). It took 415 liters of 25% iron(II) sulfate/day to control sulfide at this location.

Methods and data: This project will develop an alternative to the addition of iron salts using electrocoagulation to produce Fe^{2+} at the affected locations.

Our calculations indicate that the neutralization of 5 kg of sulfide will require approximately 17,4 kg of iron and 33 kWh per day. With an estimated cost of 6 kr/kg iron and 1,54 kr/kWh, the solution leads to an annual cost of approximately 57,000 kr. Using the same amount of iron, in the form of iron(II)sulfate will result in an annual cost of 63,300 kr. Both prices are excl. transport. For iron(II)sulfate an estimated price of 0,50 kr/kg for a 25% solution was used.

Laboratory experiments are currently being performed to measure Fe^{2+} production and electrode mass loss, pH change and H_2S removal efficiency.

Results: According to our calculations, the chemical cost of controlling sulfide could be reduced with approximately 10 %.

The advantages of the method are that only iron will be added using this process and the pH of the water will be slightly increased, shifting the equilibrium toward HS^- and increasing the efficiency of the precipitation process.

In addition, the generation of iron can be automatically controlled using real time data from H_2S sensors placed at strategic locations. The energy required for the electrocoagulation can be provided by local placed solar cells, making this approach available to remote locations.

Discussion and take-home message: Electrocoagulation has the potential to reduce the cost of controlling H_2S. It is expected that the dosage can be automatically controlled using H_2S sensors to reduce environmental impact and cost.

1-Aalborg University, 2- Teknologisk Institut, 3- Silkeborg Forsyning, 4- Sulfilogger A/S, 5- AL-2 Teknik A/S, 6- Mariagerfjord Vand.

Treatment of organic micropollutants by nature-based solutions: one of the scopes of the MULTISOURCE project

Vaidotas Kisielius, *AU-ENVS*, K. Bester, AU-ENVS and AU-WATEC**, C.A. Arias, AU-Bio and AU-WATEC***, Pedro.N. Carvalho, AU-ENVS and AU-WATEC*****

Abstract

Introduction: MULTISOURCE is a newly funded H2020 project exploring ModULar Tools for Integrating enhanced natural treatment SOlutions in URban water CyclEs. Nature-based solutions are high on the EU political agenda and also under intense research. MULTISOURCE aims to i) demonstrate seven Enhanced Natural Treatment Solutions (ENTS) for a wide range of urban waters, and ii) through a co-creation approach, develop innovative tools, methods and business models that support the implementation of such solutions. These include citywide planning, financing or long-term operations and maintenance of nature-based solutions worldwide.

In terms of technology development, there is a strong focus on water treatment, storage and reuse in urban areas. The project will deliver new knowledge about the ENTS, their ability to remove waterborne contaminants and provide effective risk reduction for chemical and biological hazards. It will also investigate the ENTS capacity to be integrated into the landscape and contribute to the improvement of urban habitats.

One of the major research topics of the project is to assess the capacity for the different ENTS pilots to treat organic micropollutants. To create a baseline scenario of potential water reuse for all ENVS pilots, we will investigate their efficiency for removal of pathogens, priority substances and contaminants of emerging concern, including microplastics. This will provide an assessment of the occurrence and fate of emerging contaminants, as well as allow to perform risk assessment within and beyond the current regulatory framework.

Methods and data: The team from Aarhus University (AU) here represented is responsible for coordinating the piloting activities, as well as characterizing the removal of persistent and emerging organic contaminants. The project includes seven pilots by INRAE (France), Rietland (Belgium), IRIDRA (Italy), MSU (USA), ICRA (Spain), NIVA (Norway) and UFZ (Germany), treating different types of wastewater, greywater, combined sewage overflow, road run-off and rainwater. Each partner will be responsible for sampling and basic water quality analysis. We at AU will perform suspect-screening and target analyses to characterize the organic micropollutants in the influent and effluent waters, as well as overall performance of all pilots. Results will be further used for the planned risk assessment analysis by NIVA (Norway).

Results: The first months have been dedicated to the development of a harmonized monitoring plan that ensures the comparability of the different ENTS systems and tailored approach for each pilot and its specificity (e.g. type of water, operation, seasonality, compounds of relevance). For the comprehensive monitoring plan, AU has developed the MULTISOURCE suspect list comprising 300 different compounds of relevance for which we will validate their presence or absence in the different waters and regions. For the quantitation of the organic micropollutants, two major target lists for wastewater and urban run-off were designed, for which several different analytical methods are currently being implemented. Before the end of this year, we expect to receive the first samples for method verification and performance of the first screening tests. We expect to show these first results at the DWF Conference.

MULTISOURCE

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Water or waste? Integrating biodiversity and communities towards urban sustainability in South Africa

Kristine Engemann, Ida Breed, Peta Brom, Titilope Onaolapo, Jens-Christian Svenning & Maya Pasgaard

Introduction: Rapidly expanding disintegrated urban areas in developing economies are presented with social, climatic, and ecological challenges. Green infrastructure (GI) offers a sustainable planning approach that integrates water-related benefits and socio-economic gains into cities' ecological fabric to improve the functioning of urban ecological systems and the quality of public spaces for greater environmental health and social well-being. Despite strong evidence of multiple benefits of GI, many research studies fail to integrate environmental justice perspectives and contributions from developing countries are lacking. This project focusses on South Africa (SA) which faces challenges from current climate change and rapid urbanization leading to an increasingly warmer and drier country with unpredictable precipitation patterns increasing droughts and flooding events. In SA, urban GI has the potential to deliver practical solutions to storm-water attenuation and alleviate heat island effects, while playing a valuable role in improving the quality of life and socioeconomic opportunities for vulnerable communities. Through an interdisciplinary, trans-national research collaboration we aimed to improve GI management, multifunctionality, and planning in City of Tshwane (CoT), South Africa. Specifically, we investigate how spatial information from geographic information systems (GIS) tools and remote-sensing data can be combined with local narratives and social-structures from surveys to guide city planners towards achieving locally relevant multifunctional GI benefits that supply more ecosystem functions and services for both hydro-ecological and socio-economic benefits.

Methods and data: Two study sites (Atteridgeville and Mabopane) were chosen for investigating the planning, management, multifunctionality, and justice of GI in CoT through a joint screening on the needs of the local stakeholders communicated through local municipal partners from CoT. Both areas are settlements that were marginalized under the Apartheid regime and are in need for intervention due to challenging infrastructural and socio-economic conditions. Obtaining a detailed spatial overview of the GI of each neighbourhood will increase the ability to efficiently manage GI and deliver multifunctional benefits, such as flooding, climate control, biodiversity protection and human health, to a greater percentage of citizens. The spatial overview came from satellite-based Earth observations (remote sensing) and GIS tools. Field work was conducted in October 2021 for both field sites using field protocols co-developed with CoT partners and across research disciplines within the research team. Ground-truthing of remote sensing data was combined with qualitative and quantitative surveys to analyze access to GI benefits from both spatial and justice perspectives, offering new knowledge on physical access requirements as well as on the social structures shaping people's ability to gain from GI.

Results: Initial remote sensing mapping and fieldwork show that both study sites could deliver climate, ecological and health benefits. Both areas are habituated with diverse native plant and animal biodiversity and contain rivers that ensure hydro-ecological functionality. The rivers could also allow for flooding alleviation in the areas already threatened by future climate change and increased precipitation, but flooding dynamics are hindered by channelling and waterway obstructions. Furthermore, both rivers are polluted from faulty infrastructure and illegal dumping, which discourages peoples' use of the area and extraction of water resources and threatens local biodiversity.

Discussion and take-home message: Our results show the great potential of marginalized green spaces in terms of delivering multifunctional benefits in line with the United Nations' Sustainable Development Goals for better health and well-being (SDG3), sustainable cities and communities (SDG11), climate action (SDG13), biodiversity protection (SDG15) and stronger justice and institutions (SDG16). To fully optimize such sites interdisciplinary and cross-institutional collaboration with multi-level inclusion of stakeholders is needed.

Constructed wetlands for the treatment of cyanotoxins: initial results

Alba Martínez i Quer**, AU-ENVS*, A. Johansen, AU-ENVS and AU-WATEC**, C.A. Arias AU-Bio and AU-WATEC ***, P.N. Carvalho, AU-ENVS and AU-WATEC

Abstract

Introduction: Events of drought and higher temperatures are occurring more often. This, together with the increased use of fertilizer in agriculture, are leading to environmental eutrophication and shortage of freshwater reservoirs. Eutrophication of our water bodies can lead to several disrupting events such as Harmful Cyanobacterial Blooms (HCB) that can release natural occurring pollutants such as cyanotoxins. Globally, more than 70% of water used for agriculture is groundwater and surface water. However, irrigation water-quality standards suffer from a lack of regulation worldwide. When episodes of water scarcity occur, vulnerable communities may be forced to irrigate their crops with cyanotoxin-polluted water. Consequently, indirect or direct human consumption of cyanotoxins happen, which may lead to several cytotoxic pathologies.

We propose the application of vertical flow (VF) constructed wetlands (CWs) as a biotechnology to treat water for irrigation. The hypothesis is that VF systems can remove cyanotoxins while preserving the nutrients from the eutrophic water. Although initial studies suggested CWs to be a suitable technology, in this respect, the mechanisms underlying cyanotoxins removal are still unknown. Our hypothesis is that members of the native microbiota are responsible for degrading the cyanotoxins.

Methods and data: We set up thirty-two 12-L unsaturated VF-CW systems with three different treatments: 1) gravel vs. Sand; 2) *Phragmites australis* vs. *Juncus effusus,* and 3) presence vs. absence of cyanotoxins. Synthetic water mimicking eutrophic surface water (containing 10 µg/L of microcystin-LR and cylindrospermopsin) fed the mesocosms systems. We are currently measuring end-point quality water parameters (TOC, TN, pH, cyanotoxins concentration), and characterizing the microbial community using 16S Amplicon DNA sequencing to see how the community is responding to the treatments, seasonal change and degradation efficiency.

Results: After almost one year of operation, several variable co-relations were found that explained the cyanotoxin removal in our systems. Besides, initial data on the microbial community structure will be discussed at the conference.

Discussion and take-home message: Data is still preliminary, but we hope that by the end of the project we can demonstrate how CWs can alleviate cyanotoxin contamination in surface waters for the benefit of human and animal health, including the mechanistic understanding of the biodegradation process.

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Management of microplastics in urban aquatic systems using vortex-based cyclone separation: what we learn from de-oiling hydrocyclone technology used in offshore oil & gas produced water treatment

Zhenyu Yang**, Dennis Severin Hansen, Stefan Jespersen, AAU Energy* Jes Vollertsen, Fan Liu, AAU Build

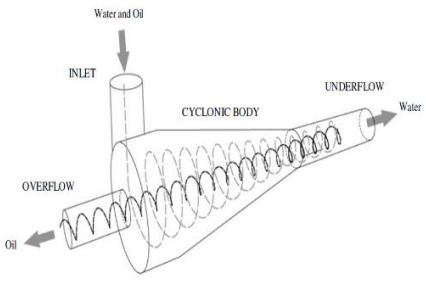
Introduction: Microplastic (MP) pollution is an emerging environmental and public health concern worldwide. Handling the increasing plastic waste is urgent due to its low degradation capabilities and potential toxic additives/adsorptions. The Waste Water Treatment Plants (WWTPs) are considered as the main source of MPs in the urban aquatic environment, though some research discovered that over 98% MPs in Danish WWTPs has been removed from the effluent water. Nevertheless, most of the removed MPs is settled in the sludge stream, which still put an risk on the environment as the 80% of the sludge are eventually recycled to land following the regulation on reusing sludge (biosolids). Another challenge correlated to MPs in urban aquatic systems is the management of stormwater handling systems. Besides potential human threads and economic losses, heavy rainfall also invokes potential pollution problems when the spiking volume is beyond the handling system's capability and/or the retention time is significantly decreased. Some research has already discovered that MP debris and fibers due to tire wear-out account for over 50% of micropollutants in urban runoff systems.

The ideal solution in handling MPs in an aquatic system is to collect them and send them into a plastic recycling loop. The popularly used sedimentation method often requires a long retention time, which can directly limit its capability, and this method also suffers from settling MPs in sludge. The filtration-based method often requires a large installation footprint and needs to frequently cope with the notorious fouling problem, which can lead to high correlated OPEX and CAPEX. Due to the situation that the understanding of characteristics, resources and fates of MPs in aquatic systems are still quite poor, some chemical- or bio-based separation technologies in principle are not recommended, in order to avoid inducing any unexpected negative side-effect(s).

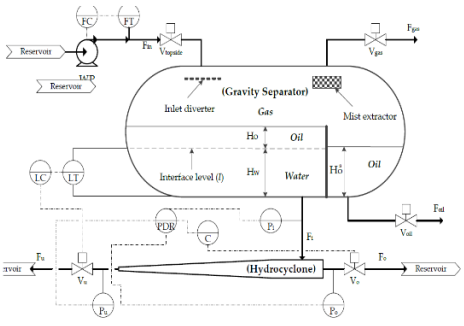
Methods and data: This work aims to prove the feasibility that MPs in the urban aquatic systems can be cost-effectively collected using a controlled vortex-based cyclone system. As a typical physical separation method, the vortex separation uses the centrepedal force generated from the dedicated mechanical design and hydrodynamical control to separate different media according to different densities. Though this is a proof-of-the-concept project, many experiences and knowledge learned from the usage of de-oiling hydrocyclone technology in offshore oil & gas production can be adapted for handling MPs in urban aquatic systems.

Results: We will report some of our research achievements in applying advanced control and monitoring technologies for optimizing the de-oiling hydrocyclone system in oil & gas production. Then we will discuss how this technology can be adapted to handle aquatic MPs, and possibly with some preliminary testing and analysis results.

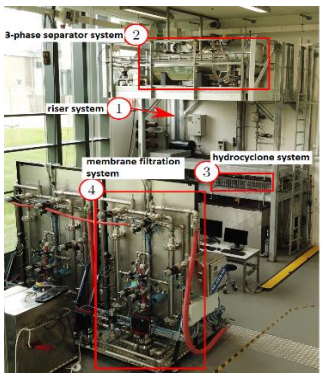
Discussion and take-home message: MP recovery, vortex-based separation, MP analysis and quantification



Single hydrocyclone configuration



Hydrocyclone coupled with separator and controls



AAU water treatment pilot-plant

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Electrochemical and Microbiological Response of Exoelectrogenic Biofilm to Polyethylene Microplastics

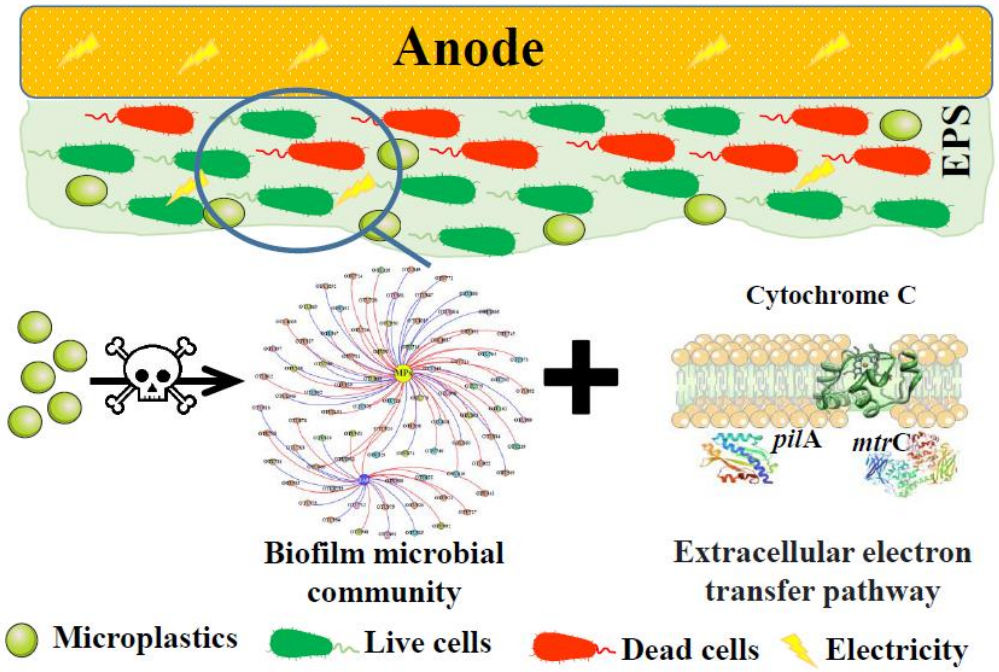
Song Wang[a], *Mingyi Xu*[b], *Yifeng Zhang*[c]

Introduction: Polyethylene (PE) microplastics are a widespread pollutant in various aquatic environments and wastewaters. Exoelectrogenic biofilm and the associated microbial electrochemical processes have recently been intensively studied for water treatment, but their response to and interaction with PE microplastics has never been reported. In this study, we investigated how and to what extent PE microplastics would affect the electrochemistry and microbiology of exoelectrogenic biofilm in two typical microbial electrochemical systems, including microbial fuel cells (MFCs) and microbial electrolysis cells (MECs).

Methods and data: The EPS were characterized with excitation-emission matrix (EEM) fluorescence spectroscopy. The viability of the biofilm on the carbon brush was observed using the Confocal Laser Scanning Microscopy (CLSM) (Leica TCS SP5, Germany). The electron transfer-related genes were quantified in triplicate through a real-time quantitative PCR detecting system including *pil*A, and *mtr*C.

Results: When the PE microplastics concentration was increased from 0 to 75 mg/L in the MECs, an apparent decline in the maximum current output (from 1.99 to 0.74 A/m2) and abundance of electroactive bacteria (EAB) in the exoelectrogenic biofilm was noticed. While in the MFCs, the current output was not significantly influenced. The EAB abundance in the biofilm was even slightly increased in the presence of 25 mg/L PE microplastics. In addition, PE microplastics restrained the viability of the exoelectrogenic biofilms in both systems, leading to a higher system electrode resistance. The dead cell ratio increased from 31.66 ± 1.24 % and 37.50 ± 0.65 % to 49.72 ± 0.34 % and 49.15 ± 3.22 % in MFC and MEC, respectively. Furthermore, the general microbial community richness and the microplastics-related operational taxonomic units decreased with the increase of PE microplastics. The quantitative PCR analysis showed the electron transfer-related genes (e.g., pilA and mtrC) and cytochrome c concentration decreased after adding microplastics, implying the suppression of the extracellular electron transfer.

Discussion and take-home message: The presence of microplastics in aquatic environment would influence the not only the environment process but also the biological performance. This study provides the first glimpse into the influence of PE microplastics on the exoelectrogenic biofilm with the potential mechanisms revealed at the gene level, laying a methodological foundation for the future development of efficient water treatment technologies.



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Going beyond data-centric—digital models for water cycle management and water facilities

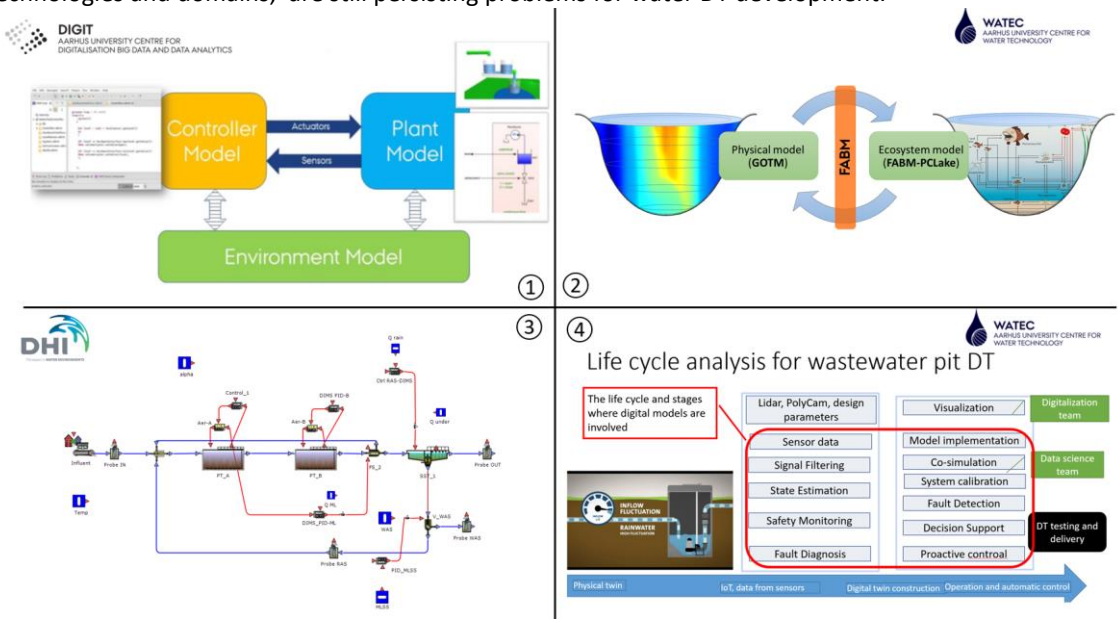
Fenjuan Rose Schmidt Hu**, WATEC, Aarhus University*, Hugo Daniel Macedo, DIGIT, Aarhus University**, Enrico U. Remigi, DHI-Group A/S *

Introduction: Initiated from the cyber-physics field, Digital Twin (DT) technologies have huge potential in today's water resource management and water facilities [1]. With today's data-centric digital solution at water sector, a basic version of DT is integrated in the natural and urban water cycle [2]. However, a full realization of a DT requires additional advances and smartness to the running systems. Barriers such as data quality and safety, as well as the technology gaps between different fields, are delaying the advances of water DT development. Among these barriers, one posing problem is the lack of knowledge-centric solutions in existing digital solutions. Knowledge-centric solutions, such as mechanistic models and statistic models which conveying abundant field knowledge, are essential part of water DT development. Since many prior knowledges are hard to encapsulate in the data repositories or to use directly in the running digital platform. Therefore, knowledge-centric models should be involved from initial operation of the DT, and the life cycle management of DT. Combined with current data-centric digital water platform, digital models in water DT will assemble the domain knowledge acquired over the last century, and to generate new values from data-centric solutions. This step will further improve the full realization of water DT, which will further reduce operational cost, mitigate the climate change impact on water resources, and to optimize water efficiency for whole water cycle.

Methods and data: We present the conceptual diagram of digital models for water DT, enriched by 3 examples of digital models in water management and water facilities: 1) a lake ecosystem model, currently applied in natural water resources management; 2) a process model for a digitally controlled pilot plant for a municipal wastewater treatment and 3) diagram for key technologies and life cycle analysis for a wastewater pit DT.

Results: 1) The aquatic ecosystem models for the natural water resource management is useful tool regarding water quality, ecosystem services, and mitigating climate change impact on natural water systems; 2) The model-based DT of the pilot WWTP allows for a more efficient online regulation of the system; 3) The functional DT system for wastewater pit provides additional functions for water regulation and cope with increasing storm whether events.

Discussion and take-home message: 1. Water DT is the next generation of digital water solutions; 2. The digital models are key parts of water DT; 3. Digital models are great tools channelling domain knowledge and field knowledge into water DT; 4. Other foreseeable challenges of water DT, such as data safety and quality, gaps between different technologies and domains, are still persisting problems for water DT development.



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[1] Agnethe Nedergaard Pedersen, Erfaringsudveksling i Vandmiljøteknikken, nr.3, 34. årgang, September, 2021, p16-19.

[2] Hugo Daniel Macedo, Digitale tvillinger i vandsektoren, Erfaringsudveksling i Vandmiljøteknikken, nr.3, 34. årgang, September, 2021, p12-15.

Evaluation of seasonal dynamics in the water balance and vegetation for an evapotranspirative willow system

Solvei M. Jensen*, *D. Isteniča***, P. Gregersen***, H. Brix*, and C.A. Arias**

Introduction: Evapotranspirative (ET) systems are decentralised nature-based wastewater treatment solutions with zero-discharge and therefore fulfils the most stringent discharge requirements. The systems are designed and dimensioned so that all the influent water to the system, namely wastewater and precipitation, is lost via evapotranspiration, i.e. the combined process of evaporation from surfaces and transpiration from vegetation. Therefore, it is imperative to ensure correct dimensioning to avoid overflow during the cold season, when water is stored, until onset of the vegetational growth period, but also to avoid system over-dimensioning that would lead to unnecessary construction costs and cause limited and impaired vegetation growth. The main objective of this study was to i) measure seasonal variation in the water balance, i.e. in-/outside system precipitation, wastewater inlet and in-system water level, ii) measure seasonal variation in the vegetation, i.e. Leaf Area Index (LAI), leaf stomatal conductance and biomass production, and last iii) evaluate the recommended system dimensioning in Denmark.

Methods and data: The willows system is located in south-central Jutland and has been operating for 10 years, treating wastewater from a single household (4 PE). Climatic data have been collected from 23 climate stations installed in three transects spanning in-/outside system as well as from the nearest official DMI weather station. The water level in the bed has been measured with 5 level loggers installed in the system. The water use was available online from the water utility. The vegetation data was collected during the growing season of 2020.

Results: A selection of the results have been included in figure 1. A seasonal variation in the LAI was apparent with the maximum LAI measured in mid-July (figure 1, a). The harvested biomass varied in-between rows (A-F) with row A producing the most biomass, and likewise there was differences in-between clones with Björn producing the most biomass. The system a dry mass production of 31 t DW ha^{-1} yr^{-1}. The daily parameters in the water balance have been plotted in figure 1c and an evaluation of the water balance will be performed based on these parameters.
Discussion and take-home message: The vegetation data clearly illustrated seasonal variation in the selected parameters, as expected, however, it also demonstrated large variation in-between the position of the willows and the clones used in the system. The water balance is currently being performed, however, preliminary results demonstrate that the system's bed was filled up earlier the expected based on the design recommendations.

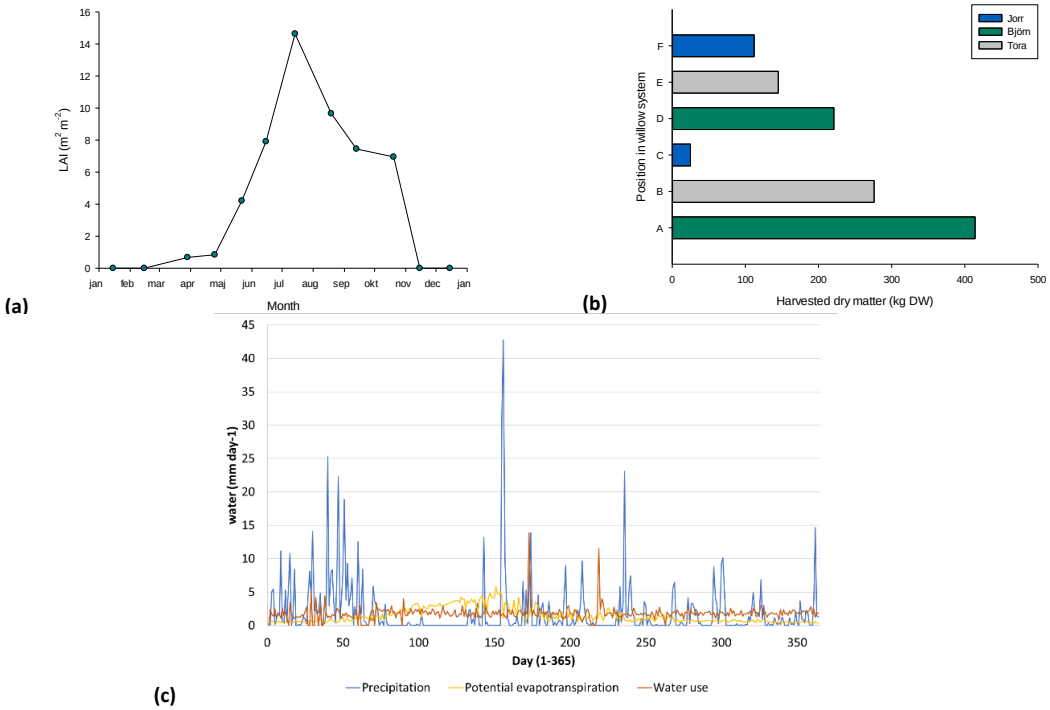

Figure 6 (a) Leaf Area Index (LAI; m^2 m^{-2}) for the system (b) harvested biomass (kg DW) based on clones and row position in the willow system and (c) Precipitation (mm day^{-1}), potential evapotranspiration (ETo, mm day^{-1}), water use (mm day^{-1}).

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Session 5: The Export strategy for Danish SME's

Time: 13:00 – 15:00

Chair: Bjørn K. Jensen, Vice-chair, Danish Water Forum and GEUS and Jesper Goodley Dannisøe, DWF secretariat.

Room 1

Sessionen er et led i Innovationsforløbet WATER TECH BOOST med deltagelse af CLEAN, DTU Water, WATEC (Aarhus Universitet), Teknologisk Institut, CALL Copenhagen (HOFOR), se https://www.cleancluster.dk/project/vandklynge-konsolidering/. Eksportfremmesessionen er det sidste af tre DWF events med fokus på offentlig og privat finansiering af forretningsudvikling i SMV.

Time	Speaker	Topic
13.00	Bjørn K. Jensen	Setting the sceen
13.10	Jeppe Falck, DI	Hvordan ser SMV'er på eksportmarkedet, og hvor ser de udfordringerne.
13.20	Ilse Korsvang, Exportforeningen	Skal vand SMV'er satse på nærmarkeder eller fjernmarkeder (Asien og Afrika) – hvad siger erfaringerne?
13.30	Søren Schou, AquaReg	Regulering som driver for eksport af danske vandløsninger
13.40	Peter Heydorn, Trade Council	Hvordan kan eksportrådet/eksportrådgiverne på ambassaderne hjælpe SMV – og på hvilke vilkår?
13.50		Discussions
14.00	Sune Kaur-Pedersen Infrastructure Finance	Er der hjælp at hente i Innovationscenter Danmark i forhold til at støtte SMV eksportinitiativer.
14.10	Lars Skov Andersen, ChinaRM	Er systemløsninger/multistakeholder konsortier en gangbar løsning for SMV til at få fodfæste på eksportmarkeder
14.20	Bjørn Kaare Jensen, DWF	Afsluttende bemærkninger.

Session 6: Groundwater resources and management

Time: 15:15 – 17:15
Chair: Anders Refsgaard, COWI and Anders Bækgaard, IWA Congress President
Room 1

Time	Speaker	Topic
15.15	Yrsa Josefina Larsson	Fate of Cyanotoxins in Treatment Wetlands: Transformation Products
15.27	Ronja Cedergreen Forchhammer	When the water rises from the ground-The relations between groundwater and sea level in Juelsminde
15.39	Rikke Markfoged	Water pre-treatment for optimization of PFAS-removal
15.51	Denys Grombacher	Updates on the Apsu Surface NMR system - Examples from Danish Field Cases
16.03	Carlos Alberto Arias	Influence of Delta-hexachlorocyclohexane (δ-HCH) to Phytophthora ×alni resistant Alnus glutinosa genotypes - evaluation of physiological parameters and remediation potential of HCH contaminated soils and waters
16.15	Henrik Madsen	Integration of Earth observation data in a global hydrological modelling and forecasting system
16.27	Klaus Hindsby	The digital European groundwater information platform – supporting the UN SDGs and the European Green Deal
16.39	Denitza Voutchkova	Natural background levels of trace elements in groundwater: concept, purpose, important factors
16.51	Tina Bundgaard Bech	Degradation of MCPA, Metolachlor and Propizonazole in the hyporheic zone of an agriculturally impacted stream

Fate of Cyanotoxins in Treatment Wetlands: Transformation Products

Yrsa Larsson, KU*, A.Martinez I Quer, AU-ENVS**, and AU-WATEC**, *C.A. Arias AU-Bio and AU-WATEC ***, A. Johansen, AU-ENVS and AU-WATEC**, H.C. Bruun Hansen, KU-PLEN*,* P.N. Carvalho, AU-ENVS*

Abstract

Introduction: Universal access to clean water is an essential sustainable development goal (SDG) due to the millions of deaths caused by hygiene-related diseases and dehydration. Cyanobacteria are formed in harmful cyanobacterial blooms and can be found in planktonic and benthic water around the world, these cause poisonous cyanotoxins. These toxins create a worldwide environmental problem as it reduces water quality, accumulate in the food chain, and cause serious health problems for humans and animals.

Advanced water treatment systems are not available everywhere in the world, in these areas an alternative system such as a constructed wetland can be both feasible and economically beneficial. Constructed wetlands have been pointed as efficient to treat cyanotoxins. During this treatment, biodegradation processes are expected to be a major process which will result in the formation of transformation products (TPs). Some organic compounds have been found to produce TPs that have a greater toxicity and are more persistent than their parent compound. We have been exploring the identification and characterization of cyanotoxins TPs. Understanding how cyanotoxins are eliminated is key to demonstrate the suitability of constructed wetland technology for implementation in vulnerable areas where there is a high risk of harmful cyanobacterial blooms.

Methods and data: Four unsaturated VF-CW systems were set up with light cycle of 14 light and 10 dark hours. All mesocosms bottoms (3 cm layer) were covered with gravel and then filled with silica filter sand (20 cm layer). The system was fed with lake water from Arresø lake for 5 months to establish a bacterial community in the mesocosms. For the time-series experiment (96 h) conducted on the system, synthetic water was then mimicked of eutrophic surface water containing 100 µg/L of microcystin-LR and cylindrospermopsin and fed with a hydraulic load of 3.5 cm/day. Samples were taken over five days to screen for TPs by non-target analysis using ExionLC Controller connected to a TripleTOF 6600 MS system (Sciex). TPs identification is being pursued using the software Metabolite Pilot (Sciex).

Results: The acquisition and processing methods for the non-target screening were optimized, and the identification of TPs is ongoing. The TP data from the time series experiment in the constructed wetlands mesocosm will be presented in the conference.

Discussion and take-home message: There are still data to process to finalize the TP screening, but we could confirm the potential to treat the cyanotoxins compounds by our recently established constructed wetland mesocosms. TPs characterization will support the demonstration of biodegradation processes and biotransformation of the cyanotoxins microcystin-LR and cylindrospermopsin.

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When the water rises from the ground
The relations between groundwater and sea level in Juelsminde

Henriette Højmark Hansen, **Ronja Cedergreen Forchhammer****, Anna Bondo Medhus, Theis Raaschou Andersen, Søren Erbs Poulsen, VIA. With support from EU life, Engell-Friss foundation and INSERO*

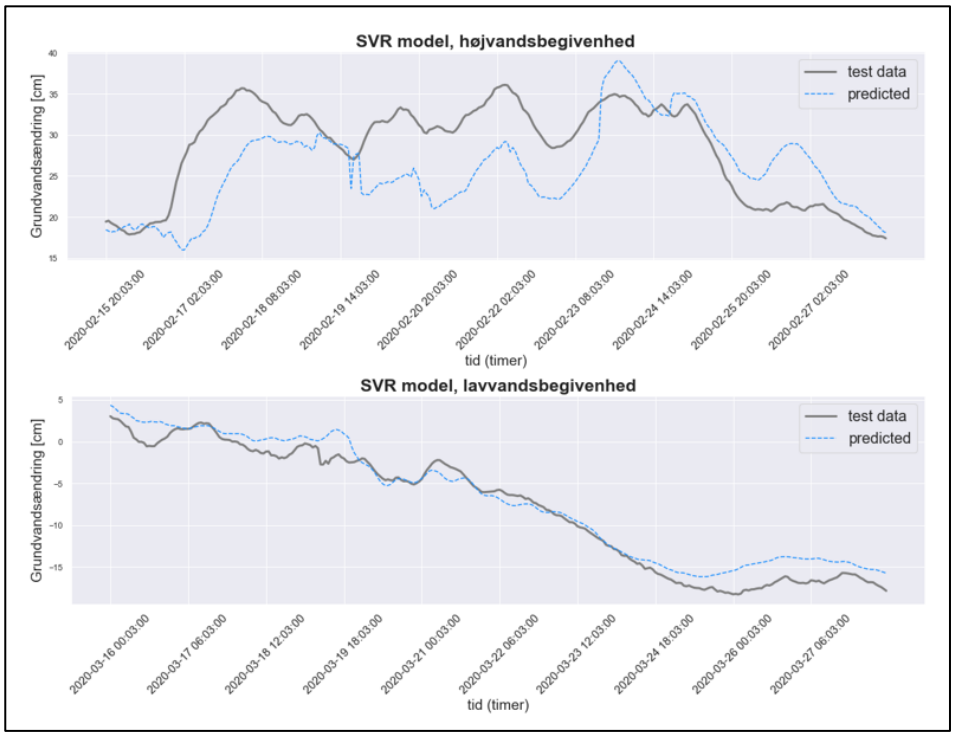
Many Danish coastal cities are threatened by climate changes. Often dikes are built in order to protect from direct flooding from the sea. When dikes are located on top of a sandy geology, high sea level may push back groundwater underneath the dike and force a flooding from below. This is case in Juelsminde, a small low lying city very prone to flooding.

The goal of this project is to examine the dynamics between groundwater and sea level in such a geology in order to obtain a model that can predict when the groundwater will flood the area. Groundwater levels in Juelsminde has been monitored by VIA University College since 2017 under the auspices of the C2C-CC project. Six groundwater loggers are installed along two profiles, three loggers on each profile. Based on this data we have examined the fluctuations of the groundwater and its connection to sea level rises. The sea level is monitored by DMI in Juelsminde harbour.

First an analysis was conducted, including 20 different elevated sea level events which were compared to groundwater level observations from the 6 loggers. As expected a systematic delay in the response inland was found. At the furthest inland location, 210 m from the shore, a lag of around 25 hours is observed. In some cases, the signal in the groundwater was hard to detect furthest inland, but closer to the ocean the signal was very clear. The decay of the amplitude of the wave signal from the sea can be described by a logarithmic function as expected but parameters vary for each event.

With confirmation that there is a relation between sea level and the groundwater level, a machine learning model was trained with the purpose of prediction. The idea is to use DMI's forecast of precipitation and sea level to predict the groundwater level inland. DMI provides weather forecasts 5 days ahead. First a comparison between different machine learning models was made. A SVR model was found to produce the best predictions. The selected code predicts the groundwater level at a logger position 24 hours after the latest input measurement.

The take home message: There is a clear connection between the fluctuations in groundwater and sea level in Juelsminde. It is possible to make a prediction 24 hours ahead based on precipitation and sea level from Juelsminde.



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Water pre-treatment for optimization of PFAS-removal

Rikke Markfoged*, S. Lindholst*, C.K Rickers*, M. Nymann**, T. Svendsen**, K. Tang***, K.M.S. Kaarsholm***, H.R. Andersen ****

Introduction:

The concern for per- or polyfluoroalkyl substances (PFAS) in our environment is increasing due to continuous new observations of PFAS-contaminated sites. PFAS was been applied widely for the purpose of adding repellent characteristics to products such as firefighting foam, water-resistant fabrics, cookware and food packaging.

Especially fire training facility sites and landfills are subjects for high PFAS concentrations. Runoff water and percolate from these sites may contain high PFAS concentrations which is, due to its persistence, distributed to recipients along its traveling, e.g. sludge in WWTS, streams, coastal areas or groundwater. It is crucial to remove PFAS upstream and as close to the source as possible.

Water contaminated with PFAS is treated by adsorption of PFAS on GAC or ion-exchange resins. The saturated adsorbent is then burned at high temperature and pressure to eliminate PFAS. Over the past years, ion-exchange resins specified for PFAS have become available at the market. Specified resins improve adsorption efficiency, but they are developed for pure drinking water. Runoff water and percolate, however, are rich in organic carbon, heavy metals, chloride, and many other substances that interfere with the adsorption-efficiency of PFAS. While aiming at PFAS, that is present in the nano molar range, competing substances, such as organic carbon, are present in the millimolar range, and hence, pre-treatment of the water is necessary to eliminate the competing substances.

The extend of pre-treatment is a balance between achieving the most effective adsorption at the lowest investment and energy demand. This presentation describes to which extent contaminated water must undergo pre-treatment and list available pre-treatment methods that potentially could lead to more efficient PFAS adsorption.

Methods:

The optimal pre-treatment of runoff and percolate water was evaluated by *i*) analyzing a wide variety of runoff and percolate water for substances of potential interference with PFAS adsorption, *ii*) evaluating bed volumes before PFAS breakthrough depending on the water composition, and *iii*) evaluating pre-treatment methods.

A wide variety of runoff and percolate waters were analyzed for organic carbon (SS, DW, TOC, COD), nitrate, ammonia, sulfate, phosphor, heavy metals, chloride, pH and PFAS.

The effect on PFAS-adsorption efficiency from organic and inorganic substance in runoff water and percolate was evaluated with laboratory and on-site resin columns. Time (Bed volumes) before breakthrough of PFAS was analyzed for both non- and pre-treated percolate water in 100-mL laboratory resin columns, and as well for a variety of raw runoff water and percolate on-site in 250-mL resin columns.

Standard pre-treatment methods such as flocculation, flotation, filtration and ozonation were evaluated for their efficiency against removing substances interfering with PFAS adsorption taking economy and energy consumption into account.

Results and discussion:

The key results to be presented will put the focus on interference from other substances to PFAS-adsorption and which degree of pre-treatment that is necessary.

The results from adsorption efficiency and pre-treatment efficiency is used for planning two pilot test facilities to be setup in Q1 of 2022.

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Updates on the Apsu Surface NMR system - Examples from Danish Field Cases

Mathias Ø. Vang*, D. Grombacher**, L. Liu***, M. Griffiths****, J. J. Larsen*****

Geophysical mapping of aquifers in Denmark has played an important role in understanding Danish groundwater systems and ensuring access to and the safeguarding of clean water supplies. Traditionally, geophysical groundwater mappings involve electrical/electromagnetic methods that produce resistivity maps, valuable to constraining hydrogeological structures but which can often leave uncertainties regarding subsurface water contents and water table depths. Surface Nuclear Magnetic Resonance (SNMR) can help provide such information. In this work we discuss recent advances to the Apsu system, a SNMR system developed at Aarhus University, with the goal of expediting measurement times and enhancing mapping rates.

Historically, a limitation of the SNMR method is the very long acquisition times, typically several hours per site. However, new developments have facilitated rapid acquisitions with improved signal quality that translates to reduced measurements times, in certain cases reducing single site measurements to ~ 30 minutes. This mapping speed makes Apsu a viable tool for regional mapping of water contents and porosity. Key to the improved performance is the development of novel acquisition protocols, called steady-state sequences. This approach uses a train of identical pulses transmitted with a spacing ranging from 50ms-200ms, where instead of letting the system return to equilibrium it is driven to a new "steady state" which can be sampled more frequently. The more compact system is also better suited to rapid mapping, as the Apsu can be carried by two people on steel frame backpacks and the whole system can be carried, as in figure 1a, and can be deployed in remote locations.

In this work, we discuss results from three field studies in Jutland, Denmark, near Aars, Silkeborg and Sunds, totalling ~120 SNMR sites. The results of the Silkeborg campaign are shown in figure 1b and figure 1c. In figure 1b the water content profile from the Apsu measurement is well correlated to the head measurement in the nearby borehole. In figure 1c the circles represent the SNMR water table and the squares the borehole estimates. The two methods highlight similar features and are in good correlation for most of the area. The SNMR result can reveal some structure to the water table which is not evident by the sparse borehole information in the area. These results highlight a significant step-forward for the SNMR technique and point towards the tool being suitable for larger-scale campaigns requiring denser data coverage than previously possible.

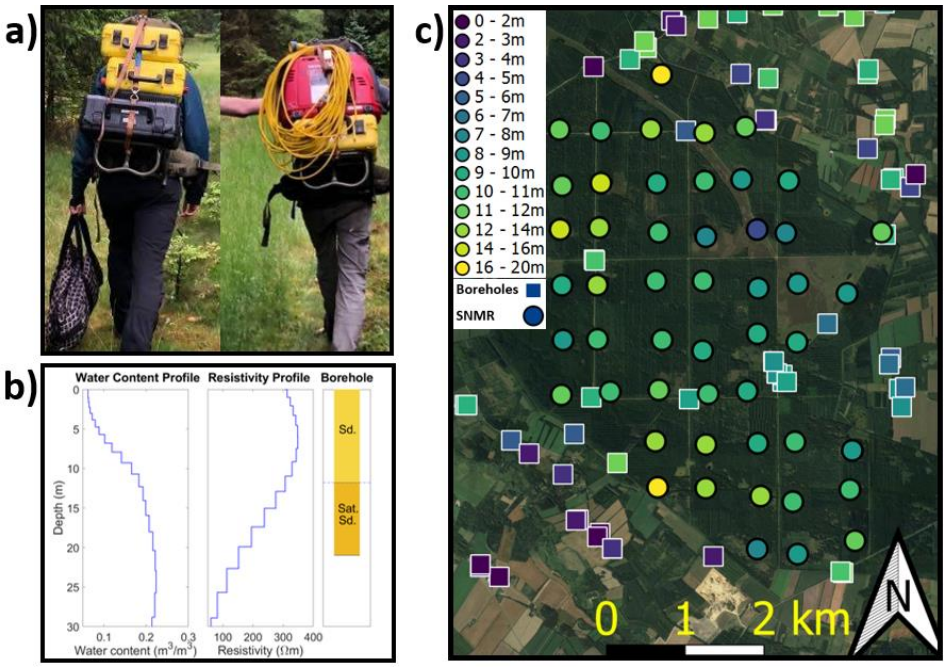

Figure 7: a) The Apsu system carried by two-person crew, b) A qualitative comparison with borehole and a resistivity measurement, c) a quantitative comparison with borehole estimated water table.

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Influence of Delta-hexachlorocyclohexane (δ-HCH) to *Phytophthora ×alni* resistant *Alnus glutinosa* genotypes - evaluation of physiological parameters and remediation potential of HCH contaminated soils and waters

S.Košková, Technical University of Liberec**, P.Štochlová,* Publ. Res. Inst***, K.Novotná,* Publ. Res. Inst****, A. Amirbekov,* Technical University of Liberec *****, **Carlos. A. Arias**, Aarhus University ****** P.Hrabák,* Technical University of Liberec ********

Introduction: Hexachlorcyclohexanes (HCHs) are the persistent organochlorine pesticides used in agriculture and non-agricultural areas. Due to the adverse effects on human health and the environment, these pesticides were banned under the Stockholm Convention. Nevertheless, many uncontrolled landfills and legacy sites contain these pesticides, which are gradually released into the soil, and to surface and ground waters. This research was focused on the relationship between the delta-isomer hexachlorocyclohexane (δ-HCH) and the progeny of different *Alnus glutinosa* (L.) Gaertn) genotypes resistant to pathogen *Phytophthora ×alni* that have the potential to remove HCH from soil. The resistant alders have been selected due to the general occurrence of alders in Europe and the robustness of the plant.

Methods and data: For this purpose, two kind of experiments were used. The experiments were performed to determine the effect of the δ-HCH on the physiological parameters of seedlings and devoted to remediation aspects. The short-term experiment (12 days) was focus on the differences in selected parameters inclunding total germination (GT), germination energy (GE), speed of germination (SG), shoot length and biomass and hormonal system's response. In the case of an 80-days-long experiment, total whole plant biomass, plant height, content of δ-HCH in the plant biomass, removal efficiency and description of the concentration differences of the selected phytohormones were monitored. Delta-isomer of HCH and related metabolites were analysed in the plant biomass and in the growing substrate using GC/MS. The plant hormones as a means of evaluating the response to a stress situation caused by an abiotic stimulus were determinated using LC/HRMS.

Results: The examined isomer affects different parameters of the tested genotypes to a different extent. The influence of δ-HCH is mostly negative, however, the growth and development of one selected genotypes were supported by the isomer or its metabolites. Regarding to the structure of the isomer, plant uptake does not appear to be in large extent. However, the presence of a plant is an important remediation element. The presence of seedlings increased the effectiveness of removal of HCH from 21 to 36 %. In the case of influence on the hormonal system, the differences in the concentrations of the selected hormones were record by all examined genotypes. Obtained results indicate an important role hormones as the mediators of the stress reaction to the δ-HCH presence.

Discussion and take-home message: The response to the δ-HCH and its metabolites is conditioned by the genetically variability. Subsequently, the research results indicate the role of the plant as a remediation accelerator, probably through released exudates and a positive effect on the soil microbiome. Furthermore, selected plant hormones may be consider as the one of the possible marker of plant's ability to germinate, growth and develop in the pesticide's presence.

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Integration of Earth observation data in a global hydrological modelling and forecasting system

Henrik Madsen*, G. Jørgensen**, P.N. Godiksen***, M. Ridler****, M. Fontana*****, A. Murray******, DHI*

Abstract

A hydrological modelling and forecasting service has been developed that integrates global scale satellite-based data products with rainfall-runoff and river routing modelling tools. The model produces key hydrological parameters such as root zone soil moisture and different runoff components on a 0.1° grid resolution, as well as river discharge at more than 1 million river points covering the entire globe. It utilises 20-years hindcasts data, short-medium range real-time forecasts (up to 10 days lead time) and seasonal forecasts (up to 9 months lead time). In the operational system, new forecasts are produced every hour when new weather prediction forecasts become available.

The hydrological model includes a grid-based rainfall-runoff model and a routing model, which routes water between model grid cells and sub-catchments, as well as through the river system. Satellite-based data products have been used for model setup and estimation of model parameters. For delineation of catchments and river networks, the HydroSHEDS products[1] were used with an average sub-catchment resolution of 100-200 km^2. A physics-based parameter estimation approach was applied, where relationships between model parameters and various physiographic characteristics were determined. Applied physiographic characteristics include global data products of topography, land use, soil type, soil characteristics, and depth to bedrock. For model forcing, various precipitation, temperature and evapotranspiration data products were analysed, including satellite-derived products as well as numerical weather prediction re-analysis products. Model performance was evaluated using river discharge data from more than 1600 locations.

Satellite-based data products that are available in real-time or near-real-time can also be integrated in the operational system for updating the hydrological model using data assimilation. We have investigated assimilation of root-zone soil moisture derived from the SMAP (Soil Moisture Active Passive) satellite. A simulated real-time test was conducted where SMAP soil moisture was assimilated in the global hydrological model every 24 hours over a period of 4 years and evaluated on the continental US. Results showed that soil moisture was corrected by assimilation of SMAP data, revealing distinct seasonal and spatial patterns. The model is, in general, too wet in winter and too dry in summer. During Spring, the North-Western US is too wet and the South-East too dry, and the opposite pattern is observed during Autumn. Evaluation of the effect of soil moisture data assimilation on simulation of river discharge shows an improvement for about 70% of the 3000 river locations analysed.

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[1] https://www.hydrosheds.org/page/overview

Digital research and information products of the four GeoERA groundwater projects for assessment and sustainable use of water resources and the subsurface in a changing climate

***Klaus Hinsby*[1], *Laurence Gourcy*[2], *Hans Peter Broers*[3], *Anker Lajer Højberg*[1*], *Marco Bianchi*[4] *and Peter van der Keur*[1]

Protecting and ensuring good status of groundwater quantity and quality are essential for sustainable development and protection of society and nature, globally, as acknowledged in the UN sustainable development goals and the European Green Deal. Too much? – too little? – and/or too polluted? are key questions to pose and answer in a changing climate with increasing pressures on water resources, severe loss of biodiversity and a projected increase in extreme events resulting in increasing risks of floods, droughts, landslides and land subsidence etc.

Easy access to digital and FAIR (Findable, Accessible, Interoperable and reusable) data on groundwater quantity and quality is imperative for informed decision making and efficient climate change mitigation and adaptation to which sustainable groundwater management will contribute. Here we briefly present selected highlights and digital data products from the four GeoERA groundwater projects developed for and made available on the digital subsurface information platform, the European Geological Data Infrastructure (EGDI), of the European geological survey organizations. The ambition is to develop EGDI as the leading information platform for sustainable and integrated management of subsurface resources in Europe and one of the leading platforms, globally.

[1]GEUS, [2]BRGM, [3]TNO, [4]BGS, [1*]now Rambøll

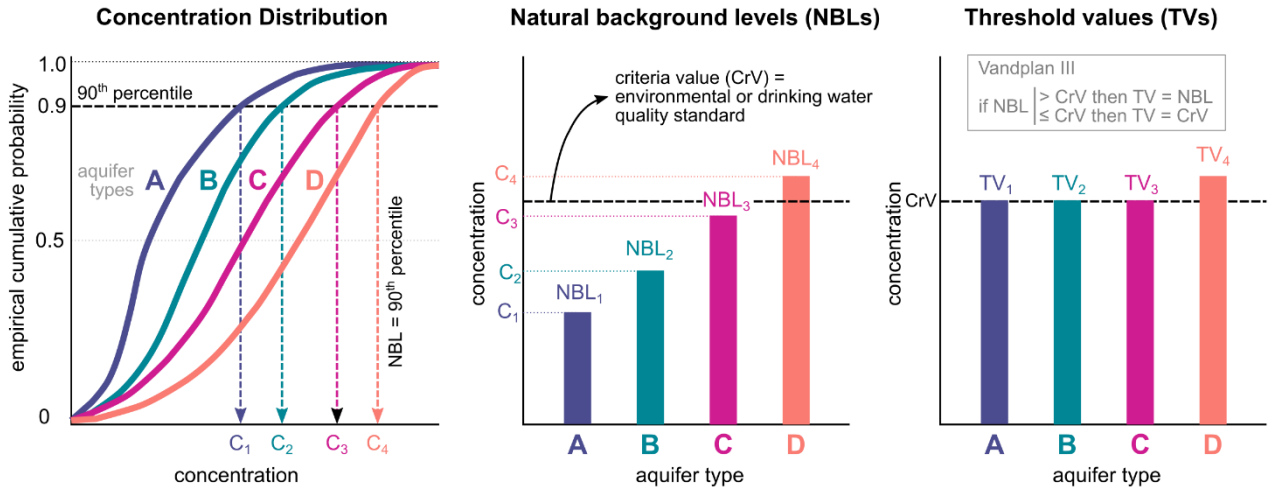
Natural background levels of trace elements in groundwater: purpose, definition, and important methodological factors

Denitza D. Voutchkova**, GEUS*, Jörg Schullehner, GEUS & AU**, Klaus Hinsby, GEUS, Mette H. Mortensen, GEUS*, Birgitte Hansen, GEUS*, Lærke Thorling, GEUS**

Abstract

The chemical status of groundwater bodies in the EU must be assessed and good status must be achieved to protect human health and groundwater-dependent or associated ecosystems, as stipulated in the EU Water Framework Directive and the Groundwater Directive (GWD) [1]. The status assessment provisions only apply for anthropogenically altered conditions, so the status of each groundwater body is assessed against element-specific threshold values (TVs). To set these TVs, first the natural background levels (NBLs) for different aquifer types (i.e. hydrogeochemical conditions) must be determined. NBL is defined as *"the concentration of a substance or the value of an indicator in a body of groundwater corresponding to no, or only very minor, anthropogenic alterations to undisturbed conditions"* (GWD, Article 2.5). In practice, NBL is a value representing the upper limit of the natural concentration distribution for a given chemical compound and aquifer type. Therefore, the major challenges in deriving NBLs for trace metals are understanding the interaction of natural and anthropogenic processes and identifying this boundary between (nearly) pristine and polluted groundwater.

The NBLs for trace metals in Danish groundwater were assessed recently as part of the Vandplan III [2] and further work was carried out in the GeoERA project HOVER [3,4]. Based on that work, here we focus on few key methodological factors in determining NBLs and discuss their importance. These factors are: 1) the definition of aquifer type, 2) the data selection and aggregation, and finally 3) the NBL computation. Aquifer types were defined based on the lithology, location, and element-specific hydrogeochemical characteristics (pH, redox, and organic matter). The data pre-selection assured that known polluted monitoring points are excluded, while the aggregation method transformed the irregular time-series for each monitoring point to a single representative value (e.g. mean of annual means vs. median). NBLs are then calculated as the 90th percentile of this pre-selected and aggregated dataset which should approximate natural groundwater composition for the specific aquifer type.



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[1] Hinsby K, et al. (2008) https://doi.org/10.1016/j.scitotenv.2008.03.018
[2] Mortensen et al. (2021) https://tinyurl.com/4w9nmbsu
[3] Voutchkova et al. (2021) https://doi.org/10.3390/w13091267
[4] Lions et al. (2021) https://doi.org/10.3390/w13111531

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Degradation of MCPA, Metolachlor and Propizonazole in the hyporheic zone of an agriculturally impacted stream

Tina B. Bech*, *Thomas Stehrer, Nora Badawi, Morten D. Schostag, Rasmus Jacobsen, Jens Aamand, Jennifer Hellal*

Non-point pesticide pollution is a worldwide problem impairing rivers and streams. The hyporheic zone underneath the streams provides an essential barrier between ground- and surface water where the saturated sediment is considered an important bioreactor with the potential to degrade a range of pollutants, including pesticides.

This study aims to evaluate the degradation potential of MCPA, metolachlor and propiconazole in hyporheic zone sediments along a 20 km long stretch of an agricultural impacted river, dominated primarily by downwelling conditions. In addition to hydrological flow and chemical parameters from river and groundwater, degradation data were further compared to pesticide sorption and community composition analyses.

Whether the sediments were downwelling (five sediments) or upwelling (one sediment) did not affect pesticide degradation, although complete mineralization to carbon dioxide was somewhat slower at upwelling conditions.

Degradation and mineralization batch experiments were set up from six sediment samples under environmentally relevant conditions (10 µg kg^{-1}). Highly variable DT50 values in the range of 1-27 days for MCPA, 11-44 days for metolachlor and 60-147 days for propiconazole were calculated. Computed DT50 values were in the range of estimated DT50 values from agricultural soils or slightly faster. Considering that agricultural soils have been exposed to greater amounts and higher concentrations of pesticides, the hyporheic zone may be an important barrier preventing pollution of surface water resources by pesticide residues.

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Session 7: The NEPTUN Innovation Project- Climate change and groundwater levels:

Time: 13:00 – 15:00: Suggestion for an Urban Water and Climate change session
Chair: Trine S. Jensen and Lotte L. Andersen CLEAN
Room 2

Part 1. Interactive session about CLEAN´s two NEPTUN projects about Water Climate Challenges

In the Danish- German Interreg project NEPTUN led by CLEAN, the Danish Environmental Cluster, two innovations projects address the challenges with too much urban water and climate changes possible effect on the groundwater level.

Both projects are facilitated by Kiel University and involve problem owners and water companies on both sites of the Danish-German border in developing new innovative solutions. The projects are aiming to develop digital warning systems/models, that can foresee the effect of extreme rainfall on either the water infrastructure in the city of Flensborg or the groundwater formation in a catchment area of a waterwork in Norderstedt

- **Early Warning systems:** Flood forecasting for urban rainwater systems combining digital hydraulic modeling with data assimilation (Partnership: Hydro and Meteo Gmbh, TBZ, LNH Water, Kjartan Ravn Consult ApS and Kiel University)
- **Decreasing groundwater level:** Analysis of decreasing groundwater levels and presentation of possible solutions to stabilize groundwater levels (Partnership: HGSim, Norderstedt Waterworks, Mattle and Kiel University)

The two climate adaptations projects are targeting to develop model-based solutions to solve 1. the congestion of the lack of capacity in sewer systems during large rainwater masses through an 'early warning system' and 2. Solutions/actions to handle falling groundwater levels and why this phenomenon happens in Schleswig -Holstein but not in the Region of South Denmark.

There are going to be interactive session in the CLEAN NEPTUN session at the DWF conference. First there will be two pitches about early warning system, Kiel University (CAU) and involved companies (represented with LNH water) presenting the problem owner challenge, the purpose and the results so far, the LNH water will tell about the modelling work so far and the expected prototype. These pitches will serve as an introduction to an interactive session – where the audience are invited to discuss 1. suggestion for improvements to the suggested solutions 2. Is the solution appliable in a wider context – what are the possibilities.

In the second section Kiel University (CAU) and participating companies (represented by HGSim, possibly on-line) will report on the challenges in modeling work in Northern Germany (data acquisition, digitization,...) and the model results. Two open source softwares that are used for hydrological modeling should be briefly explained. These pitches will serve as an introduction to an interactive session – where the audience are invited to discuss 1. suggestion for improvements to the suggested solutions 2. Is the solution appliable in a wider context – what are the possibilities.

Part 2: Presentation of the Innovations partnership funded by CLEAN: The Intelligent Well
Climate changes are challenging our design of sewage systems. It is important to digitalize our sewage systems, and adjust to future climate changes with heavy rain and increasing groundwater level. This project has a vision to be able to make a general measuring system that can either be retrofitted in existing wells or built into new wells with as little maintenance of sensors as possible and make a connection with a kind of modular platform that can be continuously expanded with new functionality over the coming years. The knowledge of knowing concentration and flow in the sewer system as early as possible will make it possible to better control water treatment processes and protect the water environment.

The partnership behind is:

- **The Intelligent Well**: Lemvig Water, Klimatorium, Geoparter Inspections, Sultilogger, Wasys, Aalborg University, Wasys, Aalborg University, Denmarks Technical University (DTU)

Green= one way presentation. Yellow = workshop (structured interaction with audience), Blue = break (none structured

Time	**Presentation**	**Responsible person**
13-00	• **Introduction** • 5 min: Introduction to CLEAN, NEPTUN innvoationsprojects and innovationspartnerships " the Intelligent Well and program of today •	Trine S. Jensen
13.05	• Part 1: Early Warning systems • Challenge from Flensborg City with flooding.	Henry Bauman, CAU
	• Development of a hydraulic model, that combines flow in pipes and on the surface	LNH-water; Lina Nyboe Jensen , Nanna Høegh
	• The size of the problem and purpose of the project and results of the project	Henry Bauman, CAU
13.25	• 20 min: Interactive session with discussion of: 1. Suggestion for improvements to the solutions 2. Is the solution appliable in a wider context – what are the possibilities?	Facilitated by Trine S. Jensen, Annika Eising. LNHwater (Lina and Nanna) and 2 persons (Agnes and Henry) in groups, as table coordinators
13.45	• 5 min: Summary with main conclusions from each group	Henry Baumann
13.50	• OpenSource Software Soil water balance model, structural model, groundwater flow model. • (role of HGsim)	HGSim (presented by **Agnes Sache**, CAU)
	• **Part 2- Decreasing groundwater level** • 10 min Pitch about challenges (data, digitization), size of the problem and purpose of the project. Hydrological modelling	Agnes Sache, CAU, Kiel University
14.05	20 min: Interactive session discussion 2 questions. 1. Suggestion for improvements to the suggested solutions 2. Is the solution appliable in a wider context – what are the possiblities	Facilitated by Trine S. Jensen, Annika Eising.
14.25	• Sum up, 5 min: Summary with main conclusions from each group	Agnes as table chairman
14.30	Short break without leaving the room, there will be an ordinary break at 15.00	Trine introduces the project and the partnership
14.35	The intelligent Well -back-group, purpose and first results	Lemvig Vand ,Lars Holmegaard,
	Way forward	Wasys, Geopartner, Sulfilogger?
14.55	Questions, feed-back to the project idea and farewell	

Declining groundwater levels: a challenge for the drinking water supply in northern Germany

A. Sachse[1], C. E. Wiegers[2], I. Irion[2], D. Schäfer[1], A. Dahmke[1]

Abstract: Declining groundwater levels due to increasing periods of drought and as a result of climate change, have been observed for years, especially in central Germany. This trend is now also emerging for some northern German regions. So far, the water-rich north of Germany has not had any problems with the quantitative drinking water supply. Is climate change the only reason for further sinking groundwater level? The Danish-German project (NEPTUN) investigates, in cooperation with local problem owners, the causes of falling groundwater levels and develops technical solutions and recommendations for future groundwater management within an innovation project.

Keywords: declining groundwater levels; groundwater recharge; northern Germany

The municipal public utilities of a northern German city have been observing declining groundwater levels at some of their observation wells for a few years despite constant withdrawal quantities.

In cooperation with a local engineering office, the reasons for the falling groundwater level are investigated and then proposed solutions for stabilizing the groundwater level as well as future measures in groundwater management are presented. For this purpose, the current water balance (especially the hydrological parameters: precipitation, evaporation and groundwater recharge) of the catchment area of the wells was analysed based on meteorological time series 1971-2020 and using a 2D / 3D water balance model.

To estimate the consequences of climate change on the water balance (e.g., groundwater recharge), 56 climate projection data sets (RCP scenarios) from Deutscher Wetterdienst (DWD) were obtained and pre-processed for the modelling period of 1971-2100.

The first results indicate that groundwater recharge in the study area has remained more or less the same over the past decade. A change can only be seen in the temporal distribution over the year. According to the model calculation, even in the dry years there was no reduction in the annual amount of groundwater recharge, since there was sufficient precipitation for groundwater recharge, especially in the winter months. Thus, other factors influencing the area's water balance and its consequences for the groundwater level must be checked.

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Integrated assessment modeling and flood forecasting for urban rainwater systems

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Abstract

The problem of effectively combining pySWMM models of urban rainwater drainage simulation with actual and predicted rain precipitation as well as online level measurements for flooding prevention is addressed. Based on a hydrodynamical model, created in SWMM an Ensemble Kalman Filter is used to keep track of the real-world measurements. Simulating this SWMM model with different rainfall data samples in parallel enables efficient flood warning if a critical water level can potentially be exceeded. All results are displayed on a user-friendly interface. The general idea and setup are presented, and first results based on historical data evaluation are discussed for a case area in the city of Flensburg.

Introduction:

The city of Flensburg has had difficulties with floods during heavy rainfall events for many years. Due to climate change, this problem will increase significantly, which makes the development of an early warning system very important. But since this does not only affect Flensburg, the solution should be transferable and usable for other cities as well.

Methods and data:

Based on the hydrodynamic model, which can be used to simulate future states, a flood forecasting tool is established. First system and measurement data are combined to set up and calibrate a model using the efficient, open-source tool SWMM. With the objective of precise simulation, the model has to be initialized from the current state of the real system. Therefore an Ensemble Kalman Filter, which uses Monte-Carlo simulation to estimate future states is applied. Predicted precipitation data and actuator settings are included to these multiple simulations to assess potential floodings.

Results:

The backend, which contains repeated simulations and iterative state updating, has been connected to an user friendly interface to display potential flood warnings. Additionally first results for the city of Flensburg based on historical rain data are presented.

Discussion and take-home message:

Due to climate change there is a need for early warning systems for heavy rainfall events. The presented approach and software enables to estimate potential floodings based on the hydrodynamical model and multiple parameters like predicted precipitation data and actuator settings. Due to the iterative state estimation the simulation is keet close to the real system measurements.

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THE INTELLIGENT WELL

L. Holmegaard (Klimatorium & Lemvig Vand) I. Schipperheijn** (Lemvig Vand), S. Holst*** (Geopartner)*

Introduction:

Climate changes are challenging our design of sewage systems. One third of all fixed assets in Denmark are underground supply pipes. Pipes are depreciated over 75 years but only last an average of 46 years in Denmark. Therefore, it is important to digitalize our sewage systems, and adjust to future climate changes with heavy rain and increasing groundwater level.

This project has a vision to be able to make a general measuring system that can either be retrofitted in existing wells or built into new wells with as little maintenance of sensors as possible and make a connection with a kind of modular platform that can be continuously expanded with new functionality over the coming years.

The intelligent well will fulfill two purposes:

1. Sensors in intelligent wells measure wastewater characteristics, to get more knowledge about wastewater in the pipe network before it runs into the wastewater treatment plant. The knowledge of knowing concentration and flow in the sewer system as early as possible will make it possible to better control water treatment processes and protect the water environment.
2. Furthermore, reflectors will get built into the intelligent wells, to provide precise x,y,z-coordinates with satellite data of specific spots in the pipe network. The ability to follow changes in z-coordinates of the pipe network will make it possible to adapt to settlements of terrain, and thereby extend the lifetime of the pipe network.

The projects ambition is to develop a pilot-product of an intelligent well, that will fulfill its purposes, as well as being an economically viable product for water utilities and a durable construction in existing pipe networks.

Methods and data

The project runs from December 1st, 2021, till December 31st, 2022. CLEAN is the project funder. The partnership behind is: Lemvig Water, Klimatorium, Geoparter Inspections, Sulfilogger, Aalborg University, Wasys, Aalborg University, Denmarks Technical University

Lemvig Water 'owns' the problem statement, is the project manager and provides testing areas as a water utility.

Sulfilogger will develop sensors to measure waste water characteristics. Wasys will provide a method to transfer data from the intelligent well to the existing control system of the wastewater treatment plant. Geopartner and DTU will develop a prototype of the well cover with integrated radarreflector. Aalborg University will develop the physical hydraulic properties of the intelligent well, in order to get a durable construction that secures the different elements in the well.

First results:

The outcome of this project will be a pilot product of the intelligent well, as well as a business plan for upscaling.

Discussion and take-home message:

By developing the intelligent well in this project, we can extend the lifetime of the pipe network and get more knowledge about the wastewater in the pipe network by one single intervention. By making this an economically viable product, the intelligent well can get implemented broadly in existing pipe networks, and thereby optimize maintenance significantly.

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Session 8: Start-ups in water – a way to drive innovation in the sector – an YWP session

Time: 15:15 – 17:15
Chair: Inês Breda, Eirini Kouzi, Solvei M. Jensen; Young Water Professionals (Moderator)
Room 2

The session will present two cases of Danish start-ups selected from the Next Generation Water Action 2021 programme. The discussion will include: How to create a business case? How to create a start-up? How to grow a business? We are looking forward to inspiring you to pursue your ideas and find ways to integrate social needs with technical knowledge.

1. 10 min – Intro: What is a start-up? The importance of innovation in the water sector. What are your business ideas? (Inês Breda)
2. 15 min – Case 1: Tollson - presentation of the business and possible overview in Canvas (Christoffer)
3. 15 min – Case 2: 4Life - presentation of the business and possible overview in Canvas (Julia)
4. 10-15 min Open panel (Christoffer, Julia and participants – Inês as facilitator)
5. 5 min Closing remarks