14th DWF WATER RESEARCH CONFERENCE

30TH JANUARY 2020

UNIVERSITY OF COPENHAGEN

THORVALDSENSVEJ 40, 1851 FREDERIKSBERG

ABSTRACTS

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

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Green transition is also blue transition

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10.10	How is water perceived within the new Green transition call of the Innovation Fund Denmark/ Thomas Mathiesen, Innovationsfonden
10.30	Concrete example on how to integrate water and climate change mitigation in a future integrated water supply facility/Hans-Martin Friis Møller, KALFOR and Chairman of DWF
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Clean water and urban growth

H.B., Madsen, S. Rasmussen***

Abstract

In many parts of the world there is a lack of clean drinking water, especially in urban areas. The Sustainable Development Goal 6 is focussing on improved water quality, sustainable withdrawals, to protect and restore water resources and implement integrated water resource management. To ensure availability and sustainable management of water, the water management has to be an integrated part of the planning in all sectors e.g. urban and master planning.

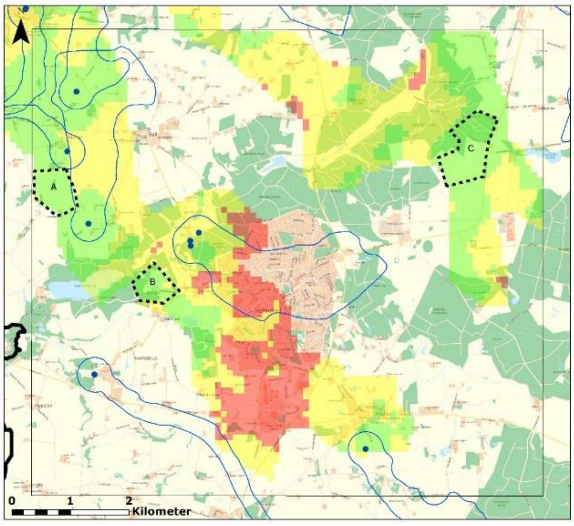
The project "Coordinated water extraction and urban planning" focuses on the need and interest to create space for further urban growth while ensuring clean drinking water for citizens in the future. The aim of the project is to access the interests of both urban growth and clean groundwater in a strategic and longer-term way to minimize conflict areas as well as long-term safe choices and priorities.

The groundwater aquifers were analyzed due to geografic spreading, thickness and sustainable resource-capacity, as well as water quality and vulnerability. The main part of the data was collected during the National Groundwater Mapping in Denmark. The results of the analysis will provide an easily applicable overview of the qualitative and quantitative assessment of the groundwater aquifers and a relative prioritization of the aquifers for recovery.

The end goal of the project was to provide the Municipality of Favrskov, Denmark, with a tool for systematic evaluation of the interests of urban growth balanced against the need for clean groundwater. This was done to help with strategic choices in urban planning and management of water resources to minimize conflicting landuse. The Municipality of Favrskov identified, where the water utilities in the future could place new extraction wells and which action was necessary to keep or recover a good groundwater quality.

The conclusions were summarized in a data sheet, which shows whether the drinking water resource is limited and, if so, which actions are needed to ensure a clean drinking water supply in the area. The actions can be new well field or forest, reduced fertilizing, no use of pesticides, restricted urban development.

The methodology can be transformed to other geografies where e.g. MAR could be a relevant solution to ensure enough clean drinking water.



**Ramboll, Olof Palmes Allé 22, DK-8200 Aarhus, Denmark, habm@ramboll.dk*
***Municipality of Favrskov, Skovvej 20, DK-8382 Hinnerup, stir@favrskov.dk*

Natural Toxins and Drinking Water Quality - An Emerging Area of Concern

L.H. Rasmussen, University College Copenhagen[*], H.C.B. Hansen, University of Copenhagen[**]

Abstract

Natural Toxins and Drinking Water Quality is in focus of the European Training Network NaToxAq. The project produce knowledge about natural toxins in aquatic environments and study the occurrence and fate from the source organisms to the consumers tap. Sixteen Early Stage Researchers and numerous associated students study a variety of problematic toxins and toxin producing plants and cyanobacteria. The approach is both *in silico* and *in vitro* using non-target and target-approaches. It is our goal to provide a toolbox that enables public authorities, the water supply and treatment sector and consumers to develop solutions for healthy drinking water free of natural toxins.

Sofar, the project has identified more than 500 potentially problematic natural toxins. Data on phytotoxins are placed in a free database, Toxic Plants–PhytoToxins, 1500+ phytotoxins of linked to 844 Central European plant species. Based on the identified suspect compounds from the database, non-target as well as targeted screening of European surface waters and groundwaters has identified several problematic natural toxins. Among cyanotoxins produced by cyanobacteria in harmful algal blooms, a major concern is the lack of environmental fate studies of cyanopeptides beyond microcystins. These toxins are comparable in frequency, concentration and toxicity to microcystins. The same goes for two other large groups of natural toxins encountered in drinking water resources: Alkaloids and terpenes. Both groups of compounds are structurally diverse, challenging the analytical scientist. An example of this is the group of pyrrolizidine alkaloids from Ragwort and Butterbur species. These hepatotoxins have been found in soil and water resources in alarming concentrations. The pyrrolizidine alkaloids comprise more than 100 different compounds with similar toxicity. Equally the illudane glycosides (terpenoid glycosides from ferns such as the well-known ptaquiloside) comprise a group of carcinogens that are found in ground- and surface water. The results demonstrate that analytical laboratories need to prepare for analysis of a variety of natural toxins capable of contaminating drinking water resources.

NaToxAq is funded by the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 722493. NaToxAq started in January 2017 and is coordinated by University of Copenhagen.

Natural coverage of Bracken ferns in Jutland. Illudane glycosides leach from Bracken and contaminates adjacent water resources.

[*] *LHRA@KP.DK: Sigurdsgade 26, 2200 Copenhagen N.*

[**] *haha@plen.ku.dk: Thorvaldsensvej 40, 1871 Frederiksberg C*

A snapshot of organic micropollutants in Danish surface waters

P.N. Carvalho, C. Liang**, S.K. Tisler***, P. Lassen****, K. Bester***** AU-ENVS*

Abstract

Organic micropollutants, including controlled compounds (e.g. biocides) or compounds of emerging concern (e.g. pharmaceuticals) are ubiquitous in the aquatic environment. They can have different sources and emission rates depending on their usage/application. Especially regarding biocides, there is rising interests to access which compounds and what levels are present in e.g. surface waters. We presently used a subset of samples to perform a broader screening for organic micropollutants and capture a snapshot of the occurrence of several compounds in Danish surface waters.

Two set of grab samples were collected: 10 locations in November 2018 (marked blue in Figure 1) and the same locations plus 8 more (marked red in Figure 1) in July 2019. Samples were analysed separately for biocides (13 compounds, both seasons) and for pharmaceuticals (36 compounds, only July 2019) by HPLC-MS/MS. Samples were injected directly in the instrument after pre-concentration (2000x) by solid-phase extraction. In addition, samples from July 2019 were also injected directly on a HPLC-HRMS instrument for a non-target and a suspect screening workflow, using in-house databases (3978 compounds containing e.g. antibiotics, pesticides or fluorochemicals).

The biocides diazion, irgarol, pyraclostrobin, terbutryn and propiconazole were detected in less than 30% of the samples from both seasons (below 10.2 ng/L). Pirimicarb, azoxystrobin and benzalkonium chlorides were detected between 54 and 75% of the cases. Carbendazim, diflufenican and tebuconazole were detected in more than 96% of the samples (below 47 ng/L). Overall, the majority of the measured concentrations ranged between 0.1 and 47 ng/L. Two notable cases with values equal or above 100 ng/L were detected: i) a single sample from the summer 2019 showing 8310 ng/L of azoxystrobin and 100 ng/L of tebuconazole and ii) all samples from November 2018 presented quantifiable levels of benzalkonium chlorides (12-BAC and 14-BAC) in the range 280 to 29500 ng/L. Interestingly, in July 2019, the frequency of detection of 12- and 14-BAC was below 36% and concentrations were below 100 ng/L.

In the July 2019 samples, 13 out of 36 pharmaceuticals were not detected. Metoprolol, carbamazepine, citalopram and losartan were the ones detected more frequently (above 50%). Overall, the majority of the measured concentrations of pharmaceuticals ranged between 0.1 and 200 ng/L. The highest concentration measured was of 1200 ng/L for gabapentin, which was detected only in 17% of the samples.

The ongoing suspect screening analysis is expected to show compounds which are not covered by the above-mentioned target methods. Furthermore, with a non-target screening method similarities and differences between the Danish surface water samples can be valuated in a broader picture.

Potential sources of the compounds to the surface wasters will be discussed during the presentation.

Figure 1 - Map with surface water sampling locations

** pedro.carvalho@envs.au.dk; ** liangcz@envs.au.dk; *** seti@envs.au.dk; **** pla@envs.au.dk; ***** kb@envs.au.dk : Aarhus University, Department of Environmental Sciences, Frederiksborgvej 399, 4000 Roskilde*

Groundwater treatment by co-oxidation of Fe(II), Mn(II) and As(III): Impact of oxidant identity on removal efficiencies and reaction products

CM. van Genuchten, Geochemistry Department, GEUS, A. Ahmad, Dutch Water Cycle Research Institute***

Abstract

Arsenic (As) contamination of groundwater used as a drinking water source is a major public health problem in rural areas of South Asia and is a growing concern in many European countries. The high toxicity of As has prompted the water sector in the Netherlands to target 1 µg/L in treated water, which is 10 times lower than the World Health Organization provisional limit. Many large-scale groundwater treatment plants rely on aeration for As removal, which is based on oxidizing natural Fe(II) present in As-contaminated groundwater with O_2 to form Fe(III) precipitates that bind As. However, aeration is often unable to decrease As levels to below 1 µg/L partly because O_2 is ineffective at oxidizing As(III), the more difficult to remove As species. Therefore, strong chemical oxidants, such as permanganate (MnO_4^-), can be used to enhance As removal via co-oxidation of Fe(II) and As(III). Strong oxidants also have the added advantage of potentially co-oxidizing Mn(II), a problematic ion that often co-occurs with As. However, little is known about how different oxidants impact the pathways of Fe(II), Mn(II) and As(III) co-oxidation and removal.

In this work, we investigated the co-oxidation of Fe(II), Mn(II) and As(III) using three different oxidants: O_2, NaOCl and $KMnO_4$. We selected these common oxidants partly because of their different reaction rates with reduced species (i.e. O_2 is slowest, NaOCl is more rapid, $KMnO_4$ is the most rapid). Co-oxidation experiments were performed in $N_{2(g)}$-purged, bicarbonate-buffered solutions at pH 7.5 initially containing 90 µM Fe(II), 9 µM Mn(II) and 0.7 µM As(III) (50 µg/L As). The solutions were either aerated (O_2 set to 9 mg/L) or were mixed with stoichiometric amounts of NaOCl or $KMnO_4$. The impact of solution composition was studied by performing experiments in the absence or presence of systematically varied P, Si and Ca concentrations. Measurements of Fe, As and Mn removal by ICP-MS were combined with solid phase characterization by synchrotron-based Fe and Mn K-edge X-ray absorption spectroscopy.

Our results indicate that the oxidant identity largely controlled the solid phase speciation and efficiency of Fe(II), Mn(II) and As(III) removal. In the O_2 system, Fe(II) oxidation was complete (0.5 h reaction time), but Mn(II) and As(III) were only partially oxidized, leading to Mn(III)-incorporated lepidocrocite with sorbed As(III,V). More effective co-oxidation was observed with NaOCl than with O_2, but a significant fraction of sorbed Mn(II) was present in the reaction products, which consisted of Mn(III)-incorporated hydrous ferric oxide (HFO) with sorbed As. $KMnO_4$ was the most effective oxidant, producing suspensions containing a mixture of As(V)-sorbed HFO and MnO_2 in all experiments, regardless of solution composition. However, the solids produced in the $KMnO_4$ system were colloidally stable and difficult to remove from the treated water, which is explained by the highly negative charge of MnO_2 preventing particle aggregation. Taken together, these results suggest a tradeoff between effective Fe(II), Mn(II) and As(III) co-oxidation using $KMnO_4$ and reduced particle trapping in rapid sand filters due to poor suspension aggregation. This diversity in structure and aggregation behavior must be considered when adjusting water treatment processes to enhance As(III) oxidative removal, particularly when $KMnO_4$ is used.

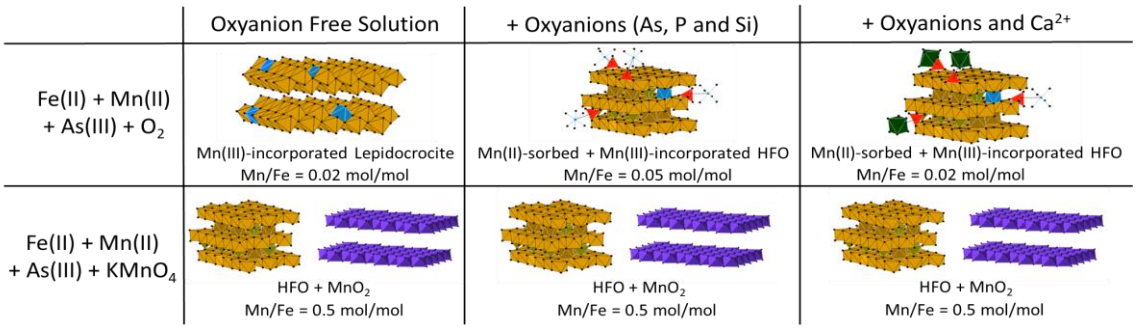


Fig. 1: Structure and composition of solids formed by Fe(II), Mn(II) and As(III) co-oxidation with O_2 or $KMnO_4$. The red polyhedra represent oxyanions. The blue and green octahedra represent Mn(III) and Ca, respectively.

** cvg@geus.dk: Øster Voldgade 10, Copenhagen, DK **arslan.ahmad@kwrwater.nl*

Sustainable removal of methane gas from exhaust air of waterworks

L.D. Christensen, Danish Technological Institute, S. Musovic, Danish Technological Institute**, H. N. Laugesen, Kemic Vandrens***, P. Underlin, Hillerød Vand****, J. W. Hansen, SAMN Forsyning******

Abstract

At Danish waterworks, groundwater is aerated and filtrated through sand filters, where a range of naturally occurring contaminants are removed before distribution to consumers. During groundwater aeration, a range of natural gasses including methane, are released. Methane concentrations in Danish groundwater, especially in reduced zones, can reach up to 40 mg CH_4/L. During groundwater treatment (i.e. aeration), the released methane ends directly in the atmosphere contributing to the global warming. In Denmark, the total methane emissions from drinking water production are estimated to be around 300 tons, assuming an average methane concentration of 0.6 mgL^{-1}. This project focuses on the development of filtration biotechnology for biological removal (oxidation) of methane originating from aeration of groundwater. Hereby, methane is converted to CO_2 with a 25 times smaller global warming potential than a methane molecule.

The developing filtration biotechnology will have a biofilter-form, which consists of a supporting matrix with a large surface area to support the development of a biofilm which actively oxidizes methane (Figure 1.1). To ensure a functional biofilm with MOB on the supporting matrix, which use methane as a carbon source, the biofilter will be trickled with C-depleted drinking water enriched with trace elements, copper, nitrogen phosphorus and potassium.

The lab-scale experiments focused on the identification of an optimal matrix for the biofilter formation in the biotechnology. During these experiments, the biofilters were enclosed in columns, where two different matrices were tested: wood chips and foam. The foam and wooden chips were inoculated with the bacterial suspension originating from the sand filter receiving methane-rich groundwater, previously shown to harbour native MOB. The inflow of air (1 L/min) and methane (0, 50 or 500 ppm) were regulated from the bottom of the column. The biofilters were trickled at the top of the column with water once a day (incl. trace elements and NPK). Samples were continuously collected for molecular analyses (qPCR), quantifying the total bacterial community and fraction of MOB. At the same time, the methane concentrations in the inflow and the outflow of each column were measured, and the consumption of methane in columns was estimated.

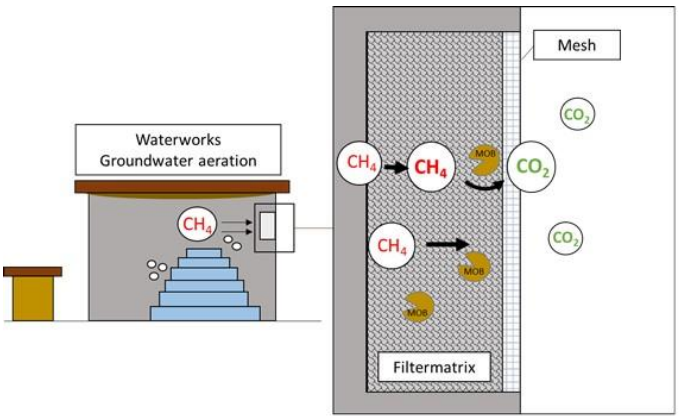


Figure 1.1 A sketch of the developing biotechnology. Exhaust air containing methane from the aeration of methane-rich groundwater is biofiltered resulting in biological conversion of methane to CO_2.

A continuous flow of methane-containing air through foam-columns over a period of 30 days increased the abundance of methane-oxidizing bacteria by 2-order of magnitude, while MOB abundance remained rather unchanged in the columns receiving air with 0 ppm methane. These results indicated that methane-selective conditions support a significant growth and establishment of MOB in the foam-matrix. The measured methane concentrations in the inlet- and outlet air from the tested replicate foam columns revealed a measurable microbial methane removal (10-15%).

** ldc@teknologisk.dk, Kongsvangs Allé 29, DK-8000 Aarhus C, Denmark*
*** smu@teknologisk.dk, Kongsvangs Allé 29, DK-8000 Aarhus C, Denmark*
**** hnl@kemic.dk, Ryttervangen 24, DK-7323 Give, Denmark*
***** pun@hfors.dk Solrødgårds Alle 6, DK-3400 Hillerød, Denmark*
****** jph@samn.dk Alrøvej 11, DK-8700 Horsens, Denmark*

The Innovative Biotechnology for Pesticide Removal at Waterworks

S. Musovic, L. Christensen and L. Friis-Holm, Danish Technological Institute, H. Laugesen, Kemic Water Technology**, R. P. Redondo and S. J. Sørensen, University of Copenhagen***, H.J. Albrechtsen, Technical University of Denmark****, N. Møller and A. Millenaar, Herning Vand *****and T.V. Chawes, Furesø Vandforsyning*******

Abstract

The supply of clean drinking water to consumers in countries producing drinking water from groundwater could be challenged in the future due to increasing appearance of pesticide-residues in groundwaters, which is an unfortunate consequence of a long-term pesticide application in the urban areas and agricultural practices. Hence, development of novel technologies to deal with pesticide-residues in water is necessary. Natural pesticide-degrading bacteria were found, and isolated, from different environments (Kryuchkova, 2014; Han, 2015). However, bioremidial application of these pesticide-degraders at polluted sites, inclusive waterworks experiencing pesticides in the groundwater, barely exists. The main bioremidial challenge is a well-known poor survival rate of any externally introduced bacteria into a well-established microbial environment.

The aim of present study was to develop a biotechnology to deal with pesticides in drinking-water sand filters at waterworks. The biotechnology innovatively applies isolation, identification, multiplication and subsequent application of natural pesticide-degrading bacterial isolates, carrying pesticide degrading gene on mobile genetic elements (MGE^P). Upon application of natural isolate carrying MGE^P into a sand filter at waterworks, MGE^P would spread to- and persist within the native sand filter bacterial population, independently of the good or poor survival of introduced isolate, thereby omitting the main bioremidial challenge.

Cultivation of pesticide-degrading bacteria from sand filter enrichments, containing a selective minimal-media with a pesticide (MCPP, Glyphosate or BAM) as a solo carbon source was successfully performed, and isolated bacterial strains (e.g. *Pseudomonas sp, Chryseobacterium sp., Klebsiella sp., Arthrobacter sp.* etc.) were tested for presence of MGEs. The suitability of Trojan Horse biotechnology, monitored as a capability of native RSF bacteria to receive a model plasmid (RP4), was demonstrated, and approx. one in 10,000 native sand filter bacteria were able to receive plasmid under optimal contact (filter-mating) conditions. The rare, natural MGE^P isolated from sand filter bacteria by a biparental-filter mating, and were closest related to *Sinorhizobium, Klebsiella and Pseudomonas* plasmids. The Trojan Horse sand transplantation approach, introducing a persistent biological pesticide removal capacity to a sand filter, was successfully demonstrated at a pilot scale level (Fig.1). It consisted of an unique transfer of a small volume of sand from well-studied filter with demonstrated biological pesticide-removal into an existing sand filter lacking the pesticide removal capacity.

Figure 1. Pilot scale setup. The groundwater (white container) added pesticides of interest was run through sand filter columns (black tubes). Columns contained solo- or mixture of sand material from a recipient sand filter and donor sand filter, shown to respectively unpossess- and possess biological pesticide degrading capacity

** smu@teknologisk.dk (corresponding author), Kongsvang Alle 29, 8000 Århus*
*** hnl@kemic.dk, Ryttervangen 24, 7323 Give*
**** sjs@bio.ku.dk, Universitetsparken 15, 2100 Copenhagen*
***** hana@env.dtu.dk, DTU-Miljø, byg. 115, 2800 Kgs. Lyngby*
****** nmj@herningvand.dk , Ålykkevej 5, 7400 Herning*
******* tvc@furesoevand.dk, Rugmarken 38, 3520 Farum*

Concentrate and degrade perfluorooctanoic acid on an adsorptive photocatalyst

Zongsu Wei, Assistant Professor (Tenure-track)*
Centre for Water Technology (WATEC) and Department of Engineering, Aarhus University

Abstract
Per- and polyfluoroalkyl substances (PFAS), which have been widely detected in various environmental media, are extremely recalcitrant to degradation due to their unique chemical structures. Thus, there is an acute need to develop effective method targeting the persistent PFAS and reduce their risks to the environment and human health. Herein, we developed a new adsorptive photocatalyst, activated carbon supported titanate nanotubes (TNTs@AC), through a one-step hydrothermal method. Indium (In^{3+}) was doped onto the TNTs@AC (In/TNTs@AC) to improve the adsorption and photocatalytic degradation of perfluorooctanoic acid (PFOA), a model PFAS in contaminated water. In batch adsorption and photocatalytic degradation experiments, In/TNTs@AC was able to adsorb ~99% PFOA within 30 min (PFOA = 100 ppb, material dosage = 2 g/L). Subsequently, the pre-sorbed PFOA was completely photodegraded under UV irradiation within 4 h, and 68% of fluorine in PFOA was completely converted into fluoride ions (defluorinated from PFOA) under UV irradiation. The photo-regenerated In/TNTs@AC can then be reused for another 5 adsorption-photodegradation cycles without significant loss in adsorption capacity or photodegradation activity. Mechanistically, In(III) in oxide form are positively charged at neutral pH, which promoted the adsorption of PFOA anions on material surface. Likewise, the doped In(III) facilitated electron transfer and inhibited hole-electron recombination for improved photocatalytic activity. Last, crystallite anatases formed on In/TNTs@AC after calcination further improved the photocatalytic activity. Therefore, In/TNTs@AC hold the promise to be a low-cost, reusable and efficient material to remove PFAS in waters.

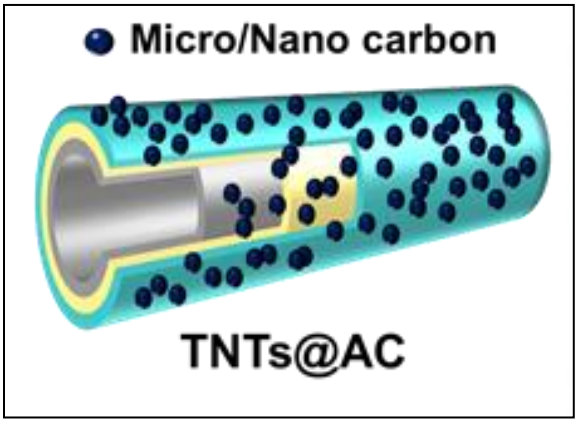


Figure 1. The core-shell structure of TNTs@AC (activated carbon supported titanate nanotubes) and a tubular structure of TNTs.

* zwei@eng.au.dk: *Hangøvej 2,8200 Aarhus N, Denmark*

Backwash efficiency evaluated based on geophysical method

Majbritt D. Lund, VIA University College, Programme for Applied Research and Development in Soil, Water & Energy,*
*Thue S. Bording, AU, Department of Geoscience, HydroGeophysics Group***

Abstract
In drinking water production, where sand filtration is used, the conditions of the sand filter affects the production performance and quality of the produced water. Regular maintenance includes backwash of filters by use of reversed and increased water flow and additional use of airflow to clean filter porosity for clogging materials. In Denmark, iron precipitates most frequently cause clogging of drinking water sand filters, and previous studies have shown these primarily to be situated in the upper 20cm of the sand filters.

Backwashing of sand filters are carried out by use of pure drinking water, which thereby constitutes a waste of water – today 2% of the annual pumped groundwater in Denmark is used for backwash procedures. Optimized control of backwash procedures hereby return a dual purpose: a) ensuring water quality and productivity and b) reduce water waste. However, there is a trade-off between filter growth following a too short/inefficient backwash and limiting water and energy use. Therefore, it is of outmost importance to be able to evaluate the right time and procedure for backwashing.

Today, different strategies are used to determine how often and which backwash procedure is needed. In most cases, the procedure for the backwash is adjusted as part of the start-up of a new or renovated sand filter at the waterworks. The period between each backwash is determined based on either a fixed period (days/weeks) or a specific volume of produced water (m^3). At some waterworks, the pressure loss, water levels, and/or turbidity of filtered water are logged and used to determine when to backwash the filters. But how to diagnose if the filter has been backwashed sufficiently? How to determine if the start-up procedure is still the best after several years of production?

A prototype for monitoring the backwash efficiency based on geophysical methods has recently been developed. The designed equipment are looking into the upper 40cm filter bed where the main part of iron precipitates are removed and are continuously monitoring the filter condition based on conductivity of the filter material, filter porosity and water.

Full-scale equipment test were performed in an open sand filter, where data was collected continuously for six months during 2018-2019.
The prototype test demonstrates that the method are able to distinguish between well backwashed filter bed and filter bed not backwashed sufficiently for optimal production performance. The results show large potential in continuously monitoring of the filter performance, here including the specific focus on the backwash efficiency.

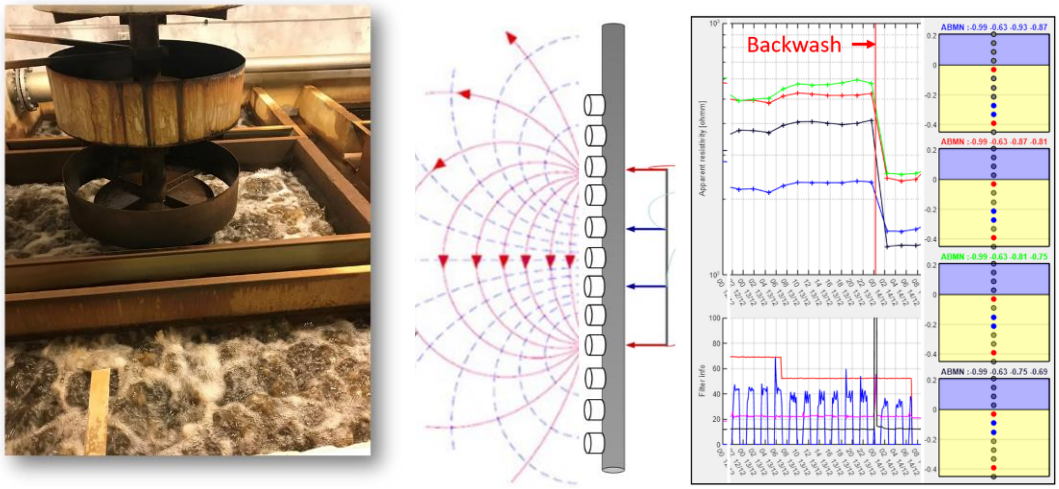


Figure 2 Backwash procedure in action, simplified equipment design, example of visualization of collected data.

The authors gratefully acknowledge the entire project team. This work was financed in part by the VUDP programme (Vandsektorens Udviklings- og Demonstrationsprogram) and was performed in close cooperation by Aarhus University, Lemvig Vand og Spildevand, NIRAS and VIA University College.

** majl@via.dk : VIA University College, Chr. M. Østergaardsvej 4, 8700 Horsens*
*** thue.bording@geo.au.dk: Department of Geoscience, Aarhus University, C.F.Møllers Allé 4, 8000 Aarhus C*

Softening of drinking water – Calcium Carbonate Precipitation Potential (CCPP) and Measured Calcium Carbonate Precipitation (MCCP)

S.V. Afshar, B. Godskesen*, H-J. Albrechtsen*, M. Hedegaard**, M. Rygaard**

Abstract

The water hardness in Greater Copenhagen varies from moderately hard (12-18 °dH) to extremely hard (> 30 °dH). The hardness of the water is caused by the presence of dissolved calcium and magnesium minerals that are naturally present in the water. Many consumers of drinking water in this area (both industrial and domestic) are troubled with calcium carbonate ($CaCO_3$) scale deposits on bathroom tiles, glassware, electric water heaters etc. The accumulation of scale deposits can lead to reduced lifetime of equipment, increased water heating costs, reduced efficiency of heat transfer, and clogging of water pipes. Consequently, some Danish water utilities have introduced central softening by reducing the water hardness. In 2017, HOFOR (Greater Copenhagen Utility) introduced central softening at Brøndbyvester Waterworks where the water is being softened from a water hardness of 21-23 °dH to 11 °dH. In the coming years, HOFOR is planning to introduce central softening to the rest of their supply area.

In the Netherlands, where softening of drinking water has been practiced since the 1970s, utility companies have started to include other parameters than just water hardness when producing softer drinking water. Recent Dutch studies argue that the potential for $CaCO_3$ scaling in water does not only depend on the water hardness, but also pH, alkalinity and other ions – mainly sodium, potassium, chloride, phosphate, sulphide, and nitrite. The scaling potential can be quantified by the Calcium Carbonate Precipitation Potential (CCPP), which is defined as the amount of $CaCO_3$ that theoretically can precipitate or dissolve from the water. Furthermore, studies also reveal a method to determine Measured Calcium Carbonate Precipitation (MCCP). However, the relation between CCPP and MCCP has not yet been studied.

The aim of this project is to study the relation between water hardness, CCPP, and MCCP. Furthermore, the project aims to evaluate if CCPP and MCCP can be used to measure the excepted effects of softening of drinking water based on scale deposits. Water samples have been collected from different parts of Denmark with variating water hardness. For each sample, the CCPP was calculated in PHREEQC and the MCCP was measured based on laboratory experiments. CCPP and MCCP were determined for water samples collected from Skælskør Nordre Waterworks (18 °dH), Kerteminde Waterworks (23,9 °dH), Skovmølleværket (18,6 °dH), Brønbyvester Waterworks (11 °dH), Herlev Water Tower (20 °dH), and from different locations in the distribution system in Brøndby, Herlev, and Lyngby (19,9 °dH). The project is expected to contribute to the future management of central softening in Danish water utilities, and ultimately reduction of scale deposits in households and industries.

** sevaf@env.dtu.dk, berg@env.dtu.dk, hana@env.dtu.dk, mryg@env.dtu.dk: Bygningstorvet, Bygning 115, 2800 Lyngby*

*** mathed@hofor.dk: Ørestads Boulevard 35, 2300 København S*

Choosing between materials with different certification – a comparative study of certification schemes for materials in contact with drinking water

A. H. Thomsen, DTU Environment, L. T. Karlby, HOFOR**, H-J. Albrechtsen, DTU Environment****

Abstract

Materials used in contact with drinking water can potentially affect the quality of the water as chemicals can migrate from the material into the water. This migration can give rise to unwanted toxic micropollutants, microbial growth and cause changes to taste and colour of the drinking water. Ultimately the materials used can pose a risk to human health, thus choosing them carefully can help maintain drinking water quality and safety. According to Article 10 in the European Drinking Water Directive, member states shall regulate the use of materials in contact with drinking water. This have led to the formulation of an array of national certification schemes in Europe. However, as the schemes differ amongst member states, challenges are imposed on the certification users; the material producers and the water utilities installing their materials. Harmonisation of the certification schemes is of increasing interest in Europe, and Article 10 is under revision in the European Union. To facilitate this process it is necessary to identify the current differences between the schemes. All the while, utilities in Denmark feel that there is no broad-covering national certification scheme, which puts the utilities in a position to choose between materials with different foreign certification. Understanding the principles and requirements behind the different certification schemes is essential when choosing one material over another. The aim of this study was therefore to compare relevant certification schemes for materials in contact with drinking water. The reviewed certification schemes include the German DVGW, the Dutch Kiwa, the French ACS, the British WRAS, the North American NSF, and the Danish DK-VAND, certification schemes that are commonly used by the Danish utilities. The comparative study assessed the different certification schemes by understanding the principles behind an approval with particular focus on their field of application, the test methods and the requirements to obtain an approval.

The study showed variations in the field of application, and while some certification schemes are suitable to certify all relevant materials to the water utilities, others have limited application to specific product types or instalment only within households (e.g. DK-VAND and WRAS). A number of European certification schemes (e.g. DVGW, Kiwa and ACS) use the principle of a positive list to regulate the material ingredients. The positive list consists of toxicologically assessed ingredients permitted for the production of a material. Other certification schemes uses the approach of specific migration limits that should be met, to receive an approval of a material. Besides testing for migration of specific chemical compounds, the European certification schemes generally include test requirements of organoleptic aspects (i.e. taste and odour), organic content (TOC) and enhanced microbial growth (EMG). While the North American, NSF, only includes the migration of chemical substances, it is a very transparent certification scheme with a comprehensive list of more than 600 acceptance criteria. When comparing the requirements for a certification, it is evident that the migration test methods vary amongst certification schemes. Even though different certification schemes applied the same method standard (e.g. European standard EN 12783-1:2014), the national certification schemes may have differences in their migration tests. Among the important test differences are the length of the migration test and the conversion of a measured concentration to an expected migration. These differences will ultimately lead to a different material evaluation against pass/fail criteria. Based on the comparative study, the certification schemes were evaluated in regards to their performance given the constraints of Danish drinking water regulation and the general needs of Danish utilities. This evaluation concluded that the German DVGW and the Dutch Kiwa are the best suitable certifications for Danish utilities, given their broad covering field of application, the comprehensive test requirements, and transparency of the schemes.

** anhot@env.dtu.dk: Bygningstorvet Bygning 115, DK-2800 Kgs. Lyngby, Denmark*
*** ltka@hofor.dk: Ørestads Boulevard 35, 2300 København S*
**** hana@env.dtu.dk: Bygningstorvet Bygning 115, DK-2800 Kgs. Lyngby, Denmark*

Characterizing the development of biofilm in PE pipes through 1.5 years in the non-chlorinated Danish drinking water distribution system

D.A. Søborg & T.L. Skovhus, VIA University College, B. Højris, GRUNDFOS Holding A/S**,*
*J.O. Andreasen & K. Brinkmann, Aarhus Vand A/S****

Abstract
During commissioning of newly installed pipes in the drinking water distribution system (DWDS), a biofilm develops on the inner pipe surface. The development of biofilm is a multistage process involving initial attachment of cells, microcolony development and biofilm maturation including building of the EPS matrix. In the end, a mature biofilm is established shaped by the environmental conditions. Despite examination of the structure and composition of biofilms in DWDS in previous studies, there is still a knowledge gab on how biofilms are shaped and affect drinking water quality and thereby the consumers. In this study, biofilm development was followed in a full-scale DWDS through 1.5 years at two locations (TBR and BUS). Focus was on identifying dominant bacteria at different stages of biofilm development. Further, to investigate how differently a biofilm develops in identical polyethylene (PE)-pipes exposed to different environmental conditions.

Young biofilms from the two different locations were both dominated by genera of *Comamonadaceae* and *Caulobacteraceae*. The community composition of the mature biofilm, however, differed between the two locations. As seen from the principal component analysis (PCA) plot in Figure 1, the samples I-T and 11-20, respectively, clustered together, which showed that a mature biofilm was reached at BUS after 8 months and at TBR after 9 months. The diversity of the mature biofilm was higher in BUS than TBR (Shannon Index of approx. 5 compared to approx. 3). Differences in the mature biofilms were related to upstream factors such as water quality, pipe material, the existing biofilm upstream the new pipe section, flow velocity, etc. Results of water samples showed the importance of reaching a mature biofilm for the biological stability of the water. Even though microbiological parameters complied with drinking water criteria within days of commissioning, a clear decrease in heterotrophic plate counts (HPC), ATP and DAPI counts was seen at the time when the microbiological diversity of biofilms reached a steady state at both locations.

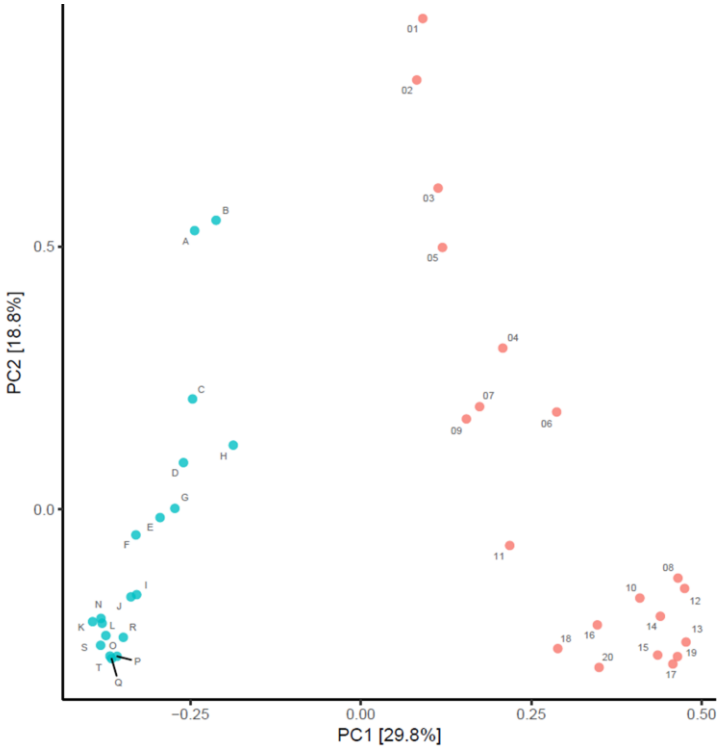


Figure 1. Principal-component analysis based on 16S rRNA gene sequencing of biofilm from test rigs TBR (1-20) and BUS (A-T). Each dot represents the full diversity in a sample at a given time from one of the two locations. Sample 1+2 (and A+B) are true replicates (and so on). After 1.5 years, samples from each location clustered separately along PC1, suggesting that the PC1 axis explains variations based on location (effect of upstream factors). Samples distributed along the PC2 axis in relation to the time of sampling (maturation of the biofilm).

** dans@via.dk & tols@via.dk: Chr. M. Østergaardsvej 4, DK-8700, Horsens, Denmark*
*** bhoejris@grundfos.com: Poul Due Jensens Vej 7, DK-8850, Bjerringbro, Denmark*
**** JOA@aarhusvand.dk & KBK@aarhusvand.dk: Gunnar Clausens Vej 34, 8260 Viby, Denmark*

Learnings from an applied research project: The role of beneficial biofilms during commissioning of new drinking water PE pipes in Aarhus, Denmark

T.L. Skovhus & D.A. Søborg, VIA University College, B. Højris, GRUNDFOS Holding A/S**, K.L. Hansen, J.O. Andreasen & K. Brinkmann, Aarhus Vand A/S****

Abstract

Biofilm is considered beneficial in the non-chlorinated Danish drinking water distribution systems, as it increases the microbiological stability. When introducing new pipe sections in the distribution network, a biofilm develops on the new pipe wall influenced by the water quality, the existing biofilm upstream the new pipe section, flow velocity, pipe material, dimensions, etc. However, the influence of biofilms on the water quality in the short-term during the commissioning phase of new pipe sections remain poorly understood.

During commissioning of new PE pipes in the existing distribution network, biofilm will start to develop on the surface when water enters the new pipe. The water company will need to flush the new pipes until the water meets the required drinking water criteria defined by the water authority (HPC22 <200 CFU/mL). The flushing period will be determined by several factors like groundwater quality, pipe material and flow velocity. During the flushing period, all water is discharged to the sewer system until it meets the drinking water criteria above.

In this study, the short-term effect was analysed of the developed biofilm in newly installed drinking water PE pipes on the water quality, to be able to optimize the commissioning procedure for installing new pipe sections in the existing pipe network to improve water safety for the consumers.

During commissioning of a new PE pipe section in the City of Aarhus, Denmark the microbiological status was monitored for both water and surface biofilm (Figure 1). This lead to documentation and evaluation of a new procedure for commissioning new pipe sections with extended focus on consumer water safety and water use. Based on data from several molecular microbiological methods (MMM) and a new online microbiological sensor, the microbiological results showed no health risk related to the increased measures of HPC22/37 during the commissioning process of new pipes. With knowledge from the study, the current protocols for commissioning new pipe sections was updated and optimized to reduce water use during the flushing period. The study highlights the importance of maintaining the natural biofilm in the non-chlorinated drinking water distribution system concerning the water quality.

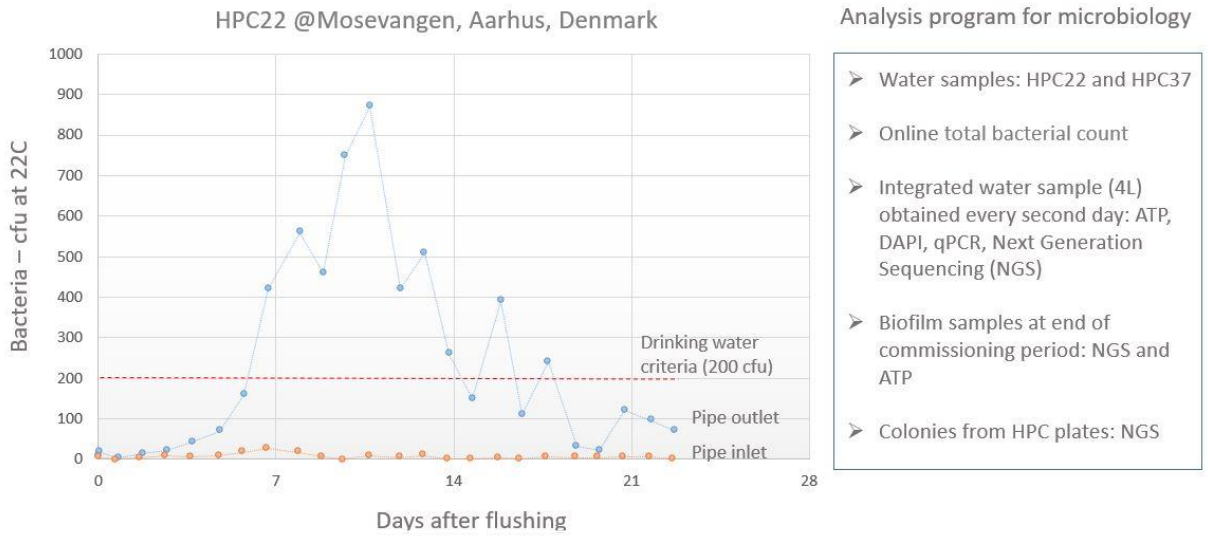


Figure 1. Result of the daily HPC22 measurements from pipe inlet (orange) and outlet (blue). Besides the regular water samples a series of other sample types and parameters was also obtained and analyzed (Box). ATP = a measure of cell activity, DAPI = a measure of total microorganism by microscopy, qPCR = a measure of total abundance of bacteria by quantitative Polymerase Chain Reaction, NGS = a measure of microbiological diversity and relative abundance by Next Generation Sequencing.

** tols@via.dk & dans@via.dk: Chr. M. Østergaardsvej 4, 8700, Horsens, Danmark*
*** bhoejris@grundfos.com: Poul Due Jensens Vej 7, 8850, Bjerringbro, Danmark*
**** KLH@aarhusvand.dk, JOA@aarhusvand.dk & KBK@aarhusvand.dk: Gunnar Clausens Vej 34, 8260 Viby J, Danmark*

Leak detection using data from smart meters

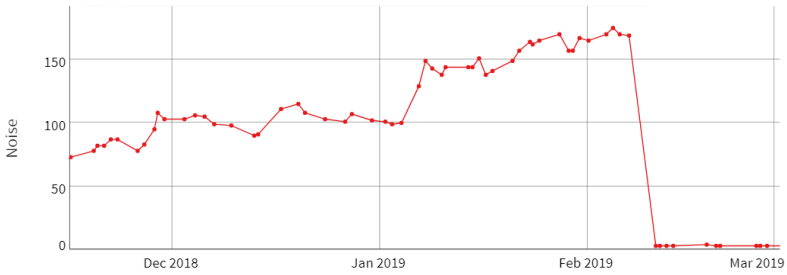
S. H. Dupont, Kamstrup A/S, K. R. Andersen, Kamstrup A/S***

Abstract

Water scarcity is a rising challenge all over the world. This combined with the fact that many countries have non-revenue water (NRW) percentages above 20% of the produced volume, makes NRW reduction a primary target for most water utilities. A key element here is finding and repairing leaks. The motivation for leak finding is further increased, since leaks can course damage to buildings and be the source of water pollution. Unfortunately continuous surveillance is difficult and leaks are therefore often first discovered when water rise to the surface.

We present a novel approach to this problem by implementing an acoustic noise sensor in a standard water meter which uses the ultrasonic measurement principle. The setup for the acoustic measurements will be described in the presentation. Having the sensor in a standard water meter makes coverage of the entire grid an inherent part of the solution since these are installed across the entire grid at all consumers. To ensure the battery life-time of the combined water meter and acoustic sensor of 16 years, the amount of radio transmitted data from the meter to the central system is limited. Therefore, a data distillation takes place in the meter. Some knowledge is lost in this data refinement, but we will show that this is highly compensated by the fine mesh setup by the numerous meters in the grid. Furthermore, we also show that signatures of ambient noise sources are still present in the time evolution of the noise figure calculated by the meter.

A field test with 1250 meters installed at two main sites (500 meters each) and 5 smaller sites (50 meters each) was conducted to verify the function of the acoustic sensor in the water meter. From the field test we have collected data examples of many different noise cases. Several examples will be shown in the presentation. Based on all the leaks and other noise sources found during the field test we have concluded that the leaks are generally more noisy than ambient noise sources and have a more stable noise pattern.
We have successfully detected 13 previously unknown leaks during the 1st year of the field test. The acoustic figures measured by the meters also makes it possible to distinguish ambient noise from leak noise and we expect in the future with more data to be able to even further improve the classification. This is to our knowledge the first implementation of acoustic noise loggers in smart water meters.



** sud@kamstrup.com: Industrivej 51, 8660 Skanderborg*
*** kan@kamstrup.com: Industrivej 51, 8660 Skanderborg*

ROOM 1

SESSION 4 and 5: Research

Time	Title	
Chair:	**Peter E. Holm**	**Presented by**
16:30	Water Sector Governance & Operations – the Danish Model	Katrine Nielsen, DTU Environment
16:45	Implementation of frameworks and stakeholder challenges - Water challenges in Argentina	Federico Luciani
17:00	Stakeholder challenges to effective water governance within the Athi basin - a water challenge in Kenya	Carol Matere
17:15	Reduction of Non-revenue water in Kahawa West Area, Nairobi - A water challenge in Kenya	Davis Shatimba Wanangwe (TBC)
17:30	Water supply as a business - a water challenge in South Africa	Wendy Tshawe
17:45	Plenum Discussion	
18:00		

Water Sector Governance & Operations – the Danish Model

P.S. Mikkelsen, S.F. Hansen*, K. Nielsen*, DTU Environment; B.K. Pedersen**, B.H. Jacobsen**, P.E. Holm**, UCPH-SCIENCE*

Abstract

Worldwide freshwater resources are under pressure due to overexploitation, pollution and climate change. At the same time, urbanisation is increasing and maintenance of water infrastructure is falling behind the needs, while demands for clean water in and around cities for leisure and amenity purposes are increasing. It is crucial to find ways to secure sustainable supplies of water of a quality suitable for drinking, agricultural and industrial production, while at the same time ensuring the stability of ecosystems and handling climate extremes like heavy rainfall events, flooding and droughts.

Danish strategic water sector cooperation programs are implemented in South Africa, China, India, Indonesia and Turkey, and there is a pronounced demand and need for training, competence and capacity building for water sector professionals working in the partnering organisations.

Under the Danida Fellowship Centre Scholarship Programme, Technical University of Denmark (DTU) and University of Copenhagen (UCPH) offer a tailored course on "Water Sector Governance and Operations – The Danish Model", in collaboration with the Geological Survey of Denmark and Greenland (GEUS), University of Southern Denmark (SDU), Aarhus University (AU), utilities and private companies. The target group is senior officers from national, provincial and local (municipal) directorates and departments, regional water utilities and catchment management authorities or similar. The course scope and form is designed to be relevant for both practitioners and policy makers and is based on state-of-the-art didactical methods used and developed at DTU and UCPH, including elements such as blended learning (including e-learning), flipped classroom, plenum lectures, hands-on exercises and operational training, hardware and software technology demonstrations, scientific symposia, stakeholder excursions, and exercises. Climate change impacts and adaption is included as an overarching topic across seven thematic course modules: (1) Water sector governance and economics, (2) Water resources management, (3) Water quality management, (4) Excursion to Jutland, including utility- and industry-visits, (5) Water supply and stormwater management, (6) Wastewater treatment and resource recovery, and (7) Water conservation and demand management.

The overall learning goals include understanding the historical background of the Danish water sector are: (i) understanding the price structure used and the use of cost-benefit analyses and the total economic value concept; (ii) understanding the institutional setup and the mandates of different stakeholders; (iii) completing a stakeholder analysis and drawing up a water governance model for the water sector in the participants' own countries; (iv) applying the fundamental principles of "good" water sector governance and operations"; (v) understanding the hydrological cycle and the modelling approaches used to estimate its components, (vi) understanding the biogeochemical processes leading to different water qualities, factors that are critical to change and control of water quality, and the major physical, chemical, and biological treatment processes that can be applied to achieve different water quality objectives; (vii) recognising the different elements of the water transportation and treatment infrastructure in urban areas and understand the interactions between them and their environmental effects; and (viii) applying an integrated approach to solve water-related issues in urban areas and improve the city overall liveability. Translation of learnings into action has special focus by requiring each participant to develop an overall personal action plan focusing on challenges in their own environmental and organisational context.

We here report on the experiences from running the course so far three times, in 2018 and 2019. Running the course equips researchers, teachers and mentors from all the involved institutions and companies with a new "lense" to better reflect on the needs of the water sector in the future, both internationally and in Denmark.

**psmi@env.dtu.dk: Bygningstorvet, Bygning 115, 2800 Lyngby*

*** peho@plen.ku.dk: Thorvaldsensvej 40, 1871 Frederiksberg C*

ROOM 2

SESSION 6, 7 and 8: Groundwater

Time	Title	
Chair:	**Anders Refsgaard and Lars Skov Andersen**	
11:15	A hectare-scale decision tool for nitrate retention estimation by integration of geophysical, geological, geochemical and hydrological data	Esben Auken, Aarhus University, Geo. Sci
11:30	Stochastic 3D redox and geological models for nitrate contamination assessment	Rasmus B Madsen, GEUS
11:45	Strategy for an improved implementation of riparian zones in the Danish nitrogen model	Saskia L. Noorduijn, GEUS
12:00	**Lunch break**	
13:00	Geophysical monitoring of the subsurface distribution of ISCO reagents in a groundwater remediation in Denmark	Thue Bording, Aarhus University, Geo science
13:15	Searching for safe water sources using a towed transient electromagnetic (tTEM) system – examples from refugee camps and the surrounding host communities in western Tanzania	Denys Grombacher, Aarhus University, Geo.Sci.
13:30	Can we measure the “unmeasurable”? Using drones and thermal imagery to study Danish wetlands	Joel Tirado-Conde, University of Cpenhagen, Dept.Geosci. & Nat. Res.Man.
13:45	TAGS-P: An innovative and data-driven tool for assessing groundwater pesticide sensitivity	Marianne Jeppesen, COWI
14:00	Synergy between ozonation and activated carbon for chloroethenes contaminated groundwater treatment	Kamilla Marie Speht Kaarsholm, DTU Env
14:15	Integrated water management in the future climate change for robust risk assessment from contaminated point sources	Agnieszka. T. Bentzen, Region of Southern Denmark
14:30	Buffer time	
14:45	**Coffee break and Posters**	
15:15	Hydroeconomic optimization methods to address management issues of groundwater overdraft in the North China Plain	Grith Martinsen, GEUS
15:30	Triple-helix partnership as a tool for increased water efficiency in the food and beverage industry	Hanne Bengaard, Landbrug & Fødevarer
15:45	Presentation of a new UV purification technique for removal of chlorinated solvents and pesticides from drinking water/remediation wells	Martin Bymose, Project Manager, Geologist, DGE Miljø- og ingeniørfirma A/S
16:00	Buffer time	
16:15		

A hectare-scale decision tool for nitrate retention estimation by integration of geophysical, geological, geochemical and hydrological data

R.R. Frederiksen, A.V. Christiansen**, T.N. Vilhelmsen***, S. Christensen**** and E. Auken*****, Department of Geoscience, Aarhus University, B. Hansen, Geological Survey of Denmark and Greenland (GEUS), Aarhus*******

Abstract

It is crucial for reducing the impact of agricultural nitrogen (N) to the aquatic environments to be able to delineate vulnerable or robust areas. The regulation of N in Denmark has moved from regional catchment scale to ID15 catchment scale, and likely to sub-ID15 scale in the years to come. A new tool integrating information from geophysical, geological, geochemical and hydrological data to predict N retention in the open landscape on a hectare-scale has been developed in the rOpen project (Innovation Fund Denmark). In rOpen the goal is to make a data-driven and transparent tool where an essential element is the incorporation of uncertainty in both the geological, geochemical and hydrological modelling and its implications for uncertainty on the predictions of N retention from agricultural fields to streams.

In short, the tool comprises five key elements:

1. Geophysical mapping using tTEM. The tTEM is an ATV-towed system that maps the top 70 m of the subsurface in high 3D resolution with data at every 10 meter along lines and with 20 meter between lines. 200 hectares are mapped per day.
2. Geological modelling using stochastic realizations of the subsurface structures based on a 3D hydrostratigraphical model produced from a clay-fraction modelling which combines lithological borehole information with geophysical resistivity models.
3. Geochemical modelling using stochastic realizations of the subsurface redox conditions based on a 3D redox model produced from a cognitive analysis combining borehole information on redox conditions with geophysical resistivity models.
4. Hydrological modelling with particle tracking that builds on FloPy, which develops MODFLOW and MODPATH models using scripting in Python.
5. Coupling of the components above (and more). For this, we have developed a script-based modelling framework that is data-driven, flexible, reproducible and cost-efficient.

In the presentation, we will summarize the central aspects of the tool with a focus on a discussion of the uncertainties. The presentation will give examples from two case studies in rOpen where ID15 areas have been mapped with geophysics (tTEM), boreholes for lithological information and geochemistry, stream gauges, and detailed root zone modelling. Everything is integrated into the overall framework producing N-retention maps at a 30x30 m resolution including uncertainty maps.

* *rasmus.rumph@geo.au.dk, CF Møllers Alle 4, bygn. 1120, 8000 Aarhus C*
** *anders.vest@geo.au.dk, CF Møllers Alle 4, bygn. 1120, 8000 Aarhus C*
*** *troels.norvin@geo.au.dk, CF Møllers Alle 4, bygn. 1120, 8000 Aarhus C*
**** *sc@geo.au.dk, Høegh-Guldbergs Gade 2, 8000 Aarhus C*
***** *esben.auken@geo.au.dk, CF Møllers Alle 4, bygn. 1120, 8000 Aarhus C*
****** *bgh@geus.dk, CF Møllers Allé 8, bygn. 1110, 8000 Aarhus*

Stochastic 3D redox and geological models for nitrate contamination assessment

RB Madsen, GEUS, H Kim**, P Sandersen***, AJ Kallesøe****, B Hansen******

Abstract

One aim of the Mapfield project, funded by the Innovation Fund Denmark, is development of techniques and concept for targeted N-regulation in Danish agriculture to protect groundwater and surface water resources. Danish N-regulation is currently based on ID15-catchment (15 km^2) areas, whereas applying a successful Mapfield concept will lead to N-regulation on individual field scale (<<15 km^2). Many water-soluble contaminants such as nitrate are naturally removed from water by redox processes in the subsurface. Redox conditions hence play a vital role in determining phases and concentrations of nitrate. Furthermore, the geological architecture of the subsurface govern the flow and transport of nitrate in aquifers. A detailed description of both redox and geology in 3D are therefore essential to assess the vulnerability of both groundwater and surface waters nitrate contamination. We propose a new methodology building joint high-resolution 3D redox and geological models of the subsurface. A schematic overview of the proposed workflow is shown in Figure 1. Firstly, two types of data are specifically gathered for the Mapfield project. Geophysical resistivity data from the newly developed ground based high-resolution towed transient electromagnetic (tTEM) method are supplemented with borehole data containing lithological and geochemical information. Combining these data with pre-existing digital elevation models and soil maps allow the delineation of the study area in geological elements. Each element is then assigned a 3D conceptual understanding (training image) of both the geology and redox within the element. Using geostatistical simulation, each element is simulated with information provided by the training images. The training images are designed in pairs such that geology and redox are consistent for each realization in the geostatistical simulation. The result is an ensemble of realizations of high-resolution 3D redox and geological models that expresses the uncertainty of the specific input data and expert geological and geochemical knowledge. The proposed methodology may therefore contribute to improve the effectiveness of groundwater and surface water management by providing quantitative uncertainty measures. The simulation setup is also flexible and allows combination with e.g. training images of hydrology to provide joint simulation of hydrology alongside geology and geochemistry.

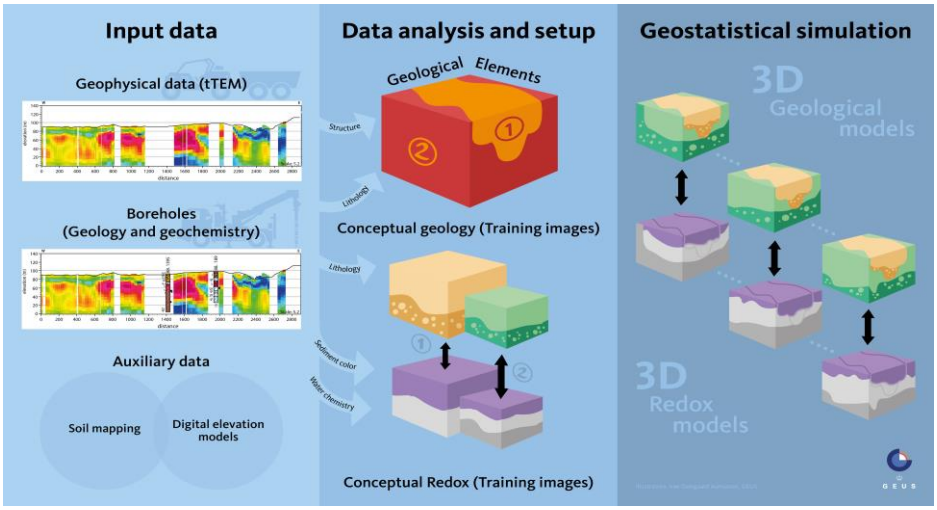


Figure 3: Proposed workflow of geological and redox modeling. The input data is gathered (left), analyzed with preexisting data to outline geological elements and training images (middle), and then simulated (right).

* rbm@geus.dk,*Geological Survey of Denmark and Greenland (GEUS), Groundwater and Quaternary Geology Mapping , C.F. Møllers Allé 8, Building 1110, 8000 Aarhus C, Denmark*

** hk@geus.dk,*GEUS*

*** psa@geus.dk,*GEUS*

**** ajk@geus.dk,*GEUS*

Strategy for an improved implementation of riparian zones in the Danish nitrogen model

S. L. Noorduijn, GEUS, A. L. Højberg**, GEUS,*

Abstract

Riparian zones and wetlands have been shown to play a significant role in buffering surface water systems from contaminant transport. At present, substantial funds have been made available to re-establish riparian lowlands across Denmark, prompting a greater focus on investigating riparian lowland properties and their efficiency in reducing nitrate loading to stream, alongside reducing greenhouse gas emissions. Surface water nitrate loads in Denmark are estimated using the national nitrogen model, whose scale is unable to account for the hydraulic effects of these small-scale features. The model is thus unable to account for the nitrate reduction in the riparian lowlands and the spatial variation in this. Therefore, to fully develop the potential of riparian lowlands, the impacts upon the hydrology need to be upscaled and incorporated into the national scale model. The challenge is how to achieve this in a consistent and transparent way.

The proposed approach is to identify key landscape features, such as drainage area, slope, and aquifer geometry which contribute to the reduction capacity of a lowland riparian zone. However, identification will rely upon a general understanding of the flow and transport conditions within the riparian zone. While many field investigations have focussed on describing the hydraulic processes within a riparian zone, very few investigations have attempted to quantify the flow pathways and/or provide insight into how this information may be used at a larger scale. Therefore, a preliminary investigation to simulate and quantify the observed flow pathways at the field scale was conducted. Data available for two field sites in Jutland (Fensholt and Holtum) will be used. These simulations will aid in identifying the keys landscape features which aid in determining the reduction capacity of riparian lowlands at the national scale.

** sano@geus.dk: Øster Voldgade 10, DK-1350 Copenhagen K*

*** alh@geus.dk: Øster Voldgade 10, DK-1350 Copenhagen K*

Geophysical monitoring of the subsurface distribution of ISCO reagents in a groundwater remediation in Denmark

T. Bording, A.V. Christiansen*, E. Auken*, Aarhus University, J.F.Christensen**, The Region of Southern Denmark*

Abstract

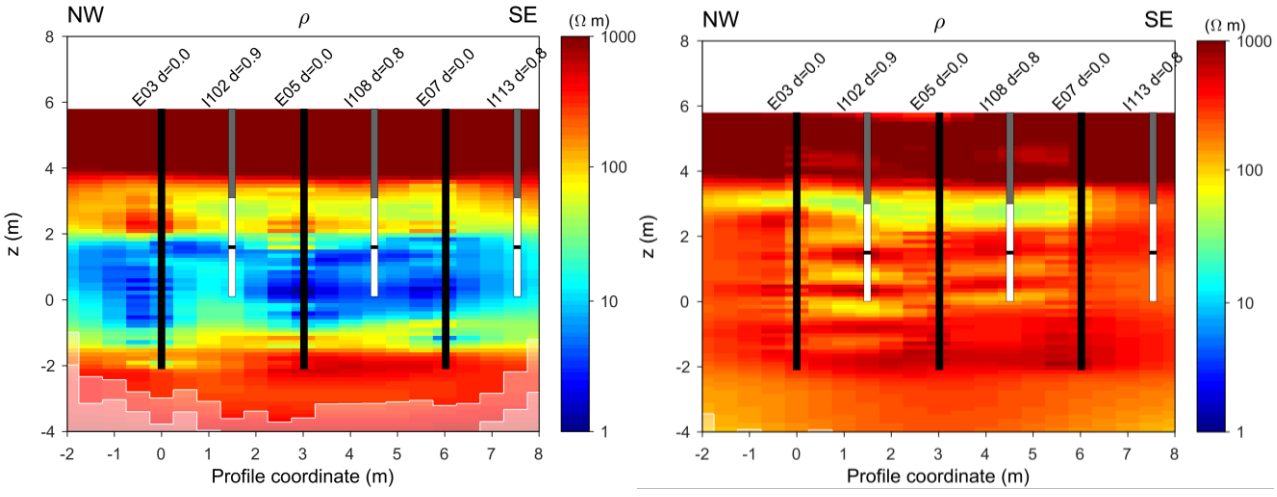
In-situ chemical oxidation (ISCO) is a well-known remediation technique used for groundwater remediation to reduce the concentrations of specific contaminants to acceptable levels. The ISCO-process only works when there is direct contact between the oxidant and the contaminants. Hence, a major challenge is to ensure that the injected reagents are distributed to the entire contaminated area. Today, the distribution is controlled with an extensive (and expensive) network of monitoring wells, which provides point information, but no information about the area between the wells. We will demonstrate how this information can be generated using geophysics.

The purpose of the project is to create a much more detailed picture of the injected reagents by means of geophysical mapping, than the image we get from traditional monitoring wells. In turn, this could lead to a better and cheaper way of documenting the distribution of injected reagents while at the same time optimizing the actual remediation process.

The site of investigation is one of Denmark`s largest polluted sites, located on the Danish west coast in Kærgaard Klitplantage. The remediation is carried out with Fenton`s Reagent activated persulfate. In connection with the remediation, we installed a geophysical test facility aiming to measure the distribution of the injected reagents by means of cross-borehole resistivity and induced polarization measurements. The measurements were performed in a subarea of pit 3 while it was treated with ISCO.

Results.

In 2018 two ISCO injection events were completed at the site, and geophysical measurements were performed before and after each injection event. The results of the geophysical measurements show that we are able to create a detailed image of the distribution of the reagent with resolution down to tens of cm as in the left image below. The image to the right shows the background level. The resolution in these images is far better than what we can obtain with traditional monitoring boreholes relying on fairly long filters and sparse lateral sampling. Furthermore, with the cross-borehole technology the distribution is measured in three dimensions, something that has not been possible before. This means that ISCO can be carried out far more targeted, and therefore somewhat cheaper.



* thue.bording@geo.au.dk , anders.vest@geo.au.dk , esben.auken@geo.au.dk: *HydroGeophysics Group, Department of Geoscience / WATEC, Aarhus University*

** joergen.f.christensen@rsyd.dk *: Damhaven 12, 7100 Vejle*

Searching for safe water sources using a towed transient electromagnetic (tTEM) system – examples from refugee camps and the surrounding host communities in western Tanzania

D. Grombacher, P. Maurya, J. Lind, and E. Auken, Hydrogeophysics Group, Department of Geoscience, Aarhus University*

Abstract

Access to a safe and sustainable drinking water source is a daily struggle for many residents of developing countries. In western Tanzania, drinking water is often sourced from springs, shallow hand dug wells, or various surface water bodies. Hand dug wells and springs are often unable to satisfy the communities' water needs, while surface water is often of poor quality – due to high turbidity. Furthermore, these water sources are often located large distances from community centers, meaning that residents must transport water over great distances – a burden often shouldered by children that must transport water using bicycles for several kilometers each day. For these communities, groundwater represents an attractive resource to meet their water needs. But drilling a well can be a significant financial burden for many communities. As such, it is imperative that measures capable of increasing the likelihood of drilling a successful well are taken. The challenge becomes determining optimal well locations and screen depths, especially in data poor regions such as western Tanzania. Geophysical methods have shown great potential to fill the data gap and to locate suitable drilling sites.

A towed transient electromagnetic (tTEM) survey was conducted in Nduta and Nyarugusu refugee camps, which are home to over 250,000 Congolese and Burundian refugees, as well as in several surrounding host communities. The tTEM system, which involves towing a transmit and receive coil behind an all-terrain vehicle (ATV) in order to conduct a transient electromagnetic measurement while driving, was able to efficiently map electrical structures in the subsurface. Collection rates often exceeded more than 20 kms of data per day. When combined with local knowledge of existing groundwater systems, consisting of known spring and hand dug well locations, the tTEM results provide a far more comprehensive picture of local groundwater systems. The tTEM system is shown to be well suited to these data poor regions and has great potential to become a powerful tool to enhance the likelihood of drilling a successful well.

** denys.grombacher@geo.au.dk: C.F. Mollers Alle, Aarhus, 8000, Denmark*

Can we measure the “unmeasurable”?
Using drones and thermal imagery to study Danish wetlands

Joel Tirado-Conde, Majken C. Looms**, Peter Engesgaard***, Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark*

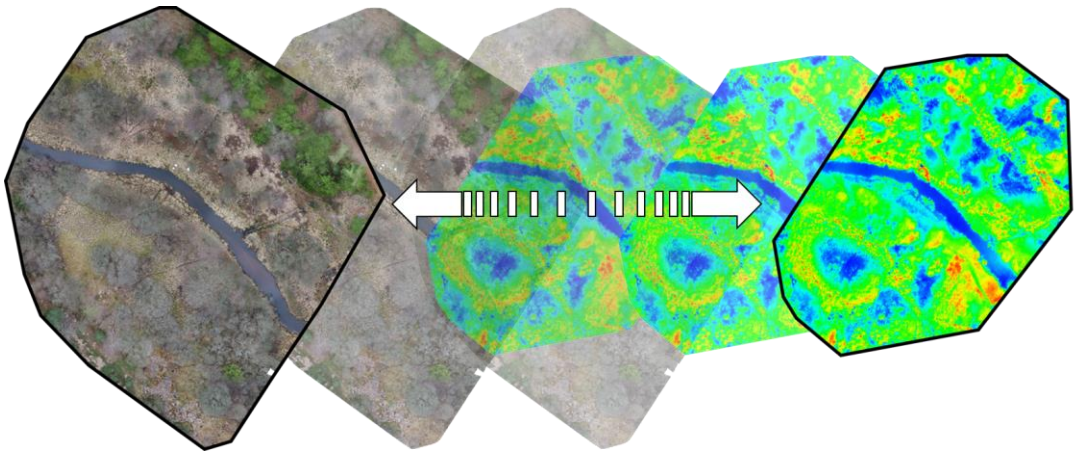
Abstract

Unmanned Aerial Vehicles (UAVs), commonly known as drones, are a technology that is becoming increasingly present in our everyday life. They have a potential to be not only tools for leisure but also to provide opportunities for monitoring natural processes at larger scales than classical methods. Their use for studying hydrological processes is still in an early stage of development but researchers are already finding promising applications for this technology that will lead to more accurate and less labour intense hydrological monitoring protocols. With drones, we will be able to measure hydrological signatures that would, otherwise, be “unmeasurable”.

Wetlands are extremely dynamical systems and their behavior depends on the characteristics of the surroundings (topography, geology and vegetation, among others) as well as on meteorological and hydrological processes. Wetlands are wet partly because they receive groundwater (or drain water) through diffuse upwelling and through springs. Studying upwelling is of great importance to e.g. evaluate the overall ecology or capacity to remove nitrate from the wetland system. One problem is that diffuse upwelling is difficult to locate and measure.

We analyze the temporal dynamics of a groundwater fed wetland in central Jutland (Denmark) using various thermal methods across a lowland stream valley over a period of around two years. A monitoring system consisting of Distributed Temperature Sensing (DTS), wells with temperature depth profiles and thermal infrared (TIR) imaging on a UAV (drone), in conjunction with hydrological and atmospheric data, provide a quasi-3D time-lapse characterization of the thermal behaviour of the ground and subsurface system.

By analyzing the temporal evolution of the temperature in both the wetland surface and the groundwater, we can infer potential locations of groundwater upwelling to the land surface and subsequent overland flow. This is relevant as previous studies have shown that it is a generally overlooked flow component that may have a big impact relative to base flow. Moreover, it serves as a test for the feasibility of using heat as a tracer to study groundwater – surface water exchanges in wetlands.



** jtc@ign.ku.dk: Øster Voldgade 10, 1350 København K*
*** mcl@ign.ku.dk: Øster Voldgade 10, 1350 København K*
**** pe@ign.ku.dk : Øster Voldgade 10, 1350 København K*

TAGS-P: An innovative and data-driven tool for assessing groundwater pesticide sensitivity

J. K. Bielefeldt[1], M. Jeppesen[2], A. Bakumenko[3], N. P. Arildskov[4], K. Rügger[5], L. Clausen[6], A. Esbjørn[7], L. T. Burgaard[8]

Abstract

In countries where groundwater is being used for drinking water and other clean water needs, protection of the resources is crucial. Therefore, there is an increasingly urgent focus on the presence of pesticides in groundwater in countries where pesticides are or have been used for agricultural and other purposes, including Denmark. Previously in Denmark, a few well-known substances were problematic to water utilities. However, new pesticides and degradation products which were not considered to pose a problem until recently have emerged and caused the closure of numerous drinking-water wells.

Upon discovery of pesticide contamination of groundwater, mitigating measures are made on a slim foundation. Often the contaminated water is diluted until standards are met or wells are closed to be substituted with new wells in other areas. The latter is expensive and space-consuming and there is no guarantee that that a new well field is free of contamination.

Consequently, there is a need for a tool that can help water utilities plan their catchment with a data-driven approach, and help Danish regions and municipalities carry out risk assessments and prioritise their efforts to protect groundwater resources. The tool will also benefit the Danish Environmental Protection Agency as well as the Ministry of Energy, Utilities and Climate since they manage and regulate the abovementioned bodies and industries with their own catchment activity that requires drinking-water quality.

In Denmark, we have access to large volumes of data on soil and groundwater. They include analysis data on a range of pesticides and hydrological parameters as well as information on areas classified as contaminated sites and top soil features (organic soil content, fracture flow etc). This data can be linked to other important factors such as precipitation, mapping of agricultural soil and urban areas, which are freely available on public platforms. To date, few projects apply machine learning on environmental and hydrological data sets, so this project will have a high news value.

In this work, we refer two projects that used machine learning to extract meaning from environmental data. In *Koch, J. et al. 2018* machine learning is used to determine the depth of the redox limit in all of Denmark. To do this, clay contents, water levels, landscape types and other parameters were used to estimate redox depths using a random forest algorithm. The same algorithm was used in *Region Midtjylland et al. 2019* to estimate high ground water levels in a large part of Jutland. Information about the aquifer types in the top soil, distance to surface waters and calculations of seasonal variations in water levels was used to determine high water levels near terrain at present and in 2050. The success of these two projects have paved way for applying machine learning to environmental data in this project.

This project aims to develop a tool TAGS-P, where a machine learning algorithm is used to build a model to predict the risk of the presence of pesticides or degradation products in a specific location in Denmark. The machine learning system is trained using two thirds of the relevant data and the training model performance is evaluated using the remaining third as a testing set.

The project is carried out by COWI in cooperation with three utility companies – Greater Copenhagen Utility (HOFOR), VCS Denmark (Vandcenter Syd) and Aalborg Utility. Data collection and structuring is carried out using COWI Connect, which gathers all accessible data sources in a coherent database. The data processing takes place in close collaboration between COWI specialists in groundwater, groundwater chemistry, contaminated sites and data analysis.

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Central Demark Region, Thisted, Morsø and Vesthimmerland Municipalities, COWI, GEUS, Scalgo 2019. Planning tool – Shallow groundwater. Description and documentation. C2CCC Coast to Coast Climate Challenge

[1]COWI A/S, jkbt@cowi.com [2]COWI A/S, mrjp@cowi.com [3]COWI A/S, albk@ cowi.com
[4]COWI A/S, npa@cowi.com [5]COWI A/S, kiru@cowi.com [6]HOFOR A/S, licl@hofor.dk
[7]Vandcenter Syd A/S, aes@vandcenter.dk [8]Aalborg Forsyning A/S, lene.burgaard@aalborg.dk

Synergy between ozonation and activated carbon for chloroethenes contaminated groundwater treatment

A. Kokkoli, DTU Environment, N. Agerholm, O3Nordic**, H.R. Andersen, DTU Environment***, K.M.S Kaarsholm, DTU Environment*****

Abstract

Contamination of soil with tetrachloroethene (PCE) and trichloroethene (TCE) frequently occurs in old industrial areas which threaten the use of groundwater for potable water. PCE and TCE are microbiologically dechlorinated into dichloroethenes (DCE) and vinyl chloride (VC) in soils. Pump-and-treat applying granular activated carbon (GAC) are frequently used as remediation technique. However, VC which has the lowest quality criteria for water as it is a carcinogen, sorbs poorly on GAC leading to frequent change of GAC material. Ozone reacts relatively fast with VC and thus combining the two treatments could be beneficial. Groundwater always contains dissolved organic matter, which has fluorescence properties. Researchers have shown relationship between ozone dose and fluorescence intensity in wastewater and water from aquaculture and have suggested to use fluorescence intensity as online control of ozone *dose delivered.*

In this work, the aim was to evaluate ozonation as a supplement to GAC filtration for remediation of chloroethenes contaminated groundwater. Furthermore, the suitability of fluorescence was investigated as an instant or online indicator of the treatment efficiency and as a cheap tool to verify the ozone dosage offline.

Based on batch experiments performed in the laboratory, the ozone dose required for 90% removal of each compound was determined. When this value is normalized with the DOC, a parameter for the sensitivity of each compound to ozonation is derived. We labelled this parameter $Z_{90\%}$. It was found that VC and trans-DCE required the lowest ozone dose to be removed followed by cis-DCE and 1,1-DCE and finally TCE (Figure 1a). This fits with expectation based on the reaction rate constants for the chloroethenes. Furthermore, it is seen that that the compounds (e.g. VC), which sorb poorly (low K_d value), are the one that needed the lowest ozone dose to be removed. This different susceptibility of chloroethes to the two treatment methods can be utilised during pump-and-treat remediation by creating a combined treatment with ozonation followed by GAC filtration. If ozone (approximately 1.5 mg O_3/mg dissolved organic carbon (DOC)) is used to removed VC and DCE and partly TCE, the lifetime of the GAC filter is estimated increase approximately 7 times.

In laboratory experiments, the relationship between fluorescence and ozone dose was investigated and two-phased decay fitted (Figure 1b insert). This fit was used to estimate the ozone dose which had reacted with the DOC in the water at the pilot plant. The mass balance for ozone showed a recovery of 80-140%. At high ozone dose, the line is more flat and there are higher uncertainty in determining the ozone dose based on the fluorescence signal.

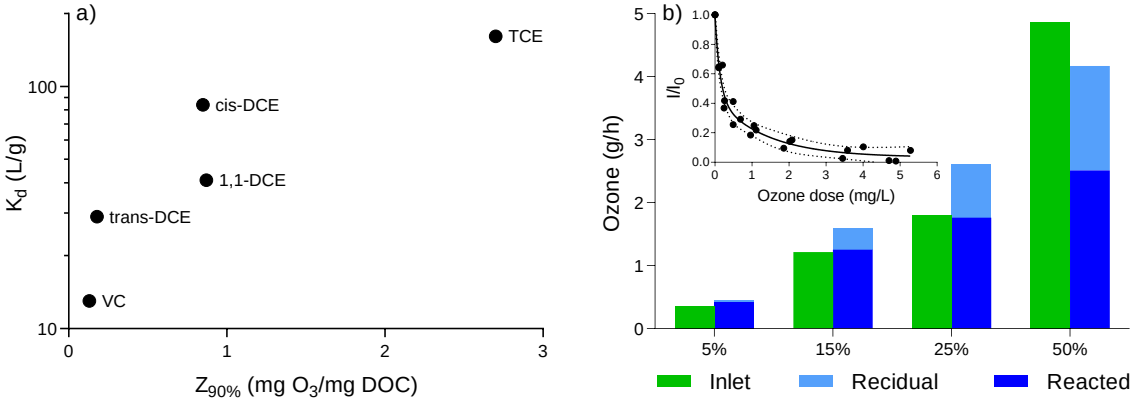


Figure 1. a) Comparison of K_d from literature with required ozone dose for 90% removal ($Z_{90\%}$) of chloroethenes. b) Ozone mass balance at the pilot plant for four setting levels of the ozone generator. Insert: Relative fluorescence intensity at different ozone doses with fit of two-phase decay. Dotted lines represent 95% confidence interval.

* arko@env.dtu.dk : *Bygningstorvet, Bygning 115, 2800 Lyngby*
** na@o3nordic.com : *Holmesøvej 9, 2660 Brøndby Strand*
*** hran@env.dtu.dk : *Bygningstorvet, Bygning 115, 2800 Lyngby*
**** kmsh@env.dtu.dk : *Bygningstorvet, Bygning 115, 2800 Lyngby*

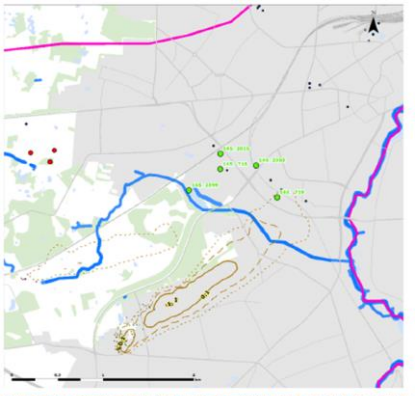
Integrated water management in the future climate change for robust risk assessment from contaminated point sources

*A. T. Bentzen, J. F. Christensen Region of Southern Denmark *, T. O. Sonnenborg, J. Kidmose, GEUS**, B. G. Neuman, G. L. Søndergaard, L. Bennedsen, B. B. Thrane, Rambøll ****

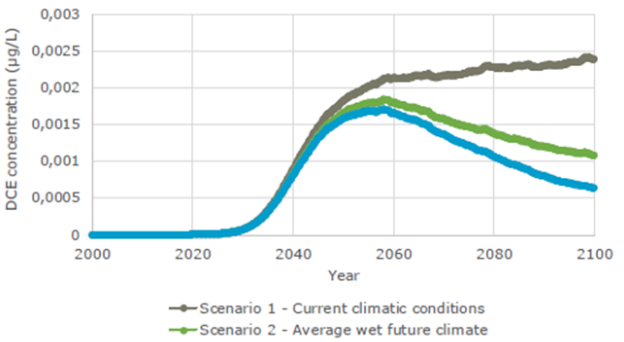
Abstract

The quality of the drinking water in Denmark is a matter of the highest priority and one of the tasks of the Danish Regions is to prevent groundwater resources from pollutants from old contaminated sites. The Regions have to deal with more than 37,000 contaminated or possibly contaminated sites, of which almost 13,000 pose a direct threat to the drinking water supply. There is a need for prioritizing tool: a risk assessment. Most of the contaminated sites are located in the cities and some of the drinking water abstractions are also still located in urban areas. The challenge is to conduct a robust risk assessment from the contaminated sites in the urban areas because of the complexity of the underground. Other challenges that affect the water cycle in urban areas are: climate change induced increase in precipitation and extreme rain; adaptation measures to avoid flooding typically involve local infiltration of rainwater and expected growth of the population of the larger cities. All these factors affect the urban hydrological cycle, including groundwater levels, groundwater and surface water flow paths, migration of pollutants from contaminated sites and the interaction of groundwater with the sewer system. Traditionally, each hydrological component has been treated separately. However, in order to secure an optimal management of the urban water cycle in a future more extreme climate an integrated hydrological modelling approach that combines the individual components is needed. It is the most efficient way to quantify the impacts of both climatic changes, adaptation measures and changes in urbanization.

Region of Southern Denmark, GEUS and Rambøll, has developed a model tool that can predict how climate change can affect the fate of contaminants in the groundwater. The work is carried out as part of the EU-project TOPSOIL, funded by the Interreg North Sea program. Two sites contaminated with chlorinated solvents are selected because of the potential threat they pose for a drinking water abstraction wellfield in the catchment of the western part of Odense city, Denmark. Based on a geological and hydrological flow model, a solute transport model is built and calibrated using concentration data from monitoring wells. Sequential degradation of the chlorinated solvents is included in the solute transport model. The calibrated solute transport model is run for 100 years under 3 different climate scenarios: 1) current climate conditions, 2) average wet future climate and 3) the wettest future climate, based on prediction from the 6 wet climate models from EU-project ENSEMBLES. The results show surprisingly that the predicted wet future climate changes have a risk-reducing effect on the simulated plumes due to a higher degree contaminant removal through increased drainage in the city caused by raised groundwater levels. The future climate scenarios result in narrower and shorter plumes over time, compared to the current climate scenario. Based on the model results we can conclude that only one of two selected sites constitutes a threat to the groundwater resource. The result is site-specific and can vary depending in the local site condition.



Simulated DCE-concentrations after 50 years of transport time, for the Valley 2 aquifer.



DCE concentrations in DGU well 145.719 at Eksercermarken well field screened in the Valley 2

** agnieszka.t.bentzen@rsyd.dk: Damhaven 12, DK-Vejle, Denmark*
*** tso@geus.dk: Geological Survey of Denmark and Greenland (GEUS), Øster Voldgade 10, DK-1350 København K*
**** bbg@ramboll.dk, Ramboll, Hannemanns Allé 53, DK-2300 Copenhagen S, Denmark*

Hydroeconomic optimization methods to address management issues of groundwater overdraft in the North China Plain

G. Martinsen, GEUS, S. Liu, IGSNRR CAS**, M. Xingguo, IGSNRR CAS**, C. Davidsen, Nordiq Group A/S***, R. Payet-burin, DTU Environment****, P. Bauer-Gottwein, DTU Environment*****

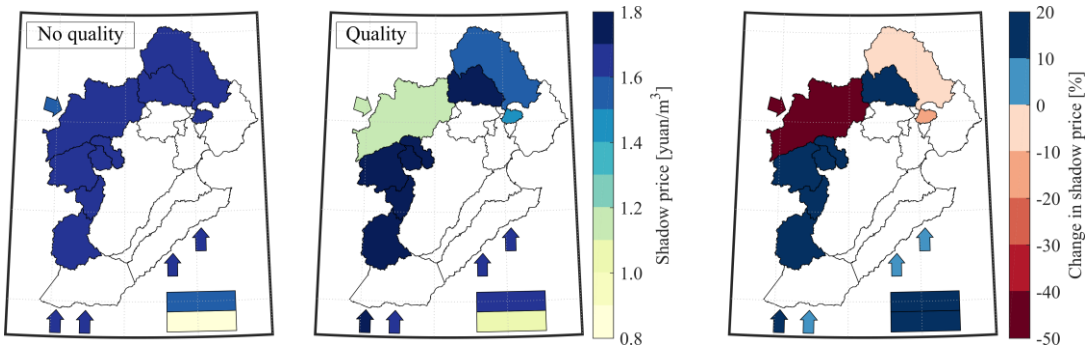
Abstract

The economic growth in China has resulted in an increased pressure on the natural resources of the nation. This pressure is reflected in the groundwater resources of the Hai River basin, located in the North China Plain, which have been declining gradually over the past decades. On top of water scarcity, it is also one of the most polluted river basins in China with more than 36.8 % of its surface water resources falling into the category of 'bad' water quality.

The water managers of the Hai River basin are likely to witness a continuous groundwater overdraft if they do not curtail the present water demand. Approaching the water management challenge as an economic resource allocation problem, this study developed a hydroeconomic optimization model to address water management question, such as 1) how costly it will be to limit the present groundwater overdraft, 2) least-cost strategies for joint water allocation and water quality management under sustainable groundwater abstractions, as well as 3) the impact of future foresight on benefit estimates of water infrastructure projects.

To address the aforementioned management questions a Linear Programming (LP) optimization model was formulated with conjunctive surface water and groundwater allocations under the objective of minimizing total water associated costs. Publicly available data of surface water quality was utilized to account for the externality of upstream pollution on downstream water use. The deterministic LP model setup assumed perfect foresight of all future water availability. To account for the cost of uncertain future hydrological events a Model Predictive Control (MPC) inspired re-optimization routine was wrapped around the LP model to simulate the impact of unforeseen future hydrological events. Unforeseen droughts, resulting in agricultural losses, were represented by accounting for crop yield responses to water allocations.

The results showed that it will be costly to reach groundwater sustainability, even under optimal management of the available water resource. Considering water quality in hydroeconomic decision support models will reveal shadow prices and least-cost strategies which will not be reflected by solely addressing water scarcity. Finally, the MPC-LP model setup revealed how project benefits for a proposed water infrastructure project in Hai River basin would be underestimated in a LP model framework assuming perfect foresight of future water availability. This highlights the importance of considering the impacts of assuming perfect foresight in a cost-benefit context.



* grm@geus.dk: Øster Voldgade 10, 1350 Copenhagen, Denmark
** liusx@igsnrr.ac.cn, moxg@igsnrr.ac.cn: 11A, Datun Road, Chaoyang District, Beijing, China
*** cmd@nordiq-group.dk: Rentemestervej 23A, 2400 Copenhagen, Denmark
**** pbau@env.dtu.dk, rapp@env.dtu.dk: Bygningstorvet, Bygning 115, 2800 Lyngby, Denmark

Triple-helix partnership as a tool for increased water efficiency in the food and beverage industry

H. Bengaard, Landbrug & Fødevarer; HJ. Albrechtsen, DTU Environment**;*
*J. Rasmussen, Water Advice***; A. Christiansen, Landbrug & Fødevarer*****

Abstract
DRIP - A triple-helix interdisciplinary innovation partnership between major water end-users from the Danish food and beverage industry, water technology providers, knowledge partners and authorities has shown ways to create effective solutions to improvement of water efficiency in the food industry which is among the largest water-consuming industries in Denmark as well as globally.

Ensuring the quality of water throughout its use is of crucial importance to secure food safety and product quality. Having Danish food and environment authorities as associated partners in the project allowed for a positive co-operation and dialogue with a focus at very early stages of the projects on important considerations regarding regulation and food safety.

While water savings and reuse are the starting point for initiation of pilot and full-scale projects in the partnership, other factors like e.g. associated energy and resource savings and released wastewater treatment plant capacity are also key to provide business cases with attractive payback times.

Initially, comprehensive mappings of resource flows in terms of water, energy, materials, products and waste through the factories (brewery, poultry abattoir, pig and cattle slaughterhouses, meat processing plants, fishmeal, dairy) were undertaken. The mappings provided the foundation for development of attractive scenarios for increased water efficiency. 20 of the most promising scenarios have been further matured into pilot and full-scale implementation projects, including e.g.:

-Total water recycling plant at Carlsberg brewery, Fredericia Denmark. Advanced recycling technologies allow for safe recycling and reuse of 90 % of all process water, thus reducing average water consumption from 2.9 l water per l of beer to 1.4 l water per l of beer.

-Further reuse of landing water at TripleNine fishmeal, Thyborøn, Denmark. New solution for handling and treatment of landing water (transport media when fish are landed) to remove dry matter enables further reuse and reduction of water consumption by 50-70 %. Dry matter content in the water that enters the production facility is at the same time increased, resulting in significant energy savings as less water must be evaporated.

-Rinse water for chicken feet production at HKScan poultry abattoir, Vinderup Denmark. A project demonstrated that water could be directed from the cleaner cooling processes to the preceding dirty processes. Resulting water savings: 50 % of the water consumption in this process step or 6-7 % of the factory's total water consumption.

Estimates for the DRIP pilot and full-scale projects show that the entire project portfolio has a total water savings potential of more than 25 % when fully implemented in full-scale operations in the participating industries which beforehand were considered highly water efficient by global standard.
The partnership consists of 18 partners: Arla, Carlsberg, Danish Crown, HK Scan, TripleNine, Alfa Laval, Aquaporin, Grundfos, Liqtech, Tetra Pak, Siemens, Ultraaqua, Technical University of Denmark, Copenhagen University, Copenhagen Business School, IN-Water, Danish Technological Institute, Danish Agriculture & Food Council. The Danish Veterinary and Food Administration and the Danish EPA are associated partners. The partnership is funded by Innovation Fund DK.

** hsb@lf.dk : Axeltorv 3, DK-1609 København V, Denmark*
***hana@env.dtu.dk : Bygningstorvet, Bygning 115, 2800 Lyngby, Denmark*
**** jar@wateradvice.dk : Tvingsbakken 10, 3200 Helsinge, Denmark*
***** anc@lf.dk : Axeltorv 3, DK-1609 København V, Denmark*

Presentation of a new UV purification technique for removal of chlorinated solvents and pesticides from drinking water/remediation wells. MUDP-project1

Martin Bymose, Project Manager, Geologist, DGE Miljø- og ingeniørfirma A/S[*]

Abstract

Our purpose is to develop the HOD-UV-technology, so that it can be used for removal of pesticides and thereby ensure operations without major reorganizations of the waterworks. With a small cost for operation of an HOD-UV-technology you ensure that even small waterworks can produce for their consumers. The goal is also to demonstrate that with a new UV-technology called HOD-UV (Hydro-Optical Disinfection – Ultra Violet) we can both reduce the cost of operating existing and future "pump & treat" (P&T) plants and reduce the use of activated carbon as well as increase capacity. With these savings, we can also indirectly save not only costs for the operation of these plants, but also on the entire handling of the active carbon plants such as production, handling and disposal.

Background

Pesticides in the ground water have in recent years become an increasingly crucial problem for waterworks. This contamination will typically result in the fact that new wells must be made with costs of about 1 million/well, before the new well is operating. The emergence of mixed pesticides such as desphenyl chloridazone has also resulted in small waterworks having had to completely shut down their plants and get water from alternative wells. Likewise, removal of chlorinated solvents (TCE, PCE and VC) in the ground water today has major long-lasting and costly consequences for the regions. This removal is typically performed in (P&T) plants, where the activated carbon filters (GAC) are the biggest factor/limitation (bottleneck) for the capacity and duration of the plants. These filters are also costly and difficult to handle with respect to OHS. The project started in 2019 with the construction of a mobile purification unit – and it will perform tests on sites with chlorinated solvents and pesticide contaminants.

UN's sustainability goals

This method contributes positively to several of the 17 sustainability goals, but to a particularly positive degree to goal 6 and goal 12 with the following sub-goals:

	Sub-goals	Reasons
	6.1 6.3	The method is intended to ensure good and cheap purification of contaminated drinking water. Ensures that a considerable part of the drinking water can be received by the consumers in a proper quality.
	12.2 12.5	Better and more efficient use of the water resources. The method will result in a significant reduction of activated carbon for purification of drinking water.

[*]:MBB@Dge.dk. Literbuen 13 2740 Skovlunde. Tlf.: 6155 7535

[1] MUDP: Danish public aid scheme under the Danish EPA, which provides grants for the development of knowledge and technology leading to strengthening of research and innovative solutions.

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ROOM 2

SESSION 9 and 10: Water Smart Cities

Time	Title	
Chair:	**Roland Löwe**	**Presented by**
16:30	Water Smart Cities world view on model uses	Roland Löwe, DTU Environment
16:45	Real time modelling and monitoring	Nina D.Sto. Domingo, DHI Carsten Thirsing, BIOFOS Anders Breinholt, HOFOR Lene Bassø, Århus Vand
17:00	Model Predictive Control for Water Smart Cities	R. Halvgaard, L. H. Drejer, A. K. V. Falk, DHI L. Bassø, Århus Water, H. Madsen, DHI
17:15	Online forecasting of flows and ammonia load at WWTP inlet	Luca Vezzaro, Krüger & DTU JW Pedersen, LH Larsen, DTU Environment C Thirsing, Biofos.
17:30	Assessment of planning objedtives in strategic planning for a case study in Højme, Odense	I. B. Gregersen, Rambøll, N. Krogsbo, VCS, J. Skrydstrup, I. L. Hansen, S. Dybkjær, R. Löwe, K. Arnbjerg-Nielsen, DTU Environment
17:45	Plenum discussion	

Water Smart Cities world view on model uses

*Roland Löwe on behalf of the Water Smart Cities Working Group **

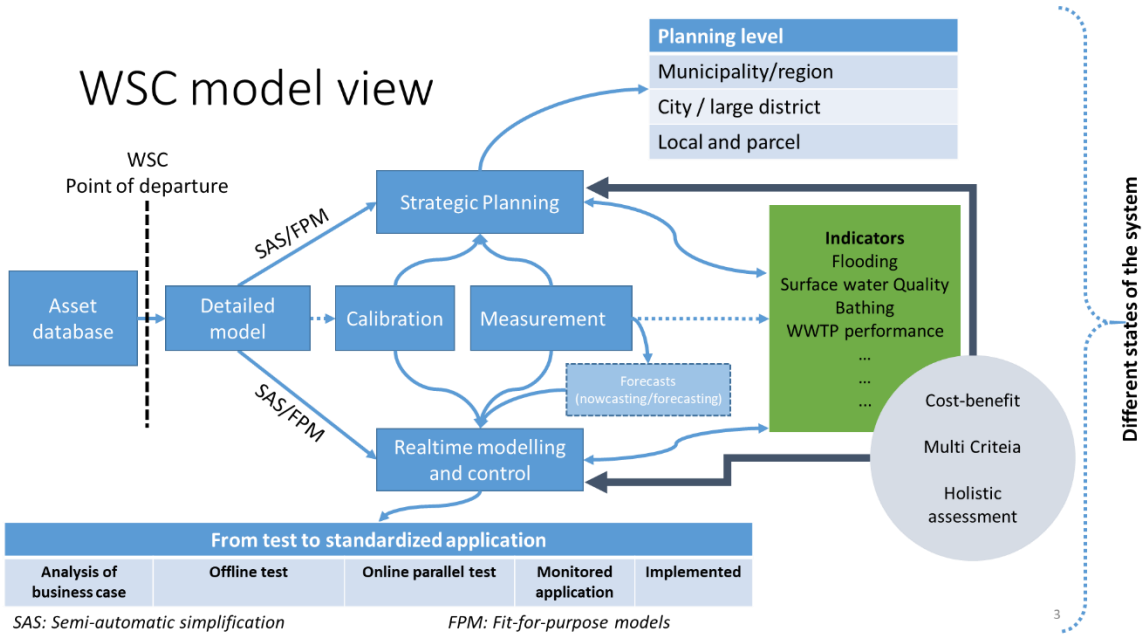
Abstract

This talk will give an overview of the modelling world view developed in the Water Smart Cities project (funded by Innovation Fund Denmark) and illustrate it with examples from the project. The world view is shown in the Figure. The digital utility uses models for both planning and real-time **purposes**, and in both cases fit-for-purpose models were applied, i.e. models with very different complexity depending on the problem at hand.

We used detailed, physically-based models derived from the utilities asset database for monitoring and planning applications where high levels of detail were required, for example, in the form of digital twins for monitoring in detail the flows in the sewer system and for testing the design of water management measures in high detail and on small spatial scales.

Much simpler models were developed and applied where fast runtimes or large number of model runs were required. Examples from the project are forecasting models for flow and ammonia, representations of the sewer system inside model predictive control algorithms, and the evaluation of water management measures and system behaviour for a variety of climate and urban development scenarios. In these cases, fit-for-purpose models were created through either a semi-automated simplification of detailed models or by directly combining grey-box model structures to sensor data. The former approach allows for an exploitation of physical knowledge about the water system, while the latter approach can be used directly whenever sensor data are available.

Further developments point towards a further integration of models, model results and data. For example, digital twins can be combined with sensor data to provide an improved monitoring of the system states and emissions from the urban water system. Similarly, remote sensing data can be combined with hydraulic model results to provide a direct and visual impact assessment of urban water management.



* rolo@env.dtu.dk : *DTU Environment, Bygningstorvet, Bygning 115, 2800 Lyngby*

Real time modelling of sewer systems

L. Bassø , M. Ahm, C. Thirsing**, A. Breinholt***, N. Sto. Domingo, A. Møller, O. Mark , DHI ****

Abstract

The Water Smart Cities project develops novel digital solutions that integrate numerical models of the urban water system with sensor networks, weather forecasts, and optimization techniques for real-time control. Two of the main cases are in Aarhus and in Copenhagen.

The project develops software for prediction models, specifically tailored for use in real-time forecasting and control systems, including development of new data assimilation procedures for updating forecast models based on sensor measurements. This includes deterministic and dynamic model for forecasting inflow and pollutant concentration to Damhusåen wastewater treatment plant. The purpose of the flow and Ammonia forecast model is to provide the operator of the wastewater treatment plant with better information concerning, when the operation of the wastewater treatment shall shift from dry weather control mode to wet weather control mode.

Further, a real time information system is being developed and setup for the Viby sewer system. For the Viby real time model, the results from the model can be evaluated in relation to measurement data from sensors in the drainage system and at Viby Wastewater treatment plant (flow and water level measurements). Evaluation is carried out with selected statistical indicators, close to real time. Further, a feature has been set up to automatically identify "rain events". The term includes a combination of recording rain events and recording of conditions in the drainage system. The method identifies the start and end of rainfall over the Viby catchment. Criteria are used to identify the start and end of rain, so that less interesting events are not included. Information about rain is e.g. combined with registration of utilized storage volume in the basin at Viby Wastewater Treatment Plant.

The developments are implemented in new digital solutions, which are deployed and tested at Greater Copenhagen Utility and Waste Water Treatment (HOFOR and BIOFOS) and Aarhus Water. In the presentation at the DWF Annual Meeting, the modelling principles behind the applications will be outlined, and the performance of the applications will be presented.

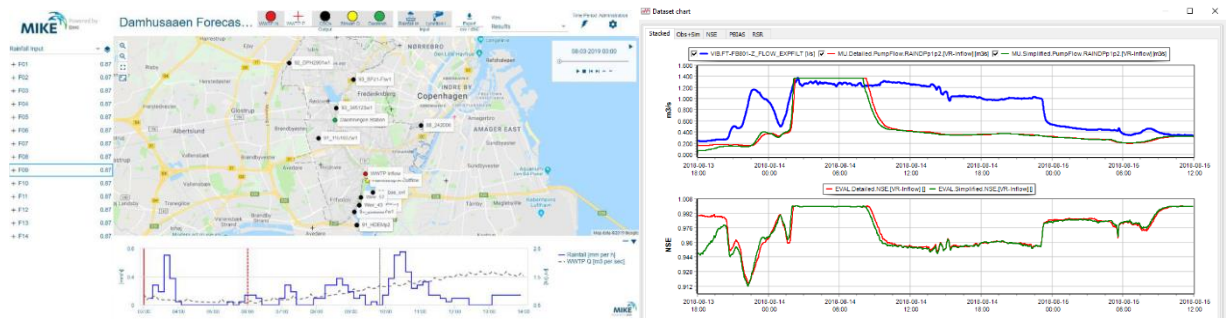


Figure 1. Interfaces of the real time applications. Left: Damhusåen, Copenhagen. Right: Viby, Aarhus.

* LBA@aarhusvand.dk msa@aarhusvand.dk *Gunnar Clausens Vej 34 DK- 8260 Viby, Denmark*
** ct@biofos.dk *Renseanlæg Lynetten, Refshalevej 250, 1432 København K*
*** anbr@hofor.dk *Ørestads Boulevard 35 | 2300 København S*
*** nsd@dhigroup.com arm@dhigroup.com omj@dhigroup.com *Agern Allé 5, 2970 Hørsholm*

Model Predictive Control for Water Smart Cities

R. Halvgaard, DHI Denmark, L. H. Drejer*, A. K. V. Falk*, L. Bassø**, Aarhus Vand, H. Madsen**

Abstract

Urban drainage systems often use retention basins to extend the storage capacity during rain events in order to mitigate overflows and flooding in cities and receiving waters. During rain events, large sewer networks require real-time control strategies to coordinate controllable flows and optimally utilize the storage capacity. An advanced control strategy like Model Predictive Control (MPC) does exactly this. MPC inherently also consumes rainfall forecasts to predict the effects on the sewer network and plan the optimal control decisions. Also the operator prioritizes the weights for the different overflow locations.

In the Water Smart Cities project [www.watersmartcities.ennv.org] we have tested DHI's MPC framework through simulation of two Danish case study areas in Aarhus and Copenhagen. The work is ongoing, and both MPC models and the MPC framework are continuously improved. We are currently implementing real-time MPC control in the operational system at the utility in Aarhus.

In the MPC framework, we apply a real-time high-fidelity simulation model, in our case a MIKE URBAN (MU) model, which is used for:

1) building computationally fast surrogate models for the MPC
2) as a validation model for offline performance evaluation of the MPC controller,
3) as an advanced software sensor that provides real-time estimates of the modelled, but physically unmeasured, states needed by the MPC, e.g. volumes in different parts of the network.

From the high-fidelity simulation model, we semi-automatically build surrogate models for the MPC that calculate the flow setpoints in the network. The real-time MU model is often too slow for making real-time network flow predictions several hours ahead.

Therefore, we build two fast surrogate models: one to forecast outflows from the passive uncontrollable upstream part of the network including the rainfall runoff, and another to decide on the optimal flow setpoints in the active controllable downstream part of the network that includes all controllable actuators and detention basins. Building the surrogate models requires a predefined rule set that depends on the objective and the specific use of the surrogate models.

The underlying optimization problems are formulated as convex programs that enables the MPC to solve for the optimal control decisions for large scale networks within seconds. The DHI MPC framework builds and solves these optimization problems specifically for water networks. It also evaluates control strategies and handles interfaces to MIKE models.

We will present the outcomes from the Water Smart Cities project related to MPC.

** rha@dhigroup.com: Agern Allé 5, DK-2970 Hørsholm, Denmark*

*** lene.basso@aarhusvand.dk: Gunnar Clausens Vej 34, DK-8260 Viby J*

Online forecasting of flows and ammonia load at WWTP inlet

L. Vezzaro, Kruger Veolia, DTU Environment**, J.W. Pedersen, DTU Environment**,*
*L.H. Larsen, DTU Environment, C. Thirsing, BIOFOS****

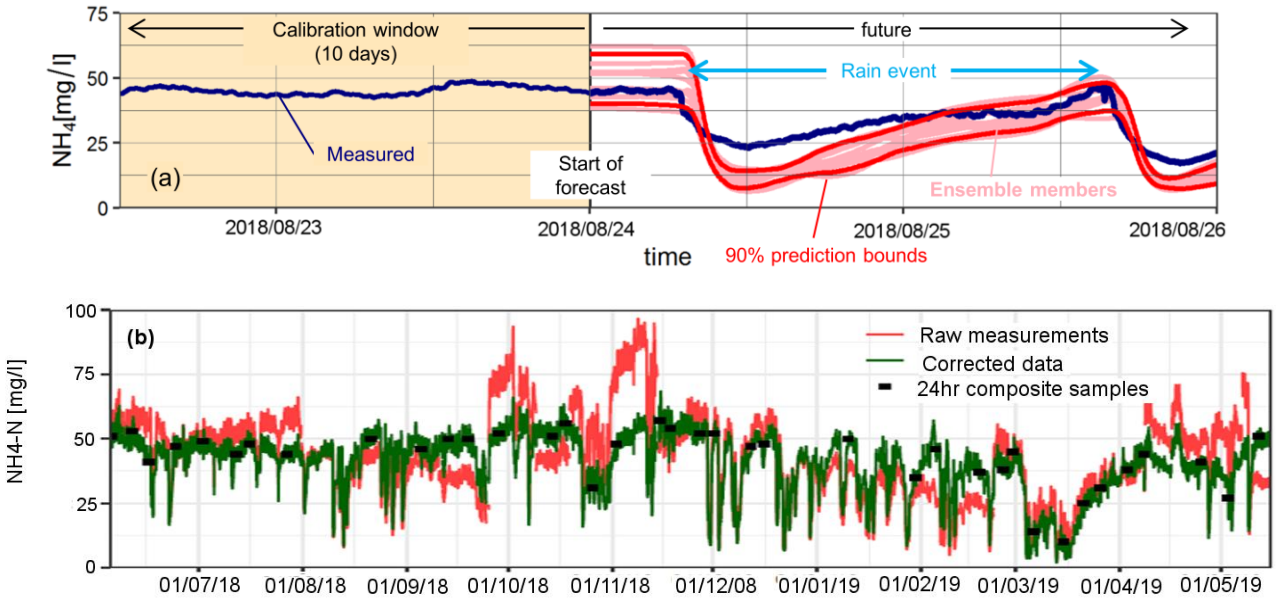
Abstract

Forecasting of future inlet flows and pollutant loads can contribute to more environmental effective operation of WasteWater Treatment Plants (WWTPs) both in dry and wet weather conditions. For example, forecasts of ammonium ($NH4^+$) inlet concentrations can be used by Model Predictive Control strategies to improve nitrogen removal (reducing aeration energy consumption) or to prioritize WWTP bypass flows (reducing the negative impacts due to discharges of untreated wastewater).

A simple data-driven model for online forecasting of ammonium concentrations at the inlet of the Damhusåen WWTP was developed. The model utilizes the high-time resolutions measurements (2 min) collected with ion-selective sensors during a monitoring campaign, started in June 2018 and still on-going. The model automatically estimates the $NH4^+$ daily load profiles based on past data, and it uses an ensemble approach to generate probabilistic forecast of the expected ammonium loads in the following 24 hours. These are then combined with flow forecast of the WWTP inlet, obtaining the expected inlet concentrations (Figure A). Flow forecasts are generated by a greybox rainfall-runoff model (using stochastic differential equations), with radar-based rainfall forecasts as input. Both the flow and the $NH4^+$ forecasts are implemented on the AQUAVISTA™ cloud platform, and they provide a new forecast every 2 minutes.

The evaluation of the forecast model performance highlighted an important challenge linked to the use of online water quality sensors, specifically with ion-selective sensors. These sensors operate in a harsh environment, and they thus require constant maintenance. Nevertheless, data from well-maintained sensors still exhibit unwanted features, like signal drifting or sudden jumps in the measured values due to sensor calibration operations. These features affect the reliability of the data-driven model, since a thorough evaluation of the sensor accuracy would require additional (costly) monitoring efforts.

Therefore, an automatic data correction procedure was developed. The correction procedure relies on the statutory daily composite samples which Danish utilities collect at the inlet of their WWTPs, i.e. on data which are already available. The corrected data have higher accuracy (Figure B), and they therefore provide a more robust background for the $NH4^+$ data-driven forecast model. Further investigations will evaluate the model performance at the inlet of other monitored WWTP, as well as the potential application in other parts of the integrated urban wastewater system, such as combined sewer overflows.



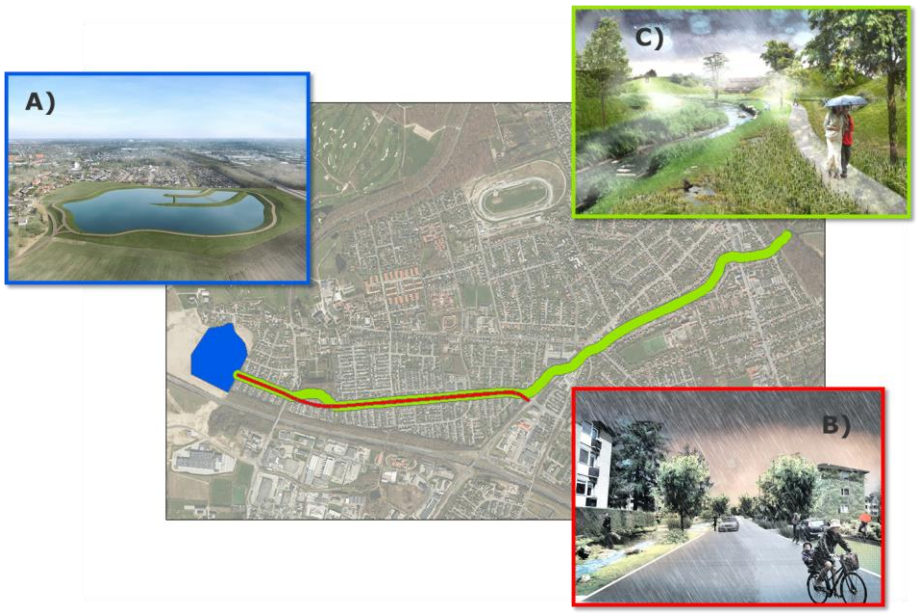
* lxv@kruger.dk: *Gladsaxevej 363, 2860 Søborg*
** luve@env.dtu.dk, jowi@env.dtu.dk: *Bygningstorvet, Bygning 115, 2800 Kgs. Lyngby*
*** ct@biofos.dk: *Refshalevej 250, 1432 København K*

Assessment of planning objectives in strategic planning for a case study in Højme, Odense

I.B. Gregersen, Rambøll, N. Kroghsbo, VSC Denmark **, J. Skrydstrup, DTU Environment***, I. L. Hansen, DTU Environment****, S. Dybkjær, DTU Environment*****, R. Löwe, DTU Environment *****, K. Arnbjerg-Nielsen, DTU Environment******

Abstract

Blue-green cities and liveability have been buzzwords for the last decade. Both in relation to climate adaptation, specifically, but also for integrated urban management in general. Many unique projects have been built under this agenda, but it is still not an integrated part of strategic planning to make the so-called 'co-benefits' part of every assessment. The term 'co-benefits' covers for example recreation, connectedness, traffic safety and biodiversity. It has been a key goal for the Water Smart Cities project to develop transparent and widely acceptable criteria for decision support in urban water management, which ensures that urban water management becomes relevant to other urban disciplines. The project work has concluded that it is essential to provide a common terminology when discussing objectives between stakeholders. The term 'co-benefits' may suggest that e.g. recreation is only a second-class objective. This does not encourage cooperation with stakeholders that see a 'co-benefit' as the main driver for their engagement, why 'planning objectives' is a better term that 'co-benefits'. Secondly the project work has concluded that methods for valuation of all planning objectives are essential, while still acknowledging that monetizing the value of e.g. recreation is difficult and that the resulting estimates are very uncertain. The initial framework for assessment of planning objectives in strategic planning is tested on a case study area in Højme; a residential area in the south western part of Odense. Low-lying parts of the residential area have been flooded frequently in the last decade, and flood risk is expected to increase as upstream areas are developed, increasing the pressure on the system. Three strategies are tested, and their performance are compared to each other with focus on six different planning objectives, covering both the traditional reduction in flood damage and 'new' objectives like traffic noise and traffic safety. The strategies are: A) a 80.000 m3 rainwater basin B) a rainwater channel C) creek restoration, see the figure below. The case study calculations are still on-going, and the presentation will focus on the conceptual aspects and the link to the overall vision for Water Smart Cities.



* ibg@ramboll.dk : Hannemanns Allé 53, DK-2300 København S
** nk@vandcenter.dk : Vandværksvej 7, DK-5000 Odense
*** jusk@env.dtu.dk : Miljøvej, Bygning 115, Kgs. Lyngby DK-2800
**** s154364@student.dtu.dk: Miljøvej, Bygning 115, Kgs. Lyngby DK-2800
***** s144365@student.dtu.dk; Miljøvej, Bygning 115, Kgs. Lyngby DK-2800
****** rolo@env.dtu.dk : Miljøvej, Bygning 115, Kgs. Lyngby DK-2800
******* karn@env.dtu.dk : Miljøvej, Bygning 115, Kgs. Lyngby DK-2800

ROOM 3

SESSION 11, 12 and 13: Wastewater

Time	Title	
Chair:	**Hans-Martin Friis Møller**	
11:15	Removal of organic micropollutants – A comparison of different approaches – results from the CLEANWATER project.	Kaj Bester, Aarhus University, Envir. Sci
11:30	Concentration dependent degradation of pharmaceuticals from wastewater in Moving Bed Biofilm Reactors (MBBR)	Sif Svendsen, Aalborg University
11:45	Metabolites of ethylene (EO) and propylene oxide (PO) containing compounds in wastewater and their biodegradation in MBBR reactors	Selina Tisler, AU-ENVS
12:00	**Lunch break**	
13:00	Effects on removal rates of pharmaceuticals in biofilters by addition of BOD	Nadia Brogård Nord, AU-ENVS
13:15	Efficient biological removal of pharmaceuticals from wastewater effluent using eXeno technology	Emma S. Rasmussen, Bios, Aarhus University
13:30	Model-based optimization of full-scale anaerobic digesters at the municipal wastewater treatment plant	Manuela Schliemann-Haug, DTU Envir
13:45	Can operational problems at full-scale activated sludge systems be solved with sludge transplantation?	Dorotthya S. Wágner, Aalborg University
14:00	Pilot-scale operation of an aquaporin-based forward osmosis process for polishing municipal wastewater effluents	Sylvie Braekevelt, Aquaporin
14:15	PFAS removal from percolate by super critical water oxidation (SCWO)	Yusef Jama, Technological Institute
14:30	Buffer time	
14:45	**Coffee break and Posters**	
15:15	Nitrification inhibition test of salty wastewater using salt-adapted nitrifying bacteria, an alternative test method to ISO method	Ravi Kumar Chhetri, DTU Envir
15:30	The New MiDAS Field Guide: Comprehensive Online Ecosystem-specific Database of Microorganisms in Wastewater Treatment Systems	Susan H. Hansen, Aalborg University
15:45	Evaluating added benefits and scalability of vertical, evaporation-based SUDS	MarkT. Randall, University of Copenhagen (IGN)
16:00	Buffer time	
16:15		

Removal of organic micropollutants – A comparison of different approaches – results from the CLEANWATER project.

N.B. Nord, R. Li**, S. Tisler***, S. Kharel****, C. Liang*****, S. Svendsen******, M. Cimbritz[+], E. Edefell [++], S. Braekevelt[#], M. Christensson[¤], Kaj Bester*******,*

Abstract

Micropollutants are usually present in wastewater at concentrations in the ng-µg/L range in wastewater treatment plants (WWTPs). Some are hydrophilic, some are persistent against chemicals and others are not susceptible to biodegradation.

Different technologies are available to mitigate these compounds, each with its specific footprint and profile.

Ozonation is relatively well-established and shows good removal rates, but has pitfalls such as formation of ozonation products (from the micropollutants), from constituents of the water (bromate formation from bromide) and it costs relative high amounts of energy.

Biofilm reactors such as MBBRs can remove a multitude of compounds, they can easily be integrated into biological WWTPs and have relatively little energy use. However, can eventually form metabolites from the pollutants that are removed.

Forward osmosis has been demonstrated to have very high removal efficiency (98%) for all compounds the CLEANWATER consortium used. It can be used as seawater-based forward osmosis membrane technology is selective to micropollutants, and can be an energy-effective way to reduce wastewater volumes and build smaller treatment plants. However, Forward osmosis is a separation technology and not a reaction technology (the up-concentrated brime needs to be treated in a separate step).

Biofilters can be used to treat stormwater, combined sewer overflow or polish wastewater from small WWTPs (100 PE). These plants can achieve high removal rates, dependent on support material and feed of the microbial communities. These installations also need very little energy. However, these plants require a lot of space making them attractive predominantly for more rural situations.

Activated sludge plants (CAS) can also remove some compounds, while membrane bioreactors (MBRs) have somewhat enhanced capabilities.

In this contribution, the results of the BONUSCLEANWATER project on the respective technologies will be discussed considering the removal of 30 target compounds as well as out of the box compounds. The technologies will also be discussed in combination as some compounds and transformation products can be removed in hybrid technologies.

This study was performed within the framework of the BONUS CLEANWATER project, funded jointly by the EU, Innovation Fund Denmark, VINNOVA and the German Ministry for Education and Science.

**nadiabnord@envs.au.dk: AU, Frederiksborgvej 399, DK-4000 Roskilde, Denmark*
***ruili@envs.au.dk: AU, Frederiksborgvej 399, DK-4000 Roskilde, Denmark*
****seti@envs.au.dk: AU, Frederiksborgvej 399, DK-4000 Roskilde, Denmark*
*****sukh@envs.au.dk: AU, Frederiksborgvej 399, DK-4000 Roskilde, Denmark*
******liangcz@envs.au.dk: AU, Frederiksborgvej 399, DK-4000 Roskilde, Denmark*
*******sibs@envs.au.dk: Frederiksborgvej 399, DK-4000 Roskilde, Denmark*
[+]michael.cimbritz@chemeng.lth.se: LU, Naturvetarvägen 14, 221 00 Lund, Sverige
[++]ellen.edefell@chemeng.lth.se, LU, Naturvetarvägen 14, 221 00 Lund, Sverige
#sbr@aquaporin.dk, Aquaporin, Nymøllevej 78, DK-2800, Kongens Lyngby, Denmark
¤magnus.christensson@anoxkaldnes.com: AnoxKaldnes, Klosterängsvägen 11, Lund, 226 47, Sweden
******** kb@envs.au.dk: Frederiksborgvej 399, DK-4000 Roskilde, Denmark*

Concentration dependent degradation of pharmaceuticals from wastewater in Moving Bed Biofilm Reactors (MBBR)

S. Svendsen, AU, H. El-taliawy**, AU, K. Bester***, AU*

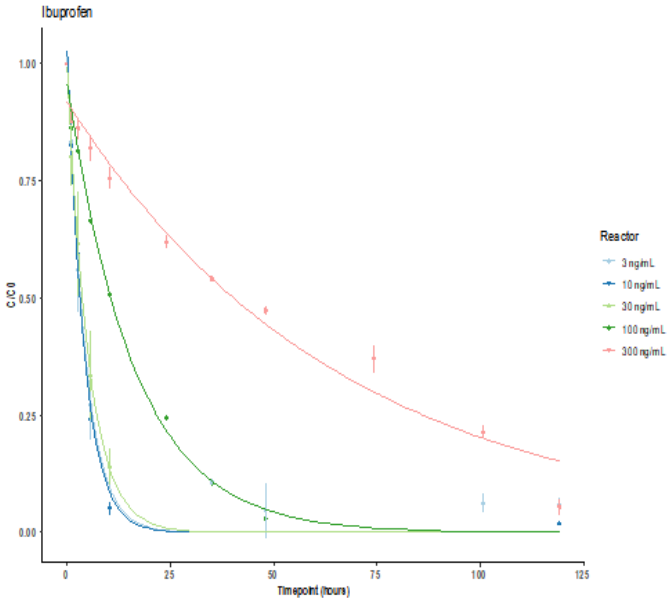
Abstract

Micropollutants are usually present in wastewater at concentrations in the ng-µg/L range. A typical group of micropollutants are pharmaceuticals, most of which cannot be efficiently removed by conventional wastewater treatment. The lack of removal during wastewater treatment results in emissions to the aquatic environment, posing a risk to aquatic organisms.

There exist a number of different polishing wastewater treatment techniques. One of these, showing promising results, is the Moving Bed Biofilm Reactors (MBBR). These consist of biofilm attached to small plastic carriers, in reactors with the wastewater flowing through.

For designing an efficient MBBR, knowledge is needed about parameters such as initial degradation rate and degradation rate constants of the pharmaceuticals. These parameters can change drastically depending on initial concentration of the compound. The experiment was a MBBR batch incubation of effluent wastewater spiked with the pharmaceutical mixture in different concentrations (0-300 µg/L). The degradation of most of the pharmaceuticals was dependent on the initial concentration. The initial degradation velocity was either following a typical Michaelis-Menten kinetic, or proportional to the initial concentration. The single first order degradation rate constants (K) showed different concentration dependencies - the K values for the different compounds were increasing, decreasing or increasing to a certain level, then decreasing, as the initial concentration increased. This underlines the fact that K values cannot be interpreted without paying attention to the tested concentration level.

However, usually the concentration effects are very little as long as the concentrations stay below 10 µg/L.



*sibs@envs.au.dk: Frederiksborgvej 399, DK-4000 Roskilde, Denmark
** eltaliawy.haitham@gmail.com: Frederiksborgvej 399, DK-4000 Roskilde, Denmark
*** kb@envs.au.dk: Frederiksborgvej 399, DK-4000 Roskilde, Denmark

Metabolites of ethylene (EO) and propylene oxide (PO) containing compounds in wastewater and their biodegradation in MBBR reactors

S. Tisler, C. Liang**, K. Bester***, AU-ENVS*

Abstract

Polyethylene glycols (PEGs) themselves, but also alcohol polyethoxylates (AEOs) which are biodegraded into PEGs are the most used non-ionic surfactants produced in Europe. For low foaming properties, the surfactants can also consist of propylene oxide (PO) groups (Polypropylene glycols (PPGs) or general polyalkylene glycols (PAG)). Data about the formation and removal of PAG in wastewater treatment as well as a risk assessment on PAG residues in the aquatic environment are limited and data on occurence of PPGs in wastewater is completely missing.

The aim of the present study was to identify precursors and metabolites of PEGs and PPGs in the wastewater effluents of two different municipal wastewater treatment plants (WWTPs) in Denmark. The homologous series of pure EO and PO polymers, as well as copolymers of one to two EO and three to twelve PO groups were detected. Carboxylated metabolites of these compounds were determined as the homologous series with the highest intensity (Figure 1).

Furthermore, the degradation of PAGs were investigated in a moving bed biofilm reactor (MBBR) as advanced treatment technology in comparison to activated sludge treatment.

In biodegradation experiments with MBBRs, the subsequent degradation of all compounds was determined, while these compounds were persistent in activated sludge treatment. Some general conclusions can be drawn: 1) The degradation kinetic of polymers with higher masses was faster. 2) The more carboxylated the compound was, the slower was the degradation (Figure 1). 3) The pure PPG precursors and metabolites were degraded slower than the related copolymers, containing one or two EO groups. MBBR degradation experiments with industrial products showed the same metabolites and were proven as possible candidate group of PAG substances in the Danish wastewater.

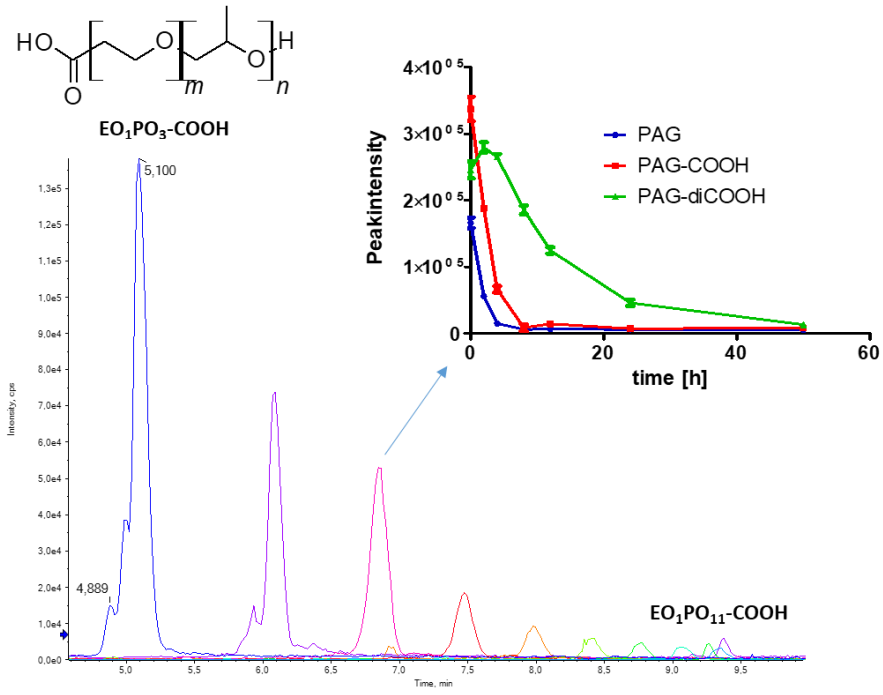


Figure 1: Extracted ion chromatogram of one out of three homologous series of the carboxylated EO/PO copolymer metabolites. The degradation in a MBBR batch experiment is shown for the precursor (PAG) and the carboxylated metabolites of EO1PO3.

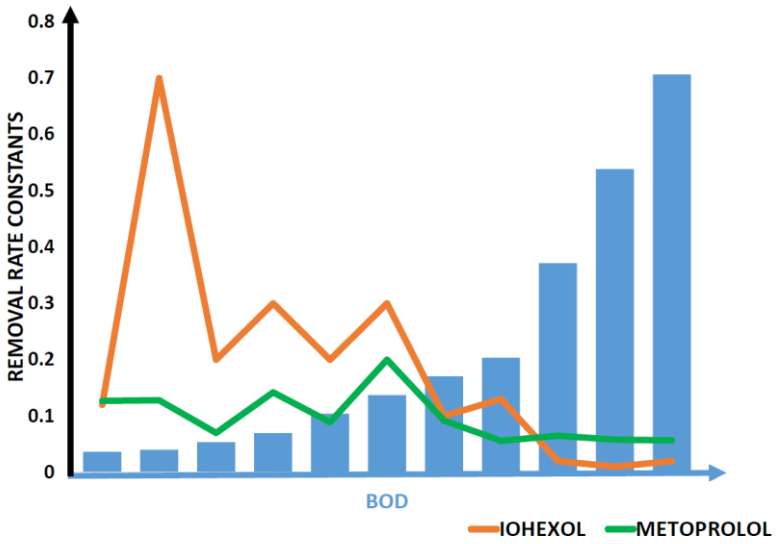
** seti@envs.au.dk**liangcz@envs.au.dk;***kb@envs.au.dk*
Frederiksborgvej 399, DK-4000 Roskilde, Denmark

Effects on removal rates of pharmaceuticals in biofilters by addition of BOD

N.B. Nord, AU-ENVS, K. Bester, AU-ENVS***

Abstract

Pharmaceuticals in polluted waters e.g. stormwater or combined sewer overflow (CSO) poses a potential risk to our local environments. Biofilters have already proven capable of removing micro-pollutants from effluent wastewater, and could provide a low maintenance solution for stormwater and CSO treatment to increase surface water quality. However, increasing carbon-loading (BOD) (as typical for CSO) on these systems could influence the removal efficiency for some compounds as seen with increasing acetate dosing (Zhang et al., 2019). As a result, this study set out to investigate the effects on removal of pharmaceuticals with pulse loadings of increased amounts of pre-settled raw wastewater to four individual biofilter systems containing different materials (sand, filtralite, stonewool, and sand amended with 1% peat). The biofilter systems alternately received pure effluent or pre-settled raw wastewater mixed with effluent during periods corresponding to two hydraulic retention times. Results showed increasing BOD concentration could affect the removal rate constants, and it could be divided into two groups; 1) compounds influenced by increased BOD: metoprolol, diclofenac, iohexol, atenolol, propranolol, venlafaxine, and citalopram 2) compounds only little or not influenced by increased BOD: sulfamethoxazole, carbamazepine, sulfamethizole, trimethoprim, iomeprol. However, under any conditions the effects of BOD did not indicate a complete degradation stop. In addition, the biofilter materials influenced (indirectly) the removal of micropollutants: While the overall highest removal determined in the following order filtralite >sand~sand amended with peat > stonewool.



* nadiabnord@envs.au.dk: *Frederiksborgvej 399, 4000 Roskilde*

** kb@envs.au.dk: *Frederiksborgvej 399, 4000 Roskilde*

Efficient biological removal of pharmaceuticals from wastewater effluent using eXeno technology

Emma S. Rasmussen*, Kasper U. Kjeldsen*, Caroline K. Rickers**, Aviaja A. Hansen***, Kai Tang****, Henrik R. Andersen****

Abstract

Wastewater treatment plants (WWTPs) based on conventional activated sludge (CAS) do not efficiently decrease micropollutants below the predicted no effect concentrations (PNEC)[1]. Bioactive pharmaceuticals are therefore released into the recipient aquatic environments with adverse effects on ecosystem functions and potentially causes damaging effects to the natural ecosystems[2]. MBBRs are a promising solution to effectively biodegrade pharmaceuticals from WWTPs at a low cost compared to other removal strategies[1]. In particular a high pharmaceutical removal potential exists in MBBRs with intermittent feeding with wastewater[3]. The pharmaceutical removal rate was furthermore positive correlated with the potential nitrification rate of the reactors offering a simple method to assess pharmaceutical removal potential of MBBRs.

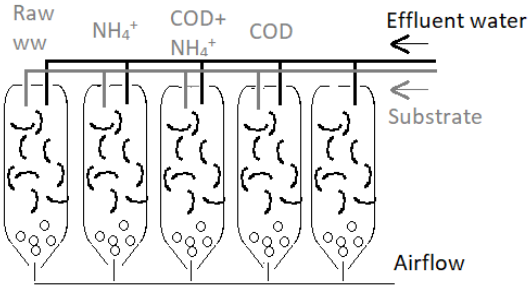


Figure 4 - MBBRs and the experimental setup of differing substrates

Our project investigates the relative impact of organic material and ammonia loading on pharmaceutical removal rates in MBBRs. A reactor fed wastewater was included for comparison with previous studies and a control reactor was fed effluent water only (Fig. 1).

Preliminary results, after 2 months operation, indicate that feeding of ammonia yields the highest nitrification rates. This, however, contradicts other studies, which have indicated organic material as the limiting factor of the system (Fig. 2).

During 2020, further work aims to map the community of the MBBR biofilms by 16S rRNA gene sequencing, to cultivate and identify diclofenac-degrading bacteria as by selective enrichment and identification of the enriched populations by 16S rRNA gene sequencing.

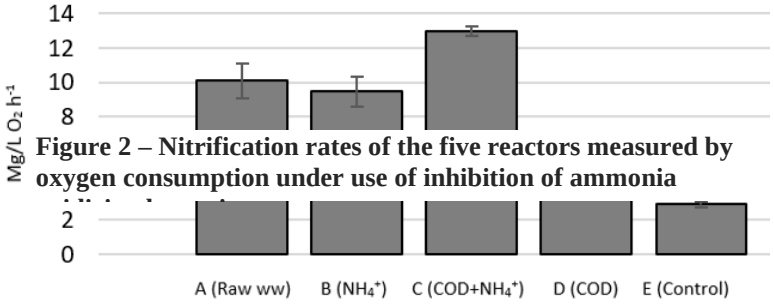


Figure 2 – Nitrification rates of the five reactors measured by oxygen consumption under use of inhibition of ammonia

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2. Fent, K., Weston, A. A. & Caminada, D. Ecotoxicology of human pharmaceuticals. *Aquat. Toxicol.* **76**, 122–159 (2006).
3. Tang, K. *et al.* Removal of pharmaceuticals in conventionally treated wastewater by a polishing moving bed biofilm reactor (MBBR) with intermittent feeding. *Bioresour. Technol.* **236**, 77–86 (2017).

* Emma.skou@bios.au.dk: Aarhus University Department of Bioscience, Ny Munkegade 116, 8000 Aarhus.
** Cakr@teknologisk.dk: Danish Technological Institute, Kongsvang allé 29, 8000 Aarhus.
*** Avh@kruger.dk : Krüger A/S, Haslegårdvænget 18, 8260 Aarhus.
**** Kait@env.dtu.dk, hran@env.dtu.dk: Department of Environmental Engineering, Technical University of Denmark, Miljøvej 113, 2800 Kgs. Lyngby.

Model-based optimization of full-scale anaerobic digesters at a municipal wastewater treatment plant

M. Schliemann-Haug, F. Polesel**, Enrico U. Remigi**, D. Thornberg***, I. Angelidaki*, P. Ramin**, B. Valverde-Pérez**

Abstract

Currently, municipal wastewater treatment plants (WWTPs) need to increase their treatment capacity while they are limited on available space in urban areas. Consequently, investments focus on process intensification. In line with this, Damhusåen WWTP (Copenhagen) is currently exploring ways to optimize the anaerobic digestion process. This study focuses on anaerobic digesters AD1 and AD2, both batch-fed continuously stirred tank reactors (CSTR) with a recycling line and receiving mixed sludge (primary and secondary) as feedstock. AD1 is a contact process with a solid-liquid separation unit in its recycling line, aiming to increase CH_4-production and sludge treatment capacity. Furthermore, sludge pre-treatment using thermal hydrolysis to further increase their treatment capacity is also considered. Calibration and validation were successfully performed for VSS, CH_4-production, pH and total VFA. The scenario analysis showed that the current operating conditions for AD1 and AD2 could be improved (Fig. 1). For AD2, high organic loading rate (OLR) and thus short solids residence time (SRT) caused an increase in CH_4-production. This increase was though an artefact of the high OLR, as a low CH_4-yield suggested that the substrate was not treated sufficiently. Solids reduction was stable at ca. 48% with a slight decreasing trend with longer SRT. For the AD1 contact process, a high OLR of 12.9 kgVS/m^3/d boosted CH_4-production considerably. CH_4-production and yield were stable with SRT, except for SRTs shorter than 10 days where CH_4-production and yield dropped. In general, higher OLR were beneficial for CH_4-production in AD1 and high SRTs increased solids reduction substantially (84% at ca. 75 days). To mimic thermal hydrolysis pretreatment (THP), we increased the biochemical methane potential by 48% and the hydrolysis rates by 70% (compared to the BMP test result of the feedstock), which resulted in increased CH_4-production by up to 40% in AD1 and 29% in AD2. The model-based evaluation showed that there is potential for increasing sludge loading in the digesters at Damhusåen WWTP. An improved operation of the contact process and/or introducing THP was useful to boost biogas production as well in case Damhusåen WWTP increases the plant or accepts sludge from other WWTP for digestion (or co-digestion).

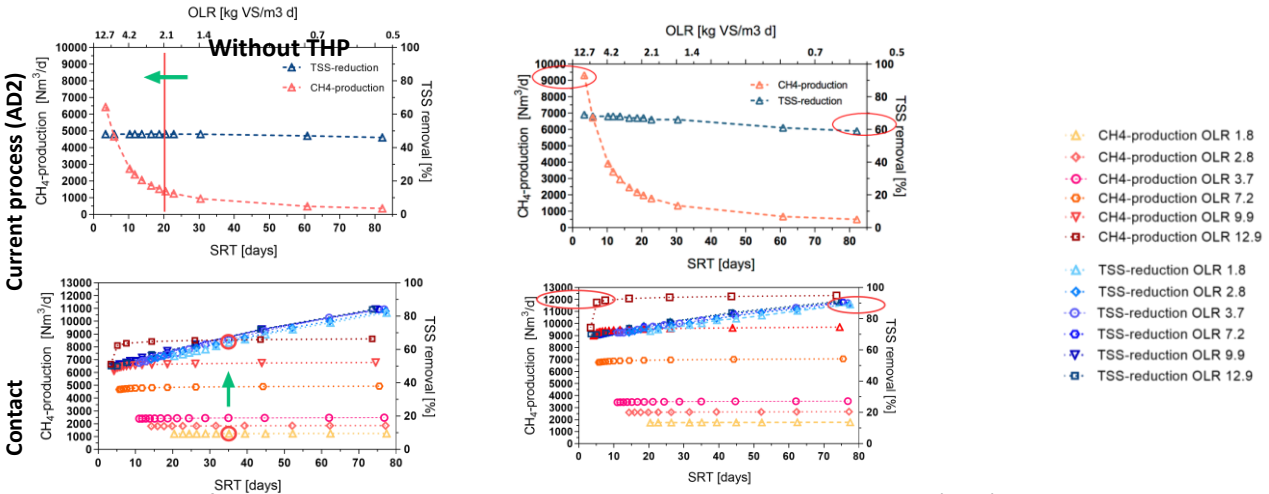


Figure 1 Results of the scenario analysis comparing the current process design (AD2) to the contact process configuration (AD1) with and without THP pre-treatment at different organic loading rates and SRT. (A) Fed-batch CSTR with recycle (AD2) without THP: The red line indicates the current OLR and SRT. (B) Fed-batch CSTR with recycle (AD2) with THP: The red circle indicate the new CH_4-production and solids reduction. (C) Fed-batch CSTR with recycle and contact process (AD1) without THP: The red circles indicate the solids reduction and CH_4-production at current operational conditions. (D) Fed-batch CSTR with recycle and contact process (AD1) with THP: The red circles indicate the new CH_4-production and solids reduction.

DTU Environment, Bygningstorvet Building 115, 2800 Kgs. Lyngby, Denmark, mams@env.dtu.dk, bvape@env.dtu.dk, ** DHI, Agern Allé 5, 2970 Hørsholm, Denmark, * Biofos A/S, Refshalevej 250, 1432 Copenhagen, Denmark*

Can operational problems at full-scale activated sludge systems be solved with sludge transplantation?

D.S. Wágner, Aalborg University, M. Stokholm-Bjerregaard, Aalborg University, Krüger A/S**, G. Dottorini, Aalborg University***, S. Kucheryavskiy, Aalborg University****, M. Nierychlo, Aalborg University*****, P.H. Nielsen, VandCenter Syd******, P.H. Nielsen, Aalborg University********

Abstract

Operational problems often arise at water resource recovery facilities (WRRFs), compromising the treatment process and resulting in poor effluent quality. Successful operation depends on optimal and well-functioning microbial communities. The overgrowth of certain bacteria can cause operational problems such as filamentous bulking, and control methods are still often unknown. The transplantation of a well-functioning microbial community into an environment with an unhealthy community was successfully shown in the field of human gut microbiome research. The aim of this study was to test the concept of biomass transplantation and assess the effect at a full-scale WRRF and the possibility of solving operational problems. Most of the biomass (75%, w/w) at Odense NØ full-scale WRRF (37,000 PE), referred to as the recipient, was replaced with biomass from the donor plant, Ejby Mølle WRRF (385,000 PE), within one day. Both plants are carrying out biological removal of N and P. Changes in plant performance and microbial community structure were followed for 1 year by collecting metadata and by16S rRNA gene amplicon sequencing using the MiDAS database for taxonomic classification. The effluent quality and settling properties were not affected by the biomass transplantation, indicating that the operation of the plant was not compromised. The microbial composition in the recipient became very similar to the donor plant following the time of transplantation but then slowly transitioned back to the original composition of the recipient plant. Assessing the specific functional groups showed the same trends (Fig. 1); when the abundance of specific species decreased due to the transplantation, it grew back to the pre-transplantation level (e.g., *Tessaracoccus*), while adding certain species, they were washed out (e.g., *Tetrasphaera*, *Micropruina*). This suggests that operational problems cannot be solved with transplantation of biomass from "healthy" plants, and that the microbial community in a certain plant is very robust to changes.

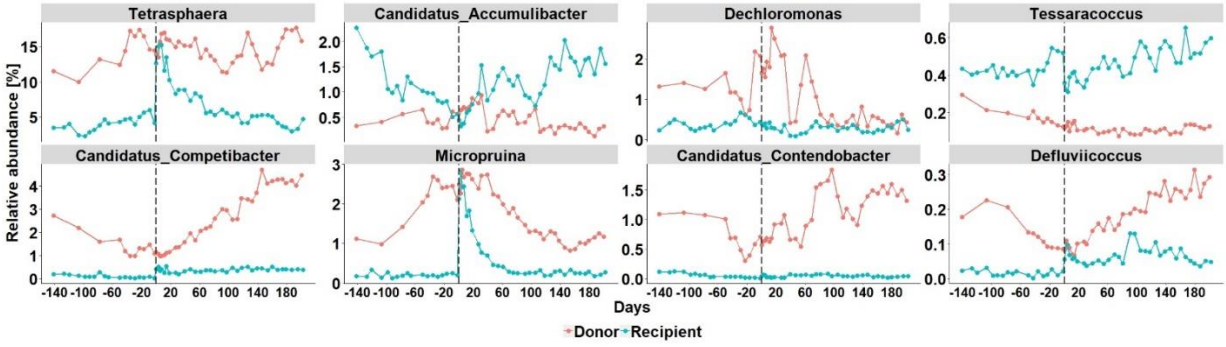


Figure 1: Polyphosphate accumulating organisms (PAO) and glycogen accumulating organisms (GAO) at the recipient and the donor WRRF. The vertical dashed line shows the time of the transplantation. The X axis shows the days before and after the transplantation.

** dsw@bio.aau.dk: Section of Biotechnology, Fredrik Bajers Vej 7H, 9220 Aalborg Øst*
*** mxs@kruger.dk: Indkildevej 6 C, 9210 Aalborg SØ*
**** gd@bio.aau.dk: Section of Biotechnology, Fredrik Bajers Vej 7H, 9220 Aalborg Øst*
***** svk@bio.aau.dk: Section of Chemical Engineering, Niels Bohrs Vej 8, 6700 Esbjerg*
***** mni@bio.aau.dk: *Section of Biotechnology, Fredrik Bajers Vej 7H, 9220 Aalborg Øst*
******* phn@vandcenter.dk: Skt. Jørgens Gade 213, 5000 Odense C*
******* phn@bio.aau.dk: *Section of Biotechnology, Fredrik Bajers Vej 7H, 9220 Aalborg Øst*

Pilot-scale operation of an aquaporin-based forward osmosis process for polishing municipal wastewater effluents

S. Braekevelt, J. Le Nepvou**, J. Frauholz*, T.G. Perez**, U. Gselman*, R. Li***, K. Bester ***, J. Vogel**

Abstract

Today's aquatic environment is increasingly challenged by the accumulation of micropollutants due to human activities. A considerable amount of such micropollutants is discharged via municipal effluents. Pressurized membrane filtration technologies have shown good performance in removing micropollutants, however their operation is energy intensive and prone to fouling, leading to high operational costs. In this study, the potential in high pollutant rejection and low fouling of using seawater-driven forward osmosis (FO) membranes is investigated at pilot-scale.

To investigate the potential, Aquaporin Inside® hollow fiber FO membranes were tested in batch and continuous mode in a pilot-scale FO unit (Figure 1), installed in Avedøre, Denmark. To reach high pollutant rejection, a biomimetic osmotic membrane enhanced with water-selective aquaporin proteins was used. The FO membranes were earlier reported to show a minimum rejection of 92% of all 21 micropollutant compounds using spiked water solutions at varying operational conditions [1]. The FO membrane modules with a permeate capacity up to 200 L/h were tested in a seawater-driven process, as well as in combination with disc-tube Reverse Osmosis draw recovery. The study shows the most recent results on the membranes' micropollutant rejection, long-term operational stability as well as an evaluation of different cleaning strategies.

This study was performed within the framework of the BONUS CLEANWATER project, funded jointly by the EU, Innovation Fund Denmark, VINNOVA and the German Ministry for Education and Science.

Figure 5: Hybrid FO-RO pilot plant with 140 L/h permeate production capacity

References

[1] Braekevelt *et al.* Impact of operational conditions on rejection of trace organic compounds in forward osmosis using aquaporin-based hollow fiber membranes. Poster presented at: Euromembrane; July 2017, Valencia, Spain.

* sbr@aquaporin.com: Aquaporin A/S, Kongens Lyngby, Denmark

** Technical University of Denmark, Department of Environmental Engineering, Kongens Lyngby, Denmark

*** Aarhus University, Faculty of Science and Technology, Department of Environmental Science, Roskilde, Denmark

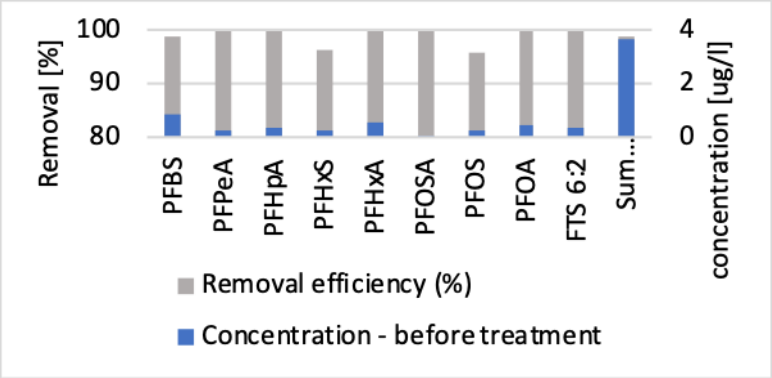
PFAS removal from percolate by super critical water oxidation (SCWO)

Y. Jama, S. Lindholst*, R.R. Andreasen*, H. R. Andersen**, A. Kokkoli**, T. Svendsen***, Z. Cai***, C. Kragelund**

Abstract

Large quantities of water and soil are presently contaminated with per- or polyfluoroalkyl substances (PFAS), that are found to be persistent, bioaccumulative and/or toxic. PFAS have been applied in many products and especially as flame retardants, and are extremely recalcitrant to conventional remediation technologies as chemical and biological degradation. Therefore, the most common solution is to adsorb PFAS on activated carbon, which is sent to destruction at specialized facilities using very high temperatures, at a high cost. The development of a method, that allows remediation of contaminated percolate at a lower cost and with reutilization of the coal used for adsorption is highly desired.

Super critical water oxidation (SCWO) is applied in the project "Removal of PFAS from percolate", financed by the Innovation Network for Environmental Technology. Treatment of percolate at high pressure and temperature mixed with oxygen results in oxidation of many organic micropollutants with up to 99.9 %. Salt and heavy metals are concentrated and kept below the super critical temperature, whereas the organics at supercritical conditions are oxidized completely. An initial study with percolate from Sörab waste deposit (SE), containing PFAS documented a successful removal of PFAS from the raw percolate.



PFAS concentration in Sörab percolate (blå) and removal efficiency in SCWO plant (grey)

Full scale SCWO plant, Aquarden Technologies

To achieve low cost treatment, a concentration step comprised of adsorption of PFAS from percolate/leachate on activated carbon and desorption with a suitable eluent will be developed in the project. The SCWO system performance is relatively independent of the PFAS concentration and an effective concentration step can therefore significantly lower the price per m^3. The concentrate is processed in the SCWO plant, while the carbon can be reused for adsorption. The purified percolate/leachate can be treated at an convenional wastewater treatment plant. Experiments are currently conducted and further results will be presented at the DWF-conference. CAPEX/OPEX are to be identified.

* cakr@dti.dk: *Kongsvang Allé 29, DK-8000 Aarhus C, DK*
** hran@env.dtu.dk : *Technical University of Denmark, Bygningstorvet, Bygning 115, 2800 Lyngby, DK*
*** ts@aquarden.com: *Aquarden Technologies, Industrivej 17, 3320 Skævinge, DK*

Nitrification inhibition test of salty wastewater using salt-adapted nitrifying bacteria, an alternative test method to ISO method

R.K. Chhetri, A. Kokkoli**, S. Karvelas***, H.R. Andersen*****

Abstract

Nitrification inhibition test is a standard method to test if the chemicals or samples received by wastewater treatment plant are toxic to the nitrifying bacteria in the wastewater treatment plant. Nitrification inhibition test based on ISO method ISO9509 or modified ISO9509 method (REFLAB method) can't differentiate the toxicity between salt and toxicant in the sample, which is unrealistic for regulation of salty wastewaters that are treated in wastewater treatment plants with sufficient volume to dilute salts to harmless levels. To overcome the toxicity due to salinity to the nitrifying bacteria, salt-adapted nitrifying bacteria were grown on the Z400 MBBR carriers. The aim of this work was to validate and compare the nitrification inhibition of samples measured from salt-adapted nitrification inhibition test method (DTU method) with REFLAB method. The new salt-adapted nitrification inhibition test was validated by investigating the statistical uncertainty on the use of new test method with the existing REFLAB method.

The inhibition concentration of formaldehyde and methanol were similar when nitrification inhibition experiment was conducted using DTU method and REFLAB method. Lower inhibition concentration of Tetrakishydroxymethyl phosphonium sulphate (THPS) was observed with the DTU method. This means it is more sensitive to THPS and thus detects it at lower concentrations. The difference between the methods might be due to sorption of chemicals into the sludge as the biomass concentration in the DTU method is lower. The new methods standard deviation of nitrification inhibition around the 50% inhibition level was below 3%. Thus, this method is suitable to test the nitrification inhibition of saline wastewater since it differentiate the toxicity between salt and actual toxicants.

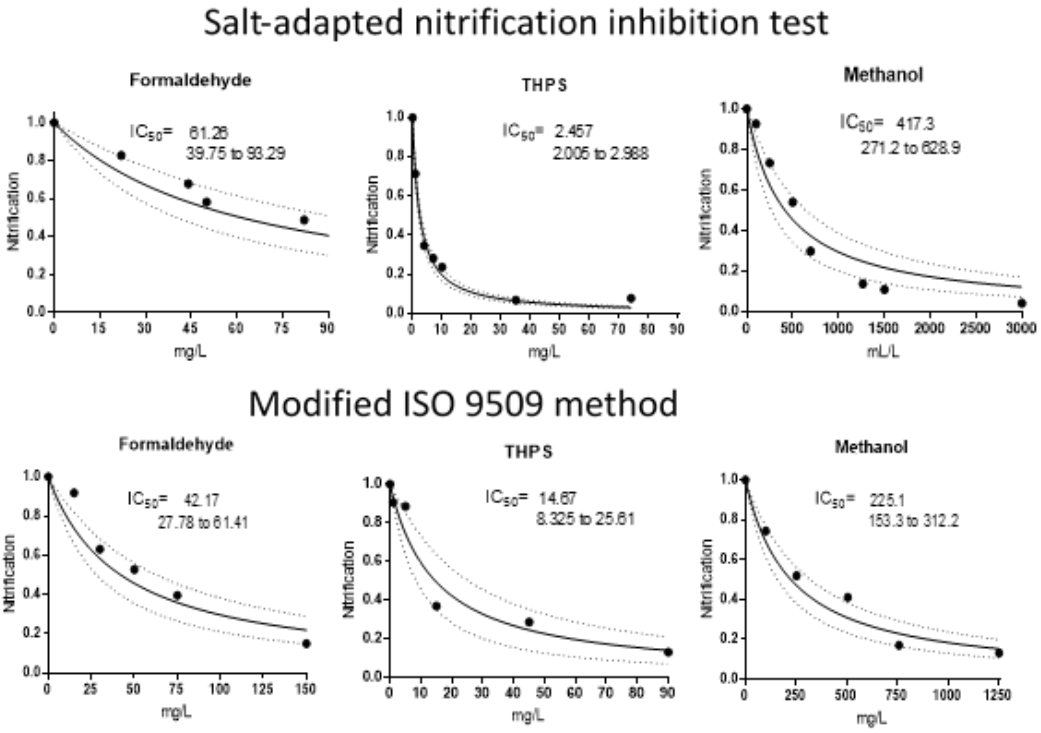


Figure 1 Dose-response curve of THPS, formaldehyde and methanol from nitrification inhibition experiments.

* rakc@env.dtu.dk : Bygningstorvet, Bygning 115, 2800 Lyngby
** arko@env.dtu.dk : Bygningstorvet, Bygning 115, 2800 Lyngby
*** sofkar@env.dtu.dk : Bygningstorvet, Bygning 115, 2800 Lyngby
**** hran@env.dtu.dk : Bygningstorvet, Bygning 115, 2800 Lyngby

The New MiDAS Field Guide: Comprehensive Online Ecosystem-specific Database of Microorganisms in Wastewater Treatment Systems

S.H. Hansen, M. Nierychlo*, Y. Xu, N. Green, K.S. Andersen, M. Dueholm, P. H. Nielsen***
Center for Microbial Communities, Aalborg University, Fredrik Bajers Vej 7H, 9220 Aalborg, Denmark

Abstract

A deep understanding of the microbial communities and their dynamics in wastewater treatment systems is a powerful tool for process surveillance, optimization and design. However, to understand the role of the microbes and the relationship between population dynamics and operational parameters of given system, a functional role must be attributed to each organism. Functional traits are often conserved at low taxonomic ranks (genus, species, strain), however, high taxonomic resolution information is missing from the large-scale public databases for many important microbes present in wastewater treatment systems.

MiDAS (Microbial Database for Activated Sludge) was established as an ecosystem-specific database to provide manually curated taxonomic assignment (MiDAS taxonomy 1.0) and associated physiological information profiles (midasfieldguide.org) for all abundant and process critical genera in activated sludge (AS) (McIlroy *et al*., 2015). Both, taxonomy and database, were later updated (MiDAS 2.0) to cover abundant microorganisms found in anaerobic digesters (AD) and influent wastewater (McIlroy *et al*., 2017). Now we present the latest update of midasfieldguide.org based on the new release of MiDAS 3 taxonomy, which proposes a provisional name for all microorganisms found in activated sludge and anaerobic digester ecosystems, down to species level. These names act as unique identifiers, making the taxonomic assignment independent of the dataset analyzed, thus making cross-study comparison possible.

The new MiDAS field guide currently includes more than 1800 genera and 4000 species found in wastewater treatment systems (compared to approx. 250 genera in the previous version). The data comes from extensive in-house full-length 16S rRNA gene sequencing including more than 20 full-scale AS WWTPs and more than 20 anaerobic digesters. Sequences of bacterial pathogens, microorganisms abundant in influent wastewater and other important microbes were added manually, if not found otherwise.

The website provides a searchable database of all microorganisms found in wastewater treatment systems. Moreover, it is now possible to blast the raw sequence against the MiDAS database and obtain MiDAS 3 taxonomic classification directly online. Species belonging to each genus are included for each microbe and their description is provided (if available). Abundance information (based on more than 10 years long in-house surveys) is provided for each species and genus. Functional information is provided for all abundant and/or important genera in AS and AD systems (if available). The database is a continuously developing resource, where information is included based on published studies characterizing the novel microorganisms.

MiDAS field guide is intended as a collaborative platform, where all working in the field are invited to contribute. It provides a common vocabulary for the identity, down to species level, of the microbes present in wastewater treatment systems, and links the names to the wealth of present and future functional information about their ecology.

16S rRNA amplicon sequencing is now routinely applied to characterize the diversity, composition, and dynamics of environmental microbial communities.

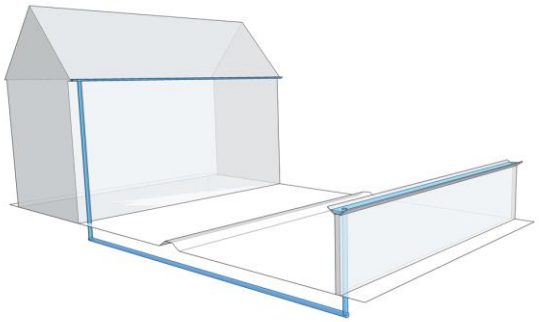
* shh@bio.aau.dk: *Fredrik Bajers Vej 7H, 9220 Aalborg, Denmark*
** phn@bio.aau.dk: *Fredrik Bajers Vej 7H, 9220 Aalborg, Denmark*

Evaluating added benefits and scalability of vertical, evaporation-based SUDS

M.T. Randall, University of Copenhagen (IGN), E. Lausen, University of Copenhagen (IGN) **,*
*K.A. Ulbak, Danish Technological Institute ***, M.B. Jensen, IGN University of Copenhagen (IGN)*****

Abstract

While SUDS (Sustainable Urban Drainage Systems) based on infiltration and detention are becoming increasingly widespread, the use of evaporation as a primary hydraulic mechanism has not yet gained ground. The Green Climate Screen is a free-standing SUDS element designed to handle up to a 5 year event by means of evaporation and infiltration. In September 2019, a 78 m long pilot was constructed and is currently receiving roof runoff from a neighbouring residential building just outside of Copenhagen (Folehaven, Valby). Runoff is transferred through a below-ground pressure pipe from the downpipe to the top of the 3 m high screen, where it is released into a perforated distribution gutter, allowing the water to be absorbed by the mineral wool in the center of the screen. The wool is hidden behind woven willow plates, all resting on a terraced planting box that provides substrate for climbers and other vegetation. On top, the screen has a small green roof facing the traffic. In addition to capturing precipitation events smaller than 5 years, additional expected added benefits include noise reduction, air quality improvement, local cooling, biodiversity support and improved urban space. This presentation outlines the extent of some added benefits based on initial lab tests and modelling, and outlines the plan for in field monitoring of the new pilot. A preliminary GIS-based analysis investigating the city-wide potential of the Green Climate Screen is also presented.



Left: The Green Climate Screen, Copenhagen, when almost fully constructed. Right: Graphical illustration of how roof-runoff is transferred into the screen by means of gravity.

* mtr@ign.ku.dk : Rolighedsvej 23,1958 Frederiksberg, Denmark
** emze@ign.ku.dk: Rolighedsvej 23,1958 Frederiksberg, Denmark
*** kru@teknologisk.dk: Gregersensvej 8, 2630 Taastrup , Denmark
**** mbj@ign.ku.dk : Rolighedsvej 23,1958 Frederiksberg, Denmark

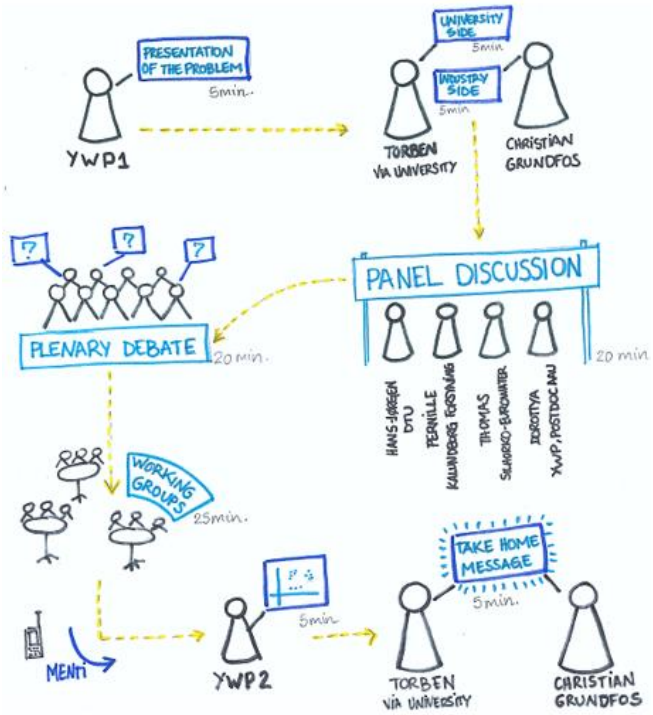
Room 3

SESSION 14 and 15: From Research to Practice; YWP Workshop

Time	Title	
Chair:	**Ines Breda**	**Presented by**
16:30	Introduction to the challenge	Ines Breda, Silhorko, YWPDK
16:35	Research and industry, the different perspectives	Torben Lund Skovhus, VIA University College Christian Schou, Grundfos
16:45	Panel debate	Hans-Jørgen Albrechtsen, DTU Pernille Ingildsen, Kalundborg Forsyning A/S Dorottya Sarolta Wágner, PostDoc AAU, YWPDK Thomas Illerman, Silhorko - Eurowater A/S
17:05	Plenary debate	Participants
17:25	Working groups including summarizing	Agnete Ansbæk, Fors, YWPDK
17:55	Take home messages	Torben Lund Skovhus, VIA University College Christian Schou, Grundfos
18:00		

FROM RESEARCH TO PRACTICE
YWPDK Workshop

The workshop aims to gather different stakeholders in the Danish water sector, to identify challenges and possible solutions to reduce the implementation time of technology resulting from applied research projects.



IWA YOUNG WATER PROFESSIONALS DENMARK
the international water association

POSTERS

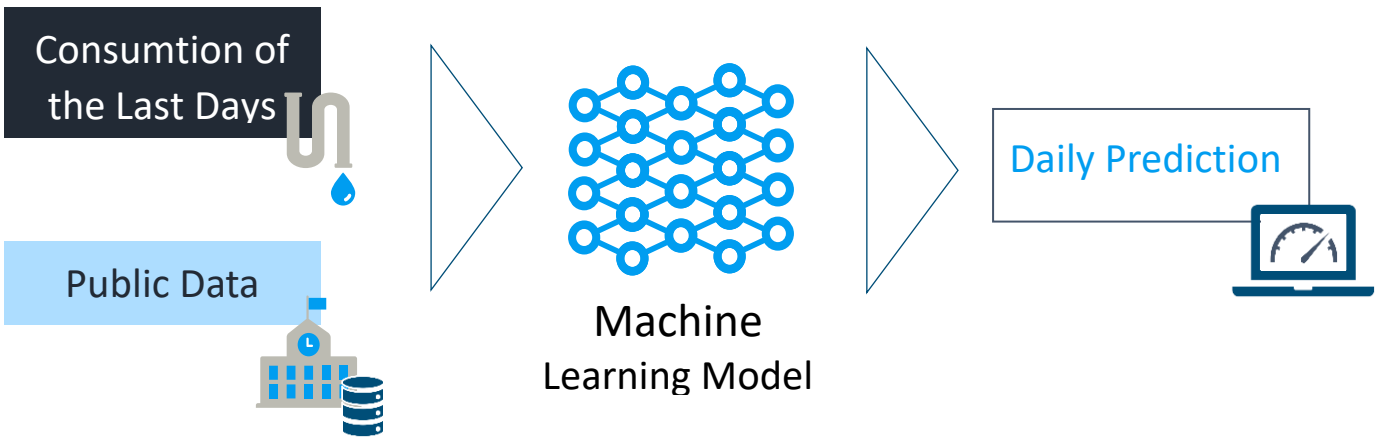
VANDALF: Linking of Chemical and Toxicological Fingerprints: A new method to prioritize monitoring and regulation of pollutants in water	**Peter Mortensen**, Eurofins, J.H. Christensen, KU-PLEN1, N. Cedergreen, KU-PLEN2, P. Mortensen, Eurofins Miljø A/S3, R. Bro, KU-FOOD4, G.F. Krog, Danish EPA5, P.H. Nielsen, VCS Denmark A/S6, J. Lundqvist, SLU7, D.E. Thornberg, BIOFOS A/S8, T. Vulpius, MSCi Aps9, M. Jakobsen10, KMC Nordhavn, N. Høgsted, Danish Environmental Portal11, J. Hollender, Eawag12
Smarter Water - Water Consumption Predictions for Cities	**Fabian Geier***, Ramboll Management Consulting, Robin Schlenga**, Ramboll Management Consulting

Smarter Water - Water Consumption Predictions for Cities

Fabian Geier, Ramboll Management Consulting, Robin Schlenga**, Ramboll Management Consulting*

Abstract

The ability to predict the short-term water usage in a water delivery system has great benefits for ground water pumping and short-term water storage. It allows for more efficient maintenance planning and reduced energy costs. We show a novel approach that utilises state of the are machine learning methods to predict the future water consumption of an entire city or of single supply areas within a city. The machine learning model is trained on two kinds of data: service utility data and public data. The service utility provides historic consumption and production data that is used for model calibration. Public data includes relevant external influences e.g. weather data and relevant calendar dates. Our approach can be easily adapted to account for characteristics of a specific city or region. The next-day prediction is statistically accurate to 94% on our validation data.



* fabian.geier@ramboll.com, Werinherstraße 79, 81541 München, Germany
** robin.schlenga@ramboll.com, Saarbrückerstr 20, 10405 Berlin, Germany

VANDALF: Linking of Chemical and Toxicological Fingerprints: A new method to prioritize monitoring and regulation of pollutants in water

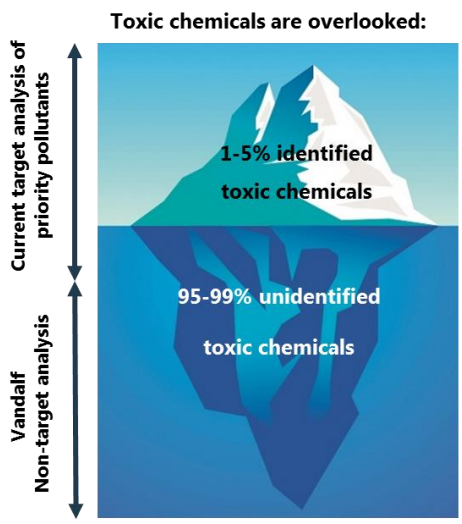
J.H. Christensen, KU-PLEN[1], N. Cedergreen, KU-PLEN[2], P. Mortensen, Eurofins Miljø A/S[3], R. Bro, KU-FOOD[4], G.F. Krog, Danish EPA[5], P.H. Nielsen, VCS Denmark A/S[6], J. Lundqvist, SLU[7], D.E. Thornberg, BIOFOS A/S[8], T. Vulpius, MSCi Aps[9], M. Jakobsen[10], KMC Nordhavn, N. Høgsted, Danish Environmental Portal[11], J. Hollender, Eawag[12]

Abstract

An international consortium including Danish, Swedish and Swiss Universities, Public Utilities and private enterprises will during the coming 4 years develop an effect-driven analytical approach for analysis of the joint chemical toxicity of wastewater.

More than 100,000 industrial chemicals are in use today in Europe and more than 1,000 new chemicals are added to the list every year. The rate at which these chemicals are being assessed by the relevant authorities is slow and by far slower than the rate of introduction of new chemicals. This paradox leaves the majority of new chemicals untested; and studies measuring the joint toxicity of whole wastewater samples and identifying how much of the toxicity is explained by the monitored chemicals show that only a minor part of the toxicity is explained by the present portfolio of standard monitored chemicals.

The vision of VANDALF is to develop and implement a flexible and effect-based tool to identify the chemicals causing the major part of toxicity in wastewater samples including chemicals of emerging concern (CEC). It will make it possible to focus monitoring programs, remediation strategies and regulatory measures on the chemicals contributing most to the overall toxicity. VANDALF will provide information on CECs which are not removed by the current wastewater treatment technologies or created in the process and therefore form basis for development of new technologies and enforcing regulatory measures on their use and emission. The core of the developmental work will be innovative use of cutting edge non-target chemical analytical technologies and use of toxicological tests on a very large number of wastewater samples from WWTPs combined through advanced statistical analysis.



Need for Vandalf

AIM

- **Safer wastewater** for human health & environment
- Need for **identification of high-risk chemicals in our water resources**
- **Improved policies:** national **policies and legislation**

IMPACT

- **Control of content in treated release wastewater**
- Upstream removal of pollutants
- Research driven industry

How?

- **Unique technologies combination** of non-targeted chemical and toxicological fingerprinting existing methods integrated through big-data analysis
- Partners cover the **entire wastewater value chain**
- **strong market potential, sales channels for a research based innovation**
- **operationality**: EPA active engagement

[1]: jch@plen.ku.dk.; Thorvaldsensvej 40, 1871 Frederiksberg C
[2]: ncf@plen.ku.dk; Thorvaldsensvej 40, 1871 Frederiksberg C
[3]: pm@eurofins.dk.; Smedeskovvej 38, 8464 Galten
[4]: rb@food.ku.dk; Thorvaldsensvej 40, 1871 Frederiksberg C
[5]: gufkr@mst.dk; Vasevej 7, 8920 Randers NV
[6]: phn@vandecenter.dk; Vandværksvej 7, 5000 Odense
[7]: johan.lundqvist@slu.se; Ulls väg 26, Uppsala, Sweden
[8]: dt@biofos.dk; Refshalevej 250, København K
[9]: tore@msconsult.dk: Bøgesvinget 8, 2740 Skovlunde
[10]: marjak@kk.dk Nordsøvej 4, 2150 København
[11]: nihoe@miljoeportal.dk Nyropsgade 30,1780 København V
[12]: juliane.hollender@eawag.ch:Überlandstrasse 133, 8600 Dübendorf, Switzerland

Overall time table

Time	Room1	Room 2	Room 3
09:30	Plenum: Green transition is also blue transition		
10:50	**Coffee break**		
11:15	Sessions 1,2 and 3: Drinking water	Sessions 6, 7 and 8: Groundwater	Sessions 11, 12 and 13: Wastewater
12:00	**Lunch break**		
13:00	Sessions 1,2 and 3: Drinking water Continued	Sessions 6, 7 and 8: Groundwater continued	Sessions 11, 12 and 13: Wastewater, continued
14:45	**Coffe break and posters**		
15.15	Sessions 1,2 and 3: Drinking water Continued	Sessions 6, 7 and 8: Groundwater continued	Sessions 11, 12 and 13: Wastewater continued
16:30	Session 4 and 5: Research	Session 9 and 10: Water Smart Cities	Session 14 and 15: From research to practice: A workshop
18:00	**Drinks, snacks and awards**		
18:45	**Dinner, only for sign-up's**		